

# EXHIBIT 1

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**UNITED STATES DISTRICT COURT  
NORTHERN DISTRICT OF CALIFORNIA**

FEDERAL TRADE COMMISSION,  
Plaintiff,

vs.

QUALCOMM INCORPORATED,  
Defendant.

Civil Action No. 17-cv-0220

**Expert Report of Edward A. Snyder Ph.D.**

**June 28, 2018**

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## I. INTRODUCTION

### A. Qualifications

1. I am the Indra K. Nooyi Dean and William S. Beinecke Professor of Economics and Management at the Yale School of Management where I have been employed since July 1, 2011. As Dean I have overall responsibilities for the school’s academic programs, its budget and financial health, and strategy. Previously, I was the Dean and George Shultz Professor of Economics at the University of Chicago Booth School of Business.
2. I began my professional career in 1978 with the Antitrust Division of the U.S. Department of Justice as a Staff Economist to the National Commission to Review Antitrust Laws and Procedures. I was a Staff Economist in the Antitrust Division on a full- and part-time basis until 1984, working on antitrust investigations in a wide range of product markets involving manufacturers, service providers, distributors, and retailers. Since then, I have worked in antitrust enforcement, conducted research on antitrust policy and business practices, taught courses in related areas, and consulted on antitrust matters.
3. I earned my M.A. in Public Policy and Ph.D. in Economics from the University of Chicago. My Ph.D. thesis focused on price-fixing and examined enforcement of Section 1 of the Sherman Antitrust Act by the U.S. Department of Justice; this involved reviewing over 200 price-fixing conspiracies. I began my academic career in 1982 at the University of Michigan Business School and over time was promoted to Chair of Business Economics and Public Policy.
4. My primary expertise is Industrial Organization, the field of economics that deals most directly with pricing and distribution of products, interactions among competitors, contracting practices, and antitrust issues. My research draws on relevant theory, investigates real-world behavior, and is predominantly empirical in nature. I conducted three scholarly projects on antitrust policy and enforcement with Thomas E. Kauper, Professor of Law Emeritus at the University of Michigan Law School and former Assistant Attorney General in charge of the Antitrust Division, U.S. Department of Justice. I have been an Editor of the *Journal of Law and Economics*.

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5. I have provided expert testimony in numerous antitrust matters and in so doing have analyzed economic and business issues in a rich variety of industry settings, including microprocessors for computers, optical disk drives, cathode ray tubes, and liquid crystal displays. I consider myself to be an expert on pricing practices, distribution of products, vertical integration and contracting, and industrial organization in general. I also consider myself to be an expert on allegations of collusion, monopolization, and other anti-competitive practices.
6. Appendix A provides my Curriculum Vitae. Appendix B provides a list of my expert testimony within the past four years.

### **B. Assignment**

7. I have been retained by counsel for defendant Qualcomm to assess the claims by the Federal Trade Commission (“FTC” or “Plaintiff”) that Qualcomm’s alleged conduct has reduced competition in the modem chip industry. I understand that Plaintiff claims that the at-issue conduct deterred or precluded entry, suppressed innovation, and forced many of Qualcomm’s competitors to exit the business of supplying Code-Division Multiple Access (“CDMA”) modem chips as well as what Plaintiff calls “premium” Long Term Evolution (“LTE”) modem chips. Plaintiff also claims that, conversely, other modem chip suppliers “would become stronger and better positioned to win future designs at Apple and other OEMs” absent the at-issue conduct.<sup>1</sup> To be clear, I do not address Plaintiff’s specific allegations of the at-issue conduct. Rather, I focus on the claimed harmful combined effects of Qualcomm’s alleged exclusionary conduct on competition in the modem chip industry and end customers. In this regard, I have been asked to evaluate the expert opinions offered by Professor Carl Shapiro concerning certain competitive effects of Qualcomm’s alleged exclusionary conduct.<sup>2</sup>

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<sup>1</sup> Federal Trade Commission’s Complaint for Equitable Relief, *Federal Trade Commission v. Qualcomm Incorporated*, January 17, 2017, ¶ 127 (“Complaint”).

<sup>2</sup> Plaintiff retained Professor Carl Shapiro to “provide an economic analysis of the likely competitive effects of Qualcomm’s commercial practices that are the subject of the FTC’s complaint in this case.” Expert Report of Carl Shapiro, May 24, 2018, ¶ 7 (“Shapiro Report”). I understand that Plaintiff has asked Professor Shapiro as well as other experts to opine on additional topics. See, e.g., Shapiro Report, ¶ 7 (“The FTC also asked me to define the relevant markets applicable to the analysis of this conduct and to assess whether Qualcomm possesses monopoly power in any of these markets.”).

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8. I have directed employees of Analysis Group, Inc., an economic research and consulting firm, to assist me in this assignment. I am being compensated at my normal hourly rate of \$1,250 for time spent on this matter, and I receive compensation based on the professional fees of Analysis Group. No compensation is contingent on the nature of my findings or on the outcome of this litigation.

### **C. Background and allegations**

9. The allegations in this matter concern *modem chips* – also identified as modem chipsets or baseband processor chipsets.<sup>3</sup> These small silicon chips, when incorporated into mobile devices, facilitate the transmission and reception of digitized data over cellular networks.<sup>4</sup> Hence, modem chips are foundational to mobile device functions, including telephone and internet access.
10. Exhibit I.C.1 depicts some aspects of the modem chip industry and its relationship to downstream firms that design and manufacture mobile devices. As indicated, the extent of vertical integration varies greatly. Firms such as Samsung have been involved in modem chip design, modem chip fabrication, mobile device design, and mobile device manufacturing. Other firms have focused on a subset of these activities. For example, “fabless” modem chip suppliers such as Qualcomm and MediaTek design modem chips and use foundries such as Taiwan Semiconductor Manufacturing Company (“TSMC”) to manufacture them.<sup>5</sup> Other firms, usually known as integrated device manufacturers (“IDMs”), both design and manufacture modem chips. For instance, Intel owns fabs to manufacture modem chips for both internal use and, more recently, for other modem chip suppliers.

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<sup>3</sup> *Modem chips* modulate and demodulate signals and thus communicate with other modems. These small silicon chips also perform a variety of radio control functions such as encoding and radio frequency shifting, and often integrate other functions executed by the application processor (“AP”). The term chipset is used to refer to a set of electronic components, such as a modem chip and radio frequency (“RF”) chip. See The Linley Group, “A Guide to 3G/4G Wireless Chips,” Fifth Edition, September 2010, pp. 29–30 (Section 3 – Handset Processors).

<sup>4</sup> As I discuss in more detail in Section III.C.1, mobile devices include handsets (such as feature phones or smartphones) but also other devices that contain modem chips and enable cellular connectivity.

<sup>5</sup> Semiconductor fabrication facilities are called “fabs.” See, e.g., Handy, Jim, “What’s It Like in a Semiconductor Fab?,” *Forbes*, December 19, 2011.

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11. Similarly, some original equipment manufacturers (“OEMs”) such as Apple and, at times, Acer, design mobile devices and use contract manufacturers such as Foxconn to manufacture them. Other OEMs, such as LG, both design and manufacture mobile devices. In addition, some OEMs design and manufacture mobile devices and also design modem chips. For example, Huawei owns HiSilicon, which designs the modem chips for some Huawei mobile devices. Overall, modem chip suppliers obtain modem chips manufactured according to their designs from either internal or external foundries, then supply those modem chips to internal or external OEMs; OEMs then sell mobile devices containing modem chips.
12. Defendant Qualcomm, in addition to designing and selling modem chips and other products, develops and licenses intellectual property that includes patents that are essential to standards (“standard-essential patents” or “SEPs”), including cellular SEPs, and patents that are not essential to standards but are nevertheless often commercially significant (“non-essential patents” or “NEPs”).<sup>6</sup>
13. The FTC alleges that Qualcomm has engaged in conduct to exclude competition, “den[ying] other [modem chip] suppliers the benefits of working with a particularly important cell phone manufacturer [i.e., Apple] and hamper[ing] their development into effective competitors,”<sup>7</sup> thereby “serv[ing] to maintain Qualcomm’s monopoly in [modem chip] markets.”<sup>8</sup> According to Plaintiff, Qualcomm’s alleged exclusionary conduct has allowed it to maintain and extend monopoly power in the sale of CDMA modem chips and “premium” LTE modem chips.<sup>9</sup> In support of its claim that Qualcomm has harmed the modem chip industry, Plaintiff alleges “a set of interrelated policies and practices” comprising three primary components.<sup>10</sup>

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<sup>6</sup> Qualcomm Incorporated is the parent company of Qualcomm Technology Licensing (“QTL”) and Qualcomm Technologies, Inc. (“QTI”), among other subsidiaries. QTL is operated by Qualcomm Incorporated, which owns the vast majority of Qualcomm’s patent portfolio and conducts the related licensing business; QTI, together with its subsidiaries including Qualcomm CDMA Technologies (“QCT”), operates “substantially all” of Qualcomm’s “products and services businesses” and “engineering, research, and development functions” (Qualcomm, “Reporting Segments,” available at <http://investor.qualcomm.com/reportingsegments.cfm>).

<sup>7</sup> Complaint, ¶¶ 1, 8.

<sup>8</sup> Complaint, ¶ 7.

<sup>9</sup> Complaint, ¶¶ 131, 144, and 147. As discussed further in Sections III.C.2.a and V.B.1, I refer to CDMA modem chips as those supporting the cdmaOne or CDMA2000 families of standards.

<sup>10</sup> Complaint, ¶ 3. I understand that Plaintiff’s allegations also include a number of other claims.

14. *First*, Plaintiff alleges harm from Qualcomm’s practice of licensing its cellular SEPs to OEMs and not providing exhaustive licenses to its SEPs to modem chip suppliers:<sup>11</sup>

Qualcomm has consistently refused to license its SEPs to competing suppliers of [modem chips]. Several of Qualcomm’s former and current competitors, including Intel, MediaTek, and Samsung, have sought SEP licenses from Qualcomm. In each instance, Qualcomm refused to grant a SEP license.

A license to Qualcomm’s cellular SEPs would provide substantial benefits to other [modem chip] suppliers and to their customers. Because Qualcomm refuses to license [...] SEPs to its competitors, these competitors cannot offer OEMs [modem chips] that convey the rights to Qualcomm’s cellular SEPs.

Qualcomm’s ability to tax its competitors’ sales via patent license terms with OEMs would be limited if it licensed cellular SEPs to its competitors. Qualcomm’s [...] competitors, unlike its OEM customers, do not depend on Qualcomm for [modem chip] supply. As a result, Qualcomm could not use a threatened disruption of [modem chip] supply to skew SEP-license negotiations with its competitors, and the royalties that would emerge from those negotiations would reflect the royalties that a court would deem reasonable.

Qualcomm’s refusal to license competing manufacturers of [modem chips], in contravention of its FRAND [i.e., fair, reasonable, and non-discriminatory] commitments, contributes to its ability to [...] maintain its monopoly.<sup>12</sup>

15. *Second*, Plaintiff alleges harm from Qualcomm’s “condition[ing] OEMs’ access to its [modem chips] on OEMs’ acceptance of a license to Qualcomm’s cellular SEPs on Qualcomm’s preferred terms,”<sup>13</sup> and requiring OEMs to pay “substantial royalties to Qualcomm on sales of [mobile devices] using a [modem chip] purchased from Qualcomm’s competitors.”<sup>14</sup>

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<sup>11</sup> Complaint, ¶¶ 112–115.

<sup>12</sup> Complaint, ¶¶ 112–115. See also Shapiro Report, ¶ 9 (“Qualcomm’s refusal to license its cellular SEPs [...] to its modem-chip rivals has [...] weaken[ed] and exclude[d] those rivals, thereby strengthening and prolonging Qualcomm’s monopoly power in the market for CDMA Modem Chips and in the market for Premium LTE Modem Chips.”).

<sup>13</sup> Complaint, ¶¶ 61, 102.

<sup>14</sup> Complaint, ¶ 61.

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According to Plaintiff, this “reduces demand for competitors’ [modem chips]”<sup>15</sup> and thereby “weakens Qualcomm’s competitors [...]”<sup>16</sup>

16. *Third*, Plaintiff alleges harm from Qualcomm’s discounting practices, where Qualcomm offered funds to certain OEMs that were “conditioned on the OEM’s acceptance of Qualcomm’s preferred terms” and “in some cases accrued based on OEMs’ purchase of Qualcomm’s [modem chips].”<sup>17</sup> It further alleges harm from Qualcomm’s entering “agreements with Apple provid[ing] for billions of dollars in conditional rebates,” where such agreements were “*de facto* exclusive deals [...]”<sup>18</sup> According to Plaintiff, such inducements led to decreased sales by other modem chip suppliers and thereby “significantly impeded the development of other [modem chip] suppliers into effective competitors to Qualcomm.”<sup>19</sup>
17. Plaintiff claims that these components of Qualcomm’s alleged exclusionary conduct have “excluded competitors, increased consumer prices, and suppressed innovation”:<sup>20</sup>

By raising OEMs’ all-in costs of using competitors’ [modem chips], Qualcomm’s conduct has also diminished OEMs’ demand for those [modem chips], reduced competitors’ sales and margins, and diminished competitors’ ability and incentive to invest and innovate.<sup>21</sup>

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<sup>15</sup> Complaint, ¶ 87.

<sup>16</sup> Complaint, ¶ 7. See also Shapiro Report, ¶ 9 (“Qualcomm will not supply its modem chips to a handset manufacturer that has not signed a patent license with Qualcomm covering Qualcomm’s cellular standard-essential patents (SEPs). [...] As a result [...], Qualcomm has been able to obtain unreasonably high royalties for its cellular SEPs [...]. Qualcomm’s unreasonably high royalties for its cellular SEPs have raised the cost to handset manufacturers of using non-Qualcomm chips. This in turn has reduced the output of non-Qualcomm modem chips [...].”).

<sup>17</sup> Complaint, ¶¶ 102, 103.

<sup>18</sup> Complaint, ¶¶ 124, 125.

<sup>19</sup> Complaint, ¶¶ 106, 130. See also Shapiro Report, ¶ 9 (“[...]Large exclusivity payments that Qualcomm made to Apple created a powerful incentive for Apple not to use non-Qualcomm modem chips in any new Apple device. [...] Qualcomm recognized that these exclusivity payments provided a strategic benefit to Qualcomm, namely the weakening [of] its modem-chip rivals, especially Intel.”).

<sup>20</sup> Complaint, ¶ 136.

<sup>21</sup> Complaint, ¶ 138. See also Shapiro Report, ¶ 301 (“[Qualcomm’s alleged exclusionary conduct] excludes rival modem-chip suppliers. In the short run, that exclusion takes the form of reducing the competitive constraint that the rivals impose on Qualcomm, which leads to reduced output of rival modem chips. [...] In the long run, that exclusion also takes the form of reduced investments by rival modem chip suppliers, leading those rivals to offer lower quality modem chips and/or to have reduced capacity. In time, the excess royalty can induce exit from the market altogether.”).

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18. Relatedly, Plaintiff claims that, absent Qualcomm’s conduct, other modem chip suppliers could have “achieve[d] a scale of business that confers research-and-development flexibility,” “learn[ed] directly from engagement with Apple’s engineering teams,” “achieve[d] technical validation by demonstrating [their] ability to meet Apple’s demanding technical requirements,” “obtain[ed] a reputational halo effect,” and attained other benefits.<sup>22</sup>

#### **D. Approach**

19. I approach my assignment by analyzing two alternative hypotheses concerning the modem chip industry: the *Industry Factors Hypothesis* and *Plaintiff’s Hypothesis*.<sup>23</sup>
20. The *Industry Factors Hypothesis* posits that relevant industry factors, identified by an analysis of the modem chip industry and grounded in relevant industrial organization principles, exert a strong influence on the structure and development of the modem chip industry. Important industry factors include the rapid innovation in the modem chip industry, where firms compete to meet the technical requirements of new wireless standards and incremental releases within those standards, to differentiate their modem chips on attributes valued by OEM purchasers and network carriers, and to customize their products to meet particular purchaser objectives. According to the *Industry Factors Hypothesis*, relevant industry factors explain the structure of the industry at any point in time, the relative success and failure of modem chip suppliers, industry changes, and observed entry and exit decisions. For example, at the industry level, dramatic shifts in product characteristics involve consequential rivalries among firms attempting to be timely-to-market with leading-edge products. Given the importance and riskiness of firm-level efforts to develop and customize products, the success and failure of firms depend on their foresight, the efficiency of their investments, and ability to execute their strategic responses to purchaser demands and industry dynamics.
21. *Plaintiff’s Hypothesis* is that Qualcomm’s alleged exclusionary conduct (i.e., as relevant here, tying of modem chips with patent licenses, refusal to provide exhaustive component-level patent licenses to modem chip suppliers, and discount agreements with Apple) reduced

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<sup>22</sup> Complaint, ¶ 129. See also Shapiro Report, ¶¶ 375–383.

<sup>23</sup> This approach of developing alternative hypotheses is fundamental to social science and economic analysis in particular.

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competition in the modem chip industry, altered industry dynamics, and allowed Qualcomm to become more successful than it otherwise would have been. According to *Plaintiff’s Hypothesis*, Qualcomm faced less competition as rival chip suppliers could not gain sales, or sufficient sales to reach efficient scale, were denied learning benefits, and were denied certification benefits from selling to Apple and other major OEMs. These predicted effects would be indicated by (a) reduced investment by Qualcomm’s competitors, (b) exit from the modem chip industry, (c) deterred entry by potential competitors, and (d) limited success of Qualcomm’s actual competitors.

22. To distinguish the two hypotheses, I engaged in several inquiries. First, I conducted an analysis of the types of economic activity that occur in the industry, including with respect to the successive and overlapping generations of wireless technologies as well as the importance of product differentiation to OEM customers. This analysis, grounded in relevant industrial organization principles, allowed me to identify the industry factors that potentially drive the economic activity in the industry, and it thus serves as the foundation of the *Industry Factors Hypothesis*. Second, to test that hypothesis, I conducted in-depth analyses of 14 modem chip suppliers,<sup>24</sup> including every major modem chip supplier since 2002, focusing on adverse outcomes such as exit and loss of customers, and on successful outcomes such as new entry into the industry and successful product development. Third, and relatedly, I studied in detail the relationships between OEMs and modem chip suppliers, which yielded insights into the reasons for differences in the numbers of suppliers used by different OEMs and the reasons why OEMs added or dropped suppliers.<sup>25</sup> Fourth, I studied the longer-run performance of the industry using standard indicators such as price and quality.
23. To the extent that these analyses show that industry factors explain outcomes in the modem chip industry and indicate strong performance, they support the *Industry Factors Hypothesis*. In this regard it is highly relevant whether firm-level factors – the ability of individual suppliers to forecast accurately, invest efficiently according to their forecasts, and execute the required

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<sup>24</sup> Modem chip suppliers analyzed include Qualcomm, Infineon, Intel, MediaTek, Samsung/Samsung S-LSI, HiSilicon, ST-Ericsson, Texas Instruments, Broadcom, Freescale, Spreadtrum, VIA Telecom, Marvell, and Nvidia. See also Sections III.D.1 and V.C.

<sup>25</sup> Major OEMs include Samsung, Nokia, Apple, LG, Huawei, Sony, and Motorola. See also Section III.D.2.

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engineering projects – explain supplier successes and failures. Given that these firm-level factors would be present with or without the at-issue conduct, such findings would indicate that industry factors, and not the at-issue conduct, explain outcomes. Similarly, if the analyses of OEM–supplier relationships indicate that the advantages of incumbent suppliers are limited given the on-going challenges to foresee, invest, and execute, then such findings would also support the *Industry Factors Hypothesis*.

24. Conversely, these analyses would yield support for *Plaintiff’s Hypothesis* if they indicated that Qualcomm’s alleged exclusionary conduct caused observed outcomes such as the exit of particular rivals; if they established that Qualcomm’s alleged exclusionary conduct had caused a reduction in investment in new products and in differentiated products; and if long-run industry performance has suffered. Of note, simply observing that the industry does not have a large number of successful competitors at the leading edge would not distinguish between the two hypotheses. The relevant questions concern whether supplier-specific outcomes arise in the context of intense rivalry that fosters strong overall industry performance.<sup>26</sup>
25. In executing my assignment, I relied on my research and experience, relevant economic literature, documents and data produced in discovery, and publicly available information. A list of the materials that I have relied upon is provided in Appendix C.<sup>27</sup>

### **E. Overview of report**

26. I summarize my conclusions in Section II. Section III contains an analysis of the modem chip industry that identifies potentially relevant industry factors – e.g., rapid innovation and product-specific investments, and OEM-varied preferences for single-sourcing or multi-sourcing modem chips. Hence, this section is the basis for the *Industry Factors Hypothesis*.

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<sup>26</sup> *Plaintiff’s Hypothesis* requires that (a) the failure or exit of certain modem chip suppliers would not have occurred absent Qualcomm’s alleged exclusionary conduct (i.e., the relevant industry factors alone cannot explain the failure, entry, or exit of modem chip suppliers), and (b) the failures of modem chip suppliers have impaired the performance of the industry.

<sup>27</sup> These materials include, for example, litigation materials such as produced documents and deposition transcripts, as well as economics literature, industry reference material, contemporaneous reporting on modem chip suppliers, OEMs, and developing cellular technologies, and industry analyses.

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27. I then evaluate the explanatory power of the industry factors thus identified on observed modem chip supplier outcomes. Specifically, Section IV analyzes modem chip supplier–OEM relationships and Section V examines Qualcomm’s own experience and the successes and failures of certain other modem chip suppliers. As stated, to the extent that the success and failure of modem chip suppliers’ performance as well as changes in modem chip supplier–OEM relationships are explained by the relevant industry factors, such evidence supports the *Industry Factors Hypothesis* and contradicts the *Plaintiff’s Hypothesis*.
28. In Section VI, I evaluate the performance of the modem chip industry to assess the evidence, if any, that Qualcomm’s alleged exclusionary conduct has harmed competition overall. If *Plaintiff’s Hypothesis* were correct, analysis of the modem chip industry should reveal clear indications of impaired performance in terms of the ability of the industry to efficiently deliver value to consumers.
29. In Section VII, I assess Professor Shapiro’s conclusions that certain modem chip supplier failures were caused by Qualcomm’s alleged exclusionary conduct. With the benefit of the insights I derived from my analyses, including the detailed case analyses in Section V, I am able to evaluate whether Professor Shapiro has isolated the effects of Qualcomm’s alleged exclusionary conduct, if any, from the effects of the relevant industry factors.

## II. SUMMARY OF CONCLUSIONS

30. I have reached three main conclusions from my analysis of the modem chip industry and my review of modem chip supplier and industry performance.
31. First, industry factors and industrial organization principles exert a strong influence on industry structure, competition among modem chip suppliers, the successes and failures of suppliers, and the relationships between suppliers and their OEM customers.
  - a. Modem chip suppliers make substantial investments, both general and specific, to develop the capability to produce innovative modem chips for mobile devices that implement new generations of wireless standards and releases within those standards. Such modem chips embody dramatically improved functionalities and so drive demand from OEMs. Suppliers differentiate their products based on attributes that are valued generally, e.g., transmission speeds and power consumption. Suppliers may further make specific investments to customize the products to meet the requirements of OEMs, network carriers, and end consumers.

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The investments by suppliers can be specific to particular products and in some cases to particular customer needs.

- b. At any given point in time, only a small number of modem chip suppliers will have cleared the multiple hurdles necessary to compete effectively at the forefront of the industry. Modem chip suppliers are rewarded if they are first or nearly first to market with *leading-edge* products that provide OEMs with opportunities to upgrade their mobile devices. Conversely, modem chip suppliers lose business if their product developments fail or they are not timely to market. Given the high ratio of research and development (“R&D”) to sales at the leading edge of the industry, the divergence between success and failure is large.
- c. Analysis of the nature of product development efforts by modem chip suppliers yields several major insights, including that success on the leading edge entails the ability to *foresee* what will be most important to future OEM demand, to *invest efficiently* according to those forecasts, and to *execute* effectively, e.g., work under tight development deadlines, customize products to meet specifications, and be able to produce high volumes of quality products. While the learning benefits and certification benefits from prior success are important, suppliers with prior success may or may not succeed going forward given the necessary foresight, efficient investment, and execution.
- d. Analysis of modem chip supplier–OEM relationships also shows that firms can compete effectively as “fast followers” and by efficiently developing and supplying products that are in the later stage of their product cycles, and that these firms can win business away from suppliers who were first to market with particular product features. In contrast to Qualcomm, which devotes substantial resources to supplying leading-edge products, other suppliers such as MediaTek have at times focused on supplying modem chips for lower-end mobile devices. Industry analysis indicates that such suppliers can succeed by targeting appropriate segments, investing accordingly, and developing the ability to supply high volumes of reliable products.
- e. The relatively small number of suppliers at a given point in time, especially at the leading edge, does not indicate a lack of competition. Industrial organization principles suggest that leaders at any one point in time are challenged by rivals and may be displaced as suppliers to major OEMs, whether or not (i) the OEM has chosen to use multiple suppliers or a single supplier, and (ii) the OEM is vertically integrated. Indeed, evidence shows that different OEMs use different numbers of modem chip suppliers and adjust the volumes of purchases among suppliers, and that even suppliers that secure a design win with a leading-edge product can later be displaced by competing suppliers.
- f. Modem chip suppliers differ in the range of their economic activities, including whether they design and manufacture their products. These differences affect how they compete and the nature of their relationships with OEMs and other industry participants. But industry analysis indicates that independent of the nature of their contractual relationships, modem chip suppliers succeed or fail based on their foresight, efficient investments, and ability to execute. Indeed, every major success

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or failure experienced by modem chip suppliers can be fully explained by these industry factors.

32. Second, analyses of modem chip suppliers do not support *Plaintiff’s Hypothesis*.

- a. Recognizing that the same set of industry factors, i.e., foresight, efficient investment, and execution, within the context of purchaser demands and other factors, would influence modem chip suppliers independent of whether the at-issue conduct was present or absent, *Plaintiff’s Hypothesis* – that Qualcomm’s alleged exclusionary conduct has impaired modem chip suppliers – is not supported by the record concerning (i) entry and exit by modem chip suppliers, and (ii) changes in supply relationships between modem chip suppliers and OEMs.
- b. The evidence shows both that (i) the observed variety of OEMs’ decisions concerning the number of suppliers from which they source modem chips and adjustments to their supply relationships have been consistent with the requirements of those OEMs, and (ii) modem chip suppliers lose and gain shares of purchases by major OEMs on an ongoing basis. Apple’s choice of one or two modem chip suppliers is consistent with its overall business strategy, the limited number of mobile devices it offers, and the high degree of customization it requires. Apple continuously evaluates its chip suppliers and, despite having started fewer new supply relationships than other OEMs in recent years, it maintains, and benefits from, robust competition among suppliers. Samsung has used a comparable number of modem chip suppliers for its flagship Galaxy S devices, but it sources from more modem chip suppliers for its broad portfolio of mobile devices.
- c. Evidence shows that OEMs on average start or end one relationship with a modem chip supplier annually. The shift to 4G wireless standards was associated with an increased rate of turnover in supply relationships in 2011-2013. Many started relationships coincided with the growing success of Spreadtrum, for example. Many ended relationships involved modem chip suppliers that failed to develop viable 4G LTE products. For example, Broadcom acquired Beceem for its 4G technologies in 2010 and acquired Renesas Mobile in 2013 to accelerate its LTE development, but it ultimately failed to secure substantial 4G design wins and exited the modem chip industry in 2014. Other modem chip suppliers that struggled to develop LTE products and exited or were acquired during this period include ST-Ericsson and VIA Telecom. While Samsung [REDACTED] provide their integrated modem chip suppliers with an internal source of demand, they exhibit willingness to source from external suppliers.
- d. Qualcomm derives its success as a modem chip supplier from its many years of industry experience and efficient investments in next-generation R&D efforts, which have enabled it to meet new technological challenges and to compete effectively on dimensions that are unrelated either to standards or to its licensed intellectual property, such as offering new functionality and better integration in LTE before competitors. Qualcomm offered the first multi-mode LTE modem chip and led the integration of multiple components onto a single chip. Even if Qualcomm had no licensing business, its modem chips would have been attractive due to their superiority from a feature and performance standpoint.

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- e. Intel, Samsung, and Huawei have vast experience and resources and invest substantial amounts in R&D. However, R&D investment is important but not sufficient to ensure success. For example, Intel’s success has been limited by poor R&D efficiency.
- f. Independent of Qualcomm’s at-issue conduct, several modem chip suppliers have made errors in foresight, and their success has been limited as a result. For example, Broadcom, which exited the modem chip industry in 2014, lacked foresight in failing to diversify its customer base, and its revenues declined substantially when Nokia’s and Samsung’s modem chip demands shifted. Broadcom also failed to foresee the need to improve data throughput and other characteristics of its modem chips. In the same vein, several modem chip suppliers have also made significant execution errors, including in how they have addressed organizational challenges. For example, Marvell, which exited the modem chip industry in 2015, lost its primary customer, Research in Motion (“RIM”), after falling behind on LTE development and consistently missing development deadlines more broadly. Marvell also failed to bring modem chips to market that were competitive in terms of size and power consumption.
- g. Independent of Qualcomm’s alleged exclusionary conduct, other modem chip suppliers have succeeded. MediaTek, HiSilicon, and Spreadtrum have demonstrated good foresight, have appropriately targeted their investments to their chosen strategies, and have executed well. [REDACTED]
- h. Modem chip suppliers’ successes and failures reflect their ability to respond to the shift in demand toward integrated solutions and, more broadly, to provide a greater range of products to OEMs. MediaTek and Qualcomm have successfully integrated application processors and other components onto their modem chips, and such integrated chips have become attractive to many OEMs seeking to reduce device size and cost. By contrast, Texas Instruments focused on hardware solutions, leaving development of the software required to enable the communication functionality of its chips to its OEM partners. Furthermore, while Texas Instruments developed some modem chips that integrated a number of other non-processor device components, it experienced difficulties integrating multimedia capabilities and exited the modem chip industry when it lost substantial sales due to foresight and execution issues.
- i. Careful and detailed analyses of the industry do not, therefore, support *Plaintiff’s Hypothesis* that Qualcomm’s alleged exclusionary conduct either (i) caused other firms to fail, or (ii) prevented other firms from succeeding. Instead, modem chip supplier outcomes have been unrelated to Qualcomm’s alleged exclusionary conduct.

33. Third, analysis of industry performance directly contradicts *Plaintiff’s Hypothesis*.
- a. According to *Plaintiff’s Hypothesis*, Qualcomm’s alleged exclusionary conduct since 2007 has impaired the modem chip industry. Standard indicators of industry performance do not, however, provide any support for such a prediction.
  - b. Investment in R&D by the industry has been substantial and has yielded huge improvements in modem chips. For example, from 2013 to 2017, maximum downlink speeds of 4G-compatible devices have increased by a factor of seven. These improvements have translated into impressive advances in the performance of mobile devices used by end consumers, including faster and more efficient performance of basic voice and data functions, as well as support for more data-intensive functionalities such as multimedia sharing, audio and video streaming, and video conferencing.
  - c. Over the time period associated with Plaintiff’s claims, modem chip prices have declined. For example, since 2012, the average price of 4G LTE modem chips has declined by half even without adjusting for a shift towards more expensive integrated chips and for quality improvements, e.g., greater processing power, that have increased consumer surplus.
34. I have also reached three main conclusions from my assessment of Professor Shapiro’s opinions regarding certain competitive effects of Qualcomm’s alleged exclusionary conduct.
35. First, Professor Shapiro’s claim that certain modem chip suppliers’ exits from the modem chip industry were caused by Qualcomm’s alleged exclusionary conduct is unsupported and fails to account for other plausible explanations.
- a. Professor Shapiro’s conclusions concerning anticompetitive effects lack foundation given that he does not consider the relevant counterfactual in which Qualcomm’s alleged exclusionary conduct is removed, but relevant industry factors influence outcomes. Without doing so, Professor Shapiro cannot isolate the effects of Qualcomm’s alleged exclusionary conduct, if any, from the effects of industry factors that would be present in a world without Qualcomm’s alleged exclusionary conduct. Given his lack of consideration of the most important alternative hypothesis and the strong evidence in support of the alternative explanation, Professor Shapiro’s conclusions in support of *Plaintiff’s Hypothesis* cannot be accepted.
  - b. My analyses establish that industry factors, including the importance of foresight, efficient investment, and execution, fully explain the outcomes that Professor Shapiro focuses on for specific modem chip suppliers. For example, Marvell was regarded as not having a LTE roadmap, and its aforementioned inability to meet delivery deadlines caused it to lose not only a major customer but, according to some, credibility more generally. Nvidia misjudged the size of the mid-tier mobile device segment it targeted, and its SoCs, which integrated its high-performance application processor onto modem chips that lacked features required for high-end

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mobile devices, were not attractive for higher-end mobile devices. ST-Ericsson’s R&D was inefficient, which ST-Ericsson [REDACTED] suppliers.

36. Second, Professor Shapiro’s claim that Qualcomm’s licensing practices harmed its modem chip rivals is unsupported.

- a. Professor Shapiro does not explain his claim that an ability to negotiate exhaustive licenses for Qualcomm’s cellular SEPs would provide Qualcomm’s modem chip rivals with “a valuable option.” He ignores the many other cellular SEP holders that do not typically offer exhaustive component-level licenses to modem chip suppliers. He also ignores that modem chip suppliers develop and sell other mobile device inputs other than modem chips, which affects their relationships with OEMs.
- b. Tellingly, Professor Shapiro does not explain how numerous modem chip suppliers have succeeded despite not having an exhaustive component-level license to Qualcomm’s SEPs. For example, modem chip suppliers such as MediaTek, Spreadtrum, HiSilicon, Samsung S-LSI, and Intel have succeeded in developing and marketing large volumes of modem chips irrespective of not having an exhaustive component-level patent license from Qualcomm.
- c. Professor Shapiro’s suggestion that modem chip suppliers’ lack of exhaustive component-level licenses for Qualcomm’s SEPs “discourages investment” is unsupported. His only supporting example is a joint venture in which [REDACTED]

[REDACTED] Moreover, Professor Shapiro did not evaluate the net effect of the decision. The individual firms continued to invest in modem chip development after the joint venture agreement was terminated. At the time the joint venture was terminated, [REDACTED]


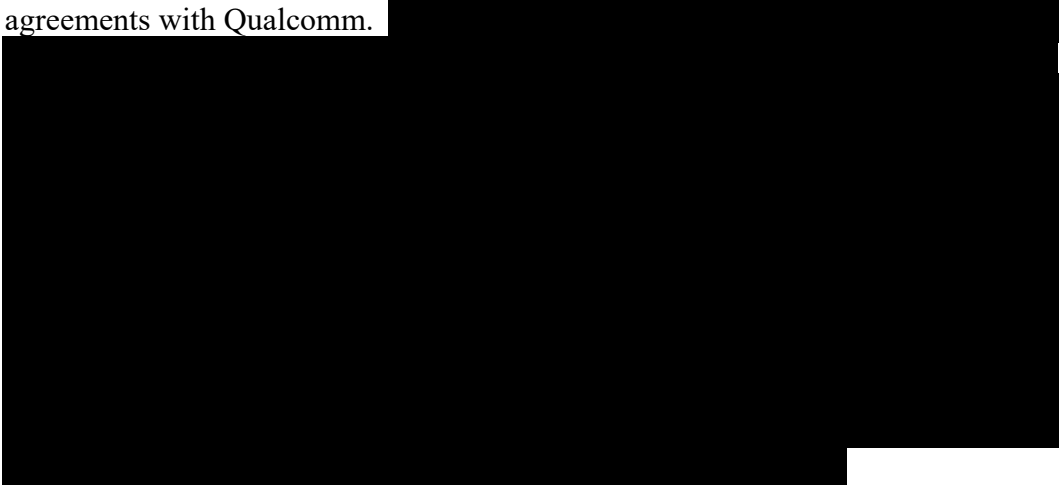
[REDACTED] Other partners in the initial joint venture formed another joint venture to develop and sell modem chips.

37. Third, Professor Shapiro’s claim that Qualcomm’s “exclusive dealing” agreements with Apple weakened its modem chip rivals is unsupported.

- a. Professor Shapiro’s suggestion that Broadcom’s and ST-Ericsson’s exits from the modem chip industry were caused by Apple’s “exclusive dealing” agreements with Qualcomm is unsupported. [REDACTED]

[REDACTED], Broadcom acquired Renesas to accelerate its LTE modem chip development, [REDACTED]

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- b. Professor Shapiro’s claim that Intel would have won sales of thin modems to Apple earlier absent Apple’s “exclusive dealing” agreements with Qualcomm is unsupported. Intel’s modem chips would not have met Apple’s requirements for reasons unrelated to Qualcomm, indicating that Apple would have continued to choose Qualcomm’s modem chips in the absence of its “exclusive dealing” agreements with Qualcomm.
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### III. INDUSTRY ANALYSIS

38. In this section, I first review fundamental industrial organization principles and then frame their relevance to the modem chip industry.<sup>28</sup> Along with neo-classical factors such as economies of scale, economies of scope, and learning, the modem chip industry is distinctive in that successive and increasingly costly investments in new generations of products are important. The process of developing a new standard or release within a standard is far from deterministic, which introduces other dimensions on which modem chip suppliers compete. Suppliers can therefore benefit both from aligning with the demands of OEMs, such as integration of the modem chip with other mobile device components, and from foreseeing the

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<sup>28</sup> For examples of the application of industrial organization economics to analyze industries, see Scherer, F.M., and David Ross, *Industrial Structure and Economic Performance*, Boston: Houghton Mifflin, 1990, and Masten, Scott E., James W. Meehan, and Edward A. Snyder, “The Costs of Organization,” *Journal of Law, Economics, & Organization*, Vol. 7, No.1, Spring 1991, pp. 1–23.

technological evolution of cellular network technologies, which can allow a supplier to become the “first to market.” In this regard, modem chips may be differentiated based on features that are important to network carriers and OEMs. In general, the investments required for leading-edge products are greater and more specific. Hence, the development and supply of such products pose greater organizational challenges compared to the supply of lower-end products.

39. In the balance of the section, I conduct an in-depth analysis of the modem chip industry, which includes descriptions of modem chip suppliers and purchasers as well as explanations of how individual modem chip suppliers and OEMs have chosen to organize and compete. The industry analysis yields insights into OEMs’ decisions regarding the number and identity of their modem chip suppliers as well as into the matching of modem chip suppliers to OEM purchasers. Given the critical role of R&D in the context of discrete technological advances, relatively few modem chip suppliers compete effectively for technological leadership at any one time but the identities of successful firms change. The analysis underscores the importance of (a) foresight, (b) efficient investment in technologies, and (c) execution of strategies.

#### **A. Industrial organization principles**

40. All industries involve a combination of competition and cooperation. Competition is well understood as the rivalry among firms selling similar products. Firms seek to increase sales by developing superior products, offering attractive terms, and servicing customers. In some models of competition, larger numbers of firms correspond to more intense competition. Such is the case when small, efficient firms sell the same, undifferentiated products. If one firm fails to offer competitive terms and products, then it will quickly lose customers.<sup>29</sup> In other contexts, competition focuses on efforts to develop leading-edge products and customize products for buyers.<sup>30</sup> The intensity of competition in such contexts is not derived from the potential for

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<sup>29</sup> For example, in the Cournot model, which is a commonly used model of competition between firms selling undifferentiated products, the equilibrium price decreases as the number of firms increases. See, e.g., Tirole, Jean, *The Theory of Industrial Organization*, Cambridge, MA: MIT Press, 1988, p. 220-21.

<sup>30</sup> When buyers are differentiated in their preferences, as is the case for OEMs purchasing customized products, classical models of competition find that the number of firms competing is not directly linked to the intensity of competition, but instead to other variables such as the initial fixed costs of production. See, e.g., Tirole, Jean, *The Theory of Industrial Organization*, Cambridge, MA: MIT Press, 1988, pp. 282–285 (describing the “Circular City” model of competition with differentiated buyers).

frequent and large shifts in market shares, but rather from the divergent consequences of success and failure over time.

41. Most cooperative efforts are organized within firms, whose activities are influenced by neo-classical principles such as the extent of economies of scale (the range of production over which average costs decline) and the extent of economies of scope (the efficiencies gained by producing multiple products compared to fewer or a single product).<sup>31</sup> Technological advancements may change the extent of such economies. Similarly, potential learning and knowhow realized from prior development efforts and production may influence what economic activities are undertaken by individual firms.<sup>32</sup>
42. So-called transaction costs influence how an industry develops, how firms are organized, and how relationships between suppliers and customers evolve.<sup>33,34</sup> Crucially, when buyers and sellers need to invest substantially in specific assets whose next best use is substantially lower, spot market transactions will not provide the incentives to make investments and will not

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<sup>31</sup> While firms may achieve various efficiencies (economies of scale, economies of scope, learning, and adaptability), they also may be burdened by agency costs and bureaucracy. See, e.g., Baumol, William J. et al., *Contestable Markets and the Theory of Industry Structure*, Harcourt Brace Jovanovich, 1982, p. 71 showing that overall scale economies result from product-specific economies of scale and/or scope. Multi-unit (M form) firms are viewed as attempting to reduce such costs compared to single-unit (U form) firms. See, e.g., Williamson, Oliver E., “Transaction Cost Economics,” edited by Schmalensee, Richard and Robert D. Willig, *Handbook of Industrial Organization*, Vol. 1, Elsevier Science Publishers B.V., 1989, p. 154 (“[...T]he bureaucratic disabilities to which internal organization is subject vary with the internal structure of the firm. Multidivisionalization, assuming that the M-form is feasible, serves as a check against the bureaucratic distortions that appear in the unitary form (U-form) of enterprise.”).

<sup>32</sup> This “technological” theory of the firm is described, for example, in section 1.2 in Tirole, Jean, *The Theory of Industrial Organization*, Cambridge, MA: MIT Press, 1988, pp. 18–21, which details how the size and number of firms can be explained by efficiencies arising from economies of scale and technological synergies.

<sup>33</sup> See, e.g., Williamson, Oliver E., “Transaction Cost Economics,” in Schmalensee, Richard and Robert D. Willig, *Handbook of Industrial Organization*, Vol. 1, Elsevier Science Publishers B.V., 1989, p. 144 (“[...T]ransaction cost economics holds that a condition of large numbers bidding at the outset does not necessarily imply that a large numbers bidding condition will obtain thereafter. Whether ex post competition is fully efficacious or not depends on whether the good or service in question is supported by durable investments in transaction specific human or physical assets. Where no such specialized investments are incurred, the initial winning bidder realizes no advantage over nonwinners.”) and p. 176 (“Transaction cost economics [...] maintains the rebuttable presumption that nonstandard forms of contracting, of which vertical integration is an extreme form, have the purpose and effect of economizing on transaction costs. It thus focuses on whether the transactions in question are supported by investments in specific assets.”).

<sup>34</sup> This theory views firms as a way to reduce costs of long-run relationships. See, e.g., “The Firm as a Long-Run Relationship,” section 1.3 in Tirole, Jean, *The Theory of Industrial Organization*, Cambridge, MA: MIT Press, 1988, pp. 21–29.

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protect firms from the dependencies resulting from such investments.<sup>35</sup> Whenever industry participants make specific investments, whether they involve technology, physical assets, timing, or location, they are subject to opportunism.<sup>36</sup> In such cases, the choices made by firms among various alternative means of organizing economic activity – i.e., long-term contracts, so-called relational contracting, quasi-vertical integration, or vertical integration – will depend on the *differences* in the costs of these alternatives.<sup>37,38</sup>

43. Long-term contracts provide a horizon during which firms can earn returns on their investments and preserve opportunities for firms to compete for new contracts. Contracts, however, cannot anticipate all relevant contingencies and so the parties face potential costs of

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<sup>35</sup> See, e.g., Williamson, Oliver E., “Transaction-Cost Economics: The Governance of Contractual Relations,” *Journal of Law and Economics*, Vol. 22, No. 2, 1979, p. 241 (“[...W]hereas recurrent spot contracting is feasible for standardized transactions [...], such contracting has seriously defective investment incentives where idiosyncratic activities are involved. [...]ost economies in production will be realized for idiosyncratic activities only if the supplier invests in a special-purpose plant and equipment or if his labor force develops transaction-specific skills in the course of contract execution (or both). The assurance of a continuing relation is needed to encourage investments of both kinds.”).

<sup>36</sup> The classic example is a firm that invests in tooling specific to one buyer. Absent contractual protections and putting aside reputational concerns, the buyer will reduce the price it is willing to pay the seller once the seller has made the necessary investment. See, e.g., Williamson, Oliver E., “Transaction-Cost Economics: The Governance of Contractual Relations,” *Journal of Law and Economics*, Vol. 22, No. 2, 1979, p. 234 (“[...O]ppportunism is especially important for economic activity that involves transaction-specific investments in human and physical capital [...] [footnote omitted]”) and p. 242 (“Although both [buyer and seller] have a long-term interest in effecting adaptations of a joint profit-maximizing kind, each also has an interest in appropriating as much of the gain as he can on each occasion to adapt.”).

<sup>37</sup> See, e.g., Coase, Robert, “The Nature of the Firm,” *Economica*, Vol. 4, No. 16, 1937, pp. 390–391 (“The main reason why it is profitable to establish a firm would seem to be that there is a cost of using the price mechanism. The most obvious cost of ‘organising’ production through the price mechanism is that of discovering what the relevant prices are. [...] The costs of negotiating and concluding a separate contract for each exchange transaction which takes place on the market must also be taken into account. [...] It may be desired to make a long-term contract for the supply of some article or service. This may be due to the fact that if one contract is made for a longer period, instead of several shorter ones, then certain costs of making each contract will be avoided. [Footnotes omitted].”). See also Simon, Herbert A., “Rationality as Process and as Product of Thought,” *The American Economic Review*, Vol. 68, No. 2, May 1978, p. 7 (“What is the predominant form of reasoning that we encounter in these theoretical treatments of social institutions? [...] Particular institutional structures or practices are seen to entail certain undesirable (for example, costly) or desirable (for example, value-producing) consequences. *Ceteris paribus*, situations and practices will be preferred when important favorable consequences are associated with them, and avoided when important unfavorable consequences are associated with them. [...]Increasing awareness of [a consequence and] new technical devices may tilt the balance between centralization and decentralization.”).

<sup>38</sup> Vertical integration refers to a firm’s contribution to multiple steps in the production of a final output. See, e.g., Scherer, F.M., and David Ross, *Industrial Market Structure and Economic Performance*, Boston: Houghton Mifflin, 1990, p. 94 (“Vertical integration in the static sense describes the extent to which firms cover the entire spectrum of production and distribution stages.”).

adjustments, haggling,<sup>39</sup> and renegotiations.<sup>40,41</sup> By contrast, vertically integrated firms have advantages both in generally adapting to new conditions and in developing and transferring knowledge within the firm, but such firms lose high-powered incentives associated with individual businesses.<sup>42</sup> Intermediate approaches whereby a buyer owns the physical assets that are used by suppliers to produce customized products may work in some circumstances, but such approaches are less useful when the specific assets involve knowhow, learning, and technology.<sup>43</sup>

44. The principles of industrial organization predict, therefore, that industries will organize their economic activity and their transactions with suppliers and customers on a continuum.<sup>44</sup> When assets are not specific and, as a result, buyers and sellers can easily match up, the industry will

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<sup>39</sup> Asset-specific investments by suppliers and customers generate so-called quasi-rents. While contracts specify how these rents will be divided, the incomplete character of contracts means that the parties have incentives to engage in costly haggling. For a discussion, see, e.g., Klein, Benjamin et al., “Vertical Integration, Appropriable Rents, and the Competitive Contracting Process,” *The Journal of Law & Economics*, Vol. 21, No. 2, October 1978, pp. 297–326.

<sup>40</sup> See, e.g., Williamson, Oliver E., “Transaction-Cost Economics: The Governance of Contractual Relations,” *Journal of Law and Economics*, Vol. 22, No. 2, 1979, pp. 250–251 (“Problems [...] arise when adaptability and contractual expense are considered. [...] Unless the need for adaptations has been contemplated from the outset and expressly provided for by the contract, which often is impossible or prohibitively expensive, adaptations across a market interface can be accomplished only by mutual, follow-on agreements.”).

<sup>41</sup> This theory relates firms to the impossibility of having complete contracts between business partners, i.e., contracts that specify an action for all possible contingencies. See, e.g., section 1.4, “The Firm as an Incomplete Contract,” in Tirole, Jean, *The Theory of Industrial Organization*, Cambridge, MA: MIT Press, 1988, pp. 29–34.

<sup>42</sup> See, e.g., Williamson, Oliver E., “Comparative Economic Organization: The Analysis of Discrete Structural Alternatives,” *Administrative Science Quarterly*, Vol. 36, No. 2, 1991, p. 279 (“As compared with the market, the use of formal organization to orchestrate coordinated adaptation of unanticipated disturbances enjoys adaptive advantages as the condition of bilateral dependency progressively builds up. But these adaptation [...] gains come at a cost. [...] internal organization degrades incentive intensity, and added bureaucratic costs result [...].”).

<sup>43</sup> See, e.g., Williamson, Oliver E., “Comparative Economic Organization: The Analysis of Discrete Structural Alternatives,” *Administrative Science Quarterly*, Vol. 36, No. 2, 1991 for a discussion of intermediate forms of organizational structures.

<sup>44</sup> Williamson, Oliver E., “Transaction-Cost Economics: The Governance of Contractual Relations,” *Journal of Law and Economics*, 1979, Vol. 22, pp. 244–245 (“[...] Special governance structures supplant standard market-cum-classical contract exchange when transaction-specific values are great.”) and pp. 247–248 (“The market is the classic nonspecific governance structure within which ‘faceless buyers and sellers ... meet ... for an instant to exchange standardized goods at equilibrium prices.’ By contrast, highly specific structures are tailored to the special needs of the transaction. Identity here clearly matters. Semi-specific structures, naturally, fall in between.”).

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feature market transactions, minimal contracting, and, in the extreme, spot transactions. Industries in the intermediate range of the continuum will rely on contracts with greater complexity and protections to encourage investment in specific assets. While contracts typically do not minimize prices at all points in time, the parties gain protections and reduce transaction costs.

45. Sourcing from multiple suppliers offers the advantage of actual competition among suppliers at a given point in time, but this strategy increases transaction costs and sacrifices the benefits from sourcing from the single supplier that offers the best terms, products, and service. These advantages and disadvantages are, therefore, traded off when firms shift to exclusive or nearly exclusive supply relationships, which typically are governed by long-term contracts. Such contractual relationships may be framed in terms of long-term relationships – so-called relational contracting – that encourage adaptation during the duration of the current contract and motivate cooperation generally based on the prospect of future contract renewals.<sup>45</sup> But relational contracting does not prevent the buyer from changing suppliers or adding suppliers; nor does it prevent the seller from shifting its future supply to other buyers. Toward the end of the continuum is vertical integration. Some firms that are integrated into the supply of inputs may decide to both sell to other buyers and source inputs from other suppliers. At the end of the continuum, the firms’ production and use of inputs are both internal.<sup>46</sup>

### **B. Implications for organizing economic activity in the modem chip industry**

46. While I go into more depth concerning various industry factors in the balance of this section, and profile individual modem chip suppliers in Section V, it is useful at this juncture to identify

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<sup>45</sup> See, e.g., Williamson, Oliver E., “Transaction-Cost Economics: The Governance of Contractual Relations,” *Journal of Law and Economics*, 1979, Vol. 22, p. 248 (“[... R]elational contracting develops for transactions of a recurring and nonstandardized kind[.]”) and p. 251 (“[...] parties have an incentive to sustain the relationship rather than to permit it to unravel, the object being to avoid the sacrifice of valued transaction-specific economies.”).

<sup>46</sup> See, e.g., Williamson, Oliver E., “Transaction-Cost Economics: The Governance of Contractual Relations,” *Journal of Law and Economics*, 1979, Vol. 22, pp. 252–253 (“Incentives for trading weaken as transactions become progressively more idiosyncratic. The reason is that ,as the specialized human and physical assets become more specialized to a single use, and hence less transferable to other uses, economies of scale can be as fully realized by the buyer as by an outside supplier. [...] Vertical integration will invariably appear in these circumstances.”).

particularly relevant industry factors and indicate their overall implications on the organization of firms in the modem chip industry.

47. The combination of (a) substantial up-front costs associated with the development and design of modem chips and the required physical capital costs, and (b) low marginal costs of production results in substantial *economies of scale* for suppliers.<sup>47</sup> For example, while modem chip suppliers at the leading edge of the industry can spend substantial amounts on modem chip-related R&D,<sup>48</sup> the marginal cost of producing a modem chip can be less than \$10.<sup>49</sup> Evidence also indicates that suppliers benefit from *economies of scope*. For example, modem chip suppliers who produce multiple different modem chips can achieve efficiency in their R&D by transferring successful R&D investments in the development of one particular chip to other models.<sup>50</sup> In addition, the evidence on prices, summarized in Exhibit VI.B.1, demonstrates that the average price of modem chips within specific categories has declined substantially over time. For example, the average price for CDMA modem chips fell from about \$13 in Q1 2008 to under \$5 in Q4 2017. Over the period from Q1 2012 to Q4 2017, the average price for LTE 4G modem chips fell from about \$25 to about \$13.<sup>51</sup> Both learning in production, whereby costs decline with cumulative output, and product-cycle effects, whereby price-cost margins on innovative products start out high but decline over time, exert downward pressures on prices.
48. These fairly common industry factors (economies of scale and scope, learning, product-cycles) coexist with a less common factor in the modem chip industry: successive shifts from one generation of wireless standards to the next,<sup>52</sup> with each shift involving a discontinuous change

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<sup>47</sup> See, e.g., Hill, Charles W.L., et al., *Strategic Management: Theory: An Integrated Approach*, 9<sup>th</sup> Ed., Stamford, CT: Cengage Learning, 2010, p. 119 (“One source of economies of scale is the ability to spread fixed costs over a large production volume.”).

<sup>48</sup> See Exhibit III.E.1 and Section III.E.2.b.ii for additional details on R&D spending by modem chip suppliers.

<sup>49</sup> For example, Qualcomm’s marginal cost of producing six different thin modems for Apple was between \$6 and \$9 in Q4 2016. See Q2014FTC00550655–0660 at 0660, email from Sanjay Mehta, Qualcomm, April 29, 2013, with attached presentation slides for Board of Directors, p. 2.

<sup>50</sup> See Section III.C.2.b for additional details.

<sup>51</sup> See Exhibit VI.B.1.

<sup>52</sup> See Section III.C.2.a for additional details about wireless standards.

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in the required product characteristics. For leading-edge, innovative suppliers, shifts to the next generation entail increasingly large investments in R&D as well as product design, the returns on which are highly variable and depend in large part on the supplier’s strategic foresight and efficiency in R&D.<sup>53</sup> Success on the leading edge of the modem chip industry demands meeting the broad functional requirements of the next-generation modem chips, designing products that match customer requirements, and being first or nearly first to market. In addition, because the standards and customer requirements include a mix of necessary and discretionary functionalities, leading modem chip suppliers must make bets on product characteristics that they believe will be most salient. Modem chips *within* generations are differentiated on many characteristics, such as backward compatibility, data transmission speed, energy use, and the integration of modem chips with other processors used in mobile devices. In addition, products of a given generation are further customized for particular OEM purchasers. Because modem chip as well as mobile device technologies have been improving at a fast pace even within generations, the success of a modem chip supplier is greatly influenced by its ability to continue producing modem chips that achieve these within-generation improvements.

49. Consistent with accepted industrial organization principles, investments by both suppliers and buyers in relatively short-lived, specific assets are far from automatic due to bilateral concerns about opportunism. Indeed, at any point in time and over time, supplying increasingly innovative products involves particularly acute organizational challenges.<sup>54</sup> As in many innovative industries, the number of firms at the leading edge of innovation is limited. In the modem chip industry, firms with foresight, efficient R&D strategy, and the ability to execute

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<sup>53</sup> For example, Exhibit III.E.1 shows that, in general, modem chip-related R&D spending has increased over the last decade for several modem chip suppliers. Moreover, anecdotal evidence suggests that R&D spending per new modem chip has also increased. For example, in 2013 Qualcomm noted that the stalling of Moore’s law has economic implications: “[t]ransistor scaling continues while economic scaling stalls” and that “[p]remium-tier product cost increases.” See Q2014FTC00014383, presentation titled “QCT Strategic Plan 2013,” Qualcomm, July 15, 2013, p. 7.

<sup>54</sup> The best strategy for meeting these organizational challenges may depend on the type of innovation, and organizational strategy may in turn influence innovation. See, e.g., Teece, David J., “Firm Organization, Industrial Structure, and Technological Innovation,” *Journal of Economic Behavior and Organization*, Vol. 31, 1996, p. 216 (“The diversity of observed forms [of organizational arrangements] in and of itself suggests that different organizational arrangements are suited to different types of competitive environments and differing types of innovation.”) and p. 222 (“[...F]irm organization (not just product market structure) must be recognized as an important determinant of innovation [...].”).

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are more likely to succeed and position themselves for future efforts. But prior success and the associated learning advantages, as discussed in my subsequent review of individual firm profiles, are neither necessary nor sufficient for future success. Staying on the leading edge requires more than having been on the leading edge. A supplier with success in one generational context may not, for example, forecast industry dynamics and invest accordingly.

50. While leading-edge innovations are of great importance in the modem chip industry, opportunities for trailing-edge competition are substantial because product generations *overlap*. Some OEMs produce mobile devices that use older generations of modem chips that are less expensive for two reasons: the original investments in their R&D were lower, and the trailing-edge modem chips are later in their product cycles. Hence, where demand is not all focused on the leading edge, the industry can accommodate larger numbers of trailing-edge competitors whose strategy is to spend less on R&D and who instead seek advantages in product design and product “resets,” whereby products within a given category are improved on various dimensions, e.g., power consumption. In addition, trailing-edge firms can compete by differentiating their products from their competitors’, for example, by providing sets of complementary technologies.<sup>55</sup>
51. These implications from industrial organization principles are clarified by categorizing modem chip products on two dimensions: (1) leading edge vs. trailing edge and (2) low customization vs. high customization. The increasingly large investments in product development and product differentiation occur on the “leading edge” and where “high customization” is required. Where demand is focused on the leading edge and highly customized products, the industry will tend to have fewer actual suppliers of these products. By contrast, products on the “trailing edge” and where only “low customization” is required entail not only lower levels of investment but also less specificity. As a result, the industry will be expected to have larger

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<sup>55</sup> See, e.g., Goldstein, Phil, “Intel, MediaTek, Broadcom and Nvidia Try to Catch Up to Qualcomm in LTE,” *FierceWireless*, January 10, 2014 (“[...] Qualcomm’s competitors are not standing still and are doing everything they can to catch up. [...] Executives from rival companies said they are seeing momentum on LTE and expect to increase that in 2014. [...] Rango [Executive Vice President of Broadcom’s mobile and wireless group] said Broadcom will differentiate itself in the LTE market by bringing ‘a tremendous suite of complementary technologies.’ He noted that Broadcom can support different Wi-Fi usage models, and that its GPS chips, which are all part of the single SoC, are more advanced than others since they use multiple satellite constellations.”).

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numbers of actual competitors for these products. Note, however, that this categorization does not imply that separate markets exist for highly customized, high-end products and less customized, low-end products, and that I do not address market definition issues here.<sup>56</sup>

52. In the period leading up to a new generation of modem chips, aspirant innovative suppliers seek to engage their customers, OEMs, as well as network carriers, to understand what specifications will emerge as required to meet the standards and what additional specifications will be valued. This activity, along with efforts to develop customized products, requires co-development of knowledge between suppliers of modem chips and their customers. Not surprisingly, given the need to accurately assess future demand, make investments, and prepare for large-scale production, firms within the modem chip industry are not all equally capable. Indeed, modem chip suppliers are expected to have different capabilities in terms of competing at the leading edge and in differentiating their products. Some of these differences may be attributed to prior success and the importance of learning, which oftentimes go together.<sup>57</sup> However, the extent to which prior success and learning carry forward may depend on factors that are difficult to discern, including the ability of a firm to distill knowledge and manage knowledge transfers over time between its design and production teams.
53. As increasingly large amounts of R&D are embodied in leading-edge modem chips, the challenge in the development and transfer of knowledge becomes more difficult. This is one of the most difficult challenges for any industry: Who owns the knowledge created in designing customized products? How should firms be compensated, if at all, for their investments? How can an innovative firm charge for knowledge without revealing its value to the potential recipient? This challenge is especially acute in the modem chip industry given the size of investments required for leading modem chip suppliers, the succession of such investments, and the ongoing efforts to differentiate products once threshold functional requirements are met.

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<sup>56</sup> I understand that another expert, Dr. Tasneem Chipty, is addressing market definition issues on behalf of Qualcomm.

<sup>57</sup> Learning reduces costs for suppliers, potentially in design and production. The extent of learning, in general, depends on prior product development and prior production volumes. See, e.g., Arce, Daniel G., “Experience, Learning, and Returns to Scale,” *Southern Economic Journal*, 2014, Vol. 80, No. 4, p. 938 (“Indeed, capturing market share is legitimized as a managerial objective specifically because of the cost efficiencies that arise from the experience curve.”).

54. Consistent with general industrial organization principles, the industry analysis presented in the rest of this section reveals that firms’ organizational choices have changed over time and that firms make different choices based on their product strategies. These changes do not reflect that the organization challenges are new. Indeed, suppliers and buyers faced these challenges with the first generation of modem chips. But over time, the nature of the challenges has evolved due to the increased value of R&D into both hardware and software, the increased importance of design, and the substantial complementary investments made by buyers. Given the costs of adjustments, some firms have become more vertically integrated in recent years to encourage the development and transfer of a broad range of information within the firm. Supplier–OEM relationships and the extent of sourcing from multiple suppliers are also found to differ based on the OEM’s product strategies, e.g., whether the OEM purchases many types of modem chips, and its mix of lower-end and higher-end modem chips. If high-end economic activity is more relevant for a firm, then alternative approaches to organizing, contracting and relational contracting, become more viable. But as indicated at the outset, the determination of how firms organize their activity and supplier–buyer relationships depends on the differences in transaction costs among different types of organizational alternatives. If a buyer can induce investments by actual and potential suppliers, then the advantages to vertical integration are reduced compared to having long-term contracts and relational contracting.<sup>58</sup> Problems with these alternatives may arise, however, if either party can transfer the design and knowhow to others.
55. Also, as would be expected given industrial organization principles, industry structure has evolved with relatively fewer actual competitors at the leading edge and relatively more actual competitors for lower-end products. The former is due not only to the large investments required and the winnowing effects of other important capabilities to be at the leading edge, but also to the tendency of buyers to source from only one or two suppliers of high-end products. The greater number of actual competitors at the trailing edge is due to the opposite

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<sup>58</sup> See, e.g., Williamson, Oliver E., “Transaction-Cost Economics: The Governance of Contractual Relations,” *Journal of Law and Economics*, 1979, Vol. 22, p. 253 (Highlighting that “[t]he advantage of vertical integration is that adaptations can be made in a sequential way without the need to consult, complete, or revise interfirm agreements. Hence, to the extent buyers can induce adaptations without incurring high-transaction costs, long-term contracts and relational contracting may be feasible options.”).

influences, i.e., lower levels of investment, less stringent requirements in terms of judgment, and the willingness of buyers to source from multiple suppliers.

56. The intensity of competition to supply high-end products need not, however, be less than the lower-end products. Based on industrial organization principles, innovative products typically have higher price-cost margins that decline over the products’ life cycle. The stakes for firms competing on the leading edge are also intense because of the difference between success and failure. One related implication is worthy of mention: the competition to secure new contracts with major buyers is expected to be particularly intense, especially for next generation products and for customized products. Buyers may face difficult choices such as whether to consider new suppliers given that doing so entails additional costs. Similarly, suppliers may be vulnerable to opportunism when they have co-developed new designs with buyers in advance of the new product.

### **C. Mobile devices, modem chips, and the evolution of wireless standards**

#### **1. Mobile devices and their components**

57. Mobile devices, or devices that provide mobile (cellular) access,<sup>59</sup> take many forms: mobile phones or “handsets” (including basic phones, feature phones, and smartphones),<sup>60</sup> tablets, laptops and other personal computers, Internet of Things (“IoT”) devices,<sup>61</sup> and Machine-to-

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<sup>59</sup> Cellular access refers to the technology that allows mobile devices to communicate through areas made of cells and transceivers. See, e.g., “Cell,” in Newton, Harry, *Newton’s Telecom Dictionary*, 31<sup>st</sup> Edition, 2018, p. 268 (“Cell is the basis for the generic industry term ‘cellular.’ A city or county is divided into smaller ‘cells,’ each of which is equipped with a base station containing low-powered radio transmitters/receivers.”).

<sup>60</sup> Basic mobile phones support only voice calls and basic text messaging. Feature phones offer some functionality beyond this, such as email and internet connectivity. Smartphones offer yet more functionality, such as support for downloaded applications (“apps”), and typically include a user interface, displayed on an interactive screen, that allows consumers to launch applications, surf the Internet, take and view photographs, and other functions. The distinctions among these types of mobile phones, particularly between feature phones and smartphones, may not always be clear-cut. See, e.g., “Definition of: feature phone,” PCMag (“feature phone[:] A cellphone that contains a fixed set of functions beyond voice calling and text messaging but is not as extensive as a smartphone. For example, feature phones may offer Web browsing and email, but they generally cannot download apps from an online marketplace.”).

<sup>61</sup> See, e.g., “Internet of Things,” in Newton, Harry, *Newton’s Telecom Dictionary*, 31<sup>st</sup> Edition, 2018, p. 678 (“The Internet of Things is a generic name for a very broad industry ‘producing’ communicating, sensing, measuring, alarming, computing devices” attached to the Internet. “With it, you should be able to monitor and adjust processes in factories, monitor and adjust irrigation and fertilizing equipment in agriculture, alert patients to changes in their health [...].”).

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Machine (“M2M”) products,<sup>62</sup> among others. In the remainder of my report, I use the term “mobile devices” to refer generally to any of the above types of mobile devices and the term “handset” to refer specifically to mobile phones.

58. Mobile devices may also incorporate additional types of connectivity, such as Wi-Fi or Bluetooth, that work only over short distances. By contrast, cellular connectivity allows a device to communicate with a cell site that may be tens of miles away – and to switch seamlessly among cell sites as the device travels across long distances.<sup>63</sup> Cellular networks therefore provide connectivity over a large geographical area, making cellular access fundamental to mobile devices’ functionality.
59. A key component that allows a mobile device to connect to a cellular network is the **modem chip**.<sup>64</sup> In a mobile device, the modem is a piece of hardware and associated software, typically implemented as a chip or chipset, that encodes information from the mobile device for transmission over radio, and vice-versa decodes radio into information for the mobile device to work with. That information may take the form of voice, text, or other data.<sup>65</sup>
60. Modem chips therefore are critical to allowing mobile devices to send and receive calls, text messages, and data over cellular networks. Modem chips can be specifically designed or

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<sup>62</sup> Machine to Machine products are devices connected to other devices and the Internet. They include fitness trackers, healthcare devices, and household appliances, among many other products. See, e.g., “Wireless M2M/IoT Markets,” Forward Concepts, 2015, p. 1.

<sup>63</sup> See, e.g., Kernighan, Brian W., *Understanding the Digital World: What You Need to Know About the Internet, Privacy, and Security*, Princeton University Press, 2017, p. 132 (“Phones talk to the closest base station, and when they move from one cell to another, a call in progress is handed off from the old base station to the new one [...]. Cell sizes vary, from a few hundred meters to a few tens of kilometers.”).

<sup>64</sup> Even though I understand that modems are sometimes implemented on more than one chip, i.e., in a chipset, whenever unambiguous I call “modem chip” the unit involved in the modem functionalities of a mobile device, for brevity.

<sup>65</sup> A modem chip is a chip that performs the function of a modem. For a definition of modem, see, e.g., “Modem,” in Newton, Harry, *Newton’s Telecom Dictionary*, 31<sup>st</sup> Edition, 2018, p. 824 (“A modem modulates (varies the characteristics of) an analog signal to carry digital information from a computer or other digital source; on the receiving end, a modem demodulates an analog carrier signal to extract the digital information the signal is carrying so that a computer or other digital device can use it.”).

optimized for different types of devices, such as from high-end to mid- or low-cost smartphones or non-handset devices such as wearables or IoT devices.<sup>66,67</sup>

61. In order for a modem chip to communicate with a cellular network, it must use the same communication protocols and technologies as the other network components. To facilitate compatibility, protocol and technology specifications are enshrined in wireless standards.<sup>68</sup> As addressed in more detail below, wireless standards have evolved extensively over time. For a modem chip to utilize a new wireless standard or release, network operators must have deployed a network using that standard or release, the chip must support that standard or release, and the device incorporating that chip must be certified by the network operators.<sup>69</sup> As discussed below, both mobile networks and modem chips can be capable of supporting multiple wireless standards. A modem chip capable of supporting a mobile device that can connect with multiple wireless standards is known as a “multi-mode” modem chip.<sup>70</sup>

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<sup>66</sup> See, e.g., Smith, Ryan, “Qualcomm Announces 205 Mobile Platform: Entry-Level LTE for India & Emerging Markets,” AnandTech, March 20, 2017.

<sup>67</sup> For example, Qualcomm repurposed its smartphone Snapdragon chip to develop the Snapdragon Wear 2100, which is dedicated solely to wearable devices such as Android Wear smart watches. See, e.g., Kaul, Aditya, “Qualcomm’s New Wearable SoC Could Trigger Growth in Standalone Wearables,” Tractica, February 16, 2016. Similarly, Intel’s Edison and Curie platforms were designed for IoT and wearable technology. See, e.g., Smith, Ryan, “IDF 2014: Intel Edison Development Platform Now Shipping,” AnandTech, September 9, 2014.

<sup>68</sup> See, e.g., “What are Standards? Why are They Important?,” IEEE Standard Association, October 3, 2011 (“Standards form the fundamental building blocks for product development by establishing consistent protocols that can be universally understood and adopted. This helps fuel compatibility and interoperability and simplifies product development, and speeds time-to-market.”).

<sup>69</sup> A standard must be supported by both ends of the communication link, the modem chip and the network (i.e., cell towers, etc.). Network operators certify this interoperability. For example, Verizon defined some criteria that modem chip manufacturers must satisfy. See, e.g., VZ-00004851–4880 at 4855 (“The goal of the chipset certification testing and approval process is to define a uniform set of criteria that will be used for all chipsets to evaluate its capabilities and conformance to industry and Verizon Wireless specifications, before it is approved to be listed in the Verizon Wireless CERTIFIED chipset List.”).

<sup>70</sup> See, e.g., “Qualcomm Introduces World’s First Complete Multi-mode 3G/LTE Integrated Solution for Smartphones,” Qualcomm Press Release, February 16, 2009 (“Multi-mode 3G/LTE chipsets will be crucial to smooth deployments of LTE by operators who are looking to complement their existing 3G networks, and the MSM8960 delivers maximum flexibility by supporting [CDMA2000] EV-DO Rev. B and HSPA+ in addition to LTE’ [...].”). See also “Intel Announces First Commercial Availability of 4G LTE Modem; Introduces Module for 4G Connected Tablets and Ultrabooks,” Intel Press Release, October 30, 2013 (“The Intel XMM 7160 is one of the world’s smallest and lowest-power multimode, multiband solutions [...]. The solution provides seamless connectivity across 2G, 3G and 4G LTE networks [...].”).

62. Within a mobile device, the modem chip is located on the motherboard (referred to as the “logic board” in Apple products), which contains, among other components, the chips that control and direct the device’s functions.<sup>71</sup> Like other chips, modem chips are designed as integrated circuits, i.e., complicated electrical circuits packed onto a single chip.<sup>72</sup> These integrated circuits are manufactured by an iterative process: a pattern is projected onto a silicon wafer, the silicon’s conductive properties are changed according to this pattern, and this is repeated to build up the circuit; connective wires are then created by laying down layers of metal and following a similar process.<sup>73</sup> Chip manufacturing processes are differentiated by “technology nodes,” which originated as an indicator of transistor length, with smaller nodes associated with higher speeds and lower power consumption.<sup>74</sup> For example, according to Samsung, its 28nm node yields speed gains of 30 percent or power-efficiency gains of 35 percent over its 45nm node.<sup>75</sup>
63. A physical silicon chip is one requirement to connect a mobile device to a cellular network. Another requirement is the software (the “stack”) programmed to operate the hardware (i.e., chip), allowing the device to communicate with the network.<sup>76</sup> In industry parlance, the

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<sup>71</sup> See, e.g., Prowse, David L. et al., *Computer Structure and Logic*, 2<sup>nd</sup> Edition, Pearson, 2014, p. 85, Figures 3–5.

<sup>72</sup> The terms “chip” and “integrated circuit” are often used interchangeably. See, e.g., “Integrated Circuit,” in Newton, Harry, *Newton’s Telecom Dictionary*, 31<sup>st</sup> Edition, 2018, p. 663 (“An integrated circuit is a piece of silicon or other semiconductor called a chip on which is etched or imprinted a network of electronic components such as transistors, diodes, resistors, etc. and their interconnections.”).

<sup>73</sup> “The History of the Integrated Circuit,” Nobelprize.org, May 5, 2003 (Explains the “very complex process” of “[b]uilding an integrated circuit.”).

<sup>74</sup> See, e.g., Naha, Abhi and Peter Whale, *Essentials of Mobile Handset Design*, Cambridge Wireless Essentials Series, 2012, pp. 109–110. See also Cunningham, Andrew, “Samsung’s New 10nm Process Promises Big Power Efficiency Improvements,” *Ars Technica*, October 17, 2016 (“According to Samsung, 10nm chips can fit 30 percent more transistors within the same physical area as a 14nm chip. Chip designers will be able to create chips that are up to 27 percent faster or chips that use up to 40 percent less power, though most chips will probably do a little of both instead of maximizing one or the other.”).

<sup>75</sup> These figures are for Samsung’s 28nm and 45nm “LP” (Low Power) process nodes. See “Samsung Qualifies 28nm LP Process Technology for High Performance Mobile Applications,” Samsung, June 6, 2011 (“Samsung Foundry has tuned its 28nm LP process technology to deliver a cutting-edge process platform with 35 percent active/standby power reduction at the same frequency or 30 percent performance boost at the same leakage over 45nm LP SoC designs.”).

<sup>76</sup> Naha, Abhi and Peter Whale, *Essentials of Mobile Handset Design*, Cambridge University Press, 2012, p. 147 (“The protocol stack software is responsible for negotiating with the network over a wide range of different tasks.”).

“modem chip” may be used colloquially to refer not only to the physical chip, but also to the software stack, and I will adopt the same convention whenever unambiguous.<sup>77</sup> There are multiple other requirements for cellular connectivity, including the antenna and the Radio Frequency (“RF”) components.<sup>78</sup>

64. Beyond the modem chip, mobile devices require a number of other components. Some of these components are relevant mostly to advanced devices, such as smartphones. Broadly, these components fall into the categories of the operating system and the hardware.
65. Operating System: A device with a user interface, such as a feature phone or a smartphone, requires an operating system (“OS”). On a feature phone, the OS is typically specific to the device OEM; on a smartphone, the OS is often, but not always, third-party software.<sup>79</sup> Globally, the leading OS on smartphones is Google’s Android, followed by Apple’s iOS (a prime example of a smartphone OS that is not third party) and trailed more distantly by Microsoft’s Windows OS and BlackBerry’s OS.<sup>80</sup> Devices with an OS may also support the download and installation of additional software, known as applications, or “apps.”

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<sup>77</sup> See, e.g., Deposition of Steve Schell, Former Wireless Systems Architect in the Hardware Team at Apple, February 28, 2018, pp. 55–56 (“Schell Deposition, Apple”) (“Q. [...] And when you say baseband are you referring to cellular modem? Let me ask it this way. When you say baseband what do you mean, Mr. Schell? A. When I use the term baseband I refer perhaps somewhat ambiguously to either the chip functionality and/or the software functionality that executes cellular protocol stack and also executes control over the RF transceiver chips and the RF front-end components in order that that -- the totality of that can communicate with the cellular networks and communicate in Apple’s product architecture, communicate with the apps processor.”).

<sup>78</sup> See, e.g., “Antenna,” in Newton, Harry, *Newton’s Telecom Dictionary*, 31<sup>st</sup> Edition, 2018, p. 118 (“An antenna is a device that converts guided signal energy into unguided (i.e., free-space) signal energy, or vice-versa. In basic telecommunications, an antenna is a device for transmitting, receiving or transmitting and receiving radio frequency (RF) signals.”). See also Bowick, Christopher, “What’s in an RF Front End?,” EE Times, February 4, 2008 (“The RF is generally defined as everything between the antenna and the digital baseband system.”); “RF Products,” Qualcomm, available at <https://www.qualcomm.com/products/rf>.

<sup>79</sup> Lee, Nicole, “The 411: Feature Phones vs. Smartphones,” CNET, March 1, 2010 (“A smartphone, as CNET defines it, has a third-party operating system. This includes all of the phones running Android, as well as those that run on the Windows Mobile and Symbian operating systems. [...] Feature phones, on the other hand, are a midway point between smartphones and basic phones. They usually have a limited proprietary operating system, and not all feature phones support third-party software.”).

<sup>80</sup> In Q4 2016, 81.7 percent of smartphones were sold with Android OS, 17.9 percent with iOS, and 0.3 percent with Windows. Blackberry and other operating systems together accounted for only 0.1 percent. “Gartner Says Worldwide Sales of Smartphones Grew 7 Percent in the Fourth Quarter of 2016,” Gartner Press Release, February 15, 2017.

66. Hardware: A mobile device may incorporate a number of physical components beyond the modem chip:
- i. *Application Processor (“AP”)*: An application processor, which includes a central processing unit (“CPU”), allows a device to run an operating system and applications.<sup>81</sup> It also interacts with various hardware components.<sup>82</sup>
  - ii. *Graphics Processing Unit (“GPU”)*: A single-chip processor that powers images displayed by the devices, particularly in the context of videos and video games.<sup>83</sup>
  - iii. *RF components, including the RF transceiver and the RF Front End (“RFFE”)*: A group of components located between the modem chip and the external-facing antenna that transmits and receives radio signals between the modem and the cell towers.<sup>84</sup>
  - iv. *Power management components*: The power management integrated circuit (“PMIC”) regulates power consumption by the other hardware components, while the power amplifier chip increases power for specific uses.<sup>85</sup>

<sup>81</sup> See, e.g., “Cellular Handsets & Chip Markets,” Forward Concepts, 2006, p. 231 (“We define application processors as DSP-centric RISC or DSP/RISC combo chips (or cores) employed primarily for multimedia, data processing and other noncommunications functions and employ a high-level operating system (O/S).”).

<sup>82</sup> Naha, Abhi and Peter Whale, *Essentials of Mobile Handset Design*, Cambridge Wireless Essentials Series, 2012, pp. 124–125 (“A key function of an application processor is to provide high-performance capabilities for the capture, storage, transmission and playback of multimedia content. [...] The application processor is also responsible for interfacing to an increasingly large number of peripheral devices such as display, touch-screen controller, camera, audio, external memory, USB, sensors, etc.”).

<sup>83</sup> Naha, Abhi and Peter Whale, *Essentials of Mobile Handset Design*, Cambridge Wireless Essentials Series, 2012, pp. 126–127 (“With the advent of early mobile data services [...] and the addition of digital cameras to mobile handsets, the requirements for multimedia processing increased dramatically. [...] As requirements became established, it also became clear that high-performance multimedia was critical [...] and thus the market conditions were right for a new breed of separate mobile media processors, now termed graphics processor units (GPUs). GPUs are systems on a chip solutions – with their own CPU, [...], memory, power management, discrete hardware and display engines.”).

<sup>84</sup> See, e.g., “RF Products,” Qualcomm, available at <https://www.qualcomm.com/products/rf>.

<sup>85</sup> See, e.g., “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 23 (“Modern cellular handsets and other mobile devices require efficient power management devices as companions to all processors [...]. As a discrete device, it can be called a system power management unit (PMU) or power management IC (PMIC).”) and p. 281 (“The Power Amplifier (PA) enables the handset to transmit digitally encoded voice and data signals to the base station tower to route a call to another phone number or Internet address. PA’s are often the most critical radio frequency component in the phone because they normally use the greatest amount of battery power in a handset and they generally dissipate the greatest amount of heat.”).

- v. *Global positioning system (“GPS”)*: GPS allows a device to figure out its geographic location, thereby supporting functionality that allows users to track their locations and receive real-time directions while travelling.<sup>86</sup>
- vi. *Camera*: Many devices have a built-in camera, which may be controlled by a separate chip.<sup>87</sup>
- vii. *Memory*: Random access memory (“RAM”) provides temporary storage of active data, supporting the OS and other applications,<sup>88</sup> while flash memory allows for the long-term storage of data.<sup>89</sup>
- viii. *Battery*: Mobile devices are powered by batteries, which are typically charged via Universal Serial Bus (“USB”) or other connection.<sup>90</sup>
- ix. *Components to support non-cellular connectivity*: Mobile devices that support non-cellular connectivity, such as Wi-Fi or Bluetooth, must incorporate chips supporting that connectivity.<sup>91</sup>
- x. *External components*: External components include the chassis, which encloses the device’s internal components,<sup>92</sup> and the screen. In smartphones and tablets, the

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<sup>86</sup> See, e.g., Kernighan, Brian W., *Understanding the Digital World: What You Need to Know About the Internet, Privacy, and Security*, Princeton University Press, 2017, p. 230 (“GPS: Global Positioning System; uses time signals from satellites to compute position on the surface of the earth. It’s one-way; GPS devices like car navigators do not broadcast to the satellites.”).

<sup>87</sup> See, e.g., “Cellular Handsets & Chip Markets,” Forward Concepts, 2006, p. 239 (“The camera application processors (CAPs), typically without image sensor, are used in large quantities in the camera phone market segment to process images from the associated image sensors.”).

<sup>88</sup> “RAM,” in Newton, Harry, *Newton’s Telecom Dictionary*, 31<sup>st</sup> Edition, 2018, p. 1044.

<sup>89</sup> “Flash Memory,” in Newton, Harry, *Newton’s Telecom Dictionary*, 31<sup>st</sup> Edition, 2018, p. 533.

<sup>90</sup> See, e.g., Kernighan, Brian W., *Understanding the Digital World: What You Need to Know About the Internet, Privacy, and Security*, Princeton University Press, 2017, p. 232 (“USB: Universal Serial Bus, a standard connector for plugging devices like external disk drives, cameras, displays and phones into computers.”).

<sup>91</sup> Sandhaus, Erin et al., “Integrated Combo Solutions Bring Seamless Mobile Connectivity to Wireless Handsets,” Texas Instruments White Paper, 2009 (“Consumers are increasingly demanding greater connectivity from their wireless phone handsets. Bluetooth®, GPS, FM radio and mobile wireless LAN (mWLAN) technologies increase the utility of the cellphone by offering additional information, wider-ranging connections, or both. [...] System-on-chip (SoC) combo solutions that integrate one or more mobile connectivity technologies on a single device have proven their value in satisfying these requirements, and a new generation of combo chips is providing even greater functionality.”).

<sup>92</sup> “Chassis,” Oxford English Dictionary Online, available at <https://en.oxforddictionaries.com/definition/chassis>.

screen is typically a touchscreen that allows the user to interact with the OS and applications.<sup>93</sup>

67. Some hardware components, such as the AP, the GPS unit, the GPU, the Wi-Fi and/or Bluetooth chip, and audio and video processors, can be incorporated onto a single chip along with the modem. A chip that integrates multiple components may be called a “system on a chip” (“SoC”).<sup>94</sup> The term SoC can be used broadly to refer to various combinations of integrated components, but it commonly refers to the integration of the modem chip with the AP and other components.<sup>95</sup> Such a setup can also be described as a modem with an integrated AP, and more generally, “integrated” may also refer to the incorporation of multiple components onto a single chip.<sup>96</sup> By contrast, when multiple mobile device components are not combined in a single chip, the modem chip is referred to as a “thin modem.”<sup>97</sup>

## 2. Wireless standards and the modem chip industry

### a. Wireless standards

68. Over the past 25 years, wireless communication technologies have undergone continuous, fast-paced evolution – for example, from transmitting only analog voice to allowing real-time video chat. Improvements in the functionality of mobile devices have been made possible, in part, by evolutions in wireless standards.
69. A wireless standard specifies the protocol used to transmit information on the available RF spectrum. The wireless standard thereby facilitates wireless communication and allows firms

<sup>93</sup> McGrath, Dylan, “ABI: 97% of Smartphones to Have Touchscreens,” EE Times, August 29, 2011 (“By 2016, smartphones with touchscreens will account for 97 percent of all smartphone volume, up from 75 percent in 2010, according to market research firm ABI Research Inc.”).

<sup>94</sup> Cunningham, Andrew, “The PC Inside Your Phone: a Guide to the System-on-a-chip,” Ars Technica, April 10, 2013 (“[...]it’s now possible to cram more and more of these previously separate components into a single chip. [...] It’s these technological advancements that have given rise to the system-on-a-chip (SoC), one monolithic chip that’s home to all of the major components that make these devices tick.”).

<sup>95</sup> “SoC,” in Newton, Harry, *Newton’s Telecom Dictionary*, 31<sup>st</sup> Edition, 2018, p. 1173.

<sup>96</sup> See, e.g., “Mobile Processors 101: Why Smartphones Are Smarter with an All-in-one Processor,” Qualcomm OnQ Blog, June 13, 2013 (“Sometimes these components exist as different chips in a device [...]. When they’re grouped together onto the processor, it’s referred to as ‘integrated.’”).

<sup>97</sup> Deposition of Thomas Lindner, Head of Sales and Marketing Department at Intel, March 23, 2018, p. 13 (“Lindner Deposition, Intel”) (“Q. And so when you refer to a slim modem or a thin modem, do you mean a modem that does not have an integrated application process? A. Correct.”).

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(device manufacturers, network carriers, and cellular base station equipment manufacturers) to participate in the industry by enabling them to develop products, services, and equipment compatible with those made by other firms in the industry.<sup>98</sup> For mobile devices to communicate with a particular cellular network’s infrastructure both the mobile device and the infrastructure equipment, as well as the network itself, must conform to the same wireless standard.<sup>99</sup> Cellular networks are deployed by carriers, also known as mobile network operators, that must acquire an RF spectrum license to provide cellular services for consumers on their networks.<sup>100</sup> Network carriers in the U.S. include AT&T, Sprint, T-Mobile, U.S. Cellular, and Verizon;<sup>101</sup> carriers in other countries include Airtel, América Móvil, China Mobile, Telefónica, and Vodafone.<sup>102</sup>

70. Convergence to a given wireless standard results from interplay among standard-development organizations (“SDOs”), industry groups, government bodies, carriers, OEMs, and chip

<sup>98</sup> See, e.g., Yoo, Youngjin, et al., “The Role of Standards in Innovation and Diffusion of Broadband Mobile Services: The Case of South Korea,” *Journal of Strategic Information Systems*, Vol. 14, 2005, p. 323 (“Our study suggests that successful innovation and diffusion of broadband mobile services are collective achievements and firms need to deploy strategies that enable them to mobilize broad socio-technical networks that include technological, institutional, political and financial resources. At the heart of such strategies, standards play critical roles as they mediate different interests and motivations among participating actors.”).

<sup>99</sup> From an economic perspective, wireless standards can be seen to solve a “coordination problem.” This coordination problem arises because a mobile device’s value to a consumer is dependent on whether it can communicate with a larger number of other devices – i.e., its value increases with the size of the network using a compatible technology. The value that consumers derive from their devices is dependent on coordination of devices using common technology. See, e.g., Tirole, Jean, *The Theory of Industrial Organization*, Cambridge, MA: MIT Press, 1988, p. 405, discussing goods with positive externalities (“Positive network externalities arise when a good is more valuable to a user the more users adopt the same good or compatible ones. The externality can be direct (a telephone user benefits from others being connected to the same network ...). ... Because of their interdependent utility functions, users must anticipate which technology will be widely used by others. This introduces coordination problems. ... In the presence of network externalities, standards (i.e., a choice of a particular technology to be adopted by everyone) are often mandated (or agreed upon) by the government or by private bodies such as industry committees.”).

<sup>100</sup> See, e.g., “Report and Order,” In the matter of Policies Regarding Mobile Spectrum Holdings and Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, Federal Communications Commission, June 2, 2014, p. 3 (“Competition among mobile wireless providers [...] depends critically upon the availability of suitable spectrum as a necessary input in the provision of mobile wireless services.”).

<sup>101</sup> See, e.g., Viswanathan, Priya, “Mobile Carriers in the U.S.,” Lifewire, March 23, 2018.

<sup>102</sup> See, e.g., “The Largest Mobile Network Operators in the World,” World Atlas, April 25, 2017.

suppliers.<sup>103</sup> SDOs work to develop and formulate standards for wireless communications.<sup>104</sup> The process involves specifying methods of encoding information and operating the network, with the goals of minimizing interference and maximizing signal quality, coverage area, efficient use of available RF spectrum, call density, and other features.<sup>105</sup>

71. The dramatic evolution of cellular network technologies is evidenced by improvements in functionalities that characterized successive generations (the “G” in 1G, 2G, etc.) and advancements within each generation, known as releases.<sup>106</sup> Exhibit III.C.1 summarizes the wireless standards and the functionalities associated with each generation of standards:

- 1G systems, introduced in the early 1980s, were limited to analog voice services. 1G systems were developed separately in different parts of the world, without the oversight of a global standard-development body.<sup>107</sup>
- 2G standards, introduced in the early 1990s, improved voice call capacity and quality, allowed the sending of text messages, and marked the beginning of basic data transmission for simple applications such as providing stock quotes and weather

<sup>103</sup> For example, some members of the European Telecommunication Standard Institute (“ETSI”) are MediaTek, Microsoft, Verizon UK, the US Cellular Corporation, and many others. See “Current members,” ETSI, available at <http://www.etsi.org/membership/current-members>.

<sup>104</sup> The main SDO groups within the wireless communications industry are the Third Generation Partnership Project (3GPP) and the Third Generation Partnership Project 2 (3GPP2). 3GPP is a consortium of seven SDOs called “Organizational Partners,” including Association of Radio Industries and Businesses (ARIB) of Japan, Alliance for Telecommunications Industry Solutions (ATIS), of the U.S., China Communications Standards Association (CCSA), European Telecommunications Standards Institute (ETSI), Telecommunications Standards Development Society, India (TSDSI), Telecommunications Technology Association (TTA) of South Korea, and Telecommunication Technology Committee (TTC) of Japan. “3GPP Partners,” 3GPP, available at <http://www.3gpp.org/about-3gpp/partners>. 3GPP2 is a consortium of five SDOs, including ARIB, CCSA, TTA, TTC, and North America’s Telecommunications Industry Association (TIA). See, e.g., “About 3GPP2,” 3GPP2, available at [https://www.3gpp2.org/Public\\_html/Misc/AboutHome.cfm](https://www.3gpp2.org/Public_html/Misc/AboutHome.cfm).

<sup>105</sup> For example, the breadth of characteristics considered while developing standards is evident in 3GPP’s organizational structure. The 3GPP hierarchy is made up of three specification groups (Radio Access Network, Service and Systems Aspects, and Core Network and Terminals) that each focus on particular areas of 3GPP specifications. See, e.g., “Specifications Groups Home,” 3GPP, available at <http://www.3gpp.org/specifications-groups/specifications-groups>.

<sup>106</sup> The term “releases” is commonly used to refer to advancements in standards. For example, for 3GPP standards, see “3GPP Standards & Release Numbers,” Radio-Electronics, available at <http://www.radio-electronics.com/info/cellulartelecomms/3gpp/standards-releases.php> (“The 3GPP standards are continually being improved. The 3GPP standards improvements are incorporated into specific releases of the standards.”).

<sup>107</sup> Ghosh, Arunabha, et al., *Fundamentals of LTE*, Pearson, 2011, p. 5. The most prominent 1G systems included the Advanced Mobile Phone Service (AMPS) in the U.S. and its variant Total Access Communication Systems (ETACS and NTACS), deployed throughout Europe and Japan, and the alternative Nordic Mobile Telephone (NMT-400) system deployed in several Scandinavian countries.

- updates.<sup>108</sup> The two main competing 2G families of standards, Global System for Mobile Communications (GSM) and cdmaOne,<sup>109</sup> used fundamentally different technologies to allocate the available spectrum efficiently.<sup>110</sup>
- 3G standards emerged in the early 2000s and facilitated mobile broadband.<sup>111</sup> Two competing industry standards groups, 3GPP and 3GPP2,<sup>112</sup> set the 3G successors to GSM and cdmaOne, respectively. 3GPP’s main 3G family of standards was UMTS (also known as WCDMA). Later, it also adopted TD-SCDMA, developed in China for deployment there.<sup>113</sup> 3GPP2’s 3G family of standards is CDMA2000.<sup>114</sup>
  - 4G standards of today improve on 3G with more efficient use of the spectrum and vastly increased peak data rates and network capacity.<sup>115</sup> Around 2008, three different technologies were proposed as candidate wireless standards for 4G: WiMAX,<sup>116</sup>

<sup>108</sup> Ghosh, Arunabha, et al., *Fundamentals of LTE*, Pearson, 2011, pp. 6–7.

<sup>109</sup> The GSM standard was originally deployed in Europe beginning in 1990 and quickly gained acceptance beyond Europe. See, e.g., Ghosh, Arunabha et al., *Fundamentals of LTE*, Pearson, 2011, pp. 7–8. In the United States, T-Mobile and AT&T are the two major carriers that deployed GSM networks. See, e.g., Sascha, Segan, “CDMA vs. GSM: What’s the Difference?,” PCMag, July 11, 2017. The 2G CDMA standard is Interim Standard 95 (IS-95), also known as cdmaOne, which was adopted by the Telecommunications Industry Authority (TIA) in the United States in 1993. It was subsequently deployed worldwide, but was primarily adopted by subscribers in North America, South Korea, Brazil, and India. In the United States, Sprint and Verizon are the two major carriers that deployed this standard. See, e.g., Ghosh, Arunabha et al., *Fundamentals of LTE*, Pearson, 2011, pp. 7, 9–10; Deposition of Eric Koliander, Vice President of Sales at Qualcomm, February 1–2, 2018, p. 134 (“Koliander Deposition, Qualcomm”).

<sup>110</sup> GSM implemented TDMA (Time Division Multiple Access) technology. cdmaOne took its name from the competing CDMA (Code Division Multiple Access) technology developed by Qualcomm. See, e.g., Ghosh, Arunabha et al., *Fundamentals of LTE*, Pearson, 2011, pp. 8–9 (“The GSM air-interface is based on a TDMA scheme where eight users are multiplexed on a single [...] frequency channel by assigning different time slots to each user. [...] Unlike in other digital wireless systems like GSM, in an IS-95 CDMA system multiple users share the same frequency channel at the same time.”).

<sup>111</sup> Naha, Abhi and Peter Whale, *Essentials of Mobile Handset Design*, Cambridge Wireless Essentials Series, 2012, pp. 30, 34.

<sup>112</sup> 3GPP worked on the successor technology to the TDMA-based GSM standard. 3GPP2 worked on the successor technology to the CDMA-based IS-95 standard. See, e.g., Ghosh, Arunabha et al., *Fundamentals of LTE*, Pearson, 2011, pp. 11, 13.

<sup>113</sup> See, e.g., Chang, Lu, “TD-SCDMA and China 3G,” Marvell White Paper, January 2012, p. 2 (“Today, there are three major 3G standards worldwide. [...] China [...] also developed their own 3G technology, Time-Division Synchronous Code Division Multiple Access (TD-SCDMA), part of the Universal Mobile Telecommunications System (UMTS).”).

<sup>114</sup> See, e.g., Ghosh, Arunabha et al., *Fundamentals of LTE*, Pearson, 2011, p. 11.

<sup>115</sup> See, e.g., Ghosh, Arunabha et al., *Fundamentals of LTE*, Pearson, 2011, p. 20 (“All three standards [HSPA+, WiMAX, and LTE] support a variety of signal processing techniques to improve performance and spectral efficiency.”).

<sup>116</sup> WiMAX stands for Worldwide Interoperability for Microwave Access. It was a competing standard developed by Intel and The Institute of Electronic and Electrical Engineers (IEEE). IEEE 802, a group within the IEEE that sometimes acts as an SDO, began efforts to develop mobile broadband standards in 2001. Intel championed the development of WiMAX in the late 2000s. See, e.g., Poole, Ian, “WiMAX History,” Radio-

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LTE,<sup>117</sup> and UMB.<sup>118</sup> LTE is currently the prevalent family of 4G standards for most global carriers.<sup>119</sup> It utilizes User Equipment (UE) categories to describe combined uplink and downlink capabilities as well as other features of devices.<sup>120</sup> 4G LTE began as data-only, requiring mobile devices to rely on backward compatibility with 2G/3G networks for voice calls.<sup>121</sup> More recently, Voice over LTE (VoLTE) has been deployed to transmit calls via LTE, and its gradual deployment in the U.S. began around 2014.<sup>122</sup> VoLTE allows carriers to remove support for 2G and 3G services, freeing up spectrum for later standards. Some carriers have already set this process in motion.<sup>123</sup>

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Electronics, available at <http://www.radio-electronics.com/info/wireless/wimax/history.php>. See also “WiMAX History in the Making,” Intel, May 7, 2008 (“Intel Capital alone is investing \$1 billion in the new Clearwire, making it the largest investment ever by Intel’s global investment organization, and its third investment in Clearwire. [...]his new company is going to focus on accelerating the deployment of the first nationwide mobile WiMAX network in the U.S.”).

<sup>117</sup> LTE stands for Long Term Evolution. LTE was developed by 3GPP as a successor to the existing 3G systems that 3GPP had developed. See, e.g., Table 1.7 in Ghosh, Arunabha et al., *Fundamentals of LTE*, Pearson, 2011, p. 24.

<sup>118</sup> UMB stands for Ultra Mobile Broadband and was developed by 3GPP2, of which Qualcomm is a member. It was developed as the direct successor to CDMA2000 3G technology. UMB eventually failed to gain traction among CDMA carriers like Verizon, which switched to LTE instead. See, e.g., “Participating Member Companies,” 3GPP2, available at [https://www.3gpp2.org/Public\\_html/Misc/memberindex.cfm](https://www.3gpp2.org/Public_html/Misc/memberindex.cfm). See also Ghosh, Arunabha et al., *Fundamentals of LTE*, Pearson, 2011, p. 16 (“[...]he 3GPP2 community had developed an evolution of IS-95 called IS-95 Rev. C, aka Ultra Mobile Broadband (UMB) [...]”); Bangeman, Eric, “Verizon Decides on LTE for 4G Wireless Broadband,” *Ars Technica*, November 29, 2007.

<sup>119</sup> Casaccia, Lorenzo, “Understanding 3GPP – Starting with the Basics,” Qualcomm OnQ Blog, August 2, 2017 (“After several technical challenges and solutions, the LTE system developed by 3GPP became the 4G standard most predominantly used and deployed, and has since become the global standard for 4G [...]”).

<sup>120</sup> As of August 2016, 3GPP listed twelve LTE UE categories, with Category 1 having the lowest uplink/downlink rates and Category 12 having the highest uplink/downlink rates. See, e.g., 3GPP, “LTE UE-Category,” August 2016, available at <http://www.3gpp.org/keywords-acronyms/1612-ue-category> (“Category information is used to allow the eNB to communicate effectively with all the UEs connected to it. The ue-Category defines a combined uplink and downlink capability as specified in 3GPP TS36.306.”).

<sup>121</sup> See, e.g., “Voice and SMS in LTE,” Rhode & Schwarz White Paper, May 2011 p. 3 (“LTE is designed as a pure packet switched system. Legacy circuit switched services are no longer supported. This implies that support of voice within LTE has to be done with voice over IP. [...]M]any network operators have decided to deploy their first commercial LTE networks focusing on support for data services [...]V]oice service support is provided by the legacy networks in this first phase of LTE deployment.”).

<sup>122</sup> VoLTE offers VoIP (Voice over IP, which allows voice signals to be transmitted as data packets) on LTE networks, thus removing the need for backward compatibility in areas where VoLTE is available. Verizon launched VoLTE in August 2014. Seifert, Dan, “Verizon Announces Initial Rollout of VoLTE, HD Voice for the ‘Coming Weeks,’” *The Verge*, August 26, 2014. Sprint has plans to launch VoLTE in the fall of 2018. See, e.g., “Sprint expects to deploy VoLTE starting this fall,” *FierceWireless*, February 14, 2018 (“Sprint has been preseeding the market with VoLTE-capable devices, and it expects to finally start commercially deploying VoLTE this fall.”).

<sup>123</sup> For example, AT&T shut down its 2G services at the end of 2016. See, e.g., “AT&T 2G Network Shutdown,” AT&T, available at <https://www.att.com/esupport/article.html#!/wireless/KM1084805> (“[...] W]e discontinued service on our 2G wireless network as of December 31, 2016.”). Meanwhile, Verizon announced in 2016 that it

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- 5G standards have been under development over the past several years. The first 5G standard, 5G NR (New Radio), was released by 3GPP in December 2017, and additional standards are expected to be released in 2018.<sup>124</sup> The 5G network is expected to be an improvement over the 4G network along several attributes, such as improved latency, lower power requirements, etc.<sup>125</sup> U.S. carriers have plans to begin rolling out 5G service gradually: AT&T, for instance, stated in January 2018 that it is planning to launch a 5G service in 12 U.S. cities by the end of 2018.<sup>126</sup>

72. Networks can support multiple generations of wireless standards. Indeed, carriers generally roll out a new standard gradually, with infrastructure to support the new standard available in some geographic areas before others.<sup>127</sup> This prolonged process delays the obsolescence of legacy technologies, as device consumers – and therefore OEMs – continue to demand those legacy technologies while they are useful in ensuring broad geographical coverage. When the major national networks rolled out LTE in the U.S., for example, they implemented it in some geographic areas before others, with data coverage in remaining areas continuing, at least for a time, to depend on earlier standards.<sup>128</sup> Moreover, even where LTE coverage was available,

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would phase out 2G service by the end of 2019, and in 2014 it reallocated some of its 3G spectrum to 4G LTE. See Dano, Mike, “Verizon to Shut Down 2G CDMA 1X Network by the End of 2019,” FierceWireless, July 13, 2016 (“Verizon [...] confirmed to FierceWireless that it is currently planning to shut down its CDMA 1X network by Dec. 31, 2019. [...] Verizon’s 2G CDMA 1X network is used by some of the carrier’s mobile phone customers for voice calling, but Verizon is working to transition its voice calling services onto its LTE network via Voice over LTE (VoLTE) technology.”). See also Goldman, David, “Verizon is Killing Off 3G,” CNN, December 4, 2014 (“In New York, Verizon (VZ) has shut off 20 MHz of airwaves that were once allocated for 3G. The cell phone giant is now running 4G-LTE over that spectrum.”).

<sup>124</sup> 3GPP, “First 5G NR Specs Approved,” December 22, 2017, available at [http://www.3gpp.org/news-events/3gpp-news/1929-nsa\\_nr\\_5g](http://www.3gpp.org/news-events/3gpp-news/1929-nsa_nr_5g).

<sup>125</sup> See, e.g., “5G Network Transformation,” 5G Americas White Paper, December 2017, p. 3 (“5G, being the next generation mobile networking standard, brings several new components. Two of the most important features are low latency (< 10ms) and high through-put (Multi-Gbps). Using these new enhancements, operators will be able to address the market by addressing new use cases. 5G enhances the use cases that LTE is able to minimally address today, and brings new revenue streams to operators by leveraging new solutions that LTE was not able to serve.”).

<sup>126</sup> “AT&T to Launch Mobile 5G in 2018,” AT&T, January 4, 2018.

<sup>127</sup> See, e.g., Reardon, Marguerite, “Verizon to Launch 4G Wireless Network December 5,” CNET, December 1, 2010. See also Goldman, David, “AT&T Launching ‘New’ New 4G Network,” CNN Money, May 25, 2011.

<sup>128</sup> Verizon initially introduced LTE in 38 metropolitan areas around the U.S. Patel, Nilay, “Verizon LTE Plans Start at \$50/Month for 5GB of Data (Update),” Engadget, December 1, 2010. Sprint’s initial LTE rollout covered 15 cities in Georgia, Missouri, and Texas. Ingraham, Nathan, “Sprint Details Full List of 15 Cities with Live LTE Service,” July 16, 2012. AT&T’s initial LTE launch occurred in five cities. Ziegler, Chris, “AT&T 4G LTE Launching in First Five Markets on Sunday,” The Verge, September 15, 2011. T-Mobile first introduced its LTE network in seven cities. Seifert, Dan, “T-Mobile LTE Network Officially Goes Live in Seven U.S. Cities,” March 26, 2013.

networks continued to rely on legacy standards for voice calls until the implementation of VoLTE.<sup>129</sup> In China, too, the rollout of LTE has been somewhat gradual, and different carriers have implemented different versions. In 2013, the country’s largest carrier, China Mobile, introduced a variant of LTE that relied on time-division duplex (TD-LTE) that followed naturally from its 3G standard, TD-SCDMA. Smaller carriers China Telecom and China Unicom introduced LTE in 2014. They preferred the frequency-division duplex (FD-LTE) variant of LTE, which followed more naturally from their 3G standards (CDMA2000 and WCDMA); the smaller carriers have, however, gone down the path of hybrid TD-LTE/FD-LTE systems due to the timing of the Chinese government’s allocation of spectrum licenses.<sup>130</sup>

73. For a mobile device to function within a wireless standard, a modem chip must support the communication protocol enshrined in that standard.<sup>131</sup> Beyond the basic threshold necessary to support a communication protocol, however, modem chips are differentiated by many other features and characteristics, such as:

<sup>129</sup> See, e.g., “Technology, Media & Telecommunications Predictions 2016,” Deloitte, available at <https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Technology-Media-Telecommunications/gx-tmt-prediction-2016-full-report.pdf>, p. 57 (“VoLTE increases capacity as it allows operators to move voice calls off 2G and 3G networks and onto the LTE (4G) network.”). See also “What Is VoLTE?,” 4G.co.uk (“[...W]ithout it whenever you make or receive a call your phone has to switch from 4G to 2G or 3G, since 4G calls aren’t supported and then once the call is finished it switches back again.”).

<sup>130</sup> See, e.g., Bell, Pete, “4G Breaks Through That Great Chinese Wall,” TeleGeography, August 24, 2016 (“In December of [2013], China Mobile – currently the largest operator by subscribers – launched commercial services over the country’s first 4G network [...]. China Mobile continues to focus on the [...] TD-LTE 4G standard. Rivals China Unicom and China Telecom have gone for a mix of TD-LTE and frequency division duplex LTE (FDD-LTE). This is due in part to Chinese regulators’ refusal to allocate spectrum licenses for the two mobile operators’ preferred FDD-LTE standard until February 2015 – more than a year after the distribution of TD-LTE concessions. Unicom’s original intention was to utilize the FDD standard almost exclusively, as it provides a smoother migration path from its W-CDMA 3G platform. CDMA2000-based 3G operator Telecom planned to use TD-LTE in urban areas and FDD-LTE elsewhere.”). See also Jing, Meng, et al., “China Issues 4G FDD-LTE Licenses,” China Daily, February 27, 2015 (“MIIT granted TD-LTE 4G licenses to the three mobile telecom carriers in December 2013 and approved experiment of TD-LTE/FDD-LTE convergence networks undertaken by China Telecom and China Unicom in June 2014.”); Kinney, Sean, “RIP TD-SCDMA,” RCR Wireless News, December 17, 2014 (“TD-SCDMA was developed by the Chinese and deployed for a limited trial in 2008. In 2009, the Chinese Ministry of Industry and Information Technology gave China Mobile a license to operate the TD-SCDMA network. China Mobile’s two major competitors, China Telecom and China Unicom, were assigned licenses to respectively operate CDMA2000 and W-CDMA networks, both international standards.”).

<sup>131</sup> See, e.g., Miller, Michael J., “New Modems, Equipment Set the Stage for Next Year’s 5G Rollouts,” PCMag, March 2, 2018 (“While the rollout of 5G networks sounds good, they won’t be very useful without devices that run on them. And those devices won’t work without 5G modems.”).

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- a. “Multi-mode” capability, the support of multiple standards – possibly spanning multiple generations, e.g., 2G/3G/4G;<sup>132</sup>
- b. Performance along dimensions such as user experience and power consumption;<sup>133</sup> and
- c. Integration of other components or functionality of the device, e.g., the application processor, Bluetooth and Wi-Fi support, and the GPS unit.<sup>134</sup>

These features and characteristics, and their importance to OEMs as they select the modem chips to incorporate in their devices, are discussed in greater depth in Section III.E.1.c.i.

*b. The modem chip industry and the modem chip product cycle*

74. The modem chip industry is shaped by both changes between standards generations and incremental developments within generations. Each new generation of standards – such as 2G, 3G, and 4G, each representing a discrete generation – marks major strides in dimensions such as transmission speed and network capacity, and whether a modem chip supports a certain standard determines its ability to communicate with networks using that standard. Innovation also continues within generations, and even within families of standards: for example, over time, 3GPP has issued “releases” introducing categories of WCDMA and LTE with higher transmission speeds.<sup>135</sup>
75. The modem chip industry is also shaped by product cycles in the mobile device market. OEMs release new and improved products at different time intervals and require modem chip

<sup>132</sup> See, e.g., “Qualcomm Introduces World’s First Complete Multi-mode 3G/LTE Integrated Solution for Smartphones,” Qualcomm Press Release, February 16, 2009 (“Multi-mode 3G/LTE chipsets will be crucial to smooth deployments of LTE by operators who are looking to complement their existing 3G networks, and the MSM8960 delivers maximum flexibility by supporting [CDMA2000] EV-DO Rev. B and HSPA+ in addition to LTE [...]).

<sup>133</sup> See, e.g., “Qualcomm Snapdragon 710 Mobile Platform Brings In-Demand Premium Features to a New Tier of Smartphones,” Qualcomm Press Release, May 23, 2018 (“The platform’s new architectures are engineered to deliver superior power efficiency, long-lasting battery life and an overall enhanced user experience.”).

<sup>134</sup> See, e.g., “Qualcomm Announces the First Commercially Sampling Tri-mode System-on-Chip,” Qualcomm Press Release, February 21, 2017 (“Key features include: [... :] Bluetooth 5 - Low Energy and CSRMESH™ connectivity [... :] Low Power Wi-Fi - 802.11n in 2.4 GHz/5 GHz bands [... :] Dual-Core Processing: [... :] Dedicated ARM® Cortex® M4 CPU for customer applications”).

<sup>135</sup> For a schedule of 3GPP releases, see Poole, Ian, “3GPP Standards & Release Numbers,” Radio-Electronics.com, available at <http://www.radio-electronics.com/info/cellular/telecomms/3gpp/standards-releases.php>. For a mapping of 3GPP releases to categories, see, e.g., “LTE UE (User Equipment) category & Class Definitions,” available at <http://www.cablefree.net/wirelesstechnology/4glte/lte-ue-category-class-definitions>.

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suppliers to meet tight product development deadlines.<sup>136</sup> The high rewards associated with developing a cutting-edge mobile device imply that OEMs frequently update their products with the most advanced features enabled by mobile device technology. Consequently, the fast pace of innovation that has characterized the mobile device industry translates into demand for innovation in the modem chip industry. For example, the demand for mobile devices with increasingly power-consuming features has translated into the demand for increasingly power-efficient modem chips.<sup>137</sup> Mobile device product cycles, therefore, exert a key influence on the modem chip industry.

76. In addition to navigating these broad product cycles, individual modem chip suppliers have their own product cycles, which mark the development and implementation of new chip models and technologies. These modem chip product cycles vary across firms. Qualcomm introduces new designs in its top-tier modem chips, then cascades or “waterfalls” them down into lower-tiered modem chips over a period of several quarters.<sup>138,139</sup> One implication of this

<sup>136</sup> For example, between 2008 and 2015, Apple released the iPhone 3G, 3GS, 4, 4S, 5, 5S, 5C, 6, 6 Plus, 6S, and 6S Plus at a rate of one or two per year. See AAPL-FTC-00128293 at 8293.

<sup>137</sup> Geuss, Megan, “Why Your Smartphone Battery Sucks,” PC World, May 18, 2011 (“Smartphone screens are getting larger and supporting higher resolutions, both of which suck power like crazy. [...] Another major power drain relates to increasingly complex apps, which impose ever-steeper processing requirements. [...] One consequence of runaway power consumption is that the makers of mobile processors are feeling a lot of pressure to produce more-efficient chips for phones.”).

<sup>138</sup> See, e.g., Exhibit CX6394, Achour Deposition, Qualcomm, Q2014FTC04334482, p. 6 (“Overview of Modem Competitiveness & Key Strategies,” January 2016).

<sup>139</sup> More generally, “waterfalling” refers to the cascade of new technologies from leading-edge products into mid- and lower-end products over time. See, e.g., Deposition of Keith Kressin, Senior Vice President of Product Management at Qualcomm, February 7–8, 2018, p. 410 (“Kressin Deposition, Qualcomm”) (“Q. And I’ll get back to this later, but one thing you just mentioned I wanted to highlight. You said that something -- something -- and I think you meant technology -- that could be in a premium-tier chipset one year might be in a lower-tier chipset at some point in the future; is that [...] correct? A. That’s accurate. Something we might start in the premium tier, some technology we might put in the premium tier could find its way into lower-tier chips at a subsequent time. Sometimes months, sometimes years, sometimes maybe never.”) and p. 411 (“[A.] But at a very general level, typically in not just Qualcomm, but any technology, you typically try and -- try and introduce new technologies that are user-valued in your -- in your higher-end products first. Then you have to work to cost-reduce to bring it down later, and while you’re cost-reducing one, you’re introducing a new technology on top. It’s a common industry, you know, technical waterfalling strategy.”). See also Investigational Hearing of Vankata Murthy Renduchintala, Former Co-President of QCT Division, Qualcomm, October 7, 2016, pp. 129–130 (“Renduchintala IH, Qualcomm”) [REDACTED]

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phenomenon is that if a supplier’s most innovative modem chip is not chosen for an OEM’s flagship device, the supplier may still be able to profit from that chip by selling it later to lower-tier devices.<sup>140</sup> [REDACTED]

[REDACTED] .<sup>142</sup>

This strategy is particularly effective for SoC suppliers. [REDACTED]

[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]<sup>143</sup> [REDACTED],

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<sup>140</sup> See, e.g., Deposition of James Thompson, Chief Technology Officer at Qualcomm, February 14–15, 2018, pp. 109–111 (“Thompson Deposition, Qualcomm”) [REDACTED]

[REDACTED] and Exhibit CX6324, Thompson Deposition, Qualcomm, p. 6.

<sup>141</sup> The term “IP core” derives from “Intellectual Property core” and refers to a module that can be used as a “building block” in constructing a chip. Qualcomm also uses the term “modem IP” to refer to a modem IP core. Note that the “IP” in these terms does not mean intellectual property, per se. See, e.g., Deposition of Baaziz Achour, SVP of Modem Engineering at Qualcomm, February 21, 2018, p. 111 (“Achour Deposition, Qualcomm”) (“Q. What is modem IP? A. [...] It’s the [...] modem subsystem that goes into the product. That’s what we refer to as modem IP. It’s not the intellectual property that’s in patents. That’s [...] different. This is really the actual technology we deliver in silicon to be included in our product.”) and p. 113 (“Q. And can the same modem IP be used in different products? A. That is correct. A good example is the MDM and the MSM. I mentioned that the same modem goes -- when I say the cat 4, for example, it goes in the MDM and it goes in the MSM, that’s the same modem IP. It’s the same piece of silicon design that we give to both the MDM team and the MDM team [sic] to put in their products. Sometimes the same modem go[es] into, like, six, seven different products.”).

<sup>142</sup> Achour Deposition, Qualcomm, pp. 114–115 [REDACTED]

[REDACTED] This discussion references Exhibit CX6394, Achour Deposition, Qualcomm, Q2014FTC04334482, p. 6 (Qualcomm, “Overview of Modem Competitiveness & Key Strategies,” January 2016).

<sup>143</sup> Exhibit CX6394, Achour Deposition, Qualcomm, Q2014FTC04334482, p. 6 (Qualcomm, “Overview of Modem Competitiveness & Key Strategies,” January 2016).

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[REDACTED]

[REDACTED] 144,145

77. The interaction of standards evolution, technological improvements, and the strategies of chip suppliers and OEMs implies that some chips are sold for a few quarters, while others can be in the market for several years. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] Several other SoCs used in smartphones and feature phones, as well as thin modems, were expected to remain in production for at least two years.<sup>148</sup>

#### **D. Modem chip suppliers and purchasers**

##### **1. Modem chip suppliers**

78. Modem chip suppliers are firms that sell modem chips to mobile device OEMs.<sup>149</sup> The number and identity of the modem chip suppliers who are active in the industry have varied considerably over time. In addition to Qualcomm, other modem chip suppliers have included, among many others, Infineon, Intel, MediaTek, Samsung/Samsung S-LSI (short for System Large-Scale Integration), Huawei/HiSilicon, ST-Ericsson, Texas Instruments, Broadcom,

<sup>144</sup> See, e.g., Exhibit AX0003, [REDACTED]

<sup>145</sup> Based on a presentation by Intel’s consultant Bain, Intel was aware of both Qualcomm’s better R&D efficiency and its better IP reuse. BAIN00051010, p. 3 (“QCOM Benchmark: 2012,” December 20, 2012, “Intel overall SOC R&D investment comparable to QCOM, but QCOM has 3x times more output”) and p. 7 (“Qualcomm has higher IP reuse vs. Intel base products”).

<sup>146</sup> Q2014FTC00010235, pp. 95, 97, presentation titled “QCT Chipset Product Roadmaps” March 2015.

<sup>147</sup> Q2014FTC00010235, pp. 95–96, presentation titled “QCT Chipset Product Roadmaps” March 2015.

<sup>148</sup> Q2014FTC00010235, pp. 96–99, presentation titled “QCT Chipset Product Roadmaps,” March 2015.

<sup>149</sup> Some modem chips suppliers, such as HiSilicon and Samsung S-LSI, sell modem chips solely, or predominantly, to their vertically integrated OEM.

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Freescall, Spreadtrum, VIA Telecom, Marvell, and Nvidia. I discuss the experiences of each of these firms within the modem chip industry in more detail in Section V.C. Exhibit III.D.1 provides a timeline of entry and exit of these suppliers.

79. Modem chip suppliers have chosen to organize in a variety of ways, and their degree of vertical integration varies widely. Some modem chip suppliers focus solely on modem chip design, while others both design and manufacture modem chips. As I discuss further in the next section, some mobile device OEMs, such as Samsung and Huawei, have also vertically integrated with captive modem chip suppliers, providing an additional level of vertical integration. The various degrees and directions in which modem chip suppliers are vertically integrated, and the corresponding flows of modem chip designs and modem chips to OEMs, are illustrated in Exhibit I.C.1.
80. The most common business model among modem chip suppliers, the “fabless” chip vendor, is the least vertically integrated.<sup>150</sup> Fabless firms focus on modem chip design, and contract with external chip foundries to manufacture chips according to their design specifications. Qualcomm is a fabless firm: it designs modem chips and then outsources their physical manufacture to other firms, such as Samsung or TSMC.<sup>151</sup> Similarly, MediaTek designs, develops, and markets modem chips but contracts with foundries such as TSMC and GlobalFoundries for manufacturing.<sup>152,153</sup>
81. Other firms, known as IDMs, choose to manufacture as well as design modem chips.<sup>154</sup> This level of vertical integration allows the modem chip supplier to save the so-called “foundry

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<sup>150</sup> See case studies in Section V.C.

<sup>151</sup> Siddiqui, Aamir, “Qualcomm Ends Foundry Partnership with Samsung and Entrusts 7nm Process to TSMC,” *xdadevelopers*, June 12, 2017.

<sup>152</sup> Real, Mark, “MediaTek Moves SoC Manufacturing From TSMC To Save Costs,” *Android Headlines*, June 27, 2017.

<sup>153</sup> MediaTek’s provision of reference designs for mobile devices may be seen as a soft form of vertical integration into device design. Qualcomm, too, provides reference designs. See discussion of reference designs in Section III.E.1.c.ii.

<sup>154</sup> See, e.g., “2016 Top Markets Report Semiconductors and Semiconductor Manufacturing Equipment: Sector Snapshot,” U.S. Department of Commerce, International Trade Administration, available at [https://www.trade.gov/topmarkets/pdf/Semiconductors\\_Semiconductors.pdf](https://www.trade.gov/topmarkets/pdf/Semiconductors_Semiconductors.pdf) (“Integrated Device Manufacturers (IDMs) design, manufacture and sell their own semiconductors. Examples are Intel or Samsung.”).

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margin,” which is the profit margin that an independent foundry would otherwise make.<sup>155</sup> A modem chip supplier may also serve as a foundry, i.e., manufacture chips of others’ design. Intel, for example, has its own fabs, which it uses to manufacture modem chips it designs, and it has recently started manufacturing modem chips for other modem chip suppliers such as Spreadtrum in its fabs as well.<sup>156</sup> Previously, Intel and Infineon, which was acquired by Intel, were fabless modem chip suppliers, as discussed further in Section V.C.1.

82. In addition to varying in their degree of vertical integration, modem chip suppliers also differ in their strategies regarding technological leadership within the industry. As I discuss in more detail in Section III.E.2.b below, some suppliers, such as Qualcomm, pursue a strategy of substantial investment in R&D in order to supply the most innovative, high-end, customized products and to be at the leading edge of the industry.<sup>157</sup> Other suppliers, including

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<sup>155</sup> See, e.g., Deposition of Aichatou Evans, Vice President of Communications and Devices, Intel, March 14–15, 2018, p. 234 (“Evans Deposition, Intel”) (“Q. What is ‘foundry margin’? A. It is when one has a – a product manufactured a[t] a foundry. We assume that there’s their cost and then the margin that they decide upon for their business. And, therefore, the total price including both their cost and a – and a foundry margin.”). See also “Could Intel’s Business Transition Impact Its Gross Margin?,” Market Realist, July 14, 2017 (“Intel is an IDM (integrated design manufacturer), which handles the end-to-end process from chip design to manufacturing to packaging to selling. [...] The IDM model enables Intel to enjoy the profits of both a fabless company and a foundry.”).

<sup>156</sup> See, e.g., Yoshida, Junko, “Intel, Spreadtrum Demo Brainchild: Is Intel getting ready for Apple?,” EE Times, Mar. 1, 2017. See also Pressman, Aaron, “Why Apple Could Be a Future Customer for Intel’s Chipmaking,” Fortune, August 27, 2016.

<sup>157</sup> See, e.g., Exhibits III.E.1 and III.E.3. See also Deposition of George S. Davis, Chief Financial Officer at Qualcomm, March 18, 2018, pp. 262–263 (“Davis Deposition, Qualcomm”) (“[Slide with Bates No. 6887–045 shows a] model -- this is intended to show the -- how both the combination of R&D investment by QTL and incorporate [...] results in very strong early IP R&D leadership at a front end of a generation [...] you end up with both IP leadership and product leadership advantages from being [...] an early leader in a generation change.”); Thompson Deposition, Qualcomm, p. 80 (“Q. And there are also fewer suppliers able to supply modems with the features that are required in the high-end? A. [...] I think there may be a few less, but it’s not that different. Most of the players in this industry could deliver a high-tier if they go after that market. It’s a matter of choice -- where you focus from a market point of view.”).

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MediaTek<sup>158</sup> and (prior to its acquisition by Intel) Infineon,<sup>159</sup> have historically chosen a strategy of being “fast followers.” Such suppliers historically have spent less on R&D in order to supply lower-cost products, or focused on less customized products used in low-end mobile devices, primarily in emerging markets.<sup>160</sup> As discussed in Section V, both strategies can lead to profitability and success in the industry, and some suppliers have adopted different strategies at different points in time.

83. Exhibit III.D.2 shows that from 2002 to 2017, according to analysis of Strategy Analytics data, there have been between 8 and 22 modem chip suppliers operating in the industry in any given year (Strategy Analytics does not separately identify all modem chip suppliers in each year). Exhibit III.D.3 shows that the composition and rankings of leading firms within the industry have changed over time. While in any given year only a few chip suppliers sell a large majority of the modem chips (between 2002 and 2017, the top five firms supplied between 81 percent and 94 percent of chips sold each year), there have been 12 different top-five suppliers between 2002 and 2017.<sup>161</sup> The exhibit also shows that, although Qualcomm has consistently ranked as the largest or second largest modem chip supplier, other firms, such as Texas Instruments,

<sup>158</sup> See, e.g., Deposition of Aaron Schafer, Senior Director of Procurement at Apple, February 28, 2018, pp. 106–107 (“Schafer Deposition, Apple”) (“Q. Do you recall why MediaTek has not yet been chosen as a modem supplier for Apple? [... A.] MediaTek has -- you know, we -- probably the industry itself has probably segmented into two -- two classes of suppliers. MediaTek is probably what I would consider a fast follower, so generally behind, you know, the top-tier, leading-edge, call it high-tier modems. Q. And your view is they’ve always been a fast follower? A. Fast -- you know, that’s probably -- you know, I don’t know what you want to -- how you want to qualify that, but they’re a follower. Q. And what does that mean, technologically, to be a follower or a fast follower? A. They’re -- you got to look at the market as in -- really, I think for smartphones, is in this high-tier, leading-edge, latest 3GPP feature set. And that’s -- that’s one segment. And then there’s another segment that’s more the lower-end phones that are sold around the world, maybe even lower -- well, lower-end geographies. I think MediaTek generally plays in that industry.”).

<sup>159</sup> See, e.g., Lindner Deposition, Intel, pp. 16–17 (“Q. Have you heard the term ‘fast follower’? A. Yes. Q. And when you were at Infineon, did the Infineon Wireless division, in your understanding, pursue a fast-follower strategy? A. Yes.”). See also Loh, Kin Wah and Hermann Eul, “Infineon Communication on the Move,” Infineon, June 1, 2005 (describing Infineon’s mobile phone business segment as in a “fast follower” position and “catching up in 3G”).

<sup>160</sup> Olson, Parmy, “iPhone a Risk with Intel’s Latest Buy,” *Forbes*, August 10, 2010 (“Infineon’s WLS has fallen behind in research and development in [long-term evolution...]. It was the same with 3G because Infineon decided that by being a ‘fast follower’ of the new technology, it might not make some of the mistakes that the leading players would.”). See also Exhibit QX0204, Loh Deposition, MediaTek, pp. 16, 22 (“Strategy Highlight[:] Serve the un-served[:] Focus on un-served users/manufacturers (2nd tier/emerging”).

<sup>161</sup> Those 12 top-five sellers between 2002 and 2017 are Agere, Freescale, Infineon, Intel, MediaTek, Qualcomm, RDA, Samsung S-LSI, Spreadtrum, ST-Ericsson, STMicroelectronics, and Texas Instruments.

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Freescall, or ST-Ericsson, gradually declined in the rankings and eventually exited the industry. Conversely, suppliers such as MediaTek and Spreadtrum have climbed up in the rankings over time, becoming the second and third largest modem chip supplier based on the number of units sold, respectively. These trends are confirmed in Exhibit III.D.4, which displays dramatic changes in the relative quantities of modem chips sold by each supplier over time. For example, Texas Instruments (TI) was the leading supplier from 2002 to 2009, and was among the top five suppliers in 2010 and 2011, yet exited the modem chip industry in 2013. Conversely, several of the largest suppliers in 2017, such as HiSilicon, MediaTek, Samsung S-LSI, and Spreadtrum, were relatively small suppliers or were not supplying modem chips a decade earlier, and Samsung S-LSI’s and HiSilicon’s shares were negligible even in 2012.

84. As discussed in Section III.C.1, the modem chip is one of many components in a mobile device. The same firms that supply modem chips may also supply other components of mobile devices. Modem chip suppliers that offer SoCs, for instance, offer several device components integrated together on a single chip. Some modem chip suppliers also sell other device components that are not integrated with the modem chip. Samsung, for instance, sells OLED smartphone screens and supplied those screens for Apple’s iPhone X.<sup>162</sup> Exhibit III.D.5 indicates which modem chip suppliers were active in the supply of some other mobile device components. The supply relationships that firms create with OEMs for the supply of other mobile device components may be beneficial in establishing and maintaining relationships for the supply of modem chips.

## **2. Modem chip purchasers**

85. Mobile device OEMs purchase modem chips and assemble them with the other components of a mobile device. The device is then sold to retailers, wireless operators, or consumers. Some of the major OEMs over time have included Samsung, Nokia, Apple, LG, Huawei, Sony, and Motorola.<sup>163</sup> Exhibit III.D.6 shows that from 2008 to 2017, the number of mobile device

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<sup>162</sup> “iPhone X Costs Apple \$370 in Materials, IHS Markit Teardown Reveals,” IHS Markit, November 8, 2017 (“The [‘Super Retina’ display] panel is supplied by Samsung Display, and [...] the panel maker will supply around 67 million flexible AMOLED units to Apple in 2017 built to the company’s unique specifications.”).

<sup>163</sup> “OEM,” in the context of mobile devices, does not refer only to manufacturing companies. Apple, for example, relies on contract manufacturers such as Foxconn to assemble its products, but is often referred to as a mobile

86. As noted above, OEMs differ in the way they organize their mobile device production and in their degree of vertical integration. Some OEMs have chosen to integrate upstream, designing and possibly manufacturing their own modem chips. As I discuss in more detail in Section IV.C, this reduces the OEM business that remains available to independent modem chip suppliers, such as Qualcomm and Intel, as OEMs source modem chips from their integrated suppliers.<sup>166</sup> [REDACTED]

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167 See Exhibit 3.

See also “Samsung Galaxy S4 Teardown,” Tech Insights (“This Galaxy S4 uses Intel’s PMB9820 baseband processor.”);

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87. Samsung, an OEM of smartphones, tablets, and other products, is fully vertically integrated from the manufacture and design of modem chips to mobile device sales. In addition to designing and manufacturing mobile devices, Samsung owns a modem supplier, Samsung S-LSI, which designs and manufactures modem chips and supplies them for Samsung’s own branded devices or sells them to Samsung’s rival OEMs.<sup>168,169</sup> Samsung’s full vertical integration facilitates the interaction of different parts of the company and lowers the transaction costs and uncertainty that characterize OEM–supplier contracts.
88. Huawei is slightly less vertically integrated than Samsung. Huawei designs and manufactures mobile devices and sells them to end consumers. It owns a modem chip supplier, HiSilicon, but unlike Samsung it does not own a foundry. In other words, HiSilicon is a fabless modem chip supplier that designs some (but not all) of the modem chips incorporated into Huawei’s mobile devices.<sup>170,171</sup>
89. Apple, differently from Huawei and Samsung, is not integrated with a modem chip designer and has preferred to buy thin modems from suppliers such as Qualcomm, Infineon, and Intel. Still, Apple designs the APs used in its mobile devices, and outsources their manufacturing to TSMC and Samsung.<sup>172</sup> As such, Apple is also vertically integrated, though not within the

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<sup>168</sup> See “About Us,” Samsung, available at <http://www.samsung.com/semiconductor/about-us/business-overview>. Note that in 2017, Samsung made its foundry business “an independent business unit.”

<sup>169</sup> See Shaik, Asif, “How Being a Component Manufacturer Helped Samsung in Becoming The Biggest Mobile Phone Brand,” InfiniGeek, November 14, 2013.

<sup>170</sup> See, e.g., “Company Overview of HiSilicon Technologies Co., Ltd.,” Bloomberg, available at <https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=29568267>. See also “Company Overview,” HiSilicon, 2017, available at <http://www.hisilicon.com/en/AboutUs/Overview>.

<sup>171</sup> See Section V.C.5 for additional details.

<sup>172</sup> See, e.g., Owen, Malcolm, “Apple’s ‘A12’ Chip Reportedly in Production Using 7nm Process from TSMC,” AppleInsider, April 23, 2018 (“Chip producer TSMC may enjoy its highest profits this year for production of the next-generation ‘A12’ processor, with a report claiming the manufacturer is ramping up volume production on its 7nm process lines in order to cope with the orders for the Apple-designed chip destined for 2018 iPhone models. [...] TSMC is reportedly the sole producer of A12 chips, after apparently securing all of orders for the component from Apple earlier this year.”). See also “From A4 to the A11 Bionic: The Evolution of Apple ‘A’

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modem chip industry. [REDACTED]

[REDACTED]

[REDACTED].<sup>174</sup>

90. Xiaomi, one of the largest mobile device OEMs worldwide, also recently released its own modem chip, the Surge S1 SoC,<sup>175</sup> and appears to be developing another, the Surge S2 SoC.<sup>176</sup> This suggests that the trend toward vertical integration of OEMs into the supply of modem chips may continue.
91. Several considerations enter into the decision to integrate vertically with different component industries and different business models have proved successful. Potential benefits of vertical integration include cost savings (including, for example, the elimination of a markup), more reliable supply schedules, and greater ability to customize the input good to the specific needs of the downstream OEM product.<sup>177</sup> Another factor that may affect the decision to vertically

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Mobile Chips,” PC Mag, September 13, 2017 (“Apple moved to its well known Ax series family of Systems on Chip (SoC) only after the iPhone 3GS which is now used iPad, iPod touch, and even the Apple TV. The chips are designed by Apple while it is usually manufactured by Samsung and TSMC.”).

<sup>173</sup> [REDACTED]

<sup>174</sup> [REDACTED]

[REDACTED] Ting-Fang, Cheng, “Apple: a Semiconductor Superpower in the Making,” Nikkei Asian Review, September 29, 2017 (“Industry sources and analysts [...] say the company is interested in building [...] modem chips for iPhones [...]. [...] Bernstein’s Li said that Apple has invested in research and development for baseband modem chips responsible for mobile communication. Currently, it purchase[s] these from Qualcomm and Intel. ‘It would not be surprising that Apple develops its own [modem chip],’ he said.”).

<sup>175</sup> Gordon, Scott Adam, “Xiaomi Reveals 64-bit Surge S1 Chipset, its First-ever SoC,” Android Authority, February 28, 2017.

<sup>176</sup> See, e.g., Ingelido, Michele, “Xiaomi Seems To Be Preparing Surge S2 SoC As Orders At TSMC Increase,” GizmoChina, April 29, 2018, available at <https://www.gizmochina.com/2018/04/29/xiaomi-seems-to-be-preparing-surge-s2-soc-as-orders-at-tsmc-increase/>.

<sup>177</sup> [REDACTED]

[REDACTED] See also Buzzell, Robert, “Is Vertical Integration Profitable?,” Harvard Business Review, January, 1983 (“Vertical integration may permit cost reduction [...]. Vertical integration may be essential to assure a supply of crucial materials.

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integrate is the scale of production. For example, according to MediaTek’s COO, Jeffrey Ju, a smartphone OEM must sell about 100 million units to justify its own modem chip arm.<sup>178</sup>

92. OEMs purchase modem chips for an array of different products. Apple, for example, uses modem chips both in the iPhone and in certain iPad tablets with cellular connectivity.<sup>179</sup> HMD Global purchases 2G modem chips for “retro” feature phones marketed under the Nokia brand, such as the Nokia 3310.<sup>180</sup> Other OEMs also produce phablets, i.e., mobile devices with a size between that of a smartphone and a tablet.<sup>181</sup>

### **E. Modem chip supplier–OEM purchaser relationships**

93. The matching of modem chip suppliers to OEM purchasers takes place in the context of multiple dynamics: generational shifts and incremental innovations in wireless standards, ongoing innovations in modem chip technology, mobile device product cycles, carrier requirements, and firm-level modem chip product cycles.
94. In this section, I consider this matching of modem chip suppliers to device OEMs from two perspectives: first from the demand side, then from the supply side. On the demand side, I consider how innovation interacts with OEMs’ requirements for modem chips, examine the factors that may influence the overall number of modem chip suppliers from which an OEM

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[...] Some claim that [...] businesses and companies that are vertically integrated, especially backward, are best equipped to innovate.”).

<sup>178</sup> “MediaTek sees only limited use of its new advanced chip in 2017,” Nikkei Asian Review, February 28, 2017.

<sup>179</sup> See, e.g., Apple Inc.’s Responses and Objections to Qualcomm Incorporated’s Second Set of Interrogatories, November 20, 2017, pp. 14–15 (Apple’s response provides a table that “identifies the baseband processors utilized in the [...] referenced products,” which include models of iPhone, iPad, and Apple Watch.).

<sup>180</sup> Kelion, Leo, “Nokia 3110 Mobile Phone Resurrected at MWC 2017,” BBC News, February 26, 2017 (“Nokia’s 3310 phone has been relaunched nearly 17 years after its debut. Many consider the original handset iconic because of its popularity and sturdiness. More than 126 million were produced before it was phased out in 2005. The revamped version will be sold under licence by the Finnish start-up HMD Global, which also unveiled several Nokia-branded Android smartphones.”).

<sup>181</sup> See, e.g., “What is a phablet and why do you need one?,” Verizon, July 28, 2017, available at <https://www.verizonwireless.com/articles/what-is-a-phablet-verizon-samsung/> (“Phablets are essentially smartphone-tablet hybrids. They’re feature-rich devices with screen sizes between 5 and 6 inches [...].”). Huawei’s MediaPad X1, for example, is a seven-inch device with mobile connectivity, including support for voice calls. See, e.g., Lai, Richard, “Huawei MediaPad X1 Is the Lightest and Narrowest 7-inch Tablet, Plus It’s a Phone,” Engadget, February 23, 2014 (“Does the world need bigger smartphones? Huawei answers this question at MWC with the launch of its MediaPad X1, a 7-inch Android tablet that lets you make phone calls.”).

sources, and finally discuss the individual modem chip and supplier characteristics that OEMs may weigh when choosing a supplier. On the supply side, I consider the challenges that a modem chip supplier faces in satisfying the various requirements of OEMs while competing effectively at the leading or trailing edge of the industry.

## 1. Factors affecting demand for modem chips

### *a. Innovation*

95. Innovation plays an important role in determining the demand for modem chips. Over time, there has been tremendous innovation in mobile devices, as well as in cellular networks and the systems and processes by which devices and networks communicate.<sup>182</sup> Each year, new devices have been released with new and improved functionality.<sup>183</sup> The demand for improved functionality is evidenced by the spikes in sales following the release of new models.<sup>184</sup> Much of this functionality requires new and improved modem chips. Demand has consistently been high for phones and other devices that are improvements over existing models along multiple dimensions, including voice quality, data speeds, application functionality, form factor or physical style,<sup>185</sup> and network coverage.<sup>186</sup>
96. Some OEMs have strategically decided to cater to this consumer demand for multi-functional, cutting-edge devices;<sup>187</sup> in turn, these OEMs demand highly customized modem chips that facilitate advanced device functionality. The precise nature of modem chip innovations that

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<sup>182</sup> See the overview of wireless standards in Section III.C.2.

<sup>183</sup> For example, Apple has released at least one new iPhone every year since 2007, improving the phone in ways such as battery consumption, storage, and camera performance over time. See, e.g., Velazco, Chris, “The iPhone 10 Years In: Everything That’s Changed from 2007 to 2017,” Engadget, September 11, 2017.

<sup>184</sup> See, e.g., Carton, Benjamin et al., “A New Smartphone for Every Fifth Person on Earth: Quantifying the New Tech Cycle,” *International Monetary Fund*, WP/18/222018, p. 4 (“Demand [...] is highly cyclical as it centers around the release of new smartphone models by global producers [...].”).

<sup>185</sup> See, e.g., “Form Factor,” Phone Scoop, available at <https://www.phonescoop.com/glossary/term.php?gid=4> (“Mobile phones come in several different physical styles (form factors) [...] common categories used [...] to describe form factors: Bar, [...], Clamshell, [...], Flip, [...] Slide, [...] Swivel.”).

<sup>186</sup> See, e.g., Shein, Esther, “Smartphone Consumer Demand Growing,” InformationWeek, July 1, 2010 (“The demand for smartphones is being fueled by a consumer desire for ultimate converged devices that support functionalities such as touchscreen, camera/video support, dual SIM card, Wi-Fi, and integrated GPS.”).

<sup>187</sup> See case studies in Section V.C.

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are demanded varies over time. As carriers adopt a new standard or new category within a standard, for example, OEMs may anticipate that modem chip support for that new standard or category – as well as backward compatibility to older standards<sup>188</sup> – is key to capturing consumer demand for devices capable of operating on the new standard or category.<sup>189</sup> At other times, other modem chip features may become more important to demand, and the relevant features may vary. [REDACTED]

[REDACTED]  
[REDACTED]  
[REDACTED].<sup>192</sup> [REDACTED]

188

[REDACTED]

189

[REDACTED]

190

[REDACTED]

191

[REDACTED]

192

[REDACTED]

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- [REDACTED]
97. Given that some OEMs’ demand is particularly high for certain new and innovative modem chip features,<sup>195</sup> being the first modem chip supplier to develop and commercialize chips incorporating important innovations (including innovations relating to the integration of other functions into the chipset) is often a key driver of success. [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]

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<sup>193</sup> Carrier aggregation “allows mobile network operators to combine a number of separate LTE carriers. This enables them to increase the peak user data rates and overall capacity of their networks and to exploit fragmented spectrum allocations.” Brydon, Alastair, “Evolution of LTE-Advanced Carrier Aggregation,” Unwired Insight, March 25, 2014. See also “The 150 Factor: Superfast LTE is Here,” Qualcomm OnQ Blog, June 26, 2013 (“Carrier Aggregation is a foundational feature of LTE Advanced. While today’s 4G LTE services are delivered over a single narrow channel—sometimes called a carrier—LTE Carrier Aggregation brings together two or more carriers to simultaneously transfer data, resulting in data delivered twice as fast. Using a transportation example, regular LTE is like a two-lane road whereas LTE Advanced is four-lane highway, meaning more data and faster speeds.”).

<sup>194</sup> [REDACTED]

<sup>195</sup> This demand is evidenced, in part, by the high prices commanded by certain novel modem chip features. See, e.g., Achour Deposition, Qualcomm, p. 78 (“Typically when something is introduced in a market first it has a lot of value, and then when it becomes kind of baseline, everybody has it, then the value diminishes and we cannot differentiate on it -- we can differentiate on performance, maybe, but it’s not a novelty anymore, so everybody has it, then it becomes less valuable from a differentiation perspective.”).

[REDACTED]

98. The rewards associated with being the first to market with a product that is in high demand – and therefore, at least for a time, the only potential supplier of a product in high demand – may be considered a type of “first-mover advantage.” Note that while the term “first-mover advantage” carries a variety of meanings in the academic literature and generally refers to advantages that, for a variety of reasons, may (or may not) accrue to a firm as the result of being the first entrant into a particular market segment,<sup>197</sup> I do not use the term in this manner. Instead, I use it to refer *specifically* to rewards accruing to a firm that is uniquely positioned to satisfy demand because it is the first to market with a new product and for a time is the *only* firm capable of producing that product.<sup>198</sup> For example, Qualcomm was the first mover into CDMA technology; it was also a pioneer in CDMA modem chips, introducing a CDMA-compatible handset (incorporating a CDMA modem) as early as 1993 and providing handsets

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<sup>196</sup> APL-QC-FTC\_12123224–3226 at 3224, email from Steve Schell, Apple, January 31, 2013.

<sup>197</sup> See, e.g., Suarez, Fernando et al., “The Half-Truth of First-Mover Advantage,” *Harvard Business Review*, April 2015, p. 122 (“A first-mover advantage can be simply defined as a firm’s ability to be better off than its competitors as a result of being first to market in a new product category”). See also Lieberman, Marvin B. et al., “First-Mover Advantages,” *Strategic Management Journal*, Vol. 9, 1988, p. 41 (“In the first stage some asymmetry is generated, enabling one particular firm to gain a head start over rivals. This first-mover opportunity may occur because the firm possesses some unique resources or foresight, or simply because of luck. Once this asymmetry is generated a variety of mechanisms may enable the firm to exploit its position; these mechanisms enhance the magnitude or durability (or both) of first-mover profits.”).

<sup>198</sup> In particular, my use of the term “first-mover advantage” diverges from others’ use of the term to describe the idea that entering a market segment first may endow a firm with advantages that persist even as other, equally capable competitors enter the market. See, e.g., Kerin, Roger A. et al., “First-Mover Advantage: A Synthesis, Conceptual Framework, and Research Propositions,” *Journal of Marketing*, Vol. 56, No. 4, 1992 pp. 34–35 (discussing how enduring first-mover advantages may arise because, among other reasons, (1) later entrants may face higher barriers to entry, and (2) first movers may have the opportunity to shape consumer preferences). In fact, the academic literature recognizes that first-mover advantages (in the literature’s broader sense of the term) are unlikely to persist in industries characterized by rapid technological innovation. See, e.g., Bohlmann, Jonathan D. et al., “Deconstructing the Pioneer’s Advantage: Examining Vintage Effects and Consumer Valuations of Quality and Variety,” *Management Science*, Vol. 48, No. 9, 2002, p. 1175 (“Pioneers in categories with high vintage effects [i.e., technological evolution] are shown to have lower market shares and higher failure rates. Similar results appear when analyzing persistence of market leadership over time.”). Thus, the first mover in such an industry is unlikely to maintain its success without continued investment and successful execution.

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for the first CDMA networks as early as 1995.<sup>199,200</sup> As carriers began adopting CDMA, Qualcomm benefited from the growth in demand for modem chips of a type it was uniquely ready to produce.<sup>201</sup> As I discuss further in Section V.B, over time, however, Qualcomm quickly ceased to be the only firm capable of supplying CDMA modem chips.

99. The first mover in the modem chip industry can benefit for several reasons. First, the ability to meet OEMs’ requirements by bringing a new modem chip to the market in time for a new product launch allows the modem chip supplier to gain new product sales. Second, it allows the supplier to enjoy higher gross margins while it is the sole supplier of an innovative modem chip.<sup>202</sup> Third, as I discuss in more detail below, being the first mover allows a modem chip supplier to enjoy an incumbency advantage because of switching costs for the OEMs.

<sup>199</sup> See, e.g., “History,” Qualcomm, available at <https://www.qualcomm.com/company/about/history> (“In March of 1993, Qualcomm introduces the industry’s first dual-mode CDMA-AMPS mobile phone [...]”). In 1994, Qualcomm went on to establish a joint venture with Sony, QPE, to produce CDMA mobile devices. See, “Telephone Joint Venture,” The New York Times, February 28, 1994 (“Qualcomm Inc. and Sony Electronics Inc. said today that they would form a \$52 million joint venture to manufacture portable phones using Qualcomm’s code division multiple access technology. [...] The joint venture, to be called Qualcomm Personal Electronics, will operate out of an existing factory in San Diego, according to Irwin Jacobs, Qualcomm’s chief executive. Production is expected to begin in the first quarter of 1995.”). See Section V.B for further details.

<sup>200</sup> See, e.g., Jacobs, Irwin M., “Statement by Dr. Irwin Mark Jacobs, Co-founder, Qualcomm, Prepared for the Hearing on Reauthorization of the SBIR and STTR Programs,” U.S. Senate Committee on Small Business and Entrepreneurship, February 17, 2011 (“The first CDMA network went commercial in Hong Kong in 1995; next two networks became operational in South Korea in 1996; and finally several networks became operational across the United States. Qualcomm provided handsets manufactured in San Diego for all of these early systems.”).

<sup>201</sup> On the flip side, firms that are not ready to produce demanded new technologies may find themselves at a considerable disadvantage. For example, [REDACTED] in Section V.C.2.

<sup>202</sup> As additional suppliers enter the modem chip industry and the supply of modem chips increases, average sales price and, therefore, gross margins can decline. Additionally, if other OEMs increase the demand for the new modem chip, the “first mover” can obtain higher margins, at least until other suppliers can begin supplying similar modem chips. Finally, and as previously discussed, because of incremental standards advancements within each standard generation, and because OEMs often demand more advanced technological features with every subsequent product release (at least for high-end devices), the later a fast follower is to market, the lower the demand for a modem chip with those features, as more advanced features replace past capabilities. This is discussed in greater detail in Section III.E.2.b.

100. Although there is substantial demand for innovative mobile devices, it is important to recognize that the industry offers a range of products at any point in time.<sup>203</sup> In addition to devices with the latest features and technologies, devices with older technology and fewer features are available. Specifically, mobile devices span the range from so-called *ultra-low-cost* handsets largely sold in emerging markets to high-end smartphones like Apple’s iPhone and Samsung’s Galaxy S.<sup>204, 205</sup> Although some OEMs specialize in a particular device segment, other OEMs produce a range of devices that utilize modem chips with different specifications. In 2015, for example, Lenovo/Motorola introduced both the Moto X Pure Edition, which included a Qualcomm Snapdragon 808 chip supporting LTE Category 9 (with download speeds up to 450 Megabits per second [Mbps]),<sup>206</sup> and the Moto G3, which used the

<sup>203</sup> In the economics literature, such industries are typically referred to as having vertically differentiated product markets. In such industries, firms will produce different products in different price ranges in order to serve different groups of consumers with differing willingness-to-pay for quality. See, e.g., Sutton, John, “Vertical Product Differentiation: Some Basic Themes,” *The American Economic Review*, Vol. 76, No. 2, 1986, p. 394 (“[...C]onsumers partition themselves by income, in such a way that brands of successively higher quality are purchased by consumers in successively higher income bands. (This reflects the fact that the utility function just defined, has the property that a consumer’s willingness to pay for quality improvements is an increasing function of income.)”). See also Waldfogel, Joel, “Preference Externalities: An Empirical Study of Who Benefits Whom in Differentiated Product Markets,” *NBER Working Paper Series*, Working Paper 7391, 1999 (“Theory predicts that in markets with increasing returns, the number of differentiated products – and resulting consumer satisfaction – grow in market size.”).

<sup>204</sup> Agar, Jon, *Constant Touch: A Global History of the Mobile Phone*, Icon Books, 2013, pp. 102–103 (“[T]he growth in just half a decade was extraordinary: from 8 per cent of the [Indian] population in 2005 to 70 percent, reaching over half of households, in 2010, according to the World Bank. [...] Partly this growth was driven by the manufacturers [...] slashing prices to chase the Indian consumer with offers of ‘ultra-low-cost’ handsets. (A similar pattern may be emerging in the 2010s, as companies such as Google work with Indian companies to develop cheap smartphones.) These ultra-low-cost handsets lacked many of the features of Western second-generation phones – screens would be black and white, not colour, and had few gizmos such as cameras or large memories.”).

<sup>205</sup> See, e.g., “Baseband/Modem & Smartphone Market,” Forward Concepts, 2017, p. 6 (“The acceptance of Samsung’s Note8 Smartphone and Apple’s iPhone 8 series to be released in September will dictate the premium market segment growth for the 2<sup>nd</sup> half of 2017, being challenged only by Huawei with a small market share in the premium segment.”). See also “Global 4G Subscriber & Smart Device Market Update,” Forward Concepts, 2015, p. 16 (“Samsung has the most to lose in this region, consequently it has several new midrange lines, including the Galaxy A, Galaxy E and the low-end Galaxy J 4G smartphones, in addition to the high-end Galaxy flagship S and Galaxy Note lines.”).

<sup>206</sup> See, e.g., “Motorola Moto X Style,” GSMArena, available at [https://www.gsmarena.com/motorola\\_moto\\_x\\_style-7229.php](https://www.gsmarena.com/motorola_moto_x_style-7229.php). See also Qualcomm, “Snapdragon 808 Processor,” available at <https://www.qualcomm.com/products/snapdragon/processors/808>.

Qualcomm Snapdragon 410 supporting only LTE Category 4 (with download speeds up to 150 Mbps).<sup>207</sup>

101. Lower-cost mobile devices typically do not require modem chips at the leading edge of technological innovation.<sup>208</sup> Thus, while innovation is often a key driver of success among leading-edge modem chip suppliers focused on customized modem chips for high-end devices, modem chip suppliers at the trailing edge of the industry may instead pursue a strategy of supplying less customized chips for “lower-end” phones.<sup>209</sup> As established in the economics literature, due to the nature of innovation, there will generally be many more suppliers capable of producing modem chips incorporating older technologies than suppliers capable of producing innovative and highly customized modem chips.<sup>210</sup> When LTE was initially introduced, for example, Qualcomm was the only major supplier capable of producing multi-mode LTE chips.<sup>211</sup> By 2011, Qualcomm faced competition for multi-mode LTE from ST-

<sup>207</sup> See, e.g., “Motorola Moto G (3rd Gen),” GSMarena, available at [https://www.gsmarena.com/motorola\\_moto\\_g\\_\(3rd\\_gen\)-7247.php](https://www.gsmarena.com/motorola_moto_g_(3rd_gen)-7247.php). See also “Snapdragon 410 Processor,” Qualcomm, available at <https://www.qualcomm.com/products/snapdragon/processors/410>.

<sup>208</sup> See, e.g., Summerson, Cameron, “Are Cheap Android Phones Worth It?,” How-To Geek, November 24, 2017 (“Most of the time, affordable phones have either current low-end hardware, or higher-end hardware from two or three years ago. [...] Right out of the gate, you have to keep in mind that you’ll be dealing with either a lower-end processor – like something from Mediatek, for example – or possibly an older Snapdragon chip, probably from somewhere around the 400 range.”).

<sup>209</sup> See Section III.D.1. Further, over time, once-novel features may become standard even in lower-end phones. See, e.g., Achour Deposition, Qualcomm, pp. 81–82 (“Q. Is category 4 LTE basic LTE? A. At that time in what -- I’m assuming you mean in 2011? Q. In 2011, yes. A. In that time category 4 was -- was roughly the -- when that category 4 was becoming the key. It was not basic, it was becoming like the -- what do you call, like the -- the high-end feature of LTE. It was the new thing, the innovative thing everybody wanted. So in that respect it was not basic LTE. It became basic LTE years down the road, but not when -- at the time when it was introduced. Q. Is category 4 LTE basic LTE today? A. Oh, yeah, it’s -- it’s -- category 4 today is shipping in our products in a very, very low tier of a product. These are very cheap phones, basic, that you can sell in India. So all those phones in India right now, they have cat 4 support. And in India phones could cost \$25, you know, these are very cheap stuff.”).

<sup>210</sup> There are generally more firms capable of producing established than cutting-edge technologies in part because the costs of imitating an existing technology are significantly lower than the costs of innovating. See, e.g., Mansfield, Edwin, “R&D and Innovation: Some Empirical Findings,” in Zvi Griliches, ed., *R&D, Patents, and Productivity*, University of Chicago Press, 1984, p. 142 (“In our sample, imitation cost averages about 65 percent of innovation cost, and imitation time averages 70 percent of innovation time.”). This has also been documented in particular in the semiconductor industry. See, e.g., Kumar, Rakesh, *Fabless Semiconductor Implementation*, McGraw Hill, 2008, pp. 16–17 (“The cost of process R&D escalates exponentially if you are the first developer of a new technology node [...]. Costs can be significantly lower if one chooses to be a ‘follower’ and be a year or more behind implementing new technologies.”).

<sup>211</sup> “Qualcomm to Ship Industry’s First Multi-mode LTE Chipsets in 2009,” Qualcomm Press Release, February 7, 2008. Additionally, in 2013 Qualcomm announced a new LTE chip that can support all LTE networks

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Ericsson, Icera, and Samsung.<sup>212</sup> By 2014, there were at least 14 LTE modem chip suppliers, at least 11 of which were supplying multi-mode LTE chips.<sup>213</sup>

102. Finally, although innovations may often sway an OEM’s choice of modem chip, OEMs do not always demand modem chips that are cutting-edge in all dimensions, even for devices that OEMs market as cutting-edge. [REDACTED]

214 [REDACTED]

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worldwide. See, e.g., “Qualcomm RF360 Front End Solution Enables Single, Global LTE Design for Next-Generation Mobile Devices,” Qualcomm Press Release, February 21, 2013 (“Qualcomm Technologies, Inc., introduced the Qualcomm RF360 Front End Solution, a comprehensive, system-level solution that addresses cellular radio frequency band fragmentation and enables for the first time a single, global 4G LTE design for mobile devices. [...] New RF devices are tightly integrated and will allow [...] the flexibility and scalability to supply OEMs of all types, from those requiring only a region-specific LTE solution, to those needing LTE global roaming support.”).

<sup>212</sup> Exhibit 3, Lederer Deposition, Qualcomm, Q2014FTC03837571, p. 2 (“Competition for multi-mode LTE in 2H 2011 from: STE, Icera, Samsung.”).

<sup>213</sup> See Exhibit III.D.2. See also “LTE Chip Market Trends,” Forward Concepts, 2014, p. 68 (“Broadcom[’s] MP6530 [...] was an integrated multi-mode modem for LTE, DC-HSPA+, GSM, GPRS and EDGE.”), p. 71 (“The Marvell Mobile PXA1928 is a single-chip quad-core A53, 5-mode Long Term Evolution (LTE) solution supporting all global mobile broadband standards, including LTE Cat4 TDD/FDD, High Speed Packet Access Plus (R8 HSPA+), Time Division High Speed Packet Access Plus (R8 TD-HSPA+) and Enhanced Data for GSM Environment (EDGE).”), p. 87 (“[Spreadtrum’s] SC9610 integrates multiple communication standards into a single-chip design, including multiband TD-LTE and TD-SCDMA and quad-band EDGE/GPRS/GSM.”), p. 88 (“[Ericsson’s] M7400 LTE/3G platform complies with the 3GPP R8 radio specification for LTE FDD, and supports a tri-band HSPA and quad-band GPRS/EDGE multi-mode modem capability.”), and p. 91 (“[Intel’s] XMM 7160 slim modem module, with X-Gold 716 baseband processor fits in less than 700mm<sup>2</sup> PCB (Printed Circuit Board) area including all necessary system components for quad band LTE, Penta-band 3G and quad band EDGE applications”); “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 44 (“Qualcomm’s newly launched MSM8960 is the first mobile processor with an integrated modem supporting TD-LTE/FDD-LTE/EVDO/WCDMA.”), p. 44 (“MediaTek’s MT6599 8-core ARM CPU, designed in a 28 nm process, with integrated baseband for LTE and TD-SCDMA / WCDMA.”), p. 66 (“Huawei, via its HiSilicon Subsidiary, has designed the Hi6920 with the ability to support LTE R9. [...] Huawei’s Hi6920 is the industry’s fastest multi-mode chip to support a complete range of standards: LTE TDD/FDD/TD-SCDMA/UMTS/GSM/EDGE/GPRS.”), p. 66 (“[Innofidei’s] 3rd generation Cat4 LTE A baseband is multimode supports 3GPP R10”), and p. 72 (“[Renesas Mobile’s] triple-mode SP2531 Modem (EDGE, 3G and 4G LTE)”; “NVIDIA Icera Modem Chipset Validated on AT&T LTE Network,” NVIDIA Press Release, May 23, 2012 (“The NVIDIA Icera 410 LTE modem delivers lightning-fast web browsing, video streaming and multiplayer gaming to tablets and clamshell devices. It is the first Icera modem to implement 4G LTE in NVIDIA’s software defined radio baseband processor. Together with its multimode radio transceiver, the chipset offers 4G LTE at category 2 data rates (up to 50 Mbps) as well as 4G HSPA+, 3G and 2G compatibility.”).

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[REDACTED]

103.

[REDACTED]

[REDACTED]

See also Achour Deposition, Qualcomm, pp. 126–127

[REDACTED]

<sup>215</sup> See, e.g., [REDACTED]

[REDACTED]

See also “Snapdragon X16 LTE Modem,” Qualcomm, available at <https://www.qualcomm.com/products/snapdragon/modems/4g-lte/x16>. (“The Snapdragon X16 LTE cellular modem employs sophisticated digital signal processing [...] all of which come together to achieve download speeds of up to 1 Gbps.”). See also [REDACTED]

<sup>216</sup> APL-QC-FTC\_26682372–2410, at 2381 (Carrier Update and Spring/Summer Launch, Apple, March 14, 2017).

<sup>217</sup> [REDACTED]

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*b. Influences on OEMs’ choices concerning number of suppliers and changes in supply relationships*

*i. OEMs must weigh countervailing factors, both statically and dynamically*

104. OEMs’ existing relationships with modem chip suppliers can influence which suppliers’ modem chips they will demand going forward. This dependence arises because of costs

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See, e.g., Achour Deposition, Qualcomm, pp. 87–88

See also

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associated with starting a new supply relationship, which in turn arise due to, for example, customization between device and chip.

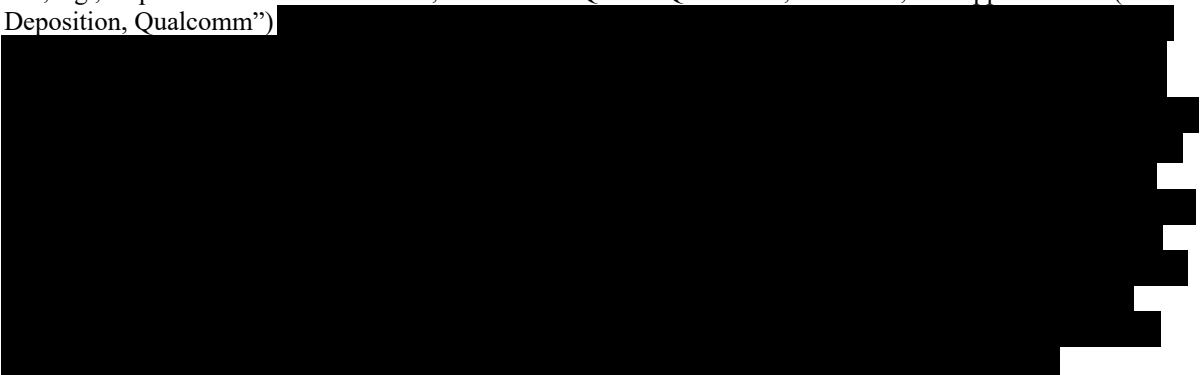
105. When deciding how many modem chip suppliers to use, either for a particular device or overall across its portfolio of mobile devices, and either at a specific time or over time, an OEM must weigh countervailing factors. The costs and benefits of using a single modem chip supplier versus sourcing chips from multiple suppliers or changing suppliers can vary widely among OEMs depending on their mobile device product portfolio, their product cycles, and other factors.

*ii. OEMs’ choice of number of suppliers for a given device*

106. Because modem chips are not generally standardized to be interchangeable in the mobile device manufacturing process, the mobile device and/or the modem chip inside it are typically designed for the other to some degree, and to a large degree customized for certain high-end mobile device OEMs like Apple. Therefore, OEMs must incur costs to work on integrating any modem chip supplier’s product into the mobile device. OEMs’ device designs take into consideration the modem chip(s) that will be incorporated in a given device, including size and connections to other components of the device. Similarly, modem chip suppliers may customize their chips and software to accommodate an OEM’s requirements. This customization is costly because mobile device OEMs may need to modify their designs if they were to change or add modem chip suppliers for a given device, and/or the new supplier may need to customize a chip and software for the OEM.<sup>221</sup> Customization costs may therefore

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<sup>221</sup> See, e.g., Deposition of Cristiano Amon, President of QCT at Qualcomm, March 12, 2018 pp. 412–413 (“Amon Deposition, Qualcomm”)



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drive down the number of modem chip suppliers that an OEM prefers to use for a specific device model, as each supplier comes with additional customization expense.<sup>222,223</sup>

107. For example, modem chips from different suppliers typically will not fit in the same socket and will not interface with other components in the device in the same way, and the electrical connections will be in different physical locations and function in different ways, absent additional customization work.<sup>224</sup> Reconciling all of these differences is costly.<sup>225</sup> Therefore, if an OEM decided to use two modem chip suppliers for a specific device, it would generally need to undertake this engineering work twice, to design a version of the device that is pin-compatible with the first modem chip supplier’s chip and another version of the device that is pin-compatible with the second supplier’s chip, an added cost that incentivizes OEMs to use the same chip supplier.

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<sup>224</sup> As an example of the level of customization required, consider the pin maps of Qualcomm Processor APQ8064E. “Qualcomm Snapdragon 600E Processor APQ8064E: Device Specification,” Qualcomm, July 2017, pp. 35–39, available at <https://developer.qualcomm.com/download/sd600/snapdragon-600-device-spec.pdf>. For the chip to correctly interface with other chips and other parts of the mobile device, the pins described in these maps must match the electrical connections of the device.

<sup>225</sup> For a discussion of switching costs perceived by BlackBerry, see Deposition of Chris Efstathiou, Former Senior Vice President of Global Supply Chain at BlackBerry, *Apple Inc. v. Qualcomm Inc.*, February 13, 2018, p. 116 (“Efstathiou Deposition, BlackBerry”) (“Q. Do you have any understanding of the cost to BlackBerry to switch chipsets from one supplier to another supplier? A. Again, that would tie to the radio protocol stack software and whether or not that came with the chip. If it didn’t and we had to write it ourselves it was a herculean effort. If it came with it then it wasn’t. So I would again leave that to the engineers to evaluate.”).

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108. Consistent with such additional engineering work, OEMs must typically increase headcount to support every additional modem chip supplier brought on. [REDACTED]
- [REDACTED]
- [REDACTED].<sup>226</sup> The additional employees work on the modem chip architecture to ensure size and layout compatibility with the mobile device, debug the software stack (which can involve “thousands” of bugs),<sup>227</sup> and facilitate interoperability testing, which is testing how the modem chip works in the device on every carrier network compatible with the device.
109. Bringing on multiple modem chip suppliers would also increase the costs of the product release and marketing, particularly if the suppliers are offering chips with differing multi-mode functionality. The OEM must ensure that the correct chips go in the correct geographic phone models, and must have separate supply chains for each.<sup>228</sup> Furthermore, sourcing from a single

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[REDACTED]

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See, e.g., Renduchintala IH, Qualcomm, pp. 158–160

[REDACTED]

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supplier typically allows OEMs to purchase a modem chip in larger quantities and qualify for quantity discounts that modem chip suppliers may offer.<sup>229</sup>

110. The marketing and product release costs limit the number of modem chip suppliers an OEM is willing to consider for a given device. Apple’s modem chip sourcing strategy is consistent with this expectation, as in the past it typically has used only one modem chip supplier for its iPhone and iPad devices. [REDACTED]

[REDACTED]<sup>230</sup>

111. On the other hand, an OEM may opt for different chip suppliers for the same device in different geographic markets, particularly when carriers or networks impose different constraints on the mobile device. As I discuss further in Section IV.A, recent models of the Samsung Galaxy S smartphone series have typically used Samsung’s own Exynos chips for some regions and a Qualcomm modem chip for other regions, while earlier models have sometimes used modem chips from other suppliers.<sup>231</sup> Similarly, in contrast to its previous strategy of using modem chips from a single supplier, Apple now uses both Intel and Qualcomm chips in its current iPhone models, the iPhone 8 and iPhone X, with Qualcomm’s chips enabling devices to work on all major U.S. carriers’ networks as well as worldwide.<sup>232</sup>

<sup>229</sup> The proliferation of quantity discounts is widely recognized. See, e.g., Altintas, Nihat et al., “Quantity Discounts Under Demand Uncertainty,” *Management Science*, Vol. 54; No. 4, 2008, p. 777 (“To motivate buyers to increase their order quantity, suppliers often rely on a well-established and widely used approach – they offer quantity discounts.”).

<sup>230</sup> [REDACTED]

<sup>231</sup> See Section IV.A for additional details.

<sup>232</sup> See, e.g., Segan, Sascha, “Exclusive: Qualcomm’s iPhone X Still Outpaces Intel’s,” PCMag, December 1, 2017 (“There are three iPhone X models sold globally. Using lab equipment, Cellular Insights tested two of them: the Qualcomm-powered A1865, sold by Sprint, Verizon, and U.S. Cellular and in Australia, China, and India; and the Intel-powered A1901, sold by most other global carriers including AT&T and T-Mobile. (The third model, A1902, is only sold in Japan.) Here in the US, we anticipate that the SIM-free model sold directly by Apple will be the A1865, as that’s the model that supports all four US carriers.”).

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112. Using more than one supplier may also mitigate risks associated with supply disruptions.<sup>233</sup>

[REDACTED]

[REDACTED]

[REDACTED] 234,235 [REDACTED]

[REDACTED]

[REDACTED].

113. In summary, the costs associated with sourcing from multiple suppliers or adding a new supplier encourage an OEM to continue procuring modem chips for a given device model from the same supplier, with few exceptions. Because the cost of customization to use a particular supplier’s chip is roughly constant no matter how many units of a device model are sold, customization costs may particularly discourage the use of a second supplier for a low-volume device. On the other hand, if an OEM expects to achieve a high sales volume for a specific device, the initial customization costs from adding a second supplier can be spread out over a larger sales volume, resulting in a smaller cost per device.

*iii. OEMs’ choice of number of suppliers for different devices at the same time*

114. For OEMs that produce a broader product portfolio, the costs and benefits of using the same modem chip supplier for multiple devices versus sourcing from multiple suppliers are different from the considerations relevant for a single device. In particular, a second supplier may

<sup>233</sup> The use of multiple suppliers is recognized as one way to build resilience against supply disruptions. See, e.g., Chopra, Sunil, and ManMohan S. Sodhi, “Managing Risk to Avoid Supply-Chain Breakdown,” *MIT Sloan Management Review*, Fall 2004, p. 55 (“Companies can counter disruptions in material flow by building inventory, or by having redundant suppliers (since it is unlikely that *all* suppliers would be disrupted simultaneously).”).

<sup>234</sup> [REDACTED] (“Q. [...] How would introducing a second supplier promote future innovation and reduce dependence? A. First, on future innovation, I think when you have two suppliers, they still want to keep some degree of pricing power. So they innovate to compete against their peers. They want to be better. We think that’s a good thing. There’s areas where we see that happening. Reduced dependence, any time we’re dependent on a supplier, there’s price risk as well as supply risk.”).

<sup>235</sup> [REDACTED]

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produce modem chips that are better suited to other devices in an OEM’s product portfolio. Therefore, an OEM that produces a broader range of products would be expected to source from a greater number of modem chip suppliers, as chips from different suppliers may be better suited for different mobile device products.<sup>236</sup> Conversely, an OEM such as Apple that limits the number of mobile devices it produces will be more likely to source modem chips from fewer suppliers.

115. The benefits of sourcing chips for multiple devices from the same supplier may exceed the costs of such a sourcing strategy. One of these benefits, for example, is the fact that OEMs, by sourcing chips for multiple devices from the same supplier, have greater power to negotiate quantity discounts. Furthermore, using a single supplier across several devices reduces the costs of adapting to each supplier’s procurement process and technical support, and it minimizes the costs of software customization.<sup>237</sup>
116. A competing consideration is the OEM’s strategy for negotiating with chip suppliers. For some OEMs, using different modem chip suppliers across different mobile devices may increase an OEM’s bargaining power and/or mitigate risk, as described above. The use, or credible consideration, of more than one supplier, even for different devices, may make it easier for an OEM to credibly threaten to shift its purchases from one supplier to the other and

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<sup>236</sup> See, e.g., Deposition of Hermann Eul, Manager of Mobile Wireless Group at Intel, March 21, 2018, p. 95 (“Eul Deposition, Intel”) (“Q. And were there any differences in approach between Samsung and Apple in terms of willingness to use new platforms? A. Samsung followed a multisourcing strategy. Q. Meaning that Samsung used baseband processors from a variety of different suppliers? [...] A. Yeah, a variety is not really clear whether that means two or five. But from different suppliers, if we keep it that simple.”).

<sup>237</sup> Such benefits of repeated transactions between a buyer and a supplier are also recognized in the economics literature. See, e.g., Williamson, Oliver E., “Transaction Cost Economics,” in Schmalensee, Richard and Robert D. Willig, *Handbook of Industrial Organization*, Vol. 1, Elsevier Science Publishers B.V., 1989, pp. 135–182, pp. 144–145 (“Rivals cannot be presumed to operate on a parity [...] once substantial investments in transaction specific assets are put in place. Winners in these circumstances enjoy advantages over nonwinners, which is to say that parity at the renewal interval is upset. Accordingly, what was a large numbers bidding condition at the outset is effectively transformed into one of bilateral supply thereafter.”).

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therefore to bargain over prices and other terms.<sup>238</sup> For example, Samsung considered chips from alternative suppliers as a way to discipline prices.<sup>239</sup>

*iv. OEMs’ choice of number of suppliers across time*

117. Finally, the considerations relevant for choosing the number of modem chip suppliers and the identities of those suppliers vary over time due to the relatively short mobile device life cycles. A modem chip supplier’s design win for one device model does not guarantee future success for other devices with the same OEM, and suppliers must compete again with the next device release. For many devices, most sales occur within the first year or two after launch, and many OEMs launch new devices every year.<sup>240</sup> This gives OEMs potential opportunities to switch modem chip suppliers or add new suppliers as they develop and launch new mobile devices (or new models of their existing devices), if they find that the benefits of doing so exceed the costs. This also implies that once an OEM decides to source modem chips for a given device from a certain supplier, other modem chip suppliers will not be able to supply chips for that device until the next model is launched, at the earliest. For instance, Apple’s decision to use Intel’s modem chips for all 2018 and/or 2019 iPhone models means that no other supplier will likely have the opportunity to supply modem chips to Apple before 2020.<sup>241</sup>

<sup>238</sup> Even the specter of dual-sourcing could be a negotiating tactic. See, e.g., Deposition of Kun Qian, Vice President of Sales at Qualcomm, February 8–9, 2018, p. 112 (“Qian Deposition, Qualcomm”) [REDACTED]

<sup>239</sup> See, e.g., Deposition of Hojin Kang, former Director of Purchasing in the Mobile Division at Samsung, February 28 – March 1, 2018, p. 38 (“Kang Deposition, Samsung”) [REDACTED]

<sup>240</sup> See, e.g., the discussion on device product cycles in section III.C.2.b.

<sup>241</sup> An Apple employee testified in February 2018 that Intel would be in 100 percent of the 2018 iPhones. Schafer Deposition, pp. 121–122 (“Q. [...] For that product that will be launched as a new product in the fall of 2018, who does Apple anticipate having modems from in that product? [A. ...] Intel. Q. Is that for all products, worldwide? A. Yes.”). Subsequently, press reports have indicated that Intel will supply 70 percent of modem chips for the 2018 iPhones. See also Sullivan, Mark, “Intel to Supply 70% of iPhone Modems this Year, 100% in 2019,” Fast Company, April 25, 2018 (“Apple is expecting Intel to supply 70% of

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118. Some OEMs may find it advantageous to continue sourcing modem chips from the same supplier(s) even as they release new devices, as there may be efficiencies associated with keeping existing supply relationships over time.<sup>242</sup> The economics literature recognizes this phenomenon as an incumbency advantage.<sup>243</sup> Some of the other types of costs mentioned above, including additional headcount, software debugging, and interoperability testing, may become less important over time, but may still encourage an OEM to continue sourcing modem chips from the same supplier.
119. On the other hand, OEMs may be more willing to bear additional customization costs if changing or adding a modem chip supplier allows them to integrate new features not offered by current suppliers, or if a change is necessary to keep up with technology or receive a lower price. In such cases, the benefit to using a new supplier is likely to outstrip the cost.<sup>244</sup> As discussed in Section IV.B, for example, the introduction of 4G LTE was followed by an increase in turnover in modem chip supplier–OEM relationships. Moreover, such important developments in wireless standards may also be accompanied by more radical mobile device redesigns, which may make it more worthwhile for an OEM to consider the most appropriate

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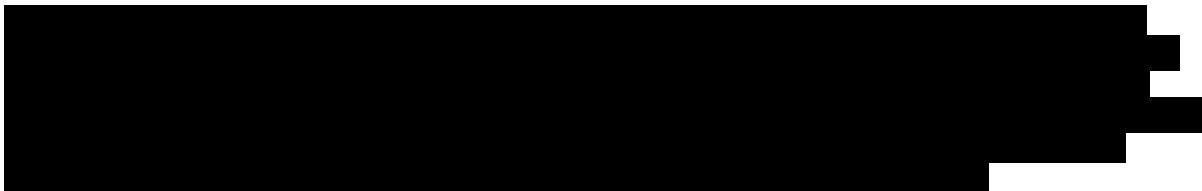
the modem chips inside the new iPhone models, which will debut this fall, and – if all goes well – plans to rely on the company for 100% of the modems in next year’s iPhones, a source with knowledge of Apple’s plans says.”).

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<sup>243</sup> See, e.g., Tunca, Tunay I. et al., “An Empirical Analysis of Price, Quality, and Incumbency in Procurement Auctions,” *Manufacturing & Service Operations Management*, Vol. 16, No. 3, 2014, p. 347 (“[...T]here are strong incentives for industrial buyers to award incumbent suppliers, since this would provide minimal disruption in their processes and allow them to do business with a known partner.”).

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supplier for its new devices. Therefore, competitive pressures on modem chip suppliers can be particularly intense when new wireless standards and subsequent category releases are being adopted on cellular networks.

120. Given these competing considerations at any given time and over time,<sup>245</sup> different OEMs may choose to source modem chips from different numbers of suppliers, and indeed an OEM may vary its number of suppliers over time.<sup>246</sup> My analysis in Section IV.A provides evidence to support these conclusions and shows that most years from 2008 to 2017 saw many changes in OEM–supplier relationships.

*c. Characteristics of modem chips and suppliers*

121. When choosing a modem chip supplier, device OEMs weigh characteristics of the supplier’s modem chips as well as characteristics of the supplier itself. Given that a single supplier may not necessarily be the best in all relevant dimensions, an OEM’s choice of modem chip supplier will depend on the relative importance it assigns to various characteristics.<sup>247</sup>

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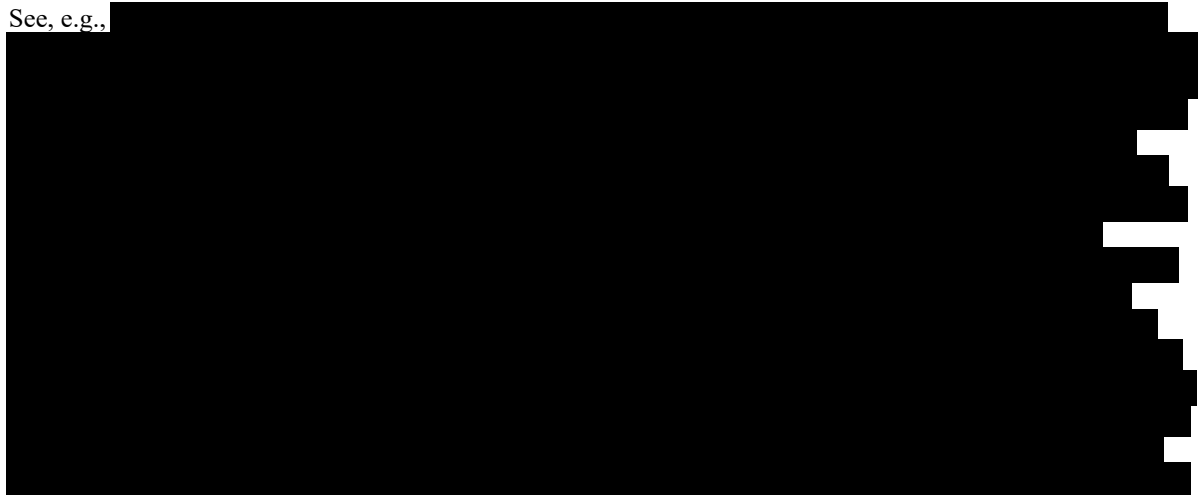
*i. Modem chip characteristics*

122. Various characteristics of modem chips are important to OEMs. These characteristics include the wireless standard or standards implemented, including the category of the standard implemented, the performance of the chip, the size of the chip, whether the chip integrates other features, and price; a supplier’s ability to deliver on these characteristics may be closely related to its success in innovation. Note that the chip characteristics that OEMs value are not independent of one another; for example, the wireless standard(s) with which a modem chip is compatible constrains elements of its performance. How competing modem chips compare across these dimensions is an important determinant of which supplier’s chip is selected for a device.
123. In addition, mobile network carriers have their own requirements that affect an OEM’s choice of a chip for a particular device. Specifically, carriers typically require that certain features and specifications be included in high-, mid-, and low-end mobile devices that operate within their networks. This in turn, affects an OEM’s demand for modem chip characteristics across devices and across geographic regions. For example, if an OEM wants to sell mobile devices in the U.S. through a particular carrier, it may have to select a chip that supports the carrier’s

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specific technological requirements, in addition to being compatible with the wireless standards that carrier uses.<sup>248,249</sup>

<sup>248</sup> See, e.g.,



Verizon’s chipset certification and approval process also includes a list of requirements that must be satisfied by chipsets to be included in Verizon’s certified chipset list. See, e.g., VZ-00004851–4880 at 4855 (“The goal of the chipset certification testing and approval process is to define a uniform set of criteria that will be used for all chipsets to evaluate its capabilities and conformance to industry and Verizon Wireless specifications, before it is approved to be listed in the Verizon Wireless CERTIFIED chipset List.”). Verizon has also encouraged OEMs to adopt certain technologies. See, e.g., “Verizon: We’ll have CBRS 3.5 GHz devices by end of 2018,” FierceWireless, April 5, 2018 (““CBRS is a key component of Verizon’s technology strategy,” the company said in a statement to FierceWirelessTech. ‘As such, Verizon has strongly encouraged all OEMs to adopt CBRS support to take advantage of this technology. CBRS-capable devices will begin entering the lineup by the end of 2018 and will continue to expand aggressively through 2019.’”).

<sup>249</sup> See, e.g., Renduchintala IH, Qualcomm, p. 44 (“Q. And was that [carrier aggregation] something that customers – it looks like something customers were willing to pay extra for; is that correct? A. It was something that network operators encouraged Qualcomm to develop and then directed their OEMs to make sure that they had in their products, yes.”), p. 46 (“Q. And then they [carriers], in turn, would turn to the OEMs who are your [Qualcomm’s] direct customers and say we want to offer this service. You need to give us a phone or a handset that has the technical capability of providing that, so go buy chips -- the implication is you better go buy chips that can do it? A. I would say what they said is if you’d like to be part of our handset portfolio, then these are the specs of the devices we’re interested in purchasing. If you’re able to deliver handsets that support those specs, we would be happy to try your devices and approve them on our network [...] What they basically said is this is what it takes to be part of our handset portfolio.”), and pp. 166–167 (“Q. [...] And what does ‘feature set’ mean in that context? A. It means advanced techniques that certain operators wanted. So it could be things like -- I’m going to get very technical here so I apologize. It would be like data interference cancellation on LTE or specific voice codex that could support voice on LTE. It could be specific peak modem rates that were required for peak performance. It was essentially the latest cutting-edge features in the modem space that some of the most advanced operators were very keen to have in their network, like technologies like four-by-four multiple input/multiple output antenna configurations which can support really high data rates.”).

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124. Wireless standard(s) implemented: Mobile device OEMs often demand chips compatible with the latest wireless standards, which are associated with higher data transmission speeds for end consumers.<sup>250</sup>
125. Primarily, this demand is for multi-mode chips.<sup>251, 252</sup> As discussed above, multi-mode functionality is important in part because carriers roll out support for new generations of wireless standards gradually. Multi-mode chips therefore often provide support for standards of multiple generations. In the case of LTE, multi-mode chips with backward compatibility have been particularly important because LTE networks initially transmitted only data, with voice calls transmitted via an older standard.<sup>253</sup> Even after the deployment of VoLTE and broad geographic carrier implementation of LTE networks, LTE devices typically still require backward compatibility, in the form of either a multi-mode chip or two separate chips, for voice transmission. More generally, backward compatibility with older standards may increase

<sup>250</sup> See, e.g., Deposition of John Grubbs, Senior Director of IP transactions at BlackBerry, March 1, 2018, pp. 212–213 (“Grubbs Deposition, BlackBerry”) (“Q. Once LTE chipsets were introduced into the market, how important were LTE-capable chipsets to BlackBerry’s business? A. I think they were extremely important. [...]s carriers made the switch over to LTE, they would [...] start requiring that new devices from BlackBerry be LTE compatible. [...] Carriers will require LTE, so we have to supply them devices with LTE.”).

<sup>251</sup> Industry reports suggest that when the first LTE multi-mode chips were released in 2011, 89 percent of all LTE chip shipments had multi-mode capabilities. By 2013, 95 percent of all LTE chip shipments were multi-mode. This proportion was forecasted to remain stable through 2018. See, e.g., “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 37. See also “LTE Chip Market Trends,” Forward Concepts, 2014, p. 59.

<sup>252</sup> [REDACTED] see, e.g., Amon Deposition, Qualcomm, pp. 406–407 [REDACTED]

<sup>253</sup> Some carriers have begun deployment of VoLTE, which provides LTE support for voice calls. See, e.g., Eul Deposition, Intel, pp. 101-102 (“Q. And was there a relationship between when CDMA would be sunsetted and when Voice over LTE technology would become available? [...] Was there a connection, in your mind, between those two issues? [...] A. Yeah, the operators that were relying on CDMA technology would have to have some alternative to do voice calls, which pretty much was that’s what CDMA was good in. And so that means there needed to be an alternative, and VoLTE was contemplated as being the voice capability of LTE.”).

the geographic and network range of the device’s connectivity and is therefore generally a carrier-driven requirement.<sup>254</sup>

126. Support for multiple contemporaneous standards may also allow a device to connect to a larger set of networks. A chip compatible with both WCDMA and CDMA2000, for example, could support 3G connections on all four major U.S. carriers.<sup>255</sup> Similarly, a chip with support for both WCDMA (introduced in the U.S. in 2004) and TD-SCDMA (for which support was introduced in China in 2008) may allow a consumer to use the device with, for example, AT&T in the U.S. and China Mobile in China.<sup>256</sup> It may also allow an OEM to use a single modem chip in the U.S. and China, simplifying design and production.<sup>257</sup> Finally, multi-mode functionality allows carriers to use frequencies that are allocated to older generations, therefore using the available spectrum more efficiently.<sup>258</sup>
127. A country’s current and historical carrier landscape may shape demand for multi-mode chips. In China, for example, where the three major carriers have used three different 3G families of

<sup>254</sup> See, e.g., Grubbs Deposition, Blackberry, p. 210 (“Q. Was it important for a chipset to be backwards compatible with LTE and either CDMA or UMTS? A. Yes. Q. Why? A. The carriers would have required that all of our devices be not only compatible with LTE, but AT&T, for example, would have required that it be backwards compatible with HSPA+, W-CDMA, and -- and maybe even GSM, whereas Verizon would have required that it be backwards compatible [...] with LTE as well as the CDMA variants [...] that preceded that.”).

<sup>255</sup> See, e.g., Kellen, “Cheat Sheet: US Wireless Carrier Bands for Unlocked Phones,” Droid Life, February 5, 2015. Note that in context, “GSM” refers to GSM’s 3G successor, WCDMA; and “CDMA” refers to the 3G successor to cdmaOne, CDMA2000.

<sup>256</sup> AT&T Wireless introduced UMTS (WCDMA) service in the U.S. in 2004. See, e.g., “UMTS Comes to U.S.,” RCR Wireless News, July 26, 2004. See also Back, Aaron, “China Mobile to Test TD-SCDMA on 60,000 Phones from April 1,” Cellular News, March 27, 2008.

<sup>257</sup>



<sup>258</sup> 4G Americas (now, 5G Americas), an industry trade organization for telecommunication services, noted the importance of using new and already allocated band in the same device. “5G Spectrum Recommendations,” 4G Americas, August 2015, pp. 7–8 (“The continuous increase in data and video traffic makes it essential to increase the amount of spectrum within which these technologies can be deployed and in a way that is compatible with currently allocated bands, so that current and new bands can be used in a complementary manner and in the same devices with comparable technology. New mobile broadband spectrum below 6 GHz can be used together with current mobile broadband spectrum in a well-understood manner.”).

128. Performance: Device OEMs value a variety of quality and performance dimensions as well as specific features and capabilities in modem chips. Two key dimensions of chip performance are data transmission speed capabilities and power consumption.<sup>263</sup> Data transmission speed is the amount of data that can be transmitted in a unit of time, typically measured in Mbps. It affects the type and quality of content that users can access through cellular data, such as

<sup>260</sup> See, e.g., SFT-07740063–0085 (Translation) at 0070, presentation titled [REDACTED] Samsung, February 20, 2016 [REDACTED]

263 For a discussion on the importance of data transmission speed in the marketing of LTE, see, e.g., Achour  
Deposition, Qualcomm, p. 87 (“That’s one aspect of [...] advanced LTE, yeah, it could be improving [...] peak  
rate. It’s always been a race to the higher peak rate every year, since 2010. This is one big aspect that probably  
gets a lot of media attention because it’s easy to refer to peak rate [...].”). See also Exhibit QX0209, Loh  
Deposition, [REDACTED]

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whether a phone is only able to transmit emails and text messages or can stream live high-definition video and provide real-time GPS mapping.

129. Power consumption, which is affected by the modem chip, the AP, and other device components, is important for battery life.<sup>264</sup> Battery life is typically measured by how long a phone can perform a certain function, such as conducting a phone call, playing music, or streaming video, between charges.<sup>265</sup> Chips with low power consumption allow phones to have longer battery life. As mobile device functionality has rapidly increased, maintaining battery life, and thus using chips with low power consumption, has become more important.<sup>266</sup>
130. Size: All else equal, reducing chip size lowers the cost and power consumption of a modem chip.<sup>267</sup> It also allows the chip to be placed in a physically smaller package, which allows for

<sup>264</sup> See, e.g., Deposition of Kevin Constantine, Head of Sales to Apple in North America at Intel, February 15–16, 2018, p. 239 (“Constantine Deposition, Intel”) (“Q. Is power usage generally an important factor in LTE modem development? A. Yes, and we think we’re pretty good at it, actually. Yeah, we think that’s a strength of ours. Q. And is power usage important because battery life in a mobile product is important to consumers? A. For example, yes.”). See also Achour Deposition, Qualcomm, p. 361 (“Q. Is power management or power efficiency an important part of designing a cell phone? A. It is the most important thing that makes a phone usable, I think. Because I remember the days where the phone had to be charged every few hours, and that really limits the adoption of the use of a phone, if someone has to find an outlet every few hours. So making the phone last at least a day, it’s a key -- very, very important aspect of designing a phone.”).

<sup>265</sup> See, e.g., “Snapdragon Performance,” Qualcomm, available at <https://www.qualcomm.com/products/snapdragon/battery-life> (“Now you can stream your favorite videos 4+ hours longer thanks to a 30% power reduction of 4K UHD premium video capture. [...] You can even talk longer - up to 2 days longer - with a 20% power reduction of continuous UHD voice. All with the new Qualcomm Spectra ISP architecture.”). See also Williams, Andrew, “Best Phones for Battery: 8 Smartphone Stamina Champs,” Techradar, December 24, 2017 (A measure of battery life cited is the battery lost from a 90-minute video played at full screen brightness: “The battery king: Huawei Mate 10 Pro [...] it lost just 9% of its battery from a 90-minute video played at full screen brightness.”).

<sup>266</sup> See, e.g., Naha, Abhi and Peter Whale, *Essentials of Mobile Handset Design*, Cambridge Wireless Essentials Series, 2012, p. 109 (“For mobile devices, unlike PCs and other mains-powered devices, power consumption is the key design issue which dominates many decisions. Trends in chipset design continue to reflect increasingly innovative approaches to reducing power consumption further. A continued focus on reducing power consumption is essential in order to mitigate the great increase in processing requirements to support functions such as high-performance graphics and multimedia, and to provide support for an increasing number of wireless air interfaces.”).

<sup>267</sup> See, e.g., Olson, Parmy, “Broadcom Challenges Qualcomm with ‘Smallest’ 4G LTE Smartphone Modem,” Forbes, February 12, 2013 (“[Broadcom] says the [smartphone modem chip BCM21892] takes up 35% less space than its previous offerings. As a result of being so small the modem chip will also be more energy efficient and cheaper to produce.”). See also Achour Deposition, Qualcomm, pp. 197–198 (“[...] Think of a product as a collection of Legos. Each Lego takes space in that product [...] each Lego has to basically reduce its area to make sure the overall cost is contained within what they target.”).

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smaller mobile devices. Again, all else equal, device OEMs prefer smaller, more compact chips, which allow them to pack more functionality into a smaller space.<sup>268</sup>

131. Integration of other features: As discussed in more detail in Section III.C.1 above, modem chips differ in their level of integration with other components, such as the AP. Most OEMs now demand SoCs because incorporating many functions in a single chip allows them to reduce device size and costs.<sup>269</sup> SoCs also tend to be more power efficient, which improves a device’s battery life.<sup>270</sup>
132. Because of advantages such as these, most OEMs have embraced SoCs, and overall the industry has shifted toward integrated solutions.<sup>271</sup> In some instances, OEMs only consider modem chip suppliers equipped to design SoCs.<sup>272</sup> Modem chip designers that do not invest in the development of modem chips incorporating other features, such as the AP, are not able to tap into the demand for SoCs.<sup>273</sup>

<sup>268</sup> See, e.g., [REDACTED]

See also Seifert, Dan, “Broadcom’s First LTE Modem Bets on Small Size and Lots of Features to Edge Out Qualcomm,” The Verge, February. 12, 2013 (“Smaller chips mean that device manufacturers have more room on their component boards, allowing them to either shrink devices down even further or make room for other features that couldn’t fit otherwise.”).

<sup>269</sup> See, e.g., Kressin Deposition, Qualcomm, pp. 39–40 (“Q. And do you present these plans as they relate to modem features? A. I usually present our -- all the customers I visit are interested in our SOC’s. I don’t visit customers to talk about our thin modems; I talk about our SOC’s.”). See also [REDACTED]

<sup>270</sup> Niu, Evan, “Is This What’s Held Back Apple, Inc.’s Cellular Baseband Ambitions?,” Nasdaq, January 18, 2017 (“Integration provides significant benefits in costs and power efficiency relative to stand-alone modems.”).

<sup>271</sup> Niu, Evan, “Is This What’s Held Back Apple, Inc.’s Cellular Baseband Ambitions?,” Nasdaq, January 18, 2017 (““There is no stand-alone modem business anymore.’ That’s NVIDIA CEO Jen-Hsun Huang from a conference call way back in 2013, when the company was developing a Tegra mobile processor with an integrated baseband modem to challenge Qualcomm (NASDAQ: QCOM). The baseband market had been shifting toward integrated solutions for years, and Qualcomm was by far the technological leader with integrated cellular connectivity. Integration provides significant benefits in costs and power efficiency relative to stand-alone modems.”).

<sup>272</sup> See, e.g., Achour Deposition, Qualcomm, pp. 105–106 [REDACTED]

<sup>273</sup> I discuss this in more detail in Section III.E.2.a, where I analyze the importance of demand foresight for modem chip suppliers.

133. Apple, meanwhile, has continued to purchase “thin modems,” thus diverging from the broad interest in SoCs. [REDACTED]
- [REDACTED] Apple’s use of thin modems has presented opportunities to firms such as Intel, which otherwise might have languished in the aftermath of its failed attempt to move the AP market towards its proprietary x86 architecture. Nonetheless, a firm that focuses on thin modems at the expense of developing SoCs in order to become an Apple supplier might lose many other OEM customers, given the widespread demand for integrated solutions by most OEMs other than Apple. Intel made the strategic decision to focus on thin modems, and the implications of this decision are discussed further in Section V.C.2.
134. Price: Price is also one of the determinants of OEMs’ choice of modem chip.<sup>275</sup> Apple has recognized this in its interrogatory responses: “With respect to component supply, Apple generally looks for the highest quality suppliers and competitive pricing.”<sup>276</sup> Other OEMs such as Samsung have also recognized the important role of price in their decision to select a modem chip.<sup>277</sup>

274

[REDACTED]

See also Dilger, Daniel Eran, “How Intel lost the mobile chip business to Apple’s Ax ARM Application Processors,” Apple Insider, January 19, 2015. See also Patterson, Alan, “Apple Talks About Sole Sourcing from TSMC,” EE Times, October 24, 2017.

<sup>275</sup> See, e.g., Efstathiou Deposition, BlackBerry, p. 137 (“Q. So was it your understanding that the strategic incentive would help Qualcomm win more business from BlackBerry? [...] A. I’m not sure it would help them win anything. I think it was a proposal. Q. How would BlackBerry evaluate the proposal? A. Total costs.”).

<sup>276</sup> Apple Inc.’s Supplemental Responses and Objections to Qualcomm Incorporated’s Second Set of Interrogatories (Nos. 26–53), p. 4.

<sup>277</sup> See, e.g., Kang Deposition, Samsung, February 28, p. 41 (“Q. I understand that. My question was just whether your goal in the initial selection, putting aside the goals that other people handled, was to obtain the best pricing and the best SCM. [...] A.] Yes. That’s right.”) and p. 46 (“Q. And so is it fair to say that performance on the one hand and pricing and schedule on the other hand were the primary factors considered by Samsung in selecting chips for use in mobile devices? [...] A.] As far as my understanding goes, those things would be major criteria for making a decision.”).

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135. The importance that OEMs place on price is also evidenced by price competition among chip suppliers.<sup>278</sup> The importance of price relative to other factors may vary by OEM and device. This observation is well established in the economics literature on differentiated products.<sup>279</sup> Particularly for OEMs that produce high-end mobile devices and target less price-sensitive consumers, quality and performance are usually weighted more than price when selecting a modem chip, whether they are considering SoCs or thin modems. [REDACTED]

[REDACTED] For OEMs producing devices targeting more cost-

<sup>278</sup> See, e.g., Chhabra Deposition, Marvell, p. 151 (“Q. Earlier, when you were testifying about a price war involving Marvell, MediaTek, Qualcomm, and Spreadtrum, was that a price war in the mid to low tier of LTE chips? [...A.] I would say so.”).

<sup>279</sup> In a differentiated product market, it can sometimes be more important for a firm to invest in the quality of its product than to reduce its costs. The benefits of selling a higher-quality product to high-willingness-to-pay consumers for a greater price may outweigh the steeper production costs. See, e.g., Shapiro, Carl and Hal R. Varian, *Information Rules: A Strategic Guide to the Information Economy*, Harvard Business School Press, 1999, pp. 25–26 (“To succeed, you must either become the price and cost leader based on your scale, or you must create a unique information resource and charge for it based on the value that it offers to consumers. [...] Do everything you can to make sure there are no close competitors by differentiating your product from others that are available.”) and 38 (“If you set your price at \$60 only the zealots will buy. If you set your price at \$20, you will sell to lots of casual users but will pass up the potential profits from selling at a high price to the zealots. Which way should you go? Answer: It depends on how many customers of each type there are.”).

280 [REDACTED]

281 [REDACTED]

<sup>282</sup> As discussed in Section III.E.1.b.ii, for example, a price-negotiation strategy reportedly was one of Apple’s motivations to source modem chips for the iPhone 7 from Intel as well as Qualcomm. Apple took this decision despite the compromise in speed associated with the Intel modems. See, e.g., Kelly, Gordon, “Apple’s New iPhones Will Change Essential Component,” *Forbes*, February 4, 2018 (“While iPhones have used a mixture of

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sensitive consumers or intended for sale in emerging markets, meanwhile, price can be expected to carry more weight in the choice of modem chip.<sup>283</sup>

*ii. Supplier characteristics*

136. In addition to the characteristics of the modem chips themselves, OEMs may value characteristics of modem chip suppliers. Relevant characteristics include the suppliers’ ability to accommodate customer requirements, their reliability, and their perceived neutrality.
137. Accommodation of particular OEM requirements: Modem chip suppliers compete on their ability to cater to OEMs’ particular requirements. In some cases, this means customizing chips and software in response to an OEM’s request to accommodate particular requirements. As follows from industrial organization principles, high customization is more likely to be observed at the leading edge of the industry. [REDACTED]
- [REDACTED] In cases where an OEM has unusual or particular requirements, a chip supplier’s success with the OEM will depend in part on the ability of the chip supplier to accommodate those requirements quickly and successfully.
138. Modem chip suppliers may also compete in the way they help OEMs to design mobile devices around their modem chips. For example, some chip suppliers provide “reference designs” to facilitate use of their chips by OEMs. Reference designs are instructions for building a basic mobile device. Suppliers such as MediaTek have created and distributed their own phone designs along with their chips.<sup>285</sup> These are helpful for smaller mobile device OEMs that do not have the resources to design their own phones, as they reduce development time.<sup>286</sup>

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Intel and Qualcomm chips for the last two generations, tests have consistently shown that Qualcomm-based iPhones deliver fast, more consistent 3G and 4G performance.”).

<sup>283</sup> See, e.g., discussion in Section III.E.1.a.

<sup>284</sup> See discussion in Section V.B for further details.

<sup>285</sup> Goldberg, Jonathan, “The MediaTek Phenomenon: The New Smartphone Disruption,” SlashData, May 8, 2013 (“So Mediatek took all that software work and bundled it into a complete package which they called a reference design for mobile phones. These reference designs were essentially blueprints for building a basic, 2G feature phone. Anyone with a 10-engineer team could buy a Mediatek chip and this would come with everything they needed to build a phone.”).

<sup>286</sup> Tilley, Arron, “MediaTek’s Plan to Take on Qualcomm in the Cut-Throat World of Mobile,” Forbes, June 3, 2015 (“MediaTek’s talent lies in getting smartphone makers up and running, fast. It provides reference designs-blueprints that new manufacturers can follow quickly to put together their own phones.”).

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Qualcomm also distributes reference designs. Its reference design program, originally focused on smartphone markets in China, has expanded globally and across phone tiers.<sup>287</sup>

139. Reliability: The importance of supplier reliability is well established in the literature on supply chain management.<sup>288</sup> Supply shortages sometimes affect modem chip suppliers’ ability to meet device OEMs’ demand.<sup>289</sup> This, in turn, hampers OEMs’ launch timelines, production, and sales, which may affect OEMs’ competitive positioning in the industry.<sup>290</sup> Naturally, OEMs prefer suppliers that can reliably meet order requests,<sup>291</sup> and they may avoid modem chip suppliers and products with uncertain reliability.<sup>292</sup> A significant interruption in supply of chips to an OEM may damage the supplier’s reputation, harming its ability to compete for the next opportunity.<sup>293</sup> Modem chip suppliers, including Qualcomm, therefore brand themselves as reputable companies and avoid measures that would make them look unreliable

<sup>287</sup> “A big year for the Qualcomm Reference Design program,” Qualcomm OnQ Blog, March 18, 2015 (“QRD has evolved from its original focus of helping to accelerate smartphone development destined for China, to being an important global program for the Chinese manufacturing ecosystem supporting devices, which are based upon Qualcomm Snapdragon™ processors by Qualcomm Technologies, around the world [...] Another important aspect of the QRD program expansion has been the reach across device tiers. What started with an emphasis on the high-volume tier has evolved to include high tier Snapdragon processors.”).

<sup>288</sup> For a discussion of the importance of information about supplier reliability (i.e., the importance of supplier reputation), see, e.g., Yang et al., “Supply Disruptions, Asymmetric Information, and a Backup Production Option,” *Management Science*, 55:2, 2009, pp. 192–209.

<sup>289</sup> See, e.g., “MediaTek Faces Chip Supply Constraints,” EE Times, August 8, 2016 (“MediaTek, Qualcomm’s largest rival in the smartphone silicon business, said it is unable to meet demand for 3G and 4G smartphone products because it underestimated the supply of chips it would need from its foundry partners.”).

<sup>290</sup> See, e.g., Efstathiou Deposition, BlackBerry, p. 141 (“Q. What effect would it have on BlackBerry’s business if a component supplier stopped shipping a component to BlackBerry? A. Missed revenue. Time to redesign.”)

<sup>291</sup> See, e.g., Chopra, Sunil and ManMohan S. Sodhi, “Managing Risk to Avoid Supply-Chain Breakdown,” *MIT Sloan Management Review*, Volume 46, Issue #1, Fall 2004, p. 53 (“Supply chain problems [...] can seriously disrupt or delay material, information and cash flows, any of which can damage sales, increase costs – or both.”).

<sup>292</sup>

<sup>293</sup> In a survey of 265 employees from 64 countries and 16 SIC (Standard Industrial Classification) industry sectors, 31 percent of respondents reported that supply chain disruptions resulted in damages to brand reputation/image. See “Supply Chain Resilience Report 2017”, Business Continuity Institute, 2017, p. 19.

140. Neutrality: As noted above, several OEMs, including Samsung and Huawei, have chosen to be vertically integrated with chip suppliers.

141. OEMs that lack an integrated modem chip supplier may sometimes be wary of relying on their competitors' captive modem chip businesses due to concerns that the captive modem chip business might favor or prioritize its OEM parent's business.<sup>296</sup> As a result, some OEMs, such as Motorola, separated their semiconductor divisions into a separate business to avoid the appearance of conflicts.<sup>297</sup> However, device OEMs were reportedly still skeptical in some cases of independent chip divisions that were previously affiliated with competitors. For instance, Freescale struggled to expand its customer base beyond its parent, Motorola, in part because of Motorola's ongoing influence.<sup>298</sup> OEMs that are reluctant to source their modem

<sup>296</sup> See, e.g., Exhibit QX505, Kalkman Deposition, Samsung LSI, February 14, 2018, p. 2 [REDACTED]  
[REDACTED]  
[REDACTED] See also  
Deposition of Todd Madderom, Director of Procurement at Motorola Mobility, March 16, 2018, p. 93–94  
 (“Madderom Deposition, Motorola”) [REDACTED]

<sup>298</sup> Faulkner, Bob, “Freescale Fantasy,” LightReading, October 8, 2008 (“Having one dominant customer, as Freescale had with Motorola, makes attracting new customers quite difficult. The first hurdle is obvious: Freescale is going to direct most of its attention to its biggest customer. The second is less obvious but just as

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chips from presently or formerly captive modem chip suppliers that are or were vertically integrated with rival OEMs artificially limit the number of suppliers that can compete on price and quality for their business.

142. In summary, my analysis of the relevance of the characteristics of modem chips and their suppliers on the demand for modem chips suggests that an OEM with specific requirements of modem chip (or supplier) features will only consider purchasing modem chips from suppliers whose products meet these requirements. [REDACTED]

[REDACTED] Because the number of suppliers whose modem chips meet all of an OEM’s specific requirements is limited, such an OEM may pay a higher price for the modem chips it purchases.

## **2. Factors affecting supply of modem chips**

143. Entering and staying competitive in the modem chip industry is a challenging endeavor. Becoming a viable competitor requires the ability to fulfil the demands of OEMs outlined in the previous section. From the modem chip supplier’s perspective, the factors that affect the ability to be successful – i.e., to have its chips demanded by OEMs – can be grouped into three areas: foresight (or alignment with demand), investment, and execution. These factors are described in more detail below, but in short they reflect: (i) the foresight, or good fortune, to have invested in technologies and standards that are demanded by network carriers and OEMs; (ii) the need to invest efficiently in R&D to overcome the technical challenges inherent in designing modem chips; and (iii) the ability to design and deliver modem chips that OEMs prefer over competitors’ chips, whether because of their innovativeness, cost-effectiveness, or features.

### *a. Foresight / Alignment with demand*

144. Modem chips are highly technical products requiring precise engineering, and the pace of innovation in the industry has been rapid. R&D therefore plays a crucial role in shaping the trajectories of modem chip suppliers. Not only does R&D require large investments (discussed in further detail below), it also requires significant lead time. Together, the rapid evolution of

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important: Motorola can influence the direction of Freescale’s development activities to what is best for it – and that may not be best for the merchant market in general.”).

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the industry and the lead time required to develop and commercialize new modem chip technologies mean that firms often must choose where to direct or prioritize R&D investments before it is known what technologies will be demanded by OEMs and carriers.<sup>299</sup>

145. A modem chip supplier therefore stands to benefit from good foresight about which modem chip technologies will take off and will be demanded in the future. In a sense, the firm is like a hockey player trying to pass the puck not to where a fast-skating teammate (i.e., demand) currently is, but to where the teammate is heading. Unlike the hockey player, however, the firm must decide the direction of its R&D *years* in advance. For example, Qualcomm began investing in CDMA in 1989, four years before the first CDMA-based standard, IS-95, was formally recognized and the first CDMA devices shipped.<sup>300</sup>
146. An example of the importance of anticipating demand is the competition between EV-DO (Evolution-Data Optimized) and EV-DV (Evolution-Data and Voice).<sup>301</sup> In the early 2000s, these two technologies emerged as competing solutions for transmitting data wirelessly on CDMA-based networks. Both chip suppliers and carriers strategized over which technology to adopt, with important competitive implications:

TI and Nokia [...] have focused much of their R&D partnership on EV-DV chipsets. Nokia has enthusiastically promoted EV-DV as far superior in capacity and performance to the data-only variant. But EV-DO is gaining ground on the basis of being available now, as operators face increasingly urgent demands from users to deliver high performance mobile data services in the near term [...]. The doubts over EV-DV really emerged last summer when Sprint, which had previously committed

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<sup>299</sup> See, e.g., Cabral, Luís M.B., *Introduction to Industrial Organization*, Cambridge, MA: MIT Press, 2000, p. 299 (“Very often, choosing an R&D strategy is choosing not just how much to invest but also how to invest. Specifically, firms must consider the strategic choice of risk of their R&D strategies. The trade-offs involved in the choice of risk are typically the following: A low-risk strategy is one that implies a low-value innovation with a high probability, whereas a high-risk strategy is one that implies a high-value innovation with a low probability.”).

<sup>300</sup> See Section V.B.1 for details on Qualcomm’s role in developing the CDMA standard.

<sup>301</sup> See, e.g., “EV-DO Definition,” GSMarena (“A 3G technology add-on for CDMA networks that allows for theoretical download speeds as fast as 2.4 Mbps, though actual rates tend to be far slower. There are two major versions: Release 0 and Revision A.”) and “EV-DV Definition,” GSMarena (“EV-DV is part of the same family of CDMA connectivity as EV-DO. Unlike EV-DO, however, EV-DV also supports voice calls. EV-DV is essentially a combination of EV-DO and 1xRTT.”).

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itself to leapfrogging EV-DO and moving straight to the more advanced standard, decided instead to upgrade to EV-DO rather than delay its 3G roll-out.<sup>302</sup>

Modem chip suppliers who lagged in EV-DO therefore faced a disadvantage with the CDMA-based carriers that adopted it.<sup>303</sup>

147. Even if a firm’s innovations are technically successful, commercial success is not guaranteed. Commercial success depends on the widespread adoption of the new technology by consumers and carriers.<sup>304</sup> For example, Broadcom invested in EDGE, a “2.5G” technology, at the expense of what became the 3G and 4G standards necessary to transmit data for smartphones, and therefore lost out as the industry shifted towards smartphones and 3G technology.<sup>305</sup> By contrast, Qualcomm initially developed and supported the UMB technology, but was able to

<sup>302</sup> White, Peter, “EV-DV could be stillborn, but GSM integration and VoIP will keep CDMA strong,” *Wireless Watch*, September 30, 2004, available at <https://rethinkresearch.biz/articles/ev-dv-could-be-stillborn-but-gsm-integration-and-voip-will-keep-cdma-strong/>.

<sup>303</sup> The EV-DO/EV-DV decision did not affect U.S. carriers such as AT&T and T-Mobile, which used 2G GSM and then adopted WCDMA (and the WCDMA advancement HSPA) for 3G; nor did it affect non-CDMA carriers abroad. See, e.g., Kellen, “Cheat Sheet: US Wireless Carrier Bands for Unlocked Phones,” *Droid Life*, February 5, 2015.

<sup>304</sup> For a discussion of the challenges firms face in making technology and R&D choices, see, e.g., Schilling, Melissa A., “Technology Success and Failure in Winner-Take-All Markets: The Impact of Learning Orientation, Timing, and Network Externalities,” *Academy of Management Journal*, 45:2, 2002, p. 387 (“Once a dominant design has been selected by the market, firms offering technologies that are incompatible with the dominant design may be forced to switch to it. In industries in which a dominant design has not yet emerged, firms face critical choices about how and when to deploy their technologies. Firms that liberally diffuse their technologies or base their new technologies on previously existing standards may gain more rapid adoption, thus improving their chances of survival. However, by doing so, they may give up much of the appropriability of their technology and have little control over its future evolution. Timing is also important; rather than simply emphasizing speed to market, firms must time entries in accordance with the evolution of complementary technologies and customer requirements.”).

<sup>305</sup> Deposition of Robert A. Rango, former Executive VP & GM, Mobile and Wireless Group and Wireless Connectivity Group and former VP and GM, Networking Infrastructure Group at Broadcom, February 13, 2018 (“Rango Deposition, Broadcom”), p. 94 (“Q. The next bullet says (as read): ‘2G EDGE, our biggest R & D investment, will have lower ROI due to smartphone popularity.’ [...] A. Up until this point, Broadcom’s biggest investment in basebands was in 2G and 2.5G, and the bullet was intended to say that, hey, feature phones are giving up share to smartphones, and therefore our investment in 2 and 2.5G would be damaged, would be harmed by it.”). See also Rango Deposition, pp. 128–129 (“Q. In the next bullet in your email, you say, quote (as read): ‘We invested in EDGE when we should have invested in 3G (mistake made four years ago. We are going to pay for this in 2012, ’13).’ [...] Q. And EDGE refers to that -- that GSM 2.5G standard that we discussed earlier; is that right? A. Correct. [...] Q. Could you explain why this was a mistake? A. Well, other than what I wrote here, I think it’s -- the pre- -- prior management, when it was a separate team, under MPG, had made a decision to invest in 2G EDGE instead of smartphone technology. And so I was referring mainly here to the fact that, in hindsight, that decision looks like the wrong one.”).

re-calibrate its development and focus on LTE when UMB failed to be adopted by carriers.<sup>306</sup> As another example, Samsung’s failure to anticipate the demand for SoCs decreased its competitiveness as a modem chip supplier, as explained in more details in Section V.C.4.

148. As discussed above, some OEMs demand innovative modem chip technologies, and as a consequence, there may be rewards to firms that are the first to offer demanded new technologies. Foresight is important in this technology race: to win, it helps to run in the right direction. Racing for first-mover advantages in innovative technologies, however, is not the only successful strategy in the modem chip industry. OEMs do not always require modem chips that are cutting-edge in all respects. Indeed, OEMs that produce mobile devices for emerging markets may place more weight on other factors, such as price and the provision of reference designs.<sup>307,308,309</sup> This provides opportunities for chip suppliers to compete in the industry even without the foresight to develop new technologies, although even these suppliers will need to foresee demand for technologies that are not on the leading edge. Examples of

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<sup>306</sup> See, e.g., Fleishman, Glenn, “Qualcomm Cancels Its Own 4G System,” *Ars Technica*, 13 November 2008 (“Ultramobile broadband (UMB) is ultra dead. [...] Qualcomm said they would stop work on its fourth-generation (4G) network technology UMB, and shift efforts to the GSM-based Long-Term Evolution (LTE) standard. [...] This was not unexpected [...] as no major carrier had committed to UMB. Qualcomm’s U.S. stalwarts, Verizon Wireless and Sprint Nextel, had chosen LTE and WiMax, respectively, for their 4G networks.”).

<sup>307</sup> See, e.g., Dalberg Advisors, “Accelerating Affordable Smartphone Ownership in Emerging Markets,” GSMA, July 2017, p. 3 (“Consumer research shows how the cost of an internet enabled handset is a critical barrier to using mobile internet for low and middle income consumers in emerging markets. [...] On the supply side, the manufacturing costs of the device itself are largely dictated by prices of key components including: the screen, chipset, memory and battery....”).

<sup>308</sup> Recognizing the price sensitivity of OEMs catering to emerging markets, TI went so far as to name one of its chips the “LoCosto.” See, e.g., Andrejczak, Matt, “TI unveils next chip for ultra low-cost phones,” *MarketWatch*, February 12, 2007 (“Texas Instruments Inc unveiled its second microchip for ultra low-cost phones Monday in a bid to cash in on growth in emerging phone markets. ... TI’s LoCosto chip is designed for phones that sell for around \$30 to \$50 in emerging markets, such as China, India, Brazil and Russia. The chip sells for around \$10 to \$15, analysts estimate. [...] In the future, manufacturers aim to sell phones for around \$20 in an attempt to tap underserved phone markets. TI said its newest LoCosto offering may help phone makers reach the goal of reducing a phone’s retail cost by cutting design costs.”).

<sup>309</sup> See, e.g., Goldberg, Jonathan, “The Mediatek Phenomenon: the New Smartphone Disruption,” *SlashData*, May 8, 2013 (“Mediatek grew up in [...] the consumer electronics supply chain in Taiwan and China. [...] They recognized that their traditional customers had very limited engineering talent. [...] None of these companies had the ability to design cellular phone software or build pretty user interfaces. [...] So Mediatek took all that software work and bundled it into a complete package which they called a reference design for mobile phones.”).

chip suppliers exploiting these opportunities include MediaTek, VIA Telecom (acquired by Intel in 2015), and Spreadtrum.<sup>310</sup>

*b. Investment*

149. Modem chip suppliers face a rapidly evolving technological environment, a heterogeneous demand characterized by OEMs with diverse requirements, and intense competition with other firms. Therefore, strategic decisions on R&D investments are key to the success of a modem chip supplier.
150. I review several factors relevant to the investment patterns in the modem chip industry. First, firms differ in the strategy and scope of their investments. Some suppliers choose to push the technological forefront of the industry, some focus on reducing production costs of existing technologies, while others invest in expanding the scope of the products they offer to OEMs. The intensity of R&D investments will therefore differ across firms in the modem chip industry, and firms’ R&D efficiency is an important factor in their success. Finally, the nature of the innovative process in modem chip technology affects modem chip suppliers’ investment decisions.

*i. Investment strategies*

151. As mentioned above, different modem chip suppliers adopt different strategies for their position in the industry and thus for their R&D investments. The suppliers that choose to push the technological forefront of the industry are referred to as “technological leaders.” Other suppliers, often referred to as “fast followers,” choose to rely on existing technologies. The strategic decision to be a technological leader or a fast follower depends to a large extent on a supplier’s perception and expectation of the tradeoffs between bearing substantial up-front costs and potentially gaining large returns in the future, versus investing less up front, avoiding the risk of introducing new technologies, and obtaining lower marginal returns on future sales.<sup>311</sup> Suppliers adopting either of the two strategies can and do participate in the standard-

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<sup>310</sup> See Section V.C for additional details.

<sup>311</sup> As mentioned in Section III.E.1, the costs of imitating an existing technology are significantly lower than the costs of innovating. See, e.g., Mansfield, Edwin, “R&D and Innovation: Some Empirical Findings,” in Zvi Griliches, ed., *R&D, Patents, and Productivity*, University of Chicago Press, 1984, p. 142 (“In our sample,

development process, without necessarily designing state-of-the-art modem chips, as not all firms that participate in standards development are involved in producing technologically innovative products.

152. Technological leaders, who advance the technological frontier or leading edge of the industry, invest heavily in R&D, bear the risks associated with such investments, and collect the rewards associated with being the first to market. As discussed in Section III.E.1.a, being first to market in this industry has several advantages including higher margins and greater profitability. In addition, technological leaders also gain prestige and familiarity with customers that they can use to maintain their leadership across multiple products and over time. However, these benefits are accompanied by greater risks to failure following this strategy: being later-than-expected to market, missing critical features, or failing to attract OEM customers can cause leading-edge firms to achieve none of the benefits of leadership while incurring all of the higher R&D costs. These unsuccessful leaders then lose business to both technological leaders who executed successfully (see Section III.E.2.c below) and fast followers, who, having foregone high levels of R&D, can charge lower prices. For technological leaders, then, efficiently allocating large resources to technological exploration is key for succeeding.
153. Fast followers, by contrast, who are typically on the trailing edge of the industry, spend less on R&D, as they can learn from the successes and failures of technological leaders and can focus more on lowering production cost and achieving large production volumes. The fast-follower strategy also has advantages and disadvantages for modem chip suppliers. On the one hand, this strategy allows firms to overcome potential barriers to entry, including high R&D costs. On the other hand, when a fast follower introduces a modem chip, its entry expands the supply of that type of older modem chip, while demand for such older modem chips has naturally declined by then, as newer modems are released. Therefore, fast followers

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imitation cost averages about 65 percent of innovation cost, and imitation time averages 70 percent of innovation time.”). This has also been documented in particular in the semiconductor industry. See, e.g., Kumar, Rakesh, *Fabless Semiconductor Implementation*, McGraw Hill, 2008, pp. 16–17 (“The cost of process R&D escalates exponentially if you are the first developer of a new technology node [...]. Costs can be significantly lower if one chooses to be a ‘follower’ and be a year or more behind implementing new technologies.”).

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experience lower average prices and gross margins compared to technological leaders who are first to market.<sup>312</sup>

154. Further, some suppliers who initially started at the trailing edge may attempt to design state-of-the-art modem chips move to the leading edge. For example, Intel acquired the fast follower Infineon in 2010 and invested heavily to produce a leading-edge modem chip. In 2016, Intel had completed its transition to technological leader by winning a contract with Apple and providing modem chips for the iPhone. Similarly, MediaTek initially launched as a trailing-edge supplier of low-cost chips for emerging markets, but it has recently attempted to become a technological leader by launching a leading-edge modem chip, the Helios X30.
155. There are many potential targets for chip supplier R&D investments. For example, suppliers can invest in implementing wireless standards, implementing new categories within those standards, improving performance (such as decreasing call drops or improving battery life), integrating other features (particularly with SoC modem chips), or reducing the size of their chips. Suppliers also can and do invest by acquiring companies that have begun R&D into a standard or technology feature, and combining these features with their own internal R&D efforts.<sup>313</sup>
156. Chip suppliers can invest in wireless standards by developing cellular technologies, working with other firms to facilitate complementary upstream and downstream technologies, and

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<sup>312</sup> As shown in Exhibit QX0120, 

<sup>313</sup> See case studies in Section V.

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taking part in SDOs. While investing in the development of standards entails some risk, as it requires resources without necessarily yielding a saleable product, these investments can benefit a firm by giving it knowledge and understanding of the underlying technologies. This, in turn, can help the chip supplier to be first to commercialize chips using state-of-the-art technology and therefore to reap first-mover advantages – particularly if the standard in which the chip supplier invested is adopted widely.<sup>314</sup>

157. Although some firms participate in the standard-development process by investing in R&D for new technologies, other firms have decided to learn about the standard-development process without producing new products.<sup>315</sup> Therefore, large R&D investments are not necessary for a modem chip supplier to contribute to the standard-development process. More generally, though, while involvement in the standard-development process can benefit a chip supplier, it is not necessary in order to build a competitive chip.<sup>316</sup>
158. Another strategic investment decision that modem chip suppliers face involves the bundle of inputs that they produce and sell to OEMs. Along this dimension, suppliers can be divided into “pure-play” and “broadliners.”<sup>317</sup> Pure-play suppliers provide one input and therefore their R&D investments can be lower, as they will involve maintaining the innovation

<sup>314</sup> Qualcomm, for example, single-handedly developed the CDMA standard based on significant R&D investments. This enabled Qualcomm to also lead the commercialization of the technology and manufacturing of CDMA modem chips. See Section V.B.1 for additional details.

<sup>315</sup>

Intel’s Asha Keddy remarked that there are different ways for a supplier to contribute to a standard. See Deposition of Asha Keddy, General Manager of Next Generation and Standards at Intel, March 7, 2018, pp. 221–222 (“Keddy Deposition, Intel”) (“[...] companies that contribute a lot [...] whether they’re contributing directly or indirectly involved, may have patents that are a part of it. [...] If Intel is chairing or Intel proposals get adopted, there is a notion that Intel is a leader [...] and then when you have products and all, there is an implicit understanding that the products implementation understands what’s going on.”).

<sup>316</sup> Achour Deposition, Qualcomm, pp. 240–241 (“Q. And so my question is, is involvement with standard setting something a modem supplier also needs to engage in to develop a modem as good as Qualcomm’s? A. Absolutely not. Actually, I don’t know [sic] for a fact. You don’t need -- because the same specs we work from are available to everybody, they’re public domain. You can go to 3GPP website, you can download all the specs you want. You don’t have to send anybody to the standards, it’s available to everybody. It’s public -- these are public documents.”).

<sup>317</sup>

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leadership for that single input. Broadliners, instead, must spend more on R&D overall, as they compete by developing and selling multiple mobile device inputs, such as APs or chips for non-modem connectivity (such as Wi-Fi or Bluetooth). In this sense, suppliers compete not only by providing better products, but also by deciding which products to supply. Therefore, competition among broadliners may result in a supplier exiting a particular segment of the semiconductor industry to allocate resources to other, more profitable, segments, in which the supplier enjoys a comparative advantage. For example, as discussed in Section V.C.13, Nvidia has earned record revenues since it exited the modem chip industry, driven by its leadership in GPU technology. Exhibit III.D.5 indicates that many modem chip suppliers were active in the supply of other mobile device components in 2010. For example, Qualcomm is a broadliner, selling not only modem chips, but also licensing standard-essential patented technology and integrating its modem chips with an AP and many other features (e.g., Wi-Fi and Bluetooth connectivity, and GPS) in its SoCs. Likewise, Broadcom is a broadliner because it supplies Wi-Fi chips and other components for mobile devices and supplied modem chips until its exit from the modem chip industry. [REDACTED]

[REDACTED].<sup>318</sup> Suppliers can also choose to pursue different strategies in different periods, and therefore, can switch categories over time. [REDACTED]

[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]

ii. *R&D intensity and efficiency*

159. Persistent technological advances in chip design and the demand for innovative modem chips make investment in R&D an important driver of success for those chip suppliers whose strategy is to lead the industry in technological innovation. R&D in the modem chip industry

[REDACTED]  
[REDACTED]

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is both expensive and time-consuming, making it one of the major hurdles to entry and sustained competitiveness at the technological forefront of the industry.

160. The R&D investment required to be a competitive player at the innovative edge of the modem chip industry is substantial. Qualcomm’s total R&D spending was \$5.5 billion in 2017, representing 25 percent of total revenue,<sup>320</sup> and its total R&D spending from 2000 to 2017 was \$47.4 billion, representing on average 21 percent of total revenue.<sup>321</sup> [REDACTED]

[REDACTED]

161. Other modem chip suppliers have also invested large amounts in developing modem chips.

[REDACTED]

162. Exhibit III.E.1 shows modem chip-related R&D spending for Qualcomm and other chip suppliers from 2005 to 2017. Because information on modem chip-related R&D is not readily

<sup>320</sup> Qualcomm invested \$5.5 billion in R&D in FY 2017, with associated revenue of \$22.3 billion. See Exhibits III.E.2 and III.E.3.

<sup>321</sup> See Exhibit III.E.3 and associated backup.

<sup>322</sup> Deposition of Serge Willenegger, Senior Vice President of Product Management at Qualcomm, February 9, 2018, pp. 127–128 (“Willenegger Deposition, Qualcomm”) [REDACTED]

See also note in QNDCAL03634914.

<sup>323</sup> See “Case COMP/AT.39.711, Annex 7.1,” Qualcomm, QNDCAL03634914 (R&D by Business Unit/Division, Labour and Non-Labour Costs, in Million USD). See also Q2014FTC04141507 for the 2017 calculations. The 2017 calculations use actual R&D spending and revenue for Q1 2017 through Q3 2017, and projected R&D spending and revenue (as of July 2017) for Q4, because the actual numbers were not available for that quarter.

<sup>324</sup> BAIN00070744, Bain presentation to Intel titled “Mobile R&D Benchmarking”, pp. 14–16.

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available for all firms for which modem chip supply is only one part of their overall business, Exhibit III.E.2 shows modem chip suppliers’ firm-wide R&D and indicates that firm-wide R&D may greatly exceed chip-specific R&D. For example, by this metric, Intel, Samsung, and Huawei have spent considerable amounts on overall R&D, suggesting that they had the means to allocate to chip-related R&D if they decided to do so. Exhibit III.E.3 shows that most modem chip suppliers’ R&D spending typically represents a large portion of their revenue, ranging between 10 and 30 percent of total revenue.

163. Given the range of overall R&D spending, it is important to note that the amount of actual R&D expenditure on modem chips is not necessarily an indicator of a modem chip supplier’s ability to invest. In fact, the realized R&D spending is the result of a modem chip supplier’s strategic decisions, which does not necessarily reflect its access to funds. In order to gauge a modem chip supplier’s actual ability to invest in R&D, one would have to consider other factors such as the supplier’s profitability, cash flows, and access to capital markets.
164. While the R&D investments necessary to remain at the leading edge of the industry are large, the gains from success are also potentially substantial. Consequently, numerous companies have made the required investments and continue to make the investments needed to develop new products. For example, Huawei has continued to invest in HiSilicon, its modem chip supplier subsidiary, even after its initial investments yielded products with technical shortcomings.<sup>325</sup> Similarly, Xiaomi recently invested substantial resources to enter the modem chip design industry, following the example of other smartphone manufacturers.<sup>326</sup>
165. Modem chip suppliers also compete and differ in their R&D efficiency. The Bain presentation cited above emphasizes this point and notes that [REDACTED]

<sup>325</sup> See, e.g., “Digitimes Research: Hisilicon AP to Give Huawei Cost Advantage in High-end Mobile Device Market,” DigiTimes, July 9, 2014 (“Hisilicon, an affiliate of Huawei, has been developing application processors for many years. The company’s early products had issues that caused resulted [sic] in poor power consumption-performance ratio. But Huawei’s strategic support and continuous R&D resource investments have helped improve Hisilicon’s products.”)

<sup>326</sup> See, e.g., “Xiaomi Reveals 64-bit Surge S1 Chipset, Its First-ever SoC,” Android Authority, February 28, 2017 (“Xiaomi has become the fourth smartphone manufacturer in the world to build its own chips after Samsung, Apple and Huawei - currently the three largest global OEMs. This is a big step for the Chinese manufacturer and will have been a huge investment in resources for R&D, production, infrastructure etc. [...] Here are some of the Surge S1’s finer details as outlined by Xiaomi: [...] Upgradeable baseband; programmable modem[.]”).

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[REDACTED], as I discuss further in Section V.C.2.<sup>327</sup>

This suggests that while the amount spent on R&D is a relevant indicator of the intensity of R&D, the efficiency of R&D is also important for success in modem chip supply.

166. Modem chip suppliers can increase their R&D efficiency by, for example, transferring successful R&D investments in the development of one particular chip to other models. Therefore, as I described above in Section III.C.2.b, chip suppliers such as Qualcomm that design a larger number of different types of chips can allocate R&D spending more efficiently by recycling IP “cores” or “blocks” from chip to chip.<sup>328</sup> This exemplifies a process common to industries characterized by large R&D investments and widely studied in the industrial organization literature. Because R&D will typically increase less than proportionately with the number of different chips produced, it is typically considered a fixed or sunk cost, and as such it leads to economies of scale.<sup>329</sup> Incremental updates of a modem chip model require less R&D than coming up with the initial design.

<sup>327</sup>

[REDACTED]

<sup>328</sup> Achour Deposition, Qualcomm, pp. 114–115

[REDACTED]

<sup>329</sup> See, e.g., Armstrong, M., and R. Porter, *Handbook of Industrial Organization*, 2007, Vol. 3, Chap. 35, p. 2313 (“[...] firms might choose to incur (additional) fixed and sunk costs [...] with a view to improving their competitive positions .... This kind of expenditure would include, for example, outlays on R&D designed to enhance the quality, or technical characteristics, of firms’ products ...; and it would include cost-reducing ‘product innovation’ in which R&D efforts are directed towards the discovery of improved production methods.”). See also Hill, Charles W.L, et al., *Strategic Management: Theory: An Integrated Approach*, 11<sup>th</sup> Ed., Stamford, CT: Cengage Learning, 2015, p. 119 (“One source of economies of scale is the ability to spread fixed costs over a large production volume.”).

167. The efficiency of R&D spending is also affected by the speed with which a modem chip supplier can make its innovations available to OEMs. Modem chips are a complex technology, and this complexity creates challenges that take time to overcome. As a result, it is not uncommon for modem chip designers – especially those without the requisite experience – to face long delays in bringing new products to market.<sup>330</sup> On some occasions, these delays can jeopardize large R&D investments, suggesting that devoting substantial resources to the development of new products is not sufficient on its own to secure a large yield. MediaTek, for example, designed the Helio X30 to compete at the technological forefront,<sup>331</sup> but delays in bringing the chip to market complicated its release and resulted in low adoption by OEMs.<sup>332</sup>
168. Some modem chip suppliers have sought to speed up the development process using shortcuts to experience by leveraging in-house engineers who have experience with related technologies and/or acquiring a company that already has experience making an element of a potential integrated product. Intel, for example, has pursued both of these approaches. In 2010, it bought Infineon in order to create an integrated chip by combining Infineon’s modem chips with its own Atom APs, drawing on its experience with PC processors.<sup>333</sup> Intel’s experience, however, illustrates the importance of experience specific to the product under design: coming from a PC background, Intel’s in-house engineers did not have experience with low-power

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<sup>330</sup> See Section V.C for additional details. For example, Nvidia faced considerable challenges when it tried to combine its own standalone AP (Tegra) with baseband modems designed by Icera after acquiring Icera in 2011. See, e.g., Exhibit Talla 2, Deposition of Deepu Talla, Vice President and General Manager at Nvidia, March 3, 2018, NVIDIA-00609189 (“Talla Deposition, Nvidia”) (“Concerns were raised that we need to deal with that integrating a modem will cause the chips to not be able to make production schedules because of carrier qualification.”). It took Nvidia three years to succeed in this effort. (Nvidia acquired Icera in 2011, but was able to release its first integrated modem chip (Tegra 4i) only in 2014. See Section V.C.13.a for more details). In another example, NXP faced delays of more than a year in bringing its first WCDMA baseband modem to market (see Section V.C.6.a for details on NXP’s delays).

<sup>331</sup> “MediaTek Sees Only Limited Use of Its New Advanced Chip in 2017,” Nikkei Asian Review, February 28, 2017 (“The Helio X30 chip [...] was first viewed as a secret weapon that MediaTek could use to close the gap with its biggest rival Qualcomm of the U.S. in cutting-edge technology.”).

<sup>332</sup> “MediaTek Sees Only Limited Use of its New Advanced Chip in 2017,” Nikkei Asian Review, February 28, 2017 (“‘We don’t expect many projects on our latest high-end chip,’ Mediatek Co-Chief Operating Officer Jeffrey Ju told reporters [...] ‘For now, we think less than 10 smartphone models will adopt this high-end X30 chip.’ [...] Besides having only a few customers for the high-end chip X30, Ju said progress in getting the chip out has been slower than expected and has been delayed about a couple of months because its contract chipmaker [...] ‘Our chip is a bit delayed because the yield rate of 10nm process technology [from TSMC] has not yet reached a satisfactory level ... and we are a bit stuck on that,’ said Ju.”).

<sup>333</sup> “Intel to buy Infineon’s wireless unit for \$1.4 billion,” CNET, August 29, 2010.

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APs, and neither Intel’s nor Infineon’s engineers had experience integrating modems and APs designed around different process technologies.<sup>334</sup> As a result, as I discuss further in Section V.C.2, Intel took over five years to develop an SoC.<sup>335</sup> Ultimately, the chip was not successful and was discontinued, indicating that even large R&D investments do not guarantee commercial success if they are not efficiently directed towards products that meet customer requirements along dimensions such as power consumption and launch timing.<sup>336,337</sup>

iii. *Nature of the innovative process*

169. Although much of the evolution in modem chip technology is continuous and incremental, some important progress occurs in discrete steps. The development and implementation of a new standard, for example, changes the modem chip industry in a discontinuous way. Other advances, such as the incorporation of multi-mode functionality, may also occur as major steps. Both Qualcomm’s invention of CDMA and its introduction of the first multi-mode LTE chip represented such steps. More recently, suppliers such as Intel, MediaTek, Qualcomm, and Samsung S-LSI have sought to bring the first 5G modem chips to market.<sup>338</sup> Discrete technological advances may create opportunities for firms to leapfrog into a position of technological leadership, replacing incumbent leaders.<sup>339</sup> Indeed, the academic literature on

<sup>334</sup> See Section V.C.2 for additional details.

<sup>335</sup> “Intel announces Atom X3 SoFIA, its new best hope for smartphone relevance,” PCWorld, March 2, 2016.

<sup>336</sup> See Section V.C.2 for more details about Intel’s R&D investments.

<sup>337</sup> For example, [REDACTED]  
[REDACTED] See Deposition of Martin Zander, Head of Strategic Initiatives and Ecosystems at ST-Ericsson, April 19, 2018, pp. 56–57 (“Zander Deposition, ST-Ericsson”) [REDACTED]  
[REDACTED]

<sup>338</sup> See, e.g., Ukonaho, Ville-Petteri, “First 5G Smartphones to Arrive 2019 Says Qualcomm,” Strategy Analytics, April 7, 2017 (“Qualcomm was first to the market with 5G capable modem but other vendors are not standing still either. Intel announced their modem at CES 2017 and Mediatek announced the co-operation with Nokia in the development of the 5G modem at MWC 2017.”). See also Horwitz, Jeremy, “Samsung reportedly working on Exynos 5G modem to power its phones in 2019,” Venture Beat, January 17, 2018.

<sup>339</sup> See, e.g., Scherer, F.M., and David Ross, *Industrial Market Structure and Economic Performance*, Third Edition, Boston: Houghton Mifflin, 1990, p. 614 (“[M]ajor innovations often bring new firms to the fore and displace laggards.”).

170. Modern chip suppliers, as discussed above, have pushed hard to bring innovations to market. Meanwhile, some innovation has been driven by OEMs' requests. OEMs provide their current and potential chip suppliers with information about the features that they and carriers demand, pushing suppliers to meet those targets. MediaTek, for instance, learned about supporting products for a broad geographical market from LG,<sup>342</sup> and about carrier requirements in particular countries from customers such as Alcatel, ZTE, Lenovo, Huawei, and Coolpad.<sup>343</sup>

342 See, e.g., Exhibit CX3553, Moynihan Deposition, MediaTek, p. 35 (“A. [...] You know, I would say LG is a good example who I – of a brand I think that’s helped us over the years in – how to say this – globalizing, so, you know, LG tends to think of a global portfolio. They’re a global brand. You know, they’re – you know, they’re going to develop a phone and launch it in many, many carriers in many, many markets simultaneously.”), pp. 89–91 (“Q. And with respect to the transition from 3G to 4G, who are the important teaching customers? A. We probably have – we probably have put them into two categories for us. Like LG, Sony and HTC would have been very important from sort of a global brand, global carrier perspective. [REDACTED]”).

REDACTED VERSION OF DOCUMENTS SOUGHT TO BE SEALED

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Meanwhile, customers such as [REDACTED] helped to drive MediaTek’s development of multimedia functionality.<sup>344</sup> The pull to meet carrier and OEM demands and requirements comes from many different purchasers of modem chips. As John Moynihan of MediaTek recognizes, “[...] different customers play different roles for different aspects of that, but, you know, all important at the end of the day.”<sup>345</sup>

171. A modem chip supplier can learn from technical engagement with an OEM, moreover, even if ultimately it does not win the OEM’s business. [REDACTED]

[REDACTED]

[REDACTED].<sup>346</sup> Similarly, [REDACTED]

[REDACTED]

[REDACTED].<sup>347</sup> Intel also received OEM feedback that may have encouraged technical innovation.<sup>348</sup>

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Coolpad. A few customers would have been important for the early phase of LTE deployments in China, which were heavily driven by the carriers there as well.”).

<sup>344</sup> Exhibit CX3553, Moynihan Deposition, MediaTek, p. 35 (“[A.] And then I would think some of these other brands, like [REDACTED], have probably helped more with some of the higher-tier multimedia features. Again, as I mentioned, their devices tend to be higher tier in feature set, higher price maybe than some of the other customers. Therefore, they’re driving more advanced displays, more advanced cameras, more advanced user features, and so, you know, those are probably the customers that are pushing us on things like camera features, which is an important feature for a lot of these devices right now.”).

<sup>345</sup> Exhibit CX3553, Moynihan Deposition, MediaTek, p. 35.

<sup>346</sup> [REDACTED]

<sup>347</sup> [REDACTED]

<sup>348</sup> See Section V.C.2 for additional details.

*c. Execution*

172. Ultimately, a supplier must develop a chip design that embodies technology and features demanded by OEMs and secure design wins from OEMs to sell those chips. To accomplish this successfully, a supplier must overcome any organizational challenges, including choosing the optimal level of integration, i.e., positioning itself on the organizational structure continuum, gaining relevant experience needed to develop new products,<sup>349</sup> obtaining sufficient and appropriate resources and production inputs,<sup>350</sup> and establishing processes for an efficient transfer of knowledge within the firm and with customers.<sup>351</sup> After applying foresight to accurately assess demand it is likely to face for its products, a modem chip supplier must acquire the necessary assets and develop products for its customers. For modem chip suppliers on the leading edge of the industry, the necessary assets must be specific to develop customized products based on specific customers’ requirements.<sup>352</sup>

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<sup>349</sup> See, e.g., Deposition of Matthew Grob, CTO and EVP at Qualcomm, January 29–30, 2018, p. 244 (“Grob Deposition, Qualcomm”) (“A. [...] We’ve been making these modems for decades and have a very large team, which is supported by many customers and many -- you know, many deployments, and a lot of experience comes from that.”). See also Achour Deposition, Qualcomm, pp. 205–206 (“Q. Does having a modem, having phones in the marketplace provide any additional validation beyond the validation provided by working with OEMs like Samsung? A. Oh, absolutely. [...] there’s a time aspect that goes into modem development, developing a quality modem. It goes beyond the smart people that applies to technology. Every company has smart people, no question. But the time it takes to learn from the field when you deploy millions of phones, and you learn, you know, the issues they’re seeing in the market, go fix them one at a time, and learn a few things, go tweak things, and keep reiterating, that process just takes time.”).

<sup>350</sup> See, e.g., [REDACTED]

<sup>351</sup> See, e.g., Achour Deposition, Qualcomm, p. 173 [REDACTED]

<sup>352</sup> See, e.g., Achour Deposition, Qualcomm, pp. 138–139 [REDACTED]

*i. Timeliness*

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<sup>354</sup> Evans Deposition, Intel, pp. 66–67; see also p. 242.

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175. Timeliness is important for the straightforward reason that OEMs developing a mobile device may rely on a particular supplier to produce the modem chips required for the product.<sup>356</sup> Failure of a modem chip supplier to meet deadlines may jeopardize its relationship with OEMs.<sup>357</sup> [REDACTED]

[REDACTED]<sup>358</sup> A modem chip supplier that struggles to meet timelines may incur significant reputational costs that will affect its ability to compete for future supply contracts.<sup>359</sup>

*ii. Manufacturing*

176. Manufacturing modem chips is a difficult technical process subject to mistakes that are often not easy to detect.<sup>360</sup> In addition to the general difficulty of producing well-functioning modem chips, suppliers may struggle to manufacture them in large enough quantities to meet the

<sup>356</sup> See, e.g., Schell Deposition, Apple, p. 11 (“Q. Why was it important for Apple to evaluate this track record of vendors in terms of meeting schedules and milestones? A. Apple does not release a lot of different products throughout the year. Apple tends to release relatively few products and wants each of those products to be as great as they can be and to be available to Apple users in a timely fashion. There are hundreds, maybe thousands of components that go into each Apple products and each one of those needs to be on an execution and delivery time line that meets the overall needs of the product schedule. So understanding a vendor’s or prospective vendor’s prior track record is one of many considerations in assessing our external partners, whether they are accustomed to, first of all, having aggressive schedules; second, being able to meet those aggressive schedules and having robust recovery processes in case things go awry.”).

<sup>357</sup> See, e.g., Marvell Technology Group Ltd., Form 10-K, for the fiscal year ended January 30, 2016 (“If we or any of our foundry subcontractors experience significant delays in this transition or fail to efficiently implement this transition, we could experience reduced manufacturing yields, delays in product deliveries and increased expenses, all of which could harm our relationships with our customers and our results of operations.”).

<sup>358</sup> [REDACTED]

<sup>359</sup> BlackBerry stopped sourcing from Marvell, for example, in part because Marvell had not been meeting BlackBerry’s timelines. See, e.g., Grubbs Deposition, BlackBerry, p. 110 (“Q. Why did BlackBerry stop purchasing baseband processors from Marvell? A. There were several reasons. We...were having some issues with deliveries from – commitments to timelines for deliveries from Marvell. They had slipped on several deadlines that they had promised to deliver things to us by.”).

<sup>360</sup> See, e.g., Burkacky, Ondrej et al., “Reimagining Fabs: Advanced Analytics in Semiconductor Manufacturing,” McKinsey, March 2017 (“Each fab has thousands of process steps, which, in turn, have thousands of parameters that can be used in different combinations. With so many factors in play, we see a lot of chip failures or defects. But the frequency of each error tends to be very low, since the parameters are seldom aligned in exactly the same way during design and production. That makes it difficult for even the strongest engineering teams to predict where and when problems will occur.”).

demand of OEMs.<sup>361</sup> This, in turn, can negatively affect the supplier’s reliability, a key characteristic required by OEMs, as explained in Section III.E.1.c.ii.

177. Fabless modem chip suppliers, which outsource the manufacturing process to independent foundries, have little control over the manufacturing process. For this reason, as described above, some suppliers choose to vertically integrate and own their own foundries or “fabs.” Samsung, for instance, considers having its own foundry to be part of its overall strength, allowing it to lower costs and to quickly supply modem chips for its own mobile devices.<sup>362</sup> On the other hand, many modem chip suppliers do not undertake in-house manufacturing because for them it is more efficient to use a third-party foundry, such as TSMC.<sup>363</sup> By achieving economies of scale in manufacturing, the relationship between a chip designer and its foundries can have important effects on the final products’ cost and time to market.
178. One reason foundry relationships can be important is that modem chips are typically designed for the specific process technology associated with a particular foundry. Porting a design from one process technology to another is costly, and specializing in a particular foundry’s process technologies (that might be well suited to a particular application) can generate efficiencies and avoid manufacturing difficulties. For example, as discussed below, Intel had a great deal of trouble with its Atom microprocessor design, which was optimized for a desktop microprocessor process, when it tried to merge it with a modem chip design optimized for a

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<sup>361</sup> See, e.g., Qualcomm, 10-Q, for the quarterly period ended December 25, 2016 (“The following could have an adverse effect on our ability to meet customer demands and/or negatively impact our revenues, business operations, profitability and/or cash flows: [...] the inability of a supplier to meet performance, quality or yield specifications or delivery schedules [...]).

<sup>362</sup> Sherr, Ian et al., “Apple Tests iPhone Screens as Large as Six Inches,” Wall Street Journal, September 5, 2013 (“Samsung’s strategy underscores a competitive advantage: [it] is able to bring products to market more quickly because it controls the entire manufacturing process for its smartphones. Samsung makes everything from chips to screens at its own factories, allowing it to change designs and pump out new products at a rapid pace. By comparison, Apple relies on many suppliers to make parts for its devices and companies such as Hon Hai Precision Industry and Pegatron Corp ... to assemble them, requiring timely coordination between all the companies.”).

<sup>363</sup> See, e.g., Hurtarte, George et al., *Understanding Fabless IC Technology*, 1<sup>st</sup> Ed., Newnes 2007 (“Going forward in today’s complex and costly semiconductor environment, it is hard to imagine that a new semiconductor company could be successfully founded as a manufacturing company. The capital costs are simply too high. In comparison, the fabless business has continued to expand, develop, and prosper. As the manufacturing needs of fabless semiconductor companies have continued to increase, the wafer foundry community has continued to expand.”).

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low-power TSMC process,<sup>364</sup> suggesting that integrating the production of the two types of chips would have been difficult. Marvell had a similar problem. It entered the AP industry by buying Intel’s AP and baseband businesses in 2006, but a subsequent switch of Intel’s designs to another foundry was expected to take several quarters.<sup>365</sup>

## F. Conclusion

179. The analysis in this section has demonstrated that characteristics of the modem chip industry and the forces behind suppliers’ success or failure exert a strong influence on the way that firms compete and on the structure of the industry.
180. Principles of industrial organization can be used to explain key features of the modem chip industry. The benefits of economies of scale and scope, the large upfront costs and small marginal cost of supplying leading-edge modem chips, and the declining modem chip prices imply that few firms will supply state-of-the-art modem chips in any period. Furthermore, demand factors such as OEMs’ preference for single-sourcing modem chips for high-end devices impose a limit on the number of modem chip suppliers that can compete at the leading edge. Thus, competition among technological leaders is not reflected by the number of firms active in the industry, but rather by large shifts in suppliers’ industry positions and different rates of their success and failure.
181. The pace of innovation in modem chip technologies is rapid. Demand for mobile devices with cutting-edge speed and functionality has in turn generated demand for innovative, highly customized modem chips. The precise features demanded vary over time and by OEM, and

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<sup>364</sup> See, e.g., Hruska, Joel, “How Intel Lost the Mobile Market, Part 2: the Rise and Neglect of Atom,” ExtremeTech, May 4, 2016 (“Intel failed to gain traction in mobile because it wasn’t willing to risk upsetting the economic model that had transformed it into a titan of computing. The company’s fabs, manufacturing strategies, and resources were geared towards large, expensive processors, not churning out huge numbers of low-cost mobile cores. Prioritizing Atom over Core would’ve required the company to retool at least some of its fabs to emphasize throughput and lower costs in order to compete with the ARM processors built at Samsung and TSMC. It would’ve meant lower gross margins and less profit per unit sold.”).

<sup>365</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2006, p. 100 (“As this report goes to press, Intel has announced (June 27, 2006) the sale of its cellular baseband business (along with that of its application processor business) to Marvell Semiconductor, Inc. Since the chip designs will be ported to a (non-Intel) silicon foundry, and personnel will have to be integrated into the Marvell operations (mostly in Israel for both companies) we expect that it will take several quarters for the transfer to be complete.”).

even OEMs that produce leading-edge devices, such as Apple, may not always demand modem chips that are on the cutting edge in every respect. Nevertheless, premium device OEMs may require modem chips to meet a minimum threshold in every feature, thus demanding modem chips that are advanced but not necessarily state-of-the-art in every respect. This implies that modem chip suppliers need to anticipate all these requirements, and those that are early to commercialize demanded new technologies can collect bountiful rewards. The economics literature emphasizes this point: industries characterized by rapid technological evolution tend to have fewer leading firms.<sup>366</sup>

182. The rapid speed of innovation in the industry implies also that current leaders must continue to innovate to stay ahead. Moreover, although much progress is continuous and incremental, occasionally it is punctuated by a discrete leap forward, such as Qualcomm’s invention of CDMA or its production of the first multi-mode LTE modem.<sup>367</sup> Such discrete steps offer a particular opportunity for innovative firms to displace current leaders at the forefront of the industry. Thus, the characteristics of the modem chip industry should be expected to result in the leadership and prosperity of a small but replaceable set of firms.
183. Advances in mobile communication technologies, in the form of the introduction of a new standard or a new category within a standard, greatly affect the success of modem chip suppliers. Firms that provide OEMs with chips that support a newly demanded technology will be rewarded and will obtain a return on their investment; those that fail to deliver the desired improvements or to deliver them in a timely fashion will not be able to recoup their investment costs. Mobile device product cycles impose a further time constraint on modem chip suppliers: failure to meet an OEM-set deadline for a product release can be costly for a modem chip supplier, particularly if large resources had been allocated to OEM-specific investments.

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<sup>366</sup> Economic theory generally supports the thesis that rapid technological change increases industry concentration, and a number of empirical studies support this thesis. Nevertheless, some theoretical and empirical studies suggest that innovation may lead to less concentration under certain conditions (e.g., when technological change reduces scale economies). For a detailed discussion of the economics literature on the relationship between innovation and industry structure, see, e.g., Chapter 2 in Swann, Peter and Jas Gill, *Corporate Vision and Rapid Technological Change: The Evolution of Market Structure*, Routledge, 1993.

<sup>367</sup> See Section V.B.

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184. On the demand side of the industry, OEMs exert a strong influence on the structure of the industry. OEMs’ incentives to constantly innovate and bring new products to market translate into requirements for modem chip suppliers. OEMs weigh countervailing factors when they interact with one or multiple modem chip suppliers, which affects the duration of the business relationship. While the customization required at the leading edge of the industry makes it costly for OEMs to engage modem chip suppliers in short-lived interactions, discrete technological improvements create opportunities for modem chip suppliers to win an OEM customer.<sup>368</sup> The varied transaction costs of different OEMs and modem chip suppliers affect the degree of vertical integration in the industry and, in turn, the opportunities available to modem chip suppliers that are not vertically integrated.
185. Furthermore, OEMs’ considerations regarding the number and identities of suppliers from which they source modem chips vary depending on whether the OEM is considering a specific device, a device product portfolio at a given time, or its portfolio over time. While sourcing modem chips from multiple suppliers or adding a new supplier for a given mobile device is costly because of the required customization and other factors discussed above, OEMs do at times source modem chips from different suppliers for the same device. In addition, as exemplified by Samsung and Apple, the number of suppliers from which different OEMs source modem chips will vary depending on the breadth of their mobile device product portfolios and the degree of customization they require. On the one hand, Samsung manufactures mobile devices at different ends of the quality spectrum and with different features; accordingly, it sources modem chips from multiple suppliers, with an increasing preference for self-supplying from its vertically integrated modem chip supplier, Samsung S-LSI. On the other hand, Apple’s limited number of highly customized mobile devices constrains the number of suppliers from which it sources modem chips. Moreover, given the relatively short mobile device lifecycle and the continuing developments in wireless technologies, the relationships between modem chip suppliers and their OEM purchasers are likely to be fluid or transient to some degree. In short, there is a rich set of industry influences on the success and failure of firms in this dynamic competitive environment.

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<sup>368</sup> The fact that OEM-supplier business relationships tend to change more in periods in which a new standard is introduced supports this fact. I elaborate this further in Section IV (see, e.g., Exhibit IV.B.2).

186. On the supply side of the industry, the race to design and manufacture successively more advanced modem chips is central to competition among modem chip suppliers. To succeed on the leading edge of the industry, a firm generally must compete in three ways. First, it must apply foresight to target its R&D and investment on technology and features that OEMs will demand years down the line. Second, it must adopt successful R&D strategies and allocate investments efficiently. Third, it must have great execution: that is, it must produce high-performing customized chips in a timely manner. Firms that lack foresight, do not invest sufficiently and efficiently in the right technologies, or that struggle in their attempts at execution, will find themselves playing catch-up.
187. A focus on highly innovative modem chips is not, however, the only successful strategy for entering and succeeding in the modem chip industry.<sup>369</sup> Indeed, the vast expansion of mobile device use in developing and emerging economies, such as China and India, has created a demand for less costly, less customized modem chips for low-cost devices that still implement the necessary standards for their regions. Operating in these economies allows a supplier to gain a foothold and experience in the production of modem chips. As discussed above in Section III.E.2.b.i, some of these suppliers have used such experience to gradually move towards the leading-edge of the industry. MediaTek, for instance, has followed this path. Another advantage of being at the trailing edge of the industry is the possibility of relying on existing technologies or features, which does not require foreseeing future demand exceptionally well or investing heavily in R&D.
188. Characteristics of the modem chip industry also have important implications for the structure of the industry overall. The three key factors that determine industry leadership – foresight, investment, and execution – imply that there will be a small number of firms at the forefront of the industry at any given time. Indeed, the high level of investment necessary to lead in a particular segment may limit the number of firms that even pursue technological leadership.
189. But just as the costs of becoming an industry leader are high, so too are the rewards to firms that are first to market and/or better with technologies that OEMs demand. These rewards incentivize R&D and entry in the modem chip industry. As the rise of industry players such

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<sup>369</sup> As discussed above, for instance, some chipmakers employ a fast-follower strategy; see, e.g., Evans Deposition, Intel, pp. 33–34.

as MediaTek and the fall of players such as TI have shown, industry leadership changes over time. Evolution in the set of industry leaders is encouraged by the nature of technological progress in the modem chip industry.

#### IV. ANALYSIS OF MODEM CHIP SUPPLIER–OEM RELATIONSHIPS

190. In this section, I review evidence related to modem chip supplier–OEM relationships, including basic facts regarding the number of modem chip suppliers selling to OEMs at any point in time and the rate at which such supplier–OEM relationships are initiated and terminated. This evidence is relevant for distinguishing between the *Industry Factors Hypothesis* and *Plaintiff’s Hypothesis*. As discussed in Section III.E.1.b, the *Industry Factors Hypothesis* supports an array of modem chip supplier–OEM relationships in terms of (a) the number of modem chip suppliers an OEM purchases from at a point in time and (b) changes in the number and identities of those modem chip suppliers over time. This is because OEMs face trade-offs – e.g., between customization costs and keeping up with leading-edge features – in making such sourcing decisions. Supporting *Plaintiff’s Hypothesis* would require demonstrating that observed outcomes in this respect are inconsistent with the *Industry Factors Hypothesis*.

##### A. Number of modem chip supplier relationships at each OEM

191. As discussed above in Section III.E.1.b, there are potential costs as well as benefits to sourcing modem chips from multiple suppliers. OEMs typically single-source modem chips for a particular device model, but they may be more likely to use multiple suppliers for a model if it is sold in different regions or on different networks.<sup>370</sup> For example, recent models of the Samsung Galaxy S-series, starting with the S6 in 2015, have all been dual-sourced using Samsung’s own Exynos SoCs for many regions, including Europe, and a Qualcomm modem chip for regions such as the U.S., Australia, China, and Japan, where compatibility with

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<sup>370</sup> See Section III.E.1.b for a detailed discussion of OEMs’ choices concerning sourcing from single or multiple suppliers.

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CDMA2000 or certain advanced LTE features were demanded by wireless carriers.<sup>371</sup> Samsung has also sourced modem chips for some models of the Galaxy from suppliers other than Samsung or Qualcomm. For instance, a variant of the Galaxy SIII in 2013 used an Intel modem chip, while the 2017 Galaxy J7 was dual-sourced between Samsung and MediaTek.<sup>372</sup> Recently, Apple has also offered some of its iPhone models in two variants, with either Intel’s or Qualcomm’s chips depending on the country and network on which the iPhone operates.<sup>373</sup>

192. Because of occasional multi-sourcing for a particular device, such as the examples just described, and because an OEM’s product range may include devices that are best suited to chips from different suppliers, an OEM typically sources modem chips from more than one supplier at the same time. This is evidenced in Exhibit IV.A.1, which shows, for each year from 2008 through 2017, the number of modem chip suppliers used by each of the 10 largest

<sup>371</sup> See, e.g., “Global 4G Subscriber & Smart Device Market Update,” Forward Concepts, 2015, p. 35 (“Samsung with the Galaxy S6 release in April last year began supplying its own 3G HSPA/4G Cat 4 modem with their Exynos 7420 octet application processor.”), p. 37 (“The Exynos 4720 is used in all S6 Models and the latest Note5, however the models supporting 3G TD-SCDMA, 3G CDMA EVDO are based on a standalone 3G/4G Qualcomm modem [...]. Also in regions, such as South Korea and Australia and Japan where Cat 6, TD-LTE bands exist, and carrier-aggregation (CA) features are demanded by operators – then the Qualcomm upgraded X5 or X8 modem is used.”) and p. 50 (“[T]he [Galaxy S6] modems are either supplied by Qualcomm (CDMA and TD models) or based upon Samsung’s Shannon 333 FDD modem chip set”). See also Jones, Landon, “Here Are the Regions Where the Exynos and Snapdragon Galaxy S9 Will Be Launched,” SamMobile, March 2018 (“As usual, one of the largest markets for flagship devices, the United States, will receive the Snapdragon 845 model. As we saw last year with the Galaxy S8 duo, the S9’s will be the first devices to rock the latest processor from Qualcomm. China is also a consistent recipient of the Snapdragon processor and this year is no different. Latin America and Japan are included in the bunch as well. The rest of the world, including the whole of Europe, will receive the native Samsung Exynos 9810 processor.”); Shah, Agam, “What chip will your Galaxy S7 or S7 Edge have?,” PCWorld, February 22, 2016 (“If you’re in the U.S., it’ll be a Qualcomm Snapdragon chip [...]. Countries in Europe and Asia will likely get models with the Exynos chip.”).

<sup>372</sup> See, e.g., “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 77 (“The [Intel] XMM6260 HSPA+ Category 14 21 Mbps is the modem inside the Samsung Galaxy SIII. The next generation supporting DC-HSPA+ up to 42 Mbps has appeared in the SIII LTE shipped into South Korea”). See also “Baseband/Modem & Smartphone Market,” Forward Concepts, 2017, p. 69 (“[MediaTek’s] MT6757 (P20) is being used in the J7max in 2017. Samsung also used its Exynos 7880 baseband processor in the J7Pro, which is feature identical (both Cat6 basebands and similar CPU cores) to the J7 Max except for the addition of 4GiB SRAM and VoLTE support on the MT6757 and the GPU performance differences of the T830 MP3 (MT6757) versus the T880 MP2 Exynos 7880.”).

<sup>373</sup> See, e.g., Segan, Sascha, “Exclusive: Qualcomm’s iPhone X Still Outpaces Intel’s,” PCMag, December 1, 2017 (“There are three iPhone X models sold globally. Using lab equipment, Cellular Insights tested two of them: the Qualcomm-powered A1865, sold by Sprint, Verizon, and U.S. Cellular and in Australia, China, and India; and the Intel-powered A1901, sold by most other global carriers including AT&T and T-Mobile. (The third model, A1902, is only sold in Japan.) Here in the US, we anticipate that the SIM-free model sold directly by Apple will be the A1865, as that’s the model that supports all four US carriers.”).

mobile device OEMs, as determined by unit sales over the period 2008–2017. Samsung, the largest modem chip purchaser, has used between four and nine different suppliers per year since 2008, including itself since 2010.<sup>374</sup> In addition to using multiple suppliers overall, OEMs tend to use multiple suppliers for LTE-compatible modem chips as well, as seen in Exhibit IV.A.2. A majority of the top OEMs have sourced LTE chips from multiple suppliers since 2013, with Samsung concurrently using as many as six different modem chip suppliers, including itself, for its LTE mobile devices. Apple, which offers a limited mobile device product range, sourced modem chips from no more than two suppliers at any time, as did Vivo, OPPO, and Sony.

193. Moreover, as shown in Exhibit IV.A.3a–b, the sourcing of modem chips from multiple suppliers is particularly prevalent for OEMs that offer a wide array of product lines. For example, in 2012, Samsung and Huawei each offered over 90 mobile device models at a wide range of price points, and they each sourced modem chips from seven different suppliers. Conversely, OEMs with fewer device models use fewer chip suppliers: in 2012, Apple used two suppliers for its four device models, while in 2017, Apple, OPPO, and Vivo, the three OEMs with the lowest number of device models, each used only two modem chip suppliers. This suggests that Apple’s decision to design and sell a limited number of iPhone models likely contributed to its use of only one or two chip suppliers throughout its history. Similarly, an inspection of Samsung’s Galaxy S series of smartphones, which is Samsung’s flagship model akin to the iPhone, shows that since 2013 Samsung appears to have used two modem chip suppliers for this line at any given time: Intel and Qualcomm in the Galaxy S4 and S5 in 2013–2014, and Samsung S-LSI and Qualcomm starting with the Galaxy S6 in 2015.<sup>375</sup>

<sup>374</sup> As noted in Exhibit IV.A.1, Strategy Analytics categorized some suppliers such as Samsung S-LSI under “Other” prior to Q2 2013. See Section V.C.4 for a detailed history of Samsung S-LSI.

<sup>375</sup> See, e.g., “LTE Chip Market Trends,” Forward Concepts, 2014, p. 86 (“[T]he Galaxy S4 Active LTE A (first Cat 4 VoLTE Smartphone) for the Korean market is using the Qualcomm MSM8974 (MDM9x25 with 2.3 GHz Krait 400) chip set.”). See also “Samsung Galaxy S4 Teardown,” TechInsights (“This Galaxy S4 uses Intel’s PMB9820 baseband processor”); “Samsung Galaxy S5 SM-G900H,” TechInsights, 2014 (“Intel[:] #X-Gold 636 / PMB9820[:] Baseband Processors & Power Management”); “Samsung Galaxy S5 SM-G9008V,” TechInsights, 2014 (“Qualcomm[:] #MSM8974AC[:] Quad-Core Snapdragon 801 Baseband / Applications Processor”); “Global 4G Subscriber & Smart Device Market Update,” Forward Concepts, 2015, p. 50 (“[T]he [Galaxy S6] modems are either supplied by Qualcomm (CDMA and TD models) or based upon Samsung’s Shannon 333 FDD modem chip set”).

**B. Changes in modem chip supplier–OEM relationships over time**

194. As discussed in the industry analysis in Section III, the fast pace of technological change in the mobile device industry generates opportunities and challenges for modem chip suppliers. Mobile devices are updated often, particularly with new models of flagship phones such as the Apple iPhone and Samsung Galaxy S being released every year. This presents opportunities for the identities of suppliers to particular OEMs to change.
195. Exhibit IV.B.1a uses Strategy Analytics data to show the number of modem chip supplier–OEM relationships initiated and terminated each year from 2008 to 2017 for the top ten OEMs as measured by mobile device unit sales over this period.<sup>376</sup> Most OEMs start or end a supplier relationship once a year on average.<sup>377</sup> Similarly, Exhibit IV.B.1b shows the number of initiated and terminated OEM relationships over the same time period from the point of view of modem chip suppliers. Some suppliers started and ended few OEM relationships, either because they already had a large number of OEM customers (e.g., Qualcomm) or because they are vertically integrated with an OEM (e.g., Samsung S-LSI and HiSilicon). Other suppliers started more relationships than they ended: for example, MediaTek’s and Spreadtrum’s growth has been accompanied by an increase in the number of their OEM customers. Finally, for suppliers that have exited the modem chip industry during this time period, including Broadcom, Marvell, ST-Ericsson, TI, and VIA Telecom, the number of ended OEM relationships exceeds the number of new relationships.
196. Exhibit IV.B.2 summarizes the OEM- and supplier-specific analyses by showing the total number of modem chip supplier–OEM relationships started and ended each year from 2008 to 2017. The large number of relationships started and ended for many years is consistent with an industry characterized by dynamic competition. In particular, the exhibit demonstrates that modem chip suppliers are not foreclosed from starting new relationships with OEMs. Further, the data show an increase in the number of new relationships around 2011 to 2013, suggesting

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<sup>376</sup> As the Strategy Analytics dataset is based on sales, it can indicate lagging supply relationships after a supplier has stopped developing new modem chips for an OEM or has exited the industry. For instance, the data indicate sales from Infineon/Intel to Apple until 2014, after Apple switched to Qualcomm, based on continued modem chip sales for older iPhone models rather than new releases.

<sup>377</sup> See Strategy Analytics, “Customised Baseband Quarterly Market Share Tracker for Qualcomm: Parts 1 and 2,” April 6, 2018.

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that the transition to 4G LTE standards spurred OEMs to seek out new suppliers. The data also show an even more distinct spike in the number of ended relationships starting in 2013. An examination of the results in Exhibit IV.B.1b reveals that many of these ended relationships involved modem chip suppliers that failed to create viable 4G LTE products, which led to their exit from the industry during this time period. I discuss these specific suppliers in more detail in Section V.C.

197. To further examine how modem chip supplier–OEM relationships change over time, Exhibit IV.B.3 shows the modem chip suppliers for the top 10 OEMs by unit sales over the 2008–2017 period, ranked by the number of modem chips the OEM purchased from the supplier in each year (as recorded by Strategy Analytics). This exhibit demonstrates that in addition to starting and ending modem chip supplier relationships, the relative importance of individual suppliers can change over time for an OEM. Of note, both Samsung and Huawei have increasingly been sourcing modem chips from their respective vertically integrated modem chip design businesses, which have become the OEMs’ largest chip suppliers by 2017. This finding is confirmed in Exhibit IV.B.4, which shows that both firms have significantly increased the fraction of their modem chip demand that they chose to self-supply, from under two percent in 2013 to over 40 percent in 2017.
198. These changing supplier–OEM dynamics contribute to changes in the success of individual modem chip suppliers over time. As wireless standards and OEM demands have evolved, modem chip suppliers have realized varying degrees of growth. Consequently, some modem chip suppliers have experienced high growth in sales while others have seen declining sales. This is shown in Exhibit IV.B.5, which lists the suppliers with the largest year-to-year growth in unit sales in each year from 2003 to 2017. Most suppliers have experienced sales growth in some years but declining sales in other years, and suppliers have typically varied in terms of their growth over time. For example, TI experienced substantial growth from 2004 to 2007 but declined significantly in 2008. Similarly, Broadcom experienced rapid growth from 2009 to 2011 but declined after that, while MediaTek has varied between high growth in years such as 2010 and declining sales in years such as 2015. The fastest growing suppliers in any one year are not necessarily the fastest growing suppliers in other years.

199. These findings are supported by Exhibit IV.B.6, which shows the overall and percentage change in modem chip units sold between 2008 and 2017. While the largest percentage changes have generally been observed for suppliers who sold relatively small numbers of modem chips in 2008, even some larger suppliers, such as Spreadtrum, MediaTek, and Qualcomm, have almost tripled their unit sales over this time period. Furthermore, this time period saw the entry of a number of new leading modem chip suppliers, including Samsung S-LSI and Intel, as well as smaller suppliers such as Altair and Sequans. Conversely, about half of the suppliers that sold modem chips in 2008 exited the industry before 2017. Notably, as mentioned above and discussed further in Section V.C, these suppliers typically exited because they failed to transition to supplying modem chips that work within the 4G LTE standard, while much of the growth from suppliers such as MediaTek and Spreadtrum can be attributed to their growth in offering LTE chips.<sup>378</sup>
200. The patterns of changes in modem chip supplier–OEM relationships over time are consistent with ongoing competition among suppliers to gain supply relationships with OEMs. The associated variation in the success of individual modem chip suppliers is further consistent with the ability of new entrants to successfully challenge incumbent suppliers and grow their share of sales through successful development of modem chips that are demanded by OEMs.

### **C. Modem chip supplier–OEM relationships for high-end mobile devices**

201. I have not been asked to opine on the alleged definition of the market for modem chips, and therefore do not present any such opinion. Because Plaintiff’s allegations focus particular attention on so-called “premium” modem chips that they allege are supplied to flagship smartphones,<sup>379</sup> which Plaintiff’s expert Professor Shapiro refers to as smartphones with a retail price over \$400,<sup>380</sup> I analyze supplier–OEM relationships for “High-End” and “Ultra High-End” mobile devices, as classified in the IDC Mobile Devices Tracker dataset that

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<sup>378</sup> See also Exhibit V.B.8 for the growth of LTE modem chip sales by supplier.

<sup>379</sup> Complaint, ¶¶ 131–134, 144.

<sup>380</sup> Shapiro Report, ¶ 62, ¶ 176, ¶ 445. For the period prior to 2013, Professor Shapiro uses a \$300 threshold. Shapiro Report, ¶ 62, ¶ 176, ¶ 445.

categorizes devices into five tiers.<sup>381</sup> As used in the IDC Mobile Devices Tracker dataset, “High-End” devices have selling prices between \$400 and \$600; “Ultra High-End” devices have selling prices over \$600.

### 1. Greater concentration among high-end OEMs

202. The economics literature suggests that industry concentration will be higher among suppliers of high-end products than among suppliers of low-end products. Designing innovative, customized, high-end devices requires large R&D investments, and a firm will be willing to supply these products only if it expects to recover its costs by capturing a large proportion of sales. As a result, these R&D-intensive, customized, high-end products will be supplied by fewer firms.<sup>382</sup> This has been recognized by modem chip industry participants as well, with an Ericsson executive attributing the OEM concentration between Apple and Samsung as a factor in Ericsson’s decision to exit the modem chip industry.<sup>383</sup> Similarly, [REDACTED]

<sup>381</sup> IDC records estimates of revenue and units sold, by quarter, for mobile devices from Q1 2004 to Q4 2017, as well as device characteristics such as vendor (i.e., OEM), model name (starting in Q1 2010), and compatible wireless standards. IDC also categorizes devices into “smartphone tiers” as “Ultra Low-End,” “Low-End,” “Mid-Range,” “High-End,” or “Ultra High-End”; I consider the devices categorized as “High-End” and “Ultra High-End” for my analyses in this section.

<sup>382</sup> As I discuss in Section III.B above, the high customization and asset specificity of modem chips at the leading edge suggests there will be fewer firms. See, e.g., Davis, Peter and Eliana Garcés, “Quantitative Techniques for Competition and Antitrust Analysis,” Princeton University Press, 2009, p. 34 (“[I]f R&D [...] expenditures involve large fixed outlays that are largely independent of the scale of production, they will result in economies of scale”) and p. 29 (“If we have substantial economies of scale, the minimum efficient size of a firm may be big relative to the size of a market and as a result there will be few active firms in the market.”). See also Williamson, Oliver E., “Intermediate Product Markets and Vertical Integration,” in Oliver Williamson, *Markets and Hierarchies: Analysis and Antitrust Implications: A Study in the Economics of Internal Organization*, The Free Press, 1975, p. 89 (“Consider an industry that produces a multicomponent product, assume that some of these components are specialized (industry specific), and assume further that among these are components for which the economies of scale in production are large in relation to the market. The market, then, will support only a few efficient-sized producers for certain components.”).

<sup>383</sup> Zander Deposition, Ericsson, p. 102 (“Q. And at a high level can you recall what the factors were that led to that decision? A. Yes, so it was several factors, [...] we saw there was a high customer concentration with literally Apple and Samsung to address within modems in premium segment.”), and p. 144 (“Q. [...] Why did the high customer concentration -- how did that impact the decision to exit the baseband chipset market? A. It made the addressable market very digital in size. [...] Samsung, using multi-supplier, never giving anyone any guarantees, so you had to qualify every day working with Samsung, while Apple have less design in slots with longer lead times, so really very difficult and costly to fight for a space [...] -- and, you know, both players together significantly dominating the market segment leaving actually no space for the handset, other handset vendors either.”).

[REDACTED] Furthermore, concentration may tend to increase over time in technically innovative industries such as the mobile device industry, because firms that succeed at innovating become more competitive.<sup>385</sup> Below, I summarize the evidence of this concentration.

203. Exhibit IV.C.1 shows the share of mobile devices sold globally each year from 2013 to 2017 by the top four OEMs across all tiers and separately for each of the five tiers. It also shows the total number of mobile devices reported as sold in the IDC data each year. There is a notable difference in the share of the top four OEMs across the tiers: sales in the low-end tiers are much less concentrated than in the high-end tiers. Specifically, sales of high-end (“HE”) devices are more concentrated than sales of low-end devices, with the top four OEMs selling approximately 80 percent of HE devices each year. Sales of ultra-high-end (“UHE”) devices are even more concentrated, with the top four OEMs selling between 92 and 98 percent of all devices each year.
204. To further show the concentration in sales of high-end devices, Exhibit IV.C.2a shows annual global sales of UHE devices from 2010 to 2017 for the top 10 OEMs selling UHE devices, and Exhibit IV.C.2b shows combined sales of UHE and HE devices. Exhibits IV.C.2c and 2d show the same information, but restricted to just LTE mobile devices. These exhibits demonstrate that sales of UHE and HE mobile devices are, in large part, the sales of Apple and Samsung whose high-end devices sold at high prices. These two OEMs accounted for the sales of

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<sup>385</sup> See, e.g., Council of Economic Advisers Issue Brief, “Benefits of competition and indicators of market power,” p. 3 (“Sometimes, a firm’s market share increases because of innovations by the firm, which results in products and services values by consumers. [...] Market share may increase as a firm realizes economies of scale, or efficiencies created by larger operations, resulting in lower costs that are passed on to consumers in the form of lower prices.”).

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approximately 90 percent of UHE devices and 75 percent of UHE and HE devices between 2011 and 2017. Apple alone sold approximately two-thirds of all UHE devices, and about half of all UHE and HE devices, between 2011 and 2017. While Apple and Samsung sold the largest volumes, numerous other firms also sold high-end devices each year. Notably, as shown in Exhibit IV.C.2d, Huawei and OPPO have grown considerably in recent years, and in 2017 each sold over 20 million high-end LTE mobile devices.

205. Concentration at the device level is also much higher in the UHE tier than in the “Ultra-Low End” (ULE) tier. Specifically, as shown in Exhibit IV.C.3, between 2010 and 2017 the top 20 UHE devices based on unit sales sold much higher volumes than the top 20 ULE devices, even though the total numbers of UHE and ULE devices sold have been roughly comparable in the last few years. As a result, the top 20 UHE devices accounted for more than 75 percent of sales of all UHE devices during this time period, while the top 20 ULE devices accounted for only 12 percent of the sales of all ULE devices. Consistent with the results in Exhibit IV.C.2a, all top 20 UHE devices were sold by either Apple or Samsung, while the top 20 ULE devices were sold by four different OEMs.
206. This concentration among HE/UHE OEMs appears to have had impacts on the modem chip suppliers as well. [REDACTED]
207. The higher concentration in sales of high-end mobile devices, when combined with the tendency of OEMs to single- or dual-source modem chips for a given device and to generally

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source from a subset of all suppliers, implies that sales of modem chips for high-end devices are likely to be more concentrated among suppliers than sales of modem chips for low-end devices. Indeed, the relatively small number of highly successful ultra-high-end mobile devices means that sales would naturally tend to be highly concentrated among a small number of suppliers of “high-end” modem chips. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

## **2. Increasing vertical integration among high-end OEMs and their modem chip suppliers**

208. The increasing self-supply of modem chips by Samsung and Huawei has important implications for the success of modem chip suppliers that are not vertically integrated. As Exhibits IV.B.3 and IV.B.4 show, both of these OEMs have been gradually reducing the number of other chip suppliers from which they source chips as the share of their self-supplied chips has grown. For example, [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

388 [REDACTED]

389 [REDACTED]

390 See Exhibit V.C.14c. [REDACTED]

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209. Samsung’s increasing use of self-supply has similarly diminished its sourcing from other chip suppliers. Samsung’s Hojin Kang testified to this, stating that as Samsung used its S-LSI modem chips in its flagship smartphones since around 2015, it has purchased fewer Qualcomm modem chips.<sup>391</sup> This has resulted in Samsung S-LSI becoming Samsung’s largest modem chip supplier by 2017, with Qualcomm the second largest, as shown in Exhibit IV.B.3. Likewise, industry analysts have noted that MediaTek has also lost out on opportunities to supply modem chips to Samsung in the “mid-range” segment.<sup>392</sup>
210. Similarly, Huawei’s increasing use of HiSilicon chips has reduced its demand for modem chips from other suppliers. Just as MediaTek was noted to have lost out due to Samsung, its sales were also restricted due to Huawei’s use of its in-house Kirin 650 and 960 SoCs.<sup>393</sup> This is also evident in Exhibit IV.B.3, as HiSilicon has displaced MediaTek and Qualcomm to become Huawei’s largest modem chip supplier since 2016.
211. The increased vertical integration of modem chip supply by these two OEMs may thus naturally limit opportunities for non-integrated modem chip suppliers to find OEM customers for their modem chips. Put differently, as Samsung and Huawei source more modem chips from their respective captive chipmakers (i.e., shift their demand from external suppliers to self-supply), the aggregate demand for chips made by independent modem chip suppliers such as Qualcomm, Intel, and MediaTek will be reduced.<sup>394</sup> Facing the threat of in-house suppliers

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<sup>391</sup> Kang Deposition, Samsung, p. 103 (“Q. And the use of LSI in the flagship phones has caused a diminution in the number of chips that Samsung was buying from Qualcomm since 2015? [...] THE WITNESS: That’s right. The use of LSI in the -- those phones starting from around that time point brought diminution in the number of chips that we purchased from Qualcomm.”).

<sup>392</sup> See, e.g., “Baseband/Modem & Smartphone Market,” Forward Concepts, 2017, p. 77 (“However, MediaTek is cut off from addressing the higher priced mid-range segment [...]. Also, they have been unsuccessful at Samsung in the same segment of the market, owing to Samsung Electronics strong investments in baseband processing now covering the mid-tier as well as premium segment.”).

<sup>393</sup> See, e.g., “Baseband/Modem & Smartphone Market,” Forward Concepts, 2017, p. 77 (“However, MediaTek is cut off from addressing the higher priced mid-range segment owing to Huawei’s strong market abroad (now over 40%), which is based upon their own HiSilicon integrated processors such as Kirin 650 and Kirin 960 baseband-processors.”).

<sup>394</sup> See, e.g., [REDACTED]

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as competitors for sockets, independent modem chip suppliers may choose to exit the business of supplying modem chips for OEMs that sell high-end devices,<sup>395</sup> decreasing the number of potential suppliers available to OEMs such as Apple that lack captive modem chip suppliers.<sup>396</sup>

#### D. Conclusion

212. The above analyses demonstrate that, as predicted by the *Industry Factors Hypothesis*, the modem chip industry is generally described by fluid relationships between modem chip suppliers and their OEM purchasers, but that OEMs differ in their decisions concerning the number of modem chip suppliers they use and adjustments in their supply relationships, consistent with their requirements and strategic choices. While mobile device OEMs tend to source from only one or two suppliers for a given device, across product portfolios, they source modem chips from multiple suppliers whose number and identity vary over time, leading to frequent turnover in industry leadership. [REDACTED]

[REDACTED]. Simultaneously, as in other industries characterized by rapid technological change, the modem chip industry has tended toward increased concentration and relatively few competitors, particularly in sales to the high end of the mobile device product spectrum, as evidenced by Apple’s and Samsung’s combined high share of sales of high-end mobile devices. This trend is reinforced by continued vertical integration of some mobile device OEMs, such as Samsung and Huawei, into the supply of modem chips. The combination of concentration among high-end OEMs and increasing vertical integration between high-end OEMs and their suppliers diminishes the amount of business available to independent modem suppliers such as Qualcomm, MediaTek, and Intel,

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<sup>395</sup> While Samsung and [REDACTED] have used self-supply for a variety of their devices, the effect may be particularly prevalent for “high-end” devices given that Samsung and [REDACTED] make up a relatively large portion of sales in those IDC categories. See Exhibit IV.C.2a–d.

<sup>396</sup> For example, if there is a minimum efficient scale for non-integrated modem chip suppliers, then reduced demand for their chips from vertically integrated OEMs may force the non-integrated suppliers to decrease their output or exit the industry (See, e.g., Chandler, Alfred, *Scale and Scope: The Dynamics of Industrial Capitalism*, Harvard University Press, 1994, p. 27 “the number of plants in an industry that could operate at minimum efficient scale at a given point in time was limited by the size of the market for that industry’s product.”).

limiting their ability to achieve a profitable scale and resulting in relatively few successful chip suppliers at the high end of the mobile device industry.

## V. ANALYSIS OF MODEM CHIP SUPPLIER PERFORMANCE

### A. Introduction

213. The industry analysis in Section III together with the analysis of modem chip supplier–OEM relationships in Section IV identify relevant industry factors and their implications for the structure and development of the modem chip industry, as well as for the successes and failures of individual modem chip suppliers. These analyses, grounded in principles of industrial organization, yield the *Industry Factors Hypothesis*, which posits that industry factors are the predominant force shaping the modem chip industry, and that the overwhelming drivers of success and failure of individual firms are their capabilities to anticipate and meet the demands of OEMs within the context of these broader industry factors. As established in Section III, the three main factors contributing to such capabilities – and thus to modem chip suppliers’ successes and failures – at the innovative forefront of the industry are: (i) foresight, or the ability to predict and align with demand; (ii) efficient and strategic investment in developing modem chip technologies; and (iii) execution, as demonstrated by timely, reliable delivery of products. However, modem chip suppliers not at the forefront of the industry can also succeed by pursuing other strategies, such as, for example, the fast-follower strategy. Section IV demonstrates how these industry factors lead to generally fluid relationships between modem chip suppliers and mobile device OEMs, with increasing concentration and vertical integration of OEMs reducing the scale available to modem chip suppliers offering their products on the merchant market. As discussed in Sections III and IV and illustrated in more depth in this section, industry factors explain the structure of the modem chip industry and the successes and failures of individual chip suppliers.
214. By contrast, *Plaintiff’s Hypothesis* predicts that modem chip suppliers exited the industry or failed to enter or succeed because Qualcomm’s alleged exclusionary conduct rendered them unable or at least less able to compete. *Plaintiff’s Hypothesis* predicts that a modem chip supplier would have been able to design and manufacture modem chips embodying the functionalities demanded by downstream customers at a certain time if its ability to learn,

innovate, and produce chips at a profitable scale were not allegedly hampered by Qualcomm’s conduct.

215. Having identified these two different hypotheses, in this section I proceed with an analysis of *Plaintiff’s Hypothesis*. In particular, I assess whether observed outcomes are contrary to those predicted by the *Industry Factors Hypothesis*, which is necessary to support *Plaintiff’s Hypothesis*. This analysis has two parts. First, I evaluate the factors underlying Qualcomm’s experience in sales of cdmaOne/CDMA2000, WCDMA, and LTE modem chips. This part of the analysis seeks to determine whether that experience is explained by industry factors or, in the alternative, requires other explanations. Second, I evaluate the success, or lack thereof, of several other modem chip suppliers during the relevant period. As in the evaluation of Qualcomm’s experience, a key component of this part of the analysis evaluates whether the failures or exits of chip suppliers during this period can be explained by industry factors or, alternatively, require other explanations.
216. As discussed in detail below, my analysis supports the *Industry Factors Hypothesis* and does not support *Plaintiff’s Hypothesis*. I find that Qualcomm is a successful modem chip supplier because of its competitive advantages and engineering prowess. Qualcomm’s foresight in choosing which wireless standards to implement and which advanced features to support; its strategic, sizeable, efficient, and sustained investments in R&D; and its effective execution including consistent, timely, and reliable supply of innovative, high-performance chips have served as its foundation for success. Similarly, I find that successes and failures of other modem chip suppliers are also explained by the *Industry Factors Hypothesis* and do not support *Plaintiff’s Hypothesis*.

### **B. Qualcomm’s experience**

217. In this section, I apply my analytic framework to Qualcomm’s experience during the evolution of 2G, 3G, and 4G wireless standards. As described below, the *Industry Factors Hypothesis* explains Qualcomm’s success in developing products for these different wireless standards. For each family of wireless standards (cdmaOne/CDMA2000, WCDMA, and LTE,

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respectively),<sup>397</sup> I evaluate Qualcomm’s strategic decisions with regards to implementing the standards and advancing the technology, Qualcomm’s ability to develop modem chips compatible with the standards, and the reasons for Qualcomm’s sustained level of performance. I attribute Qualcomm’s success over the past three decades to the industry factors identified in Section III, which have contributed to different extents to Qualcomm’s success during different generations of wireless technologies. Furthermore, consistent with evidence presented in Section IV, Qualcomm’s relationships with OEMs and other industry participants, such as network carriers, have evolved over the years, with new relationships formed while others have dissolved.

### **1. cdmaOne and CDMA2000-compatible modem chips**

218. Qualcomm’s success with CDMA cellular technology was the result of a risky, but ultimately successful, R&D strategy that began in the late 1980s. Qualcomm showed effective foresight by aggressively pursuing CDMA technology years before any other firm recognized its potential for the wireless space. After successfully demonstrating the feasibility of cellular CDMA, Qualcomm made the strategic decision to double down: in order to turn CDMA into a practical reality, it focused on the design, and initially also the manufacture, of CDMA modem chips, CDMA mobile devices, and CDMA-compatible network infrastructure. Qualcomm was then able to stay ahead of its competitors in CDMA for an extended period by way of continued innovation; many potential competitors decided to focus on other technologies, such as GSM and WCDMA, which accounted for the bulk of modem chip shipments. Despite CDMA’s expected obsolescence, ongoing requirements for backward compatibility with earlier standards have not only allowed Qualcomm to continue to profit from its strategic decision to support CDMA-compatible modem chips but also attracted other chip suppliers to enter and offer CDMA-compatible modem chips.

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<sup>397</sup> A family of wireless standards can contain multiple standards and multiple associated revisions or releases of each standard. For example, the CDMA2000 family of standards evolved through a number of versions, such as CDMA2000 1X, CDMA2000 1xEV-DO Rev. A, and CDMA2000 EV-DO Rev. B; see, e.g., “CDMA History,” CDG, available at [http://www.cdg.org/resources/cdma\\_history.asp](http://www.cdg.org/resources/cdma_history.asp). Unless specified further, I use the term “CDMA standards” to refer to the broad families of cdmaOne and CDMA2000 standards and their revisions.

219. For context, Exhibit V.B.1 shows the number of handsets sold, by technology, from 1994 to 2017. This reveals the prevalence of GSM handsets in the earlier years, the emergence of CDMA handsets in the early 2000s, and the overall rapid growth of the industry after the introduction of 3G and 4G technologies. Despite CDMA’s presence in the industry over the past two decades, shipments of CDMA-compatible handsets had not accounted for more than 20 percent of all global shipments in any year prior to the introduction of LTE. The number of CDMA handsets (with CDMA as the highest supported standard) shipped per year increased until 2011, when about 230 million handsets were shipped, before dropping below 200 million in the following few years. The prevalence of CDMA-compatible handsets increased again following the introduction of multi-mode LTE/CDMA handsets.

*a. Initial development of the CDMA technology and cdmaOne standard*

220. In the 1980s, participants in the telecommunications industry began to plan for the introduction of digital technologies to increase the capacity of cellular networks.<sup>398</sup> These 2G digital technologies would make more efficient use of the available spectrum than 1G analog technologies by converting and compressing analog voice data into digital signals.<sup>399</sup> The first 2G standards to gain acceptance in Europe and the U.S. were based on TDMA technology. In Europe, the TDMA-based GSM standard was established in 1987.<sup>400</sup> In the U.S., the TDMA-based IS-54 standard was adopted in 1989 – despite failing to achieve the tenfold increase in capacity desired by the industry.<sup>401</sup>

<sup>398</sup> Ghosh, Arunabha, et al., *Fundamentals of LTE*, Pearson, 2011, p. 6 (“2G systems were also aimed primarily toward the voice market but, unlike the first generation systems, used digital modulation [...] provid[ed] improved voice quality, capacity, and security[.]”).

<sup>399</sup> Luo, Fa-Long, *Digital Front-End in Wireless Communications and Broadcasting: Circuits and Signal Processing*, Cambridge University Press, 2011, p. 6 (“[...]the key difference between 2G and 1G communication [...] is realized by adding a digital-to-analog (D/A) converter [...]. Compared to analog systems, digital systems have [...]higher frequency efficiency. Digital data can be compressed, so digital systems have higher spectrum efficiency.”).

<sup>400</sup> See, e.g., “History,” GSMA (“Basic parameters of the GSM standard agreed in February [1987].”). See also Ghosh, Arunabha, et al., *Fundamentals of LTE*, Pearson, 2011, p. 8 (“The GSM air-interface is based on a TDMA scheme [...]”).

<sup>401</sup> See, e.g., Mock, 2005, p. 49 (“In September 1988, the Cellular Telecommunications Industry Association (CTIA) published a set of User Performance Requirements (UPR) that encouraged the industry to develop a digital wireless standard with at least ten times the capacity of the current analog networks[.]”) and pp. 57–58 (“The [European Union] had already [...]shown] that time-based wireless techniques could boost network

221. In late 1988, Qualcomm proposed using the alternative CDMA technology,<sup>402</sup> which had the potential to greatly increase network capacity relative to TDMA.<sup>403</sup> Qualcomm was well positioned to pioneer this radically different approach: its engineers had experience applying similar techniques to satellite-based communications for long-haul trucking.<sup>404</sup> Incumbents who had already invested in developing TDMA-compatible infrastructure and modem technology, and stood to lose the most from a competing standard, did not embrace CDMA.<sup>405</sup> Some industry and academic participants considered CDMA too complicated for commercial implementation and potentially infeasible.<sup>406</sup>

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capacity by at least three times by most estimates. [...] The CTIA had been working with many U.S. companies to develop a time-based wireless protocol, even though it was clear that this protocol wouldn’t meet the CTIA’s mandate for capacity. [...] The Telecommunication Industry Association (TIA) - with the endorsement of the CTIA - voted in January 1989 to select the time-based (TDMA) method of digital communication for cellular systems [...] technically termed IS-54[.]”).

- <sup>402</sup> I. Jacobs Deposition, Qualcomm, pp. 10-11 (“Q. What were the first products that Qualcomm provided to -- for use in commercial deployment of cellular networks? A. Well, there's a bit of a history to that. [...] Came back [...] to looking at CDMA research, development, roughly in November of '88, as I recall. Looked at that for a period -- looked very promising. [...] Any case, the industry was moving towards something called ‘time division,’ ‘TDMA.’ There was a big industry dispute over that. There was a vote in -- [...] I think the vote was January of '88 to go ahead with TDMA in the U.S. We went, a few months later, to stock with the first operator. [...] About CDMA -- [the operators] were interested -- of course, it had potential advantages over TDMA. We pursued that further. [...] People had looked at [CDMA] around the world for several years, [...] but] hadn’t found a way to deal with some of the difficult problems. We [...] found ways of dealing with those problems, built that into the demonstration equipment, and had a demonstration [...] in October of '89.”).
- <sup>403</sup> “Geek Page - Spread-Spectrum Technology,” *Wired*, April 1, 1995 (“While chances are CDMA won’t immediately result in the twentyfold increase in capacity that some have claimed, it will offer significantly greater capacity than TDMA - and more room for improvement.”).
- <sup>404</sup> See, e.g., Bodine, Paul, *Make It New: Essays in the History of American Business*, iUniverse, 2004, p. 158 (“If there was any segment of the U.S. transportation industry that needed the help of wireless long-distance communications it was the trucking industry. [...] Between 1985 and 1988 [Qualcomm founders] Jacobs and Viterbi began developing a wireless, two-way messaging and positioning system that would enable trucking firms to closely track their drivers’ progress across their routes while drivers and dispatchers easily beamed messages to each other. Christened OmniTRACS, the system would create continent-wide coverage by leasing the capability of existing communications satellites.”).
- <sup>405</sup> I. Jacobs Deposition, Qualcomm, pp. 10-11 (“Q. What were the first products that Qualcomm provided to -- for use in commercial deployment of cellular networks? A. [...] Any case, the industry was moving towards something called ‘time division,’ ‘TDMA.’ There was a big industry dispute over that.”).
- <sup>406</sup> For example, a Stanford University professor of electrical engineering characterized CDMA as defying the laws of physics and “something of a hoax,” see Kraul, Chris, “Down to the Wireless: Stakes High as Rivals Race to Provide Next Generation of Cellular Gear,” *Los Angeles Times*, May 20, 1996. See also Mock, 2005, p. 51 (“[T]he complexity of transmitting code-based communications in real time made [CDMA] appear to many engineers to be beyond the reaches of the current technology.”).

222. Qualcomm’s then-CEO Irwin Jacobs set an aggressive timeline for demonstrating that CDMA technology could work.<sup>407</sup> He scheduled the first demonstration of the CDMA technology for late 1989.<sup>408</sup> Reportedly, even “[m]ost of the engineers working for him thought he was nuts.”<sup>409</sup> The initial demonstration was a success, as was a second demonstration a few months later in an urban setting among tall buildings in New York City.<sup>410</sup> As a result, Qualcomm received funding from network operators and equipment vendors to continue the development of CDMA systems.<sup>411</sup> The first large-scale CDMA capacity tests using commercial-grade equipment took place in late 1991.<sup>412</sup>
223. In 1993, after Qualcomm had overcome the fundamental technical challenges associated with implementing CDMA technology, the TIA adopted CDMA and issued the Interim Standard 95 (IS-95), also known by the proprietary name cdmaOne.<sup>413</sup> This publicly available standard

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<sup>407</sup> Qualcomm’s then-CEO, Irwin M. Jacobs, believed that “if 1989 ended before CDMA went live, neither CDMA nor [Qualcomm] would survive.” Perry, Tekla S., “Irwin Jacobs: Captain of CDMA,” IEEE Spectrum, April 25, 2013.

<sup>408</sup> I. Jacobs Deposition, Qualcomm, pp. 10–11 (“Q. What were the first products that Qualcomm provided to -- for use in commercial deployment of cellular networks? A. [...] About CDMA [...], it had potential advantages over TDMA. We pursued that further. Had a meeting with a number of operators and manufacturers in Chicago in June of that year, I believe. Nobody found any holes in what we were talking about, but it was clear we needed to do a demonstration, show that we had solved with CDMA, indeed did it work -- people had looked at it around the world for several years, [...] hadn’t found a way to deal with some of the difficult problems. We had dealt with those, found ways of dealing with those problems, built that into the demonstration equipment, and had a demonstration -- again, if I have my year right, in October of ‘89.”).

<sup>409</sup> Perry, Tekla S., “Irwin Jacobs: Captain of CDMA,” IEEE Spectrum, April 25, 2013.

<sup>410</sup> See, e.g., Perry, Tekla S., “Irwin Jacobs: Captain of CDMA,” IEEE Spectrum, April 25, 2013 (“[Irwin] Jacobs[, Qualcomm’s CEO,] repeated the [successful San Diego] demonstration in January 1991 in New York City, where skeptical executives at wireless carriers thought CDMA would fail when confronted with a sea of tall buildings.”). See also I. Jacobs Deposition, Qualcomm, pp. 12–13 (“Q. What were the difficult problems with CDMA deployment that Qualcomm addressed? [...] A.] In Manhattan, you come suddenly out to an avenue with lots of energy coming from a different direction -- lots of problems with that sort that defeated many people. In any case, we came up with a very good power-control approach for CDMA.”).

<sup>411</sup> Mock, 2005, p. 81 (“Due in large part to the success of the San Diego and New York trials, Qualcomm was able to win the commitment of six leading operators and equipment vendors: AT&T, NYNEX Mobile, Ameritech Mobile Communications, Motorola, OKI Electric, and PacTel Cellular. Over the next several months, these companies collectively committed more than \$30 million to the continued development of code-based wireless into commercial-capable equipment within the next two years.”).

<sup>412</sup> “CDMA History,” CDG, available at [http://www.cdg.org/resources/cdma\\_history.asp](http://www.cdg.org/resources/cdma_history.asp).

<sup>413</sup> “CDMA History,” CDG, available at [http://www.cdg.org/resources/cdma\\_history.asp](http://www.cdg.org/resources/cdma_history.asp) (July 1993: “U.S. TIA adopts CDMA (IS-95A) as a North American digital cellular standard”; June 1997: “cdmaOne™ trademark launched by CDG for IS-95 CDMA”).

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provided a template for other manufacturers to implement cdmaOne technology in their own products.<sup>414</sup> Qualcomm spent \$25 million on R&D in 1992 and over \$27 million in 1993, when the cdmaOne standard was accepted.<sup>415</sup> However, there were still no CDMA phones or networks that could start repaying this risky investment.

*b. Development of CDMA networks*

224. Qualcomm showed foresight by pursuing the technical advantages of CDMA over TDMA and anticipating the adoption of CDMA technologies in wireless standards. However, acceptance of cdmaOne as a standard did not guarantee that the technology would be commercially successful.<sup>416</sup> Commercial success required carriers to deploy cellular networks that implemented the standard and customers to purchase cellular services on those networks. According to one of the co-founders, Irwin Jacobs, Qualcomm understood that in order for the technology to succeed, it needed to be used as widely as possible.<sup>417</sup> Stakeholders in the cellular communication industry in the early 1990s did not prioritize making large-scale investments to develop commercial CDMA-compatible devices and network infrastructure.<sup>418</sup> To promote adoption of CDMA technology, Qualcomm decided to demonstrate its viability to these stakeholders by independently designing and producing CDMA-based modem chips, devices, and network infrastructure in order to offer an end-to-end solution.<sup>419</sup>

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<sup>414</sup> Mock, 2005, p. 90 (“With formal documentation of the common air interface in hand, Qualcomm was confident that the code based wireless infrastructure and mobile units could be commercialized quickly [...].”).

<sup>415</sup> Qualcomm, 10-K, 1996.

<sup>416</sup> See, e.g., Mock, 2005, p. 113 (“Even after [...] several manufacturers signed license agreements for CDMA, none were eager to divert their efforts from other digital technologies [...].”).

<sup>417</sup> I. Jacobs Deposition, p. 28 (“Q. What was Qualcomm’s rationale in encouraging multiple manufacturers of CDMA-compliant products? A. We wanted to have the technology as used -- as widely as possible. We thought it was by far the best technology. Otherwise, we wouldn’t have continued to work on it so long and so hard. And, therefore, our approach always was to have the broadest possible use as opposed to kind of a narrow approach.”). “History,” Qualcomm, available at <https://www.qualcomm.com/company/about/history> (“In July of 1985, seven people – Dr. Irwin M. Jacobs, Dr. Andrew Viterbi, Harvey White, Franklin Antonio, Andrew Cohen, Klein Gilhousen, and Adelia Coffman found Qualcomm, opening the Company’s first office in La Jolla, California.”).

<sup>418</sup> See, e.g., Mock, 2005, p. 114 (“Some vendors were caught up in manufacturing TDMA and GSM phones, which were already ramping up to significant volumes and others just plain didn’t have enough experience in CDMA to get up to speed quickly.”).

<sup>419</sup> I. Jacobs Deposition, Qualcomm, pp. 16–17 (“Q. For the deployment in Hong Kong in roughly 1995, what were the products that Qualcomm provided? A. [...] The handsets -- there were no other handset manufacturers in

225. By 1992, Qualcomm had licensed several mobile device manufacturers, including Nokia and Motorola, but they were not showing signs of support for large-scale production.<sup>420</sup> Qualcomm made a strategic decision to invest in manufacturing early CDMA mobile devices.<sup>421</sup> Because modem chip technologies available at the time could not accommodate CDMA, Qualcomm also developed its own modem chips. In March 1993, Qualcomm introduced its first true handheld *cellular* mobile device and the first cellular mobile device based on CDMA, the CD-7000.<sup>422</sup> Lacking experience in large-scale manufacturing techniques, Qualcomm formed a joint venture with Sony Corporation in 1994, called Qualcomm Personal Electronics (QPE), to produce CDMA-based devices.<sup>423</sup> QPE supplied the handsets that were initially deployed on the first CDMA network in Hong Kong in 1995.<sup>424</sup> Within a few years, Qualcomm’s ASIC

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the world at the time that were willing to make CDMA handsets, because the probability that we’re going to be successful -- A technically, and B, commercially -- didn’t seem high to many people. So we had to go into the handset manufacturing business.”) and p. 31 (“Q. In 1994, did Qualcomm sell ASICs to equipment manufacturers? A. Yes. In ‘94 I’m sure we did [...]. [...] We then moved into the ability to both manufacture ourselves and support other manufacturers[.]”); Qualcomm, 10-K, 1996, p. 2 (“[Qualcomm] has an agreement with Nortel providing for the production and delivery of infrastructure equipment for CDMA wireless systems. Pursuant to the agreement, Nortel has access to Q[ualcomm]’s product designs for digital cellular, PCS and WLL infrastructure products and in return purchases from Q[ualcomm] a minimum percentage of Nortel’s CDMA infrastructure equipment requirements for resale to its customers.”).

<sup>420</sup> See, e.g., Mock, 2005, p. 113 (“None of the major phone manufacturers, such as Motorola and Nokia, to which Qualcomm had licensed CDMA were showing signs of support for large-scale manufacturing of code-based wireless phones [in 1992].”).

<sup>421</sup> See, e.g., Mock, 2005, p. 139 (“Having the most detailed and complete knowledge of CDMA allowed Qualcomm to turn out phones and infrastructure faster than anyone else could[.]”).

<sup>422</sup> “History,” Qualcomm, available at <https://www.qualcomm.com/company/about/history> (“In March of 1993, Qualcomm introduces the industry’s first dual-mode CDMA-AMPS mobile phone, the CD-7000 is the first in a series of CDMA-based cellular telephones designed by Qualcomm.”).

<sup>423</sup> “Telephone Joint Venture,” The New York Times, February 28, 1994 (“Qualcomm Inc. and Sony Electronics Inc. said today that they would form a \$52 million joint venture to manufacture portable phones using Qualcomm’s code division multiple access technology. [...] The joint venture, to be called Qualcomm Personal Electronics, will operate out of an existing factory in San Diego [...].”).

<sup>424</sup> I. Jacobs Deposition, Qualcomm, pp. 16–17 (“Q. For the deployment in Hong Kong in roughly 1995, what were the products that Qualcomm provided? A. [...] The handsets -- there were no other handset manufacturers in the world at the time that were willing to make CDMA handsets, because the probability that we’re going to be successful -- A technically, and B, commercially -- didn’t seem high to many people. So we had to go into the handset manufacturing business. We had built a prototype to demonstrate that we could do it. We then continued to enhance that and made that into a commercial product, ultimately set up a joint venture with Sony to manufacture here in San Diego. The handsets that were delivered to Hong Kong were all made here in San Diego by Qualcomm. Qualcomm, Sony, and Sony venture, I would think.”). See also “Statement by Dr. Irwin Mark Jacobs, Co-Founder, Qualcomm,” prepared for the hearing on reauthorization of the SBIR and STTR programs before the U.S. Senate Committee on Small Business and Entrepreneurship, February 17, 2011, p. 6 (“The first CDMA network went commercial in Hong Kong in 1995; next two networks became operational in

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unit was also shipping millions of MSM2200 chips, “the first true single chip multi-processor [...] to reach mass deployment.”<sup>425</sup>

226. By 1993, Qualcomm had also signed licenses for the manufacturing of cellular infrastructure, with licensees including AT&T and Motorola.<sup>426</sup> However, similar to the OEMs licensed to manufacture mobile devices, these licensees did not prioritize deployment of CDMA network infrastructure.<sup>427</sup> In response, Qualcomm signed a memorandum of understanding with Northern Telecom in 1994 to jointly develop CDMA network infrastructure.<sup>428</sup>
227. Although Qualcomm designed and tested its own modem chips, it has always been a fabless semiconductor company that relied on external foundries to manufacture the chips. In the early years, Qualcomm’s foundries included, Intel, IBM, and Philips,<sup>429</sup> while Qualcomm currently relies on chip manufacturing by Global Foundries, Samsung, TSMC, Semiconductor Manufacturing International Corporation (SMIC), and United Microelectronics Corporation (UMC).<sup>430</sup>

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South Korea in 1996; and finally several networks became operational across the United States. Qualcomm provided handsets manufactured in San Diego for all of these early systems.”).

<sup>425</sup> “Qualcomm Announces Major Milestone with Shipment of Six Million MSM Chips,” Qualcomm Press Release, June 18, 1997 (“In record time Qualcomm’s ASIC Business Unit has taken the latest CDMA chipsets from volume ramp-up in the second half of 1996 to major volume production and is now running at a monthly rate of approximately one million chipsets. [...] The [MSM2200] includes proprietary CDMA building blocks and several microprocessor and DSP cores integrated onto a single chip.”). See also Q2014FTC04798968–9027 at 8972, presentation titled “Modem Update,” Qualcomm, October 31, 2016.

<sup>426</sup> Mock, 2005, p. 115 (“By 1993, Qualcomm already had three major North American licensees for infrastructure–AT&T, Motorola, and Northern Telecom.”).

<sup>427</sup> Mock, 2005, p. 115 (“Of the North American [infrastructure] vendors, AT&T and Motorola were probably the biggest and had a lot invested in TDMA. They had already started to develop code-based wireless, albeit at a slower pace than Qualcomm had hoped.”).

<sup>428</sup> “Qualcomm Wins Northern Telecom as Partner,” Computer Business Review, July 18, 1994.

<sup>429</sup> Qualcomm, Form 10-K, 1996, p. 8 (“The Company currently relies on several independent foundries to manufacture all of its ASICs. The Company’s strategy is to utilize a number of qualified foundries that it believes provide cost, technology or capacity advantages for specific products. The Company currently has arranged with Intel, IBM and Philips for such ASIC manufacturing.”).

<sup>430</sup> Qualcomm, Form 10-K, 2017, p. 11 (“The primary foundry suppliers for our various digital, analog/mixed-signal, RF and PM integrated circuits are Global Foundries Inc., Samsung Electronics Co. Ltd., Semiconductor Manufacturing International Corporation, Taiwan Semiconductor Manufacturing Company and United Microelectronics Corporation.”).

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228. Once CDMA devices and network equipment were successfully developed, CDMA networks were launched by various carriers. Early cdmaOne network launches in the U.S. included Bell Atlantic Mobile and PrimeCo (both now part of Verizon),<sup>431</sup> which launched cdmaOne services in 1996.<sup>432</sup> CDMA also gained popularity outside the U.S., particularly in South East and East Asia and Latin America. Early adopters included Hutchison Telecom in Hong Kong, which launched the first commercial CDMA service in 1995, SK Telecom in Seoul and Telefonica del Peru in 1996, and MTNL in India in 1997.<sup>433</sup> Although the number of CDMA-compatible handsets shipped globally continued to generally increase, the technology has never been as widespread as the competing TDMA-based GSM standard.<sup>434</sup>
229. Qualcomm’s foresight and the success of its investments in R&D are reflected in the results delivered by the CDMA technology. According to Qualcomm’s 1996 10-K, CDMA technology ultimately delivered increased capacity (10 to 20 times compared to analog systems, in contrast to the threefold improvement offered by GSM),<sup>435</sup> higher quality of voice and data transmission, fewer dropped calls, enhanced privacy, lower power consumption and extended talk time, lower infrastructure costs due to fewer cells, and easier transition from analog to digital than TDMA.<sup>436</sup> Qualcomm also demonstrated the performance differences between CDMA and TDMA.<sup>437</sup>

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<sup>431</sup> See, e.g., Labaton, Stephen, “F.C.C. Approves Bell Atlantic-GTE Merger, Creating No. 1 Phone Company,” The New York Times, June 17, 2000.

<sup>432</sup> “CDMA History,” CDG, available at [http://www.cdg.org/resources/cdma\\_history.asp](http://www.cdg.org/resources/cdma_history.asp).

<sup>433</sup> “CDMA History,” CDG, available at [http://www.cdg.org/resources/cdma\\_history.asp](http://www.cdg.org/resources/cdma_history.asp).

<sup>434</sup> See Exhibit V.B.1.

<sup>435</sup> “The Evolution of Mobile Technologies,” Qualcomm, June 2014, p. 18, available at <https://www.qualcomm.com/media/documents/files/the-evolution-of-mobile-technologies-1g-to-2g-to-3g-to-4g-lte.pdf>.

<sup>436</sup> Qualcomm, Form 10-K, 1996, pp. 5–6.

<sup>437</sup> I. Jacobs Deposition, Qualcomm, pp. 22–24 (“Q. Did Qualcomm consider retaining CDMA as a proprietary standard? A. [...] The CTIA] asked the TDMA people to come in and demonstrate their phones which presumably were commercial at the time. They asked us to come in, demonstrate CDMA. And they asked every other manufacturer who might have a competing technology -- and there were a couple of others that did come in -- to be able to demonstrate theirs. We did a[n] audio demonstration [...]. [...] The TDMA people went up first. It sounded terrible. We came up next. It sounded great.”).

230. Over time, Qualcomm continued to develop and improve CDMA technology. The 2G cdmaOne standard was succeeded by the family of CDMA2000 standards that went through several revisions. The initial CDMA2000 1X standard was accepted as a 3G standard in 1999 and evolved to CDMA2000 1xEV-DO in 2001.<sup>438</sup> The CDMA2000 1xEV-DO standard improved transmission of data over wireless networks,<sup>439</sup> and it was further updated over time, including “Revision A” in 2004 and “Revision B” in 2006 (referred to in shorthand as “Rev. A” and “Rev. B,” respectively), the latter of which introduced carrier aggregation.<sup>440,441</sup>

*c. cdmaOne and CDMA2000 modem chip sales*

231. In addition to the practical hands-on knowledge that Qualcomm gained while building its own prototypes and designing mobile devices and infrastructure equipment, Qualcomm’s CDMA modem chip business also benefited from the technical expertise obtained during the standards development stage. Experience from the standards development process facilitated Qualcomm’s ability to respond to customer demands, exercise effective foresight, and efficiently implement the nascent technology in the design of its modem chips.
232. As indicated in Exhibit V.B.2, Qualcomm was the first company to produce cdmaOne modem chips, in 1995, and the first supplier to produce CDMA2000 modem chips, in 2000, but others followed quickly as cdmaOne and CDMA networks expanded in the late 1990s and early 2000s. A variety of different types of firms supplied these chips.<sup>442</sup> Initially, many mobile device

<sup>438</sup> “CDMA History,” CDG, available at [http://www.cdg.org/resources/cdma\\_history.asp](http://www.cdg.org/resources/cdma_history.asp).

<sup>439</sup> “EV-DO Rev. A and B: Wireless Broadband for the Masses,” Qualcomm, December 2007, p. 3, available at <https://www.qualcomm.com/media/documents/files/ev-do-rev-a-and-b-wireless-broadband-for-the-masses-whitepaper.pdf> (“With EV-DO, consumers experienced 400-600 Kbps of average downlink throughput with bursts up to 2.4 Mbps - 4 to 10 times faster than data over CDMA2000® 1X [networks].”).

<sup>440</sup> “CDMA History,” CDG, available at [http://www.cdg.org/resources/cdma\\_history.asp](http://www.cdg.org/resources/cdma_history.asp).

<sup>441</sup> “Transforming EV-DO Performance,” Qualcomm, available at <https://www.qualcomm.com/invention/technologies/ev-do/rev-b> (“The step up to Rev. B begins with a software upgrade technique called multicarrier, which aggregates up to three Rev. A channels, or carriers.”). See also I. Jacobs Deposition, Qualcomm, p. 76 (“Q. And was carrier aggregation an innovation that Qualcomm brought to CDMA-2000 because of the bandwidth limitation? A. Yes. And just the desire to get higher peak rates.”).

<sup>442</sup> As discussed in Section III.D.2, firms in the modem chip industry supply chips based on a variety of arrangements. Some firms, such as Qualcomm, Intel, and MediaTek, sell chips to mobile device OEMs on the “merchant market” and are willing to supply any OEM. Other firms are integrated or affiliated with OEMs; they sell chips either in-house exclusively (such as HiSilicon to Huawei), or primarily (such as S-LSI to Samsung), but may also supply chips to other OEMs.

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OEMs such as Motorola, Samsung, and Nokia were vertically integrated firms that produced CDMA modem chips internally for their own mobile devices.<sup>443</sup> Others, such as EoNex and VIA Telecom, were fabless chip suppliers offering CDMA chips on the merchant market.<sup>444</sup>

233. Exhibit V.B.2 also shows modem chip suppliers that were, according to industry sources, selling or self-supplying CDMA-compatible modem chips between 2004 and 2018. As the exhibit shows, in 2004 there were seven firms supplying cdmaOne or CDMA2000 modem chips; by 2008, only Qualcomm and VIA Telecom were offering such chips. By 2018, however, MediaTek, HiSilicon, Samsung S-LSI, Intel, and Xiaomi entered the segment by offering multi-mode chips that were backward compatible with CDMA.
234. VIA Telecom, which was formed by VIA Technologies after acquiring LSI Logic’s CDMA chip division in 2002,<sup>445</sup> was the most successful supplier of cdmaOne and CDMA2000 modem chips competing with Qualcomm in the merchant market. As discussed further in Section V.C.11, below, VIA Telecom specifically targeted the low-cost CDMA modem chip segment. Despite VIA Telecom’s limited investment and challenges with execution, it grew

<sup>443</sup> See, e.g., Davis Deposition, Intel, pp. 233–235 (“Q. Earlier today you referred to -- to various companies that had at least initiated CDMA development efforts at various points in time; [...]s [p. 22 of Exhibit CX1771] a listing of companies that had either attempted to develop or actually introduced CDMA chips at [...] some point in time? A. Yes. This is intended to be a list of companies which had done some development or claimed to have done development, yes. Q. Of these companies, which found any real commercial traction in the CDMA market? A. [...] So early in the market, Nokia, Motorola, and Samsung did have their own development. But that was very early, probably pre-1x even. And then -- so those are all phone makers who did their own.”) and Exhibit CX1771, VIA-QCOM000638768–8855 at 8789 (“Motorola[:] [...]Q]uit producing own chipset”; “Samsung[:] [...] Recently seem to have stopped using internal chipset”; other integrated mobile device OEMs that made attempts at developing CDMA chips include Hyundai, LG Electronics, Lucent, Nokia, Oki, and Ericsson). See also LaPedus, Mark, “Qualcomm Bars CDMA Chips Sales by VLSI Technology,” EE Times, September 10, 1999 (“Gaining ground on Qualcomm in the chip sections are two major OEMs – Motorola and Nokia. However, Motorola and Nokia separately develop their own chipsets for their own CDMA-based handsets; the two cell-phone giants do not sell these devices on the [merchant] market.”).

<sup>444</sup> “Company Overview of EoNex Technologies, Inc.,” Bloomberg. “Company Overview of VIA Telecom, Inc.,” Bloomberg.

<sup>445</sup> VIA Telecom was formed by its Taiwanese parent company VIA Technologies following the acquisition of the CDMA wireless division of LSI Logic in 2002. In 2003, Qualcomm transferred LSI Logic’s CDMA license to VIA Telecom. This non-exhaustive license “enable[d] VIA Telecom to develop, manufacture and sell cdmaOne and CDMA2000 1X ASICs to Qualcomm’s subscriber equipment licensees.” “Qualcomm and VIA Telecom Expand CDMA License Agreement,” Qualcomm Press Release, June 25, 2003. See also Hung, Faith, “Via Sets Up Wireless Unit Following LSI Logic Deal,” EE Times, July 12, 2002 (“Via Technologies Inc. has formed a unit in the U.S. to attack the wireless market following its acquisition of a unit of LSI Logic Corp. Named Via Telecom [...]”).

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its share over time by supplying chips for mobile devices sold in emerging markets, including China and India.<sup>446</sup> Exhibit V.B.3 shows that VIA Telecom consistently lagged behind Qualcomm in modem chip performance. For example, VIA Telecom’s CBP4.0 chip, released in 2001, was its first CDMA2000 1X chip and enabled a peak downlink data rate of 153 Kbps.<sup>447</sup> By then, Qualcomm had already been offering CDMA2000 1X-compatible modem chips for a year and in 2001 released a CDMA2000 1xEV-DO chip with downlink rates of 2.4 Mbps.<sup>448</sup> It was not until 2009 that VIA Telecom released its first CDMA 1xEV-DO chip, but by that time, Qualcomm had already offered CDMA 1xEV-DO “Rev. A” chips for about four years.

235.

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] Similarly, OEMs that

<sup>446</sup> See, e.g., VIA-QCOM000688592–8631 at 8607 (Slide titled “Attractive Industry Growth Momentum and Opportunities[:] Key Market Opportunities” includes India and China) and at 8611 (Slide lists “Effective access to emerging markets” under VIA Telecom heading).

<sup>447</sup> “LSI Logic Attacks TI and Qualcomm in 3G Wireless Chip Market,” EE Times, March 21, 2001 (“[...] LSI Logic will compete in the cdma2000 space with the CBP4.0, a chip that also supports IS-95B and AMPS. LSI Logic’s chip enables wireless data at speeds up to 153-kilobits-per-second.”).

<sup>448</sup> Qualcomm’s MSM5000 modem chip supported the CDMA2000 1X wireless standard and was released in 2000. Qualcomm’s MSM5500 supported the CDMA2000 1xEV-DO Release 0 standard. It was released in 2001 and allowed for a peak data rate of 2.4 Mbps. See Q2014FTC04798968–9027 at 8972, presentation titled “Modem Update,” Qualcomm, October 31, 2016.

<sup>449</sup> Amon Deposition, Qualcomm, p. 327 [REDACTED]

<sup>450</sup> Amon Deposition, Qualcomm, pp. 316–318 [REDACTED]

[REDACTED] and Exhibit CX6839, QNDCAL02130467–0469.

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demanded modem chips supporting both CDMA and WCDMA found using a two-chip solution with VIA Telecom’s CDMA chip less desirable.<sup>451</sup> [REDACTED]

[REDACTED]

[REDACTED].<sup>452</sup>

236. Even though many firms attempted to develop and sell CDMA modem chips, most of them were late to enter this segment of the industry and ultimately were not successful. In an internal presentation from 2008, VIA Telecom recognized more than 20 attempts to compete in CDMA chips that failed.<sup>453</sup>
237. The failure of competing CDMA chip suppliers to thrive appears to be due to a variety of issues but was often related to technical challenges in execution, lack of foresight, or was the result of a strategic decision to pursue development of modem chips that supported other wireless standards that were more prevalent or perceived as more promising.<sup>454</sup> For example:

- i. Many vertically integrated mobile device OEMs that initially started developing CDMA chips for their own use later ceased those internal efforts in favor of purchasing chips from suppliers on the merchant market. In 1999, an EE Times

<sup>451</sup> Deposition of Todd Miller, Vice President of Sales at NVIDIA, March 22, 2018, pp. 41–42 (“Miller Deposition, Nvidia”) (“Q. But it was your understanding actually that VIA had had a number of phones that had shipped for CDMA carriers; wasn’t that right? A. [...] At the time in the premium smartphone market, OEMs wanted to have one phone that covered both UMTS and CDMA, and so CDMA was always a problem. [...] And so we would look for any potential alternative to support an OEM to build one phone for both network technologies.”).

<sup>452</sup> See Kang Deposition, Samsung, pp. 76–77 [REDACTED]

<sup>453</sup> Davis Deposition, Intel, pp. 235–237 (“Q. Would you describe any of these companies [listed on p. 22 of Exhibit CX1771 as companies that had either attempted to develop or actually introduced CDMA chips at some point in time] as reputable technology companies? A. Sure. Qualcomm, Nokia, Motorola, Samsung, Sony. Most of them, yes. [...]Q.] At the time that this presentation was prepared, did the authors of the presentation characterize most of these efforts as -- as failed efforts? [...]A.] Yes. I think that’s what the F in the rightmost column means. And -- and the text says most of these were failures, yes. Q. Is that a fair characterization in your view? A. Well, I think so, in that they -- they weren’t in production and were abandoned at the time this was made, all of these efforts.”) and Exhibit CX1771, VIA-QCOM000638768–8855 at 8789 (“Chip technology providers - history of attrition[:] Market size attracted many attempts to compete with Q[ualcomm]. But...>20 failed!”).

<sup>454</sup> See also the discussion of CDMA modem chip development in the evaluation of other modem chip suppliers in Section V.C.

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article reported that “[h]andset OEMs have also been developing their own CDMA chipsets in order to lower their costs, but most hardware vendors [were] struggling to get these products out the door. Recently, for example, Japan’s Sony delayed its own CDMA-based chipset line due in part to undisclosed problems with the product.”<sup>455</sup> Fortune Magazine reported in 2000 that “Oki Electric, LG Electronics, and Sony all made CDMA chips for their phones but dropped those efforts in favor of buying chips from Qualcomm [...] because Qualcomm has been able to add features, like geographic-positioning circuits and MP3 music-playing capability, sooner than anyone else.”<sup>456</sup> Furthermore, Qualcomm packed more functionality into fewer chips than those of competitors, which lowered cost and allowed for more compact cell phones with lower power requirements.<sup>457</sup> In addition to the OEMs listed above, Motorola and Hyundai also gave up on developing internal CDMA chips.<sup>458</sup> Even though these industry participants ceased production and development of CDMA modem chips, their ability to potentially restore this capability and the threat of re-entry kept a check on the remaining suppliers, as recognized by market research analysts such as UBS.<sup>459</sup>

- ii. Intel abandoned efforts to produce CDMA modem chips within eight months of acquiring DSP Communications in 1999. As reported by EE Times in August 2000, Intel was “quietly backing away from the CDMA chip set market as part of a plan to focus on new and more promising wireless-IC segments” and was reported to be more bullish on the next-generation WCDMA standard.<sup>460</sup> [REDACTED]

<sup>455</sup> LaPedus, Mark, “Samsung to Develop Line of Wireless Chips,” EE Times, April 13, 1999.

<sup>456</sup> Nee, Eric, “Qualcomm Hits the Big Time Pushing a Little-Known Digital Cellular Technology from Surf’s-up San Diego, This \$4-Billion-a-Year Hotshot Wants to Be THE NEXT INTEL,” *Fortune Magazine*, May 15, 2000.

<sup>457</sup> Nee, Eric, “Qualcomm Hits the Big Time Pushing a Little-Known Digital Cellular Technology from Surf’s-up San Diego, This \$4-Billion-a-Year Hotshot Wants to Be THE NEXT INTEL,” *Fortune Magazine*, May 15, 2000 (“What’s more, Qualcomm’s ‘chip sets’ use fewer chips than those of competitors, making possible cell phones that are more compact and that need less power. The chip sets also cost less to produce [...].”).

<sup>458</sup> See VIA-QCOM000638845–8846 at 8845 (“Motorola[:] Later took over Lucent group; quit producing own chipset circa 99”; “Hyundai[:] Gave up on internal chipset”).

<sup>459</sup> QAPPCMDS07754877–4878 at 4877, email from Miran Chun, Qualcomm, August 5, 2015 (“With the evolution to cdma2000lx [sic], [...] Motorola has committed to use Qualcomm’s cdma2000lx [sic] baseband solutions [...], leaving Nokia as the only major vendor not expected to use Qualcomm’s cdma2000lx [sic] baseband solutions. We [UBS] note that if Qualcomm is to keep Motorola as a cdma2000lx [sic] handset baseband chipset customer[,] it will have to be competitive with respect to the pricing of its MSM products. We [UBS] believe [...] Motorola could look elsewhere for this capability (either via internal solutions or perhaps a third-party) if it does not consider pricing from Qualcomm reasonable [...]. Market share gains are not likely to come without a price.”).

<sup>460</sup> LaPedus, Mark, “Intel Backs Away from CDMA Chip Market,” EE Times, August 25, 2000.

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- iii. Philips entered the CDMA segment in 1999 with the acquisition of VLSI Technology, which had a CDMA chip that was well under development and was supposedly already being evaluated by several major OEMs.<sup>462</sup> Philips exited the CDMA segment shortly afterwards when it sold its CDMA technology to Holley Group in 2001.<sup>463</sup> According to Ivo Rutten, vice president and general manager at Philips, Philips wanted to “take the resources [it] used to deploy in CDMA to do a better job with GSM and GPRS” since Philips considered GSM to be a better opportunity, as “[i]t’s a bigger market and [Philips has] already got a significant market share there.”<sup>464</sup> Holley Group intended to provide chip design and software to Chinese OEMs and partnered with Hop-On to produce a disposable CDMA handset.<sup>465</sup> Not long afterward, Holley started to shift its focus away from CDMA and joined forces with Datang, Huawei, ZTE, and other Chinese corporations in a joint effort to “promote the industrialization process of TD-SCDMA and to facilitate the development of TD-LTE” by creating the TD Industry Alliance (TDIA) in October 2002.<sup>466</sup> TDIA was “committed to spreading TDD technology worldwide, integrating and coordinating industrial resources, boosting the sound

<sup>461</sup> See, e.g., Wolff Deposition, Intel, p. 263

See Section V.C.2 for further details on Intel’s

effort to acquire CDMA technology.

<sup>462</sup> See, e.g., “Philips Acquired VLSI Technology with Raised Bid,” EE Times, May 3, 1999. See also LaPedus, Mark, “Qualcomm Bars CDMA Chips Sales by VLSI Technology,” EE Times, September 10, 1999 (“Moreover, sources indicated that the VLSI-developed [CDMA] chipset was in the sampling stage and being evaluated by several major OEMs, including Ericsson and LG Electronics.”).

<sup>463</sup> See, e.g., Gregson, Reily, “Holley Group Acquires CDMA Technology from Philips,” RCR Wireless News, October 19, 2001 (“The U.S. subsidiary of China’s largest electric meter producer, the Holley Group [...] has acquired the design operations for CDMA mobile phones from Philips Semiconductors, a division of Holland’s Philips Electronics.”). See also VIA-QCOM000638845–8846 at 8845 (“Dot->VLSI->Philips->Holley[:] None, appears dead.”).

<sup>464</sup> Ristelhueber, Robert, “Philips Throttles Back on CDMA Business to Focus on GSM, GPRS,” EE Times, September 21, 2001.

<sup>465</sup> “Top CDMA Developer Holley Communications in Strategic Agreement with Hop-On,” PR Newswire, February 6, 2002 (“Peter Michaels, Chairman and CEO of Hop-On, commented, ‘This is a huge deal for us as it will give us full, FCC approved CDMA capabilities. [...] CDMA consistently offers landline voice quality and substantially broader flexibility in adding on features. [...] We will be able to materially accelerate the development of a CDMA version of our disposable, fully recyclable cell phone by leveraging tested full feature models Holley has already developed. [...]’”). See also Gregson, Reily, “Holley Group Acquires CDMA Technology from Philips,” RCR Wireless News, October 19, 2001 (“Holley Communications USA plans to provide chip design and software to China’s mobile-phone manufacturers.”).

<sup>466</sup> “TD Industry Alliance,” China Daily.

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development of the communication industry based on TD-SCDMA [and] TD-LTE.”<sup>467</sup>

- iv. Samsung was developing CDMA chips internally during the late 1990s but lost momentum when several key engineers left to found EoNex in 2000.<sup>468</sup> [REDACTED]  
[REDACTED]<sup>470</sup>
- v. TI entered the CDMA industry relatively late via acquisition of Dot Wireless, a leader in CDMA wireless technology, in 2000.<sup>471</sup> In 2003, TI formed a partnership with Nokia and STMicroelectronics.<sup>472</sup> However, the joint venture showed lack of foresight by targeting the CDMA2000 1xEV-DV standard, which was never implemented.<sup>473</sup> The partnership was eventually dissolved, ending TI’s efforts in CDMA.<sup>474</sup>
- vi. One entrant with some limited success was EoNex, a South Korean company formed when the head of Samsung’s CDMA modem chip design team left with

<sup>467</sup> “TD Industry Alliance,” China Daily.

<sup>468</sup> See, e.g., Q2014FTC03368158–8159 at 8158, email from Gerald Skiver, Qualcomm, October 10, 2002 (“Dr. Chun was previously the head of Samsung’s internal CDMA modem design team. Dr. Chun left Samsung and several key engineers on his team also left to form the new company, Eonex Technologies.”). See also Q2014FTC03369222–9223 at 9223, email from Marv Blecker, Qualcomm, October 9, 2001 (“[...] EoNex, a venture startup launched last April by former researchers at Samsung Electronics Co., SK Telecom and other firms [...]”); [REDACTED]

<sup>469</sup> See Exhibit V.B.2.

<sup>470</sup> [REDACTED]

<sup>471</sup> See, e.g., “TI Acquires Dot Wireless, a Leader in CDMA Wireless Technology,” TI Press Release, June 29, 2000. See also Yoshida, Junko, “Qualcomm Bullish in Its 2004 Outlook,” EE Times, February 23, 2004 (Sanjay Jha, QCT’s president at the time, said in an interview with EE Times that “the recent CDMA market entry by Texas Instruments and STMicroelectronics [did] not present a source of concern for him: ‘Rather, the question to ask is what took them so long to join the CDMA market.’”).

<sup>472</sup> Mannion, Patrick, “TI and STMicro Offer Modular CDMA 1x Chip Set,” EE Times, December 5, 2003 (“Texas Instruments and STMicroelectronics have jointly announced an open, modular cdma2000 1x chip set [...]. The four-chip set is the first product realization to derive from the collaboration between the two companies ‘and Nokia’ [...].”).

<sup>473</sup> See, e.g., Krazit, Tom, “TI and STM Produce Samples of 3G CDMA Chips,” IT World Canada, June 24, 2004 (“Texas Instruments Inc. (TI) and STMicroelectronics NV (STM) are producing samples of chips [...]. The new chips are based on the Evolution-Data-Voice (EV-DV) standard [...].”).

<sup>474</sup> See, e.g., Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 10 (“TI involved in a CDMA2000 1X chip development joint venture with Nokia and ST Microelectronics [...]. However, later TI, Nokia and ST Micro abandoned the JV.”). See also VIA-QCOM000638845–8846 at 8845 (“TI(2):] Entered in cooperation with Nokia; Abandoned 1x space.”).

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several key engineers in 2000.<sup>475</sup> EoNex’s first CDMA chip appeared in an LG handset in 2005, and while it was less expensive than Qualcomm’s high-end modem chips, it did not support EV-DO.<sup>476</sup> According to internal materials of one of its competitors (VIA Telecom), the development cost of EoNex chips was “extremely high,” and the team was laid off in August 2008 when the company ran out of funding and filed for bankruptcy.<sup>477</sup>

238. As the examples above demonstrate, competitors struggled to keep up with Qualcomm’s development of CDMA chips. In 1999, Qualcomm sold its mobile device business to Kyocera<sup>478</sup> and its infrastructure business to Ericsson,<sup>479</sup> at least in part to avoid competing with its customers downstream in the mobile device business. Qualcomm started to focus on technology development and the design of modem chips and software.<sup>480</sup> In 1995, Qualcomm formed the CDMA ASIC Products Unit (which in 1999 became Qualcomm CDMA

<sup>475</sup> See, e.g., Q2014FTC03368158–8159 at 8158, email from Gerald Skiver, Qualcomm, October 10, 2002 (“Dr. Chun was previously the head of Samsung’s internal CDMA modem design team. Dr. Chun left Samsung and several key engineers on his team also left to form the new company, Eonex Technologies.”). See also Q2014FTC03369222–9223 at 9223, email from Marv Blecker, Qualcomm, October 9, 2001 (“[...] EoNex, a venture startup launched last April by former researchers at Samsung Electronics Co., SK Telecom and other firms[...].”).

<sup>476</sup> Miller, Paul, “LG Goes with Korean EoNex over Qualcomm for CDMA Chips in SD280,” Engadget, December 17, 2005 (“The Eonex chip is only 2.5G [...] but they’re cheaper than the Qualcomm alternative [...].”). See also “Global Cellular Handset & Chip Markets,” Forward Concepts, 2005, pp. 288–290.

<sup>477</sup> VIA-QCOM000638845–8846 at 8845 (“EoNex[:] [...] Chip cost extremely high, and out of funding. Team was laid off August 2008.”). See also Q2014FTC03819921–9923 at 9921, email from John Kim, October 29, 2013 (“They [EoNex] are closed in 2009 and no activities at all as far as our team checked. Mtek bought Eonex CDMA equipment through auction and 4 key Eonex members are at Mtek as far as we checked.”) and email from Dave Jeon, October 29, 2013 (“I heard the same thing from our old SKT friend – EoNex went chapter7 and MTK bought CDMA IP equity.”).

<sup>478</sup> See, e.g., “Qualcomm and KYOCERA Sign Agreement for Terrestrial CDMA Phone Business,” Qualcomm Press Release, December 22, 1999. See also I. Jacobs Deposition, p. 42 (“Q. And do you recall whether Qualcomm had sold its handset business at this point in 2000? A. I’m not firm on the dates. It -- I would think it had already sold its handset business, but I’m not sure -- to Kyocera.”).

<sup>479</sup> “ERICSSON and Qualcomm Reach Global CDMA Resolution,” Qualcomm Press Release, March 25, 1999.

<sup>480</sup> I. Jacobs Deposition, pp. 42–43 (“Q. In any event, would Qualcomm have been down the road of divesting its handset business if the sale [of its infrastructure business to Ericsson] had not been completed? A. [...] We made the decision strategically that we would focus on developing technology pressing the industry ahead, continue to expand the uses for mobile, for cellular, and that our best way of doing that was, again, to focus on the technology and on the -- embedding that in chips and software that we can make available to many manufacturers [...]. People would say: You’re going to give your best software and chips to your own company first -- even though we said we would not. And, therefore, it would not be a good supplier to us. And we thought [...] that could interfere with the spread of CDMA. And so we made the decision to divest. Q. Did you observe actual customers hesitant to engage with Qualcomm’s ASIC business because Qualcomm was competing with them at a downstream level? A. We had people that complained about it -- Samsung comes to mind.”).

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Technologies (QCT) and also launched the business unit now known as Qualcomm Technology Licensing (QTL).<sup>481</sup> QCT became responsible for “design[ing] and suppl[ying] CDMA chipsets and software solutions,” while QTL managed the licensing side of the business.<sup>482</sup>

239. When it came to CDMA, Qualcomm claimed to have “out-innovated and out-executed” its competitors for a long stretch of time.<sup>483</sup> Even OEMs ultimately recognized the superiority of Qualcomm’s products over those of competing chip suppliers.<sup>484</sup> Qualcomm’s well-targeted investment strategy enabled it to consistently develop new products, including many “firsts,”<sup>485</sup> such as the first single-chip solution integrating analog and digital functionality (MSM2300),<sup>486</sup> the first chip compatible with the CDMA2000 1X standard (MSM5000),<sup>487</sup> the first chip compatible with CDMA2000 1xEV-DO (MSM5500),<sup>488</sup> the first chip compatible

<sup>481</sup> See Qualcomm, “History,” <https://www.qualcomm.com/company/about/history>.

<sup>482</sup> See Qualcomm, Form 10-K, 1999, p. F-27 (“[QTL] provides licenses to third parties related to the design, manufacture and sale of products using the Company’s CDMA technology.”).

<sup>483</sup> Achour Deposition, Qualcomm, Exhibit CX6393, Q2014FTC04332009–2011 and p. 154 (“Q. Well, did you understand Qualcomm to be differentiated from its competitors with respect to modems that implement CDMA standards at any point in time? A. Absolutely. Yeah. Q. And this chart [on page CX6393-009] illustrates that Qualcomm was differentiated vis-a-vis its competitors with respect to CDMA standards from about 2000 to 2015; is that right? A. Right. That’s correct. Q. Is that consistent with your understanding? A. Yeah, we always had a much better solution. We basically out-innovated and out-executed everybody else in competing with us.”). See also Q2014FTC04798968–9027 at 8977, presentation titled “Modem Update,” Qualcomm, October 31, 2016 (Slide titled “A history of technology firsts” states that “Qualcomm has consistently outperformed the competition. By the time a competitor launches, Qualcomm has already launched the next generation product.”).

<sup>484</sup> [REDACTED]

<sup>485</sup> Q2014FTC04798968–9027 at 8972, presentation titled “Modem Update,” Qualcomm, October 31, 2016.

<sup>486</sup> “Qualcomm Announces Next Generation Mobile Station Modem,” Qualcomm Press Release, March 3, 1997.

<sup>487</sup> “Qualcomm CDMA Technologies Announces World’s First Third-Generation Chip for CDMA Handsets,” Qualcomm Press Release, May 24, 1999.

<sup>488</sup> “Qualcomm CDMA Technologies Announces 1xEV High-Speed Data Chipset and System Software for Handsets,” Qualcomm Press Release, October 26, 2000.

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with CDMA2000 1xEV-DO Rev. A (MSM6800),<sup>489</sup> and the first chip compatible with CDMA 1xEV-DO Rev. B (MSM7850),<sup>490</sup> which included carrier aggregation.

240. There are several reasons that may have kept some modem chip suppliers from prioritizing the resources necessary to compete with Qualcomm in CDMA. First, the population of subscribers on networks compatible with cdmaOne/CDMA2000 was relatively small compared to GSM and WCDMA,<sup>491</sup> and it was expected to grow at a slower pace. Moreover, there was great uncertainty as to the future of CDMA, particularly in the 2010 to 2012 period as LTE was starting to be deployed.<sup>492</sup> As Forward Concepts noted in 2011:

CDMA2000 clearly is a viable and effective wireless technology and, to its credit, many of its innovations were brought to market ahead of competing technologies. Today, however, the GSM family has in excess of 3.8 billion subscribers – nine times the total number of subscribers in the CDMA2000 family of technologies.<sup>493</sup>

241. In addition, the sales of CDMA modem chips were not projected to grow as fast as the sales of chips compatible with competing standards. In 2013, the five-year compound annual growth rate (CAGR) across all CDMA-compatible modem chips (thin modems and modems integrated with APs, including backward-compatible multi-mode chips), was around 5 percent.<sup>494</sup> For comparison, WCDMA-only modem chips (both thin modems and modems with an integrated AP) were predicted to grow more than twice as fast at 12 percent, while LTE-compatible

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<sup>489</sup> “Qualcomm Announces On-Time Sampling of the Industry’s First CDMA2000 1xEV-DO Revision A Chipset,” Qualcomm Press Release, April 13, 2005. See also Amon Deposition, p. 297 (“Q. Who else other than Qualcomm could offer Rev A capability in modem chipsets? A. Qualcomm were the first.”)

<sup>490</sup> Murphy, Darren, “Qualcomm Unveils EV-DO Rev B Roadmap,” Engadget, March 27, 2007.

<sup>491</sup> Exhibit V.B.1 shows that CDMA-compatible handsets never accounted for more than 20 percent of global handset shipments. Investment research analysts at UBS considered WCDMA to be a more “material” opportunity relative to the CDMA “subscriber landscape”; see QAPPCMDS07754877–4878 at 4877–4878, email from Miran Chun, Qualcomm, August 5, 2015 (“We [UBS] believe [WCDMA] will be the biggest future opportunity for Qualcomm[]]. Currently there are over 700 million non-cdmaOne subscribers (GSM and TDMA) that potentially could move to WCDMA. While we [UBS] acknowledge that the actual addressable market for WCDMA is far less than 700 million, it is still likely to be material relative to the current CDMA subscriber landscape. This is particularly true when considering the ASP of a WCDMA product is likely to be materially higher than the current ASP for cdmaOne/cdma2000lx [sic] products (i.e., about \$200).”). In 2010, over 350 million WCDMA- and 1 billion GSM-compatible handsets were sold, but only 190 million CDMA-compatible ones (accounting for less than 14 percent of global handset shipments).

<sup>492</sup> As shown in Exhibit V.B.1, LTE-compatible handsets started shipping in meaningful volumes in 2012.

<sup>493</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2011, p. 43.

<sup>494</sup> “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, pp. 37 and 211.

243. The expectation of the upcoming obsolescence of CDMA was reinforced around 2011 by carriers operating CDMA networks:<sup>496</sup> for example, [REDACTED]

[REDACTED]

[REDACTED]<sup>97</sup> Considering the relatively small number of CDMA-compatible mobile devices sold every year and the environment of uncertainty surrounding the future of

496 See, e.g.,

<sup>497</sup> See, e.g., 86600DOC073410–3415 at 3411, email from Alexander Straub, Intel, March 1, 2011 (“Verizon targets to have the same coverage for LTE as CDMA by mid 2013 and plans to introduce LTE single mode connected devices by mid 2012.”). See also [REDACTED]

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cdmaOne/CDMA2000 networks, many modem chip suppliers were not internally unified regarding the best strategy to follow with respect to CDMA. For example, according to Intel’s Vice President and Chief Strategy Officer, Aichatou Evans, around 2010 Intel had internal disagreements on whether or not it was necessary to gain access to CDMA;<sup>498</sup> by 2011, Verizon’s pitch of a “2013-LTE-only-story” was received positively by Intel,<sup>499</sup> despite some employees at Intel warning that legacy technologies often last longer than initially predicted.<sup>500</sup> Email communications of MediaTek’s executives in December 2011 convey similar internal arguments: while [REDACTED]

[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]<sup>501</sup> Similarly, [REDACTED]

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[REDACTED]

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[REDACTED]

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[REDACTED]

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[REDACTED]

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[REDACTED]

[REDACTED] Some chip suppliers even attempted to actively “[i]nvest in measures to accelerate obsolescence of CDMA [technology].”<sup>503</sup>

244. Mobile device OEMs also expressed doubts about the future of CDMA technology. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

*d. Legacy cdmaOne and CDMA2000 in LTE networks*

245. As shown in Exhibit V.B.1, while annual sales of handsets supporting cdmaOne/CDMA2000 increased until 2011, when about 230 million such devices were sold globally, the rest of the industry was growing at a faster pace. In 2011, cdmaOne/CDMA2000 handsets accounted for only 13 percent of global handset shipments, down from 20 percent in 2004. Since the emergence of 4G technologies around 2010, demand for single-mode CDMA chips has been

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<sup>502</sup> SFT-07228696–8697 (Translation), “Samsung Electronics’s (S.LSI) Plan for Securing CDMA Solution,” Samsung, March 18, 2016 [REDACTED]

<sup>503</sup> [REDACTED]

<sup>504</sup> [REDACTED]

<sup>505</sup> [REDACTED]

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in continuous decline, with fewer than 11 million sold in 2016,<sup>506</sup> and CDMA’s presence in modem chips has largely been confined to multi-mode LTE chips.<sup>507</sup>

246. At least three reasons explain the pace of obsolescence of CDMA. First, LTE, when launched by itself, does not facilitate transmission of voice calls, which creates a need for backward compatibility in 4G LTE mobile devices deployed on networks without VoLTE.<sup>508</sup> Second, the deployment of VoLTE has faced delays and been “filled with false promises from carriers,” reinforcing the need for 4G devices to support earlier generations of wireless technologies in addition to LTE;<sup>509,510</sup> at least some of these delays were due to the extensive and complex testing necessary to ensure correct functioning of the mandatory support for emergency 911 calls.<sup>511</sup> Lastly, with some carriers in important regions, such as China and the U.S., still depending on CDMA networks, modem chip suppliers and mobile device OEMs recognize the

<sup>506</sup> Strategy Analytics, “Baseband Market Share Tracker Q1 2018: Samsung LSI Overtakes MediaTek,” June 2018.

<sup>507</sup> Mahe Deposition, Apple, pp. 288–289 (“Q. And then you wrote [in Exhibit PX0358] maybe you have to make a hard call that we won’t support CDMA for 2016 iPhone; so either they support VOLTE, or they don’t get a 2016 iPhone. [...] A.] I had been trying to get all of the CDMA carriers to be more aggressive in pursuing voice over LTE. Q. And why was that? A. So we don’t have to support CDMA technology on these carrier networks.”) and Exhibit PX0358, APL-QC-FTC\_00075234–5236 at 5234 (“For iPhone, the key risks are Spring, KDDI, and China Telecom. We will start pushing them to move to full VoLTE now including indoor voice coverage.. Maybe we have to make a hard call that we won’t support CDMA for 2016 iPhone so either they support VoLTE or they don’t get a[] 2016 iPhone..”).

<sup>508</sup> Eul Deposition, Intel, pp. 101–102 (“Q. And was there a relationship between when CDMA would be sunsetted and when Voice over LTE technology would become available? [...] Was there a connection, in your mind, between those two issues? [...] A. Yeah, the operators that were relying on CDMA technology would have to have some alternative to do voice calls, which pretty much was that’s what CDMA was good in. And so that means there needed to be an alternative, and VoLTE was contemplated as being the voice capability of LTE.”).

<sup>509</sup> Verizon initially planned to offer LTE-only devices in the 2012/2013 time frame but only managed to launch VoLTE in August 2014. See, e.g., [REDACTED]

[REDACTED] See also Seifert, Dan, “Verizon Announces Initial Rollout of VoLTE, HD Voice for the ‘Coming Weeks,’” The Verge, August 26, 2014.

<sup>510</sup> Welch, Chris, “T-Mobile Lights Up VoLTE in the US, AT&T to Follow Tomorrow,” The Verge, May 22, 2014 (“For wireless customers in the US, the road to Voice over LTE (VoLTE) has been long and filled with false promises from carriers, but it’s finally here.”). See als [REDACTED]

<sup>511</sup> See, e.g., “Spirent Enhances Location Availability for VoLTE E911 Calls Indoors,” BusinessWire, August 6, 2014 (“With large scale VoLTE rollouts imminent, leading operators are confronted with the need for extensive and complex testing of LTE positioning technologies to ensure VoLTE E911 works well from day one.”).

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- struggled to quickly secure CDMA solutions in order to remain competitive.<sup>515</sup>

Solution,” Samsung, March 18, 2016 [REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
Amon Deposition, Qualcomm,

SFT-07740063–0085 (Translation) at 0070, presentation titled “[REDACTED]  
[REDACTED] Samsung, February 20, 2016.

514 See, e.g., [REDACTED] See also Hah,

See, e.g., SFT-07228696–8697 (Translation), “Samsung Electronics’s (S.LSI) Plan for Securing CDMA Solution,” Samsung, March 18, 2016 [REDACTED]

[REDACTED]

[REDACTED]

- [REDACTED]

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See also

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CDMA technology in MediaTek’s chips via a collaboration in 2014,<sup>519</sup> before being acquired by Intel in October 2015.<sup>520</sup> MediaTek released its first multi-mode LTE chip with CDMA support in mid-2015. Intel announced the CDMA-compatible XMM7560 chip in February 2017, and the chip is expected to start appearing in phones later in 2018.<sup>521</sup> [REDACTED]

[REDACTED]<sup>522, 523</sup> As discussed below in Section V.C.2, Intel executives claimed that Intel could have launched a CDMA-compatible multi-mode LTE chip even earlier had it not been for Apple’s reluctance for Intel to do so. HiSilicon independently developed its own CDMA solution, which it introduced in 2016 and implemented in its Kirin

<sup>519</sup> See, e.g., “MediaTek Adds CDMA2000 and Unveils Plans for Worldmode™ Mobile Chipsets,” MediaTek Press Release, January 6, 2014.

<sup>520</sup> See, e.g., Goldstein, Phil, “Intel Continues to Pare Mobile Losses, Buys CDMA Modem Assets from VIA Telecom,” FierceWireless, October 14, 2015. See also Sections V.C.2 and V.C.11 for further details on the history of Intel, VIA Telecom, and the acquisition.

<sup>521</sup> See Section V.C.2 for further details regarding Intel’s re-entry into the CDMA segment. See also Hruska, Joel, “Intel Inside: Apple’s Next iPhone May Ditch Qualcomm Altogether,” ExtremeTech, February 6, 2018 (“[KGI Securities] expect[s] Intel to be the exclusive supplier of baseband chip for 2H18 new iPhone models [...]’ [...]he XMM 7560, finally supports both CDMA and GSM bands.”); “Intel Unveils the Intel® XMM™ 7560 Modem - Enabling the Next Generation of LTE Advanced Devices,” Intel News Fact Sheet, February 21, 2017.

<sup>522</sup> [REDACTED]

<sup>523</sup> [REDACTED]

960 chip.<sup>524</sup> In addition, Samsung S-LSI also released multi-mode chips with CDMA compatibility in early 2018, implemented in the Exynos 7872 and 9810 chips.<sup>525</sup>

*e. CDMA Conclusion*

249. Qualcomm took advantage of its expertise in satellite-based communication technology and undertook a risky strategy of entering the mobile telecommunications industry and promoting a novel technology. Even as the industry was already pursuing TDMA-based technologies, Qualcomm persisted, invested millions in developing CDMA technology, and demonstrated its feasibility by providing an end-to-end solution. The experience gained in the initial stages of the process, from designing the technology and building prototypes of modem chips and mobile devices to manufacturing infrastructure equipment and supporting carriers during the deployment of their networks, gave Qualcomm an early advantage and positioned it well to outperform competitors in the future. The superiority of CDMA technology was ultimately recognized by the industry, and it was adopted as the basis of all 3G wireless standards. Qualcomm’s strategic R&D investments and ability to offer OEMs modem chips of superior performance ultimately benefitted the millions of end-users of mobile devices that experienced better call quality and higher data rates, as compared to other standards.
250. Few of Qualcomm’s competitors succeeded in building modem chips of comparable performance and compact design. While some modem chip suppliers, such as LSI Logic/VIA Telecom, EoNex, and TI/Nokia, had limited success in East Asia, most failed to catch up and offer competitive products. Many vertically integrated OEMs could not keep up with the rapid technological progress and chose to stop the internal development of CDMA modem chips in

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<sup>524</sup> Cutress, Ian and Andrei Frumusanu, “Huawei Announces the HiSilicon Kirin 960: 4xA73 + 4xA53, G71MP8, CDMA,” AnandTech, October 19, 2016 (“One of the more interesting announcements from the Kirin briefing was the implementation of CDMA in the modem. Currently three smartphone modem providers have CDMA solutions (Qualcomm in integrated and discrete modems, Intel with discrete, Mediatek with VIA-based integrated), and we spoke with HiSilicon to confirm that this is a brand new custom CDMA solution, rather than a licensed platform.”).

<sup>525</sup> Frumusanu, Andrei, “Meizu Announces M6s with Exynos 7872,” AnandTech, January 17, 2018 (“This is also the first time we’ve seen an Exynos SoC released with integrated CDMA capability [...]”). Frumusanu, Andrei, “Samsung Announces the Galaxy S9 and S9+,” AnandTech, February 25, 2018 (“Indeed the Exynos 9810’s new modem supports CDMA.”). See also Section V.C.4 for further details regarding Samsung’s re-entry into the CDMA segment.

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favor of purchasing chips on the merchant market (e.g., [REDACTED], Sony, and Motorola) and often pursued development of modem chips compatible with other standards perceived to be in greater demand, such as GSM and WCDMA (e.g., Intel and Philips). In recent years, several suppliers decided to incorporate CDMA support into their LTE multi-mode chips, often targeting the Chinese market where the prevalent demand is for multi-mode mobile devices that can be used on any wireless network. As of March 2018, there were at least four modem chip suppliers other than Qualcomm offering multi-mode CDMA/LTE products.<sup>526</sup> Qualcomm’s success in sales of CDMA modem chips is explained by industry factors, and in particular its foresight, strategic and efficient R&D investments, and consistent execution. Similarly, the recent rapid acquisition of CDMA capabilities by several of its competitors can be explained by their initial lack of foresight; after adjusting their expectations, they were able to add CDMA compatibility quickly and without considerable R&D resources.

## 2. WCDMA-compatible modem chips

251. Qualcomm achieved further success developing 3G WCDMA technologies and modem chips. Furthermore, Qualcomm became a leader in chip integration and the SoC approach by combining many functionalities, such as the AP, multimedia, GPS, and connectivity features, into a single piece of silicon.<sup>527</sup> Qualcomm continued to foster a culture of innovation and creativity among its engineers and maintained a reliable supply of chips with consistently high quality. Thus, Qualcomm again demonstrated that success in the modem chip industry could be achieved by responsiveness to market forces, well-targeted investments into innovation, and timely execution.

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<sup>526</sup> Wyatt Deposition, Qualcomm, p. 64 (“Q. Who are Qualcomm’s CDMA competitors? A. So our CDMA competitors are MediaTek, Huawei, [Samsung’s] Exynos, Intel, Via..”)

<sup>527</sup> As discussed in Section III.E.1. integrated modem chips are sought by most of the major OEMs [REDACTED]

*a. Development of WCDMA technology and standards*

252. Despite the prevalence of TDMA-based mobile devices during the 2G era, CDMA became the underlying multiple access technology for all 3G standards.<sup>528</sup> WCDMA, ultimately the most prevalent 3G wireless standard, emerged in the early 2000s and was a CDMA-derived variant that could be adapted to interface with the existing GSM infrastructure, easing the transition to 3G for carriers with GSM-based networks.<sup>529</sup> Just as the CDMA2000 1X standard evolved into CDMA2000 1xEV-DO, the family of WCDMA standards went through multiple releases, including UMTS in 2000, HSDPA in 2002, HSUPA in 2005, and HSPA+ in 2007.<sup>530</sup>
253. As the 3G standards were evolving, Qualcomm was actively trying to identify opportunities that could provide it a competitive advantage in this fast-paced industry.<sup>531</sup> Qualcomm’s Senior Vice President of Modem Engineering, Baaziz Achour, stated that Qualcomm considered its contributions to the WCDMA standards to be important,<sup>532</sup> particularly in the

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<sup>528</sup> 3G included three families of standards: CDMA2000, WCDMA, and TD-SCDMA. TD-SCDMA was developed and deployed in China. Chang, Lu, “TD-SCDMA and China 3G,” Marvell White Paper, January 2012, p. 2 (“Today, there are three major 3G standards worldwide. Wideband Code Division Multiple Access (WCDMA), is a third-generation (3G) wireless standard, that was first published in the year 2000 [...]. WCDMA is the 3G technology used in the United States by AT&T and T-Mobile. CDMA 2000 and EV DO (Evolution-Data Optimized) were first published in 2002. [...] China [...] also developed their own 3G technology, Time-Division Synchronous Code Division Multiple Access (TD-SCDMA), part of the Universal Mobile Telecommunications System (UMTS).”).

<sup>529</sup> Mock, 2005, p. 133 (“The W-CDMA standard being put together in Europe focused exclusively on evolution from GSM, and some aspects of the design seemed to serve absolutely no purpose other than to make it incompatible with other networks in the United States and abroad. What Qualcomm saw, in effect, was an effort to perpetuate the success of GSM, not to open up to foreign competition, as the EU and the United States had politically agreed to do. [...] Moving forward in Europe meant selecting a technology that was closely aligned with GSM [...]).

<sup>530</sup> “Introducing LTE-Advanced (Part 1),” The Engineer’s Portal to Green Design, available at [http://www.low-powerdesign.com/article\\_intro\\_lte-advanced\\_part1.html](http://www.low-powerdesign.com/article_intro_lte-advanced_part1.html) (Table 1, “Evolution of UMTS specifications”).

<sup>531</sup> See, e.g., Casaccia Deposition, Qualcomm, Exhibit CX6336, QNDCAL00244983–5010 at 4994, email from Lorenzo Casaccia, Qualcomm, June 8, 2011 with an attached presentation titled “Standards\* Task Force, 3GPP input” (“Our attitude should be: ‘If we do not do this piece of work, someone else will & the opportunity will be taken by some other industry (i.e. non-cellular, non-wireless).’ If we move into an area and Ericsson or Nokia are not there, this does not mean that the area is dead; it means we may have a first-mover advantage!”).

<sup>532</sup> See, e.g., Achour Deposition, Qualcomm, pp. 35–36 (“Q. So who have been the major contributors to the WCDMA specification? A. The WCDMA specification, there were also quite a few. Nokia and Ericsson always, they always been the leaders in the -- in the standards. Lucent at the time was -- was also a big contributor. Nortel was a big contributor. [...] Samsung was also a big contributor. At the time Huawei was starting to become a serious contender in the standard to start paying attention and contributing to the standard as well in WCDMA. There are other small companies, but these are the big ones, yeah. [...] I’m sorry, TI. I

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- forgot to mention TI. [...] Q. Has Qualcomm made contributions to the WCDMA standards? A. Yeah, I assume that was -- yeah, Qualcomm of course.”).

534 See, e.g., [REDACTED]

335 Achour Deposition, Qualcomm, pp. 20–21

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on the standard contributions already for many years, allowing for faster and better implementation of features.<sup>536</sup>

*b. Qualcomm’s development of WCDMA modem chips*

255. As Exhibit V.B.5 shows, in the early 2000s while continuing to promote CDMA2000, Qualcomm also entered the WCDMA segment as several carriers started to plan their transitions to WCDMA networks. While there were other WCDMA chip designs available, such as those developed by Nokia and NTT DoCoMo, these were captive and not available to other OEMs. Japan’s operator NTT DoCoMo deployed a proprietary version of WCDMA and had an exclusive supply contract with NEC for WCDMA handsets.<sup>537</sup> Similarly, Nokia had a captive WCDMA solution manufactured by TI.<sup>538</sup>
256. Building on its expertise in CDMA technology, Qualcomm was among the first modem chip suppliers to offer WCDMA chips on the merchant market. Qualcomm’s lack of experience with TDMA technology and lack of GSM chips in its product lineup presented challenges that Qualcomm ultimately overcame. While other modem chip suppliers could draw on their experience in designing GSM-compatible chips, Qualcomm’s initial WCDMA chip (MSM5200) was not backward compatible with GSM networks, which limited any potential

<sup>536</sup> Achour Deposition, Qualcomm, pp. 173–174. [REDACTED]

<sup>537</sup> “Global Cellular Handset & Chip Markets,” Forward Concepts, 2005, p. 50 (“NTT DoCoMo was the first operator to deploy a proprietary version of WCDMA, called FOMA (Freedom of Mobile Multimedia Access), in October 2001 [...]”). NEC, Annual Report, 2001, p. 18 (“NTT DoCoMo has selected NEC to provide all the building blocks for its commercial W-CDMA system, including handsets, radio access networks and core networks. In September 2000, NEC Networks started supplying NTT DoCoMo with commercial systems for W-CDMA.”).

<sup>538</sup> Yoshida, Junko, “Group Endorses 3G Handset Criticisms,” EE Times, February 25, 2004 (“[The] Nokia 6650 [is an] early example[] of [a] 3G handset[] designed more than two years ago. [...]It incorporates Texas Instruments’ baseband/application processor [...]”). See also “Global Cellular Handset & Chip Markets,” Forward Concepts, 2005, p. 294 (WCDMA baseband chip suppliers section notes that “Nokia WCDMA solution is captive”) and p. 304 (“Although TI is the clear leader in DSP baseband chips, worldwide, their biggest play is through Nokia, which is responsible for their own intellectual property in Nokia phones.”).

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first-mover advantage for Qualcomm.<sup>539</sup> An industry report published by Forward Concepts estimated the number of WCDMA modem chips sold in 2004 to be 17 million, or less than 3 percent of the roughly 700 million handsets sold globally.<sup>540</sup> While Qualcomm reportedly already signed up 21 vendors for its MSM6250 chips at that time, its sales only accounted for 28 percent of the global shipments, or fewer than 5 million chips.<sup>541</sup>

257. As described in Section III.E.1.c.i, the emergence of smartphones in the mid-2000s created demand for modem chips with more processing power, compact design, and power efficiency, spurring the development of increasingly integrated chip solutions.<sup>542</sup> A 2005 report by Forward Concepts also identified integration as one of the necessary steps for widespread adoption of WCDMA: “Achieving higher levels of integration and simpler system designs in succeeding generations of UMTS handsets are critical in making UMTS products profitable for both handset makers and wireless service providers.”<sup>543</sup> SoCs had advantages in terms of

<sup>539</sup> “Qualcomm CDMA Technologies Announces IMT-2000 WCDMA Single-Chip Solution for Handsets,” Qualcomm Press Release, November 8, 2000. Qualcomm announced its first WCDMA modem chip also compatible with GSM (MSM6200) in February 2002; this chip started to appear in devices within two years. See, e.g., “Qualcomm Provides UMTS/GSM/GPRS Solutions for European Market,” Qualcomm Press Release, February 19, 2002. See also Qualcomm, “MSM6200™ Chipset Solution,” 2003, available at [https://en.wikichip.org/w/images/e/e6/msm6200\\_chipset.pdf](https://en.wikichip.org/w/images/e/e6/msm6200_chipset.pdf); Qualcomm, Form 10-K, 2004, p. 10 (“We began shipping samples to customers of the MSM6200 integrated circuit in June 2002, and to date several customers including Samsung, LG Electronics, Sanyo, Option and Novatel Wireless, have introduced mobile phones[.]”)

<sup>540</sup> “Global Cellular Handset & Chip Markets,” Forward Concepts, 2005, pp. 295 and 559.

<sup>541</sup> “Global Cellular Handset & Chip Markets,” Forward Concepts, 2005, pp. 294–295 (“WCDMA platform leader Qualcomm has already signed up 21 vendors for its MSM6250 chipset (including Samsung, LG, and Sanyo).”).

<sup>542</sup> While most mobile device OEMs preferred integrated solutions, Apple is unique among major OEMs in seeking thin modems and supplying its own external APs. See, e.g., Achour Deposition, Qualcomm, pp. 105–106 (“Apple is the only company that actually ships smart phone with disintegrated modem. Everybody else use[s] integrated. Whether it’s ours or theirs, it’s all integrated. MediaTek, they do integrated modem, and they’re selling two phones in China. Huawei uses their internal modem to integrate into their MSM-like product. Samsung, they use our[] MSM, which is integrated modem, or their own internal MSM as well. So it’s all integrated. Most of the smart phones, they’re using integrated modem; except for Apple, that’s disintegrated, because I guess they want to keep the AP separate from the modem because the AP is very -- you know, it’s done by Apple internally. I don’t know their reasons, but obviously they don’t -- probably I would guess it’s much harder to integrate a modem from someone else into their product.” [REDACTED])

<sup>543</sup> “Global Cellular Handset & Chip Markets,” Forward Concepts, 2005, p. 295.

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cost and performance and took up less of the valuable space in a device.<sup>544</sup> Unlike many of its competitors that previously focused exclusively on manufacturing individual components (such as thin modems or APs), Qualcomm had years of experience providing SoCs, giving it a unique advantage in leading the integration of modem chip products.<sup>545</sup> Qualcomm’s success in integrating features is a reflection of its history of highly integrated designs, willingness to take educated risks, and ability to execute. It was also the result of strategic and long-term R&D process.<sup>546</sup>

258. The integration of modem chip products happened in two stages, and Qualcomm was at the forefront of each. In the first stage, GPS and multimedia features were integrated. For example, in 2000, Qualcomm acquired SnapTrack, a firm with experience in GPS, and by 2002, Qualcomm had developed its own GPS processor, which was integrated into later models of its chips.<sup>547</sup> By 2003, Qualcomm’s chips integrated a CPU, a WCDMA modem chip, multimedia features, and a GPS unit.<sup>548</sup> In the second stage, the modem chip was also

<sup>544</sup> See, e.g., “Cellular Handset & Chip Markets,” Forward Concepts, 2006, p. 126 (“The 6250 [modem chip produced by Qualcomm] integrates an applications processor and associated memory inside the package, significantly reducing bill-of-material costs, board size and power consumption.”).

<sup>545</sup> 02014FTC04798968-9027 at 8969, presentation titled “Modem Update,” Qualcomm, October 31, 2016, at 8998.

<sup>546</sup> For example, it took six or seven years to commercialize the initial version of carrier aggregation, see Grob Deposition, Qualcomm, pp. 199–200 (“Q. Now, a project like that, you said it started in 2001 or 2002, approximately? A. The carrier aggregation part of it. Q. And how long did it take until it was commercialized? A. Six or seven years.”).

<sup>547</sup> “Qualcomm Completes Acquisition of Wireless Location Leader SnapTrack,” Qualcomm Press Release, March 2, 2000. “Qualcomm Announces Advanced Position Location Capabilities for WCDMA/UMTS and GSM/GPRS Systems,” Qualcomm Press Release, February 5, 2002.

<sup>548</sup> In 2003, Qualcomm introduced the MSM6250 chip, “a single-chip solution that includes all the advanced multimedia capabilities” and that also included fully integrated GPS; by 2005 this solution has been implemented in a large number of WCDMA devices. “Qualcomm Announces Sampling of the MSM6250 Solution for WCDMA (UMTS), GSM and GPRS,” Qualcomm Press Release, August 6, 2003. Qualcomm, Form 10-K, 2005, p. 10 (“More than 110 WCDMA/HSDPA devices based on Multimedia Platform MSM6250 and Enhanced Multimedia Platform MSM6275 integrated circuits are currently either in design or are commercially available.”)

integrated with an AP. As shown in Exhibit V.B.5, Qualcomm was among the first modem chip suppliers to introduce a WCDMA chip with an integrated AP (MSM7200) in 2006.<sup>549</sup>

259. Apart from mobile devices, Qualcomm also marketed its SoCs to data card vendors, whose products were used in laptops to connect to the cellular network. Data cards required the fastest modem chips to address the demand for high-speed connectivity, and Qualcomm’s products were well positioned to meet these needs.<sup>550</sup>

*c. WCDMA modem chip sales*

260. Exhibit V.B.1 depicts global WCDMA-compatible handset sales, which increased from roughly 20 million devices in 2004 to just over 550 million in 2012. In addition, Exhibit V.B.6 shows sales of WCDMA modem chips (excluding multi-mode LTE/WCDMA chips) by supplier over the past decade. As the large number of suppliers and the emergence and decline of certain suppliers demonstrate, the competition in the WCDMA modem chip segment has been intense.
261. Qualcomm entered this segment gradually, with sales of fewer than 5 million chips in 2004.<sup>551</sup> However, it was able to leverage experience accumulated from years of its development of CDMA chips and pursuit of compact chip design to offer competitive, integrated, and backward-compatible WCDMA solutions with desirable features in a timely manner.

<sup>549</sup> See, e.g., “Qualcomm Announces Industry’s Leading WCDMA and HSDPA Chipset and Software Solutions,” Qualcomm Press Release, February 15, 2005. See also “Qualcomm UMTS/HSDPA Solutions Selected by More Than 30 Wireless Industry Leaders for More Than 120 Devices,” Qualcomm Press Release, February 9, 2006 (“Qualcomm expects to sample the industry’s first HSUPA-capable chipset in the first quarter of calendar year 2006. The MSM7200™ will support UMTS, HSDPA and HSUPA networks with backward compatibility to GSM/GPRS/EDGE and features advanced multimedia, connectivity, position location and data capabilities.”).

<sup>550</sup> See, e.g., “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 158 (“Qualcomm’s Rev. B chipsets deliver advanced functionality in a single compact, fully optimized device. The first commercial EV-DO Rev. B products are data modems (data cards) that became available in late 2007, with additional wireless devices available in 2008.”) and p. 194 (“Qualcomm has been successful in capturing a majority of the combined CDMA and UMTS/HSxPA [data] card market. With a three-chip solution (2 RF die and a combination application/baseband processor die[]), all in a single package for the Laptop PC market, which reached 10 million in sales in 2007.”).

<sup>551</sup> Calculated as 28 percent of 17 million WCDMA modem chips. See “Global Cellular Handset & Chip Markets,” Forward Concepts, 2005, p. 295.

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262. As Exhibit V.B.6 shows, by 2008, Qualcomm joined TI as one of the leading WCDMA chip suppliers. Qualcomm’s sales of WCDMA modem chips continued to grow quickly, from roughly 80 million chips in 2008 to 300 million in 2011. Over the years, Qualcomm faced many other competitors in the WCDMA segment, including Infineon/Intel and Broadcom. [REDACTED]

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263. More recently, the competitive landscape in the WCDMA segment shifted due to the entry of low-cost chip suppliers such as MediaTek and Spreadtrum. These modem chip suppliers

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introduced the concepts of reference designs and turnkey solutions, giving OEMs a way to implement mobile device solutions quickly and cheaply but with limited flexibility.<sup>554</sup> When coupled with their focus on emerging markets, they managed to increase their modem chip sales rapidly. While MediaTek and Spreadtrum entered the WCDMA segment relatively late, in 2010 and 2013, respectively,<sup>555</sup> by 2015 they had captured two-thirds of all WCDMA chip sales (without LTE compatibility).<sup>556</sup> Some modem chip suppliers have struggled to respond to the competition from these low-cost chipmakers. For example, [REDACTED]

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*d. WCDMA Conclusion*

264. Despite a lack of experience with GSM standards, within a year of its first WCDMA-only modem chip, Qualcomm managed to offer a backward-compatible chip integrating WCDMA and GSM technologies. Qualcomm also recognized and responded to customers’ demands for increased integration. It was among the first chip suppliers to offer a WCDMA SoC, and its chip solutions generally also integrated other advanced functionalities such as GPS and multimedia support. Qualcomm’s responsiveness to the demands of industry participants and its engineering prowess allowed it to produce reliable high-performance chips and to strengthen its position in WCDMA. Qualcomm’s success in sales of WCDMA modem chips is fully explained by industry factors, namely its foresight, strategic and efficient R&D investments, and execution.

**3. LTE-compatible modem chips**

265. As a new generation of wireless technologies began to be deployed around 2010, Qualcomm again demonstrated foresight and the ability to respond to industry demands; accompanied by strategic investments in R&D and M&A activity, Qualcomm brought to the market high-

<sup>554</sup> See Sections V.C.3 and V.C.10 for additional information on MediaTek and Spreadtrum, respectively.

<sup>555</sup> See Exhibit V.B.5.

<sup>556</sup> See Exhibit V.B.6 and associated backup.

<sup>557</sup> [REDACTED]

performance, backward-compatible, integrated chips with advanced functionalities and low power requirements before many of its competitors did. For example, Qualcomm was among the first modem chip suppliers to release an LTE modem chip in 2010 and an LTE chip integrated with an AP in 2012.<sup>558</sup> Unlike other suppliers that were only producing LTE modem chips that had to be paired with other components to achieve compatibility with 3G,<sup>559</sup> Qualcomm was producing 3G/4G multi-mode chips from the start: its first LTE chip (MDM9200) was backward compatible with WCDMA, and its MDM9600 announced within a year was compatible with both CDMA and WCDMA.<sup>560</sup> As in previous generations of wireless standards, Qualcomm’s success in LTE was the result of its responsiveness to market demands, strategic and efficient investments, and strong execution.

*a. Development of LTE technology and standard*

266. The introduction of new technologies during the transition to 4G presented firms in the industry with opportunities for leapfrogging of competitors but also created challenges for firms that lacked foresight or did not target their investments appropriately, just like previous transitions in the wireless communications industry.<sup>561</sup> The three main candidate systems that were considered included UMB (Ultra Mobile Broadband), LTE, and WiMAX.<sup>562</sup>

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<sup>558</sup> See Exhibit V.B.7.

<sup>559</sup> For example, Altair Semiconductor’s FourGee 3100 and GCT Semiconductor’s GDM7240 modem chips, which were shipping in 2010, were not backward compatible with 3G standards. See, e.g., “Cellular Handset & Chip Markets,” Forward Concepts, 2011, p. 129 (“[...Altair] announced three LTE chips that began shipping in small quant[ities] by Q4 of 2010 [...]. The FourGee 3100 LTE is a Cat-3 baseband in addition to [providing] support for other 4G/OFDM technology variants, including WiMAX and Japan’s XGP.”) and p. 174 (“[...GCT Semiconductor’s] GDM7240 supports LTE Category 3 with high performance throughputs of 100Mbps [on the] downlink and 50Mbps [on the] uplink [...]. [The] GDM7240 is in volume production and is currently used in one of Verizon Wireless’ released 4G USB data modems.”).

<sup>560</sup> See, e.g., “Modem Evolution,” CTIA Special Session, May 8, 2012, p. 4 (MDM9200 is shown as supporting LTE Cat 3, DC-HSPA+, and EDGE; MDM9600 shown as supporting LTE Cat 3, DC-HSPA+, DOrB, and EDGE). See also “Qualcomm’s Snapdragon Processor and LTE Modem Power Connectivity Devices on Verizon Wireless’ New 4G LTE Network,” Qualcomm Press Release, January 5, 2011 (“Qualcomm’s MDM9600 chipset [...] supports theoretical LTE data rates with full backward compatibility to EV-DO Rev. A/Rev. B.”).

<sup>561</sup> APL-QC-FTC\_18390703–0707 at 0704, email from Ruben Caballero, Apple, April 14, 2014 (“As you know Wireless is an entirely different ball game and every time wireless technology makes a leap the players change. Take example of TI who had a huge lead in 2G but failed to make 3G modem.”).

<sup>562</sup> Panzer, Justin, “And They’re Off! WiMAX, LTE, UMB, and the Race to 4G Wireless,” Electronic Design, October 24, 2007.

267. Starting in the mid-2000s, industry participants began developing two of the candidate 4G systems, UMB and LTE, based on an alternative multiple-access technology known as OFDMA.<sup>563</sup> Qualcomm began working on UMB in 2005 but halted its development in 2008 when UMB had not garnered support among carriers and the industry was moving in a different direction towards LTE.<sup>564,565</sup> In addition to its own internal research efforts advancing OFDMA, Qualcomm also acquired Flarion Technologies (“Flarion”) in 2006 for around \$600 million.<sup>566</sup> According to Qualcomm’s then-CEO Paul Jacobs, Qualcomm intended to use Flarion’s OFDMA expertise in order to strengthen its position in the uncertain environment.<sup>567</sup> By 2007, Qualcomm had filed over 1,400 U.S. and 5,300 foreign patents related to the

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<sup>563</sup> See, e.g., Yapp, Edwin, “A Brief History of LTE,” Digital News Asia, April 30, 2013 (“The official development of LTE began in 2005 after Japanese operator NTT DoCoMo proposed a next-generation wireless standard that would seek to unify the somewhat fragmented wireless standards that had been in existence to date.”). Note that UMB was considered the next evolution of CDMA2000 and used CDMA for the uplink. See, e.g., Drucker, Elliott, “End of the Road for CDMA?,” WirelessWeek, June 1, 2008 (“Apparently succeeding CDMA as the air interface technology of choice is orthogonal frequency division multiplex (OFDM). Both LTE and UMB rely on OFDM to provide the potential for very high data rates, particularly in the downlink. However, UMB does retain a CDMA channel structure for the uplink. LTE, like the third 4G technology competitor WiMAX, uses OFDM exclusively in both the downlink and uplink.”).

<sup>564</sup> UMB was developed by Qualcomm between 2005 and 2010. Qualcomm’s Form 10-K for 2008 notes that the “3<sup>rd</sup> Generation Partnership Project 2 (3GPP2) has developed the UMB (Ultra Mobile Broadband) standard.” Qualcomm, Form 10-K, 2008, p. 2. See also Willenegger Deposition, Qualcomm, pp. 245–246 (“[T]he amount of resource invested in UMB was significant. That was a full project within Qualcomm [...]”).

<sup>565</sup> See, e.g., Fleishman, Glenn, “Qualcomm Cancels Its Own 4G System,” Ars Technica, November 13, 2008 (“Ultramobile broadband (UMB) is ultra dead. [...] Qualcomm said they would stop work on its fourth-generation (4G) network technology UMB, and shift efforts to the GSM-based Long-Term Evolution (LTE) standard. [...] This was not unexpected [...] as no major carrier had committed to UMB.”). See also Qualcomm, Form 10-K, 2009, p. 6 (“We continue to develop and commercialize 3G CDMA-based technologies [...] and are working on commercializing the OFDMA-based LTE technology. [...] Multiple wireless operators, including AT&T and Verizon Wireless, have communicated their commitment to LTE as their next generation technology path.”).

<sup>566</sup> “Qualcomm Completes Acquisition of Flarion Technologies,” Qualcomm Press Release, January 19, 2006.

<sup>567</sup> See, e.g., Wise Deposition, Qualcomm, pp. 15–16 (“Q. And what was the reason for Qualcomm acquiring Flarion? A. As the industry was looking at the next generation, evolving from 3g to 4g, there was a debate over the modulation scheme and whether it would be CDMA or OFDMA, and we wanted to position ourselves to be ready for either. And Flarion had a leading -- a head start on the development of an OFDMA platform and a fair amount of OFDMA expertise that we thought would be helpful.”). See also “Qualcomm to Acquire Flarion Technologies,” Qualcomm Press Release, August 11, 2005 (““With this acquisition, Qualcomm will be in a stronger position to support advanced development in both CDMA and OFDMA technologies,” said Dr. Paul E. Jacobs, CEO of Qualcomm. “The combination of Flarion and Qualcomm’s engineering resources greatly strengthens [Qualcomm’s] position as a continued technology innovator and leader in the wireless industry. We [Qualcomm] believe CDMA will provide the most advanced, spectrally efficient wide area wireless networks for the foreseeable future, but with Flarion we can now more effectively support operators who prefer an OFDMA or hybrid OFDM/CDMA track for differentiating their services.””).

268. Support by network carriers for LTE over WiMAX was one of the drivers of Qualcomm's success and the failures of some of its competitors. [REDACTED]

[illegible]

<sup>572</sup> Keddy Deposition, Intel, Exhibit QX73, INTEL-QCOM008077974–7987 at 7983, p. 74 (“Q. [...] Do you agree that Intel was not successful in persuading critical players, including network operators such as Verizon and China Mobile, to adopt WiMax? [...] A. [...] Basically at the end of the day, Verizon didn’t use Intel and WiMax. And so we were one of the many players, and we could not convince Verizon to use WiMax. Yes, I agree.”), and Exhibit QX74, INTEL-QCOM008124586–4587, email from Asha Keddy, Intel, June 25, 2015 with attached presentation titled “5G CSD MCM Review,” Intel, June 18, 2015, p. 61 (States that the “[e]cosystem tipped with AT&T & Verizon backing LTE” and that despite a 2-year lead to the market, large incumbent carriers were hesitant to embrace WiMAX, as LTE was the “natural path” for GSM carriers.).

As WiMAX failed to garner buy-in from carriers, the technology dwindled.<sup>574</sup>

*b. Qualcomm’s development of LTE modem chips*

269. Qualcomm was in a strong position to compete in the LTE segment due to its strategic R&D efforts and, to a lesser extent, the learning and experience it obtained while contributing to the development of the LTE standard, such as its prototyping work. Similar to its competitors,<sup>575</sup> Qualcomm channeled its engagement in the development of LTE technology into modem chip design through effective collaboration and transfer of knowledge between its Corporate R&D division and QCT, the chip-selling division.<sup>576</sup>

<sup>573</sup> INTEL-QCOM001145202–5203 at 5202, email from Asha Keddy, Intel, November 7, 2012.

<sup>574</sup> Reed, Brad, “When It Comes to the U.S. Handset Market, LTE Has Landed a Knockout Blow,” Network World, November 2, 2011 (“The chief reason for WiMAX’s downfall in the consumer handset space is a simple one: [...] WiMAX wasn’t adopted by enough carriers to make it the de facto standard for 4G mobile data in the U.S.”).

<sup>575</sup> See, e.g., Keddy Deposition, Intel, pp. 213–214 (“Q. And what is the benefit of Intel from a technology being incorporated into a standard? [...] A. So when Intel works on items that get incorporated into the standard, it helps -- In general, it tends to be that we build consensus; but it helps, because it’s kind of like steering a car or something: You know where you’re headed. And, for example, the product engineers then would work with -- work very closely with my team. And one of the job functions I have is to transfer the knowledge to the product team. You know, the standards may have some things articulated, but there’s a lot of thought and debates and why we chose to do certain things in that context, what other people may have said to get that solution. And so we are able to provide that and we’re able to make better products and quick products.”).

<sup>576</sup> Corporate R&D had the Espresso program focused on developing the LTE standards. See, e.g., Achour Deposition, Qualcomm, pp. 190–191

). See also Thompson

Deposition, Qualcomm, pp. 418–419

.<sup>578</sup> Over the period of eight years between 2010 and 2017, QCT spent almost \$26 billion (or 23 percent of its revenue) on R&D.<sup>579</sup>

.<sup>580</sup> Qualcomm was able

See, e.g., [REDACTED]

[REDACTED]

See also Zander Deposition, Ericsson, pp. 110–111 (“Q. And Qualcomm was carrying that larger R&D organization? A. Yes. Q. And was it able to come to market faster, as you described it, using the same specifications? A. When we compare it at that given point of time, yes, but that has of course differed over the years. Q. And how does the fact of a larger R&D organization facilitate a quicker time to market? A. It can allow you to run more development in parallel, and it can allow you to have more product in the portfolio so you can make more incremental steps and doing everything right in one product. Q. And having the larger R&D operations requires investment? A. Yes. Q. At the time we’re speaking of right now, 2014, 2013, 2014, did Ericsson have the same R&D investment as Qualcomm in developing the premium LTE modems? [...] A. I don’t know exactly how many engineers Qualcomm had at that time developing the modems. The understanding our team had was that Qualcomm was [REDACTED] that made the same type of development.”).

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[REDACTED]

[REDACTED]

[REDACTED] As Qualcomm and Intel were both pursuing leadership strategies, their R&D expenditures greatly exceeded the budgets of fast followers, such as MediaTek and Broadcom, or chip suppliers following other strategies, such as Spreadtrum and Marvell.<sup>582</sup>

271. Consistent and targeted investments in innovation allowed Qualcomm to reach several important milestones:<sup>583</sup>

- i. As shown in Exhibit V.B.7, Qualcomm was among the first chip suppliers to offer LTE chips and, unlike its competitors, Qualcomm incorporated backward compatibility with both 2G and 3G networks from the beginning.<sup>584</sup>

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<sup>581</sup> See, e.g., [REDACTED]

<sup>582</sup> See Section III.E for discussion on R&D of various chip suppliers.

<sup>583</sup> This section is not intended to provide an exhaustive list of Qualcomm’s innovations. Among other innovations, for example, Qualcomm also addressed the issue of LTE cellular radio frequency band fragmentation through Qualcomm’s RF360 Front End Solution, which was the first device that allowed OEMs to develop handsets with worldwide LTE mobility across carriers. See, e.g., “Qualcomm RF360 Front End Solution Enables Single, Global LTE Design for Next-Generation Mobile Devices,” Qualcomm Press Release, February 21, 2013 (“Qualcomm[’s] RF360 Front End Solution [...] is a comprehensive, system-level solution that addresses cellular radio frequency band fragmentation and enables for the first time a single, global 4G LTE design for mobile devices.”). Qualcomm also advanced multiple antenna techniques for more capacity and extended the benefits of LTE Advanced to unlicensed spectrum through LTE-U, see Achour Deposition, Qualcomm, pp. 247–248. For other examples, see “LTE Advanced - Evolving and Expanding Into New Frontiers,” Qualcomm, August 2014, p. 7, available at <https://www.qualcomm.com/media/documents/files/lte-advanced-evolving-and-expanding-into-new-frontiers.pdf>. See also Malladi Deposition, Qualcomm, pp. 448–450, discussing foundational contributions to LTE, including cell search procedure, modifications to power control, DRX and DTX cycles, and all IP network.

<sup>584</sup> See, e.g., “Modem Evolution,” Qualcomm, May 8, 2012, available at <https://www.qualcomm.com/media/documents/files/ctia-special-session-modem-evolution.pdf>, p. 4 (“World’s First Integrated LTE/3G Modem Chips” with reference to MDM9200, which supported LTE/HSPA+/EDGE, and MDM9600, which supported LTE/HSPA/EV-DO/EDGE). See also Achour Deposition, Qualcomm, pp. 82–84 (“Q. Is it consistent with your understanding that Qualcomm was unique in offering basic LTE in 2011? [...] A.] LTE was a novelty in 2011. It was really just starting. And at that time we were the only

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- ii. As shown in Exhibit V.B.7, Qualcomm was also the first chip vendor to offer an LTE chip with an integrated AP, the MSM8960, in production by 2012.<sup>585</sup> This chip supported seven modes (LTE-FDD, LTE-TDD, UMTS, CDMA2000 1xEV-DO, CDMA2000 1X, TD-SCDMA, GSM/EDGE) and allowed mobile device OEMs to offer global roaming.<sup>586</sup>
- iii. In 2013, Qualcomm launched the MDM9x25 modem series, which included the first modem chips supporting LTE Category 4 and carrier aggregation.<sup>587</sup> Carrier aggregation was becoming increasingly important because many network carriers around the world had discontinuous spectrum available and needed a way to aggregate the spectrum in order to deliver higher bandwidth.<sup>588</sup>

” 589

company that was able to deliver multimode LTE. So just taking LTE out of context is not really -- it's not really -- it doesn't do it justice, because really the -- a lot of the complications and the novelty that we worked on at that time is to work -- make LTE work with all the other technologies before it; you know, with CDMA, with WCDMA, with GSM, with TD-SCDMA in China, with all these other technologies. It's actually seven different modes. And to make all these modes work together, because when LTE got deployed it was only deployed in certain cosmopolitan areas. And as soon as you drop out of downtown, there's no LTE. So the user should not notice that the call dropped, so you have to make sure you handoff between the new technology and the old technology. So the crossing of these boundaries of new technology to old technology became -- it's really kind of a breaker if you don't do it right. So the multimode aspect is actually the most complicated thing that actually made all this possible [...].”).

<sup>585</sup> See, e.g., “Qualcomm Introduces World’s First Complete Multi-Mode 3G/LTE Integrated Solution for Smartphones,” Qualcomm Press Release, February 16, 2009. See also Koliander Deposition, Qualcomm, p. 220 (“Q. The 8960 -- was that a System on a Chip that had LTE? A. Yes. [...] MSM 8960 was our first SoC that included an application processor, as well as a cellular modem. Q. And it had LTE? A. It supported LTE.”).

<sup>586</sup> “Modem Evolution,” Qualcomm, May 8, 2012, available at <https://www.qualcomm.com/media/documents/files/ctia-special-session-modem-evolution.pdf>, p. 4.

<sup>587</sup> See, e.g., “Modem Evolution,” Qualcomm, May 8, 2012, available at <https://www.qualcomm.com/media/documents/files/ctia-special-session-modem-evolution.pdf>, p. 4 (“World’s First Integrated LTE/3G Modem with Cat4 and Carrier Aggregation” with reference to MDM9x25). See also “Qualcomm Third Generation LTE Chipsets Are First to Support HSPA+ Release 10, LTE Advanced with LTE Carrier Aggregation,” Qualcomm Press Release, February 27, 2012 (“The MDM9225 and MDM9625 chipsets are also the first to support LTE carrier aggregation and true LTE Category 4 [...].”).

<sup>588</sup> As already discussed in Section III.E.1.a, carrier aggregation allows carriers to aggregate multiple relatively narrow radio channels (in the same or different bands) and thus increase download speeds and network response times for users. See, e.g., “World’s First Mobile Device with LTE Advanced Carrier Aggregation Powered by the Qualcomm Snapdragon™ 800 Processor,” Qualcomm Press Release, June 26, 2013.

<sup>589</sup>

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Qualcomm’s Senior Vice President of Modem Engineering, Baaziz Achour, also considered carrier aggregation to be “very critical.”<sup>590</sup>

272. Qualcomm pursued a strategy of differentiation in many areas in addition to carrier aggregation.<sup>591</sup> [REDACTED]

[REDACTED].<sup>592</sup> Despite important investments in the technology and a strategy of innovation and leading-edge performance and features,<sup>593</sup> Qualcomm faced aggressive competitors (such as HiSilicon, Intel, and Samsung S-LSI) and was not always able to be first to market.<sup>594</sup> For example, HiSilicon launched 4x4 MIMO ahead of Qualcomm.<sup>595</sup>

<sup>590</sup> Achour Deposition, Qualcomm, pp. 70–71 (“So carrier aggregation as a feature by itself is very critical. The reason it is critical is because a lot of operators around the world don’t have the luxury of getting a good chunk of spectrum all in one piece. What they tend to get is 5 megahertz here, 10 megahertz here, 15 over here. So they have to have means to put all these chunks together to create [...] one big chunk of spectrum. Carrier aggregation is a means to actually collect these pieces and put them together. So in that case a lot of operators around the world have this problem, and they’re looking for a technology that allows them to aggregate these pieces of Swiss cheese spectrum they have to make it look like one big aggregate bandwidth to allow them to deliver high bandwidth.”).

<sup>591</sup> Mollenkopf Deposition, Qualcomm, pp. 117–118 [REDACTED]

<sup>592</sup> Achour Deposition, Qualcomm, Exhibit CX6386 (Q2014FTC03690064) at CX6386–016, email from Baaziz Achour, Qualcomm, September 11, 2012, with attached presentation titled “QCT Strategic Plan July 2012 Team Presentation”).

<sup>593</sup> Achour Deposition, Qualcomm, p. 92 (“Q. From your perspective is it a core strategy of Qualcomm to offer modems with leading edge features? A. That’s definitely our strategy, is to always push the envelope, always -- whether it’s performance or better power or better features, it’s always been our strategy we try to move as fast as possible and deliver much better quality than anybody else and -- and deliver that very quickly to the market, yeah.”).

<sup>594</sup> See, e.g., Thompson Deposition, Qualcomm, p. 77 [REDACTED] and Exhibit CX6311 (Q2014FTC04815247) at CX6311-004 (Qualcomm, October 2, 2013 email, with attached presentation titled “QCT OpEx Control,” [REDACTED])

<sup>595</sup> See, e.g., Achour Deposition, Qualcomm, pp. 90–91 (“Q. Is it consistent with your understanding that Qualcomm was the first to market with whatever was the most advanced version of LTE in 2013? [...] A. So, no. We have instances where -- for example, Huawei launched features before us. Actually, one key feature in

273. One of the challenges during the transition to LTE around 2010 was keeping up with the new releases of the various standards. LTE was rapidly evolving but many new features were still being added to older standards such as WCDMA, TD-SCDMA, and even GSM.<sup>596</sup> Modem chip suppliers, including Qualcomm, had to consider which specifications and features to support and where to focus their effort and investments.<sup>597</sup> This moment presented opportunities for leap-frogging by firms that had good foresight and made the right strategic decisions, but it also presented a challenge because failures in foresight could have long-lasting consequences.<sup>598</sup> With the benefit of hindsight, Baaziz Achour, Qualcomm’s Senior Vice President of Modem Engineering, believes Qualcomm made the right choices:

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LTE is 4x4 MIMO. [...] I think it was in Japan, at least they had one -- one trial or one -- you know, they were the first to announce it before we had it working in all our products. So it’s not always -- most of the time we [...] try to move as fast as possible to introduce technology first in the market, but Huawei and Samsung have been very aggressive lately, and they were able to -- in some cases to actually launch something first.”).

<sup>596</sup> See, e.g., Achour Deposition, Qualcomm, pp. 161–163 (“Q. And when you say that the standard was coming out with a lot of new features [...] in the 2010 time frame, which standard are you referring to? A. I think it was definitely LTE, because LTE was evolving very quickly. There were a lot of things being added on top of the very first release of the LTE. WCDMA was still evolving, there were a lot of features that were being added to WCDMA. TD-SCDMA in China was also evolving at the same time. So we have all these technologies moving at different speeds forward and [...] to keep our multimode competitive, we need to basically spend money on every technology to upgrade it to the latest spec and that’s a lot of effort. So we had to basically put a plan together to serialize these things. And so basically it refers to at least three different technologies that were evolving at the time. Actually even GSM, I remember even GSM was evolving. It was still -- even though it was old technology, they were still adding features into the standard at that time.”).

<sup>597</sup> Achour Deposition, Qualcomm, p. 196 [REDACTED]

<sup>598</sup> See, e.g., Thompson Deposition, Qualcomm, pp. 80–81 [REDACTED]

[REDACTED]. For example, while Spreadtrum focused on older standards such as GSM and TD-SCDMA during the early years of LTE, it was able to successfully transition to WCDMA and LTE through acquisitions and partnerships with other companies (see Section V.C.10). In contrast, due to the technological inferiority of its LTE chips, Broadcom was unable to secure LTE design wins despite its success in WCDMA (see Section V.C.8).

[...T]here were things we did not work on, we decided to defer to later because we didn't have [...] bandwidth. But in looking back now in hindsight, you know, we made the right choice. It was not by accident. It was because we really have very good relationship with our customers' customers in the market and we kind of read the market. We understood what was important.<sup>599</sup>

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<sup>600</sup> See, e.g., Achour Deposition, Qualcomm, pp. 181–183

<sup>602</sup> Qualcomm Incorporated’s Objections and Responses to Federal Trade Commission’s First Set of Interrogatories, February 28, 2018, p. 44 [REDACTED]

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[REDACTED]

[REDACTED].<sup>603</sup>

275. Consistent with its leadership position during most previous transitions in the modem chip industry,<sup>604</sup> Qualcomm remains one of the major driving forces of innovation as the industry moves closer to 5G.<sup>605</sup> In October 2017, Qualcomm was first to achieve a 5G connection on a modem chip designed for mobile devices.<sup>606</sup> Qualcomm continues towards “[m]aking 5G[ ]NR a commercial reality for 2019”<sup>607</sup> and [REDACTED].<sup>608</sup> Qualcomm prides itself on this type of advanced “blue sky research”

<sup>603</sup> See, e.g., Thompson Deposition, Qualcomm, p. 343 [REDACTED]

<sup>604</sup> See, e.g., Mollenkopf Deposition, Qualcomm, pp. 158–159 [REDACTED]

<sup>605</sup> See, e.g., Thompson Deposition, Qualcomm, pp. 315–316 [REDACTED]

[REDACTED] See also Willenegger Deposition, Qualcomm, p. 168 [REDACTED]

<sup>606</sup> “Qualcomm Achieves World’s First Announced 5G Data Connection on a 5G Modem Chipset for Mobile Devices,” Qualcomm Press Release, October 17, 2017 (“The 5G data connection demonstration [...] achieved gigabit download speeds, using several 100 MHz 5G carriers [...].”).

<sup>607</sup> “Making 5G NR a Commercial Reality,” Qualcomm, April 2018, p. 14, available at <https://www.qualcomm.com/media/documents/files/making-5g-nr-a-commercial-reality.pdf>.

<sup>608</sup> Amon Deposition, Qualcomm, pp. 278–279 (“[REDACTED]”

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that is ahead of its time and without which progress in the modem chip industry and in the wireless telecommunication industry in general would fall behind.<sup>609</sup>

*c. LTE modem chip sales*

276. Starting with the first shipments of LTE modem chips in 2010, devices using the new standard were sold predominantly in high-income countries, which rolled out LTE first.<sup>610</sup> Exhibit V.B.8 depicts global sales of LTE modem chips by supplier, growing from essentially no sales in 2010 to over 1.5 billion modem chips in 2017. Qualcomm’s performance in the sales of LTE chips has been strong from the start, and ongoing investments in innovation and consistent execution positioned it well for continued success.<sup>611</sup> Many major mobile device OEMs have sourced their chips from Qualcomm, including Apple, Samsung, Xiaomi, LG, Oppo, Vivo, and Huawei.<sup>612</sup> Qualcomm’s power-efficient, high-performing products attracted interest from industry players and garnered hundreds of design wins, ending up in many high-end mobile devices.<sup>613</sup>
277. While Qualcomm’s sales of LTE modem chips grew rapidly following the deployment of LTE networks, they plateaued around 780 million chips in recent years.<sup>614</sup> As Exhibits V.B.7 and

<sup>609</sup> Malladi Deposition, Qualcomm, pp. 25–26 [REDACTED]

<sup>610</sup> See, e.g., “Cellular Handset & Chip Markets,” Forward Concepts, 2011, p. 59 (“Seventeen operators have commercially launched LTE networks, in Austria, Denmark, Estonia, Finland, Germany, Hong Kong, Japan, Norway, Poland, Sweden, USA, and Uzbekistan.”).

<sup>611</sup> Thompson Deposition, Qualcomm, pp. 92–93 (“[REDACTED]

<sup>612</sup> Strategy Analytics, “Customised Baseband Quarterly Market Share Tracker for Qualcomm: Parts 1 and 2,” April 6, 2018.

<sup>613</sup> See, e.g., Abazovic, Fuad, “Snapdragon 835 Expected to Exceed 820 Design Wins,” Fudzilla, January 8, 2017. For example, Qualcomm’s LTE modem chips were included in versions of Apple iPhone 5, Samsung Galaxy S5 and S3, Samsung Galaxy Note 3, Sony Xperia Z1, Nokia Lumia 625, 920, and 925, HTC One M8, and many other mobile devices. See SpecTRAX data, “SpecTRAX\_Data\_and\_Analysis\_2018\_04\_20.xlsm,” Strategy Analytics, April 20, 2018.

<sup>614</sup> See Exhibit V.B.8 and associated backup.

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V.B.8 demonstrate, since the introduction of LTE, Qualcomm has faced an array of strong competitors pursuing a variety of strategies in order to offer competitive LTE products. These competitors included large companies with long histories in the semiconductor business and substantial engineering resources, such as Samsung, Intel, and Huawei/HiSilicon, but also fast followers such as MediaTek and Broadcom that targeted low-cost mobile devices, often in emerging economies. Finally, many other modem chip suppliers entered the LTE segment with limited prior experience in modem chip design, including Altair, Sequans, GCT, Leadcore, Renesas, and Nvidia. Qualcomm’s employees testified that Qualcomm was aware of, and actively monitoring, the product offerings of many of these competitors.<sup>615</sup>

*d. LTE Conclusion*

278. Qualcomm’s entry into the 4G segment was not straightforward. Just like its competitors, Qualcomm had to start working on a specific 4G technology years before the industry consolidated around a particular standard. Initially choosing a standard that was not adopted, Qualcomm had to pivot from UMB to LTE in order to not miss the opportunity to participate in the development and sales of 4G modem chips. Qualcomm’s strategy to become the industry leader in LTE technology allowed it to surpass the competition and remain at the leading edge of the industry. Qualcomm was among the first suppliers of LTE thin modems as well as the first suppliers of LTE chips with an integrated AP. As smartphones became smaller and faster, Qualcomm offered unparalleled solutions that required fewer chips and provided better power management and stronger performance. Qualcomm’s responsiveness to customer demands,

<sup>615</sup> See, e.g., Thompson Deposition, Qualcomm, pp. 103–104

also Willenegger Deposition, Qualcomm, pp. 204–206

Qualcomm, pp. 237–238 (

See

); Kressin Deposition,

extensive and strategic R&D investments, and exceptional execution fully explain its success in sales of LTE modem chips.

#### 4. Summary of Qualcomm’s experience

279. In summary, Qualcomm’s successes in each generation of wireless standards can be fully explained by industry factors.
280. Foresight: Qualcomm was alone in its decision to invest heavily in CDMA technology while other participants focused on TDMA technology. Qualcomm’s technical achievements during the initial stages of CDMA development, including its development of compatible modem chips, mobile devices, and network equipment, were integral to the commercialization of CDMA technology. As a result, Qualcomm was able to deliver high-quality products into the marketplace earlier than its competitors were. Qualcomm also retained this foresight during later generations of wireless standards. For example, it was able to participate in the development of technologies compatible with multiple wireless standards (CDMA2000, WCDMA, UMB, and LTE) in parallel and respond to changing industry dynamics in favor of WCDMA and LTE. Qualcomm’s foresight in pioneering CDMA technology served it well when the industry-wide expectations regarding obsolescence of cdmaOne/CDMA2000 networks did not materialize and OEMs continued to demand multi-mode LTE chips with CDMA compatibility. Qualcomm demonstrated foresight in selecting both the wireless technologies and features of modem chips on which to focus its R&D.
281. Investment: Qualcomm was able to back up its foresight with sustained, well-targeted, and efficient investments into the development of wireless technologies and modem chips. In the early years, Qualcomm invested heavily in the development of CDMA network technology, and these investments yielded benefits in many future generations of technologies that were built on CDMA. Qualcomm has been widely recognized for commercializing innovative modem chip technologies, and industry observers acknowledged that Qualcomm’s R&D has been particularly efficient. In addition to internal R&D, Qualcomm’s acquisitions also gave it access to certain technologies more quickly. For example, the acquisition of SnapTrack allowed Qualcomm to incorporate GPS technology into WCDMA and subsequent modem chips, while the acquisition of Flarion enhanced Qualcomm’s portfolio of OFDMA technologies.

282. Execution: Qualcomm’s foresight and strategic investments have been complemented by its ability to design high-quality products reflecting the latest developments in wireless standards and modem chip technologies and deliver them in a timely manner. Across several generations of wireless standards, Qualcomm consistently demonstrated its ability to quickly commercialize modem chip designs. Its timeliness and reliability of manufacturing led to many design wins from OEMs and helped it to stay at the forefront of the industry. Qualcomm continues to maintain its position of a widely-recognized technology leader as the mobile communications industry transitions into 5G.

### C. Outcomes for other modem chip suppliers

283. In this section, I apply my analytic framework to each major competitor in the modem chip industry during the period of interest. As I describe below, the *Industry Factors Hypothesis* explains entry and exit in the industry, as well as the performance of important industry participants such as Intel and MediaTek, without apparent room for Plaintiff’s arguments. In some instances, different industry factors have contributed to a different extent to the performance of each competitor with the passage of time or advancement in technology. I review each competitor in turn and show my findings for each factor in turn. Exhibits V.C.1 to V.C.13 show supplier-level sales information for each modem chip supplier described below. Exhibit V.D.1, discussed further in the next section, summarizes my findings.

#### 1. Infineon

##### a. Background

284. Infineon Technologies AG is a German semiconductor company that was spun off from Siemens AG in 1999.<sup>616</sup> After Infineon became an independent entity, Infineon’s Wireless Communications group became responsible for modem chip production.<sup>617</sup> Infineon quickly

<sup>616</sup> “Siemens Names Chip Spinoff Infineon,” EE Times, March 17, 1999 (“Siemens AG today said its semiconductor spinoff will be called Infineon Technologies AG when it is officially formed on April 1.”).

<sup>617</sup> Infineon, Form 20-F, 2001, p. 42 (“Our Wireless Communications business group designs, develops, manufactures and markets semiconductors and complete system solutions for a range of wireless applications [...]. Our principal products in the wireless communications market include standard and customized radio-frequency products and baseband ICs.”).

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emerged as a leader in the development of RF transceivers and thin modems,<sup>618</sup> selling these products as both standalone and integrated solutions.<sup>619</sup> Infineon’s Wireless Solutions division, a later version of the original Wireless Communications group,<sup>620</sup> would eventually be acquired by Intel in 2011.<sup>621</sup>

285. Infineon’s wireless business strategy was not to lead the modem chip industry in technological sophistication or features, but instead to pursue a fast-follower strategy.<sup>622,623</sup> According to Thomas Lindner, who worked in sales and product marketing at Infineon,<sup>624</sup> this meant that Infineon did not pursue opportunities to “exceed or to reach out too far beyond” the set of features customers were requesting, since the company lacked “the ambition to [...] add

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<sup>618</sup> See, e.g., Infineon, Form 20-F, 2000, p. 10 (“In addition to our strength in wireline, we have an outstanding market position in wireless communications. We are number one in radio frequency ICs, and number two in baseband ICs for mobile phones.”). See also “Cellular Handset & Chip Markets,” Forward Concepts, 2005, p. 280 (“Infineon is noted as a leading supplier of RF components and baseband [processors] and is also a leading cellphone module supplier.”); “Cellular Handset & Chip Markets,” Forward Concepts, 2007, p. 131 (“Infineon is the market leader in (non-captive) handset transceivers with more than 230 million units shipped in 2006.”).

<sup>619</sup> Eul Deposition, Intel, p. 31 (“Q. Did Infineon make and sell RF transceivers at this time? A. Yes. Q. And did Infineon often sell the RF transceivers together with baseband processors? A. We sold them together with the baseband processor, and we sold them standalone.”).

<sup>620</sup> Infineon, Form 20-F, 2009, p. 7 (“The Wireless Solutions segment designs, develops, manufactures and markets a wide range of ICs, other semiconductors and complete system solutions for wireless communication applications.”).

<sup>621</sup> “Intel Completes Acquisition of Infineon’s Wireless Solutions Business,” Intel Press Release, January 31, 2011 (“Intel Corporation today announced that it has completed the acquisition of the Infineon Technologies AG Wireless Solutions (WLS) business.”).

<sup>622</sup> See Sections III.D and III.E for a general overview of the fast-follower strategy.

<sup>623</sup> See, e.g., Lindner Deposition, Intel, pp. 16–17 (“Q. And when you were at Infineon, did the Infineon Wireless division, in your understanding, pursue a fast-follower strategy? A. Yes.”). See also Eul Deposition, Intel, p. 53 (“Q. And do you recall that term being used to describe how Infineon’s wireless business positioned itself? A. There are people that like to do that.”); “Infineon Communication On The Move: Lehman Brothers 3W Conference,” Infineon, June 1, 2005, p. 7 (“Strategic Re-Positioning of Infineon Communication[: ] Mobile Phone[: ] Fast follower, catching up in 3G and multimedia[: ]”).

<sup>624</sup> See, e.g., Lindner Deposition, Intel, pp. 9–10 (“Q. All right. So you joined Comneon, the Infineon subsidiary, on January 1 of 2000? A. Right. Q. And what job position did you hold then? A. I’ve had different positions in sales, marketing and customer support. So I was heading and building up the sales and marketing department. [...] I continued with sales and marketing, heading the team; and also had a role in Infineon doing the software marketing within the Mobile Platform Group. [...] Q. And how long did you stay in the software area? A. I stayed in the software area until the summer of 2010 and then changed over to Infineon to the Entry Phone division and was taking care there for strategic planning and product marketing.”).

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something on top to get in a further leading position.”<sup>625</sup> According to an industry observer, by waiting until a wireless technology had matured before attempting to release new products,<sup>626</sup> Infineon might have been able to learn from and avoid the mistakes of suppliers that were leading the way with respect to technological innovation.<sup>627</sup>

286. In 2000, Infineon released an early multi-mode modem chip implementing both GSM and GPRS.<sup>628</sup> [REDACTED]  
[REDACTED]. Infineon would go on to also supply chips for the iPhone 3G, iPhone 3GS, and iPhone 4 (GSM).<sup>630</sup> In 2006, Infineon released the E-GOLDradio and E-GOLDvoice, two single-chip GSM solutions targeting low-cost devices,<sup>631</sup> with Nokia selecting the E-GOLDvoice for a number of its entry-

<sup>625</sup> Lindner Deposition, Intel, p. 17 (“Q. And what did you understand [a ‘fast-follower’ strategy] to mean? A. [...]voiding to exceed or to reach out too far beyond so that every product during its lifetime had the right feature set. [...]W]e had not the ambition to [...] add something on top to get in a further leading position.”).

<sup>626</sup> Eul Deposition, Intel, Exhibit QX98, INTEL-QCOM005246267 at p. 2 (Infineon, “The new world: ‘From Fast Follower to Leader,’” 2010, “Follower[:] Start development after specification freeze of standard[.]”).

<sup>627</sup> Olson, Parmy, “iPhone a Risk with Intel’s Latest Buy,” *Forbes*, August 31, 2010 (“[...] Infineon decided that by being a ‘fast follower’ of the new technology [3G], it might not make some of the mistakes that the leading players would.”).

<sup>628</sup> Infineon, Form 20-F, 2001, p. 38 (“In 2000, we [...] introduced the first dual mode GPRS/GSM single baseband chip.”).

<sup>629</sup> [REDACTED]

<sup>630</sup> [REDACTED]

<sup>631</sup> See, e.g., “Cellular Handset & Chip Markets,” *Forward Concepts*, 2006, pp. 98–99 (“The E-GOLDvoice single-chip solution combines a baseband processor, RF transceiver, power management unit and RAM [...]. The chip is the heart of Infineon’s latest platform for ultra low-cost handsets, ULC2.”). See also “Cellular Handset & Chip Markets,” *Forward Concepts*, 2007, p. 174 (“Last year, Infineon unveiled its first-generation SoC platform for cheap phones [...]. The ‘E-GOLDradio’ platform reduced the number of components from 200 to 100 by combining, among other things, the baseband and RF components into a single chip. [...] Later in 2006, they unveiled ‘E-GOLDvoice’, its second generation ULC [...]”) and p. 199 (“Infineon’s single-package GSM baseband-radio E-GOLDradio and the world’s first GSM baseband-RF-PMU SoC E-GOLDvoice are enabling a Bill-of-Material (BOM) [cost] below \$16 for a GSM, voice & SMS-only handset.”).

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level handsets.<sup>632</sup> In 2007, Infineon acquired LSI Corporation’s Mobility Products Group, which had previously belonged to Agere, giving it access to Agere’s line of EDGE modem chips.<sup>633</sup> Infineon also developed 2G and 3G modem chips that appeared in handsets released by OEMs like LG and Samsung,<sup>634,635</sup> but it did not develop a modem chip that was CDMA compatible.<sup>636</sup>

287. In 2010, as LTE was emerging as a 4G standard, [REDACTED]

[REDACTED]<sup>637</sup>, <sup>638</sup> In November 2010, Infineon acquired Germany-based Blue Wonder Communications and all its employees, citing the belief that “Blue Wonder’s special LTE know-how complement[ed] the long-standing LTE development activities of [Infineon].”<sup>639</sup>

<sup>632</sup> Hammerschmidt, Christoph, “Nokia Uses Infineon Chip for Entry-Level Phones,” EE Times, February 7, 2007 (“[...] Nokia Corp. has selected Infineon Technologies AG’s E-Goldvoice line of single-chip solutions for some of its entry-level GSM phones.”).

<sup>633</sup> See, e.g., “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 126 (“In August 2007, [Infineon] entered into an agreement to acquire the Mobility Products Group of LSI Corporation, which provided it with the Agere Systems EDGE baseband solutions sold to Amoi, NEC and Samsung.”). See also LaPedus, Mark, “Infineon Buys LSI’s Mobility Product Line,” EE Times, August 20, 2007 (“LSI’s Mobility Products Group comprises mainly mobile radio baseband processors and platforms that complement Infineon’s existing portfolio. [...] Originally, LSI’s Mobility Products Group belonged to Agere Systems.”).

<sup>634</sup> Hammerschmidt, Christoph, “LG Electronics Selects Infineon Mobile Platform,” EE Times, July 17, 2006 (“Beginning with the recent introduction of new phones by LGE, Infineon’s MP-E platform [...] will be used in a series of EDGE mobile phones from LGE.”).

<sup>635</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2010, p. 82 (“Samsung is using Infineon’s complete 3G-chip platform beginning with the very successful Galaxy S in 2010 [...].”).

<sup>636</sup> Evans Deposition, Intel, p. 33 (“Q. What did you learn about the status of [Infineon’s] modem development efforts? A. [...] They had a gap in CDMA [...].”). See also Wolff Deposition, Intel, p. 26 (“Q. Did any of these chips shown here [in Exhibit QX20] on this page (page 2) have CDMA compatibility? A. No.”); Wolff Deposition, Intel, Exhibit QX20, 86600DOC074395, p. 2 (Infineon, “Infineon WLS RS Platform Roadmap,” February 2010).

<sup>637</sup> [REDACTED].

[REDACTED]

<sup>639</sup> Infineon had been working on LTE modem chip development with Blue Wonder for about 18 months prior to the acquisition date. Clarke, Peter, “Intel to Acquire Dresden LTE Firm,” EE Times, November 3, 2010, (“Infineon’s wireless business unit [...] is taking over Blue Wonder Communications GmbH, a specialist in LTE communications. Blue Wonder (Dresden, Germany) was founded in 2008 and provides LTE intellectual property. [...] Infineon’s wireless business unit has been working with Blue Wonder for about 18 months on

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[REDACTED]

[REDACTED]<sup>640</sup>

288. Intel announced its plans to acquire Infineon’s Wireless Solutions division in August 2010,<sup>641</sup> and the deal was completed in January 2011.<sup>642</sup> [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]<sup>643</sup> As discussed in Section III.C, while pure-play suppliers dedicate their efforts to the production of a single input, broadliners can offer a variety of products and supply multiple inputs. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]<sup>644</sup> The sale of the wireless group also allowed Infineon to prioritize its leading positions in its other business segments.<sup>645</sup>

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the development of baseband technologies for the Long Term Evolution (LTE) mobile standard [...]. ‘Blue Wonder’s special LTE know-how complements the long-standing LTE development activities of WLS.’”).

<sup>640</sup> [REDACTED]

<sup>641</sup> Leske, Nicola, and Noel Randewich, “Intel Buys Infineon Unit and Expands Wireless Offer,” Reuters, August 29, 2010, available at <https://www.reuters.com/article/us-infineon-intel-idUSTRE67Q3J820100830> (“[...] Intel Corp unveiled a deal [...] to buy German chipmaker Infineon Technologies AG’s wireless unit for \$1.4 billion [...].”).

<sup>642</sup> “Intel Completes Acquisition of Infineon’s Wireless Solutions Business,” Intel Press Release, January 31, 2011 (“Intel Corporation today announced that it has completed the acquisition of the Infineon Technologies AG Wireless Solutions (WLS) business.”).

<sup>643</sup> [REDACTED]

<sup>644</sup> [REDACTED]

<sup>645</sup> Infineon, Form 20-F, 2010, p. 8 (“We have also actively pressed ahead with portfolio management in the last two years: [...] an agreement was signed in summer 2010 for the sale of the mobile phone business of the Wireless Solutions (WLS) segment to Intel. By taking these measures we focused Infineon on less volatile, rapidly growing target markets in which we occupy leading market positions.”).

*b. Analysis*

289. Infineon’s outcomes in the modem chip industry can be explained by early alignment with demand despite poor long-term foresight, limited but well-targeted investment, and mixed execution. Much of Infineon’s success can be traced to its alignment with Apple’s initial specifications for the first-generation iPhone. However, Infineon never obtained CDMA technology and fell behind with respect to LTE development, which affected the company’s ability to retain its customers as new technologies were embraced. While Infineon never attempted to lead at the technological forefront of the industry and invested accordingly, its investment in business acquisitions helped expand its customer base. Finally, although Infineon excelled at developing robust low-cost solutions, Infineon’s willingness to provide customized solutions led to organizational inefficiencies, and Apple’s belief that Infineon was reluctant to dedicate resources to achieve leading-edge performance contributed to a negative perception from some employees at Apple.

290. Foresight: Infineon was well positioned to compete for Apple’s business when Apple first began designing the iPhone, but it was ill prepared to supply chips to Apple once Apple’s technological requirements evolved. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

646

648

<sup>653</sup> See Exhibit V.C.14a.

291.

[REDACTED]

292. As testified to by Intel’s Aichatou Evans, Infineon did not pursue a leading position for LTE, instead opting to serve as an implementer that would wait until the market had matured before developing LTE capability.<sup>658</sup> [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

<sup>657</sup> Williams IH, Apple, pp. 30–31 (“Q. Following the introduction of Qualcomm cellular chipsets in the CDMA iPhone 4, is it the case that Apple only used Qualcomm chipsets [...] in every new model of iPhone launched from that point up through September 2015? A. Correct.”).

<sup>658</sup> Evans Deposition, Intel, pp. 33–34 (“Q. What do you mean by the term ‘fast follower’? A. [...]the initial investment, seat at the table for leading edge did not seem to be what [Infineon] had chosen to do for LTE. They had chosen to let the market develop and then implement, essentially. So more of an implementor as opposed to a leadership setter [...].”).

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[REDACTED]

293. *Investment:* [REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]

- 
- 659 [REDACTED]
- [REDACTED]
  - [REDACTED]
  - [REDACTED]
  - [REDACTED]
  - [REDACTED]
  - [REDACTED]

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294. However, Infineon’s 2007 acquisition of LSI Corporation’s Mobility Products Group is an example of a strategic investment, which yielded widespread benefits. The LSI Corporation transaction not only gave Infineon access to Agere’s product line,<sup>665</sup> but also possibly aided Infineon in winning future Samsung sockets. At the time of the transaction, Samsung was one of a few companies purchasing Agere’s EDGE modem chips from LSI Corporation and was purchasing RF transceivers from Infineon as well.<sup>666</sup> Therefore, this acquisition presented Infineon with an opportunity to work more closely with Samsung on modem chip development, since Infineon would now be supplying Samsung with both modem chips and RF transceivers. Industry analysts also believed that the Agere assets would assist Infineon in developing competitive 3G products.<sup>667</sup> Increased communication between Infineon and Samsung and improved 3G competency may have contributed to Samsung’s selection of Infineon’s XMM6080 modem chip in 2008 and its decision to use an Infineon chip in the Galaxy S in 2010.<sup>668,669</sup>
295. Execution: Although Infineon’s low-cost offerings were desired by many mobile device OEMs, after its early wins, Infineon struggled to execute for Apple. Infineon’s 2006 E-GOLDvoice

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<sup>665</sup> Agere was acquired by LSI Logic in 2007 and the new entity was named LSI Corporation. Shortly thereafter, LSI’s Mobility Products Group, which had previously belonged to Agere, was sold to Infineon. See Exhibit III.D.1.

<sup>666</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 126 (“In August 2007, [Infineon] entered into an agreement to acquire the Mobility Products Group of LSI Corporation, which provided it with the Agere Systems EDGE baseband solutions sold to Amoi, NEC and Samsung. But, Samsung had already been buying EDGE transceivers from Infineon since 2006. [...] Infineon was already the RF supplier for many Agere platforms so the acquisition extends that partnership.”).

<sup>667</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 126 (“[...] Infineon can use Agere’s resources to beef up its 3G development effort and attempt to win 3G business at other OEMs.”).

<sup>668</sup> See, e.g., “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 173 (“[...] Samsung has committed to trying Infineon’s complete 3G-chip platform for 2008.”). See also “Samsung Selects Infineon HSDPA Platform for HEDGE Mobile Phone Family,” Infineon Press Release, April 23, 2008 (“Infineon Technologies AG today announced that Samsung Electronics, Inc., Seoul, Korea, has chosen Infineon’s HSDPA Platform XMM 6080 for their new family of HEDGE (HSDPA/EDGE) mobile handsets. [...] The platform includes the HSDPA/EDGE baseband, power management, single chip 3.5G RF transceiver and is complemented by Infineon’s protocol stack for HEDGE phones.”).

<sup>669</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2010, p. 82 (“Samsung is using Infineon’s complete 3G-chip platform beginning with the very successful Galaxy S in 2010 [...]”).

was superior to competing products along multiple dimensions. First, Infineon drastically reduced the number of separate components needed for low-cost phones by integrating more components onto a single chip as compared to, for example, TI.<sup>670</sup> Second, Infineon was able to offer the E-GOLDvoice at a lower price than competitors’ chips.<sup>671</sup> Third, Infineon was able to target the E-GOLDvoice to customers in emerging markets by offering the most in-demand features and stripping away unnecessary functionality.<sup>672</sup> As a result, Infineon realized great success with the E-GOLDvoice, a key example being the company’s 2007 entry-level handset design win with Nokia,<sup>673</sup> which took low-cost business away from TI.<sup>674</sup> The Nokia contract, along with business from other OEMs such as ZTE and Huawei and tremendous growth in the demand for low-cost devices,<sup>675</sup> enabled Infineon to ship 100 million ultra-low-cost chips in 2008 – up from 50 million chips in 2007 – and contributed to Infineon’s significant increase in chip sales from 2007 to 2008.<sup>676</sup>

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<sup>670</sup> See, e.g., “Cellular Handset & Chip Markets,” Forward Concepts, 2007, p. 192 (“E-GOLDvoice’ [...] which shrinks the number of components to less than 50 and integrates power management and static random-access memory [...]).” See also “Cellular Handset & Chip Markets,” Forward Concepts, 2008, pp. 126–127 (“Infineon actually has an advantage over TI in not requiring a separate Power Management Unit (PMU).”).

<sup>671</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 126 (“Infineon’s E-GOLDvoice is the lowest-cost GSM single-chip solution available today.”) and p. 232 (“[...]T]he world’s first GSM baseband-RF-PMU SoC, E-GOLDvoice, are enabling a Bill-of-Material (BOM) costs below \$16 for a GSM, voice & SMS-only handset.”).

<sup>672</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2008, pp. 126–127 (“In this segment [Infineon] must compete with Texas Instruments with its GSM/GPRS LoCosto single-chip (baseband and RF) solution. On the surface, having support for GPRS may seem like an advantage, but these devices are primarily targeted at the entry level voice-centric GSM handset markets in emerging countries. [...] More important is the integration of the FM radio function, which has caught on in emerging markets [...]. Infineon is embedding this function in 2008.”).

<sup>673</sup> Hammerschmidt, Christoph, “Nokia Uses Infineon Chip for Entry-Level Phones,” EE Times, February 7, 2007 (“[...] Nokia Corp. has selected Infineon Technologies AG’s E-Goldvoice line of single-chip solutions for some of its entry-level GSM phones.”).

<sup>674</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 33 (“Nokia has diversified by announcing a low-cost, GSM single-chip deal with Infineon Technologies, which could eat into TI’s ‘LoCosto’ monolithic GSM chips.”).

<sup>675</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2007, p. 191 (“We expect that by 2011, almost one of every four handset shipped globally will be an ultra-low-cost handset. [...] We expect the ultra-low-cost (ULC) market to grow annually from 12-million units in 2006 to more than 175 million in 2010.”).

<sup>676</sup> See Exhibit V.C.1. See also “Cellular Handset & Chip Markets,” Forward Concepts, 2009, p. 197 (“The Infineon huge gain in sales was attributed to Nokia’s commitment (2/07) to use the monolithic ULC2 (E-Goldvoice) for the new entry-level portfolio in 2008. [...] Nokia, ZTE, Huawei have all delivered low-cost

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296. Despite this success, Infineon inefficiently duplicated efforts and spent substantial resources crafting customized products. [REDACTED]

[REDACTED].<sup>677</sup> However, being receptive to customization also had some negative consequences for Infineon. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]<sup>678</sup>

297. Finally, [REDACTED]  
[REDACTED]. In 2008, analyst and press reports noted problems with call drops for the iPhone 3G, with one report stating that these issues “are typical of an immature chipset and radio protocol stack.”<sup>679</sup> [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

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GSM phones based on Infineon’s integrated chip. Infineon shipped 50 million in 2007 and 100 million in 2008.”).

<sup>677</sup> [REDACTED]

<sup>678</sup> [REDACTED]

<sup>679</sup> INTEL-QCOM000695940, p. 5, presentation titled “IFX Comments on Articles Reporting Call Drops of iPhones,” Infineon, August 13, 2008.

<sup>680</sup> [REDACTED]

## 2. Intel

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Communications and other investment efforts.<sup>688,689</sup> Analysts described the line of products that Intel acquired from DSP as one which Intel “pumped untold dollars into a black hole for years.”<sup>690</sup> After acquiring DSP, Intel sold a 2G SoC to British carrier O2 as well as a 3G SoC to Blackberry and to the Japanese firm NTT DoCoMo.<sup>691,692</sup> Despite these design wins, the Intel modem and AP business unit failed to gain traction in the mobile wireless space.<sup>693</sup> Analysts explained that Intel had entered the modem chip industry too late, as it “was pretty mature by the time Intel got involved” and was defined by “very thin profit margins” and “really bloodthirsty competition.”<sup>694</sup> Looking to “refocus on areas [...] core to its strength,” “eliminate nonperforming business units,” and generate cash to compete with Advanced Micro

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<sup>688</sup> LaPedus, Mark, “Updated: Intel Puts Comms-Chip Businesses Up for Sale, Says Report,” EE Times, June 3, 2006 (“Intel [...] spent more than \$10 billion to enter the communications business over the years [...].”).

<sup>689</sup> “Intel to Acquire DSP Communications, Inc. for Approximately \$1.6 Billion in Cash,” Intel Press Release, October 14, 1999 (“Intel Corporation and DSP Communications, Inc. [...] today announced the companies have entered into a definitive agreement under which Intel would acquire DSP Communications [...]. DSPC is a leading supplier of solutions for digital cellular communications products.”). See also Kawamoto, Dawn, “Intel Sells Off Communications Chip Unit,” CNET, June 27, 2006 (“Intel’s sale of its chip business for mobile handhelds and cell phones [...] will also remove a business that [...] has weighed down the company’s overall financial performance, despite billions of dollars in investments.”).

<sup>690</sup> Ferranti, Marc and Nancy Gohring, “Intel Sells Communications Unit to Marvell,” Computerworld, June 27, 2006.

<sup>691</sup> Krazit, Tom, “RIM agrees to use Intel’s Hermon Mobile Chip,” InfoWorld, September 27, 2005 (“Manitoba was an integrated design that combined an applications processor, a GSM/GPRS (Global System for Mobile Communications/General Packet Radio Services) modem, and flash memory integrated onto a single piece of silicon. However, U.K. carrier O2 Ltd. was the only company to ever release a Manitoba phone [...].”)

<sup>692</sup> While Intel’s Hermon SoC could support 3G standards, it was used by Blackberry on the legacy 2G EDGE standard. See, e.g., Krazit, Tom, “RIM agrees to use Intel’s Hermon Mobile Chip,” InfoWorld, September 27, 2005 (“[...] Hermon can run on the more advanced UMTS [...] networks [...]. RIM’s initial plans for Hermon, however, center around building a phone for EDGE [...] networks.”); See also “Marvell to Purchase Intel’s Communications and Application Processor Business for \$600 Million,” Intel Press Release, June 27, 2006 (“[Intel’s] processors, based on Intel XScale technology, include the Intel PXA9xx communications processor, codenamed ‘Hermon,’ which powers Research in Motion’s (RIM) Blackberry 8700 device.”); Krazit, Tom, “Intel’s Cell Phone Efforts Still on Hold,” CNET, March 10, 2006 (“[...]he only 3G, or third-generation, operator using Hermon is NTT DoCoMo, which is using Hermon-based modules to record wireless payments made at vending machines.”).

<sup>693</sup> Kawamoto, Dawn, “Intel Sells Off Communications Chip Unit,” CNET, June 27, 2006 (“The sale will also remove a business that struggled to take off [...].”).

<sup>694</sup> Ferranti, Marc and Nancy Gohring, “Intel Sells Communications Unit to Marvell,” Computerworld, June 27, 2006.

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Devices (AMD) in the computer processor market,<sup>695</sup> Intel sold its modem and AP business to Marvell in 2006.<sup>696</sup>

299. Following this sale to Marvell, Intel refocused its development efforts on processors that implemented its in-house x86 architecture.<sup>697</sup> More specifically, Intel adapted its processor technology that had been successful in the PC industry for use in a mobile handset.<sup>698</sup> This project culminated in 2008 when Intel released a standalone AP for mobile devices, code-named Atom, that was built on x86 technology.<sup>699</sup> In later years, Intel would go on to attempt to integrate the Atom AP with thin modems.

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<sup>695</sup> See, e.g., Smith, Tony, “Intel Chief to Chop Workforce?” The Register, April 28, 2006 (“Company executives will spend the next three months examining the business for under-performing or inefficient operations [...]”). See also Sylvester, IdaRose et al., “Event Flash: Marvell Buys Intel’s Handheld Processor Business for \$600 Million,” IDC, June 2006 (“Why now? Part of the answer is evident given Intel’s recent announcement back in April that the company would refocus on areas that were core to its strength and eliminate nonperforming business units.”); “Intel to Sell Chip Unit to Marvell,” LA Times, June 28, 2006 (“‘Intel is not as profitable as it once was, and times are looking tougher in the immediate future,’ Eric Ross, an analyst with ThinkEquity Partners, wrote in a research report. ‘Intel needs the cash to compete with Advanced Micro Devices and build the massive amount of capacity they plan.’”); Ferranti, Marc and Gohring, Nancy, “Intel Sells Communications Unit to Marvell,” ComputerWorld, June 27, 2006 (“The move is part of an Intel effort to shore up its core business in the face of increasing competitive pressure from Advanced Micro Devices Inc. and a slowing global PC market. Intel today identified mobile computing, in addition to the traditional PC market, as an area on which it plans to focus.”).

<sup>696</sup> “Marvell to Purchase Intel’s Communications and Application Processor Business for \$600 Million,” Intel Press Release, June 27, 2006.

<sup>697</sup> See, e.g., “Marvell to Purchase Intel’s Communications and Application Processor Business for \$600 Million,” Intel Press Release, June 27, 2006 (“The sale also will enable Intel to focus its investments on its core businesses, including high-performance, low-power Intel Architecture-based processors [...]”). See also Evans Deposition, Intel, p. 23 (“Q. What is ‘Intel architecture’? A. I mean, my definition of ‘Intel architecture’ is something that has – an IP that has the X86 instruction set, native.”).

<sup>698</sup> “Intel Announces Intel Atom Brand for New Family of Low-Power Processors,” Intel Press Release, March 2, 2008 (“The Intel Atom processor is based on an entirely new microarchitecture designed specifically for small devices and low power, while maintaining the Intel Core 2 Duo instruction set compatibility consumers are accustomed to when using a standard PC and the Internet.”).

<sup>699</sup> See, e.g., “Intel Announces Intel Atom Brand for New Family of Low-Power Processors,” Intel Press Release, March 2, 2008 (“The Intel Atom processor will be the name for a new family of low-power processors designed specifically for mobile Internet devices (MIDS) [...]”). See also Evans Deposition, Intel, p. 23 (“Q. [...] Does the Atom core use what is known as ‘Intel architecture’? A. Yes. Q. What is ‘Intel architecture’? A. I mean, my definition of ‘Intel architecture’ is something that has – an IP that has the X86 instruction set, native.”); “Cellular Handsets & Chip Markets,” Forward Concepts, June 2011, p. 259 (“Table 54 Stand-alone Application Processor Features & Usage (continued) [...] Company[:]; Intel [...] SA Processor Name[:]; Atom Z670.”).

300. Concurrent with investing in its Atom AP, Intel invested sizeable resources into the development of a 4G standard called WiMAX. WiMAX was a mobile wireless solution that was a technological outgrowth of Wi-Fi.<sup>700</sup> Delays in the mid-2000s diminished some of the lead WiMAX may have had on LTE.<sup>701</sup> In spite of these delays, some executives at Intel still claimed that WiMAX had a two to three year lead on LTE in 2008: as stated by Intel’s CTO of the Mobile Wireless Group, “Insatiable demand for the Mobile Internet continues to grow. WiMAX is here now to meet that demand. LTE is at least 2-3 years away.”<sup>702</sup> WiMAX definitively lost out to LTE as the accepted 4G standard nationwide in 2011 when Sprint (the remaining WiMAX advocate) announced it would stop selling WiMAX-compatible devices.<sup>703</sup>
301. After its first attempt at entry into the modem chip industry, in 2011, Intel initiated another attempt to enter the modem chip industry by acquiring Infineon’s Wireless Solutions business.<sup>704</sup> Infineon was a designer of GSM and WCDMA-compatible thin modems and a leading RF transceiver supplier whose thin modems had been selected by Apple for multiple

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<sup>700</sup> “Frequently Asked Questions about Intel WiMAX,” Intel (“What is WiMAX?[:] Overview[:] [...] WiMAX is a next-generation wireless network communications technology. The technology is similar to Wi-Fi but provides high-speed, broadband access over a larger area with less interference.”).

<sup>701</sup> See, e.g., “WiMAX Delay Shakes Investor Confidence: Realistic Deadlines Required,” *The Register*, January 21, 2005 (“Many WiMAX Forum members had expected public interoperability testing or ‘plugfests’ to start this month with fully certified equipment to be available from vendors by mid-year. Now, conformance testing, which matches specific equipment’s compatibility with the system profiles, will start in June, with plugfest beginning a month later and fully certified equipment appearing around the end of the year.”). See also Gardiner, Bryan, “Sprint Delays WiMAX Rollout, Again,” *Wired*, April 4, 2008 (“The soft-launches were delayed. Now, Sprint says it will also push back the commercial rollout of its Xohm WiMax service. [...] WiMax, of course, is perhaps best characterized by its amazing ability to \*not\* appear here in the U.S. – at least not in a commercial sense. The latest delay comes only a few months after Sprint assured CES attendees that it would begin rolling out the next-gen wireless network in April. While not giving a specific date for the new launch window (perhaps a wise move), analysts do expect the service to now appear sometime this summer. Maybe.”).

<sup>702</sup> “WiMAX and LTE – Our View,” Intel, June 6, 2008.

<sup>703</sup> Svensson, Peter, “Sprint: No More Clearwire Devices,” *USA Today*, October 7, 2011 (“Sprint Nextel Corp. said Friday that it will stop selling phones and other devices compatible with Clearwire Corp.’s [WiMAX] network at the end of next year, after it switches on its own higher-speed, fourth-generation data network.”).

<sup>704</sup> “Intel Completes Acquisition of Infineon’s Wireless Solutions Business,” Intel Press Release, January 31, 2011.

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iPhone sockets.<sup>705,706</sup> As discussed in Section V.C.1, Infineon’s business strategy was not to lead the modem industry in technological sophistication or features, but instead to pursue a fast-follower strategy.<sup>707</sup> [REDACTED]

[REDACTED]

[REDACTED].<sup>708</sup>

302. In the early 2010s, Intel released a line of 3G modems based on Infineon’s technology.<sup>709</sup> Intel’s efforts to develop a 4G LTE thin modem chip following its acquisition of Infineon’s modem chip business had less early success.

<sup>705</sup> Evans Deposition, Intel, p. 33 (“Q. What did you learn about the status of [Infineon’s] modem development efforts? A. That they had – had a lot of success; [they] had an insanely good RF team [...].”). See also “Cellular Handset & Chip Markets,” Forward Concepts, 2005, p. 280 (“Infineon is noted as a leading supplier of RF components [...]. The company’s original GSM baseband chips [...].”); Constantine Deposition, Intel, p. 19 (Q. And was [the XMM6080] a modem chip that had 3G capability, but not LTE capability? A. That’s right. During that time period, that was correct. Q. And, specifically, is that a modem chip that had what’s known as ‘WCDMA’ or sometimes ‘UMTS capability’? A. That’s correct, yes.”).

<sup>706</sup> Constantine Deposition, Intel, pp. 18–19 (“Q. All right. So while you were at Infineon, did Infineon sell modem chips to Apple for the iPhone? A. Yes. Yes, they did. Q. And did that include the XMM6080 chip for the iPhone 3G? A. I believe that is correct. [...] Q. And was that then followed by the XMM6160 chip in the iPhone 4? A. That’s correct, yes.”).

<sup>707</sup> Lindner Deposition, Intel, pp. 16–17 (“Q. And when you were at Infineon, did the Infineon Wireless division, in your understanding, pursue a fast-follower strategy? A. Yes.”). See also Evans Deposition, Intel, p. 55 (“[Infineon] had a gap around innovation, which resulted in [...] not being seen as a [...] leader, more as a fast follower [...].[...].”); “Infineon Communication on the Move,” Infineon (“Mobile Phone[:] Fast follower, catching up in 3G and multimedia[.]”).

<sup>708</sup> [REDACTED]

<sup>709</sup> See, e.g., LaPedus, Mark, “Intel-Infineon Deal: What Analysts are Saying,” EE Times, August 30, 2010 (“There are positive and negative implications for Intel regarding the Infineon transaction. Positives include: [...] (2) Infineon does have competitive wireless products including a 65-nm HSUPA platform (XMM 6160) [...].”). See also “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 81 (“[Intel] currently offer[s] four different 3G platforms, with varying data rates[:] XMM 6180 multimedia 3GPP Rel. 6, HSDPA cat 8 [...] [:] XMM 6160, based on X-Gold 616 baseband (65nm version) and RF Transceiver – HSDPA/HSUPA [...] [:] XMM 6080 HSDPA [...] [:] XMM 6130 HSDPA [...]”).

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303. [REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]

304. [REDACTED]  
[REDACTED]

- 
- [REDACTED]
  - [REDACTED]
  - [REDACTED]
  - [REDACTED]
  - [REDACTED]
  - [REDACTED]
  - [REDACTED]
  - [REDACTED]
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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

305.

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] Despite

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<sup>718</sup> See Exhibit V.C.2 and associated backup.

<sup>719</sup> “Intel Announces First Commercial Availability of 4G LTE Modem; Introduces Module for 4G Connected Tablets and Ultrabooks,” Intel Press Release, October 30, 2013 (“Intel Corporation today announced the commercial availability of its multimode, multiband 4G LTE solution. The Intel XMM 7160 platform is featured in the LTE version of the Samsung GALAXY Tab 3 (10.1), now available in Asia and Europe.”).

<sup>720</sup> [REDACTED]

<sup>721</sup> [REDACTED]

<sup>722</sup> [REDACTED]

<sup>723</sup> See, e.g., “Look Inside: Intel XMM 7160,” Intel.

<sup>724</sup> [REDACTED]

<sup>725</sup> [REDACTED]

<sup>726</sup> [REDACTED]

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[REDACTED]

[REDACTED]<sup>727</sup>

306. Intel experienced more setbacks with its next set of LTE modem chips. [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
307. Intel made strides to improve its standing in the industry in 2015. It finally acquired VIA Telecom in an attempt to add CDMA compatibility to its product portfolio.<sup>732</sup> [REDACTED]

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<sup>727</sup> See, e.g., “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 77 (“The [Intel] XMM6260 HSPA+ Category 14 21 Mbps is the modem inside the Samsung Galaxy SIII. The next generation supporting DC-HSPA+ up to 42 Mbps has appeared in the SIII LTE shipped into South Korea [...]”). See also Exhibit V.C.14c; Exhibit V.C.2.

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

<sup>732</sup> Goldstein, Phil, “Intel Continues to Pare Mobile Losses, Buys CDMA Modem Assets from VIA Telecom,” FierceWireless, October 14, 2015 (“Intel spokeswoman Stephanie Matthew confirmed to FierceWireless that the company had purchased VIA’s CDMA modem assets.”). See also [REDACTED]

[REDACTED]

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See also Hruska, Joel, “SoFIA Later: Intel Kills Upcoming Smartphone and Tablet Hardware,” ExtremeTech, April 29, 2016 (“The entire SoFIA project is canceled, in all

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] 742

310. At present, Intel’s mobile product portfolio is mostly limited to thin modems and standalone APs.<sup>743</sup> However, this has not hindered Intel’s ability to secure high-end sockets in the thin modem space, and Intel could always seek to develop an ARM-based SoC in the future. [REDACTED]
- [REDACTED]

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flavors [...]. We reached out to Intel, which confirmed the news: SoFIA 3GX, SoFIA LTE, SoFIA LTE2, and Broxton have all been canceled.”).

738 [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

<sup>742</sup> The use of external foundries is generally more expensive than using internal foundries, due to the so-called “foundry margin.” See, e.g., Tanner, Paige, “Could Intel’s Business Transition Impact Its Gross Margin?” Market Realist, July 14, 2017 (“Intel is an IDM (integrated design manufacturer), which handles the end-to-end process from chip design to manufacturing to packaging to selling. [...] The IDM model enables Intel to enjoy the profits of both a fabless company and a foundry.”). See Section III.D for further discussion on the “foundry margin.”

<sup>743</sup> See, e.g., “Baseband/Modem & Smartphone Market,” Forward Concepts, 2017, p. 65 (“Qualcomm and I[n]tel are the largest suppliers of standalone (alias Slim Modems) LTE/3G modems.”). See also “Intel Atom Processors,” Intel.

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[REDACTED] In addition, Intel is poised to be the primary, and potentially the sole, supplier for Apple’s forthcoming 2018 iPhones.<sup>745</sup>

311. With its most recent generation of LTE thin modems, to be released in 2018, Intel has succeeded in implementing CDMA backward compatibility; a technology Intel gained through its 2015 acquisition of VIA Telecom.<sup>746</sup> This new thin modem, the XMM7560, with its gigabit LTE speeds and global coverage, sets the stage for Intel’s position in 5G.<sup>747</sup>

*b. Analysis*

312. Intel’s history in the mobile space can be characterized by flawed foresight, high and inefficient investment, and execution difficulties regarding its x86-based chips and its early LTE-compatible thin modems. Intel’s focus on its PC semiconductor business unit has, at times, come at the expense of its mobile communications group. For example, the CEO of PC processor and server rival AMD claimed that Intel’s persistent focus in the 2000s on

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[REDACTED] See also Diaconescu, Adrian, “Apple Now Tipped to Retain Qualcomm as Backup Modem Supplier for Dual SIM 2018 iPhones,” PocketNow, November 20, 2017 (“[Mind-Chi Kuo, KGI Securities analyst] believes Intel will be able to supply Apple with between 70 and 80 percent ‘or more of required baseband chips’ for direct iPhone X and 8 sequels. The rest should still come from [...] Qualcomm [...]”).

<sup>746</sup> Evans Deposition, Intel, p. 316 (“Q. The XMM7560 that will be available this year will include CDMA capability, won’t it? A. Yes. [...] A. For the first time ever. Q. At Intel? A. Yes.”); See also Section V.C.11 for more background information on VIA Telecom.

<sup>747</sup> “Intel is Accelerating the 5G Future,” Intel Press Release, February 21, 2017 (“[...] Intel is at the forefront of this revolution, accelerating the path to 5G in collaboration with our customers and partners in the industry. [...] Intel’s portfolio brings a unique advantage to the acceleration of 5G. [...] Accelerating 5G from Cloud Network to Devices[:] Intel XMM 7560 modem for next generation of LTE Advanced Devices. This new modem will deliver Gigabit LTE speeds in a single SKU with global coverage.”).

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“squashing” AMD diverted attention away from Intel’s development in the mobile space.<sup>748,749</sup> Even though Intel’s first attempt at entering the modem space was relatively successful, Intel sold this early line of ARM-based modem chips to Marvell.<sup>750</sup> In addition, the sale allowed Intel to focus on developing modem chips using its proprietary x86 architecture. As a result, Intel pursued a proprietary chip and manufacturing technology that the industry did not embrace and that was difficult to transform for use in mobile devices from use in PCs. Furthermore, Intel also invested heavily in WiMAX, a 4G technology that ultimately did not gain wide popularity. Intel later successfully entered the industry when it acquiesced to demand and embraced 4G LTE rather than WiMAX when it stopped trying to use its desktop microprocessor architecture in an environment that did not demand it and when it began to offer features, like backward compatibility, that were sought after by customers.

313. In the past few years, Intel’s wins can be attributed to successful strategic acquisitions, improvements in LTE execution, and successes in learning from large mobile device OEMs and major carriers. Intel’s substantial financial resources have allowed it to invest and persist through its numerous foresight and execution challenges. Intel has invested in mobile communications R&D both internally and through the acquisition of other firms with potentially helpful technology,<sup>751</sup> such as Infineon and VIA Telecom.<sup>752</sup> In addition, Intel’s

<sup>748</sup> See also, Tanner, Paige, “Intel and AMD’s Duopoly in the PC Processor and Server Market,” Market Realist, January 15, 2016 (“AMD and Intel seem to have a duopoly in the PC processor and server market, with Intel accounting for more than an 80% share in the PC processor space and a 99% share in the server space.”).

<sup>749</sup> Madrigal, Alexis, “Paul Otellini’s Intel: Can the Company That Built the Future Survive It?,” The Atlantic, May 16, 2013 (“Ruiz, who led AMD’s last battle with Intel while he was CEO from 2002 to 2008, told me he thought Intel’s mobile progress had been slowed by their concentration on his company. ‘The focus the company has had for the past three decades on squashing AMD caused them to lose sight of the important trends towards mobility and low power,’ he said. ‘They should have focused more on their customers and the future than on trying to outdo AMD.’”).

<sup>750</sup> See, e.g., Ferranti, March and Nancy Gohring, “Intel Sells Communications Unit to Marvell,” ComputerWorld, June 27, 2006.

<sup>751</sup> For example, in [REDACTED]

[REDACTED] See also related discussion on [REDACTED] investment in Section III.E

<sup>752</sup> See, e.g., “Intel Completes Acquisition of Infineon’s Wireless Solutions Business,” Intel Press Release, January 31, 2011 (“[Dadi Perlmutter, Intel executive vice president and co-general manager of Intel Architecture Group said,] ‘[t]he acquisition [of Infineon] brings to Intel a world-class wireless portfolio and a proven track record in cellular communications, combined with our existing strength in computing positions us well for future growth.’”). See also Goldstein, Phil, “Intel Continues to Pare Mobile Losses, Buys CDMA Modem Assets from VIA Telecom,” FierceWireless, October 14, 2015 (“[Intel spokeswoman Stephanie Matthew said,] ‘VIA

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relationship with OEMs such as Samsung, Apple, and Nokia in the early 2010s helped Intel to improve upon vital features such as carrier aggregation and backward compatibility. Consequently, Intel’s recent line of LTE-compatible thin modems now offers performance that is almost comparable to modem chips offered by Qualcomm. However, Intel’s recent modem chip success has been limited to the thin-modem area, largely consisting of Intel’s sales to Apple.

*i. Foresight*

314. Intel has historically struggled to maintain strategic focus and to meet the demands of the mobile communications industry. A competitive analysis of Intel prepared by IDC in 2017 noted that Intel’s “[s]trategy swings reflect [an] inability to steer [the] organization.”<sup>753</sup> In particular, as discussed in more detail in the following paragraphs, Intel made three prominent strategic errors that slowed its growth in the modem chip industry. Although Intel’s shipment of chips declined sharply in the years leading up to 2016,<sup>754</sup> its recent efforts to respond to demand and learn from major carriers and mobile device OEMs have allowed it to improve product offerings and secure several Apple design wins for its thin-modem chips.

*a. Intel focused too heavily on x86*

315.

[REDACTED]

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Telecom will bring to Intel its CDMA technology, expertise in reference designs and complete platforms, as well as [its] skillset to deliver low-cost entry platforms.”).

<sup>753</sup> “Custom Competitive Analysis: Intel,” IDC Enabling Technologies Research Group, June 20, 2017, p. 5.

<sup>754</sup> See Exhibit V.C.2.

<sup>755</sup>

[REDACTED]

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[REDACTED]

[REDACTED]

[REDACTED]

316. Intel started developing modem chips in the early 2000s, including the Hermon chip released in 2006 that utilized the ARM architecture for the AP and implemented GSM and WCDMA standards. Intel had some success with this product offering in high-end handsets, as it was selected by RIM for use in a Blackberry device in 2006.<sup>757</sup> However, in the same year, Intel sold its ARM-based AP and modem chip product lines to Marvell,<sup>758</sup> which analysts linked in part to Intel wanting to refocus on its proprietary microprocessors.<sup>759</sup> Soon after, Intel abandoned the ARM architecture and started redeveloping its existing x86-processor architecture, used in desktop computers and servers, into a standalone AP code-named “Atom” that Intel could pair with thin modems.<sup>760</sup>

<sup>756</sup> [REDACTED]

<sup>757</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2006, p. 99 (“Realizing that they had largely missed the GSM/GPRS/EDGE market window, Intel embarked on an ambitious new UMTS [WCDMA]/GSM/EDGE chip design, codenamed ‘Hermon’ [...]. [...] The first announced Hermon customer is Research in Motion for its GSM/GPRS/EDGE Blackberry™ model 8700-series handset family.”). See also Moses, Asher, “Blackberry 8700 Review,” CNET, March 17, 2006 (“Typical Price: \$799”).

<sup>758</sup> “Marvell To Purchase Intel’s Communications And Application Processor Business for \$600 Million,” Intel Press Release, June 27, 2006 (“The business’ processors, based on Intel XScale technology, include the Intel PXA9xx communications processor, codenamed Hermon, which powers Research in Motion’s Blackberry 8700 device. [...] This planned sale does not impact the ability of other Intel business [...] to use ARM-based, Intel XScale processors.”).

<sup>759</sup> See, e.g., Sylvester, IdaRose et al., “Event Flash: Marvell Buys Intel’s Handheld Processor Business for \$600 Million,” June 2006, IDC #202382, Volume 2 (“Additionally, the timing of the announcement [...] culminates a campaign to regain product and market leadership in server microprocessors [...].”). See also Ferranti, Marc and Nancy Gohring, “Intel sells communications unit to Marvell,” ComputerWorld, June 27, 2006 (“The move is part of an Intel effort to shore up its core business in the face of increasing competitive pressure from Advanced Micro Devices Inc. and a slowing global PC market. Intel today identified mobile computing, in addition to the traditional PC market, as an area on which it plans to focus.”).

<sup>760</sup> See, e.g., “Intel Announces Intel Atom Brand for New Family of Low-Power Processor,” Intel Press Release, March 2, 2008, <http://www.intel.com/pressroom/archive/releases/2008/20080302comp.htm> (“The Intel® Atom™ processor will be the name for a new family of low-power processors designed specifically for mobile Internet devices [...]. [...] The Intel Atom processor is based on an entirely new microarchitecture designed specifically for small devices and low power, while maintaining the Intel® Core™ 2 Duo instruction set compatibility consumers are accustomed to when using a standard PC and the Internet.”). See also “Cellular

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317. Widespread adoption of Intel’s x86 architecture by the mobile industry had some practical limitations. For example, Intel’s Atom-based designs were reportedly ill suited for the mobile computing environment, as the resulting [REDACTED] [REDACTED] Chips based on the ARM architecture “are generally not as high-performance as Intel’s, but they [are] fantastically energy efficient.”<sup>762</sup> The combination of energy efficiency and low cost made ARM-based chips “exactly what mobile designers were looking for.”<sup>763</sup> In general, ARM processors dominated the handset processor space, and most mobile handsets, especially cellphones, had been developed for the rival ARM architecture, and not x86.<sup>764</sup> This meant that Intel’s Atom processor was incompatible with proprietary mobile-phone operating systems, which made “breaking into the cellphone market an uphill climb,” according to analysts.<sup>765</sup>

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Handsets & Chip Markets,” Forward Concepts, June 2011, p. 259 (“Table 54 Stand-alone Application Processor Features & Usage (continued) [...] Company[:] Intel [...] SA Processor Name[:] Atom Z670.”).

<sup>761</sup> See, e.g., Ganapati, Priya, “Why Intel’s Processors Aren’t Big on Cellphones,” Wired, July 6, 2009 (“Intel is being held back in the mobile sphere by its inability to offer power consumption on par with ARM’s chips, say analysts. [...] ‘Atom today is not suitable for cellphones,’” acknowledges [Pankaj] Kedia [a director in Intel’s ultra mobility group].”). See also [REDACTED]

[REDACTED] “#412 Special: China - Smartphones and the Cloud,” Deutsche Bank, Signals to Noise (S2N), January 24, 2012, p. 5 (“Moreover, we did not speak with a single handset maker who said they would even consider using Atom or x86 in their phones, echoing the commonly held view that x86 is not power efficient for cellular. [...] Designed originally for PCs with ample room for fans, heat sinks and cooling elements x86, they tell us, give off far more heat than other processors. Cell phones have rigorous temperature specs in addition to the more widely known RF requirements. [...] There is no room in a phone for a fan or heat sink [...]).

<sup>762</sup> Madrigal, Alexis, “Paul Otellini’s Intel: Can the Company That Built the Future Survive It?,” The Atlantic, May 16, 2013.

<sup>763</sup> Madrigal, Alexis, “Paul Otellini’s Intel: Can the Company That Built the Future Survive It?,” The Atlantic, May 16, 2013.

<sup>764</sup> See, e.g., Ganapati, Priya, “Why Intel’s Processors Aren’t Big on Cellphones,” Wired, July 6, 2009 (“Meanwhile, Intel rival ARM, whose chips are packaged and sold through companies such as Qualcomm, Samsung and Texas Instruments, has gained nearly 90 percent of the cellphone processor market. ‘Traditionally cellphones have been designed on the ARM processor and it is not easy to change it,’ says Jack Gold, principal analyst with consulting firm J. Gold Associates.”).

<sup>765</sup> Ganapati, Priya, “Why Intel’s Processors Aren’t Big on Cellphones,” Wired, July 6, 2009 (“Add to that the notion that Atom is untested for mobile phones and the fact that many proprietary mobile-phone operating systems are not compatible with Intel’s x86 architecture [...]).

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED].<sup>770</sup>

- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] The SoC business was canceled in 2016.<sup>778</sup>

*b. Intel prioritized investment into WiMAX, which was ultimately not adopted as a standard*

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

<sup>778</sup> Hruska, Joel, “SoFIA Later: Intel Kills Upcoming Smartphone and Tablet Hardware,” ExtremeTech, April 29, 2016 (“According to an article by Patrick Moorhead of Moor Insights & Strategy [... t]he entire SoFIA project is canceled, in all flavors [...]. We reached out to Intel, which confirmed the news: SoFIA 3GX, SoFIA LTE, SoFIA LTE2, and Broxton have all been canceled.”).

322. First, WiMAX could not offer the same breadth of coverage as could LTE, all else equal, which hampered WiMAX from becoming a successful interface for smartphones and other mobile devices. [REDACTED]

<sup>781</sup> See, e.g., “Frequently Asked Questions about Intel WiMAX,” Intel (“What is WiMAX [:] Overview: [...] WiMAX is a next-generation wireless network communications technology. The technology is similar to Wi-Fi but provides high-speed, broadband access over a larger area with less interference.”). See also

limited by the difficulties WiMAX had traveling sizable distances and in penetrating barriers such as walls.<sup>785</sup>

323. Second, although WiMAX development started with a multi-year lead over LTE,<sup>786</sup> development of a mobile WiMAX network was delayed.<sup>787</sup> According to an employee at GlobalFoundries, a semiconductor foundry, WiMAX backers squandered their development lead by focusing first on fixed (non-mobile) applications of WiMAX before working on mobility solutions.<sup>788</sup> This lost time allowed those companies that backed LTE to catch up.<sup>789</sup>
324. Finally, WiMAX failed to achieve widespread adoption by network carriers. While Sprint initially supported the WiMAX standard,<sup>790</sup> carriers such as Verizon and AT&T instead supported LTE.<sup>791</sup> The number of phone users on LTE networks grew quickly, surpassing

<sup>785</sup> Segan, Sascha, “WiMAX vs. LTE: Should You Switch?,” PCMag, May 16, 2012 (“Sprint’s WiMAX system has always been challenged by being on the very high frequency 2.6 GHz band. The band can support a lot of users, but it has trouble with distance and wall penetration.”).

<sup>786</sup> Hamblen, Matt, “WiMAX vs. Long Term Evolution: Let the Battle Begin,” Computerworld, May 14, 2008 (“Still, as of now, LTE is not even a set standard. [...] The IEEE [...] picked 802.16e as its mobile WiMAX standard in late 2005 [...]. Intel executives still believed that WiMAX had a 2-3 year lead on LTE as of 2008. See, e.g., “WiMAX and LTE – Our View,” Intel, June 6, 2008 (“Insatiable demand for the Mobile Internet continues to grow. WiMAX is here now to meet that demand. LTE is at least 2-3 years away.”).

<sup>787</sup> See, e.g., “WiMAX Delay Shakes Investor Confidence: Realistic Deadlines Required,” The Register, January 21, 2005 (“Many WiMAX Forum members had expected public interoperability testing or ‘plugfests’ to start this month with fully certified equipment to be available from vendors by mid-year. Now, conformance testing, which matches specific equipment’s compatibility with the system profiles, will start in June, with plugfest beginning a month later and fully certified equipment appearing around the end of the year.”). See also Gardiner, Bryan, “Sprint Delays WiMAX Rollout, Again,” Wired, April 4, 2008 (“WiMax, of course, is perhaps best characterized by its amazing ability to \*not\* appear here in the U.S. – at least not in a commercial sense. The latest delay comes only a few months after Sprint assured CES attendees that it would begin rolling out the next-gen wireless network in April. While not giving a specific date for the new launch window (perhaps a wise move), analysts do expect the service to now appear sometime this summer. Maybe.”).

<sup>788</sup> APL-QC-FTC\_37372708–2709 at 2708, email from Amitabh Kumar, GlobalFoundries, November 3, 2014 (“WiMAX needed to go after the mobility market earlier and grab the time to market advantage. The decision of the WiMAX backers to first focus on [...] fixed play [...] and delay mobility play [...] provided additional time for LTE backers to catch up[.]”).

<sup>789</sup> APL-QC-FTC\_37372708–2709 at 2708, email from Amitabh Kumar, GlobalFoundries, November 3, 2014 (“The decision of the WiMAX backers to first focus on [...] fixed play [...] and delay mobility play [...] provided additional time for LTE backers to catch up[.]”).

<sup>790</sup> Reed, Brad, “LTE vs. WiMAX: When it comes to the U.S. handset market, LTE has landed a knockout blow,” Network World, November 2, 2011 (“The other reason that WiMAX never caught on in the United States is that the only carrier to adopt it early on happened to be Sprint.”).

<sup>791</sup> See, e.g., Reed, Brad “LTE vs. WiMAX: When it comes to the U.S. handset market, LTE has landed a knockout blow,” Network World, November 2, 2011 (“Once Sprint gets its LTE network up and running, it will mean that all three major wireless carriers in the United States support LTE, as both Verizon and AT&T already

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those on WiMAX in 2011.<sup>792</sup> In October 2011, Sprint announced that it would stop selling phones compatible with its WiMAX network,<sup>793</sup> leaving LTE the de facto 4G standard.<sup>794</sup>

[REDACTED]

commercially deployed LTE in various markets.”). See also “LTE: The Future of Mobile Broadband Technology,” Verizon, 2009, p. 3 (“Verizon Wireless chose LTE over WiMAX as the technological foundation for its 4G wireless broadband network.”).

<sup>792</sup> See, e.g., Lam, Wayne, “Global LTE Subscribers Set to More Than Double in 2013 and Exceed 100 million,” IHS Markit, January 22, 2013 (“Since being adopted in 2010 with just 612,000 users, the 4G next-generation wireless technology has grown by leaps and bounds, surging by an astounding factor of 22 to 13.2 million subscribers in 2011 [...].”). See also Exhibit QX74, Keddy Deposition, Intel, INTEL-QCOM008124586, p. 61 (Slide contains a graph of ‘worldwide mobile subscriptions’ in millions for LTE and WiMAX, demonstrating that WiMAX had more subscribers than LTE from 2007 through part of 2011. Then the graph shows that LTE overtook WiMAX in terms of mobile subscriptions in 2011, stating “WiMAX first to market but quickly overtaken by LTE[.]”).

<sup>793</sup> Svensson, Peter, “Sprint: No More Clearwire Devices,” USA Today, October 7, 2011 (“Sprint Nextel Corp. said Friday that it will stop selling phones and other devices compatible with Clearwire Corp’s [WiMAX] network at the end of next year, after it switches on its own higher-speed, fourth-generation data network.”).

<sup>794</sup> Reed, Brad, “When it comes to the U.S. handset market, LTE has landed a knockout blow,” Network World, November 2, 2011 (“The chief reason for WiMAX’s downfall in the consumer handset space is a simple one: the tech industry likes uniformity and WiMAX wasn’t adopted by enough carriers to make it the de facto standard for 4G mobile data in the U.S. [...] ‘WiMAX has suffered significantly in the past two years as LTE has been adopted by more and more commercial operators around the world,’ writes wireless analyst Andy Seybold. ‘It should be clear to everyone by now that LTE will be the 4G technology of choice for worldwide deployment [...]’”).

<sup>795</sup> [REDACTED]

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[REDACTED]

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[REDACTED]

[REDACTED]

*c. Intel failed to offer features that were widely demanded*

326. Intel did not align its product offerings with the features often demanded by mobile device OEMs. As sales of Intel’s thin modems declined in the mid-2010s,<sup>801</sup> customers left Intel in favor of its competitors’ product offerings.<sup>802</sup>
327. In 2011, Intel acquired Infineon in order to re-enter the mobile communications space. [REDACTED]

<sup>797</sup> Exhibit QX74, Keddy Deposition, Intel, INTEL-QCOM008124586, p. 61.

<sup>798</sup> See, e.g., [REDACTED]

also Exhibit V.B.7.

<sup>799</sup> Exhibit QX75, Keddy Deposition, Intel, INTEL-QCOM001145202 at 5202.

<sup>800</sup> See, e.g., [REDACTED]

Exhibit V.B.7.; Exhibit V.B.8

<sup>801</sup> See, e.g., Exhibit V.C.2. See also [REDACTED]

<sup>802</sup> See, e. [REDACTED]

See also Section V.C.1 for further discussion on Infineon's product portfolio its support for 2G

<sup>805</sup> See, e.g., “Intel Unveils the XMM 7560 Modem – Enabling the Next Generation of LTE Advanced Devices,” Intel Press Release, February 21, 2017 (“Six mode operation, including [...] CDMA/EVDO for markets worldwide.”). See also [REDACTED]

806 [REDACTED]  
[REDACTED]  
[REDACTED] See also Exhibit V.B.1.

[REDACTED]

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[REDACTED]

811

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<sup>808</sup> See Section V.B.1.c for a discussion of industry-wide uncertainty regarding the future of CDMA. See also

[REDACTED]

■ [REDACTED]

■ [REDACTED]

■ [REDACTED]

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] Intel did not take concrete steps to deliver on CDMA until 2015. Intel’s acquisition of the CDMA assets of VIA Telecom was only finalized in 2015.<sup>815</sup> [REDACTED]

[REDACTED]

[REDACTED].<sup>816</sup> Intel’s integration of VIA Telecom’s technology is ongoing, but appears to be proceeding smoothly thus far.<sup>817</sup> Intel modem chips that have integrated VIA Telecom’s CDMA technology will be released in 2018.<sup>818</sup>

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[REDACTED]

[REDACTED]

[REDACTED]

<sup>815</sup> “Via Telecom Completes Sale of Part of Assets to Intel Corporation,” VIA Technologies Press Release, October 1, 2015 (“VIA Technologies, Inc. announced that VIA Telecom had completed the sale of part of its assets to Intel Corporation.”).

[REDACTED]

[REDACTED] Intel have been technically capable of integrating CDMA capability into the XMM 7480? A. I believe so.”)

[REDACTED]

<sup>818</sup> See, e.g., “Intel Unveils the XMM 7560 Modem – Enabling the Next Generation of LTE Advanced Devices,” Intel Press Release, February 21, 2017 (“Six mode operation, including [...] CDMA/EVDO for markets worldwide[.]”). See also Lindner Deposition, Intel, p. 60 (“Q. All right. So we are sitting here in March 2018. Will the XMM 7560 modem platform ship for commercial use later this year? A. Yes. Q. And will the XMM

[REDACTED]
[REDACTED] [REDACTED]
[REDACTED]
[REDACTED] [REDACTED]
[REDACTED]
[REDACTED] 821,822

Intel also has not offered competitive SoCs, instead focusing on thin modems.

[REDACTED]

[REDACTED]

[REDACTED] [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

819 [REDACTED]

820 [REDACTED]

821 [REDACTED]

[REDACTED]

■ [REDACTED]

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

332. Intel finally achieved technical success with the SoFIA 3G and 3G-R in 2015.<sup>826</sup> However, the SoFIA 3G was viewed by some to be an inferior product, as it only offered 3G rather than 4G support [REDACTED]. Rather than investing in and completing development of LTE SoCs, Intel discontinued the SoFIA line in 2016.<sup>828</sup> [REDACTED]

[REDACTED]

[REDACTED]

<sup>826</sup> Eassa, Ashraf, “Intel Corporation’s Most Disappointing Product in 2015,” The Motley Fool, December 22, 2015 (“The only integrated applications processor and modem products that Intel brought to market this year were chips known as SoFIA 3G [...] and SoFIA 3G-R [...].”).

<sup>827</sup> Eassa, Ashraf, “Intel Corporation’s Most Disappointing Product in 2015,” The Motley Fool, December 22, 2015 (“The only integrated applications processor and modem products that Intel brought to market this year were chips known as SoFIA 3G -- a very weak, undifferentiated applications processor with support for only the 3G cellular standard -- and SoFIA 3G-R in collaboration with Rockchip, a slightly less-bad applications processor still with only 3G support.”). See also [REDACTED]

<sup>828</sup> See, e.g., [REDACTED]

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333. Intel has used previous discussions and product engagements with network carriers and mobile device OEMs to guide and test its product development – even where those engagements did

829 [REDACTED]

<sup>831</sup> See, e.g., Apple Exhibit 1, Wolff Deposition, Intel, INTEL-QCOM000573628–3632 at 3632 (“This week Intel and Apple officially entered into a long-term partnership for Intel’s LTE modem and other wireless technologies to be used in Apple products. The first intersection point being Intel’s XMM7360 chipset (3<sup>rd</sup> generation LTE modem) to be delivered into Apple’s iPhone and iPad projects for the 2016 launch.”).

■ [REDACTED]

■ [REDACTED]

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not result in sales to the OEM.

[REDACTED]

834

[REDACTED]

■ [REDACTED]

■ [REDACTED]

■ [REDACTED]

■ [REDACTED]

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[REDACTED]

[REDACTED]

[REDACTED]

334. This collaborative work with OEMs and network carriers allowed Intel to refine and improve its chip offerings. In the wake of these collaborative partnerships, Intel secured Apple’s iPhone socket in 2016 with its XMM7360.<sup>840</sup> As shown in Exhibit V.C.14a, between 2016 and 2017, Intel has won Apple’s modem chip business at the expense of Qualcomm.<sup>841</sup> This set the stage for Intel to win the most, if not all of, Apple socket over Qualcomm for the 2018 iPhone products.<sup>842</sup>

335.

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

839

[REDACTED]

[REDACTED]

[REDACTED] See also my discussion of “pipe cleaners” in Section III.E.

<sup>840</sup> Wolff Deposition, Intel, pp. 168–169 (“Q. Do you consider the XMM7360 to have been a commercial success? A. Yes. Q. And among others, this was included in the Apple iPhone 7 in 2016; right? A. Yes.”).

<sup>841</sup> See Exhibit V.C.14a.

<sup>842</sup> Blevins Deposition, Apple, p. 76 (“Q. What is the procurement decision for the flagship iPhones to be launched in in 2018? A. [...Intel] has been chosen as the baseband provider for our 2018 product launch. Q. The only baseband provider for the 2018 product launches? A. Correct. [...]. Q. Is that true across all products, not just iPhones? [...] A. I was referring to iPhone specifically.”). See also Diaconescu, Adrian, “Apple Now Tipped to Retain Qualcomm as Backup Modem Supplier for Dual SIM 2018 iPhones,” PocketNow, November 20, 2017 (“[Mind-Chi Kuo, KGI Securities analyst] believes Intel will be able to supply Apple with between 70 and 80 percent ‘or more of required baseband chips’ for direct iPhone X and 8 sequels. The rest should still come from [...] Qualcomm [...]”).

843

[REDACTED]

[REDACTED]

[REDACTED]

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]<sup>5</sup> Furthermore, Intel has identified China as “an important market at the forefront of 5G” and, through its partnership with Chinese modem chip suppliers Spreadtrum and RDA,<sup>846</sup> has announced a “strategic collaboration” on a 5G mobile platform that combines an Intel thin modem with Spreadtrum AP technology.<sup>847</sup> Intel’s official press release described the goal of this collaboration as “making a 5G smartphone experience a compelling reality for consumers in China.”<sup>848</sup>

336. In addition to developing 5G technologies, Intel continues to expand the applications of its thin modems. [REDACTED]

[REDACTED]

[REDACTED]

844

[REDACTED]

845

[REDACTED]

<sup>846</sup> Shih, Gerry and Noel Randewich, “Intel to Invest up to \$1.5 Billion in Two Chinese Mobile Chipmakers,” Reuters, September 25, 2014 (“Intel will acquire the stake in Spreadtrum Communications and RDA Microelectronics [...]”). See also Section V.C.10 for further discussion on Spreadtrum and the Intel-Spreadtrum relationship.

<sup>847</sup> “Intel and UniGroup Spreadtrum & RDA Announce 5G Strategic Collaboration,” Intel Press Release, February 22, 2018.

<sup>848</sup> “Intel and UniGroup Spreadtrum & RDA Announce 5G Strategic Collaboration,” Intel Press Release, February 22, 2018.

849

[REDACTED]

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[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED] in machine-to-machine communication  
and the Internet of Things.<sup>854</sup> [REDACTED]

850

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852

853

<sup>854</sup> Evans Deposition, Intel, pp. 28–30 (“Q. And is ‘IoT’ the ‘Internet of Things’? A. Yes. Q. And is the Internet of Things an example of what you call ‘machine-to-machine communication’? A. It’s the beginning of that. [...] Q. Do you envision the Internet of Things will be an increasingly common [use for] what you refer to as ‘premium baseband processors’? A. I think, over the next [...] 20 or 30 years with [...] the advancements that we are seeing around what we call the machines from robots to autonomous-driven cars, and so on, and AI. Some of those segments will require a premium baseband chipset.”).

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[REDACTED].<sup>855</sup> In addition, Sprint has announced an agreement to sell “Intel-based 5G connected PCs” in its stores in 2019.<sup>856</sup>

*ii. Investment*

337. Intel has invested billions of dollars in acquiring companies with modem chip products and in its own mobile wireless R&D.<sup>857</sup> Moreover, Intel’s spending on new product development has, at times, eclipsed that of other technology firms.<sup>858</sup> As discussed in Section V.C.1, Intel also acquired Infineon’s Wireless Solutions Division in 2011 and invested a considerable amount in order to transform Infineon from a fast follower into a technological leader.<sup>859,860</sup> [REDACTED]

<sup>855</sup> See, e.g., [REDACTED]

<sup>856</sup> Abazovic, Fuad, “Sprint in Bed with Qualcomm and Intel,” Fudzilla, June 5, 2018.

<sup>857</sup> See, e.g., “Intel to Acquire DSP Communications, Inc. for Approximately \$1.6 Billion in Cash,” Intel Press Release, October 14, 1999 (“Intel Corporation and DSP Communications, Inc. [...] today announced the companies have entered into a definitive agreement under which Intel would acquire DSP Communications [...]. DSPC is a leading supplier of solutions for digital cellular communications products.”). See also [REDACTED]

<sup>858</sup> Madrigal, Alexis, “Paul Otellini’s Intel: Can the Company That Built the Future Survive It?” The Atlantic, May 16, 2013 (“But Paul Otellini’s Intel spent \$19.5 billion on R&D during 2011 and 2012. That’s \$8 billion more than Google. And a substantial amount of Intel’s innovation comes from its manufacturing operations, and Intel spent another \$20 billion building factories during the last two years. That’s nearly \$40 billion dedicated to bringing new products into being in just two years[.]”).

<sup>859</sup> See, e.g., Leske, Nicola, and Noel Randewich, “Intel Buys Infineon Unit and Expands Wireless Offer,” Reuters, August 30, 2010 (“U.S. chipmaker Intel Corp unveiled a deal on Monday to buy German chipmaker Infineon Technologies AG’s wireless unit for \$1.4 billion [...].”). See also “Intel Completes Acquisition of Infineon’s Wireless Solutions Business,” Intel Press Release, January 31, 2011.

<sup>860</sup> [REDACTED]

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[REDACTED]

[REDACTED]

[REDACTED] The acquisitions of assets from Infineon and VIA Telecom helped Intel achieve this goal.<sup>864</sup> Now, Intel’s modems support GSM, WCDMA, TD-SCDMA, LTE, and as of 2018, also CDMA customers.<sup>865</sup>

338. Intel has strategically invested in and pursued partnerships with a few Chinese modem chip suppliers, including Spreadtrum and RDA.<sup>866</sup> In 2014, it was reported that Intel paid up to \$1.5 billion for a minority stake in both firms.<sup>867</sup> The deal was intended to strengthen Intel’s position in China, while simultaneously granting Spreadtrum access to Intel’s proprietary x86 architecture.<sup>868</sup> In 2017, Spreadtrum announced that it had created an SoC that relied on the

<sup>861</sup> Goldstein, Phil, “Intel Continues to Pare Mobile Losses, Buys CDMA Modem Assets from VIA Telecom,” FierceWireless, October 14, 2015 (“Intel spokeswoman Stephanie Matthew confirmed to FierceWireless that the company had purchased VIA’s CDMA modem assets.”).

<sup>864</sup> Infineon’s Wireless Solutions Business sold GSM and WCDMA modem chips. See Section V.C.1.

<sup>865</sup> “Intel Mobile Modem Solutions,” Intel (Column titled “Protocols” lists the wireless standards that each 4G LTE, 3G, and 2G Intel modem supports, including GSM, HSPA+, TD-SCDMA, LTE, and CDMA.).

<sup>866</sup> Shih, Gerry and Noel Randewich, “Intel to Invest Up to \$1.5 Billion in Two Chinese Mobile Chipmakers,” Reuters, September 25, 2014 (“Intel will acquire the stake in Spreadtrum Communications and RDA Microelectronics [...]”).

<sup>867</sup> Shih, Gerry and Noel Randewich, “Intel to Invest up to \$1.5 Billion in Two Chinese Mobile Chipmakers,” Reuters, September 25, 2014 (“Intel Corp INTC.O said it will pay as much as \$1.5 billion for a 20 percent stake in two mobile chipmakers with ties to the Chinese government [...]”).

<sup>868</sup> “Intel and Tsinghua Unigroup Collaborate to Accelerate Development and Adoption of Intel-Based Modem Devices,” Intel Press Release, September 25, 2014 (“The purpose of the agreements is to expand the product offerings and adoption for Intel-based mobile devices in China and worldwide [...]. [...] Under the terms of the agreement, Spreadtrum Communications, Inc. will jointly create and sell a family of Intel Architecture-based system-on-chips (SoCs).”).

339. Although Intel has invested a comparable amount to Qualcomm in R&D, as of 2015 Qualcomm's investments had generally been more efficient and effective. [REDACTED]

<sup>869</sup> Eassa, Ashraf, “Spreadtrum Announces Intel-Made Mobile Chip,” The Motley Fool, March 6, 2017 (“At Mobile World Congress, China-based mobile chip vendor Spreadtrum announced a new chip dubbed the SC9861G-IA [...]. The chip is unique for a couple of reasons. The first is that it uses eight of Intel’s (NASDAQ:INTC) Atom-based processor cores codenamed Airmont. The second is that it is built by Intel using its 14-nanometer chip manufacturing technology.”).

871 [REDACTED]

872 [REDACTED]

<sup>873</sup> See, e.g., [REDACTED]

874 [REDACTED]

875 [REDACTED]

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340. These marked differences in R&D efficiency, experienced over a multi-year period, had a large impact on Intel’s performance relative to Qualcomm’s, especially when considered as a function of R&D investment. Though Intel’s recent LTE offerings have achieved commercial success,<sup>876</sup> [REDACTED]

[REDACTED].<sup>877</sup>

341. [REDACTED]  
 [REDACTED]<sup>878</sup> In fact, a 2017 press release about 5G Intel stated that “early investments in the cloud and core network technologies have resulted in significant developments in the next generation of connectivity and the next-generation core.”<sup>879</sup> Furthermore, 5G is one initiative in which Intel has leveraged its investments in Chinese firms Spreadtrum and RDA. In 2018 Intel announced that the “companies plan to develop a 5G smartphone platform for the China market that will feature an Intel 5G modem and will be targeted to coincide with 5G network deployments [in China] in 2019.”<sup>880</sup>

<sup>876</sup> See, e.g., Wolff Deposition, Intel, pp. 167–169 (“Q. [...W]as the 7160 platform commercially successful or not? A. It achieved the targeted quantities and the targeted revenue. [...] Q. [...] And in your view, the sales volume for the 7260 was a success? A. The 7260 was a success, big success. [...] Q. Would you consider the 7262 to have been successful? A. It was a development vehicle to get TD-SCDMA commercially launched, like 7160 was for LTE. And all these assets have been combined successfully in 7360 and are shipping in highest volume today. Q. Do you consider the XMM7360 to have been a commercial success? A. Yes.”).

<sup>877</sup> See, e.g., [REDACTED]

<sup>878</sup> [REDACTED]

<sup>879</sup> “Intel is Accelerating the 5G Future,” Intel Press Release, February 21, 2017.

<sup>880</sup> “Intel and UniGroup Spreadtrum & RDA Announce 5G Strategic Collaboration,” Intel Press Release, February 22, 2018.

iii. *Execution*

342. Intel’s executives have noted that Intel has at times bogged down its efficient execution in the mobile communications space. For example, reflecting on Intel’s earlier endeavors, former CEO Paul Otellini stated that while he recognized the emergence of low-end mobile devices, he “wasn’t able to get the Intel machine turning fast enough” and, consequently, Intel “[wasn’t] able to get [its] arms around [the explosion of low-end devices] early enough.”<sup>881</sup>
343. Before entering the mobile communications space, Intel possessed considerable technical expertise from its computing products. Although Intel’s x86 architecture was successful in laptops and PCs, it was not as well suited for mobile applications as the ARM architecture because x86 was an older design for desktop processors.<sup>882</sup> Intel’s early attempts to use x86 in mobile products resulted in power-inefficient modem chips that became too hot to use in

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<sup>881</sup> Madrigal, Alexis, “Paul Otellini’s Intel: Can the Company That Built the Future Survive It?” *The Atlantic*, May 16, 2013.

<sup>882</sup> See, e.g., “#412 Special: China - Smartphones and the Cloud,” Deutsche Bank, January 24, 2012, p. 5 (“[...W]e did not speak with a single handset maker who said they would even consider using Atom or x86 in their phones, echoing the commonly held view that x86 is not power efficient for cellular. [...] Designed originally for PCs with ample room for fans, heat sinks and cooling elements[,] x86, they tell us, give[s] off far more heat than other processors. Cell phones have rigorous temperature specs in addition to the more widely known RF requirements. [...] There is no room in a phone for a fan or heat sink [...].”). See also Ganapati, Priya, “Why Intel’s Processors Aren’t Big on Cellphones,” *Wired*, July 6, 2009 (“Intel’s low-power processor has fast become the silicon of choice for tiny computers – but not cellphone makers. [...] ‘Traditionally cellphones have been designed on the ARM processor and it is not easy to change it,’ says Jack Gold, principal analyst with consulting firm J. Gold Associates. ‘And cellphone makers don’t want to. ARM-based chips have a significant advantage over the current generation Atom processors for quite a few reasons.’ [...] The current generation of Atom processor was never meant to go on cellphones, says Pankaj Kedia, a director in Intel’s ultra mobility group. [...] ‘Atom today is not suitable for cellphones,’ acknowledges Kedia. [...] [A]nalysts are clear that ARM right now ranks much well ahead of Intel Atom.”); Evans Deposition, Intel, p. 23 (“Q. [...] Does the Atom core use what is known as ‘Intel architecture’? A. Yes. Q. What is ‘Intel architecture’? A. I mean, my definition of ‘Intel architecture’ is something that has – an IP that has the X86 instruction set, native.”).

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smartphones.<sup>883</sup> While Intel started development of its x86-based solutions in 2008, it was still working to resolve these power issues in 2012.<sup>884</sup>

344. Additionally, the acquisition of Infineon presented a failed opportunity for Intel to develop integrated chips. [REDACTED]

[REDACTED].<sup>885</sup> These problems limited Intel’s revenue opportunities, since mobile device OEMs increasingly demanded SoCs.<sup>886</sup> Intel launched its Atom-based SoC, called SoFIA, in 2015 and for 3G standards

<sup>883</sup> See, e.g., “S2N #406 - Notes from the Week,” Deutsche Bank, November 18, 2011, p. 3 (“Our checks continue to indicate that handset makers are reluctant to use x86 for phones due to concerns over power consumption and thermal footprint.”). See also Ganapati, Priya, “Why Intel’s Processors Aren’t Big on Cellphones,” Wired, July 6, 2009 (“Consider these numbers for a moment (from ARM). For a 1000 mAH battery, the Intel Atom Z500 Atom processor running at 800 MHz offers 19 hours of sleep time and overall battery life of 7 hours. An ARM Cortex-A8 at 800 MHz offers weeks of sleep time and 6.9 days of average battery life – an order of magnitude greater.”).

<sup>884</sup> See, e.g., “Intel Announces Intel Atom Brand for New Family of Low-Power Processors,” Intel Press Release, March 2, 2008 (“The Intel Atom™ processor will be the name for a new family of low-power processors designed specifically for mobile Internet devices [...] arriving later this year.”). See also “Cellular Handset & Tablet Chip Markets,” Forward Concepts, 2012, p. 93 (“Intel has been pushing hard for Smartphone vendors to use their Atom processor, via the upcoming Medfield variant. [...] In this path the industry still harbors concerns that Intel’s x86 architecture consumes too much power.”); “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 178 (“Intel has struggled to reduce the power consumption of its Atom chips to mobile handset levels [...].”).

<sup>885</sup> See, e.g., [REDACTED]. See also Cunningham, Andrew, “Intel Chases Cheap Android Tablets, Lets Another Company Use Its CPU Cores,” Ars Technica, May 27, 2014 (“All SoFIA parts are being manufactured at TSMC, which already manufactures the stand-alone versions of Intel’s modems—Intel’s Mobile Communications division was once a third party called Infineon, and Infineon’s designs were made for TSMC’s manufacturing processes.”).

<sup>886</sup> See, e.g., “Global 4G Subscriber & Smart Device Market Update,” Forward Concepts, 2015, pp. 64–65 (“There seem to be only a few high-volume designs that utilize stand-alone cellular modems (the largest of which is the iPhone), and unless Intel can win one or more of them, it probably won’t be able to bring in substantial revenue and profit dollars with this part (or future stand-alone modems). Intel’s Atom ‘Sofia’ X3 is Intel’s best hope for the smartphone market, as the SoC contains an integrated 3G radio along with an application processor.”). [REDACTED]

345.

890 See, e.g.,

891 See, e.g.,

While Intel halted the production of its SoC lines in 2016, its agreements allowed Spreadtrum and Rockchip to continue using the Atom x86 architecture for their own SoCs. Spreadtrum launched an integrated LTE SoC using an Atom-based architecture known as Airmont in 2017. This chip does not carry the Intel brand and Intel is uninvolved with marketing or helping OEMs integrate Spreadtrum’s product into mobile devices. See, e.g. Shah, Agam, “Intel Isn’t Done With x86 Smartphones Yet,” PCWorld, February 27, 2017 (“Smartphones with Intel-based x86 chips aren’t dead yet. Intel may have stopped making Atom chips for smartphones, but a partner is keeping that effort alive. Chinese chip maker Spreadtrum is still making x86 smartphone chips based on the Atom architecture named Airmont. [...] Intel struck a partnership with Spreadtrum in 2014 to make variants of Atom smartphone chips for the Chinese market. Intel also struck a similar deal with Rockchip, and said it would continue to honor those partnerships. Rockchip is making Atom chips for IoT devices [...].”). See also Eassa, Ashraf, “Spreadtrum Announces Intel-Made Mobile Chip,” The Motley Fool, March 6, 2017 (“At Mobile World Congress, China-based mobile chip vendor Spreadtrum announced a new chip dubbed the SC9861G-IA [...]. The chip is unique for a couple of reasons. The first is that it uses eight of Intel’s (NASDAQ:INTC) Atom-based processor cores codenamed Airmont. The second is that it is built by Intel using its 14-nanometer chip manufacturing technology.”); Shilov, Anton, “Spreadtrum SC9861G-IA: An

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] 898

### 3. MediaTek

#### *a. Background*

347. MediaTek is a Taiwanese fabless semiconductor design firm, spun off from United Microelectronics Corporation in 1997.<sup>899</sup> While the company initially designed and sold optical drives in China, it later expanded into the modem chip industry.<sup>900</sup> MediaTek started

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Intel Atom Octocore Smartphone SoC on 14nm with LTE,” AnandTech, March 15, 2017 (“The chip will not carry the Intel Atom brand, and thus Intel will not help makers of devices to integrate it or make any other incentives to popularize the platform. It will also not invest in its advertising.”).

<sup>896</sup> See, e.g., [REDACTED]

<sup>897</sup> See, e.g., Evans Deposition, Intel, p. 316 (“Q. The XMM7560 that will be available this year will include CDMA capability, won’t it? A. Yes. Q. Now are you aware – A. For the first time ever. Q. At Intel? A. Yes.”). See also Schafer Deposition, Apple, pp. 292–293 (“Q. It wouldn’t be possible to use 100 percent Intel baseband processors unless Intel could be providing a CDMA-compliant multimode LTE baseband. Isn’t that right? A. Yes.”); Blevins Deposition, Apple, p. 76 (“Q. What is the procurement decision for the flagship iPhones to be launched in 2018? A. [...Intel] has been chosen as the baseband provider for our 2018 product launch. Q. The only baseband provider for the 2018 product launches? A. Correct. [...] Q. Is that true across all products, not just iPhones? [...] A. I was referring to iPhone specifically.”); See also Diaconescu, Adrian, “Apple Now Tipped to Retain Qualcomm as Backup Modem Supplier for Dual SIM 2018 iPhones,” PocketNow, November 20, 2017 (“[Mind-Chi Kuo, KGI Securities analyst] believes Intel will be able to supply Apple with between 70 and 80 percent ‘or more of required baseband chips’ for direct iPhone X and 8 sequels. The rest should still come from [...] Qualcomm [...]”).

<sup>898</sup> [REDACTED]

<sup>899</sup> See, e.g., “Overview,” MediaTek. See also Kwong, Robin, “MediaTek Breaks Out into Mobile Phones,” *Financial Times*, March 16, 2011.

<sup>900</sup> See, e.g., Kwong, Robin, “MediaTek Breaks Out Into Mobile Phones,” *Financial Times*, March 16, 2011 (“In its early years, MediaTek made chips for CD and DVD drives in computers, and later chips for home DVD players and digital TV sets.”).

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investing in R&D for the modem chip industry in 2001 and sold its first GSM modem chips in 2004.<sup>901</sup> In its first few years in the modem chip industry, MediaTek had limited global presence and mainly targeted low-end Chinese mobile device OEMs.<sup>902</sup> It pursued a relatively novel strategy of providing OEMs with software solutions and reference designs, allowing even resource-constrained OEMs to produce handsets quickly and cheaply. By lowering barriers to entry in the mobile device industry, MediaTek was able to secure a broad set of customers and experienced significant growth.<sup>903</sup>

348. In 2008, MediaTek acquired the wireless chip division of Analog Devices, gaining access to both its TD-SCDMA technology and its relationships with major OEMs such as LG.<sup>904</sup> Toward the end of the decade, MediaTek began to pursue WCDMA technologies and smartphones, releasing its first standalone WCDMA chip in 2010 and its first WCDMA modem chip with an integrated AP in 2011.<sup>905</sup> Targeting the fast-growing but “un-served” low-end smartphone segment, MediaTek’s WCDMA sales grew rapidly through the early

<sup>901</sup> See, e.g., BAIN00002230, p.14, presentation titled “Wireless Semicon Market Overview,” Bain, March 2011 (“Initial investment in handset R&D in 2001 [...]”). See also MediaTek 2007 Annual Report, p. 6 (“Jan. 2004[:] Launched GSM Mobile Phone Chipsets[.]”).

<sup>902</sup> BAIN00002230, p. 10 (“MediaTek focuses on low-end Chinese ODMs [original device manufacturers]”). MediaTek’s chips were also widely used among Chinese grey-market phone manufacturers. See, e.g., “Cellular Handset & Tablet Chip Markets,” Forward Concepts, 2011, p. 261 (“Many of the non-Smartphones in the Shanzhai [Chinese imitation and pirated brands and goods] Phone market are powered by a MediaTek chipset [...]”). See also “Cellular Handset & Chip Markets,” Forward Concepts, 2009, p. 151 (“MediaTek’s baseband solutions [...] are widely used by many nonlicensed handset manufacturers in 2005.”).

<sup>903</sup> BAIN00002230, p. 14 (“Major growth from wireless as Chinese grey-market and low-tier ODM/OEMs explode [...]. By 2005, >50% penetration of low-tier players worldwide.”).

<sup>904</sup> See, e.g., Moynihan Deposition, MediaTek, p. 14 (“A. [...] MediaTek did not have a TD-SCDMA solution, ADI did. [...] Q. Did you come to understand why MediaTek acquired the Analog Devices wireless business? A. I mean, what was conveyed to us at the time from management of MediaTek was it [REDACTED], and target more global Tier 1 OEMs.”). See als [REDACTED].

<sup>905</sup> See Exhibit V.B.5.

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2010s.<sup>906</sup> In 2010, MediaTek overtook TI and Qualcomm to become the world’s largest supplier of modem chips, and it has remained the second largest supplier since 2011.<sup>907</sup>

349. Pursuing the strategy of being a fast follower,<sup>908</sup> MediaTek released its first standalone and AP-integrated LTE chips in 2014, a few years after some of its competitors.<sup>909</sup> More recently, MediaTek targeted mid- to high-end mobile devices with its Helio X and P series LTE SoCs, first released in 2015.<sup>910</sup> MediaTek also incorporated support for CDMA into its chips starting in 2015.<sup>911</sup> This allowed the company to strengthen its position in China and gain design wins in new geographies such as the U.S.<sup>912</sup> [REDACTED]

<sup>906</sup> See, e.g., MTK\_00115960–5961, p. 17, email from CC Lien, MediaTek, April 6, 2011, with attached presentation titled “2010 Long Term Plan WCP2,” July 29, 2010 (“Emerging Market Smartphones growing faster than Developed Markets[;] CAGR of 30.4% in Emerging vs 18.5% in Developed Markets (2010 - 2015)[;] Emerging Market Volumes exceed Developed Markets by 2013[;] [...] lower cost of entry due to open-source SW & increasing capability of Chinese OEM/ODMs should drive increased Smartphone adoption - especially low-cost smart phones”) and p. 19 [REDACTED]

[REDACTED] also Exhibit V.C.3.

<sup>907</sup> See Exhibit III.D.3.

<sup>908</sup> Moynihan IH, MediaTek, pp. 221–222 (“Q. Was MediaTek’s model to this point to follow the technological standard? A. [...] We certainly weren’t the first into the chipset business for mobile phones. And if there is such a thing, the way MediaTek tends to approach these markets is we tend to come with very complete solutions, very complete reference designs. If we’re not coming into the market first, we do tend to start as a follower. That’s fair. [...] We try to be a fast follower.”).

<sup>909</sup> See Exhibit V.B.7.

<sup>910</sup> See, e.g., Sima, Claudiu, “MediaTek Unveils the Helio Range of SoC; 64-bit Units with 480fps Slow-Motion Videos Support,” GSMDome, March 30, 2015 (“Today, MediaTek, a pretty important player on the SoC market, announced the launch of a new range of processors that will arrive on high-end smartphones. The new products from this range are called Helio X and Helio P [...]”). See also Wang, Lisa, “MediaTek Looks to Regain Market Share,” Taipei Times, December 28, 2017 (“Helio P series [...] target smartphones with a price tag of 1,500 yuan to 3,000 yuan (US\$230 to US\$460) [...] the Helio X series [...] is used in premium phones.”).

<sup>911</sup> See Exhibit V.B.2.

<sup>912</sup> See, e.g., “Baseband/Modem & Smartphone Market,,” Forward Concepts, 2017, p. 76 (“China Telecom on the other hand was not an addressable market [for MediaTek] even in China until [...] they added CDMA 2000 and EVDO RA modes of operation [...]”). See also “First MediaTek-Powered Smartphone Introduced by Sprint,” MediaTek Press Release, September 16, 2016 (“The first MediaTek-enabled smartphone for Sprint launched today, breaking new ground for MediaTek in the U.S. market.”); Moynihan Deposition, MediaTek, pp. 115–116 (“Q. [...] Have you been able to observe that [MediaTek’s acquisition of CDMA capability] did, in fact, lead to increased sales? A. I mean, I can certainly point to a few isolated specific cases where, without having CDMA, we would not have won those slots. Yes. Q. And what slots come to mind? A. One design win with LG for a slot at Verizon and around the same time one at Sprint that probably led to a few more designs after that, also with LG.”).

[REDACTED]

*b. Analysis*

350. Throughout its history, MediaTek has generally shown strong foresight, well-targeted investments, and at times lagging but overall solid execution. MediaTek has effectively aligned its modem chip offerings with segments experiencing growing demand and has leveraged its experience obtained from working with a wide array of OEMs to increase the competitiveness of its future products. The company has strategically used technology acquisitions to gain access to new customers and geographic regions and has demonstrated the ability to compete at progressively higher-end tiers.

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<sup>913</sup> See, e.g., [REDACTED]

<sup>914</sup> [REDACTED]

<sup>915</sup> Weinstein, Austin, “Intel Blows Keep Coming as Apple Modem Contract May Be at Risk,” Bloomberg, June 27, 2018, <https://www.bloomberg.com/news/articles/2018-06-27/intel-blows-keep-coming-as-apple-modem-contract-may-be-at-risk> (“MediaTek Inc., which manufactures modems, might displace Intel for the product at Apple, which he says has been rumored to be working on their own modem.”).

<sup>916</sup> [REDACTED]

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351. *Foresight*: Four strategic decisions have largely defined MediaTek’s success over the years. First, upon entering the modem chip industry, MediaTek exploited an opportunity to expand sales of mobile devices in emerging markets by lowering OEMs’ barriers to entry. MediaTek targeted its R&D investments into providing software solutions and detailed reference designs, which considerably shortened OEMs’ design and production cycles, from 18 months to six according to its own estimate,<sup>917</sup> and reportedly enabled OEMs with no experience and fewer than 10 staff to design mobile devices.<sup>918</sup>
352. Second, after being slow to supply WCDMA products, and facing increased competition from other low-cost suppliers such as Spreadtrum,<sup>919</sup> MediaTek created an opportunity for renewed sales by focusing on low-end smartphones. MediaTek did not start developing WCDMA modem chips until 2005, six years after the standard was released.<sup>920</sup> As a result of its delayed start and other execution issues discussed below, MediaTek did not release its first WCDMA chip until 2010, well after most firms in the industry.<sup>921</sup> Responding to its challenging position, MediaTek attempted to “democratiz[e] smartphones” by bringing high end features to low-end mobile devices.<sup>922</sup> MediaTek introduced WCDMA modem chips, [REDACTED]

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<sup>917</sup> Tilley, Aaron, “MediaTek’s Plan to Take on Qualcomm and Move Up in the Cut-Throat World of Mobile,” *Forbes*, June 3, 2015 (“MediaTek’s talent lies in getting smartphone makers up and running, fast. It provides reference designs--blueprints that new manufacturers can follow quickly to put together their own phones. ‘We reduce the whole phone-design, mass-production cycle from one and a half years to six months,’ says MediaTek’s senior vice president, Jeffrey Ju.”).

<sup>918</sup> Kwong, Robin, “MediaTek Breaks Out Into Mobile Phones,” *Financial Times*, March 16, 2011 (“Instead of just offering a chip to power the phone, MediaTek also provided its customers with reference designs and a suite of ‘turnkey software solutions.’ By making these available, the company drastically lowered the entry barrier to the mobile phone manufacturing industry. The relative ease with which a phone could be made using MediaTek’s solution was highlighted by the company’s early customers, who typically had no previous experience in the phone industry and sometimes fewer than 10 staff.”).

<sup>919</sup> See, e.g., So, Sherman, “Battered MediaTek Rearms with Android,” *Asia Times*, April 5, 2011 (“[...]its rival, Spreadtrum, after years of trial, finally, came up with a chip that is stable enough for phone manufacturers,” said an industry insider, ‘With a price about 10-15% lower than MediaTek’s, the Spreadtrum product quickly gained market share.’”).

<sup>920</sup> MTK\_00533746, p. 3, presentation titled [REDACTED]

<sup>921</sup> See Exhibit V.B.5.

<sup>922</sup> MTK\_00748746, p. 12, presentation titled “MWS All-Hands Meeting,” MediaTek, November 28, 2012.

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[REDACTED],<sup>923</sup> that would be cost-competitive to serve the rapidly growing emerging-market smartphone segment.<sup>924</sup> As a result of this as well as its good execution discussed below, MediaTek’s WCDMA sales grew swiftly.<sup>925</sup>

353. Third, building upon its success serving low-cost device OEMs, MediaTek continued expanding over time into supplying modem chips for medium and higher-tier mobile devices. In early 2015, MediaTek announced two SoC series, Helio X and P, targeted at mid-tier to high-end devices.<sup>926</sup> [REDACTED]

[REDACTED].<sup>927</sup> Having identified a growing “new premium” trend of consumers wanting high-end features at more affordable prices, MediaTek in 2017 incorporated some of the high-end features of the Helio X series into the lower-priced Helio P series.<sup>928</sup> Making the Helio P

<sup>923</sup> [REDACTED].

<sup>924</sup> See, e.g., “MediaTek Launches MT6575 Android Platform,” MediaTek Press Release, February 13, 2012 (“MediaTek [...] today announced the availability of the MT6575, its 3rd generation platform for mid and entry-level Android smartphones. [...] ‘We expect significant growth in entry and mid-level smartphones, with wholesale prices under US\$190, over the coming years. We forecast that this segment will almost triple in size from 191 million shipments in 2012 to 551 million by 2016. At that time, we also expect approximately 75% of those entry and mid-level smartphones to ship to emerging markets’ said Neil Mawston, Executive Director, Global Wireless Practice, at Strategy Analytics. The MediaTek MT6575 platform is ideally suited to cater to a wide range of smartphone devices that target this growing segment in multiple markets around the world.”).

<sup>925</sup> See Exhibit V.C.3.

<sup>926</sup> While the Helio X series targeted “extreme” performance, the Helio P series balanced performance with price and power consumption. See, e.g., Moynihan Deposition, MediaTek, p. 66 (“A. The way we positioned it was that the Helio X line was the high-end line. X was sort of, I think, associated with extreme. P was positioned below that, and, like I said, we’ve always sort of tried to talk about power -- a balanced power, performance, price dimension.”).

<sup>927</sup> [REDACTED].

<sup>928</sup> See, e.g., MTK\_00450489–0491 at 0490, email from Kevin Keating, MediaTek, November 8, 2017 (“[...]W]e are focused on the P series because that is where the demand is in the market. Plus the fact we have pulled higher end features down into the P series to meet this new premium trend of consumers wanting more for less.”). See also Moynihan Deposition, MediaTek, p. 286 (“Q. Sorry. Would you say, though, that MediaTek is competing in the high-end segment? A. [...] I think with the new Helio P products that we just announced, we start to move into a slightly higher tier than we’ve been in. [...]E]xternally we call this the new premium tier. [...] Q. And how would you characterize how the new premium tier compares with the flagship segment? A. Slightly lower features, slightly lower price.”).

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series the focus of its development efforts led to several design wins.<sup>929</sup> [REDACTED]

[REDACTED]<sup>30</sup>

354. Fourth, MediaTek has also demonstrated foresight by leveraging the learning accumulated by working with a diverse set of OEMs in order to increase the future competitiveness of its products. [REDACTED]

[REDACTED]<sup>31</sup> Similarly, MediaTek has used its relationships with region-specific OEMs such as Alcatel, ZTE, Lenovo, Huawei, and Coolpad to develop modem chips that cater to the demands of network carriers in certain geographies.<sup>932</sup> In addition, working with customers such as [REDACTED] has enabled MediaTek to improve its chip design for high-

<sup>929</sup> Wang, Lisa, “MediaTek Looks to Regain Market Share,” Taipei Times, December 28, 2017 (“The change [to focus on the Helio P series] has borne fruit, with the Helio P series processors being adopted by some of the world’s top five mobile phone brands, including China’s tier-one mobile brands Huawei Technologies Inc [...], Oppo Mobile Telecommunications Corp [...] and Vivo Electronics Corp [...]”).

<sup>930</sup> As discussed in Sections III.E.1.b and IV.A, [REDACTED]

See, e.g., [REDACTED]

<sup>931</sup> [REDACTED]

<sup>932</sup> [REDACTED]

[REDACTED] and pp. 89–91 (“Q. And with respect to the transition from 3G to 4G, who are the important teaching customers? A. [...] And then for the early phases for our LTE, the other ones that would have been important were Alcatel and ZTE. [REDACTED]

[REDACTED] [...] And we’d have had a few more for China, so for the deployment of LTE in China we might have relied on people like Lenovo, Huawei, for example, Coolpad.”).

end devices.<sup>933</sup> [REDACTED]

[REDACTED]<sup>934</sup>

355. Investment: MediaTek has invested in R&D consistently throughout its history, but, in keeping with its strategy of being a fast follower, it has typically only invested a fraction of the amount spent by industry leaders.<sup>935</sup> According to UBM TechInsights analysis from 2010, MediaTek’s R&D investment was “primarily focused on integration and reducing cost;” as such, MediaTek did not “publicly demonstrate any particular core technology,” and much of the IP it owned had originated at other companies.<sup>936</sup> Instead, MediaTek used technology acquisitions as a means of bolstering its existing product lines and quickly gaining access to new customers and technologies. To strengthen its software solutions and chip integration, between 2004 and 2006 MediaTek aggressively bought technology from several smaller firms.<sup>937</sup> In January

<sup>933</sup> See, e.g., Moynihan IH, MediaTek, pp. 34–35 (“Q. Who are the teaching customers? A. [...] And then I would think some of these other brands, like [REDACTED], have probably helped more with some of the higher-tier multimedia features. Again, as I mentioned, their devices tend to be higher tier in feature set, higher price maybe than some of the other customers. Therefore, they’re driving more advanced displays, more advanced cameras, more advanced user features, and so, you know, those are probably the customers that are pushing us on things like camera features, which is an important feature for a lot of these devices right now.”).

<sup>934</sup> Senior technical MediaTek representatives have visited Apple on numerous occasions to discuss its mobile [REDACTED]

<sup>935</sup> See Exhibits III.E.1 and III.E.2.

<sup>936</sup> McGrath, Dylan, “Feeling the Heat, MediaTek Seeks a Comeback,” EE Times, December 20, 2010 (“The TechInsights study found that MediaTek owns roughly 3,000 patents and patent applications worldwide, with the majority in the U.S., China and Taiwan. Many of those patents and applications were transferred to MediaTek from other companies, including about 225 that were originally owned by IBM.”).

<sup>937</sup> See, e.g., “Taiwan’s Top Chip House Stretches Beyond Optical Storage,” EE Times, April 11, 2005 (“[MediaTek] has bought Pixtel Communications Inc., a handset software specialist for man-machine interfaces that once did contract work for Motorola Inc. It came with a 70-man team in India, which will allow Mediatek to offer strong software support, especially for Chinese handset OEMs that are still weak in that area.”). See also Nystedt, Dan, “MediaTek Expands Mobile Phone Business,” IDG News Service via InfoWorld, October

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2008, MediaTek obtained access to TD-SCDMA technology and relationships with major OEMs such as LG through its acquisition of Analog Devices’ wireless chip division. In order to boost its development of 4G products, MediaTek also signed a software licensing agreement with NTT DoCoMo for the Japanese firm’s LTE technology.<sup>938</sup>

356. In October 2013, MediaTek licensed CDMA technology from VIA Telecom.<sup>939</sup> While MediaTek had previously specified the use of standalone VIA Telecom modem chips in its reference designs, this collaboration allowed MediaTek to integrate CDMA capability into its chips, which the company claimed reduced power consumption and device manufacturing costs.<sup>940</sup> This helped MediaTek sell backward-compatible LTE chips to carriers such as China Telecom, Verizon, and Sprint that operated CDMA networks, leading to its first design wins in the U.S. in 2016.<sup>941</sup> [REDACTED]

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30, 2006 (“Taiwanese chip designer MediaTek Inc. said it paid US\$13 million for a number of mobile phone software applications in a bid to expand the acceptance of its communications chips. The deal with Beijing software developer Pollex Mobile Software Co Ltd. comes at a time other companies are shying away from the mobile phone market due to intense competition.”); “Cellular Handset & Chip Markets,” Forward Concepts, 2007, p. 183 (“MediaTek has bought a 31.55% stake in Airoha Technology from BenQ Group for US\$18.6M, making MediaTek the largest shareholder. Airoha develops RF solutions in WLAN market segment and has also been attempting to enter the GPRS market as well.”).

<sup>938</sup> “MediaTek Signs LTE Licensing Agreement with NTT DOCOMO,” MediaTek Press Release, July 27, 2010 (“MediaTek Inc. [...] announces it has entered into a licensing agreement with NTT DOCOMO, INC. regarding ‘LTE-PF,’ a mobile-terminal platform based on Long Term Evolution (LTE). Upon the completion of the LTE-PF licensing agreement with DOCOMO, MediaTek plans to integrate this LTE technology with its 2G and 3G technologies to provide solutions for Japan and global markets.”).

<sup>939</sup> See, e.g., Loh Deposition, MediaTek, p. 102 (“Q. Are you aware that in October 2013, MediaTek entered a CDMA technology license with VIA Telecom? A. Yes, I know that.”).

<sup>940</sup> “MediaTek Adds CDMA2000 and Unveils Plans for Worldmode™ Mobile Chipsets,” MediaTek Press Release, January 6, 2014 (“MediaTek already uses VIA Telecom baseband processors as a discrete part in its existing mobile reference designs, and now, incorporating CDMA2000 technology into new SOC designs will significantly reduce manufacturing costs and power consumption for mobile devices.”).

<sup>941</sup> See, e.g., “Baseband/Modem & Smartphone Market,” Forward Concepts, 2017, p. 76 (“China Telecom on the other hand was not an addressable market [for MediaTek] even in China until [...] they added CDMA 2000 and EVDO RA modes of operation [...].”). See also “First MediaTek-Powered Smartphone Introduced by Sprint,” MediaTek Press Release, September 16, 2016 (“The first MediaTek-enabled smartphone for Sprint launched today, breaking new ground for MediaTek in the U.S. market. This marks MediaTek’s first premium chipset offered in a device on a major U.S. carrier network. [...] MediaTek helio P10 offers high-performance 4G LTE octa-core processors as well as the older modems, such as, CDMA2000, WCDMA, HSPA+ and GSM.”); “First MediaTek-Powered Smartphone Launched by Verizon Wireless,” MediaTek Press Release, October 20, 2016 (“MediaTek today announces the launch of the first-ever MediaTek-powered CDMA/LTE smartphone by Verizon Wireless. The LG Stylo™ 2 V marks MediaTek’s debut as a certified smartphone chipset provider to Verizon Wireless.”).

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED].<sup>943</sup>

357. Execution: MediaTek has demonstrated the ability to consistently execute in product development, despite roadblocks and initially unfavorable positions. MediaTek did not start developing its first WCDMA chip until 2005, by which point several competitors including Qualcomm, TI, and Ericsson Mobile Platforms (EMP) had already developed and released WCDMA chips.<sup>944</sup> Following its acquisition of the Analog Devices wireless division, MediaTek did not ship its first WCDMA modem chips until 2010, in part because it decided to integrate Analog Devices’ RF transceiver with its WCDMA modem chip.<sup>945</sup>
358. Another reason for the delayed development of its WCDMA modem chip was understaffing, as MediaTek was simultaneously also developing its first SoC for a smartphone.<sup>946</sup> Despite

942

[REDACTED]

943

See, e.g., [REDACTED]

944

See Exhibit V.B.5.

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Moynihan Deposition, MediaTek, pp. 24–25 (“Q. Do you recall that there were delays that were encountered in integrating these Othello RF transceivers with the existing MediaTek W-CDMA baseband development process? A. [...] I think there was probably work that had to be done to -- typically these are two separate chips anyway. There’s probably some work to do on the interfacing that maybe had to be redone or had to require some extra work, but that is sort of part of the normal development.”).

946

See, e.g., MTK\_00601420, p. 11, presentation titled “All Hands Communications MediaTek USA, Inc.,” MediaTek, January 15, 201 [REDACTED]

[REDACTED] See also Loh Deposition, MediaTek, pp. 27–28 (“Q. And when did MediaTek start selling SoCs for smartphones? [...] A. I can’t remember. Q. Do you remember a general time frame? A. 2010, 2011.”).

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these hurdles, MediaTek was eventually able to execute and create successful WCDMA products. In 2012, MediaTek released the MT6575 and MT6577 AP-integrated WCDMA chips that targeted smartphones in emerging markets with a device price point below \$200.<sup>947</sup>

[REDACTED]  
[REDACTED]  
[REDACTED].<sup>948</sup> Due in part to its foresight in targeting this segment and its execution in creating high-performing chips tailored for it, MediaTek became the world’s second-largest supplier of WCDMA chips in 2013.<sup>949</sup>

359. More recently, MediaTek has been making headway in the execution of chip development for use in medium and higher-end products, again overcoming an initially difficult position to reach competitiveness. [REDACTED], debuted in 2015 to target mid-tier to high-end mobile devices, [REDACTED]

<sup>947</sup> See, e.g., “MediaTek Set to Break Price Barrier for Mid-Entry Smartphones with MT6577 Powered Handsets From Micromax & Spice,” MediaTek Press Release, September 13, 2012 (“The MT6577 features a dual 1GHz Cortex™-A9 application processor from ARM, [...] MediaTek’s proven 3G/HSPA modem, and runs the latest Android 4.0 ‘Ice Cream Sandwich’ (ICS) operating system. [...] Developed specifically for the fastest growing sub-\$200 smartphone segment [...].”). See also “MediaTek Launches MT6575 Android Platform,” MediaTek Press Release, February 13, 2012 (“MediaTek Inc. [...] today announced the availability of the MT6575, its 3rd generation platform for mid and entry-level Android smartphones. The MT6575 platform offers a 1GHz ARM® Cortex™-A9 processor, a proven 3G/HSPA modem and runs the latest ‘Ice-Cream Sandwich’ Android 4.0 release. ‘We expect significant growth in entry and mid - level smartphones, with wholesale prices under US\$190, over the coming years. We forecast that this segment will almost triple in size from 191 million shipments in 2012 to 551 million by 2016. At that time, we also expect approximately 75% of those entry and mid - level smartphones to ship to emerging markets’ said Neil Mawston, Executive Director, Global Wireless Practice, at Strategy Analytics.”).

<sup>948</sup> [REDACTED]  
[REDACTED]  
[REDACTED]. See, e.g., Wyatt Deposition, Qualcomm, Exhibit CX5760, at CX5760-017  
[REDACTED]  
[REDACTED] and at CX5760-018  
[REDACTED]. See also Rosgani, “Understanding MediaTek MTK MT6577 Chipset,” GizmoChina, July 20, 2012 (“MTK platform’s first dual-core MT6575T, because of the importance of this dual-core, it changed its name to MT6577.”).

<sup>949</sup> In 2013, MediaTek sold over 118 million chips for which WCDMA was the highest standard, which was second only to Qualcomm. See Exhibit V.B.6.

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[REDACTED].<sup>950</sup> However, with these chips, one MediaTek executive believed that its gap in LTE technology with Qualcomm was “narrowing.”<sup>951</sup> Similarly, after MediaTek focused on the Helio P series in 2017, it displayed strong execution, and, according to the testimony of a MediaTek employee, the Helio P60 substantially narrowed the gap in quality with the similarly targeted Qualcomm Snapdragon 600 series.<sup>952</sup> MediaTek has recently secured sales for Helio P series SoCs at Samsung, [REDACTED]

[REDACTED] This execution prowess in creating progressively higher-performing modem chips has also enabled MediaTek to shed an initially poor reputation for supplying low-performance chips to grey-market OEMs and join the set of modem chip suppliers considered for leading smartphones [REDACTED]

<sup>950</sup> See, e.g., QNDCAL03572280, p. 8, email from Will Wyatt, Qualcomm, February 2, 2016, with attached presentation titled “FY16 Strat Pricing” [REDACTED]

See also [REDACTED]

<sup>951</sup> See, e.g., Fried, Ina, “MediaTek Tried 10-Core Chip in Latest Bid to Crack High-End Phone Market,” Recode, May 12, 2015 (“‘We are certainly moving away from the whole image of being a low-cost provider,’ Bhushan said. Bhushan acknowledged Qualcomm still has an edge in LTE modem technology, but he said the gap is narrowing.”). See also Moynihan Deposition, MediaTek, p. 283 (“Q. Do you believe that MediaTek has closed the gap a lot on Qualcomm on the modem technologies? [...] A. Yes. I think the gap is probably a little bit shorter today than it was in 2010.”).

<sup>952</sup> See, e.g., Moynihan Deposition, MediaTek, pp. 53–55 (“Q. Is it your view, sir, that the Helio P60 will be -- will have as good a CPU as the Qualcomm Snapdragon 600 series? [...] A. [...] I do take the view that the Helio P60 probably presents to customers a CPU performance that may be in the ballpark of comparison with some of the products of the Snapdragon 600 family. [...] Q. Do you believe that the Helio P60 has multimedia capabilities comparable to those of the Qualcomm Snapdragon 600 series? A. Comparable is probably a good word. Yes.”) and p. 103 (“A. I think the, you know, the new Helio P product, that P60 product that we just announced, probably does start to compete with the Snapdragon 600 series.”).

<sup>953</sup> See, e.g., Exhibit V.C.14c. See also “Samsung Galaxy On Max with Helio P25 in India,” MediaTek, July 27, 2017 (“Powered by the MediaTek Helio P25, the Samsung Galaxy On Max brings pictures alive, even in low-light conditions [...]”).

<sup>954</sup> SFT-2366213–6219 at 6214, Samsung internal analysis of MediaTek [REDACTED]

<sup>955</sup> [REDACTED]

#### 4. Samsung / Samsung S-LSI

##### *a. Background*

360. Samsung has been involved in the semiconductor industry since the 1970s, and since the late 1980s, telecommunications and semiconductor products have been among its core business lines.<sup>956</sup> Samsung’s S-LSI division, designs modem chips and has provided foundry services, including services for outside chip suppliers.<sup>957</sup> In 2017, Samsung reorganized its business units and separated foundry operations from the Samsung S-LSI unit.<sup>958</sup> As of 2017, Samsung is the largest mobile device OEM, which also makes it the largest vertically integrated mobile device OEM.<sup>959</sup>

361. [REDACTED].<sup>960</sup> By 1999, it was producing CDMA chips for its own devices.<sup>961</sup> [REDACTED]

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<sup>956</sup> Samsung first entered the Semiconductor industry in 1974 with the acquisition of Hankook Semiconductor. Samsung then made telecommunications and semiconductors part of its core business in 1988, when Samsung Semiconductor & Telecommunications Co. merged with Samsung Electronics. See, e.g., “Planting the Seeds,” Samsung. See also “History 1989-1980,” Samsung.

<sup>957</sup> See, e.g., Kim Deposition, Samsung, pp. 23–24 (“Q. And what does [Samsung S-LSI] do? A. They engaged in manufacturing their own products within that business division, System LSI, and also responsible for selling those. Q. And is one of those products modem chips for cellular devices? A. Yes, it is one of those.”). See also Kang Deposition, Samsung, p. 193 (“While you were at Samsung Mobile, were you aware that Samsung had a foundry business? A. Yes. I was. Q. What business unit within Samsung was responsible for the foundry business? A. Samsung LSI. Q. And were you aware, during your time at Samsung Mobile, of whether SLSI produced any chips for Qualcomm as part of the Samsung’s foundry business? A. Yes, I was.”).

<sup>958</sup> See, e.g., “About Us,” Samsung. See also “Samsung Electronics Finally Splits Foundry Business out of System LSI Division,” The Korea Economic Daily, May 12, 2017 (“Samsung Electronics will spin off its foundry operation from the System LSI division to create an independent business unit.”)

<sup>959</sup> Samsung sold almost 370 million mobile devices globally in 2017, the largest of any mobile device OEM. See Exhibit III.D.7.

<sup>960</sup> SFT-0016284-6296 at 6295 (translation), Samsung internal report titled “The Need to Develop In-House Modem,” Samsung, April 5, 2007 (“[:] August 1997: CDMA T/F was formed with 40 members (Mobile, S-LSI, Telecommunications Research Institute) [:] The T/F began to develop the IS-95A CDMA terminal modem as its in-house development objective.”).

<sup>961</sup> See, e.g., LaPedus, Mark, “Samsung to Develop Line of Wireless Chips,” EE Times, April 13, 1999 (“Hoping to lessen its dependence on Qualcomm Inc. in the wireless-chip arena, Samsung Electronics Co. Ltd. Has disclosed an aggressive strategy to develop components for its own CDMA-based handset lines. [...] Samsung

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

362. In 2010, Samsung S-LSI was among the first suppliers to release an LTE modem chip.<sup>965</sup> By 2012, Samsung was using Samsung S-LSI LTE chips in some of its Galaxy S series phones, which had become its flagship mobile device family.<sup>966</sup> Since that time, Samsung’s reliance on outside suppliers for modem chips for its devices has greatly decreased; while Samsung was self-supplying less than two percent of its modem chips in 2013, it was self-supplying almost 42 percent in 2017.<sup>967</sup> Additionally, in 2018 Samsung S-LSI introduced CDMA compatibility into at least two integrated Exynos SoCs.<sup>968</sup>

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plans to develop its own line of digital-cellular chipsets [...]. [...] Last week Samsung said it has begun producing the SCom 3000 CDMA chip set [...].”).

<sup>962</sup> Lee Deposition, Samsung, p. 28 [REDACTED]

<sup>963</sup> See, e.g., Q2014FTC03368158–8159 at 8158, email from Gerald Skiver, Qualcomm, October 10, 2002 (“Dr. Chun was previously the head of Samsung’s internal CDMA modem design team. Dr. Chun left Samsung and several key engineers on his team also left to form the new company, Eonex Technologies.”). See also Q2014FTC03369222–9223 at 9223, email from Marv Blecker, Qualcomm, October 9, 2001 (“[...] EoNex, a venture startup launched last April by former researchers at Samsung Electronics Co., SK Telecom and other firms[...].”).

<sup>964</sup> SFT-4857460 at 461 (translation), presentation titled “CDMA Acquisition History and Progress,” Samsung, January 27, 2016 ([REDACTED])

<sup>965</sup> See Exhibit V.B.7.

<sup>966</sup> See, e.g., SFT-12948733, p. 1, presentation titled “Samsung Modem Roadmap,” Samsung, July 2012 (“Galaxy S III LTE launched successfully with CMC221 + Pega Q combination in Korea[.]”). See also Dolcourt, Jessica, “Why Samsung’s U.S. Galaxy S III Has a Dual-Core Processor (and Why You Shouldn’t Care),” CNET, June 6, 2012 (“In just a couple of weeks, the U.S. will receive its first Samsung Galaxy S III Smartphones. The flagship phones share most of the features of the global version of the device [...].”).

<sup>967</sup> See Exhibit IV.B.4.

<sup>968</sup> See, e.g., Frumusanu, Andrei, “Meizu Announces M6s with Exynos 7872,” AnandTech, January 17, 2018 (“This is also the first time we’ve seen an Exynos SoC released with integrated CDMA capability [...].”). See also Frumusanu, Andrei, “Samsung Announces the Galaxy S9 and S9+,” AnandTech, February 25, 2018 (“Indeed the Exynos 9810’s new modem supports CDMA.”). See also Mu-Hyun, Cho, “Samsung Boosts Mid-Tier Exynos 7 AP with Deep Learning Image Processing,” ZDNet, March 22, 2018 (“It has a 6 mode modem that covers 2G DCMA to 4G LTE [...].”). See also “Mobile Processor Exynos 7 Series (7885),” Samsung,

*b. Analysis*

363. Samsung S-LSI displayed adequate foresight, substantial and sustained investment, and sufficient execution to develop and sell modem products for Samsung’s mobile devices. Samsung S-LSI’s LTE modem chips have recently come to be considered of high quality and are used extensively in its own mobile devices. However, adoption of Samsung S-LSI’s modem chips by other OEMs has been limited due to a lack of an integrated AP in earlier products as well as reported hesitation among mobile device OEMs to support and source modem chips from a competitor.
364. Foresight: Samsung S-LSI’s foresight has been mixed. Beginning with the release of its first CDMA chip in 1999, Samsung S-LSI continued developing modem chips that could eventually be used in Samsung’s mobile devices.<sup>969</sup> [REDACTED]

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available at <http://www.samsung.com/semiconductor/minisite/exynos/products/mobileprocessor/exynos-7-series-7885> (“The modem supports multi-modes from 2G to 4G including CDMA [...]”).

<sup>969</sup> See, e.g., LaPedus, Mark, “Samsung to Develop Line of Wireless Chips,” EE Times, April 13, 1999 (“Hoping to lessen its dependence on Qualcomm Inc. in the wireless-chip arena, Samsung Electronics Co. Ltd. Has disclosed an aggressive strategy to develop components for its own CDMA-based handset lines. [...] Samsung plans to develop its own line of digital-cellular chipsets [...]. [...] Last week Samsung said it has begun producing the SCom 3000 CDMA chip set [...]”). See also SFT-07563848 at 849 (translation), internal report titled “[REDACTED] Samsung, April 14, 2016 ([REDACTED])”).

<sup>970</sup> See, e.g., SFT-4857460 at 461, presentation titled “CDMA Acquisition History and Progress,” Samsung, January 27, 2016 [REDACTED]

<sup>971</sup> Kalkman Deposition, Samsung, pp. 239–240 [REDACTED]

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365. Samsung S-LSI showed effective foresight in its early focus on LTE. Samsung S-LSI began to focus on producing LTE chips in 2006.<sup>972</sup> By 2010, Samsung S-LSI had developed an LTE chip,<sup>973</sup> and by 2013, Samsung began using its self-supplied LTE chips in the Galaxy Note series of mobile devices.<sup>974</sup> [REDACTED]
- [REDACTED]
- [REDACTED].<sup>975</sup> In late 2014 and early 2015, Samsung opted for an internally sourced non-integrated solution due to concerns over the performance of Qualcomm’s MSM8994 in the Galaxy S6.<sup>976</sup> Samsung S-LSI increased the number of chips it supplied to Samsung every year from 2013, becoming Samsung’s largest supplier in 2017, when it supplied 42 percent of modem chips used in Samsung devices.<sup>977</sup>
366. However, during this time, Samsung S-LSI’s modem chips at first did not provide certain features demanded by other OEMs. For example, in 2011, Samsung S-LSI had not yet developed an SoC solution, whereas other modem chip suppliers already had integrated designs, which concerned some potential customers.<sup>978</sup> [REDACTED]

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<sup>972</sup> See, e.g., SFT-4731218 at 1221 (translation), email from Jung-In Kim, Samsung, October 29, 201 [REDACTED]

<sup>973</sup> See Exhibit V.B.7.

<sup>974</sup> Kang Deposition, Samsung, pp. 222–223 [REDACTED]

<sup>975</sup> Kang Deposition, Samsung, pp. 87–89 [REDACTED]

<sup>976</sup> Kang Deposition, Samsung, p. 96 (“Q. And does that refresh your recollection that in late 2014 and early 2015, Samsung was unhappy with the performance of the MSM 8994 for the Galaxy S6 and, therefore, ultimately opted for an LSI two-chip solution for that phone? A. Yes, it does.”).

<sup>977</sup> See Exhibits IV.B.3 and IV.B.4.

<sup>978</sup> Kalkman Deposition, Samsung, pp. 239–24 [REDACTED]

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Despite this, Samsung S-LSI has recently pursued efforts to expand its customer pool for modem chips, including via ongoing discussions with ZTE.<sup>980</sup> Samsung S-LSI has also sold components other than modem chips to outside OEMs, and in 2017, Samsung S-LSI announced plans to expand its contract manufacturing business in addition to growing its direct sales to other OEMs.<sup>981</sup>

367. Investment: Samsung has invested substantial amounts in its modem chip R&D. Although Samsung reportedly considered acquiring Infineon’s modem chip division in 2011,<sup>982</sup> since the 1990s, it has developed its products internally and largely without acquisitions. With access to over 20,000 engineers worldwide, Samsung spent \$37 billion on all forms of R&D between 2005 and 2010,<sup>983</sup> and another \$87 billion between 2011 and 2017.<sup>984</sup> Samsung is expected to

See also Exhibits V.B.5 and V.B.7.

<sup>979</sup> See, e.g., “Customised Baseband Quarterly Market Share Tracker for Qualcomm: Parts 1 and 2,” Strategy Analytics, April 6, 2018. See also Kang Deposition, Samsung, pp. 152–153

<sup>980</sup> Lee, Joyce and Ju-Min Park, “Samsung in Talks with ZTE, Others to Supply Mobile Processor Chips: Executive,” Reuters, May 15, 2018 (“Samsung Electronics is in talks with several smartphone makers including China’s ZTE to supply mobile processor chips [...]).

<sup>981</sup> See, e.g., Tibken, Shara, “Samsung Makes a Lot of Money from Chips, but Phones Struggle,” CNet, April 25, 2018 (“[...] Samsung] sells more memory chips than any other company on the planet.”). See also Deposition of Andrew Hong, Senior UX Program Manager at Samsung, March 7, 2018 p. 36 (Hong Deposition, Samsung,)

Lee, Joyce and Se Young Lee, “Samsung Takes Aim at TSMC with Plans to Triple Chip Foundry Market Share,” Reuters, July 24, 2017 (“Samsung Electronics plans to triple the market share of its contract chip manufacturing business within the next five years by aggressively adding clients, a senior company executive said, as it targets new growth drivers for the chips business.”).

<sup>982</sup> “Samsung Electronics,” Macquarie Equities Research, November 17, 2011, p. 22 (“We understand that Samsung is keen on developing a baseband chip (modem chip) solution. In fact, many industry watchers believed that SEC was highly interested in Infineon’s baseband chip division (Wireless Solutions Business), which was later sold to Intel for US\$1.4bn.”).

<sup>983</sup> Fried, Ina, “Samsung: Apple Didn’t Invent the Rectangle,” AllThingsD, July 31, 2012 (“They’ve spent \$35 billion in R&D from 2005 to 2010. Over 20,000 engineers working on R&D worldwide with more than 1,000 designers.”).

<sup>984</sup> See Exhibit III.E.2 and associated backup.

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participate in the development of 5G technology, and its R&D efforts have already yielded many related patents.<sup>985</sup>

368. Execution: Samsung S-LSI’s effective execution allowed it to continue Samsung’s strategy of producing CDMA chips for its own devices through 2005.<sup>986</sup> Samsung S-LSI released its first LTE chips by 2010, around the same time as other modem chip suppliers such as Qualcomm,<sup>987</sup> though its chips trailed Qualcomm’s in features in the early 2010s. For example, Samsung S-LSI’s early LTE chips did not have an integrated AP or backward compatibility with 3G standards, while Qualcomm released the MSM8960 modem chip, which had such features, in 2012.<sup>988</sup> Samsung S-LSI’s LTE chips continued to advance to the point that in 2014 Samsung started using its own Exynos chips rather than Qualcomm chips in some versions of its flagship Galaxy S phones.<sup>989</sup> In 2015, Samsung S-LSI announced the Exynos 8 chip, which was its first LTE SoC.<sup>990</sup> In 2016, a Bain presentation to Intel suggested that Samsung S-LSI would be one of the top four suppliers of SoCs by 2020,<sup>991</sup> and in 2017, Samsung S-LSI announced

<sup>985</sup> “Top Companies Leading 5G Development,” Netscribes, November 9, 2017 (“What’s more interesting is that 31% of 5G patents are assigned to only six companies. Samsung has a major share with over 600 patents and is followed by other large corporations such as Intel, Nokia, Huawei, Ericsson, and ZTE.”).

<sup>986</sup> See, e.g., SFT-07563848 (translation), internal report titled [REDACTED]

<sup>987</sup> See Exhibit V.B.7.

<sup>988</sup> “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 60 (“Qualcomm, Renesas Mobile, and Nvidia-Icera were the sole suppliers of multimode (MM) 3G and Cat 3 FDD-LTE basebands during 2012. Both GCT and Samsung shipped single-mode Cat 3 LTE basebands which, when paired with a 3G baseband, offered equivalent functionality.”). See also Exhibit V.B.7.

<sup>989</sup> Kang Deposition, Samsung, p. 96 (“Q. And does that refresh your recollection that in late 2014 and early 2015, Samsung was unhappy with the performance of the MSM 8994 for the Galaxy S6 and, therefore, ultimately opted for an LSI two-chip solution for that phone? A. Yes, it does.”). See also “Galaxy S6 32GB (Verizon),” Samsung (“[...] while the lightning-fast Samsung Exynos 7420 Octa-core 64-bit processor delivers the most power and speed we’ve ever put in a smartphone.”).

<sup>990</sup> Cunningham, Andrew, “Samsung’s New Exynos 8 SoC Includes an LTE Modem and Its First Custom CPU,” Ars Technica, November 12, 2015 (“[...] Today Samsung has announced its next-generation Exynos 8 SoC, the Octa 8890 [...] Samsung is integrating an LTE modem into the chip for the first time [...]”).

<sup>991</sup> [REDACTED]

the launch of the Exynos 8895, which *Computerworld* deemed “as good as [Qualcomm’s] Snapdragon 835, and better than MediaTek’s Helio X30.”<sup>992</sup>

## 5. HiSilicon

### a. Background

369. HiSilicon Technologies (HiSilicon) is a fabless semiconductor vendor and a wholly owned subsidiary of Huawei, a Chinese company that is the world’s third-largest smartphone OEM and the second-largest network infrastructure supplier.<sup>993</sup> Huawei established its internal chip design center in 1991 and founded HiSilicon in 2004 as a subsidiary from this design center.<sup>994</sup>
370. Aside from some early grey-market sales of its K3 reference design,<sup>995</sup> HiSilicon has focused entirely on selling modem chips to Huawei.<sup>996</sup> [REDACTED]  
[REDACTED] HiSilicon launched its first modem chip in 2006.<sup>998</sup> In 2009, HiSilicon released the

<sup>992</sup> Shah, Agam, “Beyond Smartphones, Samsung Wants Its Exynos 9 Chip in VR Headsets,” *Computerworld*, March 1, 2017.

<sup>993</sup> See, e.g., “Company Overview,” HiSilicon. See also Huawei 2016 Annual Report, p. 60 (“Huawei Investment & Holding Co., Ltd. [...] is a limited liability company established in Shenzhen in the People’s Republic of China [...]”) and p. 95 (“Name of subsidiaries[:] [...] HiSilicon Technologies Co., Ltd. [...] Proportion of ownership interest[:] [...] 100% [...] Principal activities[:] [...] Development and sale of semiconductors.”); “Global 4G Subscriber & Smart Device Market Update,” Forward Concepts, 2015, p. 42 (“Huawei is the #3 smartphone OEM and that helps HiSilicon achieve the scale needed to sustain expensive mobile chipset development. Further, Huawei is the second largest mobile infrastructure equipment supplier as well.”).

<sup>994</sup> Clarke, Peter, “HiSilicon Extends ARM Licenses for 3G/4G Comms,” *EE Times*, August 2, 2011 (“HiSilicon, formed in 2004 and previously Huawei’s ASIC design center since 1991, provides ASICs and application-specific standard products for communication networks and digital media.”).

<sup>995</sup> See, e.g., “Cellular Handset & Tablet Chip Markets,” Forward Concepts, 2012, p. 159 (“Many of the non-Smartphones in the Shanzhai [Chinese imitation and pirated brands and goods] Phone market are powered by a MediaTek chipset [...]. [...] Much of the Shanzhai Smartphone market activity has been dominated by Huawei’s HiSilicon K3 (Hi3611) Windows Mobile 6.1 reference solution.”). See also Jingjing, Zhou, “The History of China’s Chip Ups and Downs: China’s Star Market has Accounted for 60% of the Market, Huawei Carried the Banner,” *China IT News*, April 25, 2018 (“In 2009, Huawei launched the first K3 processor for the open market. Positioning competed with Spreadtrum and MediaTek to compete in the Shanzhai market. [...] Huawei did not use [K3] in its own products.”).

<sup>996</sup> See, e.g., “2015 LTE Baseband Competition Hotting up, Qualcomm’s Lead Shrinking,” *Strategy Analytics*, January 12, 2015, p. 5 (“HiSilicon and Samsung currently supply basebands to their respective in-house customers Huawei and Samsung Mobile only.”).

<sup>997</sup> [REDACTED]

<sup>998</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2009, p. 112.

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K3, which supported Windows Mobile and combined its own AP with a modem from Spreadtrum or Infineon.<sup>999</sup> By this time, HiSilicon also had a team of more than 1,200 engineers focused on developing technologies such as LTE modem chips.<sup>1000</sup> Reflecting this engineering effort, HiSilicon released LTE modem chips of increasing complexity: a single-mode LTE modem chip in 2011,<sup>1001</sup> a multi-mode LTE/WCDMA modem chip in 2012,<sup>1002</sup> and an LTE SoC in 2014.<sup>1003</sup>

371. After internally developing CDMA technology, HiSilicon added CDMA support to its multi-mode modem chips starting with the Kirin 960, released in 2016.<sup>1004</sup> While HiSilicon provided chips for 45 percent of Huawei’s handsets in 2017 and has been Huawei’s largest chip supplier since 2016,<sup>1005</sup> the company faced a recent setback when a Huawei deal to sell smartphones in the U.S. fell through.<sup>1006</sup> Despite this setback, HiSilicon’s year-over-year growth in the

<sup>999</sup> “HiSilicon Introduces Solution for Windows-based Smart Phone,” Free Online Library, July 7, 2009 (“HiSilicon announced its ‘Hisilicon K3’ solution in March this year. The solution is composed of a Hisilicon-designed application processor and a modem chip supplied by Spreadtrum [...] or Infineon [...]. Their modem chips support Windows Mobile 6.1 OS.”).

<sup>1000</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2009, p. 112 (“[HiSilicon] is also developing technologies such as long-term evolution (LTE) [...]. The company has dedicated a 1,200-strong R&D team to the segment, spread across centers located in China, India, Sweden and the US.”).

<sup>1001</sup> HiSilicon’s LTE modem was commercially sampled in Q4 2010 and available in mobile devices beginning in Q2 2011. See, e.g., Q2014FTC04417597, p. 30 (“Huawei[:] [...] Hi6910[:] CS Date[:] Q4’10[:] Modem[:] LTE only[:] 1<sup>st</sup> End Product Available[:] Fixed CPE device Q2’11”).

<sup>1002</sup> “HiSilicon Releases Leading LTE Multi-mode Chipset,” HiSilicon Press Release, February 27, 2012 (“HiSilicon Technologies today releases Balong 710, the world’s first multi-mode chipset supporting 3GPP Release 9 and LTE Category 4 [...]. [...] Some leading features of Balong 710 are as following: LTE FDD mode [...] TD-LTE mode [...] WCDMA Dual Carrier with MIMO [...].”).

<sup>1003</sup> “Global 4G Subscriber & Smart Device Market Update,” Forward Concepts, 2015, p. 221 (“HiSilicon, Huawei’s in-house silicon business unit, has launched its first LTE-integrated applications processors Kirin 910 and Kirin 920 in 2014.”).

<sup>1004</sup> See, e.g., Cutress, Ian and Andrei Frumusanu, “Huawei Announces the HiSilicon Kirin 960: 4xA73 + 4xA53, G71MP8, CDMA,” AnandTech, October 19, 2016 (“Currently three smartphone modem providers have CDMA solutions (Qualcomm in integrated and discrete modems, Intel with discrete, Mediatek with VIA-based integrated), and we spoke with HiSilicon to confirm that this is a brand new custom CDMA solution, rather than a licensed platform.”). See also Triggs, Robert, “HiSilicon’s Kirin 960 is Ready to Take on Samsung and Qualcomm,” Android Authority, October 31, 2016 (“Huawei has boosted the performance of its latest LTE modem and has also introduced support for CDMA technology [...]. [...] HiSilicon has created its own custom CDMA solution.”).

<sup>1005</sup> See Exhibits IV.B.3 and IV.B.4.

<sup>1006</sup> See, e.g., Mozur, Paul, “AT&T Drops Huawei’s New Smartphone Amid Security Worries,” The New York Times, January 9, 2018 (“AT&T walked away from a deal to sell the Huawei smartphone, the Mate 10, to customers in the United States just before the partnership was set to be unveiled [...]. [...] Last month, a group

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number of modem chips sold has outpaced most modem chip suppliers over the 2014–2017 period.<sup>1007</sup>

*b. Analysis*

372. HiSilicon’s success has been due to its strong foresight, substantial and strategic investments, and consistent ability to execute its chip development and design. HiSilicon gained experience from supplying modem chips for a broad variety of Huawei mobile devices and internally developed its own CDMA technology, thus unlocking new potential sales in multi-mode LTE chips. HiSilicon has invested heavily in developing technology, including through a large team of engineers, and has reliably brought new products with demanded features to market year after year.

373. Foresight: Since its formation, HiSilicon has shown strong foresight that has helped to sustain and grow its business. First, HiSilicon showed foresight by providing Huawei with modem chips that fit Huawei’s needs. [REDACTED]

[REDACTED]<sup>1008</sup> In addition to supplying Huawei’s flagship mobile devices with its 900-series Kirin SoCs,<sup>1009</sup> [REDACTED]

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of lawmakers wrote a letter to the Federal Communications Commission expressing misgivings about a potential deal between Huawei and an unnamed American telecommunications company to sell its consumer products in the United States.”). See also Stolyar, Brenda, “U.S. lawmakers reportedly pressure AT&T to completely cut ties with Huawei,” Digital Trends, January 16, 2018 (“The news comes after AT&T was reportedly pressured into dropping the deal earlier this month – due to a letter written by a group of lawmakers to the Federal Communications Commission expressing their concerns over Huawei’s plans to sell its products through a U.S. carrier [...]. The letter specifically cited Huawei’s ties to the Chinese government – a concern that has caused the company difficulty breaking into the U.S. in the past.”).

<sup>1007</sup> See Exhibit IV.B.5.

<sup>1008</sup> [REDACTED]

<sup>1009</sup> See, e.g., R, Rahul, “Huawei Ascend Mate 3 Expected to Go Official on 4 September: Flagship Smartphone to Feature 6.1in Display and 13MP Camera,” International Business Times, August 18, 2014 (“Another aspect that people can look out for in the next Ascend Mate is the Huawei Kirin 920 octa-core processor, which was

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[REDACTED]<sup>1010</sup> Due in part to its foresight and planning, HiSilicon has progressively increased the number of chips it has supplied to Huawei in each year since at least 2013.<sup>1011</sup> Going forward, Huawei has indicated that it will continue to source chips from HiSilicon as part of a “multi-vendor strategy” that includes purchasing modem chips from HiSilicon, MediaTek, and Qualcomm.<sup>1012</sup>

374. More recently, HiSilicon has demonstrated foresight in its development of CDMA technology for use in multi-mode chips. [REDACTED]

[REDACTED]<sup>1013</sup> While modem chip

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recently made official by Huawei.”). See also “Global 4G Subscriber & Smart Device Market Update,” Forward Concepts, 2015, p. 43 (“The Ascend Mate 8 [...] smartphone introduced October 2015 embeds the Kirin930 [sic] platform. [...] The Ascend Mate 7 was among the first Huawei smartphone[s] to embed the earlier Kirin 925 [...] in September of 2014. The Honor 6 Plus PE embedded the chips in December of 2014 [...]”); Humrick, Matt, “The Huawei Mate 9 Review,” AnandTech, January 27, 2017 (“Making its debut inside the Mate 9’s aluminum chassis is HiSilicon’s new Kirin 960 SoC.”); Cutress, Ian, “Hands-on & More with Huawei’s Mate 10 and Mate 10 Pro: Kirin 970 Meets Artificial Intelligence,” AnandTech, October 16, 2017 (“[...] Huawei is taking the wraps off of their latest generation flagship smartphone, the Mate 10 series. Powered by subsidiary HiSilicon’s 970 SoC [...]”).

<sup>1010</sup> See, e.g., [REDACTED]

[REDACTED] See also Cragg, Oliver, “Huawei P Smart with EMUI 8.0, FullView display launches on Vodafone UK,” Android Authority, February 1, 2018 (“The Huawei P Smart is coming to the UK in partnership with Vodafone. The budget device, which is available on various contract plans or on Pay as you go for £229. [...] The UK model is powered by the Chinese giant’s octa-core Kirin 659 chipset [...]”); Van Camp, Jeffrey, “Review: Honor 7X,” Wired, February 22, 2018 (“[...] I was excited to check out the new Honor 7X, an affordable phone that promises to run fast. [...] A \$200 device with most of the cutting-edge features is still the holy grail of the smartphone world. [...] [A]nd now Honor wants to join the club. [...] When you first boot it up, the 7X is snappy, running on 2016’s Android 7.0 with Huawei’s Emotion UI interface slapped on top, 3GB of RAM, 32GB of internal memory (with MicroSD slot), and a custom eight core Kirin 659 processor [...]”).

<sup>1011</sup> See Exhibit IV.B.4.

<sup>1012</sup> Tao, Li and Yingzhi Yang, “Huawei Has Been Building Its Substitute to Android for a Rainy Day. Is That Day Looming?,” South China Morning Post, April 27, 2018 (“[Huawei] will continue to buy chip sets from [...] Qualcomm and [...] MediaTek [...]. Its Kirin chips will be used on its own smartphones and not sold to external customers [...]. ‘We remain committed to this multi-vendor strategy, as it is critical to ensure healthy development of the smartphone business,’ Huawei’s rotating chairman Eric Xu said [...]”).

<sup>1013</sup> See, e.g., [REDACTED]

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suppliers such as MediaTek and Intel elected to acquire CDMA technology from another chip supplier,<sup>1014</sup> as discussed above, [REDACTED]

[REDACTED]<sup>1015</sup> Since most Chinese customers demand mobile devices that support all wireless standards used in China, including CDMA,<sup>1016</sup> [REDACTED]

[REDACTED]<sup>1017</sup> Although HiSilicon’s investment in CDMA has not yet allowed HiSilicon to sell modem chips in the U.S. or Canada,<sup>1018</sup> this appears to stem from geopolitical factors rather than from any issues

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<sup>1014</sup> See Section V.C.2 and Section V.C.3.

[REDACTED]

<sup>1016</sup>

<sup>1017</sup>

<sup>1018</sup> “Baseband/Modem & Smartphone Market,” Forward Concepts, 2017, p. 85 (“There were two models using the Kirin960 and supporting the CDMA EVDO RA baseband modem, but it is noted that CDMA EVDO RA usage

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related to HiSilicon’s CDMA solution. Huawei attempted to negotiate a deal with AT&T to sell its smartphones in the U.S., but the deal fell through in early 2018, reportedly due to national security concerns voiced by U.S. lawmakers.<sup>1019</sup>

375. Investment: Although HiSilicon’s early modem chips did not achieve much commercial success,<sup>1020</sup> the company’s substantial investment in LTE put it in a position to succeed with the new standard. As a result, the company’s Kirin LTE SoCs are now on the cutting edge of modem chip technology.<sup>1021</sup> Moreover, HiSilicon receives consistent support from its parent company Huawei, and even though HiSilicon does not sell its modem chips to other OEMs, industry analysts assert that Huawei’s position as the world’s third-largest smartphone OEM affords HiSilicon the scale and funding necessary to continue investing in R&D.<sup>1022</sup>

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in North America requires a 9-month certification process. Huawei has little or no market in Canada or the United States.”).

<sup>1019</sup> See, e.g., Mozur, Paul, “AT&T Drops Huawei’s New Smartphone Amid Security Worries,” The New York Times, January 9, 2018 (“AT&T walked away from a deal to sell the Huawei smartphone, the Mate 10, to customers in the United States just before the partnership was set to be unveiled [...]. [...] [L]ast month, a group of lawmakers wrote a letter to the Federal Communications Commission expressing misgivings about a potential deal between Huawei and an unnamed American telecommunications company to sell its consumer products in the United States.”). See also Stolyar, Brenda, “U.S. lawmakers reportedly pressure AT&T to completely cut ties with Huawei,” Digital Trends, January 16, 2018 (“The news comes after AT&T was reportedly pressured into dropping the deal earlier this month – due to a letter written by a group of lawmakers to the Federal Communications Commission expressing their concerns over Huawei’s plans to sell its products through a U.S. carrier [...]. The letter specifically cited Huawei’s ties to the Chinese government – a concern that has caused the company difficulty breaking into the U.S. in the past.”).

<sup>1020</sup> See Exhibit V.C.5.

<sup>1021</sup> See, e.g., Triggs, Robert, “HiSilicon’s Kirin 960 Is Ready to Take on Samsung and Qualcomm,” Android Authority, October 31, 2016 (“[...]he Kirin 960’s LTE modem supports Category 12 download, with 4x carrier aggregation, 4x4 MIMO, 256 QAM spatial stream modulation, and download speeds up to 600Mbps. The SoC also boasts Category 13 upload capabilities, which tops out at 150Mbps. This is right in the same category as the Snapdragon 820 and Exynos 8890.”). See also Real, Mark, “Kirin 970 Is the First Mobile SoC That Supports Cat. 18 LTE,” Android Headlines, September 18, 2017 (“Huawei’s Kirin 970 processor attained maximum data speeds of 1.2Gbps in a test conducted with the equipment supplier Rohde & Schwarz (R&S). This makes the Kirin 970 as the first smartphone chipset to formally support Category 18 LTE. In contrast, Qualcomm’s current flagship product, the Snapdragon 835, supports Category 16 downlink LTE, and can achieve maximum download speeds of 1Gbps.”).

<sup>1022</sup> See, e.g., “Global 4G Subscriber & Smart Device Market Update,” Forward Concepts, 2015, p. 42 (“Huawei sees HiSilicon as a strategic investment and has been supporting it consistently. First Huawei is the #3 smartphone OEM and that helps HiSilicon achieve the scale needed to sustain expensive mobile chipset development.”). See also Tao, Li and Yingzhi Yang, “Huawei Has Been Building Its Substitute to Android for a Rainy Day. Is That Day Looming?,” South China Morning Post, April 27, 2018 (“Huawei has one of the largest research budgets in technology, spending US\$14.2 billion [in 2017] on research and development [...].

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376. *Execution:* HiSilicon has shown a consistent ability to execute in its chip development. HiSilicon has steadily improved the quality of its chips to the point where its 2016 and 2017 Kirin 900-series offerings, the Kirin 960 and Kirin 970, respectively, were considered by industry analysts to be competitive with any other available modem chip.<sup>1023</sup> HiSilicon’s development of CDMA technology also illustrates its strength in execution; [REDACTED]
- [REDACTED]
- [REDACTED]

## 6. ST-Ericsson / Ericsson

### a. Background

377. ST-Ericsson was created in 2009 as a 50/50 joint venture between Swedish network infrastructure provider Ericsson and French/Italian semiconductor company STMicroelectronics.<sup>1025</sup> ST-Ericsson was the culmination of several modem chip-related acquisitions and joint ventures by its parent firms:<sup>1026</sup>

- a. In 2001, Ericsson and Sony merged their mobile device businesses (with the exception of Ericsson’s mobile platform unit) to form the Sony Ericsson joint

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[...] As a result of that spending, Huawei’s HiSilicon unit, a Shenzhen-based semiconductor company, was able to develop the Kirin chip, which has increasingly been used in its namesake handsets [...].”).

<sup>1023</sup> See, e.g., Triggs, Robert, “HiSilicon’s Kirin 960 Is Ready to Take on Samsung and Qualcomm,” Android Authority, October 31, 2016 (“The Kirin 960 is undoubtedly HiSilicon’s best SoC to date, thanks to a range of new high-end features, and it handily competes with the best SoCs on the market right now.”). See also Frumusanu, Andrei, “HiSilicon Kirin 970 – Android SoC Power & Performance Overview,” AnandTech, January 22, 2018 (“HiSilicon’s new [Kirin 970] proves itself as an excellent smartphone SoC that’s well-able to compete with Qualcomm’s and Samsung’s best SoCs.”).

<sup>1024</sup> [REDACTED]

<sup>1025</sup> See, e.g., STMicroelectronics, 20-F, 2009, p.11. See also “Ericsson and STMicroelectronics to Create World Leader in Semiconductors and Platforms for Mobile Applications,” Ericsson Press Release, August 20, 2008; “About Us,” Ericsson; “Ericsson Sweden,” Ericsson; “Who We Are,” STMicroelectronics.

<sup>1026</sup> See Exhibit III.D.1.

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venture.<sup>1027</sup> Ericsson used the residual mobile platform R&D group to establish the chip design and mobile platform team Ericsson Mobile Platforms (EMP).<sup>1028</sup> EMP would eventually become part of the ST-Ericsson joint venture.

- b. STMicroelectronics historically designed and manufactured multimedia APs and connectivity chips,<sup>1029</sup> and it began designing modem chips in late 2007.<sup>1030</sup> In August 2008, it merged its modem chip business with that of chip vendor NXP in an 80/20 joint venture under the name ST-NXP.<sup>1031</sup> Shortly after the ST-NXP joint venture was announced, STMicroelectronics and Ericsson announced a 50/50 joint venture merging their respective modem chip businesses ST-NXP and EMP to create ST-Ericsson.<sup>1032,1033</sup>

378. The stated goal of the ST-Ericsson joint venture was to create a world leader in the modem chip industry through increased scale, relationships with a wider set of customers, and the

<sup>1027</sup> See, e.g., “Sony and Ericsson Complete Joint Venture Agreement,” Sony Press Release, August 28, 2001 (“Sony Corporation and Telefonaktiebolaget LM Ericsson today announced that they have agreed terms to merge their mobile phone businesses worldwide [...]. The two companies which signed their Memorandum of Understanding in April are well on schedule and set to establish the joint venture, Sony Ericsson Mobile Communications [...].”). See also “Ericsson and Sony to Create World Leader in Mobile Phones,” Sony Press Release, April 24, 2001 (“Ericsson’s Mobile Technology Platform unit will remain as a separate organization and will supply state of the art technology to the new company.”).

<sup>1028</sup> Kornby, Michael, “The EMP Story,” Ericsson Review, 2005 (“Established in September 2001, Ericsson Mobile Platforms is based on the research and development (R&D) group that developed the core technology for Ericsson’s mobile phones throughout the 1990s.”).

<sup>1029</sup> STMicroelectronics, 20-F, 2006, p. 26 (“We offer a family of products, known as the ‘Nomadik’ family, addressing the market for multimedia application processor chips. [...] To respond to the market need for increased functionality of handsets, we created the Connectivity Division to address wireless LAN (‘WLAN’), Bluetooth and connectivity requirements.”).

<sup>1030</sup> STMicroelectronics began modem chip design when Nokia, its leading customer, transferred approximately 185 engineers to STMicroelectronics to design and manufacture WCDMA modem chips. See, e.g., STMicroelectronics, 20-F, 2006, p. 12 (“As of December 31, 2006, our largest customer was Nokia, which accounted for 21.8% of our 2006 net revenues, compared to 22.4% in 2005 and 17.1% in 2004.”). See also “Nokia and STMicroelectronics Close the Agreement in 3G Chipset Development,” Nokia Press Release, November 5, 2007.

<sup>1031</sup> See, e.g., “STMicro, NXP Merge \$3 Bln Wireless Chip Operations,” Reuters, April 10, 2008 (“STMicroelectronics (STM.PA) and NXP NXP.UL will merge their wireless chip businesses into a \$3 billion joint venture controlled by STMicro [...]. STMicro said it would pay NXP \$1.55 billion to own 80 percent of the venture [...].”). See also STMicroelectronics, 20-F, 2009, p. 26 (“The wireless segment resulted from the combination of our wireless business with NXP’s to create ST-NXP Wireless as of August 2, 2008.”).

<sup>1032</sup> “Ericsson and STMicroelectronics to Create World Leader in Semiconductors and Platforms for Mobile Applications,” Ericsson Press Release, August 20, 2008 (“STMicroelectronics (NYSE:STM) and Ericsson (NASDAQ:ERIC) today announced an agreement to merge Ericsson Mobile Platforms and ST-NXP Wireless into a joint venture. The 50/50 joint venture [...].”).

<sup>1033</sup> Since ST-NXP was an 80/20 joint venture between ST and NXP, ST acquired NXP’s remaining shares in ST-NXP in the process of forming ST-Ericsson. See STMicroelectronics, Form 20-F, for the fiscal year ended December 31, 2009, p. 9.

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combination of complementary product offerings.<sup>1034</sup> The joint venture initially sold legacy products from its parent companies, including multimedia and connectivity chips as well as GSM, WCDMA, and TD-SCDMA modem chips.<sup>1035</sup>

379.

[REDACTED]

[REDACTED]

[REDACTED].<sup>1036</sup>

[REDACTED]

[REDACTED].<sup>1037</sup> [REDACTED]

<sup>1034</sup> See, e.g., “Ericsson and STMicroelectronics to Create World Leader in Semiconductors and Platforms for Mobile Applications,” Ericsson Press Release, August 20, 2008 (“By combining the complementary strengths and product offerings of Ericsson and ST in platforms and semiconductors the joint venture is well positioned to become a world leader,” said Carl-Henric Svanberg, President and CEO of Ericsson. “The industry continues to develop at a swift pace and customers see benefits from our broad offering. This partnership is a perfect fit and secures a complete offering, as well as the necessary scale for technology leadership.”). See also Zander Deposition, Ericsson, pp. 42–43 (“Q. What was the reason that Ericsson had for establishing the STMicro joint venture? [...] A. [...] Another reason was that STMicroelectronics at that time had consolidated several assets, for example the NXP wireless they acquired, and they have also acquired the digital baseband team from Nokia, they had acquired connectivity assets such as Wi-Fi, Bluetooth. So by creating the joint venture with STMicroelectronics that also gave access to a customer base that was wider than the [...] Ericsson mobile platform customer base.”).

<sup>1035</sup> See, e.g., “Ericsson and STMicroelectronics to Create World Leader in Semiconductors and Platforms for Mobile Applications,” Ericsson Press Release, August 20, 2008 (“In the joint venture, ST contributes its industry-leading multimedia and connectivity solutions as well as a complete world-class 2G/EDGE platform and strong 3G offering [...]. Ericsson contributes its industry-leading 3G and LTE platform technology [...].”). See also Exhibit V.C.6.

<sup>1036</sup> See, e.g., Zander Deposition, Ericsson, pp. 45–46

[REDACTED]

[REDACTED] p. 73

[REDACTED], and

[REDACTED] p. 172

[REDACTED]

<sup>1037</sup> See, e.g., Q2014FTC03837571–7600 at 7596, email from Jim Lederer, Qualcomm, February 28, 2011, with attachment titled “QCT Competitive Update” [REDACTED]

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[REDACTED]<sup>1038</sup> [REDACTED]

[REDACTED] [REDACTED]<sup>1040</sup> [REDACTED]

[REDACTED]

[REDACTED]<sup>1041</sup> and did not result in meaningful LTE sales as ST-Ericsson shipped fewer than 300 LTE-compatible chips each year from 2010 through 2013.<sup>1042</sup>

380. By 2012, ST-Ericsson’s GSM and TD-SCDMA modem chip sales had fallen significantly.<sup>1043</sup>

[REDACTED]<sup>1044</sup> STMicroelectronics announced its decision to leave the joint venture in late 2012,<sup>1045</sup> and ST-Ericsson officially

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[REDACTED] See also ERIC-QCOM-00041193–1290 at 1276, presentation titled “ST-Ericsson Board Meeting,” ST-Ericsson, January 20, 2012.

<sup>1038</sup> See, e.g., Q2014FTC03837571–7600 at 7596, email from Jim Lederer, Qualcomm, February 28, 2011, with attachment titled “QCT Competitive Update” [REDACTED]

<sup>1039</sup> “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 74 (“The first M700 chip set supported LTE UE Class3 Release 8 (100 Mbps downlink and 50 Mbps uplinks) interface but did not integrate 3G HSPA legacy modem technology.”).

<sup>1040</sup> ERIC-QCOM-00040884–0947 at 0888. [REDACTED]

<sup>1041</sup> [REDACTED]  
[REDACTED] ee also ERIC-QCOM-0042033, p. 6, [REDACTED]

<sup>1042</sup> See Exhibit V.C.6.

<sup>1043</sup> See Exhibit V.C.6.

<sup>1044</sup> Zander Deposition, Ericsson, p. 46 [REDACTED]

<sup>1045</sup> “STMicroelectronics: ST Announces New Strategic Plan,” Yahoo Finance via Marketwire, December 10, 2012 (“‘Today we are announcing the new ST, aligned with the new market environment,’ said Carlo Bozotti, President and CEO of ST. ‘Based on that, we have made the decision to exit ST-Ericsson after a transition period.’ [...] ‘The new ST will be more focused, leaner and better positioned to deliver value to our customers and our shareholders, targeting to rapidly achieve operating margins of 10 percent.’”).

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dissolved in early 2013.<sup>1046</sup> In the split, STMicroelectronics assumed the legacy 2G/3G modem business, RF and power management chips, and the NovaThor integrated APs.<sup>1047</sup> STMicroelectronics continued to provide support for these legacy products but ceased effort to develop new models.<sup>1048</sup> Ericsson continued to develop LTE thin modems on its own, but eventually decided to exit the thin modem business in September 2014 and pursue growth opportunities in other areas.<sup>1049</sup>

*b. Analysis*

381. ST-Ericsson made crucial errors in foresight, investment, and execution. ST-Ericsson was overly dependent on certain customers, experienced critical R&D inefficiencies, and was constantly delayed in product development, resulting in a dissolution of the joint venture in early 2013. After developing an LTE thin modem on its own, Ericsson decided that uncertainties stemming from thin modem customer concentration made investing in its network infrastructure business a less risky alternative to staying in the modem chip industry.

382. Foresight: [REDACTED]

<sup>1046</sup> O’Brien, Kevin J., “Ericsson and ST Microelectronics to Dissolve Venture,” The New York Times, March 18, 2013 (“Ericsson and STMicroelectronics announced plans on Monday to dissolve their unprofitable four-year-old Swiss venture, ST-Ericsson [...].”).

<sup>1047</sup> See, e.g., Kundojjala, Sravan, “The Breakup of ST-Ericsson,” Strategy Analytics, March 18, 2013 (“STMicro will oversee the existing products including legacy modem business, RF, Power Management and NovaThor integrated apps processors.”).

<sup>1048</sup> See, e.g., Clarke, Peter, “ST Takes 2G and 3G, Ericsson Gets LTE Modem,” EE Times Asia, March 20, 2013 (“In a conference call earlier this week, STMicroelectronics Carlo Bozotti assured that existing products and customers will continue to be supported though the company will cease development of complete hardware-software platforms for mobile equipments.”).

<sup>1049</sup> See, e.g., “Ericsson and STMicroelectronics Complete Transaction to Split Up ST-Ericsson,” Ericsson Press Release, August 5, 2013 (“Effective August 2, 2013 Ericsson has taken on the design, development and sales of the LTE multimode thin modem solutions, including 2G, 3G and 4G interoperability.”). See also “Ericsson Discontinues Development of Modems - Shifts Part of Investment into Radio Networks,” Ericsson Press Release, September 18, 2014 (“Ericsson [...] today announced it will discontinue future development of modems and shift parts of resources in modems to radio network R&D to better capture growth opportunities in this area.”).

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[REDACTED].<sup>1050,1051</sup> However, industry analysts noted that when Nokia and Sony Ericsson began losing share in mobile device sales, ST-Ericsson’s sales dropped concurrently, as there were fewer Nokia and Sony Ericsson mobile devices into which it could sell chips.<sup>1052</sup> In addition to Nokia’s falling device sales harming ST-Ericsson’s non-modem chip sales, Nokia made the abrupt decision to migrate its devices to the Windows Phone 7 operating system. [REDACTED]

[REDACTED].<sup>1053</sup> Additionally, many of ST-Ericsson’s early customers for TD-SCDMA modem chips were non-Chinese device OEMs, which lost sales as the demand in

<sup>1050</sup> See, e.g., ERIC-QCOM\_SDCA-00042073–2163 at 2146, presentation titled “ST-Ericsson Board Meeting,” ST-Ericsson, April 20, 2012. See also ERIC-QCOM-00041734, presentation titled “ST-Ericsson Board Meeting Briefing,” Ericsson, October 19, 2012, p. 18.

<sup>1051</sup> ST-Ericsson’s sales to Nokia consisted mainly of products such as RF chips. However, [REDACTED]. See, e.g., Zander Deposition, Ericsson, pp. 59–60 [REDACTED]. See also Q2014FTC03837571–7600 at 7596, email from Jim Lederer, Qualcomm, February 28, 2011 with attachment titled “QCT Competitive Update” [REDACTED]

<sup>1052</sup> See, e.g., Kundojjala, Sravan, “The Breakup of ST-Ericsson,” Strategy Analytics, March 18, 2013 (“In retrospect, we think that Ericsson and ST Micro’s venture to create a European cellular chip powerhouse was always going to be a challenge, one that ultimately ended in failure, not just because of the difficulty of integrating disparate cultures from different companies, but also because the formation of ST-Ericsson coincided with a drastic decline in the joint-venture’s top customers, Nokia and Sony Ericsson (now Sony).”). See also Taylor, Chris, “ST-Ericsson Responds to Dimming Prospects with More Cost-Cutting, Focus on New Technology,” Strategy Analytics, June 4, 2012 (“ST-Ericsson’s main customers lost market share in 2011, among these Nokia and Sony-Ericsson, accounting for much of ST-Ericsson’s loss of sales.”).

<sup>1053</sup> See, e.g., Q2014FTC03837571–7600 at 7596, email from Jim Lederer, Qualcomm, February 28, 2011 with attachment titled “QCT Competitive Update” [REDACTED]

[REDACTED] See also ERIC-QCOM-00040883, p. 3, “ST-Ericsson Board Members Briefing,” Ericsson, October 2011 [REDACTED]

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China moved away from foreign suppliers.<sup>1054</sup> ST-Ericsson’s TD-SCDMA shipments fell, losing an opportunity to capitalize on the growing TD-SCDMA shipments industry-wide.<sup>1055</sup>

383. After the split of ST-Ericsson in 2013, Ericsson inherited the LTE thin modem product line, which some at Ericsson considered to be synergistic with the network infrastructure business.<sup>1056</sup> The company continued development of the M7450 LTE modem chip started by ST-Ericsson.<sup>1057</sup> Ericsson completed the M7450 and achieved a design win at Samsung,<sup>1058</sup>

[REDACTED]  
[REDACTED]  
[REDACTED].<sup>1060</sup> Overall, there was uncertainty

<sup>1054</sup> “Cellular Handset & Tablet Chip Markets,” Forward Concepts, April 2012, p. 118 (“ST-Ericsson’s shipments in TD-HSPA declined from 2010 as the midrange market shifted away from foreign suppliers Samsung, Motorola, HTC and Nokia, leaving them with Huawei as their only active bidder.”).

<sup>1055</sup> Sales of modem chips for which TD-SCDMA was the highest standard across all firms rose from 18 million in 2009 to 95 million in 2012. During the same period, ST-Ericsson’s share of sales of chips for which TD-SCDMA was the highest standard fell from 37 percent to three percent. See Exhibit V.C.6 and associated backup.

<sup>1056</sup> Zander Deposition, Ericsson, p. 207 (“Q. And so why was Ericsson focusing on LTE multimode thin modems for smartphones and tablets at this time? A. [...]ur strategic interest in ST-Ericsson was the cellular technology that supported our radio business, and with the technology leadership that Ericsson has in its radio business we also had an interest of having a corresponding modem to support that business, hence we wanted to focus on the latest technologies with the most reference to our core business.”).

<sup>1057</sup> Zander Deposition, Ericsson, p. 57 (“Q. [...] Do you recall whether ST-Ericsson joint venture was able to deliver the M7450 technologies? A. The M7450 was finalized and commercially launched after the joint venture was terminated.”) and p. 108 (“Q. And then did Ericsson invest more to commercialize that product? A. [...]We execute and then we brought 7450 to the market, and to -- to determine, you know, if -- if that would be a good foundation to increase the bets.”).

<sup>1058</sup> ERC-CID-00000313, document titled “Item 5.2 Modems Update,” Ericsson (“In September 2013 we presented the outcome from the break-up of ST-Ericsson, strategic options for Modems and a step-wise approach for value creation. The direction was to bring M7450 to market and explore potential license/modules. BMOD has executed well on the stepwise value creation plan and successfully validated the 7450 modem on the market with initial commercial ramp together with Samsung.”).

<sup>1059</sup> [REDACTED]

<sup>1060</sup> [REDACTED]

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to staying in the thin modem business. According to an Ericsson executive, demand for thin modems came primarily from Apple and Samsung, and their procurement policies made winning business with them unpredictable and costly.<sup>1061</sup> [REDACTED]

[REDACTED]<sup>1062</sup>

384. Investment: [REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]

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<sup>1061</sup> Zander Deposition, Ericsson, p. 144 [REDACTED]  
[REDACTED]

<sup>1062</sup> Zander Deposition, Ericsson, p. 102 [REDACTED]  
[REDACTED]

<sup>1063</sup> Zander Deposition, Ericsson, pp. 171–172 [REDACTED]  
[REDACTED]

<sup>1064</sup> ERIC-QCOM-00040884–0947 at 0900, [REDACTED]  
[REDACTED]

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[REDACTED]

[REDACTED]”<sup>1065</sup>

385. Furthermore, since the company was formed by merging the wireless units of EMP, NXP, and STMicroelectronics, it inherited numerous legacy R&D sites.<sup>1066</sup> [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]<sup>1068</sup> Three years into its existence, ST-Ericsson announced a new strategic direction to attempt to address some of these issues. With the new strategic direction, ST-Ericsson planned to focus on its modem chips integrated with APs and to both reduce operating expenses and improve R&D execution by consolidating R&D sites.<sup>1069</sup>

<sup>1065</sup> ERIC-QCOM-00040884-0947 at 0901, [REDACTED]

<sup>1066</sup> Clarke, Peter, “ST-Ericsson to Close R&D Sites,” EE Times, July 27, 2011 (“ST-Ericsson is 50:50 joint venture between STMicroelectronics NV and Ericsson AB and also includes employees from NXP’s wireless business that were wrapped up into ST-NXP prior to the formation of ST-Ericsson in February 2009. As such, it has numerous legacy sites in France, Switzerland, the United Kingdom and China and the far-east.”).

<sup>1067</sup> Zander Deposition, Ericsson, p. 46 [REDACTED]

p. 172 (

<sup>1068</sup> Zander Deposition, Ericsson, pp. 45–46 [REDACTED]

and p. 73

<sup>1069</sup> “Ericsson’s JV ST-Ericsson Announces New Strategic Direction,” Ericsson Press Release, April 23, 2012 (“The new strategic direction leverages on ST-Ericsson’s unique capability to deliver complete system solutions for smartphones and tablets; competitive integrated modem plus application processor solutions (ModAp) will be the key differentiating offering through a combined approach of development and alliances. [...] In addition to

386. Execution: ST-Ericsson made key missteps in execution that tie strongly to its failure as a joint venture. Despite strong initial sales of both GSM and TD-SCDMA modem chips, ST-Ericsson failed to consistently execute in modem chip development, losing out on potential sales and profits. After being established, ST-Ericsson continued to sell legacy GSM modem chips, which originally accounted for the vast majority of modem chips shipped.<sup>1070</sup> Though ST-Ericsson was attempting to reconcile overlapping product portfolios and develop new smartphone SoCs,<sup>1071</sup> it was late to add features such as dual-SIM support and multimedia capabilities to its 2G products.<sup>1072</sup> Correspondingly, in 2012, ST-Ericsson’s GSM business suffered a sharp drop in the number of modem chips shipped.<sup>1073</sup>

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this strategy change, the company will focus on improving R&D execution and accelerating time-to-market, while reducing the overall operating expenses. The activities will be consolidated into a significantly smaller number of sites, which will be specialized by technology as ‘centers of excellence.’”).

<sup>1070</sup> See Exhibit V.C.6.

<sup>1071</sup> See, e.g., Taylor, Chris, “ST-Ericsson Responds to Dimming Prospects with More Cost-Cutting, Focus on New Technology,” Strategy Analytics, June 4, 2012 (“In its haste to rationalize three overlapping product portfolios, ST-Ericsson did not protect its legacy 2G, 2.5G and 3G products adequately, suffering a rather precipitous drop in sales in 2011.”). See also “Cellular Handset & Tablet Chip Markets,” Forward Concepts, 2012, p. 103 (“ST-Ericsson is suffering as sales of older chip lines decline, while its newer Smartphone and tablet chips are just getting started in late 2011.”).

<sup>1072</sup> See, e.g., “Cellular Handset & Tablet Chip Markets,” Forward Concepts, 2012, p. 122 (“The monolithic single-chip suppliers, namely Intel now and ST-Ericsson, lagged in supporting Dual-SIM receiver capability[.]”) and p. 130 (“Broadcom [...] ha[d] the unique advantage of H.264 decoding and GPRS/EDGE Class 32 support. ST-Ericsson only recently introduced the E4915 supporting H.264 video playback.”). See also “Cellular Handset & Chip Markets,” Forward Concepts, 2011, p. 122 (“In 2G [MediaTek] gained an advantage by embedding a low-cost 54-MHz ARM7, adding very basic multimedia features at a lower cost than the ULC competition. Adding early VGA-2MP camera support, MP3 Music, and small screen video playback features quicker and for less money than Infineon or ST-Ericsson.”).

<sup>1073</sup> In 2012, ST-Ericsson shipped fewer than 80 million GSM-only modem chips (6.6 percent of all GSM-only chips shipped in 2012), which was a marked decrease from the 123 million GSM-only modem chips it sold in 2009 (12.4 percent of all GSM-only chips shipped in 2009). See Strategy Analytics, “Baseband Market Share Tracker Q1 2018: Samsung LSI Overtakes MediaTek,” June 2018.

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387. NXP also brought TD-SCDMA experience to ST-Ericsson,<sup>1074</sup> and the joint venture took further steps to capitalize on that experience.<sup>1075</sup> While ST-Ericsson had a strong initial position, TD-SCDMA volumes were relatively small across the industry.<sup>1076</sup> As industry-wide TD-SCDMA shipments grew, ST-Ericsson lost a large volume of sales to Spreadtrum and Marvell.<sup>1077</sup> In addition to the aforementioned shift in TD-SCDMA away from non-Chinese mobile device OEMs, industry analysts noted that Spreadtrum and Marvell were also able to develop superior products, providing compatibility with newer operating systems and supporting updated standards such as TD-HSPA and TD-LTE.<sup>1078</sup>

<sup>1074</sup> In 2003, Philips Semiconductors (which would later spin off from Philips Electronics to become NXP) partnered with Datang Mobile Communications and Samsung to create the T3G joint venture intended to design and license chipsets for China’s developing TD-SCDMA standard. Later on, NXP also worked independently with T3G to design TD-SCDMA modem chips. See, e.g., Walko, John and Mike Clendenin, “Joint Venture Gives China’s 3G Spec a Boost,” EE Times, January 23, 2003. See also “China Receives NXP-T3G TD-SCDMA Solution,” EE Times Asia, May 29, 2008 (“Building on their leadership in TD-SCDMA, NXP Semiconductors and T3G Technologies have announced that the next-generation 3G cellular system solution T3G7208 is now commercially available in China.”).

<sup>1075</sup> ST-Ericsson bought out T3G in late 2008, as the joint venture was still coming together, and in May 2009, ST-Ericsson announced a strategic partnership with China Mobile to support the development of mobile devices for the TD-SCDMA standard. See, e.g., Clarke, Peter, “ST-Ericsson’s Acquisition of TD-SCDMA Pioneer, Pays Off,” EE Times, May 26, 2009 (“China Mobile is set to work with T3G Technology Co. Ltd. (Beijing, China) which was acquired by ST-Ericsson in November 2008.”) See also “ST-Ericsson Reports Second Quarter 2009 Financial Results,” Ericsson Press Release, July 23, 2009 (“In May, ST-Ericsson announced a strategic partnership with China Mobile to drive development of both high-end and low-cost handsets, based on 3G standard TD-SCDMA.”).

<sup>1076</sup> ST-Ericsson sold nearly 7 million chips for which TD-SCDMA was the highest standard in 2009, which was 36.9 percent of the total number of chips for which TD-SCDMA was the highest standard sold that year. See Strategy Analytics, “Baseband Market Share Tracker Q1 2018: Samsung LSI Overtakes MediaTek,” June 2018.

<sup>1077</sup> Sales of chips for which TD-SCDMA was the highest standard across all firms rose from 18 million in 2009 to 95 million in 2012. During the same period, as ST-Ericsson’s share of sales of chips for which TD-SCDMA was the highest standard fell from 37 percent to 3 percent, Spreadtrum’s share grew from five percent to 51 percent and Marvell’s share grew from no shipments to 17 percent. See Strategy Analytics, “Baseband Market Share Tracker Q1 2018: Samsung LSI Overtakes MediaTek,” June 2018.

<sup>1078</sup> See, e.g., “Cellular Handset & Tablet Chip Markets,” Forward Concepts, 2012, p. 111 (“We believe [Spreadtrum won a contract with Samsung] because of their integrated TD-LTE and TD-SCDMA baseband, which places them ahead of competition in 2012.”) and p. 118 (“Spreadtrum holds the strongest position, entering 2012 with its single-chip TD-SCDMA/HSDPA/GSM/GPRS baseband designed in a 40nm CMOS process.”). See also “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 94 (“[Spreadtrum] supported TD-HSPA with a dual mode TD-SCDMA RF transceiver, which placed them ahead of competition for feature phones and thin modems.”), p. 97 (“Marvell’s PXA918 was the first single-chip [modem with integrated AP] solution to feature China’s TD-SCDMA standard support to enable mobile developers to design Android 2.3 Smartphones.”), and p. 104 (“Marvel [sic] dominated the Smartphone segment with the early introduction of the PXA918, PXA920 and PXA920HT single core TD[-]SCDMA line up.”).

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388. ST-Ericsson also consistently struggled to meet product development schedules and lost out on design wins at several major OEMs as a result. [REDACTED]

1079 Zander Deposition, pp. 68–69

1080

1081 Zander Deposition, Ericsson, pp. 194–196

1082

Deposition, Ericsson, p. 58

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[REDACTED]

[REDACTED]

[REDACTED]

## 7. Texas Instruments

### *a. Background*

389. Texas Instruments (TI) is a global semiconductor design and manufacturing company with a wide range of products. The company started producing semiconductors after it invented the silicon transistor in 1954 and the integrated circuit in 1958.<sup>1085</sup> TI entered the modem chip industry in the early 1990s and primarily developed 2G and 3G chips.<sup>1086</sup> While TI provided both hardware and software components for 2G modem chips, for 3G chips it focused primarily

[REDACTED]

[Zander Deposition, Ericsson, pp. 196–197](#)

[REDACTED]

1083

[REDACTED]

1084 ERIC-QCOM-00040883, p. 2, presentation titled “ST-Ericsson Board Members Meeting,” Ericsson, October 2011- ([REDACTED])

1085 “History of Innovation,” Texas Instruments.

1086 In 1990, TI obtained its first 2G design win with Ericsson. In 1993, TI obtained cellular 2G design win with Nokia, though it acted as a foundry for Nokia’s modem chip designs. Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 10 (“Exhibit 2: Texas Instruments’ Key Cellular Baseband Activities”) and p. 17 (“TI’s GSM/GPRS customers currently include Nokia, Motorola, Sony Ericsson, [...] TI’s 3G baseband customers include Nokia and Motorola, although TI doesn’t have a baseband design of its own and it only manufactures chips for Nokia’s in-house baseband designs. Until recently, TI also had a similar foundry relation with EMP [...]. TI started a custom 3G programme with Motorola in mid-2008 [...].”).

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on providing the hardware, relying on its customers to develop the extensive software needed for the modem chips to function.<sup>1087</sup>

390. In the 2G segment, TI improved its products by acquiring Condat AG in 2002.<sup>1088</sup> In 2003, by partnering with Nokia and STMicroelectronics, TI developed a CDMA2000 product.<sup>1089</sup> By 2007, TI had released several low-cost GSM chips that were popular in China and a number of other countries.<sup>1090</sup>
391. In the 3G segment, TI’s early WCDMA offerings were popular among OEMs that were willing to internally develop modem chip software.<sup>1091</sup> While TI’s competitors offered both the hardware and embedded software required for modem chips to run, OEMs purchased TI’s fabricated WCDMA hardware and provided the software themselves. In 2005, TI attempted to provide both software and hardware for 3G products by partnering with NTT DoCoMo, but

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<sup>1087</sup> Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, pp. 5–6 (“TI doesn’t have a W-CDMA baseband design of its own unlike GSM/GPRS/EDGE basebands. The company only plays a foundry role to manufacture W-CDMA baseband ASICs for Nokia, Motorola and EMP’s in-house designs.”).

<sup>1088</sup> “Texas Instruments to Acquire Condat, Strengthening Its Chipset Solutions in Wireless Technology,” Texas Instruments Press Release, March 1, 2002 (“Texas Instruments [...] and Condat AG [...] announced today an agreement by which TI would acquire Condat. This acquisition enables TI to provide a complete GSM/GPRS chipset solution to its customers.”).

<sup>1089</sup> Mannion, Patrick, “TI and STMicro Offer Modular CDMA 1x Chip Set,” EE Times, December 5, 2003 (“Texas Instruments and STMicroelectronics have jointly announced an open, modular cdma2000 1x chip set [...]. The four-chip set is the first product realization to derive from the collaboration between the two companies ‘ and Nokia ’ [...].”).

<sup>1090</sup> “Cell Phones Set to Ring Up More Success,” Shanghai Daily, November 23, 2007 (“Our market share in China is several percentage points higher than the global level as demand surges for low-cost single-chip products LoCosto and eCosto,” said Xie Bing, Texas Instruments’ China president.”).

<sup>1091</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2009, p. 155 (“Texas Instruments continues as the global leader in ‘stackless’ WCDMA baseband chip sales as it supplies Nokia Corp.— and (decreasingly to) EMP/ST-Ericsson [...]. [...] TI supplies the silicon, and EMP the 3G-protocol stack and software based voice/audio codecs-”).

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this effort ultimately failed.<sup>1092</sup> TI soon returned to focusing on hardware for its 3G offerings.<sup>1093</sup>

392. TI was the largest modem chip supplier throughout the early and mid-2000s, peaking in 2007 with roughly 577 million modem chips shipped.<sup>1094</sup> However, in 2008, TI’s modem chip sales started dropping.<sup>1095</sup> In the 2G segment, TI faced competition from competitors such as MediaTek and Spreadtrum that catered to low-end devices,<sup>1096</sup> and in the 3G segment, OEMs switched to purchasing solutions that came with both hardware and software components.<sup>1097</sup> In 2008, TI announced that it would phase out its modem chip business to focus instead on APs,<sup>1098</sup> and in 2012, TI exited the modem chip business altogether.<sup>1099</sup>

<sup>1092</sup> See, e.g., “Texas Instruments Offers New Mobile Chip,” NBC News, November 29, 2005 (“TI developed the chip with Japan’s top mobile carrier, NTT DoCoMo Inc [...]. [...] TI’s new product, known as the OMAPV2230, represents a move beyond the custom W-CDMA chips TI makes [...].”). See also “Examine the Global Mobile Phone Platform (Baseband) Industry Report, 2007-2008,” MarketWired, May 19, 2008 (“TI has launched only one 3G baseband product, OMAPV2230, which is not that popular in the market.”); Strauss, Will, “DSP Market Bulletin – 10/29/07,” Forward Concepts, October 29, 2007 (“Earlier this year, TI quietly ceased development of its [WCDMA] baseband chip (OMAPV2230) that was first announced in November, 2005. The OMAPV2230 sampled, but did not go into production [...].”).

<sup>1093</sup> Strauss, Will, “DSP Market Bulletin – 10/29/07,” Forward Concepts, October 29, 2007 (“The cancellation coincided with the idea that in the near term TI could make more money continuing to ship UMTS baseband silicon designed by its customer. (read: Nokia).”).

<sup>1094</sup> See Exhibit III.D.3. See also Exhibit V.C.7, which indicates that, according to Strategy Analytics, TI sold about 577 million modem chips in 2007.

<sup>1095</sup> TI’s modem chip sales dropped to roughly 470 million chips in 2008 and continued to decline thereafter. See Exhibit V.C.7.

<sup>1096</sup> See, e.g., Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, pp. 6–7 (“TI has had some success with its own baseband designs in the low-end GSM/GPRS market [...]. However, TI faced increased competition from Infineon, MediaTek and Spreadtrum in this segment.”).

<sup>1097</sup> Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 18 (“The cellular baseband market is shifting from custom ASICs to ASSP solutions as handset manufacturers like Nokia, Motorola and Sony Ericsson are turning to off-the-shelf solutions to focus more on user experience and software. This has left TI vulnerable as the company currently doesn’t have a 3G baseband design of its own [...].”).

<sup>1098</sup> Barak, Sylvie, “TI Calls Baseband a Distraction, but Is It?” EE Times, November 10, 2011 (“TI made a strategic decision in 2008 to phase out of the baseband segment and focus on two key wireless growth areas: OMAP [Open Multimedia Applications Platform] processors and wireless connectivity solutions,” said the firm’s Director of Strategic Marketing, Avner Goren [...].”).

<sup>1099</sup> McDougall, Paul, “TI Cuts 1,700 Jobs, Exits Mobile Chip Market,” InformationWeek, November 15, 2012 (“Texas Instruments said it will lay off about 1,700 workers, or about 5% of its total workforce, as part of a restructuring that will see it exit the market for mobile chips that power smartphones and tablets [...].”). Strategy Analytics records roughly 3.2 million modem chip sales for TI in 2013, but these appear to be legacy

*b. Analysis*

393. TI’s foresight, investment, and execution in the 1990s and early 2000s worked well. The company focused on low-cost GSM products, invested in both R&D and an acquisition, and was able to sell a large number of 2G and hardware-oriented 3G modem chips. From at least as early as 2002 through 2009, TI was the top supplier of modem chips each year in terms of unit sales.<sup>1100</sup> However, the company was unable to maintain this success. TI relied on its largest customers for modem chip software, focused its investment on hardware instead of software at a time when OEMs wanted both, invested in 3G and 4G standards that did not gain popularity, and encountered price and component integration difficulties.
394. Foresight: TI’s focus on low-cost GSM products led to a large number of sales in the 1990s and 2000s, including high demand in China for TI’s LoCosto and eCosto low-cost 2G chips.<sup>1101</sup> The LoCosto chips supported both voice-centric GSM phones and higher-end 2G devices, allowing mobile device OEMs to use the chips in emerging markets that used the GSM standard, such as China, India, Brazil, and Africa, as well as in feature phones in regions such as Europe, Asia, and the U.S.<sup>1102</sup> However, TI did not adequately respond to the emergence of low-cost competitors such as MediaTek, Spreadtrum, and Infineon, causing its sales of LoCosto chips to stagnate in 2008.<sup>1103</sup>

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sales after TI’s 2012 announcement. See Texas Instruments Form 10-Q, Q1 2013, p. 6 (“Effective January 1, 2013, the Wireless segment was eliminated. [...] Financial results for baseband products and Wireless products for the smartphone and consumer tablet markets, both of which are product lines that we have announced we are exiting, are included in Other and are collectively referred to as ‘legacy wireless products.’”). See also Exhibit V.C.7 and associated backup.

<sup>1100</sup> See Exhibit III.D.3.

<sup>1101</sup> “Cell Phones Set to Ring Up More Success,” Shanghai Daily, November 23, 2007 (“‘Our market share in China is several percentage points higher than the global level as demand surges for low-cost single-chip products LoCosto and eCosto,’ said Xie Bing, Texas Instruments’ China president.”).

<sup>1102</sup> “Semiconductor Insights: Texas Instruments ‘LoCosto RF’ and Baseband Single Chip Solution Recognized as Most Innovative Baseband and/or Applications Processor,” MarketWired, November 9, 2006 (“A further competitive differentiator for TI’s LoCosto family of scalable single-chip solutions is that it ranges in capability from supporting GSM voice-centric phones, to GPRS devices that support a robust set of features for the higher end of emerging markets. [...] This allows customers flexibility to address growing GSM-based regions like China, India, Brazil and Africa, and feature phone markets such as Europe, Asia and U.S.”).

<sup>1103</sup> Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, pp. 6–7 (“TI has had some success with its own baseband designs in the low-end GSM/GPRS market [...]. However, TI faced increased competition from Infineon, MediaTek and Spreadtrum

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395. TI’s strategic decisions outside of 2G revolved around the use of partnerships in product development. Its focus on hardware components, while its OEM customers developed the required 3G software, led to mixed results and left TI vulnerable to the actions of its partners. Although initially successful, TI’s lack of software experience backfired when device OEMs began switching to suppliers that designed modem chips with both hardware and software.<sup>1104</sup> This gap prevented TI from finding new customers. [REDACTED]

[REDACTED]”<sup>1105</sup>

396. Meanwhile, other partnerships failed to generate substantial sales, as TI engaged in two partnerships involving technology standards that were never widely adopted. First, TI formed a partnership with Nokia and STMicroelectronics to develop modem chips for the CDMA2000 1X standard and later the CDMA2000 1xEV-DV standard.<sup>1106</sup> However, many wireless carriers ended up deploying CDMA2000 1xEV-DO instead of EV-DV,<sup>1107</sup> and the joint

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in this segment. We estimate that the company shipped approximately 32 million LoCosto units in 2007, but not much more than this in 2008.”).

<sup>1104</sup> Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 18 (“The cellular baseband market is shifting from custom ASICs to ASSP solutions as handset manufacturers like Nokia, Motorola and Sony Ericsson are turning to off-the-shelf solutions to focus more on user experience and software. This has left TI vulnerable as the company currently doesn’t have a 3G baseband design of its own [...].”).

<sup>1105</sup> [REDACTED]

<sup>1106</sup> See, e.g., Mannion, Patrick, “TI and STMicro Offer Modular CDMA 1x Chip Set,” EE Times, December 5, 2003 (“Texas Instruments and STMicroelectronics have jointly announced an open, modular cdma2000 1x chip set [...]. The four-chip set is the first product realization to derive from the collaboration between the two companies ‘ and Nokia ’ [...].”). See also Krazit, Tom, “TI and STM Produce Samples of 3G CDMA Chips,” IT World Canada, June 24, 2004 (“Texas Instruments Inc. (TI) and STMicroelectronics NV (STM) are producing samples of chips [...]. The new chips are based on the Evolution-Data-Voice (EV-DV) standard that accelerates the bandwidth of CDMA cellular networks [...].”).

<sup>1107</sup> “What is 1xEV-DV Standard?,” GeekInterview, March 2, 2008, available at <http://www.learn.geekinterview.com/it/wireless/what-is-1xev-dv-standard.html> (“At the time of its commercial release, 1xEV-DV compatible equipment was not made available in time to meet market demands. [...] In addition to this, a number of telecommunications networks such as Verizon Wireless and Sprint Nextel, among others, chose to deploy 1xEV-DO.”). See also Section III.E.2.

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venture eventually dissolved.<sup>1108</sup> Second, TI made a deal with Motorola to provide foundry and design expertise for Motorola’s WiMAX efforts.<sup>1109</sup> However, WiMAX never became a widely used 4G standard.<sup>1110</sup>

397. Additionally, TI’s WCDMA chip design, in collaboration with NTT DoCoMo, never went into final production, as TI had miscalculated its expectations of modem chip demand in Japan.<sup>1111</sup> After this setback, TI’s continuing focus on fabricating the hardware components of its custom chips for Nokia only exacerbated TI’s inability to provide a full 3G chip solution. In 2008, roughly 65 percent of TI’s wireless revenue came from its fabricated products with Nokia and EMP.<sup>1112</sup> TI’s sales rapidly declined in the late 2000s when both Nokia and EMP switched to other suppliers.<sup>1113</sup>
398. Investment: TI’s acquisition of Condat in 2002 allowed TI to develop complete 2G solutions; Condat’s wireless R&D facilities also gave TI a total of eight wireless R&D facilities throughout the world.<sup>1114</sup> TI’s approach to R&D was focused on hardware as opposed to

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<sup>1108</sup> Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 10 (“TI involved in a CDMA2000 1X chip development joint venture with Nokia and ST Microelectronics [...]. However, later TI, Nokia and ST Micro abandoned the JV.”).

<sup>1109</sup> “OMAP Gets Break in Moto Design Win,” EE Times Asia, March 16, 2007 (“TI will develop custom WiMAX chipsets, including both baseband DSP and analog/RF components, for Motorola applications [...]. TI will also provide process, foundry and design expertise for the WiMAX effort.”).

<sup>1110</sup> See Section III.C.2.

<sup>1111</sup> Strauss, Will, “DSP Market Bulletin – 10/29/07,” Forward Concepts, October 29, 2007 (“The OMAPV2230 sampled, but did not go into production. TI has stated that the chipset market in Japan, where it originally invested, did not develop as they expected. The cancellation led to approximately 300 layoffs, worldwide.. [sic] [...] The cancellation coincided with the idea that in the near term TI could make more money continuing to ship UMTS baseband silicon designed by its customer. (read: Nokia).”).

<sup>1112</sup> Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, pp. 6 and 12.

<sup>1113</sup> See, e.g., Sideco, Francis, “Qualcomm and ST-Ericsson Shine, Even as Wireless Chip Market Tanks,” IHS Markit, April 30, 2009 (“Texas Instruments Inc. (TI), suffered the worst performance among the Top-5 suppliers in 2008, with revenue plunging by 22.5 percent for the year. The company continued to share [sic] as its major customer, Nokia, took steps to diversify its supply base and engage more with other wireless chip makers.”). See also Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 5 (“The recent diversification of the supplier base at Nokia was a big blow to TI’s baseband ambitions and this, along with the loss of EMP (Ericsson Mobile Platforms) to ST-Ericsson, caused the company to rethink its baseband market strategy.”).

<sup>1114</sup> “Texas Instruments to Acquire Condat, Strengthening Its Chipset Solutions in Wireless Technology,” Texas Instruments Press Release, March 1, 2002 (“This acquisition enables TI to provide a complete GSM/GPRS

software and relied heavily on partnerships with other technology firms. However, TI under-invested in its 3G modem technology.<sup>1115</sup> Although TI invested comparable amounts overall, it invested less than competitors in developing complete modem chip solutions.<sup>1116</sup> When TI exited the modem chip industry in 2012, it considered the industry to have become “too resource and investment intensive.”<sup>1117</sup>

399. *Execution:* TI’s execution in GSM modem chips since the late 1990s led to popular products for many years. For example, in 2004, TI developed the modem chip industry’s first integrated GSM single-chip solution, which combined the modem chip with a number of other non-processor device components, and sold it to Nokia.<sup>1118</sup> TI’s integration of multiple features for its low-cost LoCosto and eCosto chips likewise made them viable for emerging GSM regions such as China and India as well as for Europe and the U.S.<sup>1119</sup>

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chipset solution to its customers. [...] The company will now have eight wireless R&D centers serving the major regions of the world.”).

<sup>1115</sup> Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 18 (“TI under-invested in 3G basebands and as a result lost its EMP account and is losing share at its largest customer Nokia also.”).

<sup>1116</sup> See, e.g., Exhibits III.E.1–3. See also Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 5 (“[...] [T]he company [TI] hasn’t invested in ASSP baseband solutions as much as its competitors.”).

<sup>1117</sup> Lomas, Natasha, “Texas Instruments Cuts 1,700 Jobs as It’s Driven Away from Mobile Chip Market by the Rise of Custom Chipmaking,” Techcrunch, November 15, 2012.

<sup>1118</sup> “Texas Instruments Delivers Industry’s First Integrated Single-Chip Solution for Mobile Phones to Nokia,” EE Times, January 24, 2005 (“Texas Instruments Incorporated and Nokia have announced a collaboration whereby Nokia will incorporate a single-chip mobile phone solution [...]. [...] The announcement fulfills a commitment TI made in 2002 when the company announced its intention to integrate the bulk of handset electronics on a single chip, including digital baseband, SRAM, logic, RF, power management and analog functions, and to sample the first product in 2004. The first version of the single-chip solution [...] sampled in December 2004 [...]. [...] With the industry’s first integrated single-chip solution, TI and Nokia are bringing more affordable, advanced mobile phones to consumers worldwide.”).

<sup>1119</sup> See, e.g., “Semiconductor Insights: Texas Instruments ‘LoCosto RF’ and Baseband Single Chip Solution Recognized as Most Innovative Baseband and/or Applications Processor,” MarketWired, November 9, 2006 (“TI’s LoCosto platform is designed to reduce the bill of materials count by integrating both the RF and baseband functionality into a single chip. [...] This allows customers flexibility to address growing GSM-based regions like China, India, Brazil and Africa, and feature phone markets such as Europe, Asia and U.S.”). See also “Texas Instruments Single-Chip Cell Phone Technology Will Make Multimedia Phones Affordable for Mass Market,” Texas Instruments Press Release, November 17, 2006 (“The ‘eCosto’ platform represents the latest advancement [...]. Integrating the RF transceiver and analog codec with the digital baseband significantly reduces board space, extends battery life, and makes for a more powerful and versatile handset.”).

400. However, TI struggled to obtain year-over-year improvements in its 3G technology that would lead to mass adoption. In addition to its struggle to design 3G protocol stacks,<sup>1120</sup> TI fell behind in developing competitive 3G chips due to difficulties in integrating multimedia capabilities and its underestimation of the time needed to produce and sell transceivers.<sup>1121</sup> According to one analyst, “TI had more than 1,000 engineers working on cellular RF and basebands, but failed to keep up with competitors. According to competitors TI has never done a good job in software and system integration, leaving those tasks to its customers.”<sup>1122</sup>

## 8. Broadcom

### *a. Background*

401. Broadcom was founded in 1991 to develop chips for communications technologies.<sup>1123</sup> One of the primary components of Broadcom’s business strategy involved the acquisition of other firms and technologies.<sup>1124</sup> In 2002, Broadcom entered the modem chip industry when it acquired Mobilink and its GSM technology.<sup>1125</sup> In 2004 it acquired Zyray Wireless and its

<sup>1120</sup> See, e.g., “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 133 (TI’s giant challenge is not the digital basebands, but a 3G software stack that work and a WCDMA and EDGE RF transceiver development.”).

<sup>1121</sup> Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 17 (“TI underestimated the investment and time-to-market requirements of developing transceivers, then compounded this mistake with 3G basebands. We believe that TI also underestimated the difficulty of integrating multimedia capabilities into its SoCs.”).

<sup>1122</sup> Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 17.

<sup>1123</sup> “Broadcom Corporation History,” FundingUniverse (“Broadcom was founded as a private company in 1991 [...]. The company’s basic strategy was to focus on emerging markets in communications that used cable or wire. Using its design cell library and silicon compiler technology, it was able to quickly develop chip products, or integrated circuits (ICs), for applications such as Fast Ethernet or advanced cable TV systems.”).

<sup>1124</sup> See, e.g., Mishra, Rajat, and Nick Santhanam, “At the Core of Communications: An Interview with Broadcom’s Scott McGregor,” McKinsey & Company, 2012, p. 77 (“Scott McGregor: We decided to build M&A as a core competency at Broadcom. It is not about how big the M&A team is; it is more about owner-ship and accountability in the M&A function. At Broadcom, I would say about two-thirds of the acquisitions we’ve done have created value.”). See also Broadcom, 10-K, 2010 (“A key element of our business strategy involves the acquisition of businesses, products or technologies that allow us to reduce the time required to develop new technologies and products and bring them to market, complement our existing product offerings, expand our market coverage, increase our engineering workforce or enhance our technological capabilities.”).

<sup>1125</sup> See, e.g., Gain, Bruce, “Broadcom to Acquire Mobilink in \$251 Million Deal,” EE Times, April 8, 2002 (“Broadcom Corp. today agreed to purchase Mobilink Telecom Inc. [...] in a move to enter the handset baseband market. Mobilink [...] currently offers volume production of baseband chipsets for [GSM] chipsets.”).

WCDMA technology.<sup>1126</sup> From 2003 through 2009, Broadcom released multiple 2G and 3G chips and secured design wins with large customers such as Nokia and Samsung.<sup>1127</sup>

402. In 2010, after a few years of internal investment in LTE, Broadcom acquired Beceem for its 4G WiMAX and LTE technology.<sup>1128</sup> Broadcom announced its first LTE chip, the BCM21892, in February 2013, nearly five months after the release of Apple’s first LTE iPhone, the iPhone 5.<sup>1129</sup> Though Broadcom’s initial LTE effort had not yet resulted in product shipments, Broadcom acquired Renesas Mobile in September 2013 in an attempt to “accelerate” its LTE

<sup>1126</sup> See, e.g., “Broadcom Acquires Zyray Wireless for \$96M,” EDN Network, June 17, 2004 (“Broadcom Corp. took aim at 3G today, announced that it has signed a definitive agreement to acquire Zyray Wireless Inc., a leading provider of baseband co-processors addressing WCDMA mobile devices.”).

<sup>1127</sup> See, e.g., “Broadcom Pushes into Handset Market with China’s Bird,” EE Times, March 18, 2003 (“[...] Broadcom also announced that Ningbo Bird has taken its V09 GSM handset into production based on a Broadcom reference design and that a range of multimedia-capable GSM/GPRS clamshell handsets are in development based on a Broadcom reference design. All of these handsets are based on the ML2011 GSM baseband processor and BCM2121 GPRS baseband processor developed by Broadcom’s mobile communications business unit formerly known as Mobilink Telecom [...].”). See also Mannion, Patrick, “Broadcom Rolls Combo Platform,” EE Times, February 17, 2005 (“Broadcom Corp.’s summer 2004 acquisition of Zyray Wireless has borne fruit in the form of a complete UMTS W-CDMA modem chip. [...] The BCM2140 W-CDMA modem is the first production-ready instantiation of a test chip Zyray had developed when it was a standalone company [...].”); “Nokia Selects Broadcom as a Chipset Supplier for Future EDGE Phones,” Broadcom Press Release, August 8, 2007 (“Broadcom [...] announced that Nokia Corporation has selected Broadcom’s advanced single-chip cellular baseband processor and its companion power management unit (PMU) for selected future EDGE mobile phones. [...] Broadcom first announced the BCM21331 (‘Venus’) single-chip EDGE multimedia processor at 3GSM in February 2007.”); Bangeman, Eric, “Broadcom Touts New ‘3G Phone on a Chip,’ Could Show Up in 3G iPhone,” Ars Technica, October 15, 2007 (“Semiconductor firm Broadcom has become the first chipmaker to announce a single-chip 3G phone solution. [...] The BCM21551 combines a 3G baseband transceiver, Bluetooth 2.1, and a multiband RF transceiver on a single chip.”); Goldstein, Phil, “Samsung to Run Future EDGE Phones on Broadcom Chips,” FierceWireless, February 10, 2009 (“Broadcom announced that Samsung would be incorporating its single-chip cellular platform for future EDGE-based phones [...].”).

<sup>1128</sup> See, e.g., Merritt, Rick, “Analysis: Inside Broadcom’s Bid for Beceem, LTE,” EE Times, October 13, 2010 (“‘We have had internal development work on LTE in Broadcom for a few years,’ [General Manager of Broadcom’s Mobile Platforms Group Scott] Bibaud said. ‘What we get with Beceem is technology that has seen a lot more of the market and a fuller team to accelerate our time to market,’ he said.”). See also Gardner, William, “Broadcom to Acquire Beceem for \$316 Million,” Network Computing, October 13, 2010 (“[...] Broadcom moved to take out a position in 4G by acquiring Beceem Communications, a leader in long-term evolution (LTE) and WiMax wireless technology. [...] The acquisition would give Broadcom access to Beceem’s pioneering 4G multimode LTE-WiMax network expertise [...].”).

<sup>1129</sup> See, e.g., Exhibit QX1012, Rango Deposition, Broadcom, BRCM165581–5583 at 5581, document titled “Broadcom Introduces Industry’s Smallest 4G LTE-Advanced Modem for Smartphone and Tablet Market,” Broadcom, February 12, 2013 (“Broadcom Corporation (NASDAQ: BRCM), a global innovation leader in semiconductor solutions for wired and wireless communications, today introduced the industry’s smallest 4G LTE-Advanced modem.”). See also “Apple Introduces iPhone 5,” Apple Press Release, September 12, 2012 (“Apple today announced iPhone 5 [...]. [...] iPhone 5 supports ultrafast wireless standards including LTE and DC-HSDPA [...].”).

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development.<sup>1130</sup> Broadcom “canceled all” projects related to the BCM21892, “fired half of the team [...] and put new people in charge of the modem program.”<sup>1131</sup> In late 2013, Broadcom announced its first integrated LTE chip, the M320 (also known as EOS2), that would ship in 2014,<sup>1132</sup> and Broadcom proceeded to secure low-volume design wins with Samsung and other mobile device OEMs.<sup>1133</sup>

403. Broadcom increased its annual modem chip sales each year from 2008 to 2011.<sup>1134</sup> However, by 2011, 2G chips had become a small part of Broadcom’s business, leaving the company’s

<sup>1130</sup> See, e.g., Exhibit QX1018, McGregor Deposition, Broadcom, BROADCOM-USFTC00000100, pp. 4–5, presentation titled “Project Ravello Deal Presentation,” September 3, 2013 (“Rationale[:] Accelerate our LTE program and take clear #2 position in industry[.] [...] Converged Roadmap Integrates Best Technology[.]”). See also Yoshida, Junko, “Broadcom Buys Renesas’ LTE Assets – IP, SoC & Engineers,” EE Times, September 4, 2013 (“With the new acquisition deal, Broadcom, which has shipped no LTE products to date, will suddenly own a dual-core LTE SoC, developed by Renesas Mobile, ready for volume production and certified by leading global operators in North America, Japan, and Europe. [...] Strauss noted, ‘Actually, long-suffering Broadcom’s LTE program was a long way from a fielded product. Now, they say they’ll be shipping LTE in 1H/14. After all, the Renesas part has been qualified at Verizon, AT&T and NTT DoCoMo.’”).

<sup>1131</sup> See, e.g., McGregor Deposition, Broadcom, pp. 118–119 (“Q. Well, let’s see. Looking at the second email from the top of the page it’s from you to Mr. Khamisy. It says, ‘Thanks, Asad. I figured it didn’t make sense to review last year’s mobile goals since we’ve canceled all those projects, fired half of the team, acquired the Renesas modem team, and put new people in charge of the modem program.’ [...] Q. Well, in substance is this pretty much what happened when you acquired Renesas? A. Half the team would refer to a subset of the group, okay. Acquire the Renesas modem team, yes, I think that’s at face value, put new people in charge of the modem program. Yes, that’s correct. Q. And cancel the preexisting projects, meaning what? A. They were based on the -- we had a roadmap that would go forward five years. Okay. And all the future products on that roadmap that were based on the prior modem would have been canceled. Yeah. That’s what it means to replace the modem.”). See also Exhibit QX1020, McGregor Deposition, Broadcom, BRCM172776-2777 at 2776; Rango Deposition, Broadcom, p. 145 (“Q. Was the BCM21892 ever sold in commercial quantities? A. I don’t believe so.”).

<sup>1132</sup> See, e.g., Rango Deposition, Broadcom, p. 167 (“Q. Did Broadcom have an in-production LTE chipset in February 2013? A. I think, just to keep the record straight, the first LTE solution that Broadcom had came after the Renesas acquisition, which I believe was in 2013, and it was the EOS2 chip.”). See also “Analyst Day 2013,” Broadcom, p. 55 (Slide titled “Portfolio of 3G and 4G SOC Platforms”); Ray, Tiernan, “Broadcom Rises: Street Cheers Turn in LTE Outlook,” Barrons, December 10, 2013 (“[Broadcom] also announced that its M320 dual-core LTE SoC would ship into a Samsung phone in early 2014.”).

<sup>1133</sup> See e.g., Goldstein, Phil, “Intel, MediaTek, Broadcom and Nvidia Try to Catch Up to Qualcomm in LTE,” FierceWireless, January 10, 2014 (“Broadcom has made significant strides on LTE, especially after it acquired LTE-related assets from affiliates of Renesas in September. Broadcom’s M320 dual-core LTE System-on-a-Chip will be shipping in at least one Samsung phone in the first quarter, though the companies aren’t releasing details.”). See also Exhibit QX1015, Rango Deposition, Broadcom, BCRM000173–0205 at 0186, presentation titled “Mobile and Wireless,” Broadcom, November 12, 2013 (Slide titled “EOS2 Pricing and Gross Margin Environment”); Exhibit V.C.8.

<sup>1134</sup> See Exhibit V.C.8.

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3G products as its main revenue drivers.<sup>1135</sup> After 2011, Broadcom struggled to maintain large volume shipments of 2G and 3G chips as Nokia and Samsung decreased their modem chip orders.<sup>1136</sup> Broadcom failed to secure substantial design wins for its 4G products, selling fewer than 1 million LTE modem chips in 2014.<sup>1137</sup> Broadcom’s LTE modem chip products were criticized as being “neither leading edge nor first to market,”<sup>1138</sup> [REDACTED]  
[REDACTED].<sup>1139</sup> Broadcom found that “by the time [it] had a viable product line,” the prices it was able to obtain for its chips were lower than it had anticipated and it was facing price pressure from the “many

<sup>1135</sup> See, e.g., Rango Deposition, Broadcom, p. 202 (“Q. When you say chip ASPs had fallen faster than you forecast, you’re including 2G chips; right? [A.] Not so much. By that time, by the time that -- 2011 to 2014, 2G chips really became a very small part of Broadcom’s business. It was mostly 3G and even 4G.”).

<sup>1136</sup> Broadcom sold roughly 58 million 2G and 3G handset modem chips to Nokia in 2011, but fewer than 1 million in 2013. Broadcom’s 2G and 3G modem chip sales to Samsung decreased yearly from 2012 to 2014, having sold roughly 77 million, 68 million, and 55 million units respectively. See Strategy Analytics, “Customised Baseband Quarterly Market Share Tracker for Qualcomm: Parts 1 and 2,” April 6, 2018.

<sup>1137</sup> See Exhibit V.C.8 and associated backup.

<sup>1138</sup> Kundojjala, Sravan, “Intense 3G Price Competition and 4G LTE R&D Took Toll on Broadcom Baseband Business,” Strategy Analytics, June 2, 2014.

<sup>1139</sup>

See also Kang Deposition, Samsung, p. 37

Exhibit QX1021, McGregor Deposition, Broadcom, BRCM174046–4047 at 4046 (email from Michael Hurlston, Broadcom, May 2, 2014, noting that Broadcom’s first LTE SoC, “Aruba,” “is 1-2 quarters behind the competition,” and response from Scott McGregor, Broadcom, May 3, 2014, remarking “FYI. Sigh. No Brownie points for trying hard in this industry if your competition does even better.”); Exhibit QX1005, Rango Deposition, Broadcom, BRCM173161–3162, email from Patrick Henderson, Broadcom, May 7, 2014 (“The Apple team did not think that BRCM has the level of technical maturity required for a 2016 product.” [...] “Their perception is that we have no great advantage in performance or features and they have some concerns in the areas of: envelope tracking and carrier aggregation[.]”).

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competitors in the marketplace.”<sup>1140,1141</sup> Broadcom ultimately exited the modem chip industry in 2014.<sup>1142</sup>

*b. Analysis*

404. Broadcom’s fast-follower strategy involved meeting demand largely by acquiring other firms’ technologies.<sup>1143</sup> Broadcom had sufficient foresight, investment, and execution for earlier products, with the company obtaining key wins with its GSM and WCDMA products and executing well through 2009. However, Broadcom demonstrated incorrect foresight, made poor investment decisions, and struggled with execution related to LTE chip development, causing the company’s modem chips to lag behind those offered by competitors. Eventually, Broadcom exited the industry.
405. Foresight: Broadcom’s M&A approach succeeded and failed in part depending on the accuracy of the company’s alignment with the development of modem chip standards. Partly

<sup>1140</sup> See, e.g., Rango Deposition, Broadcom, pp. 250–251 (“[Exhibit QX1015] was showing the gross margin for the EOS2 at the four customers that we had – Samsung, ZTE, Sony, and HTC – and the aggregate gross margin forecast for 2014. Q. And were these gross margins for these four customers acceptable? A. When you say “acceptable,” do you mean – can you – were we happy with them? Q. Were you happy with them when you were running the business? A. No. Because our goal was at least, as I mentioned, 50 percent gross margin as a general target. So these gross margins were not attractive. But I’m sure that in the presentation we talked about how we would try to improve them.”). See also Exhibit QX1015, Rango Deposition, Broadcom, at BRCM000186.

<sup>1141</sup> See, e.g., Rango Deposition, Broadcom, pp. 28–29 (“Q. A while back in this -- in your testimony, you -- I was asking you about why the cellular baseband business at Broadcom was not able to reach a sustainable financial success. And one thing you mentioned was market conditions. Can you elaborate on what you meant by ‘market conditions’? A. Yeah. By the time Broadcom had a viable product line, the prices in the cellular baseband business decreased at a rate that was faster than our financial projections. And I think that led to some of the challenges of trying to make the business profitable, as ASPs declined at a much more rapid rate than we had projected. Q. Do you have an understanding as to why the ASPs were declining faster than projected? A. Could have been a number of things. There was many competitors in the marketplace. Certainly there’s at least three or four different companies vying for each piece of business. I’m sure that contributed to it. Market was growing very rapidly as well, which led to a lot of price erosion.”).

<sup>1142</sup> Goldstein, Phil, “Broadcom CEO: We Were Losing \$2M Per Day in Cellular Baseband Biz,” FierceWireless, January 15, 2015 (“Broadcom got out of the cellular baseband business in mid-2014 because it was losing \$2 million per day staying in that market, which is dominated by Qualcomm [...], Intel, MediaTek and others, according to CEO Scott McGregor.”).

<sup>1143</sup> Naeher, Ulrich et al., “The Evolution of Business Models in a Disrupted Value Chain,” McKinsey, 2011, p. 37 (“Broadcom is a good example of a fast follower.”).

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due to its earlier acquisitions,<sup>1144</sup> Broadcom released its first WCDMA chip before Marvell, MediaTek, and other competitors did.<sup>1145</sup> Broadcom also initiated LTE research early, but it decided to purchase Beceem in part to pursue a WiMAX/LTE multi-mode chip.<sup>1146</sup> Ultimately, the WiMAX standard did not gain wide adoption, and Broadcom was unable to produce LTE chips via its internal research and the Beceem acquisition alone. In fact, Broadcom did not release LTE chips until after it purchased Renesas Mobile in 2013;<sup>1147</sup> one analyst cited Broadcom as “at least two years and maybe three years behind” in developing its LTE products.<sup>1148</sup>

406. Broadcom was slow to shift resources away from less advanced technologies. Despite its early success in developing WCDMA chips, in the late 2000s, according to Robert Rango, former Executive Vice President and General Manager of the Networking Infrastructure Group at Broadcom, the firm chose to invest into 2G EDGE rather than 3G.<sup>1149</sup> Broadcom also did not foresee necessary technological improvements to keep its products competitive. [REDACTED]

<sup>1144</sup> See, e.g., Mannion, Patrick, “Broadcom Rolls Combo Platform,” EE Times, February 17, 2005 (“Broadcom Corp.’s summer 2004 acquisition of Zyrray Wireless has borne fruit in the form of a complete UMTS W-CDMA modem chip. [...] The BCM2140 W-CDMA modem is the first production-ready instantiation of a test chip Zyrray had developed when it was a standalone company [...].”).

<sup>1145</sup> See Exhibit V.B.5.

<sup>1146</sup> See, e.g., Merritt, Rick, “Analysis: Inside Broadcom’s Bid for Beceem, LTE,” EE Times, October 13, 2010 (“‘We have had internal development work on LTE in Broadcom for a few years,’ [general manager of Broadcom’s mobile platforms group Scott] Bibaud said. ‘What we get with Beceem is technology that has seen a lot more of the market and a fuller team to accelerate our time to market,’ he said.”). See also “Broadcom Sees WiMAX/LTE Combo Key Differentiator with Beceem Buy,” FierceWireless, October 14, 2010 (“[Broadcom’s Scott] Bibaud said the company choose [sic] Beceem because of its longevity and leadership in the WiMAX space [...]. But WiMAX is a means to an end. Beceem has been touting [...] its multimode LTE/WiMAX chipset strategy. [...] ‘We’ll be focused on multi-mode WiMAX/LTE moving forward,’ Bibaud said.”).

<sup>1147</sup> See, e.g., Yoshida, Junko, “Broadcom Buys Renesas’ LTE Assets – IP, SoC & Engineers,” EE Times, September 4, 2013 (“With the new acquisition deal, Broadcom, which has shipped no LTE products to date, will suddenly own a dual-core LTE SoC, developed by Renesas Mobile, ready for volume production and certified by leading global operators in North America, Japan, and Europe.”).

<sup>1148</sup> See, e.g., Goldstein, Phil, “Broadcom Could Sell Cellular Baseband Unit, but Buyers Are Not Apparent,” FierceWireless, June 2, 2014 (“[...] Broadcom] still has ‘a big problem,’ according to Forward Concepts analyst Will Strauss. [...] ‘No. 1 is they are at least two years and maybe three years behind in getting to the LTE modem market,’ he told FierceWireless.”). See also Exhibit V.C.8.

<sup>1149</sup> Exhibit QX1005, Rango Deposition, Broadcom, BRCM174660–4661 at 4660, email from Robert Rango, Broadcom, July 25, 2011 (“As I have said many times, we are generations behind Q[ualcomm] for multiple reasons;[:] We invested in edge when we should have invested in 3G (mistake made four years ago. We are going to pay for this in 2012, 13).”).

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

407. Broadcom also demonstrated poor foresight by selling the majority of its products to a few major customers.<sup>1153</sup> This was especially true for Broadcom’s modem chip business; in 2011, Broadcom’s two largest customers, Nokia and Samsung, comprised roughly 98 percent of Broadcom’s modem chip sales. As a result, between 2011 and 2014, Broadcom’s sales declined when Nokia and Samsung decreased their modem chip orders.<sup>1154</sup> [REDACTED]

1150

[REDACTED]

[REDACTED]

[REDACTED]

- <sup>1152</sup> See, e.g., McGregor Deposition, Broadcom, pp. 40–41 (“Q. Why did [Broadcom’s internally developed] technology have a worse forecast than if you did the acquisition? A. Because the customer requirements changed and so the technology we originally developed for a particular market set of assumptions changed and the customer asked us to do a higher end version of LTE, which we had not originally targeted and so by doing an acquisition it put us back on track to be able to deliver that higher end technology. Q. Which customer are you referring to? A. Apple. [...] They subsequently told us that they had awarded the low end of the market to Qualcomm and they asked us to develop chips for the mid and high end of the market.”). [REDACTED]

[REDACTED]

- <sup>1153</sup> See, e.g., Broadcom, 10-K, 2010 (“A small number of customers have historically accounted for a substantial portion of our net revenue. Sales to our five largest customers represented 38.9%, 34.6% and 35.8% of our net revenue in 2010, 2009 and 2008, respectively.”).

- <sup>1154</sup> In 2011, Nokia and Samsung made up roughly 50 percent and 48 percent of Broadcom’s total modem chip sales, respectively. Nokia’s modem chip orders decreased by roughly 165 million between 2011 and 2013. Broadcom’s modem chips comprised 14 percent of Nokia’s total modem chip purchases in 2011, but comprised less than one percent in 2013. Between 2012 and 2014, Broadcom’s modem chip sales to Samsung continuously decreased. See Strategy Analytics, “Customised Baseband Quarterly Market Share Tracker for Qualcomm: Parts 1 and 2,” April 6, 2018. See also McGregor Deposition, Broadcom, p. 50 (“Q. Was Samsung business also important to the success of Broadcom’s cellular baseband business? A. Samsung was by far our

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[REDACTED]  
[REDACTED] 1155

408. Investment: According to industry analysts and others, Broadcom’s rationale for investing in its modem chip business had been to expand its connectivity business (Bluetooth and Wi-Fi) to mid- to low-end smartphones.<sup>1156</sup> Broadcom invested primarily by acquiring companies with technological assets, in some respects acting more like a private equity firm than an R&D powerhouse. Broadcom’s efforts to rapidly turn GSM and WCDMA acquisitions into chip sales were initially successful. Broadcom released GSM modem chips one year after acquiring Mobilink, and offered WCDMA modem chips one year after acquiring Zyray Wireless.<sup>1157</sup>

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largest customer and we in some quarters during this period were the largest supplier of basebands to Samsung.”).

<sup>1155</sup> See, e.g., McGregor Deposition, Broadcom, p. 52 (“Q. What about China were you competing there as well? A. We were competing in China. We believed that it was difficult to get sufficient market share in China in order for that to be really a positive contributor for a number of reasons. The Chinese cell phone manufacturers generally preferred to work with Chinese suppliers and the profitability of that market is significantly below the Korea and Cupertino opportunities for us. [...] Q. With respect to the China area, who were Broadcom’s competitors? A. Competitors in China included Qualcomm, MediaTek, those were the two largest.”). [REDACTED]

<sup>1156</sup> Broadcom’s “connectivity business” includes wireless products such as Wi-Fi and Bluetooth. See, e.g., “Broadcom’s Expanding Portfolio Will Help It Defend Its Connectivity Market Share,” *Forbes*, January 11, 2016 (“Broadcom has been the leader in connectivity solutions for many years, currently accounting for approximately 30% of the market. Thanks to Broadcom, wireless technologies such as Bluetooth and Wi-Fi have become household names.”). See also Kundojjala, Sravan, “Intense 3G Price Competition and 4G LTE R&D Took Toll on Broadcom Baseband Business,” *Strategy Analytics*, June 2, 2014 (“The rationale for Broadcom to invest in basebands had been to expand its connectivity business to mid-to-low range smartphones where a complete platform approach is relevant, allowing Broadcom to capture more dollar content while expanding in the high-end at the same time.”); McGregor Deposition, Broadcom, pp. 252–253 (“Q. Because of the connectivity business did Broadcom have a greater incentive to stay in the cellular baseband business than a stand-alone baseband provider would? A. Absolutely. And if you look at our financials, at first glance on the baseband business you say, well, why would you want to be in this business? I mean, you are showing that, you know, you are only going to make a relatively small amount of profit. And the answer was that we felt that that would enable us to offer better products to our customer if we could offer combined offerings.”).

<sup>1157</sup> See, e.g., “Broadcom Pushes into Handset Market with China’s Bird,” *EE Times*, March 18, 2003 (“[...] Broadcom also announced that Ningbo Bird has taken its V09 GSM handset into production based on a

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However, as discussed above, in the late 2000s Broadcom fell behind in 3G chip development because its investment was misguided, putting more resources into older technologies at the expense of newer ones.<sup>1158</sup>

409. Repeating its own mistakes, Broadcom had neither efficient nor sufficient investment in 4G technology. By acquiring Beceem and its 4G technology, Broadcom was able to allocate other resources towards its 2G and 3G products.<sup>1159</sup> However, Broadcom’s investment in Beceem initially focused on the development of a combination LTE/WiMAX chip.<sup>1160</sup> A year after the acquisition, Broadcom acknowledged that WiMAX’s position in the U.S. was fading and had its Beceem team shift focus to develop LTE products.<sup>1161</sup> Even so, by 2013, Broadcom had not been able to develop a competitive LTE chip and had to purchase Renesas Mobile to ship one quickly.<sup>1162</sup> According to Robert Rango, former EVP of Broadcom’s Mobile and Wireless Group, Broadcom’s slow internal LTE development was due to the company’s investment

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Broadcom reference design and that a range of multimedia-capable GSM/GPRS clamshell handsets are in development based on a Broadcom reference design. All of these handsets are based on the ML2011 GSM baseband processor and BCM2121 GPRS baseband processor developed by Broadcom’s mobile communications business unit formerly known as Mobilink Telecom [...].”). See also Mannion, Patrick, “Broadcom Rolls Combo Platform,” EE Times, February 17, 2005 (“Broadcom Corp.’s summer 2004 acquisition of Zyrray Wireless has borne fruit in the form of a complete UMTS W-CDMA modem chip. [...] The BCM2140 W-CDMA modem is the first production-ready instantiation of a test chip Zyrray had developed when it was a standalone company [...].”).

<sup>1158</sup> BRCM174660-4661 at 4660 (Broadcom, July 25, 2011 email from Robert Rango to Eric Brandt “As I have said many times, we are generations behind Q for multiple reasons[:]; We invested in edge when we should have invested in 3G (mistake made four years ago. We are going to pay for this in 2012, 13).”).

<sup>1159</sup> “Broadcom Sees WiMAX/LTE Combo Key Differentiator with Beceem Buy,” FierceWireless, October 14, 2010 (“Rather than focusing its R&D on LTE, Broadcom chose to focus on additional opportunities in the 2G and 3G chip market, Scott Bibaud, Broadcom’s executive vice president and general manager for mobile platforms, told FierceBroadbandWireless.”).

<sup>1160</sup> See, e.g., Goldstein, Phil, “Broadcom Acknowledges WiMAX’s U.S. Decline,” FierceWireless, August 12, 2011 (“Beceem [...] has hedged its bets with an LTE/WiMAX combo chip.”).

<sup>1161</sup> See, e.g., Goldstein, Phil, “Broadcom Acknowledges WiMAX’s U.S. Decline,” FierceWireless, August 12, 2011 (“Broadcom, which bought WiMAX/LTE chipmaker Beceem last year for \$316 million in a bid to get a leg up in the 4G market, is acknowledging that WiMAX’s position in the U.S. market is fading fast. [...] Broadcom executive Michael] Hurlston said Broadcom is ‘re-tasking’ its Beceem team to focus on LTE.”).

<sup>1162</sup> Yoshida, Junko, “Broadcom Buys Renesas’ LTE Assets – IP, SoC & Engineers,” EE Times, September 4, 2013 (“With the new acquisition deal, Broadcom, which has shipped no LTE products to date, will suddenly own a dual-core LTE SoC, developed by Renesas Mobile, ready for volume production and certified by leading global operators in North America, Japan, and Europe.”).

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deficiencies, such as insufficient engineering staff and equipment shortages.<sup>1163</sup> These deficiencies stifled Broadcom’s ability to develop an LTE chip. According to one analyst estimate, by 2014, “Broadcom [had] spent over \$3 billion on cellular baseband related R&D since 2007 without profit.”<sup>1164</sup>

410. Execution: Broadcom’s 2G and 3G execution initially led to strong sales.<sup>1165</sup> From 2003 through 2009, the company released progressively more advanced chips. In 2003, Broadcom released a GPRS single-chip modem, which integrated all the analog and digital baseband processing functions as well as multiple other circuit functions.<sup>1166</sup> In 2007, Broadcom integrated a 3G modem, Bluetooth technology, and a multiband RF transceiver on a single

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<sup>1163</sup> Rango Deposition, Broadcom, pp. 30–31 (“Q. Another factor you mentioned in your earlier testimony was the need for more resources. Could you explain some more about that? A. Yeah. I think at Broadcom, since we started the cellular business with this acquisition of Mobilink, there was always a need -- and it was a startup company with limited resources -- there was always a need to add more resources to it. And as more cellular standards have emerged, 3G and 4G and then various versions of 4G emerged, we, you know, certainly had to have more resources. Which in the light of those decreasing ASPs made it very tough. [...] Q. When you refer to the need for more resources, what -- what are those resources? A. People. People. Equipment. Test resources. FAEs, field application engineers. Mostly people resources in this space because a lot of it is software development.”).

<sup>1164</sup> Kundojjala, Sravan, “Intense 3G Price Competition and 4G LTE R&D Took Toll on Broadcom Baseband Business,” Strategy Analytics, June 2, 2014.

<sup>1165</sup> Broadcom’s combined GSM and WCDMA modem chip sales increased yearly from 2008 to 2011. See Exhibit V.C.8.

<sup>1166</sup> See, e.g., “Broadcom Pushes into Handset Market with China’s Bird,” EE Times, March 18, 2003 (“[...] Broadcom also announced that Ningbo Bird has taken its V09 GSM handset into production based on a Broadcom reference design and that a range of multimedia-capable GSM/GPRS clamshell handsets are in development based on a Broadcom reference design. All of these handsets are based on the ML2011 GSM baseband processor and BCM2121 GPRS baseband processor developed by Broadcom’s mobile communications business unit formerly known as Mobilink Telecom [...].”). See also “BCM2121 Product Brief,” Broadcom, 2003 (“The BCM2121 contains all analog and digital GSM and multislot GPRS baseband processing functions on a single silicon substrate. [...] To further reduce overall component count and BOM cost, the BCM2121 integrates a number of typical PCB circuit functions such as a PA controller, echo cancellation, noise suppression, and hands-free answer sensing.”).

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chip.<sup>1167</sup> In the same year, Nokia chose Broadcom’s 2G EDGE chips because they “deliver[ed] an advanced feature-set at low power, small size, and low system cost.”<sup>1168</sup>

411. Despite Broadcom’s initial successes, the company encountered execution challenges in the 3G segment. [REDACTED]

[REDACTED].<sup>1169</sup> Broadcom also began to lose 3G modem chip sales to its largest customers. For instance, in 2013, Samsung chose to use Qualcomm’s chips for its Samsung Galaxy Grand 2, even though it had used a Broadcom chip in the previous Galaxy Grand.<sup>1170</sup> Meanwhile, Nokia, which had predominantly used Broadcom for its 2G products, started sourcing modem chips from other suppliers for its 3G products.<sup>1171</sup> One analyst cited Broadcom’s decline in 3G as being due to “intense competition [...] and the maturity of 3G baseband technology,”<sup>1172</sup> and stated that Broadcom was unable to keep up because it viewed

<sup>1167</sup> Bangeman, Eric, “Broadcom Touts New ‘3G Phone on a Chip,’ Could Show Up in 3G iPhone,” Ars Technica, October 15, 2007 (“Semiconductor firm Broadcom has become the first chipmaker to announce a single-chip 3G phone solution. Dubbed the BCM21551, Broadcom’s ‘3G phone on a chip’ moves all of the tech needed for a 3G mobile phone to a single 65nm die [...]. [...] The BCM21551 combines a 3G baseband transceiver, Bluetooth 2.1, and a multiband RF transceiver on a single chip.”).

<sup>1168</sup> “Nokia Selects Broadcom as a Chipset Supplier for Future EDGE Phones,” Broadcom Press Release, August 8, 2007.

<sup>1169</sup> [REDACTED]

<sup>1170</sup> Khedekar, Naina, “Samsung Galaxy Grand 2: A Specifications Review,” First Post, December, 23, 2013 (“Unlike the dual-core Broadcom chipset seen in the Grand, the Grand 2 comes equipped with a quad-core Qualcomm chipset – most likely the Snapdragon 400 - clocked at 1.2GHz”).

<sup>1171</sup> See, e.g., “Cellular Handset & Tablet Chip Markets,” Forward Concepts, 2012, p. 88 (“Broadcom has not captured large 3G WCDMA/HSDPA baseband sales at Nokia [...].”). See also Kirk, Jeremy, “Nokia Discontinues Some Chipset Development,” PC World, August 8, 2007 (“Texas Instruments Inc. will continue to be the primary supplier for a range of chips used in Nokia phones, Suominen said. However, Nokia also said it has picked Broadcom Corp. to supply chips with EDGE (Enhanced Data Rates for GSM Evolution) technology. Earlier this year, Nokia picked Infineon Technologies AG as a supplier for GSM (Global System for Mobile Communications) chips.”).

<sup>1172</sup> Kundojjala, Sravan, “Intense 3G Price Competition and 4G LTE R&D Took Toll on Broadcom Baseband Business,” Strategy Analytics, June 2, 2014.

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its modem chip business as an add-on to its connectivity business, and it thus lagged in developing competitive products.<sup>1173</sup>

412. Broadcom’s transition to supplying LTE modem chips was unsuccessful and eventually contributed to its exit from the industry. While Broadcom had secured design wins for its LTE modem chips with Samsung, ZTE, Sony, and HTC,<sup>1174</sup> the sales of those chips were minimal.<sup>1175</sup> [REDACTED]

<sup>1173</sup> Kundojjala, Sravan, “Intense 3G Price Competition and 4G LTE R&D Took Toll on Broadcom Baseband Business,” Strategy Analytics, June 2, 2014 (“In contrast to its connectivity chip business, Broadcom’s baseband chips were neither leading edge nor first to market. This situation left Broadcom in catch-up mode in basebands and only upcoming LTE SoCs and thin modems would have made it a high-end player in the baseband market. Unlike Qualcomm, Broadcom viewed its baseband business as supplementary to its connectivity business. For Qualcomm the baseband modem comes first and everything else is a revenue expansion opportunity.”).

<sup>1174</sup> BCRM000173–0205 at BCRM000186 (Broadcom, Mobile and Wireless Presentation, November 12, 2013, “EOS2 Pricing and Gross Margin Environment”).

<sup>1175</sup> Broadcom sold fewer than 1 million LTE modem chips in 2014. See Exhibit V.C.8.

<sup>1176</sup> [REDACTED] See also Forward Concepts, 2014, p. 69 (“In early 2013, Broadcom announced the BCM21892 3G/4G thin baseband which includes support for [...] LTE-Advanced with both TDD and FDD duplex modes.”).

<sup>1177</sup> [REDACTED]

<sup>1178</sup> [REDACTED] See also Exhibit QX1005, Rango Deposition, Broadcom, BRCM173161–3162 at 3161, email from Patrick Henderson, Broadcom, May 7, 2014 (“[Apple’s] perception is that we have no great advantage in performance or features and they have some concerns in the areas of: envelope tracking and carrier aggregation[;] [...] Commercially, we were in the ballpark for terms and pricing but offered no advantage versus competition[.]”). See also Exhibit QX1006, Rango Deposition, Broadcom, BRCM173157–3158 at 3157, email from Patrick Henderson, Broadcom, May

## 9. Freescale

### a. Background

413. Freescale was initially a division within Motorola. It produced semiconductors and was most recognized for its automotive chip business.<sup>1179</sup> Motorola made an early foray into CDMA in the 1990s, when it worked on developing modem chips for its own CDMA-based handsets, but abandoned this effort around 1999.<sup>1180</sup> In 2004, Motorola spun off Freescale, allowing Freescale to become an independent company and one of the world’s largest semiconductor suppliers.<sup>1181</sup> Freescale’s Wireless and Mobile Solutions Group continued to supply GSM, and later also WCDMA, modem chips for Motorola’s mobile devices following the split.<sup>1182</sup>

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13, 2014 (“Technically, [Tony Blevins of Apple] indicated that we were about a quarter off of where they would need to be for a more positive outcome.”)

<sup>1179</sup> See, e.g., Keever, Scott, “A Brief History of Freescale Semiconductor,” Direct Components, August 19, 2017 (“Freescale started off as a division of Motorola back in 1948. During this time period, Freescale was known for producing semiconductors and one of the first high-power transistors available for commercial use.”). See also Doraiswamy, Deepa, “Freescale Semiconductor – Freed from Motorola,” Frost & Sullivan, March 15, 2004 (“The chip division of Motorola is the most recognized in the semiconductor industry for its automotive chip business. [...] Freescale carries with it enormous expertise and experience in the semiconductor industry that can be considered an invaluable asset.”).

<sup>1180</sup> See, e.g., Davis Deposition, Intel, pp. 233–235 (“Q. Earlier today you referred to -- to various companies that had at least initiated CDMA development efforts at various points in time; [...]s [p. 22 of Exhibit CX1771] a listing of companies that had either attempted to develop or actually introduced CDMA chips at [...] some point in time? A. Yes. This is intended to be a list of companies which had done some development or claimed to have done development, yes. Q. Of these companies, which found any real commercial traction in the CDMA market? A. [...] So early in the market, Nokia, Motorola, and Samsung did have their own development. But that was very early, probably pre-1x even. And then -- so those are all phone makers who did their own.”) and Exhibit CX1771, VIA-QCOM000638768–8855 at 8789 (Motorola’s start date listed as 1992; “Result[.] [...]Q]uit producing own chipset circa 99”). See also LaPedus, Mark, “Qualcomm Bars CDMA Chips Sales by VLSI Technology,” EE Times, September 10, 1999 (“Gaining ground on Qualcomm in the chip sections are two major OEMs – Motorola and Nokia. However, Motorola and Nokia separately develop their own chipsets for their own CDMA-based handsets; the two cell-phone giants do not sell these devices on the [merchant] market.”).

<sup>1181</sup> See, e.g., “Freescale Semiconductor Completes Spin-off from Motorola,” Business Wire, December 2, 2004 (“Freescale Semiconductor [...] began its new era as a fully independent company today following Motorola, Inc.’s distribution of its remaining equity interest in Freescale on Dec. 2, 2004. [...] Freescale is the third-largest independent semiconductor company in the U.S. It is the global market share leader in semiconductors for automotive applications, communications processors and wireless infrastructure -- and among the leaders in several other large and growing industry segments.”).

<sup>1182</sup> See, e.g., Freescale, 10-K, 2004, p. 11 (“[Freescale’s Wireless and Mobile Solutions Group] designs, manufactures and markets platform-level products and semiconductors used in the design and manufacturing of wireless mobile devices such as cellular phones, smartphones, personal digital assistants (PDAs), two-way messaging devices, global positioning systems, mobile gaming devices and wireless consumer electronics. [...] Currently, over 90% of our sales in this group are derived from cellular handsets, with Motorola being our

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414. In 2005, Freescale acquired PrairieComm, which had assets including technology for a broad set of modem chip standards.<sup>1183</sup> However, due to a failure to expand its customer base and lack of its own 3G modem chip software, Freescale’s modem chip sales began to decline in 2006 after Motorola started switching to alternative suppliers.<sup>1184,1185</sup> Freescale faced further challenges in form of resource constraints when it was saddled with a large amount of debt after being acquired in 2006 in a “disastrous” buyout with a “rich price tag” by a group of private equity firms.<sup>1186</sup> The CEO of Signals Research Group stated in April 2008 that Freescale was “not on [his] short list of the cell-phone chipmakers that will survive.”<sup>1187</sup> In October 2008 Freescale confirmed that it planned to exit the modem chip industry.<sup>1188</sup> The

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largest end customer [...]”) and p. 12 (“We offer platform-level products for leading cellular protocols, including Global Systems for Mobile Communications (GSM), General Packet Radio Service (GPRS), Enhanced Data for GSM Evolution (EDGE), integrated digital enhanced network (iDEN) and Universal Mobile Telecommunications System (UMTS) [...]). See also Exhibit V.B.5; “Freescale Closer to Cutting Cord from Parent Motorola,” RCR Wireless, May 24, 2004 (“But [Freescale] will still have strong ties with Motorola. ‘Motorola will commit, on behalf of its cellular subscriber businesses, to purchase from us substantially all its cellular baseband semiconductor requirements,’ said Freescale.”).

<sup>1183</sup> “Company Overview of PrairieComm, Inc.,” Bloomberg (“As of February 7, 2005, PrairieComm, Inc. was acquired by Freescale Semiconductor Inc. PrairieComm, Inc. develops and markets chipsets, embedded software, and licensed intellectual property for CDMA, TDMA, GSM, and 3G UMTS wireless technologies.”).

<sup>1184</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 125 (“Freescale suffers from not having a broad customers base to draw upon. They sell largely digital basebands to Motorola for GPRS, EDGE and UMTS phones. They suffer from not having mastered their own 3G software stacks for UMTS, WCDMA and HSxPA. Although Freescale owns its StarCore DSP chip technology, the 3G stack that it has been shipping to Motorola belongs to Motorola...which won’t allow Freescale to deploy it in chips to other handset vendors.”).

<sup>1185</sup> See Exhibit V.C.9.

<sup>1186</sup> Thornton, Emily et al., “When a Buyout Goes Bad,” Bloomberg, April 3, 2008 (“The acquisition of Freescale [by a group of private equity firms] had provoked much skepticism in the buyout world. [...] Freescale’s rich price tag – \$17.6 billion, then the biggest tech buyout ever – raised more doubts among the financial cognoscenti. [...] In paying so much, the buyers – some of the world’s biggest and most respected dealmakers – were essentially betting that nothing would go wrong. [...] But Freescale’s owners saddled it with \$9.5 billion to pay for the deal. Now the company must come up with \$375 million in interest payments every six months. [...] But few recent buyouts have been more disastrous than Freescale’s. [...] The deal closed on Dec. 1, 2006.”).

<sup>1187</sup> Thornton, Emily et al., “When a Buyout Goes Bad,” Bloomberg, April 3, 2008.

<sup>1188</sup> See, e.g., “Freescale Semiconductor Announces Third Quarter 2009 Results,” Business Wire, October 22, 2009 (“The year over year sales decline was attributable to the company’s decision in 2008 to exit its cellular handset business [...]). See also Deffree, Suzanne, “Freescale Exiting Mobile ICs, Opens Opportunity for Qualcomm,” The EDN Network, October 3, 2008 (“[...] Freescale Semiconductor has announced that it is exploring options for its cellular handset chipset business that include the unit’s sale or the formation of a joint venture.”).

company continued with legacy sales through 2013,<sup>1189</sup> with “aims to increase its investments in the automotive and networking markets.”<sup>1190</sup>

*b. Analysis*

415. After spinning off from Motorola, Freescale’s experience in the modem chip industry was marred by poor foresight and weak execution, despite its level of investment being comparable to other modem chip suppliers. Freescale did not diversify its customer base, and fell behind its competitors in producing modem chips with features demanded by OEMs. Although Freescale was able to successfully bring products to market following the acquisition of PrairieComm in 2005, the company was unable to produce competitive modem chips after 2006. Freescale eventually exited the modem chip industry.
416. Foresight: Freescale struggled to expand its customer base as an independent entity. At the time of the split from Motorola, Freescale “claim[ed] that its independence [would] extend its customer base” and “increase its ability to pursue strategic acquisitions,”<sup>1191</sup> but these expectations were ultimately not fulfilled.<sup>1192</sup> Prior to the spinoff, demand for Freescale’s modem chips was heavily dependent on sales of Motorola’s mobile devices, as Motorola accounted for roughly two-thirds of Freescale’s sales.<sup>1193</sup> When it was established in 2004, Freescale entered into a multi-year purchase and supply agreement in which Motorola committed to purchase substantially all modem chips for its mobile devices from Freescale

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<sup>1189</sup> See Exhibit V.C.9.

<sup>1190</sup> Deffree, Suzanne, “Freescale Exiting Mobile ICs, Opens Opportunity for Qualcomm,” EDN Network, October 3, 2008 (“Freescale said it is [exploring options for its cellular handset business that include the unit’s sale or the formation of a joint venture] as it aims to increase its investments in the automotive and networking markets [...].”).

<sup>1191</sup> “Freescale Closer to Cutting Cord from Parent Motorola,” RCR Wireless News, May 24, 2004 (“Freescale claims that its independence will extend its customer base, give it direct access to capital markets, increase its ability to pursue strategic acquisitions and offer employees more direct incentives [...].”).

<sup>1192</sup> “Baseband Market Share Q3-2009: Infineon and Broadcom Are Improving Market Share,” Strategy Analytics, February 26, 2010 (“We expect Freescale to wind down its cellular baseband business in the next 12-24 months and halt production as the company failed to diversify its customer base.”).

<sup>1193</sup> Freescale, 10-K, 2004, p. 11 (“Currently, over 90% of our sales in this group are derived from cellular handsets, with Motorola being our largest end customer, representing 74%, 69% and 73% of WMSG’s 2004, 2003, and 2002 sales, respectively.”).

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through 2006.<sup>1194</sup> Once the purchase and supply agreement ended, Motorola shifted much of its modem chip purchases to Qualcomm and later to TI,<sup>1195</sup> impacting what had historically been one of Freescale’s large revenue sources.<sup>1196</sup> In the meantime, Freescale failed to attract other new customers.<sup>1197</sup> Industry analysts noted in 2008 that “Freescale suffer[ed] from not having a broad customer base to draw upon.”<sup>1198</sup> Freescale’s difficulty in obtaining new customers was partly due to the fact that the IP for the software stack in its 3G modem chips was owned by Motorola and thus could not be shipped to other OEMs.<sup>1199</sup>

417. Investment: Freescale made an investment in its modem chip business via its 2005 acquisition of PrairieComm.<sup>1200</sup> PrairieComm was a privately held company with a background in the

<sup>1194</sup> See, e.g., “Semiconductor Purchase Agreement,” SEC, April 4, 2004 (“If Freescale is competitive with respect to pricing, timing and features, then through December 31, 2006, Motorola will purchase from Freescale 100% of Motorola’s total purchases of Baseband Semiconductor Family products.”). See also Freescale, 10-K, 2004, p. 11 (“As part of our separation from Motorola, we entered into a multi-year purchase and supply agreement through the end of 2006. Under this agreement, Motorola has committed, on behalf of its cellular subscriber businesses, to purchase from us substantially all of its cellular baseband semiconductor requirements (other than cellular baseband products based on code division multiple access technologies which we do not design) for cellular handsets designed by Motorola and manufactured by or for Motorola through 2006.”).

<sup>1195</sup> White, Peter, “Motorola-TI Deal Shifts Market for Nokia and Intel, in Quest for Affordable 3G,” Rethink Research, February 5, 2007 (“Just two months after signing a major chip deal with Qualcomm, Motorola has spread its post-Freescale wings still further and formed a close alliance with Texas Instruments, one that may bode ill for Intel as well as Freescale itself in the high end cellphone processor market. [...] Since its exclusive agreement with Freescale ended, Motorola has lacked such a close alliance.”).

<sup>1196</sup> See, e.g., White, Peter, “Motorola-TI Deal Shifts Market for Nokia and Intel, in Quest for Affordable 3G,” Rethink Research, February 5, 2007 (“Of course, this is bad news for Freescale, which took 25% of its revenue from its former parent in 2005.”). See also Thornton, Emily et al., “When a Buyout Goes Bad,” Bloomberg, April 3, 2008 (“Sales started slipping just months after [the acquisition of Freescale by a group of private equity firms in December 2006]. Freescale’s biggest customer, former parent Motorola, slashed orders, and Freescale wasn’t able to add enough new customers to offset the shortfall. Revenues for 2007 tumbled 10%, to \$5.7 billion, even as the industry’s increased 5%. And the news keeps getting worse: On Mar. 26 [2008], Motorola announced it was spinning off its cell-phone unit, raising more concerns for Freescale.”).

<sup>1197</sup> Thornton, Emily et al., “When a Buyout Goes Bad,” Bloomberg, April 3, 2008 (“Soon after [the first quarter of 2007], giant cellphone maker Nokia (NOK), which Freescale had been counting on as a new customer, decided not to use the company’s chips in a new phone model.”).

<sup>1198</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 125.

<sup>1199</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 125 (“[Freescale] suffer[s] from not having mastered their own 3G software stacks for UMTS, WCDMA and HSxPA. Although Freescale owns its StarCore DSP chip technology, the 3G stack that it has been shipping to Motorola belongs to Motorola...which won’t allow Freescale to deploy it in chips to other handset vendors.”).

<sup>1200</sup> The financial terms of the acquisition were not disclosed. “Freescale Strengthens 3G Leadership; Acquires Assets of PrairieComm, Inc.” Business Wire, February 7, 2005 (“Freescale Semiconductor, Inc. continues to build on its technology leadership with the acquisition of the assets of PrairieComm, Inc. [...] Financial terms of the deal will not be disclosed.”).

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development and sales of products for the GSM, TDMA, CDMA, and WCDMA (UMTS) standards.<sup>1201</sup> As part of the transaction, 120 employees of PrairieComm joined Freescale.<sup>1202</sup>

418. The magnitude of Freescale’s firm-wide R&D investment was generally comparable to that of many of its competitors.<sup>1203</sup> However, following the acquisition of Freescale by the group of private equity firms in 2006, Freescale had “a hard [...] time scraping up the \$1.2 billion for R&D [...] it need[ed] each year to remain competitive” because of large interest payments on its debt.<sup>1204</sup> The company decided to slightly reduce its R&D budget and focus on efficiency and allocation of resources.<sup>1205</sup>
419. Execution: While Freescale shipped over 50 million modem chips each year from 2002 through 2007, sales of its modem chips began to stall in 2005.<sup>1206</sup> As Freescale’s products were delayed and less competitive, Motorola began purchasing modem chips from other suppliers.<sup>1207</sup> By

<sup>1201</sup> “Company Overview of PrairieComm, Inc.,” Bloomberg (“As of February 7, 2005, PrairieComm, Inc. was acquired by Freescale Semiconductor Inc. PrairieComm, Inc. develops and markets chipsets, embedded software, and licensed intellectual property for CDMA, TDMA, GSM, and 3G UMTS wireless technologies.”).

<sup>1202</sup> “Freescale Strengthens 3G Leadership; Acquires Assets of PrairieComm, Inc.” Business Wire, February 7, 2005 (“Freescale Semiconductor, Inc. continues to build on its technology leadership with the acquisition of the assets of PrairieComm, Inc. [...] PrairieComm is recognized for its world-class engineering of cellular products including software, system-on-chip designs and platform designs. The company has a strong background in development and sales of CDMA, TDMA, GSM and UMTS product lines. [...] About 120 employees are joining Freescale as part of this transaction -- 60 in India and 60 in the United States.”).

<sup>1203</sup> See Exhibits III.E.1–3.

<sup>1204</sup> Thornton, Emily et al., “When a Buyout Goes Bad,” Bloomberg, April 3, 2008 (“But Freescale’s owners saddled it with \$9.5 billion to pay for the deal. Now the company must come up with \$375 million in interest payments every six months. [...] But given its huge interest payments, Freescale is having a hard enough time scraping up the \$1.2 billion for R&D and \$400 million for capital expenditures it says it needs each year to remain competitive. [...] To make ends meet, the company is reorganizing operations, revamping its product lines, and scouring for customers. All options are on the table – including, for the first time, a breakup.”).

<sup>1205</sup> Thornton, Emily et al., “When a Buyout Goes Bad,” Bloomberg, April 3, 2008 (“The private equity firms were also trying not to fulfill their critics’ most pointed prediction: that they would slash the precious R&D budget. After several meetings, the board decided to trim only modestly, from \$1.2 billion to \$1.13 billion. But [Freescale’s CEO] Mayer would have to spend the money more wisely. [...] He also reorganized divisions by chip type rather than customer type, so that he could assess how each product was faring and allocate resources better. Among his first changes: moving R&D funds from the mobile handset group to the more- stable auto-chip business.”).

<sup>1206</sup> See Exhibit V.C.9.

<sup>1207</sup> See, e.g., Nuttall, Chris, “Freescale Lacks Scale, Plans Retreat from Mobile Chips,” Financial Times, October 2, 2008 (“Motorola has been buying more chips from Qualcomm, hitting Freescale’s market share further and reducing its revenues from Motorola to below 25 per cent of its total chip sales.”). See also “Cellular Handset & Chip Markets,” Forward Concepts, 2008, pp. 37–38 (“Motorola has also been damaged relying on Freescale for HSDPA and EDGE baseband modem technology. Freescale was late with its HSDPA chip set [...].

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December 2007 Freescale was “sitting on a pile of unsold inventory.”<sup>1208</sup> In 2008, Forward Concepts reflected that Freescale was still suffering from “not having mastered [its] own 3G software stacks,”<sup>1209</sup> and Strategy Analytics concluded that Freescale “was not able [to] keep pace with other [WCDMA] chip suppliers.”<sup>1210</sup> Freescale announced its plan to leave the modem chip industry in October 2008,<sup>1211</sup> and ceased legacy sales by 2013.<sup>1212</sup>

## 10. Spreadtrum

### *a. Background*

420. Founded as a private firm in 2001 in Shanghai, China, Spreadtrum is a fabless semiconductor company.<sup>1213</sup> Spreadtrum was taken public in 2007,<sup>1214</sup> and, after a drastic decline in revenue in 2008,<sup>1215</sup> underwent management changes in 2009.<sup>1216</sup> In 2013, Spreadtrum was acquired

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Fortunately [Motorola] looked at the alternatives, and has renegotiated a deal with CDMA chip supplier, Qualcomm, for 3G HSPA devices.”).

<sup>1208</sup> Thornton, Emily et al., “When a Buyout Goes Bad,” Bloomberg, April 3, 2008 (“In December, 2007, [...] Freescale was sitting on a pile of unsold inventory.”).

<sup>1209</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 125 (“[Freescale] suffer[s] from not having mastered their own 3G software stacks for UMTS, WCDMA and HSxPA. Although Freescale owns its StarCore DSP chip technology, the 3G stack that it has been shipping to Motorola belongs to Motorola...which won’t allow Freescale to deploy it in chips to other handset vendors.”).

<sup>1210</sup> “Baseband Market Share Q3-2009: Infineon and Broadcom Are Improving Market Share,” Strategy Analytics, February 26, 2010 (“[...] Freescale also announced its intention to exit from the cellular baseband market in Q3-2008. The company was not able [to] keep pace with other W-CDMA chip suppliers and as a result Motorola discontinued Freescale as a W-CDMA supplier.”);

<sup>1211</sup> “Freescale to Focus on Core Units, Exit Mobile IC Business,” EE Times, October 2, 2008 (“Freescale Semiconductor has confirmed speculation that it plans to eventually exit the wireless handset chip set business and is weighing several options for the unit.”).

<sup>1212</sup> See Exhibit V.C.9.

<sup>1213</sup> “Corporate Overview,” Spreadtrum.

<sup>1214</sup> “Spreadtrum Communications, Inc. Prices Initial Public Offering,” Spreadtrum Press Release, June 27, 2007.

<sup>1215</sup> Spreadtrum, 20-F, 2009, p. 8 (“However, in 2008 and during the first half of 2009, we experienced dramatic rates of decline in revenue. Our revenue increased 35.9% from 2006 to \$145.5 million in 2007, but our revenue declined 24.4% from 2007 to \$109.9 million in 2008.”).

<sup>1216</sup> See, e.g., “Spreadtrum Communications, Inc. Announces CEO Appointment,” Spreadtrum Press Release, February 13, 2009. See also Balasubramanyam Seshan, “Key Takeaways from Spreadtrum Call over Muddy Waters Questions,” International Business Times, June 30, 2011 (“Please explain the sales increase in light of the 2009 management changes [...]”).

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by Tsinghua Unigroup, an operating subsidiary of a state-owned Chinese corporation.<sup>1217</sup> Subsequently, in 2014, 20 percent of Tsinghua Unigroup was acquired by Intel, giving Spreadtrum access to some of Intel’s manufacturing and processor technology.<sup>1218</sup>

421. Though Spreadtrum initially sold “turnkey solutions” that bundled its modem chips with a set of third-party mobile components,<sup>1219</sup> in the mid-2000s the company moved towards offering thin modems as standalone products.<sup>1220</sup> As shown in Exhibit V.C.10, by 2008 Spreadtrum had released standalone modem chips that supported the GSM standard as well as modem chips that supported TD-SCDMA, the standard used by China Mobile. Spreadtrum continued to sell large numbers of TD-SCDMA and GSM-compatible modem chips through 2014 and at least 2017, respectively,<sup>1221</sup> long after newer wireless standards gained traction.<sup>1222</sup> In addition, sales of Spreadtrum’s GSM-only modems increased year-over-year through 2016.<sup>1223</sup>

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<sup>1217</sup> “Tsinghua Holdings to Buy Chipmaker Spreadtrum,” Reuters, July 12, 2013 (“[...] Spreadtrum Communications will be acquired by a unit of government-owned Tsinghua Holdings for a raised offer price of about \$1.78 billion.”).

<sup>1218</sup> See, e.g., “Intel and Tsinghua Unigroup Collaborate to Accelerate Development and Adoption of Intel-Based Modem Devices,” Intel Press Release, September 25, 2014 (“Intel also has agreed to invest [...] for a minority stake of approximately 20 percent of the holding company under Tsinghua Unigroup [...] Under the terms of the agreement, Spreadtrum Communications, Inc. will jointly create and sell a family of Intel Architecture-based system-on-chips.”). See also “Spreadtrum Launches 14nm 8-core 64-bit Mid- and High-End LTE SoC Platform,” Spreadtrum Press Release, February 27, 2017 (“Built on Intel’s 14nm foundry platform, SC9861G-IA is targeting the global mid-level and premium smartphone market [...].”).

<sup>1219</sup> See, e.g., Spreadtrum, 20-F, 2007, p. 35 (“[...] We offer turnkey solutions, which include devices that combine our baseband semiconductors and other third-party wireless handset components such as transceivers and memory semiconductors [...].”). See also “Global Cellular Handset and Chip Markets,” Forward Concepts, 2005, p. 307 (“Spreadtrum is currently shipping a GSM/GPRS baseband chipset [...]. The SC6600 is a fully integrated GSM/GPRS single mixed signal chip containing all digital and analog functionality for a GSM/GPRS wireless phone.”).

<sup>1220</sup> Spreadtrum, 20-F, 2007, p. 33 (“We derive substantially all of our revenue from the sale of baseband semiconductors and turnkey solutions, which include modules and bundled solutions. Our baseband semiconductor revenue has increased from \$4.1 million for 2005 to \$54.9 million for 2006 and \$127.1 million for 2007. As a percentage of revenue, sales of baseband semiconductors were 0.0%, 0.6%, 10.7%, 51.3% and 87.4% in 2003, 2004, 2005, 2006 and 2007 respectively. Turnkey solutions have been used to help promote and enable the rapid adoption of our baseband processor solutions. [...] Revenue from turnkey solutions as a percentage of revenue decreased from 48.7% in 2006 to 12.6% in 2007 as we focused on our higher margin baseband semiconductors.”).

<sup>1221</sup> See Exhibit V.C.10.

<sup>1222</sup> See Exhibit V.B.1.

<sup>1223</sup> See Exhibit V.C.10.

422. Spreadtrum’s focus on GSM and TD-SCDMA limited its ability to keep up with other wireless standards. Spreadtrum released its first WCDMA-compatible chip years after its competitors, in 2013,<sup>1224</sup> and two years after it acquired WCDMA provider MobilePeak.<sup>1225</sup> Continuing its strategy of targeting emerging markets,<sup>1226</sup> Spreadtrum successfully achieved a large share of sales of WCDMA-compatible modem chips (without 4G compatibility) from 2014 onward,<sup>1227</sup> despite decreasing use by OEMs of chips with WCDMA, but not 4G, technology.<sup>1228</sup> Spreadtrum also added 4G compatibility to its product portfolio in 2012, developing LTE chips for use in China.<sup>1229</sup> Similar to its strategy with earlier generations of wireless standards, Spreadtrum has subsequently used its LTE product offerings to expand in emerging markets.<sup>1230</sup> As of 2017, Spreadtrum began to leverage access to Intel’s processor technology to develop SoCs specifically targeting mid-tier and high-end smartphones.<sup>1231</sup> This Intel–

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<sup>1224</sup> See Exhibit V.B.5.

<sup>1225</sup> “Spreadtrum Takes Majority Stake in MobilePeak,” EE Times, October 3, 2011, available at [https://www.eetimes.com/document.asp?doc\\_id=1260348](https://www.eetimes.com/document.asp?doc_id=1260348) (“Spreadtrum (Shanghai) said the acquisition of MobilePeak would allow the company to enter the global 3G and LTE markets with WCDMA/HSPA+ technology.”).

<sup>1226</sup> See, e.g., “Spreadtrum Announces WCDMA Design Win,” Spreadtrum Press Release, July 30, 2013 (“The SC7701B opens up a new opportunity for WCDMA devices in emerging markets[.]”). See also “Spreadtrum Communications Joins with Brazil’s Rockcel to Launch a Smartphone for Ordinary Consumers,” Spreadtrum Press Release, August 5, 2016 (“Spreadtrum Communications (‘Spreadtrum’), a leading fabless semiconductor company in China with advanced technology in 2G, 3G, and 4G wireless communication standards, today announced that its WCDMA/HSPA (+) chipset SC7731G has been adopted by Brazilian mobile manufacturer Rockcel in its newly released Quartzo smartphone. [...] ‘Spreadtrum will continue to work closely with its customers and to provide emerging markets all around the world with affordable product solutions that deliver a better user experience.’”).

<sup>1227</sup> See Exhibit V.B.6

<sup>1228</sup> See Exhibits V.B.1 and V.B.6.

<sup>1229</sup> “Spreadtrum Introduces Single-Chip MultiMode TD-LTE/TD-SCDMA/GSM Baseband Modem at CES 2012,” Spreadtrum Press Release, January 9, 2012 (“Our single-chip multi-mode TD-LTE solution is a highly integrated platform specifically designed for the communication standards in use in China[.]”).

<sup>1230</sup> See, e.g., “Spreadtrum LTE SoC Platform Powers Bharat 2, the Latest Smartphone from Micromax,” Spreadtrum Press Release, April 24, 2017 (“We are delighted to partner with Micromax, one of the leading mobile phone manufacturers in India, for its smartphone, Bharat 2.”). See also “Spreadtrum Partners with Algerian Cellphone Maker Condor to Provide North African Users a High-Performance LTE Smartphone Solution,” Spreadtrum Press Release, December 15, 2016.

<sup>1231</sup> See, e.g., “Spreadtrum Launches 14nm 8-core 64-bit Mid- and High-End LTE SoC Platform,” Spreadtrum Press Release, February 27, 2017 (“Built on Intel’s [...] platform, [Spreadtrum’s LTE SoC] is targeting the global mid-level and premium smartphone market [...].”). See also Yan, James, “2017 Spreadtrum Global Partner Conference Highlights New Strategy,” Counterpoint, September 7, 2017 (“The SC98531 uses Intel’s advanced

Spreadtrum partnership may help Spreadtrum target medium- to high-end customers with 4G and even 5G solutions in the years to come.<sup>1232</sup>

*b. Analysis*

423. Spreadtrum’s success in modem chip development has been characterized by effective foresight, strategic investments and acquisitions, and the ability to execute chip designs on time and at low cost. Spreadtrum has tended to focus on standards that are China-specific or popular in emerging markets. For example, it drove its sales with GSM and TD-SCDMA compatible modem chips through the early 2010s. Spreadtrum’s historical commitment to low-priced, high-quality products has enabled it to undercut competitors such as MediaTek and rapidly generate sales. In recent years, Spreadtrum has replicated its strategy successfully in the WCDMA and LTE segments, particularly in emerging markets.
424. Foresight: In order to establish its business, Spreadtrum focused first on selling “turnkey solutions.”<sup>1233</sup> Turnkey solutions allowed new OEMs to purchase a Spreadtrum modem chip as part of a set of assembled or unassembled components that addressed many different mobile device functionalities.<sup>1234</sup> As Spreadtrum noted in its 2007 annual report, purchasing

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14-nanometer process technology and utilizes the Intel Airmont processor architecture. It’s designed for the global mid-range 4G market.”).

<sup>1232</sup> See, e.g., “Spreadtrum Launches 14nm 8-core 64-bit Mid- and High-End LTE SoC Platform,” Spreadtrum Press Release, February 27, 2017 (“Built on Intel’s[...] platform, [Spreadtrum’s LTE SoC] is targeting the global mid-level and premium smartphone market [ ...]. [...] Dr. Leo Li, Chairman and CEO of Spreadtrum [said] ‘Looking ahead, Spreadtrum plans to continue innovating and creating more high-end and differentiated products and services.’”). See also “Intel and UniGroup Spreadtrum & RDA Announce 5G Strategic Collaboration,” Intel Press Release, February 22, 2018 (“[...T]he companies will collaborate on 5G and develop Spreadtrum’s first Android-based high-end 5G smartphone solution [...].”).

<sup>1233</sup> See, e.g., “Spreadtrum Communications’ CEO Discusses Q4 2012 Results - Earnings Call Transcript,” Seeking Alpha, February 26, 2013 (“This fast successful ramp of our smartphone chipset was a result of a strong expertise in low cost chipset designs and smartphone software and our ability to meet customer needs quickly and effectively with our turnkey solutions.”). See also Spreadtrum, 20-F, 2007, p. 33 (“We derive substantially all of our revenue from the sale of baseband semiconductors and turnkey solutions, which include modules and bundled solutions. [...] As a percentage of revenue, sales of baseband semiconductors were 0.0%, 0.6%, 10.7%, 51.3% and 87.4% in 2003, 2004, 2005, 2006 and 2007 respectively. Turnkey solutions have been used to help promote and enable the rapid adoption of our baseband processor solutions. [...] Revenue from turnkey solutions as a percentage of revenue decreased from 48.7% in 2006 to 12.6% in 2007[.]”).

<sup>1234</sup> See, e.g., Spreadtrum, 20-F, 2007, p. 35 (“[...] We offer turnkey solutions, which include devices that combine our baseband semiconductors and other third-party wireless handset components such as transceivers and memory semiconductors[.]”) and p. 37 (“We provide turnkey solutions for our customers who want a more complete solution and to decrease time-to-market for their products.”). See also “Spreadtrum Profile: Well

compatible parts in combination allowed mobile device OEMs to release their devices more quickly.<sup>1235</sup> This strategy worked, and it propelled Spreadtrum to its first profitable quarter and year in 2006.<sup>1236</sup> Over time, however, Spreadtrum’s product offerings shifted toward standalone modem chips, which yielded higher margins, without including these additional turnkey components.<sup>1237</sup> Spreadtrum’s standalone modem chip revenues rose from \$4 million in 2005 (11 percent of the company’s revenue) to \$127 million in 2007 (87 percent).<sup>1238</sup> In 2007, Spreadtrum announced its intention to phase out its “turnkey solutions” business by 2008.<sup>1239</sup>

425. In addition, Spreadtrum did not rush to adopt the WCDMA standard, which worked well in conjunction with its focus on the low-cost segment. By continuing to focus on GSM and TD-SCDMA technology while its competitors focused on transitioning to WCDMA,<sup>1240</sup>

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Positioned for Mobile Processor Success,” Strategy Analytics, January 2014, p. 14 (“Spreadtrum’s turnkey solutions business model produces an edge in the low-end market.”).

<sup>1235</sup> Spreadtrum, 20-F, 2007, p. 37 (“We provide turnkey solutions for our customers who want a more complete solution and to decrease the time-to-market for their products.”).

<sup>1236</sup> See, e.g., Spreadtrum, 20-F, 2007, p. 33 (“We first became profitable in the first quarter of 2006 [...]”). See also Jönsson, Anette, “Spreadtrum Prices IPO Above the Range,” FinanceAsia, June 28, 2007 (“[Spreadtrum] became profitable in the first quarter 2006 and posted a net profit of \$14.4 million last year. In the first quarter of 2007 it managed a \$2 million profit.”).

<sup>1237</sup> Spreadtrum, 20-F, 2007, p. 33 (“Revenue from turnkey solutions as a percentage of revenue decreased from 48.7% in 2006 to 12.6% in 2007 as we focused on our higher margin baseband semiconductors.”).

<sup>1238</sup> Spreadtrum, 20-F, 2007, p. 33.

<sup>1239</sup> See, e.g., Spreadtrum, 20-F, 2007, p. 33 (“We phased out our handset board business in 2006, and we intend to phase out our module business in 2008.”). See also “Integration & Consolidation: The Roadmap for Wireless Semiconductors,” Citigroup Global Markets, November 29, 2007, p. 63 (“Historically, [Spreadtrum] supplied handset boards and turnkey services in addition to baseband chips – boards were phased out in 2006 and the module business is being phased out during 2007.”).

<sup>1240</sup> For example, between 2004 and 2006 Spreadtrum released the SC6600, SC6800, and SC8800 baseband semiconductors. The two former chips were compatible with GSM while the latter was compatible with GSM and TD-SCDMA. See, e.g., Spreadtrum, 20-F, 2007, pp. 36–37. See also Spreadtrum 20-F, 2012, p. 15 (“To date, most of our revenue has been derived from the sale of products that support 2G, 2.5G, 2.75G, and 3G wireless standards, such as GSM, GPRS, EDGE, and TD-SCDMA.”); “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 13 (“Although it presently constitutes a relatively small part of the cellular handset market at 154 million units growing from 93 million sold in 2006, WCDMA handsets embody the more advanced capabilities and features. In addition, it is the fastest-growing market segment, growing almost 65% in 2007. Consequently, it is a central focus for many handset suppliers.”). Note that MediaTek’s first WCDMA and LTE chips were released in 2013 and 2012, respectively. See Exhibits V.B.5 and V.B.7.

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Spreadtrum continued to grow its sales in both GSM and TD-SCDMA.<sup>1241</sup> As of 2016, Spreadtrum was the largest supplier of GSM-only modem chips and the only supplier whose GSM sales did not decline relative to the previous year.<sup>1242</sup> When Spreadtrum finally did develop WCDMA chips, it did so within two years.<sup>1243</sup> Departing from its earlier pattern of late adoption of standards, Spreadtrum announced its TD-LTE-compatible modem chip in January 2012, almost two years before China Mobile’s launch of its TD-LTE network.<sup>1244</sup> As the volume of WCDMA chips (without 4G compatibility) began to decline worldwide in 2015,<sup>1245</sup> Spreadtrum added FD-LTE-compatible chips to its product line.<sup>1246</sup>

426. Investment: The company’s efforts have included research into improving product offerings for the TD-SCDMA standard that,<sup>1247</sup> while geographically concentrated in certain markets,

<sup>1241</sup> For example, Spreadtrum sold over 275 million GSM chips each year between 2014 and 2017. Similarly, Spreadtrum sold over 40 million TD-SCDMA chips each year between 2012 and 2014. See, e.g., Exhibit V.C.10. See also “Cellular Handset and Chip Markets,” Forward Concepts, 2011, p. 84 (“Spreadtrum holds the best position [in TD-SCDMA], entering 2011 with its single-chip TD-SCDMA/HSDPA/GSM/GPRS baseband [...]”).

<sup>1242</sup> In particular, Spreadtrum sold around 300 million GSM-only chips in each of 2015 and 2016. See Exhibit V.C.10 and associated backup.

<sup>1243</sup> Spreadtrum acquired a majority stake in WCDMA modem chip designer MobilePeak in October 2011. By July 2013, Spreadtrum announced design wins for WCDMA products. See, e.g., Spreadtrum, 20-F, 2012, p. 28. See also “Spreadtrum Announces WCDMA Design Win,” Spreadtrum Press Release, July 30, 2013.

<sup>1244</sup> “Spreadtrum Introduces Single-Chip MultiMode TD-LTE/TD-SCDMA/GSM Baseband Modem at CES 2012,” Cision PR Newswire, January 9, 2012 (“Spreadtrum Communications, Inc. [...] today introduced its first TD-LTE baseband modem, the SC9610.”). See also Goldstein, Phil, “China Mobile Launches TD-LTE Service - but iPhone is Still MIA,” FierceWireless, December 18, 2013 (“China Mobile officially launched TD-LTE service Wednesday [...]”); “Cellular Handset & Chip Markets,” Forward Concepts, 2012, p. 111 (“Spreadtrum Communications in September announced their first major TD-SCDMA contract with Samsung. We believe this is because of their integrated TD-LTE and TD-SCDMA baseband, which places them ahead of competition in 2012.”).

<sup>1245</sup> See Exhibit V.B.6.

<sup>1246</sup> See, e.g., “Spreadtrum Announces Volume Shipments of 28nm Quad-Core 5-mode LTE and WCDMA SoC Platforms,” Spreadtrum Press Release, April 2, 2015 (“Spreadtrum Communications (‘Spreadtrum’) [...] today introduced [a] new quad-core SoC platform[], the SC9830A, which supports 5-mode LTE [...]. [...] The SC9830A [...] supports [...] LTE FDD [...]”).

<sup>1247</sup> Spreadtrum 20-F, 2009, p. 78 (“Our issued patents and pending patent applications relate primarily to technology we have developed for baseband semiconductors, including TD-SCDMA [...] and GSM/GPRS technologies.”). See also Spreadtrum, 20-F, 2012, p. 45 (“In the second quarter of 2009, Spreadtrum Shanghai entered into two multi-party contracts with a telecom operator to participate in the subsidy program sponsored by the telecom operator for the promotion of TD-SCDMA products. According to the contracts, the telecom operator agreed to contribute certain research and development funds to Spreadtrum Shanghai to subsidize its research and development of TD-SCDMA products if Spreadtrum Shanghai were to achieve certain milestones and targets.”).

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brought Spreadtrum a considerable volume of sales.<sup>1248</sup> Spreadtrum leveraged both its past experience with TD-SCDMA and its resources acquired from MobilePeak in 2011 to later develop multi-mode LTE products.<sup>1249</sup> Spreadtrum, furthermore, has enjoyed advantages in R&D spending, due to the relatively low payroll costs of Chinese engineers and grants from both the Chinese government and a TD-SCDMA network carrier.<sup>1250</sup>

427. Spreadtrum focused on low-cost GSM and TD-SCDMA products for a long period of time, and it invested in WCDMA later than its competitors.<sup>1251</sup> However, its investment in WCDMA development, once initiated, was sufficient to create WCDMA chips that ultimately secured several sockets.<sup>1252</sup>

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<sup>1248</sup> See Exhibit V.C.10.

<sup>1249</sup> See, e.g., “Spreadtrum Takes Majority Stake in MobilePeak,” EE Times, October 3, 2011, available at [https://www.eetimes.com/document.asp?doc\\_id=1260348](https://www.eetimes.com/document.asp?doc_id=1260348) (“Spreadtrum (Shanghai) said the acquisition of MobilePeak would allow the company to enter the global 3G and LTE markets with WCDMA/HSPA+ technology. MobilePeak’s 3G technology combined with Spreadtrum’s 40-nm baseband platform will enable Spreadtrum to deliver low-cost, high-performance WCDMA solutions for the global market and serve as a foundation for the company’s next-generation multi-mode 3G/4G solutions, Spreadtrum said.”). See also “Spreadtrum Introduces Single-Chip MultiMode TD-LTE/TD-SCDMA/GSM Baseband Modem at CES 2012,” Spreadtrum Press Release, January 9, 2012 (“The depth of experience we bring in TD-SCDMA products, combined with our early leadership in China’s 4G network evolution, positions Spreadtrum as a long-term leading provider of multimode baseband solutions.”).

<sup>1250</sup> See, e.g., Taulli, Tom, “Speedy Spreadtrum,” The Motley Fool, July 3, 2007 (“With fairly low wage rates, the company has a much easier time getting to profitability. Lower payroll costs also leave management free to devote more cash to R&D efforts. Of its 727 employees, 514 are engineers, and about half have master’s degrees or doctorates.”). See also Spreadtrum, 20-F, 2012, p. 44 (“Our research and development expenses have been partially offset by subsidies, including grants we have received from PRC government authorities and a telecom operator. For the years ended December 31, 2010, 2011 and 2012, \$5.0 million, \$2.9 million and \$23.4 million were recorded as offsets to research and development expenses incurred, respectively. As of December 31, 2010, 2011 and 2012, we had total unearned subsidies of \$7.2 million, \$24.2 million and \$14.2 million, respectively, since the requirements for those specific research and development projects had not been fulfilled. We expect to meet all these requirements in later periods before the deadlines set by the government. In addition to the government subsidies, for the years ended December 31, 2010, 2011 and 2012, \$2.9 million, \$10.3 million and \$1.5 million were recorded as offsets to research and development expenses incurred, respectively, which are related to a subsidy program sponsored by a telecom operator for the promotion of TD-SCDMA products [...].”).

<sup>1251</sup> For example, Spreadtrum released its first WCDMA chip and first FD-LTE chip in 2013 and 2015, respectively. Qualcomm’s first WCDMA and LTE chips were released in 2006 and 2012, respectively. See Exhibits V.B.5 and V.B.7. See also Spreadtrum 20-F, 2009, p. 78 (“Our issued patents and pending patent applications relate primarily to technology we have developed for baseband semiconductors, including TD-SCDMA [...] and GSM/GPRS technologies [...].”).

<sup>1252</sup> For instance, Spreadtrum spent \$31 million in 2011 to acquire a majority stake in WCDMA modem chip designer MobilePeak. By July 2013, Spreadtrum announced design wins for WCDMA products. See, e.g.,

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428. Execution: Spreadtrum’s execution has been characterized by its ability, in most years, to deliver products on time and at a price that undercut its competitors. Following a slowdown of the Chinese economy and production problems it faced in 2008, Spreadtrum fell behind in the development of its new products.<sup>1253</sup> Spreadtrum then reorganized its management team in 2009,<sup>1254</sup> and focused on improving product quality and offering prices 10 to 15 percent lower than those of MediaTek.<sup>1255</sup> These measures allowed Spreadtrum to rapidly regain momentum and return to profitability by 2010.<sup>1256</sup>
429. Spreadtrum’s low prices and stable product quality have allowed it to capture a greater proportion of the low-end handset segment at the expense of MediaTek.<sup>1257</sup> While MediaTek focused on bringing high-end features to low-end mobile devices,<sup>1258</sup> Spreadtrum expanded its role in TD-SCDMA.<sup>1259</sup> In January 2011, Spreadtrum became the first modem chip

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Spreadtrum, 20-F, 2012, pp. 5 and 28. See also “Spreadtrum Announces WCDMA Design Win,” Spreadtrum Press Release, July 30, 2013.

<sup>1253</sup> “Spreadtrum Communications Inc. Announces Third Quarter 2008 Results,” Spreadtrum Press Release, November 6, 2008 (“Q3 was a challenging quarter for us. The slowing Chinese economy dampened domestic consumption, including demand for mobile phones in the Chinese market. This resulted in a negative impact on a number of our customers. Furthermore, we were affected by the delayed impact of product transition issues. We have since resolved these issues and customers are working on new designs.”).

<sup>1254</sup> “Spreadtrum Communications, Inc. Announces CEO Appointment,” Spreadtrum Press Release, February 13, 2009. See also Balasubramanyam Seshan, “Key Takeaways from Spreadtrum Call over Muddy Waters Questions,” International Business Times, June 30, 2011 (“Please explain the sales increase in light of the 2009 management changes [...]”).

<sup>1255</sup> So, Sherman, “Battered MediaTek Rearms with Android,” Asia Times, April 5, 2011 (“‘[MediaTek’s] rival, Spreadtrum, after years of trial, finally, came up with a chip that is stable enough for phone manufacturers,’ said an industry insider, ‘With a price about 10-15% lower than MediaTek’s, the Spreadtrum product quickly gained market share.’”).

<sup>1256</sup> After incurring losses of over \$100 million between Q3 2008 and Q2 2009, Spreadtrum returned to profitability in Q3 2009 and reported a net income of \$67 million in 2010. Spreadtrum, 20-F, 2012, p. 7.

<sup>1257</sup> So, Sherman, “Battered MediaTek Rearms with Android,” Asia Times, April 5, 2011 (“Spreadtrum previously held about 10% of the low-end mobile phone market. With a stable and lower-priced product, its share increased rapidly to about 20-25% at the end of last year, the industry insider estimated. MediaTek’s market share shrank to 70% while MStar held on to the remaining 5%.”). See also Section V.C.3 on MediaTek.

<sup>1258</sup> See, e.g., MTK\_00748746, p. 11, presentation titled “MWS All-Hands Meeting,” MediaTek, November 28, 2012 [REDACTED]. See also Section V.C.3 for further discussion on MediaTek.

<sup>1259</sup> See Exhibit V.C.10.

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designer to ship a 40nm TD-SCDMA chip,<sup>1260</sup> which was described as “a year ahead of its major competitors” and could “deliver low-cost low-power TD handsets at the price of a 2G handset.”<sup>1261</sup> Spreadtrum offered an integrated modem chip for TD-SCDMA the following year.<sup>1262</sup>

430. Building upon its TD-SCDMA products, in 2012, Spreadtrum began supplying LTE products for use in China.<sup>1263</sup> Due, again, to its low prices and decent performance,<sup>1264</sup> Spreadtrum increased its global share of sales of non-4G WCDMA-compatible modem chips from 1.5 percent in 2013 to 39 percent in 2016.<sup>1265</sup> Spreadtrum also expanded its LTE products into other regions, such as India and North Africa,<sup>1266</sup> and increased its global share in LTE chips from 0.4 percent in 2014 to 6.2 percent in 2016.<sup>1267</sup>

<sup>1260</sup> Spreadtrum, 20-F, 2012, p. 30 (“We introduced our first 40 nanometer-based TD-SCDMA baseband semiconductors in January 2011 and were the first baseband semiconductor company globally to ship a baseband product based on this process node.”).

<sup>1261</sup> Royal Bank of Scotland, “Spreadtrum Comm: Spreading Its Wings,” March 4, 2011, p. 1. See also Spreadtrum, 20-F, 2012, p. 30.

<sup>1262</sup> “Comprehensive Cellphone and Tablet Chip Markets,” Forward Concepts, 2013, p. 104 (“[... ]n 3Q 2012, several single core Smartphones appeared embedded with MediaTek (MT6517) and Spreadtrum (SC8810) processors.”) and p. 100 (“[... ]he SC8810 is an integrated, low-power platform for TD-SCDMA mainstream Smartphones.”).

<sup>1263</sup> Spreadtrum released its first TD-LTE modem chip in January 2012, even though China Mobile did not launch its TD-LTE network until December 2013. See, e.g., “Spreadtrum Introduces Single-Chip MultiMode TD-LTE/TD-SCDMA/GSM Baseband Modem at CES 2012,” Spreadtrum Press Release, January 9, 2012. See also Goldstein, Phil, “China Mobile Launches TD-LTE Service - but iPhone is Still MIA,” FierceWireless, December 18, 2013 (“China Mobile officially launched TD-LTE service Wednesday, as had been expected.”).

<sup>1264</sup> “Facing More Headwinds into 2015; Downgrading to Hold,” Deutsche Bank, September 23, 2014 (“We note that Spreadtrum has recently entered mass production for its WCDMA products after going through a slow first three quarters of this year. Spreadtrum usually is behind in technology compared to tier one rivals; however, it is famous in its low-price strategy, as seen in 2G feature phone and TD smartphone. Our checks suggest that its new WCDMA products have decent performance and attractive ASPs [average sale prices].”).

<sup>1265</sup> See Exhibit V.B.6 and associated backup.

<sup>1266</sup> See, e.g., “Spreadtrum LTE SoC Platform Powers Bharat 2, the Latest Smartphone from Micromax,” Spreadtrum Press Release, April 24, 2017 (“We are delighted to partner with Micromax, one of the leading mobile phone manufacturers in India, for its smartphone, Bharat 2.”). See also “Spreadtrum Partners with Algerian Cellphone Maker Condor to Provide North African Users a High-Performance LTE Smartphone Solution,” Spreadtrum Press Release, December 15, 2016 (“Spreadtrum Communications (‘Spreadtrum’), a leading fabless semiconductor company in China with advanced technology in 2G, 3G, and 4G wireless communication standards, today announced that its LTE SoC platform SC9832 has been adopted by Algerian cellphone brand Condor. The two companies will collaborate to provide North African users with a high-performance LTE smartphone solution.”).

<sup>1267</sup> See Exhibit V.B.8 and associated backup.

431. Since 2014, Spreadtrum has also been able to leverage Intel’s technology to improve its products. Intel, which purchased 20 percent of Spreadtrum’s parent company in 2014,<sup>1268</sup> supplied Spreadtrum with processor technology and access to its advanced 14nm manufacturing process.<sup>1269</sup> Spreadtrum also relied on Intel’s technology in its 2017 SC9861G-IA chip targeting the “global mid-level and premium smartphone.”<sup>1270</sup>

## 11. VIA Telecom

### *a. Background*

432. VIA Telecom was formed in 2002 by the Taiwanese PC chip designer VIA Technologies through the acquisition of the CDMA design team of San Diego-based LSI Logic.<sup>1271</sup> VIA Telecom’s strategy was to deliver low-cost CDMA solutions on a global scale.<sup>1272</sup> In a 2007 presentation, VIA Telecom described itself as a “low cost CDMA chipset alternative” with a “focus on driving low cost solutions with essential core applications (e.g., voice and data).”<sup>1273</sup>

<sup>1268</sup> Shih, Gerry and Noel Randewich, “Intel to Invest Up to \$1.5 Billion in Two Chinese Mobile Chipmakers,” Reuters, September 25, 2014 (“Intel Corp INTC.O said it will pay as much as \$1.5 billion for a 20 percent stake in two mobile chipmakers with ties to the Chinese government [...]. Intel will acquire the stake in Spreadtrum Communications and RDA Microelectronics through a deal with Tsinghua Unigroup, a government-affiliated private equity firm which owns the two mobile chipmakers.”).

<sup>1269</sup> See, e.g., “Intel and Tsinghua Unigroup Collaborate to Accelerate Development and Adoption of Intel-Based Modem Devices,” Intel Press Release, September 25, 2014 (“Intel also has agreed to invest [...] for a minority stake of approximately 20 percent of the holding company under Tsinghua Unigroup [...]. [...] Under the terms of the agreement, Spreadtrum Communications, Inc. will jointly create and sell a family of Intel Architecture-based system-on-chips.”). See also “Spreadtrum Launches 14nm 8-core 64-bit Mid- and High-End LTE SoC Platform,” Spreadtrum Press Release, February 27, 2017 (“The successful launch of SC9861G-IA, Spreadtrum’s first high-end LTE chip platform based on an Intel architecture and designed on Intel Custom Foundry’s 14nm technology platform [...].”).

<sup>1270</sup> “Spreadtrum Launches 14nm 8-core 64-bit Mid- and High-End LTE SoC Platform,” Spreadtrum Press Release, February 27, 2017.

<sup>1271</sup> Hung, Faith, “Via Sets Up Wireless Unit Following LSI Logic Deal,” EE Times, July 12, 2002 (“Via Technologies Inc. has formed a unit in the U.S. to attack the wireless market following its acquisition of a unit of LSI Logic Corp. Named Via Telecom, the new unit is focusing on the development of chipsets used in 2.5G and WCDMA mobile phones. The setup comes less than two months after Taipei-based Via Technologies bought the CDMA design team of LSI Logic Corp., San Diego, Calif.”).

<sup>1272</sup> Davis Deposition, Intel, Exhibit QX58, VIA-QCOM000688592 at p. 32 (VIA Telecom, “VIA Telecom Presentation,” September 2007, “Strategy and Business Objective[.] [VIA Telecom]’s vision is to become the low cost CDMA baseband solution provider worldwide.”).

<sup>1273</sup> Davis Deposition, Intel, Exhibit QX58, VIA-QCOM000688592 at p. 18 (VIA Telecom, “VIA Telecom Presentation,” September 2007).

433. VIA Telecom’s initial CDMA product line had been developed by LSI Logic.<sup>1274</sup> VIA Telecom released two CDMA2000 1X modem chips by 2006,<sup>1275</sup> launched its first CDMA 1xEV-DO chip in 2009,<sup>1276</sup> and by 2011 was supplying chips to major OEMs including Motorola and Samsung.<sup>1277</sup> The company also developed a dual-mode GSM/CDMA chip in 2011.<sup>1278</sup>
434. VIA Telecom’s consistent releases of CDMA modem chips for low-end and emerging markets contributed to a steady increase in sales through 2012.<sup>1279</sup> However, since VIA Telecom never developed its own LTE chip,<sup>1280</sup> the demand for the company’s chips dropped precipitously

<sup>1274</sup> As of 2002, LSI Logic was selling two CDMA modem chips, the SignalSphere CBP 3.0 and the SignalSphere CBP 4.0. See, e.g., Lemon, Sumner, “Via Resolves CDMA Licensing Question with Qualcomm,” InfoWorld, June 26, 2003 (“At the time the acquisition was announced, LSI Logic offered two baseband processors for CDMA handsets: the SignalSphere CBP 3.0 [...] and the SignalSphere CBP 4.0 [...].”). See also “Global Cellular Handset & Chip Markets,” Forward Concepts, 2005, pp. 292–293 (“VIA Telecom’s single-chip CBP4.0 CDMA Baseband Processor [...] is said to be the industry’s most integrated single chip baseband processor solutions, providing a complete cdma2000 Release 0 solution [...]. In July 2004, LG Telecom [...] announced launching of an ultra-slim and lightweight bar type PCS phone (NS1000) adopting VIA’s CDMA chip (CBP4.0).”).

<sup>1275</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2006, p. 113 (“The CBP 5.0 is a complete 3G CDMA2000® 1X Release 0 solution and is backward-compatible to IS 95 standards. Maximized to deliver optimum performance and high affordability, CBP5.0 includes the essential features manufacturers need to be successful in today’s entry-level phone market. [...] The CBP6.0 baseband provides a network-compliant 3G CDMA2000® 1X Release A solution. [...] Products using VIA Telecom’s chips] all appear to be [...] targeted at offering a lower-cost CDMA non-browser, SMS- and voice-centric CDMA handsets.”).

<sup>1276</sup> Davis Deposition, Intel, Exhibit QX65, VIA-QCOM00568897 at p. 4 (VIA Telecom, “VIA Telecom,” February 2, 2015, “2009[:] [...] Launched 3G EVDO chipset CBP7.0/7.1.”).

<sup>1277</sup> See, e.g., “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 90 (“VIA Telecom’s introduction of EV-DO contributed to its 55% growth in CDMA baseband chip sales. [...] The CDMA1x EV-DO units were mostly sold to Motorola and Samsung for EVDO-LTE Smartphones at Verizon.”) and p. 92 (“VIA Telecom’s EVDO Rev A CBP7.1 baseband device has been found inside Samsung’s Stealth Smartphone and the Galaxy Tab 10.1. Yulong’s Coolpad D530 and E239 Smartphones embeds the CBP7.1 baseband with 600MHz OMAP 3630 application processor sold to Reliance (India) and China Telecom (China). The Kunlun-Wind River Android Smartphone uses the CBP7.0 inside targeted the \$100 market.”). See also Klug, Brian, “Samsung Droid Charge Review - Droid Goes LTE,” AnandTech, June 22, 2011 (“What’s particularly curious about the Charge is that there’s no Qualcomm baseband for CDMA2000. Both 1x and EVDO are handled by VIA Telecom’s CBP7.1 baseband.”).

<sup>1278</sup> “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 92 (“In 2011, VIA also added a dual baseband, supporting either GSM/CDMA or GSM-GSM dual-call and dual-standby modes. This is an important feature for India, China and other parts of Asia. [...] VIA Telecom’s single-chip CBP2.0 baseband processors support CDMA2000-1x RTT and CDMA2000/GSM dual-mode technologies.”).

<sup>1279</sup> See Exhibit V.C.11.

<sup>1280</sup> Davis Deposition, Intel, pp. 32–33 (“Q. Did VIA Telecom ever work on a multimode chipset that would have involved LTE capability? A. [...] I would say that the simple answer is probably no, but we did have some,

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after 2012 as CDMA single mode chip sales declined and LTE chip sales rose.<sup>1281</sup> [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] 1282 [REDACTED]

[REDACTED] 1284,1285

*b. Analysis*

435. VIA Telecom was relatively successful in achieving its initial goals as a low-cost CDMA modem chip supplier. However, the company was unable to expand its position in the industry and was eventually forced to sell its CDMA business due to poor long-term alignment with

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say, simulation and system design, some exploration in LTE. But [...] it certainly did not result in a chip, and I wouldn’t say that we had a chip project with LTE.”).

<sup>1281</sup> See Exhibits V.B.1 and V.C.11.

<sup>1282</sup> [REDACTED]

<sup>1283</sup> [REDACTED]

<sup>1284</sup> Goldstein, Phil, “Intel Continues to Pare Mobile Losses, Buys CDMA Modem Assets from VIA Telecom,” FierceWireless, October 14, 2015 (“Intel spokeswoman Stephanie Matthew confirmed to FierceWireless that [Intel] had purchased VIA’s CDMA modem assets.”).

<sup>1285</sup> [REDACTED]

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demand and limited R&D investments. Though VIA Telecom realized favorable outcomes from its decision to target OEMs selling low-end CDMA devices in emerging markets, success in more recent years was hindered by the company’s lack of LTE expertise. As mobile device OEMs increased demand for modem chips with non-CDMA technology in the early 2010s, VIA Telecom, constrained by its niche position in the industry, was unable to provide such solutions on its own.

436. *Foresight*: In its early years as a CDMA modem chip supplier, VIA Telecom showed good foresight, but later succumbed to technological change that led to its sale to Intel. [REDACTED]

[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED].<sup>1287</sup> Partially as a result

of its efforts in the low-end space, the company’s sales increased each year between 2008 and 2012.<sup>1288</sup>

437. [REDACTED]  
[REDACTED]  
[REDACTED]<sup>1289</sup>

<sup>1286</sup> [REDACTED]

<sup>1287</sup> [REDACTED]

<sup>1288</sup> See Exhibit V.C.11.

<sup>1289</sup> See, e.g., [REDACTED]  
[REDACTED]  
[REDACTED] See also Section III.E  
for a discussion of EV-DO and EV-DV.

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VIA Telecom was also late to develop EV-DO modem chips. While Qualcomm launched its first EV-DO chip in 2001, VIA Telecom did not reach this milestone until 2009.<sup>1290</sup> Although VIA Telecom nearly caught up to Qualcomm in terms of the CDMA standards its modem chips supported, this outcome can be partially attributed to the fact that, according to former VIA Telecom CTO, Mark Davis, further development of the CDMA standard did not progress at the same pace as it had in earlier years.<sup>1291</sup>

438. Additionally, VIA Telecom was not in a position to thrive as network carriers began to shift to LTE. As early as 2008, VIA Telecom stated in a presentation its view that LTE was going to become the global 4G standard.<sup>1292</sup> However, the company did not develop an LTE chip at this time. According to Intel’s Hermann Eul, in 2011, representatives from VIA Telecom privately acknowledged that “[VIA Telecom’s] business [was] not doing well in the long run as CDMA is to[o] niche [... to] stand alone.”<sup>1293</sup> [REDACTED]

<sup>1290</sup> See Exhibit V.B.3.

<sup>1291</sup> Davis Deposition, Intel, p. 62 (“Q. Let me try it this way: [while you were at VIA Telecom,] [w]as VIA Telecom trying to develop the newest and latest features to include before anybody else in CDMA chipsets? A. [...] Of course our goal was to always design the best product that we could. It was [...] hard to keep up with the evolution of the standard at some points. Later in the evolution of 3GPP2, it became a little bit easier to catch up because the evolution slowed down.”).

<sup>1292</sup> VIA-QCOM000638768–8844 at 8818, presentation titled “VIA Telecom Presentation,” VIA Telecom, November 2008 (“[...E]ventually there will be one world standard: LTE[.]”).

<sup>1293</sup> INTEL-QCOM007840873–0878 at 0875, email from Hermann Eul, Intel, August 4, 2011.

<sup>1294</sup> [REDACTED]

<sup>1295</sup> [REDACTED]

439. Investment: [REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED] it limited the company's  
ability to expand its product portfolio by offering modem chips with more advanced features.  
For example, VIA Telecom never invested in developing integrated chips due to the high cost  
associated with such an endeavor.<sup>1301</sup>

1301 See, e.g., [REDACTED]

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440. Execution: VIA Telecom’s emphasis on developing low-cost modem chips made the company attractive to OEMs designing budget handsets. Because of the low cost of its modem chips, VIA Telecom achieved numerous design wins with OEMs targeting emerging markets.<sup>1302</sup> The “aggressive pricing” of VIA Telecom’s CDMA2000 1xEV-DO modem chips was one of the primary reasons for their success.<sup>1303</sup> Even though these modem chips sampled for an extended period before commercialization and trailed Qualcomm’s CDMA2000 1xEV-DO products in modem performance and features offered,<sup>1304, 1305</sup> [REDACTED]
- [REDACTED]

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<sup>1302</sup> See, e.g., “Cellular Handset & Chip Markets,” Forward Concepts, 2006, p. 113 (“We are aware of five small handset suppliers using Via Telecom’s chip sets in handsets in China --- Dragon, Toranado, Aspen, ArTennis, and one card supplier. These products all appear to be all targeted at offering a lower-cost CDMA non-browser, SMS- and voice-centric CDMA handsets.”). See also “Cellular Handset & Chip Markets,” Forward Concepts, 2008, p. 156 (“VIA Telecom has received certification of its CDMA 2000 1xRTT-compliant handset chipsets from Nokia, with the handset vendor’s China-based ODM partner BYD to start shipping CDMA handsets with VIA Telecom’s chipsets to Nokia in early 2008. [...] Dopod joins the growing list of other customers such as Haier and Inventec who have chosen VIA’s CDMA Baseband Processor (‘CBP’) solution for ultra low and low-cost handset solutions targeting the emerging markets.”).

<sup>1303</sup> See, e.g., Lederer Deposition, Exhibit 3, Q2014FTC03837571–7600 at 7599 (Qualcomm, February 28, 2011 email, with attached presentation on QCT Competitive Perspective, February 2011, [REDACTED])

[REDACTED] See also “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 91 (“VIA Telecom has been able to price the two-chip EVDO Rev A platform based on a 3rd party RF cheaper than the Qualcomm QSC6085 single-device --- a hybrid device embedding three die, PMU, RF and EVDO Rev A baseband.”).

<sup>1304</sup> See, e.g., Lederer Deposition, Exhibit 3, Q2014FTC03837571–7600 at 7590 (Qualcomm, February 28, 2011 email, with attached presentation on QCT Competitive Perspective, February 2011, [REDACTED]). See also “Cellular Handset & Chip Markets,” Forward Concepts, 2011, p. 104 (“VIA Telecom’s EV-DO baseband products sampled in Q2 2009 to the China market, and the company expected volume shipments to begin by early 2010. However, we have yet to see the chip set in any handsets.”).

<sup>1305</sup> See, e.g., Lederer Deposition, Exhibit 3, Q2014FTC03837571–7600 at 7599 (Qualcomm, February 28, 2011 email, with attached presentation on QCT Competitive Perspective, February 2011, [REDACTED]). See also “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 91 (“Qualcomm and VIA Telecom are the sole suppliers of CDMA20001x, chipsets...in addition to the more advanced CDMA EV-DO- Rev. 0, RevA, or RevB units. [...] During 2012 Qualcomm introduced CDMA-Advanced 1X technology (quadrupling voice calls), simultaneous voice and EV-DO data, and dual-carrier (dual-cell) CDMA Rev B, doubling data rates from 3 Mbps theoretical supplied by Revision A. Qualcomm offers a secondary advantage over VIA Telecom, which includes support for GPS and assisted GPS (A-GPS), Advanced 1X and Rev B support. The GPS receiver is embedded inside the RF Transceiver and software supported via the Qualcomm basebands.”).

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[REDACTED].<sup>1306</sup> As noted by industry analysts and also acknowledged by VIA Telecom, some of VIA Telecom’s success was also due to a desire of mobile device OEMs such as Samsung and Motorola to diversify their supplier portfolios and add a non-Qualcomm source of CDMA modem chips.<sup>1307</sup>

## 12. Marvell

### *a. Background*

441. Marvell, a fabless semiconductor company founded in 1995,<sup>1308</sup> entered the modem chip industry by acquiring Intel’s modem chip and AP business in 2006.<sup>1309</sup> By 2009, Marvell had produced multiple WCDMA and TD-SCDMA modem chips.<sup>1310</sup> Marvell sold the majority of

<sup>1306</sup> [REDACTED]

<sup>1307</sup> See, e.g., Lederer Deposition, Exhibit 3, Q2014FTC03837571–7600 at 7599 (Qualcomm, February 28, 2011 email, with attached presentation on QCT Competitive Perspective, February 2011, [REDACTED]

[REDACTED] See also “Comprehensive Cellphone & Tablet Chip Markets,” Forward Concepts, 2013, p. 91 (“It is clear that Motorola and Samsung would prefer to have an alternative supplier [to Qualcomm] for CDMA 1X EVDO Rev A.”); [REDACTED]

<sup>1308</sup> “Marvell Technology Group Company Profile,” DesignNews (“Founded in 1995, Marvell Technology Group Ltd. has operations worldwide and more than 7,000 employees. [...] A leading fabless semiconductor company, Marvell ships over one billion chips a year.”).

<sup>1309</sup> “Marvell Completes Acquisition of Intel’s Communications and Applications Processor Business,” Marvell Press Release, November 8, 2006 (“[M]arvell Technology Group, Ltd. [...] today announced that it has completed the acquisition of Intel’s cellular and applications processor business. [...] This purchase will give Marvell a strong presence in the growing market segment for cellular baseband and applications processors used in cellular and smart handheld devices.”).

<sup>1310</sup> Marvell developed modem chips for the following standards: GSM, GPRS, EDGE, WCDMA, HSPDA, and TD-SCDMA. Kundojjala, Sravan and Stephen Entwistle, “Baseband Processor Profile: Time for Marvell to Reconsider Its Baseband Position,” Strategy Analytics, November 2009, p. 9 (“Exhibit 5: Marvell’s GSM/GPRS/EDGE/W-CDMA/HSDPA/TD-SCDMA baseband processors”).

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its WCDMA modem chips to its largest customer,<sup>1311</sup> BlackBerry (RIM),<sup>1312</sup> and sold its TD-SCDMA modem chips to Chinese mobile device OEMs.<sup>1313</sup>

442. In 2012, BlackBerry’s year-over-year mobile device sales began decreasing, and the company’s modem chip purchases from Marvell declined.<sup>1314</sup> Despite losing WCDMA modem chip sales from BlackBerry, Marvell was well positioned to generate sales in the TD-SCDMA segment.<sup>1315</sup> Marvell also made progress in the LTE segment by sampling its first multi-mode LTE chip in late 2011.<sup>1316</sup> As Chinese carriers started to switch from TD-SCDMA to LTE networks,<sup>1317</sup> Marvell faced increased pressure to compete in the LTE segment.

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<sup>1311</sup> From 2008 to 2017, approximately 65 percent of Marvell’s total WCDMA handset modem chip sales went to BlackBerry. See Strategy Analytics, “Customised Baseband Quarterly Market Share Tracker for Qualcomm: Parts 1 and 2,” April 6, 2018. See also Chhabra Deposition, Marvell, pp. 16–17 (“Q. [...] At the time you were senior director for product lines in the mobile group, who were Marvell’s principal customers? A. BlackBerry, and maybe other customers in other places. Q. Was BlackBerry at that time by far Marvell’s largest customer? A. Yes.”).

<sup>1312</sup> RIM re-branded itself as BlackBerry in 2013. See, e.g., Rocha, Euan and Sinead Carew, “RIM Rebrands as BlackBerry; Launches Nifty New Devices,” Reuters, January 30, 2013 (“Chief Executive Thorsten Heins also announced that RIM was abandoning the name it has used since its inception in 1985 to take the name of its signature product, signaling his hopes for a fresh start for the company that pioneered on-your-hip email. ‘From this point forward, RIM becomes BlackBerry,’ Heins said at the New York launch. ‘It is one brand; it is one promise.’”).

<sup>1313</sup> Chinese OEMs Coolpad, Huawei, and ZTE comprised three of the top five customers for Marvell, as measured by devices sold from 2008 through 2017. See Strategy Analytics, “Customised Baseband Quarterly Market Share Tracker for Qualcomm: Parts 1 and 2,” April 6, 2018. See also “Marvell Empowers Mass Market TD-SCDMA OPhones with PXA920 Chipset,” Marvell Press Release, September 8, 2009 (“[M]arvell [...] today announced the culmination of several years of investment in the China smartphone market with the introduction of the Marvell PXA920, the first single-chip solution enabling mass market availability of TD-SCDMA smartphones by the world’s largest carrier, China Mobile. [...] The PXA920 processor [...] is China Mobile OPhone ready [...].”).

<sup>1314</sup> BlackBerry’s chip purchases from Marvell declined yearly from 2010 through 2015 as BlackBerry’s overall volume of modem chip purchases declined from 2011 through 2017. See Exhibit V.C.14b.

<sup>1315</sup> Yoshida, Junko, “Analysts Clash Over Where Marvell Ranks Among Smartphone Suppliers,” EE Times, October 15, 2012 (“‘Marvell is a major supplier of application processors [and baseband], not only for Research in Motion (RIM) but also for China TD-SCDMA cellphones from companies like Asus, Huawei, Lenovo, Sony, TCL-Alcatel, Tianyu and ZTE,’ Strauss noted.”).

<sup>1316</sup> “Marvell Launches Multi-mode LTE to Initiate a New Era of Global Connectivity,” DigiTimes, June 28, 2012 (“It is note-worthy that Marvell’s first multi-mode LTE chip sampled in October 2011 has performed extremely well in a variety of verifications.”).

<sup>1317</sup> Kinney, Sean, “RIP: China Mobile’s TD-SCDMA 3G Network (2009-2014),” RCR Wireless News, December 17, 2014 (“China Mobile, the largest mobile carrier in the world, is reportedly cutting expansion of its TD-SCDMA 3G network and focusing on its TD-LTE network, which supports 4G connectivity. [...] From that report: ‘In the past year, demand for 3G wireless has been fading as consumers migrate to newer, faster 4G services, including a network built on China Mobile’s 4G TD-LTE standard.’”).

443. From 2013 through 2015, Marvell released multiple LTE chips that integrated APs as well as GPS, Bluetooth, and Wi-Fi technologies.<sup>1318</sup> Marvell secured LTE design wins with Samsung and other OEMs;<sup>1319</sup> however, over time, these design wins did not generate enough unit sales to compensate for decreases in the company’s WCDMA and TD-SCDMA chip sales.<sup>1320</sup> Facing declining sales and a limited major OEM customer base, in 2015 Marvell decided to exit the modem chip industry and instead focus on its IoT and automotive businesses.<sup>1321</sup>

<sup>1318</sup> See, e.g., “Marvell Unveils Industry’s First Mass Market Quad-core 5-mode Category 4 LTE Single-chip Solution, Accelerating Mobile Broadband Adoption Worldwide,” Marvell Press Release, May 20, 2013 (“Marvell introduces the PXA1088 LTE, expanding the best-in-class unified multi-core worldmode single-chip ARMADA Mobile family with LTE Category 4 capability and 5-mode cellular support.”). See also Yoshida, Junko, “Will New SoCs Keep Marvell at No. 2 in China’s LTE Market?” EE Times, November 17, 2014 (“Marvell announced Monday (Nov. 17) two new 64-bit mobile processors targeting the fast growing global LTE market: a new mobile SoC based on octa-cores for high performance smartphones and tablets and another that uses quad-cores for economy models. [...] Marvell’s new mobile processor featuring eight ARM Cortex A53 cores, called Armada Mobile PXA1936, delivers five basebands. [...] Asked what differentiates Marvell’s chips in the Armada family, Forward Concepts’ Strauss pointed out that Marvell’s LTE/TD-SCDMA modem gathers GPS, Bluetooth, and Wi-Fi all on the same die.”).

<sup>1319</sup> See, e.g., “Meizu Launches its Flagship MX4 Pro Premium 4G LTE Smartphone for China Mobile and China Unicom Powered by Marvell’s ARMADA Mobile 5-mode 4G LTE Solution,” Marvell Press Release, November 19, 2014 (“Marvell’s ARMADA Mobile PXA1802 5-mode 4G LTE modem is at the core of Meizu’s Flagship MX4 Pro Premium Smartphone, now available for more than one billion of combined subscribers of China Mobile and China Unicom.”). See also “Marvell’s Mobile LTE Solution to Power Lenovo’s First TD-LTE Advanced Smartphone,” Marvell Press Release, February 18, 2014 (“Marvell’s industry leading ARMADA Mobile quad-core PXA1088 LTE single-chip platform enables high performance, field-proven connectivity and cost effective solution for Lenovo’s A788T mainstream 4G LTE smartphone.”); “Samsung Launches New Global Mass Market Galaxy J1 LTE Smartphone Powered by Marvell’s Industry-Leading ARMADA Mobile PXA1908 Platform,” Marvell Press Release, March 2, 2015 (“[...]he Marvell ARMADA Mobile PXA1908 platform and advanced Avastar 88W8777 wireless connectivity solution were selected by Samsung Mobile to power select models of its new global mass market LTE smartphone, the recently announced Samsung Galaxy J1 LTE smartphone.”).

<sup>1320</sup> Marvell’s total modem chip sales dropped by roughly 25 million from 2014 to 2015. Its combined TD-SCDMA and WCDMA modem chip sales had decreased by approximately 27 million, while its LTE modem chip sales had only increased by about 3 million. See Exhibit V.C.12 and associated backup. In 2014, Marvell shipped roughly 15 million chips to its largest customer, Samsung, with fewer than 10 million modem chips sold to each of its other OEM customers. See Strategy Analytics, “Customised Baseband Quarterly Market Share Tracker for Qualcomm: Parts 1 and 2,” April 6, 2018.

<sup>1321</sup> “Marvell Technology Group Ltd. Announces Significant Restructuring of Mobile Platform Business,” Marvell Press Release, September 24, 2015 (“Marvell will continue its strong commitment to wireless connectivity such as WiFi and other wireless standards needed to support its strategies in existing markets as well as expanding into emerging opportunities in IoT and automotive. [...] [Marvell] plans to significantly downsize the mobile platform organization to refocus its technology to emerging opportunities in IoT, automotive, and networking.”).

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Marvell stopped selling modem chips after 2016,<sup>1322</sup> and was unable to find a buyer for its modem chip business.<sup>1323</sup>

*b. Analysis*

444. Marvell’s exit from the modem chip industry was primarily due to its poor foresight regarding LTE development, inefficient R&D investments, and inferior execution compared to its competitors. Initially, Marvell was a strong competitor as it had acquired WCDMA technology from Intel and had entered the TD-SCDMA segment early. However, Marvell was late to develop competitive LTE chips and struggled to sell them on schedule. [REDACTED]

[REDACTED]

[REDACTED] As a result, Marvell was unable to effectively compete on either the high-end or low-end.

445. Foresight: Marvell had mixed success in producing chips for new wireless standards. In 2006, Marvell entered the WCDMA segment by acquiring Intel’s chip business,<sup>1324</sup> whereas suppliers such as Qualcomm and Broadcom had entered beforehand.<sup>1325</sup> However, two years later, Marvell exhibited strategic foresight by investing in TD-SCDMA with the intention of growing its business in China.<sup>1326</sup> Marvell collaborated with China Mobile to release its first TD-SCDMA chip in 2009, which China Mobile used in its OPhone handsets.<sup>1327</sup> Between

<sup>1322</sup> See Exhibit V.C.12.

<sup>1323</sup> Eassa, Ashraf, “3 Reasons Marvell Wasn’t Able to Find a Buyer for Its Mobile Business,” The Motley Fool, September 28, 2015.

<sup>1324</sup> In 2005, Intel announced its PXA9xx WCDMA processors. In 2006, Intel sold its communication processor and application processor business unit to Marvell. Kundojjala, Sravan and Stephen Entwistle, “Baseband Processor Profile: Time for Marvell to Reconsider Its Baseband Position,” Strategy Analytics, November 2009, p. 6 (“Exhibit 1: Marvell’s Key Cellular Baseband Activities[:] [...] [;] July 2006 [...] Intel divests its communication processor and application processor business unit to Marvell [...] [;] 2005 [...] Intel announces PXA9xx W-CDMA processors[.]”)

<sup>1325</sup> Qualcomm and Broadcom entered the WCDMA segment in 2001 and 2005, respectively (See Exhibit V.B.5).

<sup>1326</sup> Chang, Lu, “TD-SCDMA and China 3G,” Marvell White Paper, January 2012, p. 5 (“Recognizing the potential of the China and TD-SCDMA market, Marvell made a strategic decision in 2008 to invest in the development of TD-SCDMA technology for a single-chip smartphone solution.”).

<sup>1327</sup> “Marvell Empowers Mass Market TD-SCDMA OPhones with PXA920 Chipset,” Marvell Press Release, September 8, 2009 (“[M]arvell [...] today announced the culmination of several years of investment in the China smartphone market with the introduction of the Marvell PXA920, the first single-chip solution enabling

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2011 and 2013, Marvell’s year-over-year sales of TD-SCDMA chips consistently increased.<sup>1328</sup> However, according to analysts at Strategy Analytics, Marvell’s TD-SCDMA strategy was not able to offset lost sales from its biggest customer, BlackBerry.<sup>1329</sup> Furthermore, Marvell’s overall TD-SCDMA sales were smaller than sales of its competitors, such as MediaTek and Spreadtrum.<sup>1330</sup>

446. Despite Marvell’s foresight in TD-SCDMA, analyst reports indicate that the company was not adequately prepared for the emergence of the LTE standard. By 2009, analysts at Strategy Analytics believed that Marvell did not have an LTE roadmap, and that this “could put Marvell behind its competitors.”<sup>1331</sup> This lack of foresight preceded execution issues; at the end of 2010, Marvell indicated that it would not be able to deploy LTE chips in 2011, and that it would potentially fail to deploy LTE chips with backward compatibility by 2013.<sup>1332</sup>
447. Investment: Marvell’s investment in modem chip technology was substantial but inefficient. Marvell entered the modem chip industry in 2006 by acquiring Intel’s modem chip and AP

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mass market availability of TD-SCDMA smartphones by the world’s largest carrier, China Mobile. [...] The PXA920 processor [...] is China Mobile OPhone ready [...]. [...] ‘China Mobile will work closely with Marvell [...] to deploy the PXA920 and we look forward to the rapid launch of next generation TD-SCDMA OPhones based on the Marvell PXA920.’”).

<sup>1328</sup> In 2011, 2012, and 2013, Marvell sold roughly 4 million, 16 million, and 19 million TD-SCDMA modem chip units, respectively. See Exhibit V.C.12.

<sup>1329</sup> Yoshida, Junko, “Analysts Clash Over Where Marvell Ranks Among Smartphone Suppliers,” EE Times, October 15, 2012 (“According to Strategy Analytics, Marvell’s strong performance in TD-SCDMA smartphone apps processor shipments to China Mobile were not enough to offset declining shipments at RIM, a big Marvell customer.”).

<sup>1330</sup> Between 2011 and 2013, Marvell sold a total of roughly 40 million TD-SCDMA modem chips. During the same period, MediaTek and Spreadtrum sold a total of roughly 110 million and 163 million TD-SCDMA modem chips, respectively. See Exhibits V.C.3, V.C.10, V.C.12, and associated backups.

<sup>1331</sup> Kundojjala, Sravan and Stephen Entwistle, “Baseband Processor Profile: Time for Marvell to Reconsider Its Baseband Position,” Strategy Analytics, November 2009, p. 11 (“Marvell currently does not have HSPA basebands and a visible LTE product roadmap. We believe this lack of an LTE roadmap could put Marvell behind its competitors Qualcomm, ST-Ericsson and Infineon.”).

<sup>1332</sup> See, e.g., Chhabra Deposition, Marvell, p. 44 (“Q. And so was it already clear to you toward the end of 2010 that Marvell would miss stage 1 of LTE deployment? A. Yes. [...] Q. Do you see that there’s an arrow next to stage 2, at 2013, which reads, ‘We could be at edge of Missing this cycle’? A. Yes. Q. And did you believe at this time that Marvell was at the edge of missing stage 2 of LTE deployment in 2013? A. Global level, yes.”). See also Exhibit QX301, Chhabra Deposition, Marvell, MRVL-00112437–2470 at 2451, presentation titled “CCBU,” Marvell, November 2011 (“Stage 1 @ 2011[:] LTE Data only [...] Stage 2 @ 2013[:] LTE Data with CS fallback[:] Multimode handsets[:]”).

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businesses for \$600 million,<sup>1333</sup> and inherited BlackBerry as a customer.<sup>1334</sup> Marvell’s modem chip R&D spending was generally on the order of \$1 billion, or about 30 percent of its revenue.<sup>1335</sup> As of 2009, the company was employing over 4,000 R&D personnel.<sup>1336</sup> While Marvell’s R&D expenditures did not match those of the leaders in the industry, its spending was substantial and comparable to other followers such as MediaTek or Broadcom.<sup>1337</sup> However, according to Vivek Chhabra, former VP of Marvell’s mobile group, Marvell had not allocated its R&D resources effectively because it had invested in multiple design centers.<sup>1338</sup> Chhabra also indicated that it would have been more efficient for Marvell to “consolidate design centers” and “streamline products.”<sup>1339</sup> By financial quarter Q1 2016,<sup>1340</sup> Marvell had a negative operating income of \$43 million, partially due to unnecessary R&D expenses.<sup>1341</sup>

448. Execution: Marvell was unable to execute and develop cost-effective and technologically competitive modem chips. Marvell fell behind its competitors in developing certain modem chip features desired by customers, such as multi-SIM support.<sup>1342</sup> In addition, Marvell did

<sup>1333</sup> “Marvell to Purchase Intel’s Communications and Application Processor Business for \$600 Million,” Intel Press Release, June 27, 2006 (“Marvell Technology Group, Ltd. and Intel Corporation today announced that they have signed an agreement for Intel to sell its communications and application processor business to Marvell for a purchase price of \$600 million plus the assumption by Marvell of certain liabilities.”).

<sup>1334</sup> “Marvell to Purchase Intel’s Communications and Application Processor Business for \$600 Million,” Intel Press Release, June 27, 2006 (“[Intel’s communications and application] processors, based on Intel XScale technology, include the Intel PXA9xx communications processor, codenamed ‘Hermon,’ which powers Research in Motion’s (RIM) Blackberry 8700 device.”).

<sup>1335</sup> See Exhibit III.E.1 and III.E.3.

<sup>1336</sup> Kundojjala, Sravan and Stephen Entwistle, “Baseband Processor Profile: Time for Marvell to Reconsider Its Baseband Position,” Strategy Analytics, November 2009, p. 7.

<sup>1337</sup> See Exhibit III.E.1.

<sup>1338</sup> Chhabra Deposition, Marvell, p. 177 (“Q. Was it your view that Marvell’s R&D expenses were excessive [in 2015]? A. My view was that they were not allocated properly. Q. Okay. How were they allocated? A. Multiple design centers.”).

<sup>1339</sup> Chhabra Deposition, Marvell, p. 177.

<sup>1340</sup> Marvell’s financial quarter Q1 2016 ended on May 2, 2015 (Marvell, Form 10-Q, Q1 2016, p. 1).

<sup>1341</sup> Chhabra Deposition, Marvell, pp. 176–177 (“Q. And after considering operating expenses, the operating income for the first quarter of 2016 was negative \$43 million. [...] Q. Is it your understanding that this negative operating income was driven by pricing pressure in the market? A. One of the reasons. Q. What were the other reasons? A. Could be unnecessarily [sic] R&D expense. Q. What sorts of activities did the R&D expenses cover? A. Building the chipsets, designing new chipsets, modem activities.”).

<sup>1342</sup> See, e.g., Chhabra Deposition, Marvell, pp. 34–35 (“Q. Do you see the next bullet reads, ‘Dual Mode Dual Standby Modem capability lagging behind across platforms’? A. Yes. Q. And did you believe that Marvell’s

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not have its own RF transceivers or its own modem protocol software stack and had to source them from third parties.<sup>1343</sup> Marvell also had to rely on external vendors for GPS technology, increasing the cost and size of its modem chips.<sup>1344</sup>

449. In addition to chip development issues, Marvell struggled to deliver its modem chips in a timely manner. [REDACTED]

[REDACTED]<sup>1345</sup> Marvell’s late LTE development and inability to meet delivery deadlines particularly damaged its relationship with BlackBerry. [REDACTED]

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dual mode dual standby capability was lagging behind its competitors? A. Yes. Q. And did you have a view as to why that was? A. Hearing from customers and market feedback from the requirements. Q. All right. So you were hearing market feedback and hearing from customers that dual mode dual standby was a feature that at least certain customers desired? A. Yes. Q. And do you know why Marvell was behind some of its competitors in developing that feature? A. Is what was available at that time and what the market need was, there could have been gap. There could be gap [...] between what’s available from Marvell at that time and what is coming [...] from the customer desire.”). See also “Dual-SIM - Definition,” GSM Arena (“[Dual-SIM] specifies whether a device is capable of supporting two SIM cards. The two major types of dual-SIM phones are active and standby. Dual-SIM Standby (DSS) requires the user to specify which of the two SIMs is able to make and receive calls, while Dual-SIM Active (DSA) enables both cards to receive calls at the same time. [...] More recent models feature Dual SIM Dual Standby (DSDS) technology which enables them to have two active SIMs with only one transceiver.”).

<sup>1343</sup> Kundojjala, Sravan and Stephen Entwistle, “Baseband Processor Profile: Time for Marvell to Reconsider Its Baseband Position,” Strategy Analytics, November 2009, p. 11 (“Marvell did not inherited [sic] a complete modem protocol software stack from Intel and the company had to license it from TTPCom to port it to its PXA 90x products. Competitor companies have in-house protocol stacks which disadvantages Marvell when competing in the cellular baseband market. [...] Marvell currently depends on third parties to source RF transceivers that work with its cellular basebands.”).

<sup>1344</sup> Chhabra Deposition, Marvell, pp. 36–38 (“Q. And did Marvell’s reliance on external vendors for GPS and NFC technology increase the cost of the overall chipset solution? A. Yes. [...] Q. [...] Did Marvell’s reliance on external vendors for GPS and NFC technology have implications for the overall printed circuit board size? A. Yes. Q. And what were those implications? A. More chips. Q. And did more chips then lead to a larger size? A. Larger printed board size. Q. And for some OEM customers, could that be undesirable? A. Possible.”).

<sup>1345</sup> [REDACTED]

<sup>1346</sup> See Exhibit V.C.14b.

<sup>1347</sup> See, e.g., [REDACTED]

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] 1350

450. Marvell continued to execute poorly as it entered the low-end and high-end LTE segments. In the low-end LTE segment, Marvell managed to secure design wins with Samsung.<sup>1351</sup> However, Samsung did not purchase a large volume of Marvell’s modem chips; between 2014 and 2015, only approximately 3 percent of Samsung’s LTE handsets contained Marvell’s

[REDACTED]

<sup>1348</sup> Grubbs Deposition, BlackBerry, pp. 110–112 (“Q. Why did BlackBerry stop purchasing BlackBerry baseband processors chips from Marvell? A. There were several reasons. We [...] were having some issues with [...] commitments to timelines for deliveries from Marvell. They had slipped on several deadlines that they had promised to deliver things to us by. They apparently -- or from what I -- what I understand were about two years behind on LTE development. [...] Q. And two years behind whom? A. Qualcomm.”).

<sup>1349</sup> See, e.g., Pimentel, Benjamin, “Marvell Shares Fall on Downgrade,” MarketWatch, August 26, 2008 (“Benjamin said Marvell appears to have lost the design for Research In Motion’s Javelin to Freescale.”). See also “Further Explanation on Why We Are Waiting Sooo Long for BlackBerry 7 Smartphones to be Released,” CrackBerry, June 17, 2011 (“RIM was originally going to continue to use Marvell for at least one more generation of their top of the line GSM BlackBerry Smartphones [...]. But someone at somepoint in recent months must have woken up one morning and realized that 800MHz would be laughable in their top tier devices [...]. With Marvell’s offerings looking lackluster compared to Qualcomm’s, for RIM that meant a big undertaking relatively late in the commercialization cycle of these new devices as they would be abandoning Marvell for the new high-end phones.”); Exhibit V.C.14b.

<sup>1350</sup> Kundojjala, Sravan and Stephen Entwistle, “Baseband Processor Profile: Time for Marvell to Reconsider Its Baseband Position,” Strategy Analytics, November 2009, p. 12 (“Marvell’s only significant baseband customer is Research in Motion (RIM) and the company hasn’t been able to expand to high volume vendors like Nokia and Samsung.”).

<sup>1351</sup> See, e.g., Chhabra Deposition, Marvell, p. 151 (“Q. Did Marvell have any chips that were intended for use in high-tier smartphones? A. Not when I was running the business. Q. What tier of smartphones were Marvell’s chips being incorporated into when you were running the business? A. I would say mid to low tier.”). See also “Samsung Launches New Global Mass Market Galaxy J1 LTE Smartphone Powered by Marvell’s Industry-Leading ARMADA Mobile PXA1908 Platform,” Marvell Press Release, March 2, 2015 (“[...]the Marvell ARMADA Mobile PXA1908 platform and advanced Avastar 88W8777 wireless connectivity solution were selected by Samsung Mobile to power select models of its new global mass market LTE smartphone, the recently announced Samsung Galaxy J1 LTE smartphone.”); Rougeau, Michael, “Samsung is Officially Trying Out a New Letter with the Galaxy J1,” TechRadar, January 29, 2015 (“The J1 was rumored earlier in January [...]. Now the company has officially launched the handset, a low-end device [...].”).

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chips.<sup>1352</sup> Furthermore, among Chinese OEMs, Qualcomm’s modem chips became popular because they had “strong performance/function balance,” while Marvell’s chips had high component costs and limited technology support.<sup>1353</sup> Marvell was also engaged in a price war with Spreadtrum, MediaTek, and Qualcomm,<sup>1354</sup> which partially caused Marvell’s gross product margins to decline.<sup>1355</sup>

451. In the high-end LTE segment, Marvell’s chips, such as the PXA1936, were deemed technologically inferior by the time they were released.<sup>1356</sup> [REDACTED]

<sup>1352</sup> See Strategy Analytics, “Customised Baseband Quarterly Market Share Tracker for Qualcomm: Parts 1 and 2,” April 6, 2018.

<sup>1353</sup> Lin, Eric, “DigiTimes Research: Qualcomm Far Ahead of Marvell and MediaTek in China LTE Market,” DigiTimes, June 19, 2014 (“Qualcomm is currently pushing its Snapdragon 400 series as the mainstream platform for the LTE market and because of the series’ friendly pricing and strong performance/function balance, the platform has achieved high popularity in the market. [...] As for Marvell, the company released its LTE solutions at the same time as Qualcomm, but limited by its business scale and supporting personnel, Marvell has been unable to offer a technology support as competitive as Qualcomm’s, while component costs for its solutions are also higher. It has a lot less clients than Qualcomm. Despite the fact that Marvell and Qualcomm both released their LTE solutions at about the same time, Marvell’s LTE chip shipments have been a lot weaker than those of Qualcomm.”).

<sup>1354</sup> Chhabra Deposition, Marvell, p. 151 (“Q. Earlier, when you were testifying about a price war involving Marvell, MediaTek, Qualcomm, and Spreadtrum, was that a price war in the mid to low tier of LTE chips? [...] [A.] I would say so.”).

<sup>1355</sup> Chhabra Deposition, Marvell, p. 127 (“Q. I believe you stated earlier that you do recall that OEMs were starting to demand lower chipset prices at least from Marvell. Do I -- do I have that right? A. Yes. [...] Q. And was the primary reason why Marvell’s gross product margins were declining that the prices were declining? [...] [A.] I would say so, but at the same time, there’s a cost part of it, as well. Q. Sure. And at the time in 2015, when you were head of the mobile group, did you attribute the decline in Marvell’s gross product margins largely to a price decline as opposed to a cost increase? A. Yes.”).

<sup>1356</sup> Taylor, Chris, “Qualcomm Steps Up, Two More Chipset Suppliers Drop Out,” Strategy Analytics, September 29, 2015 (“MediaTek, Samsung, Hisilicon (Huawei), Marvell and Intel offer or have announced integrated baseband-applications processors comparable to the Snapdragon 820, but many of these SoCs target smartphones below the premium tier, and none can support Cat. 12 DL and Cat. 13 UL. One example is Marvell’s PXA1936, which targeted the premium tier when it was announced almost a year ago. Now, this SoC looks dated compared to both the Snapdragon 810 and the new Snapdragon 820, with lower performance and fewer features.”).

<sup>1357</sup> [REDACTED]

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[REDACTED] After facing challenges in both LTE segments, Marvell exited the modem chip industry.

### 13. Nvidia

#### *a. Background*

452. Nvidia was founded in 1993 and throughout its history has focused on creating graphics technology.<sup>1359</sup> Nvidia released its first AP designed for mobile devices under the “Tegra” family of processors in 2008.<sup>1360</sup> Initially, Nvidia’s Tegra chips were used mostly in tablets,<sup>1361</sup> with the first handsets to use the Tegra chip being the Microsoft Kin devices in 2010.<sup>1362</sup>
453. In 2011, Nvidia entered the cellular modem industry by acquiring Icera, along with its modem technology, for \$367 million.<sup>1363</sup> At the time of the acquisition, Icera has an established base of OEM customers for 3G WCDMA chips.<sup>1364</sup> The Icera deal was reportedly intended to enable Nvidia to integrate Icera’s technology into Nvidia’s existing AP solutions for tablets and some smartphones, while also combining its existing Tegra APs with outside suppliers’

[REDACTED]

1358 [REDACTED]

<sup>1359</sup> “About Nvidia,” Nvidia, available at [http://www.nvidia.com/page/corporate\\_timeline.html](http://www.nvidia.com/page/corporate_timeline.html).

<sup>1360</sup> “About Nvidia,” Nvidia, available at [http://www.nvidia.com/page/corporate\\_timeline.html](http://www.nvidia.com/page/corporate_timeline.html).

<sup>1361</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2011, p. 266 (“Tegra 2’s initial focus is on larger 7-10 inch screen tablets [...]).” See also Cross, Jason, “Nvidia Unveils Tegra 2: Targets Android Tablets,” PCWorld, January 8, 2010 (“Nvidia is initially promoting tablets with this new design rather than smartphones [...]).”).

<sup>1362</sup> Shah, Agam, “Microsoft’s Kin are the First Tegra Smartphones,” PC World, April 13, 2010 (“The first smartphones based on Nvidia’s low-power Tegra chips will soon be here, in the form of the new Kin devices announced by Microsoft earlier on Monday.”)..

<sup>1363</sup> “Nvidia Completes Acquisition of Icera, a Leader in Wireless-Modem, RF Technology,” Nvidia Press Release, June 13, 2011 (“Nvidia announced today that it has completed its \$367 million cash acquisition of Icera [...]).”).

<sup>1364</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2011, p. 127 (“Icera (now part of NVIDIA) is the closest competitor to Qualcomm, and is well positioned to do the same with its field proven 3G HSPA+ [WCDMA]. [...] They have already established a large client base in HSPA+ and are quite well positioned as a platform supplier – both transceivers and baseband.”).

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modems for high-end smartphones.<sup>1365</sup> As part of this roadmap for integrated chips, Nvidia executives envisioned a three-tiered mobile device industry, with the tiers being 1) high-end smartphones, 2) mid-tier, or “mainstream,” phones, and 3) low-end, or “big volume” phones.<sup>1366</sup> In 2013, Nvidia released its first LTE SoC called the “Tegra 4i.”<sup>1367</sup> The Tegra 4i was released with phones in Latin America and Europe.<sup>1368</sup> This chip had multi-mode capabilities and was compatible with LTE, 3G, and 2G, although it was not equipped to provide CDMA service.<sup>1369</sup>

454. By 2015, Nvidia decided to focus instead on other lines of business, including deep learning, virtual reality, and self-driving cars. Nvidia believed that although “having modem technology

<sup>1365</sup> Takahashi, Dean, “Nvidia Acquires Icera Mobile Wireless Chip Maker for \$367M,” VentureBeat, May 9, 2011 (“The deal will [...allow Nvidia to] integrate Icera’s technology into Nvidia’s own solution for tablets and smartphones.”). See also Talla Deposition, pp. 112-113 (“Q. Let’s break it up, then, and let’s talk first about premium phones. What were the factors that made it difficult to sell -- to be successful in the business of selling modems for the premium smartphone market? A. I think the premium smartphone market, Icera, we were not targeting our modem for the premium smartphone market [...]. So that -- Nvidia and Icera, we were never targeting the modem. We were targeting that space with our application processor, but trying to pair with a third-party modem.”).

<sup>1366</sup> Talla Deposition, Nvidia, p. 108 (“In what way did the market commoditize pretty quickly? A. [...] So what I meant by commoditize pretty quickly is, when we started the market, in around the 2012-13 time frame, we looked at the market as three different segments: One was high-end premium smartphone; the second, the middle, was a middle end or a mainstream, if you will, that will offer close to premium performance; and then at the very low end, you know, very big volume.”). See also Talla Deposition, Nvidia, p. 111 (“Q. And were the modems that Nvidia launched in the LTE space – would you have considered them high-end, in the high-end tier? A. No. We considered them in the mainstream. So that was the whole premise of our investment: [...] we would target the mainstream by offering a high-end application processor performance, but bring that to the mainstream with a mainstream modem.”).

<sup>1367</sup> See, e.g., “Nvidia Introduces Its First Integrated Tegra LTE Processor,” Nvidia Press Release, February 19, 2013 (“Nvidia today introduced its first fully integrated 4G LTE mobile processor, the Nvidia Tegra 4i [...].”). See also “Cellular Handset & Chip Markets,” Forward Concepts, 2014, p. 72 (“Among the first announced usage of the T[egra]4i SP3X is the Xiaomi Mi-3 64GB Smartphone [...].”).

<sup>1368</sup> Talla Deposition, Nvidia, pp. 110–111 (“Q. And you mentioned that Nvidia was the only supplier besides Qualcomm to launch an LTE-compliant modem. Is that correct? A. No. [...] And we ended up actually being one of the first of the manufacture[r]s, in fact, to launch a successful phone in multiple geographies. So Latin America and Europe are the two examples I gave of the Tegra 4i. Both of those were launched in 2014.”). See also “Cellular Handset & Chip Markets,” Forward Concepts, 2014, p. 72 (“In February 2014, Nvidia announced a cellphone “socket” for its Tegra 4i LTE comprocessor at Wiko Mobile, said to be France’s fastest growing local phone maker. [...] LG has announced that they are using the Tegra 4i in their new G2 Mini smartphone in South America.”).

<sup>1369</sup> See, e.g., Cooper, Sean, “Nvidia Tegra 4i Software Update Adds LTE-Advanced Speeds,” Engadget, May 21, 2013 (“Tegra 4i’s modem is also multi-mode. It delivers 4G LTE Advanced and is backward compatible so it can offer LTE Cat 3, 3G, and 2G.”). See also Segan, Sascha, “Nvidia’s Tegra 4i: Four Cores, No Contract,” PCMag, February 19, 2013 (“There’s no CDMA, though, which means Tegra 4i might not fuel phones on Sprint’s and Verizon’s networks [...].”).

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for a platform company [was] an advantage,” given the company’s strengths in other areas, it could get a higher return on investment in other industries.<sup>1370</sup> Therefore, the company shut down its modem business.<sup>1371</sup> Nvidia continues to produce successful Tegra APs,<sup>1372</sup> and it recently announced record quarterly revenues of \$3.21 billion, driven by its leadership in GPU technology, including in mobile platforms.<sup>1373</sup>

*b. Analysis*

455. Despite Nvidia’s strong performance in APs, its brief history in the cellular modem industry exhibited poor foresight, limited investment, but reasonable execution in the modems it did produce. These factors limited the success of its modem chips. When Nvidia entered the industry in 2011, the company planned to focus its modem efforts on the “mainstream” phone segment.<sup>1374</sup> This plan eventually led to Nvidia’s decision to exit the modem industry, as it

<sup>1370</sup> NVIDIA-00608755–8758 at 8757, email from Deepu Talla, Nvidia, May 14, 2015 (“We felt (and still feel) that having modem technology for a platform company is an advantage. However, we had to wind down as we have higher ROI elsewhere and we need to grow in deep learning, virtual reality, and self-driving cars.”).

<sup>1371</sup> “Nvidia to Wind Down Icera Modem Operations,” Nvidia Press Release, May 5, 2015 (“Nvidia today announced that it will wind down its Icera modem operations in the second quarter of fiscal 2016. The company is open to a sale of the technology or operations. [...] Going forward, the company expects to partner with third-party modem suppliers and will no longer develop its own.”).

<sup>1372</sup> See, e.g., Niu, Evan, “Appreciating Nvidia Corporation’s Stunning Tegra Recovery,” The Motley Fool, November 12, 2016, (“Last quarter, Tegra sales soared 87% to \$241 million, driven by both gaming development platforms and momentum in automotive.”). See also Talla Deposition, Nvidia, pp. 60–61 (“Q. And can you tell me again what the product name for Erista ended up being? A. TX1. Q. And is that still on the market? A. It is certainly on the market. [...] It is in -- if you are familiar with the Nintendo Switch game console, it includes the Tegra X1. The Shield Android TV includes the Tegra X1. There’s plenty of video analytics devices all over the world that’s doing autonomous machines. TX1, and also a lot of robots. Plenty of customer interactions for that device.”).

<sup>1373</sup> “Nvidia Announces Financial Results for First Quarter Fiscal 2019,” Thursday, May 10, 2018 (“N[vidia] today reported record revenue for the first quarter ended April 29, 2018, of \$3.21 billion, up 66 percent from \$1.94 billion a year earlier, and up 10 percent from \$2.91 billion in the previous quarter. [...] ‘We had a strong quarter with growth across every platform,’ said Jensen Huang, founder and chief executive officer of N[vidia]. [...] ‘At the heart of our opportunity is the incredible growth of computing demand of AI, just as traditional computing has slowed. The GPU computing approach we have pioneered is ideal for filling this vacuum. And our invention of the Tensor Core GPU has further enhanced our strong position to power the AI era,’ he said. [...] New Platforms:] [...] Announced that Arm will integrate the open-source N[vidia] Deep Learning Accelerator to bring AI inference to mobile, consumer electronics and Internet of Things devices.”).

<sup>1374</sup> Talla Deposition, Nvidia, p. 111 (“Q. And were the modems that Nvidia launched in the LTE space – would you have considered them high-end, in the high-end tier? A. No. We considered them in the mainstream. So that was the whole premise of our investment: [...] we would target the mainstream by offering a high-end application processor performance, but bring that to the mainstream with a mainstream modem.”).

later assessed the “mainstream” phone segment as not sizable enough compared to the high-end and volume segments. Nvidia’s firm-wide investment while in the modem industry was lower than its competitors in absolute terms but similar in percentage of revenue. In execution, Nvidia was able to successfully produce integrated chips, but these chips were lacking compared to those of Nvidia’s competitors in such features as CDMA and LTE Category.

456. *Foresight*: Nvidia’s late entrance and subsequent exit from the modem chip industry were largely due to a view of the industry that did not materialize. Nvidia used its existing APs to pair with other suppliers’ modems for supplying high-end smartphones once Nvidia entered the mobile industry.<sup>1375</sup> Nvidia then assessed that “visual computing graphics and Nvidia core competencies [would] be an important technology for smartphone mobile computing,” which led to its purchase of Icera.<sup>1376</sup>
457. Following its entrance into the modem chip industry, Nvidia poorly aligned its modem chip strategy with the demands of the smartphone industry. Given Nvidia’s strengths in producing APs, the company chose to target what it felt would be mainstream devices by providing SoCs with high-performing APs and mid-tier modems.<sup>1377</sup> However, Nvidia later assessed that the cellular industry changed following the rapid advancement of LTE technology, such that by 2015 OEMs instead prioritized either “high-end” or “volume” devices, as opposed to “mid-tier” devices.<sup>1378</sup>

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<sup>1375</sup> Talla Deposition, Nvidia, p. 56 (“Q. So your strategy was to use your modem for what you call mainstream phones and then pair your AP with somebody else’s modem for the -- for the -- what you called high-end phones. A. Correct.”).

<sup>1376</sup> Talla Deposition, p. 107 (“Q. [...] What did you mean by your assessment that Nvidia acquired Icera for phones? A. [...] We felt like visual computing graphics and Nvidia core competencies will be an important technology for smartphone mobile computing, and that’s when we decided to make the investment into it. [...] So that’s the reason why we acquired Icera, because we thought long before, as we made the investment into this whole space, that we needed a modem strategy as well.”).

<sup>1377</sup> Talla Deposition, p. 111 (“Q. And were the modems that Nvidia launched in the LTE space [...] in the high-end tier? A. No. We considered them in the mainstream. So that was the whole premise of the investment: that we cannot -- you know, we would target the mainstream by offering a high-end application processor performance, but bring that to the mainstream with a mainstream modem.”).

<sup>1378</sup> Talla Deposition pp. 108–109 (“A. [...] when we started the market, in around the 2012-13 time frame, we looked at the market as three different segments: One was high-end premium smartphone, the second, the middle, was a middle end or a mainstream, if you will, that will offer close to premium performance; and then at the very low end, you know, very big volume. [...] But what we found is, by 2015 time frame, the market, instead of having all those different tiers, quickly consolidated to the premium and the volume tier.”).

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458. Additionally, Nvidia planned to supply mainstream phones with chips that did not have CDMA capabilities and then pair its AP with a CDMA-capable modem for high-end devices.<sup>1379</sup> As discussed above, these non-integrated solutions tended to be less popular than SoCs, for technical and economic reasons.<sup>1380</sup>
459. Investment: Nvidia’s investment in the modem industry came largely through the acquisition of Icera in 2011. As seen in Exhibits III.E.2–3, Nvidia’s firm-wide investment was generally lower than its industry competitors in absolute terms but comparable as a percentage of revenue. Nvidia’s investments likely prioritized its other core competencies over its modems.<sup>1381</sup> By early 2015, Nvidia divested from modem technology.<sup>1382</sup>
460. Execution: In developing competitive integrated chips internally, Nvidia’s execution in the modem industry had limited success. For high-end devices, Nvidia only produced APs and used outside suppliers’ modems to sell two-chip solutions to mobile device OEMs. Following the purchase of Icera, Nvidia planned to integrate Icera’s existing LTE designs into its own integrated chip for mainstream devices.<sup>1383</sup>
461. As Nvidia developed its integrated Tegra modem chip, outside analysts expressed doubts as to the effectiveness of Nvidia’s Tegra SoC compared to competitors.<sup>1384</sup> By the time it was ready

<sup>1379</sup> Talla Deposition, p. 55–56 (“A. [...] And the very high end of the market, you need the -- you know, on the high end of the market, you need CDMA; you need other features that our modem was -- the roadmap in that time frame was not supporting it. [...] Q. So your strategy was to use your modem for what you call mainstream phones and then pair your AP with somebody else’s modem for the [...] high-end phones. A. Correct.”).

<sup>1380</sup> See Section III.E.1.c.i.

<sup>1381</sup> For instance, Nvidia continued to produce its Tegra APs after it stopped making cellular modems. Niu, Evan, “Appreciating Nvidia Corporation’s Stunning Tegra Recovery,” The Motley Fool, November 12, 2016 (“Last Quarter [2016 Q3], Tegra sales soared 87% [...]”).

<sup>1382</sup> NVIDIA-00608755–8758 at 8757, email from Deepu Talla, Nvidia, May 14, 2015 (“We felt (and still feel) that having modem technology for a platform company is an advantage. However, we had to wind down as we have higher ROI elsewhere and we need to grow in deep learning, virtual reality, and self-driving cars.”).

<sup>1383</sup> Talla Deposition, pp. 112–113 (“Q. Let’s break it up, then, and let’s talk first about premium phones. What were the factors that made it difficult to sell -- to be successful in the business of selling modems for the premium smartphone market? A. I think the premium smartphone market, Icera, we were not targeting our modem for the premium smartphone market [...]. So that -- Nvidia and Icera, we were never targeting the modem. We were targeting that space with our application processor, but trying to pair with a third-party modem.”).

<sup>1384</sup> “Equity Research: Nvidia Corporation,” Wells Fargo Securities, July 31, 2013 (“We continue to have doubts as to Tegra’s ability to grow in the smartphone space in the long run, with Nvidia trying to use its Icera soft modem technology to compete against entrenched companies that have well established traditional baseband

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for release, the Tegra 4i had limited modem capabilities: the Tegra 4i only supported LTE Category 3 and Category 4,<sup>1385</sup> whereas Qualcomm had by that time released a chip supporting Category 6.<sup>1386</sup> Moreover, Nvidia faced challenges during development related to the poor power consumption of its modem chips.<sup>1387</sup> Shortly following the release of the Tegra 4i, Nvidia had no design wins for mobile devices for future chips.<sup>1388</sup> Although there were plans for a follow-up SoC for the Tegra 4i, which was codenamed “Raven,” Nvidia canceled this modem chip while it was still in development.<sup>1389</sup> Similarly, Nvidia finished the design for a thin modem (the i600), but it was unable to successfully get this product to market prior to its decision to divest from the modem industry.<sup>1390</sup>

#### D. Conclusion

462. As can be seen from my analysis of modem chip supplier performance, industry participants that attempt to supply modem chips have experienced a wide variety of outcomes. While some have flourished and are expected to continue to do so in the near future, others have struggled to develop or sell products. Still others have succeeded for a period but then lost their

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products such as Qualcomm, Intel (the acquired Infineon division) and Mediatek.”). See also Zafar, Ramish, “Future of Tegra 4i Looks Uncertain - Could be Nvidia’s First and Last Effort for Mainstream Phones,” WCCF Tech, March 28, 2014 (“With complications present in manufacturing a successor [...], Nvidia is faced with very limited options. Therefore it seems highly unlikely that a successor for the 4i will be introduce[d] [...].”).

<sup>1385</sup> “Introducing Nvidia Tegra 4, The World’s Fastest Mobile Processor,” Nvidia (“[Tegra 4i LTE] Cat3/Cat 4+CA 100-150.”).

<sup>1386</sup> See, e.g., “Qualcomm Powers World’s First Commercial LTE Advanced Category 6 Smartphone,” Qualcomm Press Release, June 18, 2014 (“Qualcomm Technologies, Inc. [...] today announced that the Qualcomm Snapdragon 805 processor and Qualcomm Gobi 9x35 modem are powering the Samsung Galaxy S5 [...], the world’s first commercially available LT Advanced Cat 6 smartphone.”).

<sup>1387</sup> NVIDIA-00609140–9141, email from Rick Dingle, Nvidia, July 19, 2013 (“Power[:] We are still not in great shape on power, or I should say we are not really at what we can achieve with the current platform[.] [...] This is a blocker to adoption until this is good enough[.]”).

<sup>1388</sup> Niu, Evan, “Nvidia Corporation Tries Again,” The Motley Fool, July 22, 2014 (“The newest Tegra K1 chips that were announced at CES earlier this year has exactly zero design wins in phones that investors know of, and losing a spot at one of the world’s fastest growing smartphone makers doesn’t exactly inspire confidence.”).

<sup>1389</sup> Talla Deposition, p. 26 (“Q. Okay, and there was a product called Raven? A. There was a product on the roadmap called Raven, yes, but eventually we decided not to do it. Q. And what was Raven? A. Raven was the follow-on to Tegra 4i. Q. So it would be an integrated -- A. Integrated, right.”).

<sup>1390</sup> Talla Deposition, p. 92 (“Q. And then you said the next priority was you canceled the Raven modem and kind of replaced it with a data-only i600 modem. A. Correct. Thin -- i600 modem data first, but a thin modem. Q. And did that i600 ever launch? A. Once we decided to divest in 2015, we, obviously, canceled that effort.”).

competitive edge due to failures of foresight, investment, and/or execution. These results align with what I would expect to see based on the *Industry Factors Hypothesis*, and because support for *Plaintiff’s Hypothesis* would require observing outcomes inconsistent with the *Industry Factors Hypothesis*, they therefore provide evidence contrary to *Plaintiff’s Hypothesis*.

463. The process of foresight, investment, and execution does not happen linearly or for one product at a time. Even as a modem chip supplier continues to refine and improve its offerings for one particular generation of modem chips, it must simultaneously prepare for the next generation of standards and technology if it is to remain successful in the industry over long periods of time. Firms must invest efficiently, particularly when preparing to incorporate new standards, releases within those standards, or major technologies into their chips. As can be seen by examining the outcomes of modem chip suppliers, companies have accomplished this with differing degrees of success. For example, while Intel had difficulty selling its 3G products, it has found success recently in 4G LTE; Broadcom, on the other hand, successfully sold 3G products but ultimately stopped producing modem chips when it was unable to create viable 4G LTE products. As shown through both industry-level analyses in **Sections III and IV** and the assessment of individual firms in this section, the highly dynamic nature of the industry continuously creates new opportunities for firms while simultaneously putting pressure on existing participants to continue innovating.
464. I have concluded that industry factors explain the successes and failures and the related entry and exit decisions of firms, contrary to *Plaintiff’s Hypothesis*, which posits that Qualcomm’s alleged exclusionary conduct drove such outcomes. Below, I summarize the evidence for this conclusion arising from the application of my analytic framework to the firms in the industry, and then present **Exhibit V.D.1** with a summary of results by supplier.<sup>1391</sup>
465. Foresight: Firms must exercise foresight across a wide range of decision points to anticipate features demanded by OEMs and downstream customers. For example, firms must decide how to invest in improving current products (e.g., by further integrating chips or providing backward compatibility); what future standards to begin developing (e.g., LTE versus WiMAX); what customers to attempt to sell to (e.g., OEMs participating in emerging markets

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<sup>1391</sup> For additional information regarding points summarized in this section, see my analysis and sources in Section V.C.

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and/or those targeting high-end downstream customers); and what product characteristics will be most important to these customers (e.g., low-cost turnkey solutions and/or thin modems).

466. Based on a supplier’s expectations of the future, it will develop one or multiple products that it believes has the capability of generating sales and ultimately profit. A firm with incorrect foresight will fail to sell sufficient products based on those decisions, while a firm with successful foresight will be well positioned to sell products if it can invest efficiently and execute on its plans. Across the set of decisions that firms make, those without sufficient foresight will lose sales and, over time, may exit the industry completely. Examples of such failures in foresight include the following:

a.



- b. Although TI’s early modem chip activities enabled it to be one of the largest modem chip suppliers for much of the 2000s, it did not remain successful. TI’s reliance on its customers to provide modem chip software proved troublesome when the industry transitioned to 3G, as potential customers decided to purchase modem chips from other suppliers that were able to provide both software and hardware components. Additionally, TI failed to foresee the threat from low-cost competitors such as MediaTek, Spreadtrum, and Infineon, and it was undercut on price for 2G modem chips.
- c. Foresight errors precipitated ST-Ericsson’s exit. For example, ST-Ericsson lacked foresight by failing to diversify its customer base. As a result, when Nokia migrated its phones to the Windows operating system, which ST-Ericsson’s SoC did not support, ST-Ericsson faced a substantial drop-off in demand. Additionally, after the split of ST-Ericsson in 2013, Ericsson focused on developing thin modems at a time when demand for such products was shrinking, and Ericsson achieved few design wins before exiting the industry itself.
- d. Broadcom exercised poor foresight in setting its priorities for investing in 2G, 3G, and 4G technologies. For example, while Broadcom continued to invest in 2G and 3G technologies, it did not focus on producing 4G modem chips until 2010, when it acquired Beceem. However, Broadcom did not start shipping LTE modem chips until 2014, after it had also acquired Renesas to accelerate its LTE modem chip development. This delay was potentially related to Broadcom’s decision not to re-task Beceem to focus on LTE until 2011, having allowed it to split its expertise between WiMAX and LTE prior to that.

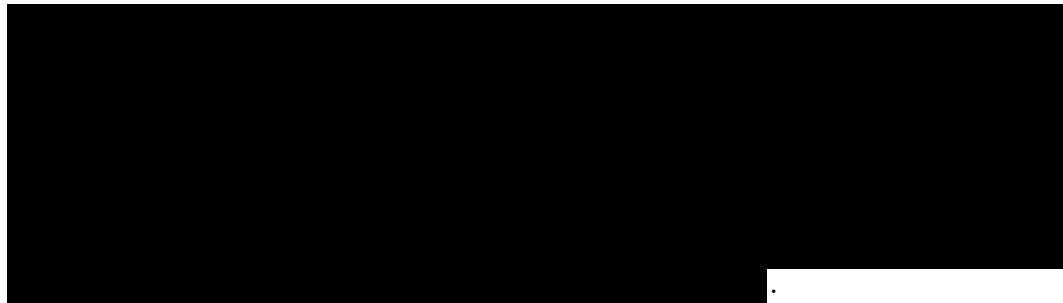
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- e. Nvidia erred by attempting to provide products that were not demanded. For example, it created SoCs by combining its high-performance AP with mid-performance modem chips for use in mid-tier phones. However, after the advancement of LTE technology, Nvidia reassessed that mid-tier phones were no longer a viable segment of the industry. Additionally, Nvidia planned to pair its AP with a CDMA-capable modem for high-end devices, but these non-integrated solutions tended to be less popular than SoCs.

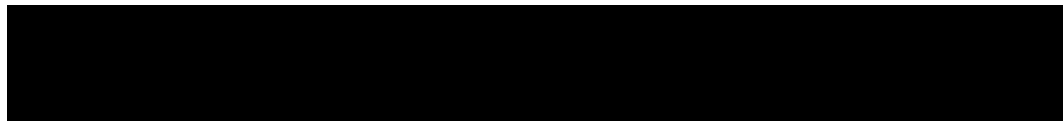
467. Investment: The experiences of different firms show that R&D investment alone is not sufficient for a firm to succeed; rather, a modem chip supplier must allocate its investments efficiently. Firms have chosen to invest either by internal R&D efforts or by coupling these efforts with the targeted acquisition of firms that have previously developed modem chips or related technology. Lack of efficient and targeted investment, or an inability to combine acquired technology and once-external R&D efforts with its internal R&D efforts, may prevent a supplier from successfully creating desirable modem chip products.

468. My analyses demonstrate that modem chip suppliers have developed individualized strategies for investment and innovation as they compete with one another for sales, but in some cases have invested inefficiently and failed to capitalize as a result. For example:

a.



b.



ST-Ericsson split apart in 2013.

- c. While Broadcom used a fast-follower strategy and invested successfully in GSM and WCDMA through its acquisitions of assets from Mobilink and of Zyray Wireless, its LTE acquisitions were unsuccessful despite acquiring both Beceem and Renesas Mobile, as Apple found its modem chips inferior to other options.

469. Importantly, as these examples illustrate, substantial investment is not sufficient in itself to ensure success in the modem chip industry. In particular, Intel’s often-low R&D efficiency – i.e., poor productivity in terms of converting investment to development of products in high demand – resulted in limited success at times despite substantial investment. In addition, good

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foresight is needed to ensure investment is well directed, and strong execution is necessary to bring a product to market quickly and with demanded product characteristics.

470. Execution: Finally, investment and foresight cannot make up for poor execution. To execute successfully, a modem chip supplier must deliver products on time and with functionality desired by the customers that the firm is targeting. Satisfactory execution in only one year is insufficient; the firm must continue to deliver new products year after year, each with incremental improvements relative to competitors and relative to what the firm has previously offered. Firms that are delayed in delivering products can easily be surpassed by competitors that keep up with rapidly evolving technology. Additionally, considerable advantage comes from being the first competitor to market with products that have a given set of demanded features.

471. Examples of the importance of execution include the following:

- a. Marvell lost its primary customer, Blackberry, after falling behind on LTE development and consistently missing development deadlines more broadly. Moreover, Marvell relied on third parties for GPS technology that increased the cost and size of its modem chips, and its modem chips were considered at a disadvantage with respect to power consumption. Following failures of execution, Marvell exited in 2015.
- b. TI fell behind in developing 3G chips following, among other problems, delayed transceiver development and difficulties integrating various multimedia capabilities. TI began phasing out its modem chip business in 2008 and exited the modem chip industry altogether in 2012.
- c. Following the development of successful products through 2005, Freescale struggled to master its own 3G software and was not able to keep pace with other WCDMA chip suppliers. Freescale announced its exit from the modem chip industry in 2008 and ceased legacy sales in 2013.
- d. Other chip suppliers also struggled to offer advanced features on the timelines demanded by OEMs. [REDACTED]

472. Because a firm's success can be limited by poor foresight, poor investment, or poor execution in isolation, as demonstrated by my analysis and the specific examples above, success requires performance on all dimensions. Examples of modem chip suppliers that have achieved such performance, and that have earned success as a result, include the following:

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a.

[REDACTED]

b. As Spreadtrum entered the modem chip industry, it focused on providing low-cost turnkey solutions to enable the growth of low-cost OEMs. It used acquisitions and strategic R&D investments to focus effectively on providing low cost technology. Spreadtrum’s modem chip sales have grown substantially, from just under 115 million units in 2010 to over 460 million in 2017.

c.

[REDACTED]

d. Samsung has strategically leveraged its fabrication capabilities in its modem chip manufacturing and has a long history of extensive R&D into all parts of the mobile device supply chain. Samsung S-LSI’s LTE modem chips have improved considerably over the past few years, to the point where certain of its SoCs have been deemed as good as Qualcomm’s. As a result, Samsung has substantially shifted its modem chip sourcing from external suppliers such as Qualcomm to its internal self-supply:

[REDACTED]

e.

[REDACTED]

More recently, Intel was selected to be the primary and potentially exclusive supplier of modem chips for Apple’s iPhone.

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473. Of note, these firms have succeeded irrespective of not having an exhaustive component-level patent license from Qualcomm.<sup>1392</sup> Therefore, their success contraindicates a key component of *Plaintiff’s Hypothesis* – that modem chip suppliers cannot compete effectively without an exhaustive license to Qualcomm’s cellular SEPs. Instead, their success has derived from their ability to consistently exercise foresight, appropriately target their investments to their chosen strategies, and execute well in developing chips with desirable characteristics, integrating additional features, and otherwise striving to meet OEMs’ requirements.
474. The industry factors I have emphasized throughout, when taken together, explain the success, failure, exit, and entry seen within the modem chip industry. Exhibit V.D.1 summarizes the insights gained from my analysis of individual modem chip suppliers. Put simply, when firms have demonstrated poor foresight, investment, and/or execution, they have had limited success, while firms that have consistently demonstrated strong foresight, efficient and targeted investment, and effective execution have succeeded. This body of evidence is inconsistent with *Plaintiff’s Hypothesis* and strongly supports the *Industry Factors Hypothesis*.

## VI. ANALYSIS OF INDUSTRY PERFORMANCE

475. *Plaintiff’s Hypothesis* predicts that Qualcomm’s alleged exclusionary conduct has inhibited competition and driven modem chip suppliers out of the industry, which I would expect to lead to poor performance in the modem chip industry overall. In this section, I directly examine the performance of the modem chip and mobile device industries and evaluate whether there is evidence of any such impaired performance.

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<sup>1392</sup> Qualcomm Incorporated’s Objections and Supplemental Responses to Apple Inc.’s Special Interrogatory Nos. 9, 12, 13 and 15 and Interrogatory Nos. 19, 20 and 31, March 10, 2018, pp. 14–37 [REDACTED]

[REDACTED] As discussed above, MediaTek was successful prior to, during, and after this agreement. [REDACTED]

[REDACTED]

476. Performance in this context refers to the ability of the industry to efficiently deliver value to consumers. Key measures of performance include the pace of innovation, quality-adjusted prices, and overall benefits to consumers. I address each of these in turn, and I show that the industry has exhibited impressive performance on each dimension, which is inconsistent with *Plaintiff’s Hypothesis*.

### **A. Pace of innovation**

477. In this subsection, I document the rapid pace of innovation observed in the modem chip industry with two groups of metrics: investments of modem chip designers in innovation, as measured by their R&D spending; and the resulting improvements in modem chip quality and efficiency.

478. As discussed above and shown in Exhibit III.E.3, the pace of innovation in the modem chip industry is well documented by the intensity of R&D. Firms in the modem chip industry have been consistently investing around 23 percent of their revenues into R&D, second only to the biotechnology industry (27 percent) but more than other innovative industries such as pharmaceuticals (14 percent).<sup>1393</sup>

479. The continued R&D investment in innovation of modem chips has been translated into impressive improvements in the performance of mobile devices used by end consumers. Some of the most important and valued features of devices can be directly traced to improvements in modem chip performance, including the data transmission speed, power consumption, and size.<sup>1394</sup> Specifically, technological innovations in increasing downlink and uplink speeds have allowed mobile devices to perform the basic voice and data functions (e.g., email) of mobile phones faster and more efficiently than before. They have also enabled the newer and more data intensive functionalities that consumers demand, including for example multimedia

<sup>1393</sup> See, e.g., Bezerra, Julio et al., “The Mobile Revolution,” BCG, January 2015, pp. 27–29 and Exhibit 14 at p. 29.

<sup>1394</sup> For example, according to Will Strauss, founder and president of Forward Concepts, a market research publisher focusing on digital signal processing: “Without modems, smartphones would be little more than personal information managers or personal digital assistants (PDAs). [...] Smartphones consist of two main components: Modems and application processors. [...] Application processors with 4, 6, 8 or even 10 CPUs become irrelevant if the ‘on-the-air’ performance is hindered by poor LTE modems.” Strauss, Will, “How LTE Modems Make or Break a Smartphone,” EE Times, December 16, 2015.

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sharing, audio and video streaming, and video conferencing.<sup>1395</sup> Reductions in size and improvements in the power efficiency of modem chips resulted in smaller devices with longer battery life and available talk time.

480. Furthermore, improvements in modem chip technologies prodded the development of innovative functionalities enabled by the high-bandwidth mobile data communication. Before modem chips allowed access to high-bandwidth mobile data communication, consumers were limited to the computing ability and storage that the device OEM initially included in a mobile device, or the data downloaded through a stationary network. Accessing a reliable high-bandwidth connection through an advanced modem chip gave consumers access to more powerful computing and storage capability. The list of innovations enabled by advancements in modem chips is long and varied. For example, while speech recognition remains a computationally intensive task, mobile devices are able to offload more difficult recognition tasks to a large remote server because they have the mobile bandwidth to do that quickly.<sup>1396</sup> Similarly, storage may be offloaded to remote servers, alleviating concerns about running out of storage when away from home. For instance, pictures taken on vacation can transparently be uploaded to the cloud via the cellular network.<sup>1397</sup> MLB Advanced Media allows fans to watch baseball games while riding a train or waiting on a bench.<sup>1398</sup> Google Maps and Waze use cellular data to keep a driver’s route constantly updated, accommodating traffic and detours.<sup>1399</sup>

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<sup>1395</sup> See, e.g., SFT-17749084 at p. 16 (showing that the exponential growth in data transmission was accompanied by the introduction of multimedia, streaming, and video conferencing).

<sup>1396</sup> See, e.g., Nusca, Andrew, “How Voice Recognition Will Change the World,” ZDNet, November 4, 2011.

<sup>1397</sup> See, e.g., “Apple Introduces iCloud,” Apple, June 6, 2011, available at <https://www.apple.com/newsroom/2011/06/06Apple-Introduces-iCloud/> (“iCloud’s innovative Photo Stream service automatically uploads the photos you take or import on any of your devices and wirelessly pushes them to all your devices and computers. So you can use your iPhone to take a dozen photos of your friends during the afternoon baseball game, and they will be ready to share with the entire group on your iPad (or even Apple TV®) when you return home.”).

<sup>1398</sup> Hoffert, John, “How MLB Advanced Media Is Taking a More Tech-Focused Business Approach,” SportTechie, available at <https://www.sporttechie.com/how-mlb-advanced-media-is-taking-a-more-tech-focused-business-approach/>.

<sup>1399</sup> “Waze” homepage, available at <https://www.waze.com/>.

481. These functionalities depend crucially on the data transmission speed associated with modem chips. Exhibit VI.A.1 shows that the maximum downlink speed among all 3G-compatible devices available at a given time has increased from 3.6 Mbps in Q4 2007 to 100 Mbps in Q1 2013, while the maximum uplink speed has increased from 0.38 Mbps in Q4 2007 to 50 Mbps in Q1 2013. Among 4G-compatible devices, the maximum downlink speed has increased from 150 Mbps in Q1 2013 to 1,024 Mbps in Q2 2017, while the maximum uplink speed has increased from 50 Mbps in Q1 2013 to 150 Mbps in Q2 2017. These improvements in speed would allow, for example, for a two-hour HD movie that took over three hours to download on a 3G-compatible device in 2007 to be downloaded on a 4G-compatible device in 39 seconds in 2017, on a cellular network able to provide data at the maximum available speed.<sup>1400</sup>
482. The downlink and uplink speeds described above and shown in Exhibit VI.A.1 are the theoretical maximum speeds, which represent the total capacity available to the set of connected devices in a particular sector of a base station.<sup>1401</sup> These theoretical speeds are often much faster than the speeds that are experienced by subscribers in practice, because they do not adjust for factors such as the distance of the device from the base station, network traffic, and even the weather.<sup>1402</sup> However, actual average speeds that are experienced by consumers have also grown rapidly. Exhibits VI.A.2 and VI.A.3 show the average connection speed and average peak connection speed over time for a few selected countries from 2010 to 2017.<sup>1403</sup> For example, in the U.S., the average connection speed increased from less than 1 Mbps in Q1 2010 to 6.7 Mbps in Q2 2016 and to 10.7 Mbps in Q1 2017, and the peak connection speed increased from less than 2.5 Mbps in Q1 2010 to 33 Mbps in Q2 2016. The exhibits show not

<sup>1400</sup> A two-hour HD movie is approximately 5GB (or 40,000 Mb) of data, which can be download in 11,111 seconds or 185 minutes on a 3.6 Mbps connection and in 39 seconds on a 1,024 Mbps connection. See, e.g., “Internet Data Calculator,” AT&T, available at <https://www.att.com/esupport/data-calculator/index.jsp> (showing that two hours of streaming high-definition video corresponds to 5GB of data usage).

<sup>1401</sup> See, e.g., “Realistic LTE Performance: From Peak Rate to Subscriber Experience,” Motorola White Paper, 2009, p. 4, available at [https://www.apwpt.org/downloads/realistic\\_lte\\_experience\\_wp\\_motorola\\_aug2009.pdf](https://www.apwpt.org/downloads/realistic_lte_experience_wp_motorola_aug2009.pdf).

<sup>1402</sup> See, e.g., Segan, Sascha, “Theoretical 4G Speeds Aren’t Real Speeds,” PCMag, December 3, 2010.

<sup>1403</sup> According to Akamai, “the ‘average peak connection speed’ metric represents an average of the maximum measured connection speeds. [...] The average is used in order to mitigate the impact of unrepresentative maximum measured connection speeds. In contrast to the average measured connection speed, the average peak connection speed metric is more representative of what many end-user Internet connections are capable of.” See, e.g., Akamai, “The State of the Internet, 4th Quarter, 2010 Report,” p. 31.

only overall growth in speeds but also variation within and across countries. As an example, the peak mobile speeds for the four U.S. mobile network carriers ranged from 8.8 Mbps to 27.7 Mbps in Q4 2013. The average peak connection speed in Brazil was 22 Mbps in Q1 2016, while the peak average connection speed in Germany reached over 170 Mbps in the same quarter.

483. Examination of wireless data traffic reveals that not only were these improvements in speed rapidly evolving, they were also highly demanded by consumers. In particular, the volume of mobile data traffic in the U.S. has increased in recent years, growing by a factor of 35 from 2010 to 2016, when it reached 13.7 EB.<sup>1404</sup> The total wireless data consumed in the U.S. in 2016 is equivalent, for example, to streaming HD video for nearly 1.6 million years.<sup>1405</sup> Exhibit VI.A.4 shows that average data traffic per device has continued to increase at a rapid pace, and Exhibit VI.A.5 shows that global mobile data traffic has increased to over 100 EB per year, growing by a factor of 14 from 2011 to 2016. These results indicate that the output of the modem chip and mobile device industries has been expanding at a remarkable rate.
484. Improvements in integrated AP functionality have also contributed to the innovative mobile devices functionalities described above. For example, increasing AP speed and the number of CPU cores allow for faster and smoother mobile device performance.<sup>1406</sup> Exhibit VI.A.6 shows that between Q2 2012 and Q1 2017 the processor speed grew from 0.90 GHz to 1.27 GHz for 3G mobile devices and from 1.42 GHz to 1.74 GHz for 4G mobile devices. Similarly, Exhibit VI.A.7 shows that the average number of CPU cores increased from 1.4 to 3.5 for 3G mobile devices and from 1.9 to 5.7 for 4G mobile devices. Given that 89 percent of mobile devices sold in Q2 2012 supported 3G as their highest standard, while in Q1 2017 88 percent supported 4G as their highest standard, the processor speed of a typical device almost doubled

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<sup>1404</sup> 1 Exabyte = 10<sup>18</sup> bytes or 1 trillion MB.

<sup>1405</sup> “Wireless Snapshot 2017,” CTIA, available at <https://www.ctia.org/docs/default-source/default-document-library/ctia-wireless-snapshot.pdf>.

<sup>1406</sup> See, e.g., Naha, Abhi and Peter Whale, *Essentials of Mobile Handset Design*, Cambridge University Press, 2012, pp. 111–113 (“By introducing a multi-core approach, it becomes possible to run two (or more) functions at the same time for a particular clock speed. So, in theory at least, it should be possible to double the performance of a chipset for the same power consumption by moving from a single- to a dual-core architecture.”).

and the average number of CPU cores in a typical device increased by more than a factor of four over this time period.<sup>1407</sup>

## **B. Price trends**

485. In this subsection, I examine the price trends in the modem chip and mobile device industries. Exhibit VI.B.1 shows that average selling prices of modem chips have declined considerably over time. While the prices of modem chips generally increase with each successive generation of wireless standards, the observed downward trends are similar for each new generation. The differences in prices across generations can be attributed to improving technology along various dimensions, including data transmission speeds, AP integration, and multi-mode functionality.
486. The observed decline in prices is even more impressive after accounting for the fact that the average modem chip in, say, 2008 was very different from the average modem chip in 2012. Data collected by Forward Concepts show that, for example, from 2008 to 2012, the share of SoCs has grown from six to 33 percent of all modem chip units. In the same period, SoCs were significantly more expensive than thin modems: in 2012, the former cost, on average, more than four times the latter. Nonetheless, steep declines in the prices of both thin modems and SoCs still result in the average price declines depicted in Exhibit VI.B.1. Prices vary greatly even within thin modems and within SoCs, depending on the presence of multi-mode functionality. For example, between 2011 and 2013, LTE multi-mode thin modems were on average 149 percent more expensive than LTE single-mode thin modem chips. The average price of LTE modem chips has declined even as the share of multi-mode thin modem chips has continued to grow from 89 percent in 2011 to 92 percent in 2013.<sup>1408</sup>
487. A comparison of Exhibit VI.B.1 to Exhibits VI.A.1, VI.A.6, and VI.A.7 suggests that although prices of modem chips compatible with 4G standards were higher than those of chips compatible with 3G standards, their performance, measured by maximum transmission speed, AP speed, and the number of CPU cores, was higher as well. For example, in Q2 2012, the

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<sup>1407</sup> See IDC, “IDC’s Worldwide Mobile Phone Tracker,” Q4 2017.

<sup>1408</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2013; “LTE Chip Market Trends,” Forward Concepts, 2014.

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prices of 4G modem chips were almost twice as high as those of 3G chips and eight times higher than those of 2G chips. At the same time, 4G modem chips allowed devices to download data more than twice as fast as 3G-compatible devices, and more than 32 times faster than 2G-compatible devices in terms of maximum downlink speed. The APs of 4G-compatible devices were also 57 percent faster than the APs of 3G-compatible devices and 182 percent faster than those of 2G-compatible devices, and 4G-compatible devices had on average 1.90 CPU cores, whereas 3G- and 2G-compatible devices had 1.44 and 1 CPU cores, respectively.

488. Further, the exhibits indicate that as modem chip prices declined over time, their performance along all these dimensions continued to increase rapidly. In particular, from Q1 2010 to Q2 2017, 3G modem chips became 62 percent less expensive, while 3G-compatible handsets became almost ten times faster, in terms of maximum downlink speed. During the same time, their processor speed increased by 134 percent and the average number of CPU cores more than tripled. Similarly, between Q2 2012 and Q2 2017, prices of 4G modem chips declined by almost 50 percent, while the maximum downlink speed of 4G-compatible handsets increased more than tenfold, their processor speed increased by 24 percent, and the average number of CPU cores tripled.
489. These observed modem chip price declines follow similar trends as those found in industry surveys for the cost of data. For example, a study by BCG found that as the maximum downlink speeds increased from 20 kbps for 2G technologies to 250 Mbps for 4G technologies and data volumes increased exponentially, the cost of network infrastructure per megabyte fell by 98 percent and the global average cost of mobile subscriptions per megabyte fell by 99 percent between 2G and 4G technologies.<sup>1409</sup>

### **C. Consumer surplus**

490. Consumer surplus is a widely used measure of the impact that a good or a service has on consumers. Formally, consumer surplus generated by a product is defined as the difference between the amount that a consumer is willing to pay for the product and the product’s

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<sup>1409</sup> Bezerra, Julio et al., “The Mobile Revolution,” BCG, January 2015, p. 9.

price.<sup>1410</sup> As an example, suppose that the price of a smartphone is \$700 and that a consumer values it at \$1,000 or, in other words, a consumer would be willing to pay up to \$1,000 for that smartphone. In this case, the consumer surplus generated by the sale of that smartphone to that consumer is \$300. Total consumer surplus, or consumer surplus in brief, sums the impact of a product on all buyers, accounting for the fact that different consumers differ in the value they derive from that particular product.

491. Measuring the overall impact of improvements in modem chips on consumers presents many challenges stemming from the complexity of the mobile internet ecosystem, which includes participants such as OEMs; providers of telecommunications network, infrastructure, and services; and operating system, software, and app developers.<sup>1411</sup> Technological improvements in modem chips have effects on many other parts of the ecosystem. In this subsection, I present some estimates of the consumer surplus attributable to mobile devices. While the total change in consumer surplus is due to advancements in different parts of the mobile technology, improvements in the modem chip technology explain a substantial part of this change. At the end of the subsection, I discuss academic literature that attempts to single out the contribution of particular features to the surplus generated by mobile handsets.
492. An early analysis of the market for mobile devices, from the time of their introduction in the U.S. in 1983 to 1996, estimated that the gain in consumer welfare attributable to cellular technologies was between \$24 billion and \$50 billion per year.<sup>1412</sup> After the introduction of 2G wireless standards, this surplus was re-estimated to range from \$53 billion to \$111 billion per year.<sup>1413</sup> In 2000, the Council of Economic Advisers used this estimate to argue that the

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<sup>1410</sup> See, e.g., Marshall, Alfred, “Principle of Economics,” MacMillan, 8<sup>th</sup> edition, 1920, p. 103 (“The excess of the price which he would be willing to pay rather than go without the thing, over that which he actually does pay, is the economic measure of this surplus satisfaction. It may be called *consumer’s surplus*.”).

<sup>1411</sup> See, e.g., Bock, Wolfgang et al., “The Mobile Internet Economy in Europe,” BCG, December 10, 2014, Exhibit 9.

<sup>1412</sup> Hausman, Jerry A., “Valuing the Effect of Regulation on New Services in Telecommunications,” *Brookings Papers on Economic Activity, Economic Studies Program, The Brookings Institution*, Vol. 28, 1997, pp. 22–23 (“The gain in consumer welfare measured as the compensating variation is in the range of \$24 billion to \$50 billion per year ...”).

<sup>1413</sup> Hausman, Jerry A., “Mobile Telephone,” in Cave, Martin E. et al., *Handbook of Telecommunication Economics*, Volume 1, Emerald Group Publishing Limited, 2002.

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3G wireless technology would bring benefits of the same order to the U.S. economy.<sup>1414</sup> Studies focusing on South Korea have found that the consumer surplus from mobile communications grew from \$72 million in 1996 to \$8.8 billion in 2004,<sup>1415</sup> and that by 2014 the consumer surplus in South Korea had risen to roughly twice as much, at \$18 billion per year.<sup>1416</sup>

493. Consumer surplus from mobile technologies has also been measured with surveys, which yield a self-reported measure of the dollar value attributed by consumers to their use of smartphones. This method differs from the way economists typically measure surplus, but the results are analogous, in that they consistently indicate that consumers have derived substantial benefits from mobile technology. For example, BCG estimated consumer surplus due to mobile internet (and the induced market for apps, services, and access) to be about \$1 trillion per year in EU5 (France, Germany, Italy, Spain, and United Kingdom) alone,<sup>1417</sup> and it found that data on the demographics of smartphone users suggest that this consumer surplus is bound to increase.<sup>1418</sup> Another BCG study estimated the surplus created by different generations of mobile technologies and found that mobile technologies have created approximately \$1.5 trillion of annual consumer surplus in the U.S. and around \$4.8 trillion combined in five other countries studied (Germany, South Korea, Brazil, China, and India).<sup>1419</sup> The study further concluded that 3G and 4G capabilities contributed to approximately 65 percent of this overall consumer surplus.<sup>1420</sup>

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<sup>1414</sup> “The Economic Impact of Third-Generation Wireless Technology,” The Council of Economic Advisers, 2000, p. 1 (“The annual consumer benefit from today’s wireless telephone services is estimated at \$53 \$111 billion. The consumer benefits from 3G services will likely be of this order of magnitude.”).

<sup>1415</sup> Lee, Duk Hee and Dong Hee Lee, “Estimating Consumer Surplus in the Mobile Telecommunication Market: the Case of Korea,” *Telecommunications Policy*, Volume 30, issue 10-11, 2006, Table 3.

<sup>1416</sup> Lee, Stephanie, “Quantifying the Benefits of Smartphone Adoption: Digital Device Substitution and Digital Consumption Expansion,” 2017, available at <https://ssrn.com/abstract=3014995>.

<sup>1417</sup> Bock, Wolfgang et al., “The Mobile Internet Economy in Europe,” BCG, December 10, 2014.

<sup>1418</sup> Bock, Wolfgang et al., “The Mobile Internet Economy in Europe,” BCG, December 10, 2014 (“Consumer surplus and the other benefits of the mobile Internet are only set to increase - exponentially. ... Smartphone penetration among 16- to 24-year-olds in the UK is 88 percent, compared with 65 percent for other age groups.”).

<sup>1419</sup> Bezerra, Julio et al., “The Mobile Revolution,” BCG, January 2015, Exhibit 12.

<sup>1420</sup> Bezerra, Julio et al., “The Mobile Revolution,” BCG, January 2015, p. 23.

494. Several factors provide additional evidence of an increase in consumer surplus generated by mobile devices, including the decrease in the average price of smartphones,<sup>1421</sup> the increased willingness to pay for smartphones, and the penetration of mobile devices over time. For example, worldwide sales of smartphones have grown more than 12-fold since their first commercial launch, from 122 million units in 2007 to 1,536 million units in 2017.<sup>1422</sup>
495. Mobile device, and particularly smartphone, penetration has been increasing over time. According to a survey of 40 countries (including emerging and developing countries as well as advanced economies) conducted by the Pew Research Center, in 2015 the median country had a 43 percent smartphone penetration and an additional 45 percent cellphone adoption.<sup>1423</sup> Smartphone ownership was found to be the highest in South Korea, at 88 percent, with the remaining 12 percent of the adult population owning a cellphone. In the U.S, smartphone penetration was 72 percent and an additional 19 percent of adults reported owning a cellphone.<sup>1424</sup>
496. The modem chip is one of many components that contribute to the overall consumer surplus from mobile devices. Available evidence indicates that consumers are willing to pay considerably more for a smartphone with LTE technology,<sup>1425</sup> suggesting that the modem chip has an effect on consumers’ demand and, therefore, on their surplus.

<sup>1421</sup> See, e.g., Bock, Wolfgang et al., “The Growth of the Global Mobile Internet Economy,” BCG, February 10, 2015 (“Average smartphone selling prices fell 25 percent worldwide between 2011 and 2013 and are expected to drop a further 19 percent by 2017 [...]”). See also Exhibit 2 in “The Growth of the Global Mobile Internet Economy,” BCG, February 10, 2015.

<sup>1422</sup> See, e.g., “Number of Smartphones Sold to End Users Worldwide from 2007 to 2017 (in Million Units),” 2018, Statista, available at <https://www.statista.com/statistics/263437/global-smartphone-sales-to-end-users-since-2007/>.

<sup>1423</sup> “Smartphone Ownership and Internet Usage Continues to Climb in Emerging Economies,” Pew Research Center, February, 2016 (“Overall, a global median of 43% say that they own a cellphone that is a smartphone, which is defined as a cellphone that can access the internet and apps, such as an iPhone or an Android. An additional 45% across the 40 countries say they have a cellphone that is not a smartphone. A median of only 12% among respondents say that they do not own a cellphone of any kind.”).

<sup>1424</sup> “Smartphone Ownership and Internet Usage Continues to Climb in Emerging Economies,” Pew Research Center, February 2016, p. 16.

<sup>1425</sup> See, e.g., Montenegro, José A. and José L. Torres, “Consumer Preferences and Implicit Prices of Smartphone Characteristics,” *Working Papers, Universidad de Malaga, Department of Economic Theory, Malaga Economic Theory Research Center*, No. 2016-04, 2016, Table 4. Hedonic regression results.

**D. Conclusion**

497. Standard indicators of industry performance do not provide any support for *Plaintiff’s Hypothesis*. The modem chip industry has performed incredibly well, delivering huge improvements in modem chips at the same time as prices continued to decline. Specifically, while the performance of modem chips improved greatly in terms of their transmission speed, processor speed, and the number of CPU cores, modem chip prices roughly halved. For example, maximum downlink speed increased from 150 Mbps in 2013 and to 1,024 Mbps in 2017 among 4G-compatible devices, while prices of 4G LTE modem chips have declined by approximately half since 2012. Along with other improvements, e.g., greater processing power, the modem chip industry has contributed to increased levels of consumer surplus. This performance is evidence against the implication of *Plaintiff’s Hypothesis* that Qualcomm’s alleged exclusionary conduct has impaired industry performance.

**VII. ASSESSMENT OF PROFESSOR SHAPIRO’S OPINIONS**

498. In this section, I address Professor Shapiro’s conclusions that certain adverse outcomes for individual modem chip suppliers have been caused by Qualcomm’s alleged exclusionary conduct. Based on a three-part theory of anticompetitive effects,<sup>1426</sup> Professor Shapiro concludes that Qualcomm’s alleged exclusionary conduct (a) reduced the output of rival suppliers’ modem chips, (b) discouraged investment by Qualcomm’s rivals, (c) caused rivals to exit, and (d) delayed entry by rivals into his claimed “market for CDMA Modem Chips”

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<sup>1426</sup> Professor Shapiro’s theory of anticompetitive harm has three main components.

*First*, Professor Shapiro contends that, “[a]s a result of Qualcomm’s no-license/no-chips policy, Qualcomm has been able to obtain unreasonably high royalties for its cellular SEPs,” and that this has “raised the cost to handset manufacturers of using non-Qualcomm chips.”

*Second*, Professor Shapiro contends that “Qualcomm’s policy of refusing to license its cellular SEPs to its rivals [...] has worked in concert with Qualcomm’s no-license/no-chips policy to raise the royalties for Qualcomm’s cellular SEPs [...], and to raise the combined cost to handset manufacturers of a modem chip and a Qualcomm cellular SEP license.”

*Third*, Professor Shapiro contends that Qualcomm has “obtain[ed] exclusivity at Apple” by making “large exclusivity payments” that “created a powerful incentive for Apple not to use non-Qualcomm modem chips in any new Apple device.”

Shapiro Report, ¶ 9.

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and “market for Premium LTE Modem Chips.”<sup>1427</sup> Professor Shapiro’s conclusions are, of course, in contrast to my conclusion that modem chip supplier outcomes have been fully explained by industry factors and were not caused by Qualcomm’s alleged exclusionary conduct. My conclusion is based on development of the *Industry Factors Hypothesis* and identification of relevant industry factors in Section III as well as my tests of the *Industry Factors Hypothesis* against *Plaintiff’s Hypothesis* in Section IV, Section V, and Section VI.

499. As I explain in this section, Professor Shapiro’s conclusions concerning anticompetitive effects lack foundation.<sup>1428</sup> Professor Shapiro does not evaluate his claims against the clearly relevant counterfactual in which Qualcomm’s alleged exclusionary conduct is removed, but relevant industry factors influence outcomes. Without doing so, Professor Shapiro cannot isolate the effects of Qualcomm’s alleged exclusionary conduct, if any, from the effects of industry factors that would be present in a world without Qualcomm’s alleged exclusionary conduct.
500. Applying the insights from my detailed case analyses in Section V of 14 modem chip suppliers, including all major modem chip suppliers since 2002, it is clear that Professor Shapiro’s claims concerning TI, Broadcom, Marvell, Nvidia, ST-Ericsson, MediaTek, the “Dragonfly” joint venture, and Intel all suffer from a fundamental deficiency, i.e., that Professor Shapiro does not have a clear counterfactual and is therefore not able to causally connect and isolate the effects of Qualcomm’s alleged exclusionary conduct. Beyond citing only scant evidence to support his claims that Qualcomm’s alleged exclusionary conduct may have been related to certain outcomes of these companies as modem chip suppliers, Professor Shapiro does not consider that industry factors and industrial organization principles generally could account for those outcomes and indeed, as supported by the extensive evidence presented above, do account for those outcomes.
501. The case-by-case evaluations below of Professor Shapiro’s claims demonstrate clearly that industry factors, including the importance of foresight, efficient investment, and execution,

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<sup>1427</sup> Shapiro Report, ¶¶ 9, 258.

<sup>1428</sup> To be clear, I do not address all aspects of Professor Shapiro’s opinions. I focus on the modem chip supplier outcomes that Professor Shapiro asserts have resulted from Qualcomm’s alleged exclusionary conduct through his proposed theoretical mechanisms, and I assess whether Professor Shapiro has a sufficient basis to conclude that such outcomes were caused by those mechanisms rather than other unrelated industry factors. In that regard, lack of assessment of any of Professor Shapiro’s opinions does not indicate agreement on my part. I understand that other Qualcomm experts are addressing other aspects of Professor Shapiro’s opinions.

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fully explain the outcomes that Professor Shapiro cites. Given his lack of consideration of the most important alternative hypothesis and the strong evidence in support of the alternative explanation, Professor Shapiro’s conclusions in support of *Plaintiff’s Hypothesis* cannot be accepted. Indeed, all of his claimed anticompetitive outcomes are fully explained by industry factors.

**A. Claimed anticompetitive effects in terms of certain modem chip suppliers’ margins and exits**

502. Given his theory concerning Qualcomm’s alleged “no-license/no-chips policy,” which I interpret as a claim that Qualcomm “ties” its modem chips to its patent licenses,<sup>1429</sup> Professor Shapiro claims that Qualcomm excluded rival modem chip suppliers.<sup>1430</sup> Even though he acknowledges that “it is difficult to isolate the effect of Qualcomm’s conduct on its modem chip rivals,”<sup>1431</sup> he concludes that Qualcomm’s alleged exclusionary conduct caused the exits

<sup>1429</sup> Professor Shapiro refers to Qualcomm’s alleged “no-license/no-chips policy” as Qualcomm’s “linking the supply of modem chips to the royalty rate [...]” Shapiro Report, ¶ 275. Antitrust economists typically refer to cases where “buyers wanting to purchase one (‘tying’) product” must “also buy a second (‘tied’) product” as “tying” or “tie-in sales.” “Tying the Sale of Two Products,” FTC, available at <https://www.ftc.gov/tips-advice/competition-guidance/guide-antitrust-laws/single-firm-conduct/tying-sale-two-products>.

<sup>1430</sup> Professor Shapiro asserts that “Qualcomm is using the market power associated with its modem chips to induce OEMs to agree to pay a per-handset royalty in excess of a reasonable level when purchasing modem chips from any of Qualcomm’s rivals. [...] Put simply, an OEM’s demand for a rival modem chip is reduced if the OEM must pay the excess royalty  $x$  when it uses a rival modem chip.” Shapiro Report, ¶ 298. He asserts further that “this excess royalty excludes rival modem-chip suppliers. In the short run, that exclusion takes the form of reducing the competitive constraint that the rivals impose on Qualcomm, which leads to reduced output of rival modem chips. [...] In the long run, that exclusion also takes the form of reduced investments by rival modem chip suppliers, leading those rivals to offer lower quality modem chips and/or to have reduced capacity. In time, the excess royalty can induce exit from the market altogether.” Shapiro Report, ¶ 301. In doing so, he ignores testimony by

<sup>1431</sup> Shapiro Report, ¶ 302.

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of TI, Broadcom, Marvell, Nvidia, and ST-Ericsson.<sup>1432</sup> He also suggests that Qualcomm’s alleged exclusionary conduct affected the margins of Broadcom, Marvell, Nvidia, and MediaTek.<sup>1433</sup>

503. The record on the experiences of each of these rival suppliers does not support Professor Shapiro’s claims. Instead, industry factors account for each case, and Professor Shapiro has not demonstrated that outcomes would have been different given these industry factors in the counterfactual world where Qualcomm did not have a “no-license/no-chips policy.”

### 1. Texas Instruments

504. Professor Shapiro’s inclusion of TI on his list of firms that “stopped selling modem chips between 2012 and 2015” and that had “sale[s] of Premium LTE Modem Chips” is not consistent with TI’s timeline.<sup>1434</sup> As explained in Section V.C.7, TI decided as early as 2008, prior to the launch of any LTE networks, to phase out its modem chip business in favor of APs. Indeed, elsewhere in his report, Professor Shapiro himself does not include TI on his list of modem chip suppliers that exited between September 2012 and September 2015.<sup>1435</sup> TI, which was the largest modem chip supplier until 2009,<sup>1436</sup> completed its exit from the modem chip industry by 2013. I have seen no evidence that it had any LTE products planned or in development prior to its exit. Indeed, Nvidia’s Deepu Talla, formerly of TI, testified that TI’s AP sales were impaired by lack of a LTE solution.<sup>1437</sup>

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<sup>1432</sup> Shapiro Report, ¶¶ 258, 302.

<sup>1433</sup> Shapiro Report, ¶¶ 302–304, 334.

<sup>1434</sup> Shapiro Report, ¶ 302.

<sup>1435</sup> Shapiro Report, ¶ 251 (“Between September 2012 and September 2015, Broadcom, ST-Ericsson, Nvidia, and Marvell all exited the modem chip business [...].”).

<sup>1436</sup> See Exhibit III.D.3.

<sup>1437</sup> Talla Deposition, Nvidia, pp. 14–15 (“Q. And prior to Nvidia, did you work at Texas Instruments? A. Yes. [...] Q. And the TI -- TI had an applications processor. Is that right? A. Correct. Q. And that was referred to as OMAP, O-M-A-P? A. That’s correct. Q. And at any point in time were you the head of the OMAP business unit? A. Not the complete OMAP business unit, but I was reporting in to the complete general manager of the OMAP business unit.”) and pp. 103–104 (“Q. Okay. And what did you discuss about TI? A. The same idea that access -- lack of access to a thin modem from Qualcomm impaired TI OMAP also. [...] Q. [...] TI sold OMAP to OEMs that used other thin modems, did they not? [...] [A.] Yes. We would sell an application processor. And the idea is to pair with any thin modem in the market [...]. [...] Q. But TI was successful in selling to Motorola, for example, with other modems other than Qualcomm, were they not? [...] [A.] In 2009, ’10, ’11, that was absolutely true. But the landscape completely changed with 4G LTE starting in 2012, and

505. As discussed in Section V.C.7 and summarized in Exhibit V.D.1, TI’s exit from the modem chip industry is fully explained by industry factors. TI’s 2G modem chips eventually became uncompetitive, and TI lost business to MediaTek, Spreadtrum, and Infineon.<sup>1438</sup> Within 3G, TI was regarded as being focused on hardware only, and analysts expressed that TI was thus vulnerable, as demand from OEMs was shifting toward 3G modem chips with embedded software.<sup>1439</sup> Indeed, TI sold a large share of its modem chips to Nokia and EMP,<sup>1440</sup> and its sales thus fell rapidly when these OEMs switched to other modem chip suppliers.<sup>1441</sup> Analysts attributed this in part to TI’s “under-invest[ment] in 3G,”<sup>1442</sup> although TI’s overall R&D spending was comparable to that of other modem chip suppliers at the time.<sup>1443</sup> In addition,

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Qualcomm thin modems were not available starting in that time. [...] Q. So it was really the lack of LTE that impaired TI. A. Primarily.”).

<sup>1438</sup> See, e.g., Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, pp. 6–7 (“TI has had some success with its own baseband designs in the low-end GSM/GPRS market [...]. However, TI faced increased competition from Infineon, MediaTek and Spreadtrum in this segment.”). See also McGrath, Dylan, “Why OMAP Can’t Compete in Smartphones,” EE Times, September 27, 2012 (“TI, having tired of the baseband business after being undercut on price by MediaTek and others, had no intention of reversing its field.”).

<sup>1439</sup> See, e.g., Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 18 (“The cellular baseband market is shifting from custom ASICs to ASSP solutions as handset manufacturers like Nokia, Motorola and Sony Ericsson are turning to off-the-shelf solutions to focus more on user experience and software. This has left TI vulnerable as the company currently doesn’t have a 3G baseband design of its own [...].”).

Cellular Handset & Chip Markets,” Forward Concepts, 2009, p. 155 (“Texas Instruments continues as the global leader in ‘stackless’ WCDMA baseband chip sales [...]. [...] TI supplies the silicon, and EMP the 3G-protocol stack and software based voice/audio codecs-”).

<sup>1440</sup> Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, pp. 5, 12.

<sup>1441</sup> See, e.g., Sideco, Francis, “Qualcomm and ST-Ericsson Shine, Even as Wireless Chip Market Tanks,” IHS Markit, April 30, 2009 (“Texas Instruments Inc. (TI), suffered the worst performance among the Top-5 suppliers in 2008, with revenue plunging by 22.5 percent for the year. The company continued to share [sic] as its major customer, Nokia, took steps to diversify its supply base and engage more with other wireless chip makers.”). See also Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 5 (“The recent diversification of the supplier base at Nokia was a big blow to TI’s baseband ambitions and this, along with the loss of EMP (Ericsson Mobile Platforms) to ST-Ericsson, caused the company to rethink its baseband market strategy.”).

<sup>1442</sup> Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 18 (“TI under-invested in 3G basebands and as a result lost its EMP account and is losing share at its largest customer Nokia also.”).

<sup>1443</sup> See Exhibit III.E.1 and Exhibit III.E.2.

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TI executed poorly in terms of its attempts to respond to OEMs’ demands for integrated solutions and for components beyond modem chips. Analysts expressed that, while TI had established a large engineering team, it underestimated the difficulty of integrating multimedia capabilities onto its modem chips and lagged in transceiver development.<sup>1444</sup>

506. Each of these factors would be present in the counterfactual world absent Qualcomm’s alleged exclusionary conduct. Professor Shapiro’s approach thus erroneously attributes the effects of these industry factors to such conduct. In addition, Professor Shapiro provides no information regarding, for example, TI’s modem chip margins or R&D strategy or spending, let alone evidence that Qualcomm’s alleged exclusionary conduct caused TI’s exit from the modem chip industry. To the contrary, a report he cites states that TI exited the modem chip industry in connection with the shift from 2G to 3G technology (i.e., prior to the subsequent shift from 3G to 4G), due in part to “increasing competition.”<sup>1445</sup>

## 2. Broadcom

507. While Professor Shapiro claims that low margins caused or contributed to Broadcom’s exit from the modem chip industry, he provides no evidence that Qualcomm’s alleged exclusionary conduct caused Broadcom’s margins to be low or caused Broadcom to exit the modem chip industry, and he does not evaluate the relevant alternative hypothesis.<sup>1446</sup> Professor Shapiro in fact cites a document that attributes Broadcom’s slowing sales of 3G modem chips in 2013, and low 3G margins generally, to “intense competition” related to low “barrier[s] to entry in

<sup>1444</sup> Kundojjala, Sravan and Stuart Robinson, “Baseband Processor Profile: Texas Instruments’ Baseband Exit,” Strategy Analytics, June 2009, p. 17 (“TI underestimated the investment and time-to-market requirements of developing transceivers, then compounded this mistake with 3G basebands. We believe that TI also underestimated the difficulty of integrating multimedia capabilities into its SoCs. TI had more than 1,000 engineers working on cellular RF and basebands, but failed to keep up with competitors. According to competitors, TI has never done a good job in software and system integration, leaving those tasks to its customers.”). See also Zander Deposition, Ericsson, p. 77 (“Q. Has TI supplied integrated solutions? A. They have provided integrated solutions for feature phones only. Q. Okay. Was there a reason that you understood or that TI did not provide the integrated solutions for smartphones? A. The reason was because they did not have access to the technology. Q. And why was that? A. The cellular technology, because they couldn’t develop it themselves.”).

<sup>1445</sup> Shapiro Report, ¶ 251 n.525, citing Macquarie Research, “US Semiconductors: The Money Pit,” September 18, 2014, p. 9. See also Shapiro Report, ¶ 258.

<sup>1446</sup> Shapiro Report, ¶ 303.

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3G” and the “maturity of 3G baseband technology.”<sup>1447</sup> The same document states that, notwithstanding Broadcom’s “access to a dual-core LTE SoC that was ready for volume production and was carrier-validated by leading global operators in North America, Japan and Europe” following its acquisition of Renesas in 2013, its “technological roadmap” was “still considered to be behind peers like Qualcomm, MediaTek and Marvell Technology” when it exited the modem chip industry in 2014.<sup>1448</sup> Moreover, elsewhere in his report, Professor Shapiro himself notes an industry factor independent of Qualcomm’s alleged exclusionary conduct that would be expected to affect Broadcom’s margins – namely, competition arising from Samsung’s plan to “use multi-sourcing from Intel, Broadcom, and Samsung’s internal modem chip business” and to “drive down the prices it faced” – but he fails to account for this industry factor in his discussion of Broadcom’s margins.<sup>1449</sup>

508. As discussed in Section V.C.8 and summarized in Exhibit V.D.1, Broadcom’s exit from the modem chip industry is fully explained by industry factors, each of which would be present in the counterfactual world absent Qualcomm’s alleged exclusionary conduct. Broadcom exercised poor foresight in setting its priorities for investing in 2G, 3G, and 4G technologies. Broadcom’s Robert Rango stated in 2011 that Broadcom had “invested in [2G EDGE] when we should have invested in 3G [...] four years ago,” and he characterized this as a “mistake” that Broadcom would “pay for.”<sup>1450</sup> In addition, while Broadcom continued to invest in 2G and 3G technologies, it did not focus on producing 4G modem chips until 2010. At that point, after having searched for a 4G acquisition for about a year, Broadcom acquired Beceem, which it acknowledged was likely a more costly strategy than having developed a 4G solution in

<sup>1447</sup> Shapiro Report, ¶ 251 n.525, citing Trefis Team, “Rising Competition Forces Broadcom to Exit the Baseband Market,” *Forbes*, June 4, 2014.

<sup>1448</sup> Shapiro Report, ¶ 251 n.525, citing Trefis Team, “Rising Competition Forces Broadcom to Exit the Baseband Market,” *Forbes*, June 4, 2014.

<sup>1449</sup> Shapiro Report, ¶ 188. See also Rango Deposition, Broadcom, pp. 28–29 (“By the time Broadcom had a viable product line, the prices in the cellular baseband business decreased at a rate that was faster than our financial projections. [...] Q. Do you have an understanding as to why the ASPs were declining faster than projected? A. Could have been a number of things. There was many competitors in the marketplace. Certainly there’s at least three or four different companies vying for each piece of business. I’m sure that contributed to it. Market was growing very rapidly as well, which led to a lot of price erosion.”).

<sup>1450</sup> BRCM174660–4661 at 4660, email from Robert Rango, Broadcom, July 25, 2011 (“We invested in edge when we should have invested in 3G (mistake made four years ago. We are going to pay for this in 2012, 13)[.]”).

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house.<sup>1451</sup> It also proved to be an unsuccessful strategy, as Broadcom did not start shipping LTE modem chips until 2014, after it had also acquired Renesas to accelerate its LTE modem chip development.<sup>1452</sup> This failure was potentially related to Broadcom’s decision not to re-task Beceem to focus on LTE until 2011, having allowed it to split its expertise between WiMAX and LTE prior to that.<sup>1453</sup>

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<sup>1451</sup> See, e.g., “Broadcom Sees WiMAX/LTE Combo Key Differentiator with Beceem Buy,” FierceWireless, October 14, 2010 (“Broadcom announced it has signed a \$316-million deal to acquire Beceem Communications to enable it to get a leg up in the next-generation chip market that consists of WiMAX and LTE. [...] ‘The development costs associated with 4G are substantial. We have technologists who could have developed this, but we saw opportunities in 2G and 3G we wanted to leverage instead. So we let outside startups continue to invest,’ [general manager of Broadcom’s mobile platforms group Scott] Bibaud said. ‘It probably meant that we could have built a 4G solution a little more cheaply if we built it in-house [...]’ Broadcom has been searching for a 4G chip acquisition for about a year.”). See also Merritt, Rick, “Analysis: Inside Broadcom’s Bid for Beceem, LTE,” EE Times, October 13, 2010 (“‘We have had internal development work on LTE in Broadcom for a few years,’ Bibaud said. ‘What we get with Beceem is technology that has seen a lot more of the market and a fuller team to accelerate our time to market,’ he said. The Beceem deal ‘is not a big surprise – it was well known Broadcom was looking for a 4G core,’ said Eran Eshed, co-founder and vice president of marketing at Altair Semiconductor [...]”).

<sup>1452</sup> See, e.g., Rango Deposition, Broadcom, p. 167 (“Q. Did Broadcom have an in-production LTE chipset in February 2013? A. I think, just to keep the record straight, the first LTE solution that Broadcom had came after the Renesas acquisition, which I believe was in 2013, and it was the EOS2 chip. So I don’t know -- this was February 2013, and I think that acquisition happened in 2013, but I -- I can’t recall the exact date.”). See also “Analyst Day 2013,” Broadcom, p. 55 (slide titled “Portfolio of 3G and 4G SoC Platforms,” listing the M320/EOS2 as a 4G LTE SoC); Ray, Tiernan, “Broadcom Rises: Street Cheers Turn in LTE Outlook,” Barrons, December 10, 2013 (“[...] Broadcom] announced that its M320 dual-core LTE SoC would ship into a Samsung phone in early 2014.”); BROADCOM-USFTC00000100, pp. 4–5, presentation titled “Project Ravello Deal Presentation,” Broadcom, September 3, 2013 (“Rationale[:] Accelerate our LTE program and take clear #2 position in industry[.]”); Yoshida, Junko, “Broadcom Buys Renesas’ LTE Assets – IP, SoC & Engineers,” EE Times, September 4, 2013 (“With the new acquisition deal, Broadcom, which has shipped no LTE products to date, will suddenly own a dual-core LTE SoC, developed by Renesas Mobile, ready for volume production and certified by leading global operators in North America, Japan, and Europe.”).

<sup>1453</sup> “Broadcom Acknowledges WiMAX’s U.S. Decline,” FierceWireless, August 12, 2011 (“Broadcom, which bought WiMAX/LTE chipmaker Beceem last year or \$316 million in a bid to get a leg up in the 4G market, is acknowledging that WiMAX’s position in the U.S. market is fading fast. [...] Hurlston [i.e., Michael Hurlston, senior vice president of Broadcom’s wireless LAN business at the time] said Broadcom is ‘re-tasking’ its Beceem team to focus on LTE. Beceem [...] has hedged its bets with an LTE/WiMAX combo chip.”).

1454

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[REDACTED]

### 3. Marvell

510. According to Professor Shapiro, low margins also caused or contributed to Marvell’s exit from the modem chip industry.<sup>1457</sup> Professor Shapiro again provides no evidence that Qualcomm’s alleged exclusionary conduct was the cause and does not evaluate the relevant alternative hypothesis. One document he cites attributes Marvell’s declining mobile and wireless revenues into 2015 to “modem pressures” stemming from “the slowdown in the Chinese economy.”<sup>1458</sup> The same document also notes that Marvell’s early success had been in China, “where new competitors are emerging most strongly.”<sup>1459</sup>
511. As discussed in Section V.C.12 and summarized in Exhibit V.D.1, Marvell’s exit from the modem chip industry is fully explained by industry factors. Marvell demonstrated poor foresight in failing to plan adequately in advance for LTE development. Analysts stated in 2009 that Marvell did not have a LTE roadmap and predicted that Marvell could fall behind

[REDACTED]

1456 [REDACTED]

<sup>1457</sup> Shapiro Report, ¶ 303.

<sup>1458</sup> Gabriel, Caroline, “Marvell is Latest Casualty of Mobile Modem Meltdown,” Rethink Technology Research, October 2, 2015. See also Shapiro Report, ¶ 251 n.525.

<sup>1459</sup> Gabriel, Caroline, “Marvell is Latest Casualty of Mobile Modem Meltdown,” Rethink Technology Research, October 2, 2015. See also Shapiro Report, ¶ 251 n.525.

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competitors as a result.<sup>1460</sup> In addition to its late LTE development, Marvell also failed to meet delivery deadlines, which caused it to lose a major customer, BlackBerry; some also expressed that Marvell had lost credibility more broadly.<sup>1461</sup> Moreover, Marvell relied on third parties for RF transceivers, certain software, and GPS technology, which increased the cost and size of its modem chips and reduced Marvell’s ability to compete on the number of components it could supply OEMs.<sup>1462</sup> [REDACTED]

[REDACTED] Marvell also faced pricing pressure from Spreadtrum, MediaTek, and Qualcomm in sales for lower-end mobile devices.<sup>1464</sup>

#### 4. Nvidia

512. As in other cases, Professor Shapiro asserts that Nvidia’s exit from the modem chip industry was related to “depressed margins.”<sup>1465</sup> But he provides no evidence that Qualcomm’s alleged

<sup>1460</sup> Kundojjala, Sravan and Stephen Entwistle, “Baseband Processor Profile: Time for Marvell to Reconsider Its Baseband Position,” Strategy Analytics, November 2009, p. 11 (“Marvell currently does not have HSPA basebands and a visible LTE product roadmap. We believe this lack of an LTE roadmap could put Marvell behind its competitors Qualcomm, ST-Ericsson and Infineon.”).

<sup>1461</sup> See, e.g., Grubbs Deposition, BlackBerry, pp. 110–112 (“Q. Why did BlackBerry stop purchasing BlackBerry baseband processors chips from Marvell? A. There were several reasons. We [...] were having some issues with [...] commitments to timelines for deliveries from Marvell. They had slipped on several deadlines that they had promised to deliver things to us by. They apparently -- or from what I -- what I understand were about two years behind on LTE development.”). [REDACTED]

<sup>1462</sup> See, e.g., Kundojjala, Sravan and Stephen Entwistle, “Baseband Processor Profile: Time for Marvell to Reconsider Its Baseband Position,” Strategy Analytics, November 2009, p. 11 (“Marvell did not inherited [sic] a complete modem protocol software stack from Intel and the company had to license it from TTPCom to port it to its PXA 90x products. Competitor companies have in-house protocol stacks which disadvantages Marvell when competing in the cellular baseband market. [...] Marvell currently depends on third parties to source RF transceivers that work with its cellular basebands.”). See also Chhabra Deposition, Marvell, pp. 36–38 (“Q. And did Marvell’s reliance on external vendors for GPS and NFC technology increase the cost of the overall chipset solution? A. Yes. [...] Q. [...] Did Marvell’s reliance on external vendors for GPS and NFC technology have implications for the overall printed circuit board size? A. Yes. Q. And what were those implications? A. More chips. Q. And did more chips then lead to a larger size? A. Larger printed board size. Q. And for some OEM customers, could that be undesirable? A. Possible.”).

<sup>1463</sup> [REDACTED].”).

<sup>1464</sup> Chhabra Deposition, Marvell, p. 151 (“Q. Earlier, when you were testifying about a price war involving Marvell, MediaTek, Qualcomm, and Spreadtrum, was that a price war in the mid to low tier of LTE chips? [...] [A.] I would say so.”).

<sup>1465</sup> Shapiro Report, ¶ 303.

exclusionary conduct decreased Nvidia’s margins or caused its exit. A document he cites indicates that Nvidia’s “plan of integrating the Icera modems into its Tegra processors never fully materialized.”<sup>1466</sup> Another document he cites states that, “although [Nv]idia has roots in graphics chips, its Tegra chip does not stand out among GPU solutions” and was “losing support in super high-end smartphones [...]”.<sup>1467</sup>

513. As discussed in Section V.C.13 and summarized in Exhibit V.D.1, industry factors fully explain Nvidia’s experience and eventual exit from the modem chip industry. Nvidia demonstrated poor foresight with respect to its modem chip business by misjudging the size of different mobile device segments. Specifically, Nvidia’s strategy was to integrate its high-performing APs onto its Icera modem chips, which lacked features required for high-end mobile devices. This strategy was premised on Nvidia’s anticipation that this combination would be successful in what it considered “mainstream” mid-tier mobile devices.<sup>1468</sup> However, Nvidia later assessed that this was no longer a large enough segment, as OEMs focused more on producing either higher-end mobile devices or lower-end and high-volume mobile devices.<sup>1469</sup>
514. Related, Nvidia’s strategic decision not to develop CDMA solutions reduced its ability to compete for sales of modem chips used in high-end mobile devices. As Nvidia recognized, OEMs typically demand CDMA support for their high-end mobile devices. Because Nvidia’s

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<sup>1466</sup> “Nvidia To Sell Its Icera Business & Exit The Mobile Chip Market,” *Forbes*, May 7, 2015. See also Shapiro Report, ¶ 251 n.525.

<sup>1467</sup> Yu, Peter, “The Building Blocks of a 4G Superphone,” *BNP Paribas*, May 9, 2013, pp. 22, 27. See also Shapiro Report, ¶ 251 n.526.

<sup>1468</sup> See, e.g., Talla Deposition, Nvidia, p. 111 (“Q. And were the modems that Nvidia launched in the LTE space [...] in the high-end tier? A. No. We considered them in the mainstream. So that was the whole premise of our investment: that we cannot -- you know, we would target the mainstream by offering a high-end application processor performance, but bring that to the mainstream with a mainstream modem.”). See also Talla Deposition, Nvidia, p. 64 (“So our positioning with Tegra 4i was, we were offering very close to Qualcomm’s premium-end application processor performance, but at a mainstream segment price, based on our application processor advantage.”).

<sup>1469</sup> Talla Deposition, Nvidia, pp. 107–109 (“Q. In what way did the market commoditize pretty quickly? A. [...] When we started the market, in around the 2012-13 time frame, we looked at the market as three different segments: One was high-end premium smartphone; the second, the middle, was a middle end or a mainstream, if you will, that will offer close to premium performance; and then at the very low end, you know, very big volume. [...] But what we found is, by 2015 time frame, the market, instead of having all those different tiers, quickly consolidated to the premium and the volume tier.”).

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modem chips did not provide CDMA support, OEMs wishing to use one of Nvidia’s APs in a high-end device would need to pair it with a modem chip supporting CDMA from another supplier.<sup>1470</sup> However, as explained in Section III.E.1.c.i and Section V.C.4.b, OEMs’ demand has increasingly shifted toward integrated solutions due to size, cost, and power consumption concerns, and Nvidia did not provide an integrated solution with CDMA support. In addition, Nvidia faced execution challenges at times related to the power consumption of its thin modems and SoCs.<sup>1471</sup>

515. Nvidia announced in 2015 that it would exit the modem chip industry to focus on other areas where it believed its expertise would result in greater returns, such as virtual reality and self-driving cars.<sup>1472</sup> It continues to produce successful Tegra APs,<sup>1473</sup> and it recently announced

<sup>1470</sup> Talla Deposition, Nvidia, pp. 55–56 (“Q. [...] Is it correct that you ended up deciding not to have an integrated modem for Erista? A. Correct. Q. And why? Why was that? A. Because it was a premium application processor, and it was going after the very high end of the market. And the very high end of the market, you need the -- you know, on the high end of the market, you need CDMA; you need other features that our modem was -- the roadmap in that time frame was not supporting it. [...] Q. So your strategy was to [...] pair your AP with somebody else’s modem for the [...] high-end phones. A. Correct.”).

<sup>1471</sup> See, e.g., Exhibit QX2685, Miller Deposition, Nvidia, p. 4 (“i500 validation program[:] Project is ongoing as planned. But LG has 2 main concerns. One is RF performance which is under LG’s expectation. And the other is high power consumption.”). See also Exhibit QX2684, Miller Deposition, Nvidia, p. 5 (“[...] i450 could meet neither performance requirement no[r] power consumption requirement[.]”); Exhibit QX2731, Talla Deposition, Nvidia, pp. 1–2 (“Power[:] We are still not in great shape on power, or I should say we are not really at what we can achieve with the current platform[.] [...] This is a blocker to adoption until this is good enough[.]”).

<sup>1472</sup> See, e.g., “Nvidia to Wind Down Icera Modem Operations,” Nvidia Press Releases, May 5, 2015, (“Nvidia today announced that it will wind down its Icera modem operations in the second quarter of fiscal 2016. The company is open to a sale of the technology or operations.”). See also Exhibit CX4051, Talla Deposition, Nvidia, CX-4051-001–004 at 003–004 (also marked NVIDIA-00609168–9173), email from Deepu Talla, May 14, 2015 (“We felt (and still feel) that having modem technology for a platform company is an advantage. However, we had to wind down as we have higher ROI elsewhere and we need to grow in deep learning, virtual reality, and self-driving cars. [...] Going after the phone/mobile revolution was cover charge even if we did not succeed in phones today. We are looking at other ways (GPU IP) to address the phone market. Our DNA is technology and platform leadership. Which means that we need to be #1 in a market truly to build a sustainable business.”).

<sup>1473</sup> See, e.g., Niu, Evan, “Appreciating Nvidia Corporation’s Stunning Tegra Recovery,” The Motley Fool, November 12, 2016, (“Last quarter, Tegra sales soared 87% to \$241 million, driven by both gaming development platforms and momentum in automotive.”). See also Talla Deposition, Nvidia, pp. 60–61 (“Q. And can you tell me again what the product name for Erista ended up being? A. TX1. Q. And is that still on the market? A. It is certainly on the market. [...] It is in -- if you are familiar with the Nintendo Switch game console, it includes the Tegra X1. The Shield Android TV includes the Tegra X1. There’s plenty of video analytics devices all over the world that’s doing autonomous machines. TX1, and also a lot of robots. Plenty of customer interactions for that device.”).

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record quarterly revenues of \$3.21 billion, driven by its leadership in GPU technology, including in mobile platforms.<sup>1474</sup>

## 5. ST-Ericsson

516. Professor Shapiro provides no information regarding, for example, ST-Ericsson’s modem chip margins or R&D strategy or spending. Nor does he establish that Qualcomm’s alleged exclusionary conduct caused harm to this rival. To the contrary, one of the source documents that Professor Shapiro cites attributes Ericsson’s exit from the modem chip industry in 2014, following the break-up of ST-Ericsson in 2013, in part to the fact that “more device makers choose to buy system-on-a-chip solutions with modems married to application processors, which Ericsson d[id] not offer.”<sup>1475</sup>
517. As discussed in Section V.C.6 and summarized in Exhibit V.D.1, ST-Ericsson’s exit is fully explained by industry factors, each of which would be present in the counterfactual world absent Qualcomm’s alleged exclusionary conduct. The record indicates [REDACTED] [REDACTED].<sup>1476</sup> As a result, when its customers’ mobile device sales fell, and when, around 2010, Nokia migrated its phones to the Windows operating system, which the SoC that ST-Ericsson was developing at the time would not support, ST-Ericsson faced a drop-off in demand.<sup>1477</sup> Additionally, after the split of ST-

<sup>1474</sup> “Nvidia Announces Financial Results for First Quarter Fiscal 2019,” May 10, 2018 (“N[vidia] today reported record revenue for the first quarter ended April 29, 2018, of \$3.21 billion, up 66 percent from \$1.94 billion a year earlier, and up 10 percent from \$2.91 billion in the previous quarter. [...] ‘We had a strong quarter with growth across every platform,’ said Jensen Huang, founder and chief executive officer of N[vidia]. [...] ‘At the heart of our opportunity is the incredible growth of computing demand of AI, just as traditional computing has slowed. The GPU computing approach we have pioneered is ideal for filling this vacuum. And our invention of the Tensor Core GPU has further enhanced our strong position to power the AI era,’ he said. [...] New Platforms[:] [...] Announced that Arm will integrate the open-source N[vidia] Deep Learning Accelerator to bring AI inference to mobile, consumer electronics and Internet of Things devices.”).

<sup>1475</sup> Goldstein, Phil, “Ericsson To Exit Wireless-Modem Market, Cut 1,000 Jobs,” FierceWireless, September 18, 2014. See also Shapiro Report, ¶ 251 n.525.

<sup>1476</sup> See, e.g., ERIC-QCOM\_SDCA-00042073–2163 at 2146, presentation titled “ST-Ericsson Board Meeting,” ST-Ericsson, April 20, 2012 [REDACTED]

<sup>1477</sup> See, e.g., Taylor, Chris, “ST-Ericsson Responds to Dimming Prospects with More Cost-Cutting, Focus on New Technology,” Strategy Analytics, June 4, 2012 (“ST-Ericsson’s main customers lost market share in 2011, among these Nokia and Sony-Ericsson, accounting for much of ST-Ericsson’s loss of sales.”). See also “Cellular Handset & Tablet Chip Markets,” Forward Concepts, 2012, p. 118 (“ST-Ericsson’s shipments in TD-

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Ericsson in 2013, Ericsson focused on developing thin modems,<sup>1478</sup> while OEMs, as discussed in Section III.E.1.c.i, have increasingly demanded integrated solutions. [REDACTED]

1479

518.

HSPA declined from 2010 as the midrange market shifted away from foreign suppliers Samsung, Motorola, HTC and Nokia, leaving them with Huawei as their only active bidder.”); Q2014FTC03837571–7600 at 7596, email from Jim Lederer, Qualcomm, February 28, 2011, with attachment titled “QCT Competitive Update”

<sup>1478</sup> Zander Deposition, Ericsson, p. 207 (“Q. And so why was Ericsson focusing on LTE multimode thin modems for smartphones and tablets at this time [i.e., after the split of ST-Ericsson]? A. [...O]ur strategic interest in ST-Ericsson was the cellular technology that supported our radio business, and with the technology leadership that Ericsson has in its radio business we also had an interest of having a corresponding modem to support that business, hence we wanted to focus on the latest technologies with the most reference to our core business.”).

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<sup>1480</sup> See, e.g., ERIC-QCOM-00040884–0947 at 0901,

also Zander Deposition, Ericsson, p. 73

and p. 172

<sup>1481</sup> See, e.g., Zander Deposition, Ericsson, pp. 68–69

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[REDACTED]

## 6. MediaTek

519. Professor Shapiro also discusses forecasted margins for certain modem chips made by MediaTek, which, as discussed in Section V.C.3 and summarized in Exhibit V.D.1, has been a successful modem chip supplier.<sup>1484</sup> Professor Shapiro provides no evidence that Qualcomm’s alleged exclusionary conduct has had any causal impact on MediaTek’s modem chip margins or other outcomes. [REDACTED]

[REDACTED]

[REDACTED]

See also ERIC-QCOM-00040883, p. 2, presentation titled “ST-Ericsson Board Members Briefing,” Ericsson, October 2011 [REDACTED]

1482 [REDACTED]

1483 [REDACTED]

1484 Professor Shapiro asserts that, “as MediaTek has attempted to move from lower tiers to the premium tier, it has found that the margins it earns on its more premium products are unsustainable.” Shapiro Report, ¶ 304.

1485 [REDACTED].

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520.

[REDACTED]

[REDACTED] 1486

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] 1488

In doing so, he ignores MediaTek’s recent successes and ongoing efforts to develop modem chips for higher-end mobile devices. For example, as discussed in Section V.C.3, MediaTek in 2017 incorporated some of the high-end features of its Helio X series into its lower-priced Helio P series in response to emerging demand trends.<sup>1489</sup> Mr. Moynihan testified that he believes MediaTek is now competing with Qualcomm in that segment and, more generally, that MediaTek has closed the gap with Qualcomm on modem chip technologies since 2010, including by doing a better job than Qualcomm in certain dimensions such as power consumption.<sup>1490</sup> [REDACTED]

1486

[REDACTED]

1487

[REDACTED]

1488 Shapiro Report, ¶ 304.

1489 See, e.g.,

[REDACTED]

<sup>1490</sup> Moynihan Deposition, MediaTek, pp. 283–286 (“Q. Do you believe that MediaTek has closed the gap a lot on Qualcomm on the modem technologies? [...] In the time period from 2010 to 2017. A. Yes. I think the gap is probably a little bit shorter today than it was in 2010. [...] Q. Do you believe that MediaTek has tended to do a better job than Qualcomm on power consumption and batter life? A. Yeah. I think -- I think we’ve -- at least I’ve seen enough data internally that suggests under certain use cases that’s true. Yes. [...] Do you believe that at the high end, there are certain features on which MediaTek is doing a bit better and other features in which Qualcomm is doing a bit better? A. [...] I think, yes, I think on some -- some technologies, some

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

521. Professor Shapiro also ignores MediaTek’s earlier success supplying modem chips for lower-end mobile devices. As discussed in Section V.C.3, MediaTek sold its first GSM modem chips in 2004,<sup>1493</sup> and it exploited the opportunity for increased sales presented by growing demand for mobile devices in emerging economies.<sup>1494</sup> In particular, MediaTek also provided software solutions and detailed reference designs, which aided OEMs in shortening their mobile device design and production cycles.<sup>1495</sup> MediaTek introduced its first WCDMA modem chip in 2010 and its first WCDMA modem chip with integrated AP in 2011,<sup>1496</sup> and its WCDMA sales grew

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features around the multimedia user experience, CPU, yeah, I think we’re doing a pretty good job. [...] Q. Okay. Is it your view that MediaTek is competing, today, with Qualcomm in the new premium tier? A. I think we’re starting to, yes.”).

1491 [REDACTED]

1492 [REDACTED]

1493 MediaTek 2007 Annual Report, p. 6 (“Jan. 2004[:] Launched GSM Mobile Phone Chipsets[.]”).

1494 [REDACTED]

1495 See, e.g., Kwong, Robin, “MediaTek Breaks Out Into Mobile Phones,” Financial Times, March 16, 2011 (“Instead of just offering a chip to power the phone, MediaTek also provided its customers with reference designs and a suite of ‘turnkey software solutions.’ By making these available, the company drastically lowered the entry barrier to the mobile phone manufacturing industry. The relative ease with which a phone could be made using MediaTek’s solution was highlighted by the company’s early customers, who typically had no previous experience in the phone industry and sometimes fewer than 10 staff.”). See also Tilley, Aaron, “MediaTek’s Plan to Take on Qualcomm and Move Up in the Cut-Throat World of Mobile,” Forbes, June 3, 2015 (“MediaTek’s talent lies in getting smartphone makers up and running, fast. It provides reference designs-blueprints that new manufacturers can follow quickly to put together their own phones. ‘We reduce the whole phone-design, mass-production cycle from one and a half years to six months,’ says MediaTek’s senior vice president, Jeffrey Ju.”).

1496 See Exhibit V.B.5.

rapidly thereafter,<sup>1497</sup> based in part on its strategy of bringing high end features to low-end mobile devices.<sup>1498</sup> In 2010, MediaTek overtook TI and Qualcomm to become the world’s largest supplier of modem chips, and it has remained the second largest supplier since 2011.<sup>1499</sup>

### **B. Claimed anticompetitive effects of Qualcomm’s licensing practices**

522. Given his theory concerning Qualcomm’s licensing practices, Professor Shapiro claims that Qualcomm harmed its rivals by “eliminating a valuable option” to them and by “discourag[ing] investment.”<sup>1500</sup>
523. Not only does Professor Shapiro acknowledge that, in the absence of “excess royalties,” the “effects of Qualcomm’s refusal to license to its modem-chip rivals might be relatively minor,”<sup>1501</sup> he fails to establish that any harm has actually arisen through either of these channels.

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<sup>1497</sup> See Exhibit V.C.3.

<sup>1498</sup> See, e.g., MTK\_00748746, p. 12, presentation titled “MWS All-Hands Meeting,” MediaTek, November 28, 2012. See also “MediaTek Launches MT6575 Android Platform,” MediaTek Press Release, February 13, 2012 (“MediaTek [...] today announced the availability of the MT6575, its 3rd generation platform for mid and entry-level Android smartphones. [...] ‘We expect significant growth in entry and mid-level smartphones, with wholesale prices under US\$190, over the coming years. We forecast that this segment will almost triple in size from 191 million shipments in 2012 to 551 million by 2016. At that time, we also expect approximately 75% of those entry and mid-level smartphones to ship to emerging markets’ said Neil Mawston, Executive Director, Global Wireless Practice, at Strategy Analytics. The MediaTek MT6575 platform is ideally suited to cater to a wide range of smartphone devices that target this growing segment in multiple markets around the world.”).

<sup>1499</sup> See Exhibit III.D.3.

<sup>1500</sup> Professor Shapiro claims that Qualcomm’s practice of licensing OEMs and not providing modem chip suppliers with exhaustive licenses to its SEPs harms modem chip suppliers in two ways, separate from the harm he claims arises from his theory of Qualcomm’s charging “excess royalties.”

*First*, Professor Shapiro asserts that, “[b]ecause Qualcomm’s policy of refusing to license its modem chip rivals precludes those rivals from offering customers licensed modem chips, Qualcomm’s refusal to license its modem chip rivals directly harms those rivals and weakens them as competitors to Qualcomm by eliminating a valuable option that would otherwise be available to them.”

*Second*, Professor Shapiro asserts that “Qualcomm’s refusal to license its modem chip rivals further harms competition to the extent that rivals’ inability to obtain a license from Qualcomm on reasonable terms discourages investment.”

Shapiro Report, ¶¶ 326–328, 334.

<sup>1501</sup> Shapiro Report, ¶¶ 328, 334.

**1. Claimed harm from “eliminating a valuable option”**

524. Professor Shapiro does not identify why the option of licensing cellular SEPs from Qualcomm would be “valuable” to other modem chip suppliers. To the extent he is suggesting that OEMs may prefer to purchase modem chips from suppliers that have an exhaustive license to Qualcomm’s cellular SEPs because they would then not require patent licenses, he has not established that assertion.

525. Professor Shapiro ignores that there are many cellular SEP holders other than Qualcomm,<sup>1502</sup> and that these other cellular patent holders do not typically offer exhaustive component-level licenses to modem chip suppliers. [REDACTED]

[REDACTED]<sup>504</sup> As another example, Via Licensing licenses a pool of LTE SEPs on behalf of several licensors (i.e., the SEP holders),<sup>1505</sup> and modem chip suppliers such as MediaTek,

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<sup>1502</sup> See, e.g., Hong Deposition, Samsung, pp. 248–249 (“Q. But there are SEP holders, aside from Qualcomm, in the cellular industry. Is that correct? A. Sure, yes. [...] My understanding is that there are companies other than Qualcomm that hold standards essential patents in the cellular field.”).

<sup>1503</sup> [REDACTED]

<sup>1504</sup> [REDACTED]

<sup>1505</sup> Deposition of Taraneh Maghame, Senior Director of Wireless Programs and Corporate Development at Via Licensing, March 14, 2018, pp. 15–16 (“Maghame Deposition, Via Licensing”) (“The LTE pool consists of a number of companies that have joined our program as licensors. In doing so, they have signed what we call a

Intel, Spreadtrum, HiSilicon, and Samsung have not held licenses to Via Licensing’s LTE patent pool.<sup>1506</sup> MediaTek, however, is a licensor to Via Licensing’s LTE patent pool.<sup>1507</sup> Professor Shapiro does not explain why, if MediaTek considers SEP licenses “valuable,” it does not hold a license for a patent pool to which MediaTek itself is a licensor. Professor Shapiro also does not assess whether an exhaustive component-level SEP license from these parties would be more or less of a “valuable option” than an exhaustive license for Qualcomm’s cellular SEPs, or whether an exhaustive license for Qualcomm’s cellular SEPs would be a “valuable option” in the absence of exhaustive component-level licenses from other SEP holders.

526. Professor Shapiro also ignores the “valuable options” modem chip suppliers have in terms of the range of mobile device inputs they offer OEMs. As discussed in Section III.E.2.b.i, many modem chip suppliers have chosen to be broadliners, i.e., they compete by developing and selling multiple mobile device components, such as APs, RF transceivers, GPS chips, and chips for non-modem connectivity (such as Wi-Fi or Bluetooth), in addition to modem chips.<sup>1508</sup> Broadliners generally must invest more in R&D than other modem chip suppliers to develop the full portfolio of products they offer, but they also have more opportunities to earn revenue given their broader portfolios. Furthermore, if a modem chip supplier pursuing a broad product line strategy decides to exit the modem chip industry, its decision may be motivated not by a failure to achieve profitability in selling modem chips, but rather by the opportunity to earn higher returns by allocating more resources to other segments of the semiconductor industry where it has a comparative advantage. For example, as discussed in Section V.C.13 and

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commercialization agreement, which gives Via the ability to license all of their standard-essential patents that relate to LTE to third parties as part of a pool license. [...] And then, of course, as the licensing administrator for the patent pool, we negotiate licenses with third parties who then assign a patent license agreement, a PLA, whereby they get rights to all of the standard-essential patents for LTE that are owned or controlled by our licensors.”).

<sup>1506</sup> Maghame Deposition, Via Licensing, pp. 113–114 (“Q. Okay. Do you know if MediaTek is a licensee today of the LTE pool? A. It is not. Q. Do you know if Intel is a licensee of the LTE pool? A. It is not. Q. Do you know if Spreadtrum is a licensee of the LTE pool? A. It is not. [...] Q. Do you know if HiSilicon is a licensee of the LTE pool? A. No, it’s not. Q. Do you know if Samsung is a licensee of the LTE pool? A. No [...] it’s not.”).

<sup>1507</sup> Maghame Deposition, Via Licensing, p. 109 (“Q. [...]B]y this particular addendum, MediaTek joined the Via LTE licensor pool. Correct? A. That’s right.”) and p. 113 (“So MediaTek, at least at this point in time, was a licensor, but it was not a licensee. Correct? A. That’s correct.”).

<sup>1508</sup> See Exhibit III.D.5.

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Section VII.A.4, Nvidia has earned record revenues since it exited the modem chip industry, driven by its leadership in GPU technology. Professor Shapiro does not assess how relationships between modem chip suppliers and OEMs are affected by the development and sale of all the products in suppliers’ portfolios of mobile device inputs.

527. In addition, Professor Shapiro offers no examples of modem chip suppliers that he claims were harmed by not having the “valuable option” he asserts an exhaustive license to Qualcomm’s cellular SEPs would have provided. Moreover, Professor Shapiro does not explain how, conversely, numerous modem chip suppliers have succeeded despite not having an exhaustive component-level license to Qualcomm’s SEPs. As discussed in Section V.D and summarized in Exhibit V.D.1, several modem chip suppliers have succeeded irrespective of not having an exhaustive component-level patent license from Qualcomm. For example:

- a. MediaTek’s strategy has, in the past, focused in part on designing modem chips targeted at low-end mobile devices with some features normally targeted only toward high-end mobile devices. MediaTek has expanded its capabilities over time to shift away from supplying modem chips primarily for low-end mobile devices toward also targeting high-end mobile devices. It also incorporated support for CDMA into its modem chips starting in 2015. [REDACTED]
- b. Spreadtrum used acquisitions and strategic R&D investments effectively to focus on providing low-cost technology. Spreadtrum’s modem chip sales have grown substantially, from just under 115 million units in 2010 to over 460 million in 2017.
- c. [REDACTED]
- d. Samsung has strategically leveraged its fabrication capabilities in its modem chip manufacturing and has a long history of extensive R&D into all parts of the mobile device supply chain. Samsung S-LSI’s LTE modem chips have improved considerably over the past few years, to the point where certain of its SoCs have

<sup>1509</sup> Professor Shapiro states that HiSilicon produced its first modem chip in 2014, but he appears to be mistaken. See Shapiro Report, ¶ 387. As discussed in Section V.C.5, HiSilicon launched its first modem chip in 2006. Indeed, Professor Shapiro’s own Figure 4 and associated backup indicate HiSilicon modem chip sales for each year shown, i.e., 2008–2016.

been deemed as good as Qualcomm’s, [REDACTED]

e. [REDACTED]

## 2. Claimed harm from “discourag[ing] investment”

528. Professor Shapiro offers a single example where he claims that a lack of an exhaustive component-level SEP license from Qualcomm “discourage[d] investment” in modem chip supply, related to a joint venture involving Samsung and others.<sup>1510</sup> However, Professor Shapiro fails to demonstrate that the lack of an exhaustive component-level SEP license caused investment in modem chip development to decline in this example. Specifically, he ignores evidence that the joint venture likely would have been terminated even if it had obtained an exhaustive component-level SEP license from Qualcomm, and he ignores evidence that Samsung and other partners [REDACTED]

### a. Background on the joint venture

529. Samsung used “Dragonfly” as a code name for a joint venture it explored with NTT DoCoMo, Fujitsu, NEC, and Panasonic beginning in 2011.<sup>1511</sup> [REDACTED]

[REDACTED].<sup>1512</sup> [REDACTED]

<sup>1510</sup> Professor Shapiro asserts that, [REDACTED]

[REDACTED] Shapiro Report, ¶ 327.

<sup>1511</sup> See, e.g., “DoCoMo, Others to Make Smartphone Chips With Samsung: Report,” Reuters, September 12, 2011. See also Kim Deposition, Samsung, p. 106.

<sup>1512</sup> Kim Deposition, Samsung, p. 106 [REDACTED]



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532. Furthermore, Professor Shapiro ignores factors that explain the termination of the joint venture. An internal Samsung memo lists “key show stopper issues” that are independent of Qualcomm.

[REDACTED]

[REDACTED]

[REDACTED]<sup>1518</sup> In addition, [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]<sup>1519</sup>

533. Therefore, it is inappropriate to conclude that Dragonfly would have continued in Professor Shapiro’s counterfactual world, in which modem chip suppliers could obtain an exhaustive license for Qualcomm’s cellular SEPs. That is, even if the joint venture had obtained an exhaustive component-level SEP license from Qualcomm, there were still several reasons that the joint venture likely would have been terminated.

*c. Partners in the joint venture continued to invest in modem chip development*

534. Moreover, even if Dragonfly had continued in Professor Shapiro’s counterfactual world, notwithstanding the reasons it likely would have been terminated independent of Qualcomm discussed above, it would also be inappropriate to conclude that investment in modem chip development would have been any greater in that counterfactual world than it was in the actual world. This is because, in the actual world, the joint venture partners continued their modem chip development efforts after Dragonfly was terminated.
535. Four months after the Dragonfly joint venture agreement was terminated, NTT DoCoMo, Fujitsu, and NEC formed a new joint venture called Access Network Technology Ltd., with

<sup>1518</sup> SFT-0036334–6336 at 6334–6335, memo titled “S.LSI Strategic Growth Development (SGD) Weekly Highlights,” Samsung, March 24, 2012.

<sup>1519</sup> SFT-0036334–6336 at 6335, memo titled “S.LSI Strategic Growth Development (SGD) Weekly Highlights,” Samsung, March 24, 2012 [REDACTED]

[REDACTED] SFT-0036334–6336 at 6335, memo titled “S.LSI Strategic Growth Development (SGD) Weekly Highlights,” Samsung, March 24, 2012.

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the same modem chip development objectives as the former Dragonfly.<sup>1520</sup> NTT DoCoMo and Qualcomm appear to have been on good terms at this point.<sup>1521</sup> Over the next 18 months, Access Network Technology developed modem chips that were used in some Fujitsu smartphones. However, after failing to establish a substantial customer base, in part due to competition from MediaTek in the low-cost segment in China, the joint venture decided to exit the modem chip industry.<sup>1522</sup>

536.

[REDACTED]  
[REDACTED]  
[REDACTED].<sup>1523</sup> More generally, as discussed in Section V.C.4, Samsung had developed its first LTE modem chip by 2010,<sup>1524</sup> and it continued to make improvements to its LTE modem chips thereafter. Samsung released its first SoC in 2015,<sup>1525</sup> and by 2017, some analysts deemed certain Samsung SoCs to be as good as certain Qualcomm

<sup>1520</sup> “Qualcomm Will Battle Asian Chip Makers For China’s Smartphone Market,” *Forbes*, August 6, 2012 (“Of the original five that had initially come together last year, only Fujitsu, NTT DoCoMo and NEC Corp agreed to create a new collaboration named Access Network Technology Ltd., with Samsung and Panasonic dropping off. However, the idea still remains the same – to develop home-grown mobile chipsets and reduce dependence on foreign players such as Qualcomm. While the focus initially will be on the Japanese market, Fujitsu hopes to expand internationally and capture 7% of the global market share of smartphone chips by 2014.”).

<sup>1521</sup> QAPPCMSD10052361, Email from Satoru Adachi, NTT DoCoMo, to Jeff Altman, Qualcomm, April 1, 2012 (“I’m really appreciate [sic] your cooperation and effort so far to achieve a new and good relationship between Qualcomm and DOCOMO.”).

<sup>1522</sup> “Fujitsu, DoCoMo, NEC Abandon Development of Smartphone Chips,” *Nikkei Asian Review*, February 27, 2014 (“Taiwanese chipmaker MediaTek supplies low-cost chips for the affordable smartphones sweeping across China, boosting its market share. Fujitsu smartphones used Access Network Technology’s chips for a time, but the venture was unable to cultivate a customer base either at home or abroad. Its current global market share is believed to be close to zero.”).

<sup>1523</sup> SFT-0036334–6336 at 6335, memo titled “S.LSI Strategic Growth Development (SGD) Weekly Highlights,” Samsung, March 24, 2012. See also Hong Deposition, Samsung, pp. 250–251 [REDACTED]  
[REDACTED]  
[REDACTED]

<sup>1524</sup> Professor Shapiro asserts that the LTE modem chips Samsung sold in 2010 were for data cards only, but he appears to be mistaken. Shapiro Report, n.131 (“[T]hese early Samsung LTE modems were LTE-capable dongles, which are USB devices enabling a personal computer to access a wireless network, as opposed to modem chips for handsets [...].”). As indicated in Exhibit V.B.7, Samsung launched its Craft handset, with self-supplied LTE modem chips, in 2010.

<sup>1525</sup> Cunningham, Andrew, “Samsung’s New Exynos 8 SoC Includes an LTE Modem and Its First Custom CPU,” *Ars Technica*, November 12, 2015 (“[...T]oday Samsung has announced its next-generation Exynos 8 SoC, the Octa 8890 [...] Samsung is integrating an LTE modem into the chip for the first time [...].”).

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Snapdragon 800 series SoCs.<sup>1526</sup> Samsung also introduced at least two SoCs supporting CDMA in 2018, and Samsung S-LSI has been Samsung’s largest modem chip supplier since 2017.<sup>1527</sup>

537. Even if Dragonfly had continued, Samsung’s investment in the joint venture would have been minimal. [REDACTED]

[REDACTED] 1528 [REDACTED]

[REDACTED] 1530 [REDACTED]

<sup>1526</sup> Shah, Agam, “Beyond Smartphones, Samsung Wants Its Exynos 9 Chip in VR Headsets,” Computerworld, March 1, 2017 (“On paper, the Exynos 8895 chip is as good as the Snapdragon 835, and better than MediaTek’s Helio X30.”).

<sup>1527</sup> Frumusanu, Andrei, “Meizu Announces M6s with Exynos 7872,” AnandTech, January 17, 2018 (“This is also the first time we’ve seen an Exynos SoC released with integrated CDMA capability [...]”); Frumusanu, Andrei, “Samsung Announces the Galaxy S9 and S9+,” AnandTech, February 25, 2018 (“Indeed the Exynos 9810’s new modem supports CDMA.”); “Mobile Processor Exynos 7 Series (7885),” Samsung (“The modem supports multi-modes from 2G to 4G including CDMA [...]”); Exhibit IV.B.3, Exhibit V.B.2, and Exhibit V.C.14c.

<sup>1528</sup> SFT-0036334–6336 at 6335, memo titled “S.LSI Strategic Growth Development (SGD) Weekly Highlights,” Samsung, March 24, 2012.

<sup>1529</sup> [REDACTED]. Exhibit CX2628, Hong Deposition, Samsung, SFT-0036341–6382 at 6348–6349, 6351. [REDACTED]. See “Treasury Reporting Rates of Exchange As of December 31, 2011,” U.S. Department of the Treasury, available at <https://www.fiscal.treasury.gov/fsreports/rpt/treasRptRateExch/1211.pdf>. See also “NTT DoCoMo to Dissolve Communication Platform Planning Co., Ltd.,” NTT DoCoMo Press Release, April 2, 2012 (“[...T]he company signed [the joint venture agreement] with Fujitsu Limited, Fujitsu Semiconductor Limited, NEC Corporation, Panasonic Mobile Communications Co., Ltd. and Samsung Electronics Co., Ltd. in December 2011”).

<sup>1530</sup> [REDACTED] nt. Exhibit CX2628, Hong Deposition, Samsung, at 6349, 6351. [REDACTED]. See “Treasury Reporting Rates of Exchange As of December 31, 2011,” U.S. Department of the Treasury, available at <https://www.fiscal.treasury.gov/fsreports/rpt/treasRptRateExch/1211.pdf>. See also “NTT DoCoMo to Dissolve Communication Platform Planning Co., Ltd.,” NTT DoCoMo Press Release, April 2, 2012 (“[...T]he company signed [the joint venture agreement] with Fujitsu Limited, Fujitsu Semiconductor Limited, NEC Corporation, Panasonic Mobile Communications Co., Ltd. and Samsung Electronics Co., Ltd. in December 2011”).

[REDACTED]

[REDACTED] 1531

### **C. Claimed anticompetitive effects of Qualcomm’s “exclusive dealing” agreements with Apple**

538. Given his theory concerning Qualcomm’s “exclusive dealing” agreements with Apple, Professor Shapiro claims that Qualcomm weakened its modem chip rivals.<sup>1532</sup> However, he does not establish that Apple’s agreements with Qualcomm caused any modem chip supplier to be foreclosed from Apple or other customers.

#### **1. Broadcom and ST-Ericsson**

539. Professor Shapiro suggests that Broadcom and ST-Ericsson exited the business of supplying modem chips “in response” to Apple’s signing various agreements with Qualcomm in 2013.<sup>1533</sup> However, there are several problems with his assertion.

[REDACTED]

[REDACTED]

[REDACTED] As discussed above, I have shown that Broadcom’s and ST-Ericsson’s outcomes are fully explained by industry factors. [REDACTED]

[REDACTED]

Professor Shapiro’s approach thus erroneously attributes the effects of these industry factors to those agreements.

<sup>1531</sup> See Exhibit III.E.2. See also Exhibit III.E.1. Data on Samsung’s modem chip-related R&D are not available. I note that Broadcom’s 2012 mobile and wireless R&D, for example, was approximately \$1 billion, compared to approximately \$2.3 billion firm-wide. Renesas had the lowest modem chip-related R&D in 2012 among all modem chip suppliers shown in Exhibit III.E.1, with mobile SoC R&D of approximately \$100 million.

<sup>1532</sup> Professor Shapiro asserts that certain agreements between Apple and Qualcomm “created a powerful incentive for Apple not to use non-Qualcomm modem chips in any new Apple device” and that this “provided a strategic benefit to Qualcomm, namely the weakening [of] its modem-chip rivals, especially Intel.” Shapiro Report, ¶ 9. See also Shapiro Report, Section V.E.

<sup>1533</sup> Shapiro Report, ¶ 366.

<sup>1534</sup> Shapiro Report, ¶¶ 256, 366, citing Investigative Testimony of Tony Blevins, Apple, January 28, 2016.

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541.

[REDACTED]

<sup>1535</sup> Zander Deposition, Ericsson, pp. 194–196

[REDACTED]

<sup>1536</sup>

[REDACTED]

See also Section V.C.6 and  
Section VII.A.5 above; Zander Deposition, Ericsson, pp. 196–197

[REDACTED]

■

[REDACTED]

See also Section V.C.6 and  
Section VII.A.5 above.

<sup>1538</sup>

[REDACTED]

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[REDACTED]

542.

[REDACTED]

543. Second, as I discuss below, Professor Shapiro suggests that Apple would have chosen Intel rather than Qualcomm for at least some of its mobile devices released between 2014 and 2016

1539

[REDACTED]

See also Section V.C.8 and Section VII.A.2 above.

1540

[REDACTED]

in his counterfactual world. Specifically, Professor Shapiro asserts that, absent Apple’s 2013 agreements with Qualcomm, “[s]ome” of Apple’s 2014–2016 iPad models “most likely” would have used Intel modem chips, and this “could well have led” Apple to source modem chips from Intel for an iPhone prior to 2016 as well.<sup>1541</sup> However, as discussed in Section V and summarized below, Qualcomm’s design wins over Intel with Apple were based on the superiority of Qualcomm’s modem chips, which would also have been the case absent Qualcomm’s alleged exclusionary conduct. In any case, to the extent Professor Shapiro is concluding that Apple would have sourced modem chips only from Intel and Qualcomm absent Apple’s 2013 agreements with Qualcomm, his conclusion implies that Apple would not have sourced modem chips from either Broadcom or ST-Ericsson in the counterfactual world. Thus, to the extent Broadcom and ST-Ericsson exited the modem chip industry in part because Apple did not choose them as modem chip suppliers in the actual world, they also would have exited in the counterfactual world absent Apple’s 2013 agreements with Qualcomm, as Apple also would not have chosen them as modem chip suppliers in that counterfactual world either.

544. Third, as discussed in Section IV, Apple typically sources modem chips from one or two suppliers, driven by its strategic decision to focus on a small portfolio of highly customized mobile devices. This is an industry factor that also would have been present in the counterfactual world absent Qualcomm’s alleged exclusionary conduct. Therefore, to the extent Professor Shapiro is concluding that, instead of Apple’s sourcing only from Intel and Qualcomm, Apple could source modem chips from each of Qualcomm, Broadcom, ST-Ericsson, and Intel in the counterfactual world, that conclusion does not make sense. Even if Apple had chosen not to use Qualcomm modem chips for any of its 2013–2014 and subsequent mobile devices, the evidence is inconsistent with Apple’s sourcing modem chips from all of the other three modem chip suppliers. Hence, even if Apple had determined that all three suppliers could supply modem chips meeting its requirements, contrary to the evidence above for Broadcom and ST-Ericsson and contrary to the evidence below for Intel, one or more of them would nonetheless have failed to supply Apple with modem chips. Moreover, Professor Shapiro suggests that Apple would have sourced modem chips from Intel for at least some of its mobile devices. Thus, to the extent ST-Ericsson and Broadcom exited the modem chip

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<sup>1541</sup> Shapiro Report, ¶ 365.

industry in part because Apple did not choose them as modem chip suppliers in the actual world, at least one of them would have exited in the counterfactual world absent Apple’s 2013 agreements with Qualcomm, as Apple also would not have chosen at least one of them as a modem chip supplier in that counterfactual world either.

## 2. Intel

545. Professor Shapiro claims that Intel was excluded from supplying modem chips to Apple by Qualcomm’s “exclusive dealing” agreements with Apple.<sup>1542</sup> However, his claims have a number of flaws.
546. First, as discussed in Section V.B, Qualcomm’s design wins have been based on the superiority of its modem chips. Moreover, as discussed in Section V.C.2 and summarized in Exhibit V.D.1, Intel had a number of problems with foresight, inefficient investment, and execution that substantially impaired its success with mobile device OEMs. These factors would also have been present in a counterfactual world where Qualcomm’s alleged “exclusive dealing” agreements were not in place. Therefore, Professor Shapiro has no basis to claim that Apple would have chosen to use Intel modem chips earlier than it actually did absent those agreements.
547. Professor Shapiro asserts specifically that [REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]  
[REDACTED]

<sup>1542</sup> Professor Shapiro asserts that Apple’s “exclusive dealing” agreements with Qualcomm “provided a strategic benefit to Qualcomm, namely the weakening [of] its modem-chip rivals, especially Intel” and that “[e]xclusion from Apple denied Intel scale” and “weakened Intel’s incentives to invest in modem development,” such that “Intel could not compete as effectively for the business of other OEMs.” Shapiro Report, ¶¶ 9, 369, and 384.

<sup>1543</sup> Shapiro Report, ¶ 362.

<sup>1544</sup> Shapiro Report, ¶ 362.

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[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

548.

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] Furthermore, some at Apple indicated that Intel’s ability to meet Apple’s 2015 requirements was also uncertain, as Intel’s “7292 [i]s the next possible intercept point, for 2015 products, but this emphasizes the importance of intra-band carrier aggregation which is still TBD in I[n]tel’s own technical investigations.”<sup>1548</sup>

549.

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

<sup>1546</sup> APL-QC-FTC\_12123224–3226 at 3224, email from Steve Schell, Apple, January 31, 2013. See also Apple Inc.’s First Supplemental Responses to Interrogatory Nos. 1, 6, 7, 11, and 21 of Qualcomm Incorporated’s First Set of Interrogatories, January 5, 2018, p. 8.

<sup>1547</sup> APL-QC-FTC\_01197513–7514 at 7513, email from Steve Schell, Apple, January 31, 2013. See also Apple Inc.’s First Supplemental Responses to Interrogatory Nos. 1, 6, 7, 11, and 21 of Qualcomm Incorporated’s First Set of Interrogatories, January 5, 2018, pp. 8, 24; “Qualcomm Third Generation LTE Chipsets Are First to Support HSPA+ Release 10, LTE Advanced with LTE Carrier Aggregation,” Qualcomm Press Release, February 27, 2012 (announcing that Qualcomm’s MDM9225 would begin sampling in the fourth quarter of 2012 and would support carrier aggregation).

<sup>1548</sup> APL-QC-FTC\_12123224–3226 at 3225, email from Steve Schell, Apple, January 31, 2013.

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[REDACTED]

550. In fact, as discussed in Section III.E.1.a, [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED]
- [REDACTED] Others in the industry have made similar statements. For example, in a 2013 article on Paul Otellini, Intel’s outgoing CEO at the time, Magnus Hyde, a former TSMC executive, was quoted as saying that “Intel is still suffering with the inability [...] to enter a new major segment that changes the game,” and that this would “probably be a problem going forward.”<sup>1553</sup> Similarly, as discussed in Section V.C.2, Mr. Otellini was quoted as saying that it “took a while to move the machine” at Intel in terms of being “able to build chips for \$10 and sell a lot of them.”<sup>1554</sup> Mr. Otellini also related that, years earlier, he had decided against pushing Intel to win the opportunity to supply Apple when it was developing the first iPhone:

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<sup>1549</sup> Shapiro Report, ¶ 362, citing APL-QC-FTC\_00389948 and APL-QC-FTC\_00364563.

<sup>1550</sup> Shapiro Report, ¶ 362, [REDACTED]

<sup>1551</sup> Shapiro Report, ¶ 362.

<sup>1552</sup> APL-QC-FTC\_12123224–3226 at 3224, email from Steve Schell, Apple, January 31, 2013.

<sup>1553</sup> Madrigal, Alexis C., “Paul Otellini’s Intel: Can the Company That Built the Future Survive It?,” The Atlantic, May 16, 2013.

<sup>1554</sup> Madrigal, Alexis C., “Paul Otellini’s Intel: Can the Company That Built the Future Survive It?,” The Atlantic, May 16, 2013.

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We ended up not winning it or passing on it, depending on how you want to view it. [...]here was a chip that they were interested in that they wanted to pay a certain price for and not a nickel more and that price was below our forecasted cost. I couldn’t see it. [...] And in hindsight, the forecasted cost was wrong and the volume was 100x what anyone thought.<sup>1555</sup>

551. Second, in claiming that Intel “could not compete as effectively for the business of other OEMs” as a result of Qualcomm’s alleged “exclusive dealing” agreements with Apple,<sup>1556</sup> Professor Shapiro ignores other factors that would have impaired Intel’s ability to compete in a counterfactual world absent those agreements. For example, even if Apple had chosen to use Intel’s modem chips in some of its 2014 mobile devices in that counterfactual world, despite its numerous concerns discussed above, other OEMs may still have had the same concerns when considering Intel’s modem chips. Professor Shapiro does not explain how Intel could have competed effectively for sales to other OEMs given issues such as uncertainty in its ability to meet its development milestones and lack of support for carrier aggregation. His suggestion that Apple, other OEMs, or consumers would have been better off given such issues is mere speculation.<sup>1557</sup>

552. As another example, as discussed in Section V.C.2, Intel canceled its SoFIA line of SoCs in 2016 after its lengthy development and eventual release in 2015 of its SoFIA 3G and 3G-R SoCs.<sup>1558</sup> [REDACTED]

<sup>1555</sup> Madrigal, Alexis C., “Paul Otellini’s Intel: Can the Company That Built the Future Survive It?,” The Atlantic, May 16, 2013.

<sup>1556</sup> Shapiro Report, ¶ 384.

<sup>1557</sup> Shapiro Report, ¶ 384 (“Because Intel was weakened as a rival to Qualcomm by Qualcomm’s agreements with Apple, Intel could not compete as effectively for the business of other OEMs. [...] These OEMs were harmed by the lack of viable alternative suppliers of Premium LTE Modem Chips during this period of time.”).

<sup>1558</sup> Eassa, Ashraf, “Intel Corporation’s Most Disappointing Product in 2015,” The Motley Fool, December 22, 2015 (“The only integrated applications processor and modem products that Intel brought to market this year were chips known as SoFIA 3G [...] and SoFIA 3G-R.”); Hruska, Joel, “SoFIA Later: Intel Kills Upcoming Smartphone and Tablet Hardware,” ExtremeTech, April 29, 2016 (“The entire SoFIA project is canceled, in all flavors [...]. We reached out to Intel, which confirmed the news: SoFIA 3GX, SoFIA LTE, SoFIA LTE2, and Broxton have all been canceled.”).

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[REDACTED].<sup>1559</sup> Having no SoC to offer, as was the case for Intel except for its 3G products in 2015 and 2016, limits a modem chip supplier’s potential customers, as few mobile device OEMs other than Apple demand thin modems. Professor Shapiro acknowledges that, “[b]ecause Intel [...] was focused on thin modems and did not have a high-end SOC option, Intel could not immediately turn to customers who required SOC’s,”<sup>1560</sup> but he then contradicts himself by suggesting that Intel could indeed have turned to and even “compete[d] [...] effectively for the business” of such customers absent Qualcomm’s alleged “exclusive dealing” agreements with Apple, despite having no SoC to offer.<sup>1561</sup>

553. Third, in claiming that Intel’s “incentives to invest in modem development” were weakened as a result of Qualcomm’s alleged “exclusive dealing” agreements with Apple,<sup>1562</sup> Professor Shapiro ignores that Intel has typically invested a comparable amount to Qualcomm in R&D.<sup>1563</sup> However, as discussed in Section III.E.2.b.ii and Section V.C.2, while Intel has invested billions of dollars in acquiring companies with modem chip products and in its own R&D, its investments have tended to be inefficient in that they have led to the successful development of fewer products compared to its competitors’ efforts.
554. Fourth, Professor Shapiro asserts that “[s]upplying modem chips to Apple’s [...] latest flagship handsets provides a modem chip supplier significant financial and strategic benefits,” including “learn[ing] directly from engaging with the engineering teams at Apple [...]”<sup>1564</sup>

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<sup>1559</sup> See, e.g., [REDACTED]

[REDACTED] See also Intel, Press Release, “Intel is Accelerating the 5G Future,” February 21, 2017 (“Intel is at the forefront of this revolution, accelerating the path to 5G in collaboration with our customers and partners in the industry [...]. Intel’s portfolio brings a unique advantage to the acceleration of 5G.”); Exhibit QX93, Evans Deposition, Intel, INTEL-QCOM002458604, p. 33 (“iCDG PGBP Summary[:] 5G – LEAD, End to End is Intel’s advantage ... [.]”).

<sup>1560</sup> Shapiro Report, ¶ 368.

<sup>1561</sup> Shapiro Report, ¶ 384.

<sup>1562</sup> Shapiro Report, ¶ 369.

<sup>1563</sup> See Exhibit III.E.1, Exhibit III.E.2, and Section III.E.2.b.ii.

<sup>1564</sup> Shapiro Report, ¶ 42.

However, Professor Shapiro ignores that modem chip suppliers can engage directly with engineering teams at Apple without supplying modem chips to Apple, as is clear from his discussions of Intel’s interactions with Apple prior to its design wins with Apple. Moreover, as discussed in Section V.C.2, Intel has engaged with and learned from other OEMs. ■

Furthermore, even if Intel could have obtained benefits from supplying thin modems to Apple that it could not have obtained through all of these other interactions, those benefits may have been of limited value to Intel in terms of achieving other design wins, as other OEMs primarily demand SoCs, which, as discussed above, Intel has not developed successfully beyond its 3G SoCs that were available in 2015 and 2016 only.

**D. Claimed barriers to entry**

555. Professor Shapiro asserts that Qualcomm’s alleged exclusionary conduct represents a barrier to entry into modem chip supply.<sup>1567</sup> He also suggests that a number of other barriers to entry exist.<sup>1568</sup> His discussion of barriers to entry is flawed for at least the following two reasons.
556. First, and generally, Professor Shapiro does not differentiate between barriers to *de novo* entry into the modem chip industry and entry into his claimed CDMA and “premium” LTE modem chip markets by existing modem chip suppliers. This is an important distinction when evaluating barriers to entry into these claimed markets. For example, in asserting that “the full value of CDMA is only realized with complementary multi-mode technology, backwards compatibility, and advanced LTE,” such that “an investment in CDMA requires contemporaneous development of complementary technologies,”<sup>1569</sup> Professor Shapiro ignores that incumbent modem chip suppliers may already have developed such “complementary technologies.” Such modem chip suppliers would not face incremental costs to developing those “complementary technologies,” and this claimed barrier to entry would therefore not exist for such modem chip suppliers. Similarly, Professor Shapiro asserts that “an entrant into the market for Premium LTE Modem Chips would need to make a substantial investment in research and development.”<sup>1570</sup> However, as discussed in Section III.E.2.b.ii, numerous companies have already made the required investments, and continue to make the investments needed to develop new products. These companies include Intel, Samsung, and Huawei, each with firm-wide R&D of more than \$13 billion in 2017, more than twice as much as Qualcomm’s firm-wide R&D in 2017 of \$5.5 billion.<sup>1571</sup>
557. Second, Professor Shapiro ignores the large number of firms that have entered his claimed markets. Such entry indicates that firms have overcome his claimed barriers to entry, which calls into question the existence or at least the magnitude of those claimed barriers to entry.

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<sup>1567</sup> Shapiro Report, ¶¶ 220–221, 257–258.

<sup>1568</sup> Shapiro Report, ¶¶ 217–219, 249–256.

<sup>1569</sup> Shapiro Report, ¶ 218.

<sup>1570</sup> Shapiro Report, ¶ 249.

<sup>1571</sup> See Exhibit III.E.2.

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For example, Professor Shapiro suggests that firms could be deterred from developing CDMA modem chips because “CDMA specifications are poorly documented,”<sup>1572</sup> but he ignores that many modem chip suppliers appear to have interpreted and implemented that documentation successfully. In particular, by including only 2008 through 2016 in his figure showing CDMA sales volumes, Professor Shapiro ignores modem chip suppliers that developed CDMA modem chips outside that period, including Samsung, Intel, and HiSilicon. By 1999, nine modem chip suppliers had developed modem chips supporting cdmaOne, and by 2004, five modem chip suppliers had developed modem chips supporting CDMA2000. As of 2018, five modem chip suppliers have developed LTE/CDMA2000 multi-mode modem chips.<sup>1573</sup>

558. Furthermore, as discussed in Section V.B.1.c, there has frequently been considerable uncertainty in the industry regarding the future of CDMA due to, for example, the relatively small subscriber base,<sup>1574</sup> fluctuating sales forecasts,<sup>1575</sup> and ambiguity from carriers.<sup>1576</sup> Due in part to these factors, some modem chip suppliers have made strategic decisions, independently of any claimed barriers to entry, not to prioritize CDMA development.<sup>1577</sup>

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<sup>1572</sup> Shapiro Report, ¶ 217.

<sup>1573</sup> See Exhibit V.B.2.

<sup>1574</sup> “Cellular Handset & Chip Markets,” Forward Concepts, 2011, p. 43 (“CDMA2000 clearly is a viable and effective wireless technology and, to its credit, many of its innovations were brought to market ahead of competing technologies. Today, however, the GSM family has in excess of 3.8 billion subscribers – nine times the total number of subscribers in the CDMA2000 family of technologies.”).

<sup>1575</sup> See Exhibit V.B.4.

<sup>1576</sup> See, e.g., [REDACTED]

<sup>1577</sup> See, e.g., Ristelhueber, Robert, “Philips Throttles Back on CDMA Business to Focus on GSM, GPRS,” EE Times, September 21, 2001 (“Philips will also stop developing standard chipsets for CDMA handsets, and focus its efforts on the GSM and GPRS cellular standards, said Ivo Rutten, vice president and general manager of BL Cellular Americas at Philips, Sunnyvale, Calif. [...] Rutten said GSM represented a better opportunity for the company. ‘It’s a bigger market and we’ve already got a significant market share there.’”). See also LaPedus, Mark, “Intel Backs Away from CDMA Chip Market,” EE Times, August 25, 2000 (“Instead of CDMA, Intel will focus more on developing and selling cell-phone chip sets for other digital-cellular standards, such as TDMA [...], PDC [...], and third-generation (3G) wireless, according to Ronald Smith, vice president and general manager of Intel’s Wireless Communications and Computing Group. [...] Smith added that Intel is more bullish on a next-generation CDMA standard called W-CDMA, which is being endorsed by Motorola, Nokia, NTT, and other large OEMs and carriers.”).

Therefore, absent these factors, even more modem chip suppliers may have developed CDMA solutions.

559. As another example, Professor Shapiro himself acknowledges that there has been considerable entry into his claimed “market for Premium LTE Modem Chips,” stating that Samsung, HiSilicon, Intel, and MediaTek all entered that claimed market between 2014 and 2016.<sup>1578</sup>

**E. Professor Shapiro acknowledges the importance of industry factors**

560. In several places in his report, Professor Shapiro appears to acknowledge that industry factors unrelated to Qualcomm’s alleged exclusionary conduct are important determinants of industry outcomes. However, his discussion of industry outcomes fails to account for these industry factors, and he instead attributes those outcomes, without basis, to Qualcomm’s alleged exclusionary conduct.
561. For example, as discussed in Section III.E.1, rewards can be high for first movers in the modem chip industry. Professor Shapiro appears to agree, stating that “Qualcomm enjoyed a significant first-mover advantage in the sale of LTE chips,” that, “at the time of the transition to LTE and in the two years after, Qualcomm possessed a one-to-two year lead on premium LTE features,” and that this “conferred a competitive advantage on Qualcomm.”<sup>1579</sup>
562. As another example, as discussed in Section IV.C.2, the increasing self-supply of modem chips by Samsung and Huawei has important implications for the success of modem chip suppliers that are not vertically integrated, because it diminishes these OEMs’ sourcing from other modem chip suppliers. Professor Shapiro likewise states that “Qualcomm faced competition from Samsung’s Galaxy S4 largely from Samsung’s own LTE solutions,” and he cites [REDACTED]  
[REDACTED].<sup>1580</sup> As discussed in Section III.D.2, Xiaomi also recently released its own modem chip and appears to be developing another. This suggests that the trend toward vertical integration of OEMs into the supply of modem chips may continue, resulting in further competitive

<sup>1578</sup> Shapiro Report, ¶ 223.

<sup>1579</sup> Shapiro Report, ¶¶ 232–234.

<sup>1580</sup> Shapiro Report, ¶¶ 186–187.

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pressures such as those noted by Professor Shapiro but ignored by him in explaining industry outcomes.

563. In addition, as discussed in Section III.F, success in the modem chip industry at a point in time does not guarantee continued success in itself, in that current leaders must continue to innovate to stay ahead. Professor Shapiro’s discussion of entry into his claimed “market for Premium LTE Modem Chips” illustrates this notion that even leading modem chip suppliers face continuous competitive threats. In particular, he states that “Qualcomm’s share of Premium LTE Modem Chips decreased in 2015 and again in 2016 as Samsung, Intel, and MediaTek increased their volumes of premium LTE chips” and that this “entry by rivals MediaTek, Intel, and Samsung led to downward pressure on Qualcomm’s prices – including in Premium LTE Modem Chips.”<sup>1581</sup>
564. The foregoing examples demonstrate that Professor Shapiro himself acknowledges the explanatory power of industry factors on industry outcomes. However, as discussed throughout this section, Professor Shapiro fails to account for industry factors in his discussion of industry outcomes. His conclusions in support of *Plaintiff’s Hypothesis* therefore cannot be accepted.

## F. Conclusion

565. Professor Shapiro has provided no basis for his conclusion that Qualcomm’s alleged exclusionary conduct has caused anticompetitive effects on modem chip supplier outcomes. He has failed to undertake an analysis that isolates potential anticompetitive effects from the effects of industry factors, he has provided no empirical evidence to support his conjectures, and he has disregarded evidence contrary to his conclusions.
566. Professor Shapiro’s conclusions are also contradicted by the evidence. As my analyses have demonstrated, when firms have exited the modem chip industry, their exits have been fully explained by industry factors and those firms’ own strategic decisions, not by Qualcomm’s alleged exclusionary conduct. More generally, when firms have demonstrated poor foresight, inefficient investment, and/or weak execution, they have had limited success, while firms that

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<sup>1581</sup> Shapiro Report, ¶¶ 183–185.

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have consistently demonstrated strong foresight, efficient and targeted investment, and effective execution have succeeded.

567. Moreover, Professor Shapiro’s conclusions are contradicted by the performance of the modem chip industry. As discussed in Section VI, the modem chip industry has performed remarkably well in terms of rapid innovation, declining prices, and increased levels of consumer surplus. This performance corroborates my conclusion that Professor Shapiro’s claims of anticompetitive effects are not supported.

A handwritten signature in black ink, reading "Edward A. Snyder", written over a horizontal line.

Edward A. Snyder

June 28, 2018

**APPENDIX A**  
**Curriculum Vitae**

**EDWARD A. SNYDER**

**CONTACT INFORMATION:**

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**EDUCATION**

B.A., Colby College, 1975 (Economics, Government)

M.A., University of Chicago, 1978 (Public Policy)

Ph.D., University of Chicago, 1984 (Economics)

**CURRENT APPOINTMENTS**

(July 2011 to present; on partial sabbatical leave from August 2017 to July 2018)

**Yale School of Management**

Indra K. Nooyi Dean

William S. Beinecke Professor of Economics and Management

**Yale Department of Economics**

Professor of Economics (Secondary Appointment)

*Major research interests:* Industrial Organization, Antitrust Economics, Law and Economics, Financial Institutions.

*Decanal Responsibilities:*

Overall academic, financial, and administrative leadership of Yale School of Management;

Member of the Yale University Cabinet (2013 – 2017);

Member of Yale University Cabinet Steering Committee (2016 - 2017);

Chair, Steering Committee, Global Network for Advanced Management (2012 to Present);

Member of the Yale School of Management Board of Advisors (2011 to present);

Member of Yale SOM's Appointments, Curriculum, and Strategy Committee (2014 – 2017); and

Member of Yale University Carbon Task Force (2015 - 2016).

*Teaching:*

- “Analysis of Global Competition Law” (co-taught with Pierre Cremieux and Fiona Scott Morton); Fall 2013.
- “Field Project in Commercial Real Estate Development: Yale Golf Course” (co-taught with Roland Betts); Fall 2015.

*Major achievements and initiatives:*

- Conception and development of the Global Network for Advanced Management (GNAM), a network of 32 top business schools.
- Conception and introduction in 2012 of the Master of Advanced Management – a one-year degree program, post-MBA, for students from GNAM member schools.
- Introduction in 2017 of Master of Management Studies, a one-year degree program with multiple tracks of study.
- Introduction of Global Studies Requirement and Global Studies Accounts for all MBAs and MAM students.
- New Leadership Curriculum for all MBAs and MAM students.
- Establishment of the Initiative for Organizational Performance.
- Development and introduction of Foundational Courses for Yale Master-level students and Yale College students.
- Build-out of Yale SOM's Entrepreneurship Program and appointment of Inaugural Director of Entrepreneurship Programs.
- Appointment of Yale SOM's first Director of Community and Inclusion.
- Substantial increase in scholarship support for Masters-level students.
- Central role in establishment of Yale Center Beijing in 2014 and responsible for subsequent management of the Center.
- Establishment of the Yale SOM Council of Global Advisors.
- Launch of school-wide initiatives on Asset Management, Healthcare, and Sustainability.
- Increased levels of alumni involvement; the highest percentage of annual giving by alumni of any Yale academic unit.
- Six consecutive years of operating surpluses (FY2012-FY2017).
- Improvements in the influence, visibility, and recognition of Yale SOM.

## PREVIOUS APPOINTMENTS

### **University of Chicago, Booth School of Business**

Dean, University of Chicago Booth School of Business (July 1, 2001 to June 30, 2010); George Shultz Professor of Economics (July 1, 2001 to June 30, 2011).

*Decanal Responsibilities:* Overall academic, financial, and administrative leadership of the school.

*Teaching responsibilities:* Economic Analysis of Major Policy Issues (co-taught with Gary S. Becker and Kevin M. Murphy).

*Editor:* Journal of Law & Economics (2002 – 2009)

*Major achievements and initiatives:*

- Dramatic increases in the number of endowed faculty professorships, endowed faculty fellowships, and the endowments in research and teaching centers.
- Nine years of 17.1% annual growth of MBA scholarship support.
- Naming of the school with unrestricted funds provided by David Booth – the largest gift (\$300m) to the University of Chicago and the largest gift ever to a business school.
- Increased the school's endowment from approximately \$200m in 2001 to over \$500m, independent of the Booth gift.
- Substantial improvements in the influence, visibility, and recognition of the school, including improved rankings, e.g., BusinessWeek #1 rankings in 2006, 2008, and 2010, and Economist #1 rankings in 2006 and 2009.
- Improvements in the quality and diversity of the MBA classes.
- Large increases in support for PhD students, including dramatic increases in endowment for PhD program.
- Established the Global Advisory Board, with Councils for Asia; the Americas; and Europe, Middle East, and Africa.
- Oversaw the launch of the Initiative on Chicago Price Theory, which became the Becker Center.
- Developed funding for the Fama-Miller Center.
- Successfully moved the School's Europe Campus from Barcelona to London.
- Moved into the school's new campus (Harper Center) in Hyde Park on time and on budget.
- Developed first-of-kind positioning advertising campaign by a business school.
- Appointments of two women to decanal positions.
- Elimination of debt on three facilities.
- Cumulative operating surpluses of \$100.4m over nine-year period.

*Service to the University:*

- Member, Academic Leadership Group, July 2001 – June 2010.
- Oversight Responsibilities for two University Centers (Stigler Center and Becker Center).
- Member, Provost Ad Hoc Tenure Review Committees, 2002 – 2010.
- Member, Board of Directors, Argonne National Laboratories, July 2008 – June 2010.
- Member of various Dean and VP Search Committees, 2003 – 2009.
- Advisory work on University's globalization efforts, 2007 – 2010.
- Member, Social Sciences Deans Group, 2009 – 2010.

**University of Virginia**

Dean and Charles C. Abbott Professor of Business Administration (July 1998 – June 2001)

*Decanal Responsibilities:* Overall academic, financial, and administrative leadership of the Darden School.

*Major achievements and initiatives:*

- First MBA Program growth in 24 years.
- Increase in nine-year capital campaign from \$98m to \$212m.
- Establishment of Batten Institute in 1999.
- Established Financial Self-Sufficiency for the Darden School, eliminating reliance on unrestricted state support.
- Completion Phase II of new Darden Grounds.

- Increased diversity of MBA classes.
- Appointments of two women to decanal positions.
- Appointments of two African-Americans to faculty positions.
- Innovative programs on e-business with global partners.
- Established program partnerships with University of Michigan and University of California at Berkeley.

### **University of Michigan**

Senior Associate Dean, University of Michigan Business School (1995-1998)

*Responsibilities:* MBA Programs (full-time, evening, global); BBA Program, and Masters of Accounting Program. Managed many of the School's international programs and corporate relationships. Oversight of Admissions & Student Services and the Office of Career Development. Significant responsibility for faculty recruitment and development. Member of School's Executive Committee.

*Major achievements and initiatives:*

- Global initiatives including International Multi-disciplinary Action Program (IMAP) and Brazil node of Global MBA program.
- Integration of admissions and career development functions.
- Rationalization of real estate curriculum.

Director, Davidson Institute at the University of Michigan Business School (1992-1995)

*Responsibilities:* Executive and academic leadership to establish a legally-independent Institute focused on business and public policy issues in transition economies and emerging markets.

*Major achievements and initiatives:*

- Developed corporate relationships in China, Central Europe, India, and Russia, and with U.S. firms committed to operating in transition economies.
- Major research initiative on bank privatization in Central Europe and Russia.
- Design and development of in-company projects involving teams of Master's level students working in transition economies.
- Design and delivery of executive education programs for managers from transition economies.
- Progressive increases in outside funding contributing to a \$3m quasi-endowment for the Institute.

Chair, Business Economics and Public Policy (1992-1995)

*Responsibilities:* Curriculum and staffing of BBA and MBA courses. Faculty development of group of 11 faculty members specializing in business economics.

Faculty Member (1982-1994)

*Responsibilities:* MBA Core course coordinator of *Applied Microeconomics* (four years). Design and development of *Competitive Tactics*, a course analyzing competition and cooperation among firms; marketing and distribution of products; and related antitrust issues.

Member, Board of Directors, Davidson Institute (focusing on transition economies and emerging markets) (1995-1998)

Member, Executive Committee, Tauber Manufacturing Institute, University of Michigan (1996-1998)

Member, Executive Committee, Erb Institute (focusing on environmental management), University of Michigan (1996-1998)

Research Consultant, Federal Home Loan Bank Board / U.S. Sen. Comm. on Banking (1989)

Consultant, Antitrust Division, U.S. Department of Justice (1982-1985)

### **University of Chicago**

John M. Olin Visiting Associate Professor, Center for the Study of the Economy and the State (1991-1992)

### **Antitrust Division, U.S. Department of Justice**

Economist (1978-1982; intermittent service through 1985)

Staff Economist, National Commission to Review Antitrust Laws and Procedures (1978-1979)

### **PUBLICATIONS**

#### Articles in Journals:

“Enforcement of Anti-Collusion Laws Against Domestic and Foreign Firms” (Co-author: Pierre Cremieux), Journal of Law & Economics, Vol. 59 (November 2016), pp. 775-803.  
Reprinted in Concurrences, No.4-2017 (in press).

“Proof of Common Impact in Antitrust Litigation: The Value of Regression Analysis”, (Co-authors: Pierre Cremieux and Ian Simmons), The George Mason Law Review, Summer 2010, pp. 939-967.

“Bank Privatization in Transitional Economics: A General Framework with Application to Hungary’s Magyar Kulkereskedelmi Bank Transaction”, (Co-authors: Karen Schnatterly, Roger C. Kormendi and Christopher Jereb), The Financier, vol. 5, No. 2 & 3 (1998), pp. 6-23.

“Allocation of Litigation Costs--American and English Rules,” (Co-author: James W. Hughes) in The New Palgrave Dictionary of Economics and the Law, ed. Peter Newman, Macmillan Publishers Ltd, vol. 51 (1998), pp. 51-56.

“Transactional Structures of Bank Privatizations in Central Europe and Russia,” (Co-author Anna Meyendorff), Journal of Comparative Economics, (August 1997), pp. 5-30.

“Privatization and Performance of the Czech Republic’s Komerční Banka,” (Co-author: Roger C. Kormendi), Journal of Comparative Economics, (August 1997), pp. 97-128.

“Litigation under the English and American Rules: Theory and Evidence,” (Co-author: James W. Hughes), Journal of Law & Economics, vol. 38 (April 1995), pp. 227-250.

- “United States v. United Shoe Machine Corporation: On the Merits,”* (Co-author: Scott E. Masten), Journal of Law & Economics, vol. 36 (April 1993), pp. 33-70.  
Reprinted in Transaction Cost Economics, vol. 2, O. Williamson and S. Masten, eds., (Edward Elgar Publishing, Ltd., London), 1995, pp. 588-625.  
Reprinted in Case Studies in Contracting and Organization, S. Masten, ed., (Oxford University Press), 1996, pp. 224-254.  
Reprinted in Journal of Reprints for Antitrust Law and Economics, issue on Landmark Antitrust Decisions Revisited, 26, 1997, pp. 643-680.  
Reprinted in Pricing Tactics, Strategies, and Outcomes, (M. Waldman & J. Johnson, ed.). Cheltenham, UK: Edward Elgar Publishing. 2007
- “Misuse of the Antitrust Laws: The Competitor Plaintiff,” (Co-author: Thomas E. Kauper), Michigan Law Review, vol. 90, (December 1991), pp. 551-603.  
Reprinted in The Journal of Reprints for Antitrust Law and Economics, vol. 25, no. 2, (1995), pp. 657-709.
- “The Costs of Organization,” (Co-authors: Scott E. Masten and James W. Meehan, Jr.), Journal of Law, Economics, and Organization, vol. 7, (Spring 1991), pp. 1-25.  
Reprinted in Transaction Cost Economics, vol. 2, O. Williamson and S. Masten, eds., (Edward Elgar Publishing, Ltd., London), 1995, pp. 119-143.
- “The Effect of Higher Criminal Penalties on Antitrust Enforcement,” Journal of Law & Economics, vol. 33, (October 1990), pp. 439-462.
- “The English Rule for Allocating Legal Costs: Evidence Confronts Theory,” (Co-author: James W. Hughes) Journal of Law, Economics, and Organization, vol. 6, (Fall 1990), pp. 345-380.
- “The Design and Duration of Contracts: Strategic and Efficiency Considerations,” (Co-author: Scott E. Masten) Law and Contemporary Problems, vol. 52 (Winter 1989), pp. 63-85.
- “The Origins and Resolution of the Thrift Crisis,” (Co-authors: Roger C. Kormendi, Victor L. Bernard, S. Craig Pirrong) Journal of Applied Corporate Finance, vol. 2 (Fall 1989), pp. 85-100.
- “Vertical Integration in the U.S. Auto Industry: A Note on the Influence of Transactions Specific Assets,” (Co-authors: Scott E. Masten, James W. Meehan, Jr.) Journal of Economic Behavior and Organization, vol. 12 (October 1989), pp. 265-73.
- “New Insights into the Decline of Antitrust Enforcement,” Contemporary Policy Issues, vol. 7 (October 1989), pp. 1-18.
- “Policy Analysis of Medical Malpractice Reforms: What Can We Learn from Claims Data?” (Co-author: James W. Hughes) Journal of Business & Economic Statistics, vol. 7, (October 1989), pp. 423-431.
- “Evaluating Medical Malpractice Reforms,” (Co-author: James W. Hughes) Contemporary Policy Issues, vol. 7, (April 1989), pp. 83-98.
- “An Inquiry into the Efficiency of Private Antitrust Enforcement,” (Co-Author: Thomas E. Kauper), Georgetown Law Journal, vol. 74, (April 1986), pp. 401-469.

“Efficient Assignment of Rights to Sue for Antitrust Damages,” Journal of Law & Economics, vol. 28, (May 1985), pp. 469-482. Reprinted in The Journal of Reprints for Antitrust Law and Economics, vol. 25, no. 2, (1995), pp. 969-982.

Books / Articles in Books and Volumes:

“Competitive Discounts and Antitrust Policy,” (Co-authors: Kevin M. Murphy and Robert H. Topel), The Oxford Handbook of International Antitrust Economics, Volume 2, (2015), edited by Roger D. Blair and D. Daniel Sokol, Chapter 5, pp. 89-119.

“Five Easy Questions”, Ch.2.3, in Leadership Development for a Global World: The Role of Companies and Business Schools, J.Canals (ed.), Palgrave Macmillan Ltd. Houndmills, Basingstoke, London 2012, pp. 145-160.

Globalization of Management Education: Changing International Structures, Adaptive Strategies, and the Impact on Institutions, (Co-authors: Chair of AACSB Taskforce Robert F. Bruner, et al.), Emerald Group Publishing, (2011).

“Social Learning and Transaction Cost Economics,” Advances in Strategic Management, A. Huff and J. Walsh, eds., (1997), pp. 223-228.

Crisis Resolution in the Thrift Industry, (Co-authors: Roger C. Kormendi, Victor L. Bernard, S. Craig Pirrong), Kluwer Academic Press, (1989).

“Private Antitrust Cases That Follow on Government Cases,” (Co-Author: Thomas E. Kauper) in Private Antitrust Enforcement: New Learning and New Evidence, ed. Lawrence J. White, M.I.T. Press, (1988), pp. 329-370.

“Minimizing Waste Water Treatment Costs at the Plant Level,” (Co-Author: Dan Yaron) in Environmental Policy, vol. II, ed. George Tolley, et al., Ballinger Publishing Co., (1983), pp. 115-136.

Report to the President and the Attorney General of the National Commission for the Review of Antitrust Laws and Procedures, (January 1979), co-authored Chapter 11 on Insurance.

Working Papers / Research in Progress :

“Aftermath of the *Sealy* Antitrust Litigation.” (Co-author: Michael J. Moore). (June 2006).

“Napsterizing Pharmaceuticals: Access, Innovation, and Welfare.” (Co-authors: James W. Hughes and Michael J. Moore). (January 2011).

Book Reviews:

Confessions of an Economic Hit Man, John Perkins, (Berrett Koehler 2004), Journal of Economic Literature, vol. 43 (December 2005), pp. 1063-1065.

Concentration and Price, ed. Leonard W. Weiss, (M.I.T. Press, 1989), Journal of Economic Literature, vol. 30 (September 1991), pp. 1205-1207.

Impact Evaluations of Federal Trade Commission Vertical Restraints Cases, ed. Robert H. Lande, et al., (Federal Trade Commission, 1984), Journal of Economic Literature, vol. 24 (December 1986), pp. 47-48.

Other Publications:

“Exponential Alliance,” (Co-authors David Bach and Camino de Paz), BizEd, (July/August 2017), pp. 18-27.

“Five Good Questions”, CFO Insights (May 14, 2015).

“The Future of §2 Enforcement and the Analysis of Dominant Firms,” 2010 Antitrust Section Symposium: New York State Bar Association, pp. 12-23.

“A New Approach to Antitrust Class Certification.” (Co-authors: Pierre Cremieux and Ian Simmons), Law 360, (June 14, 2010).

Amicus Brief from Group of Antitrust Economists in Support of Defendants-Appellees, In re: Effexor XR Antitrust Litigation, No. 15-1184 (3<sup>rd</sup> Cir. February 23, 2016).

Amicus Brief from Group of Antitrust Economists to the U.S. Court of Appeals for the Third Circuit, filed May 10, 2016, regarding Wellbutrin XL Antitrust Litigation (E.D. Pa. September 23, 2015).

Amicus Brief from Group of Antitrust Economists to the U.S. Court of Appeals for the Third Circuit, filed December 21, 2015, regarding Mylan Pharmaceuticals Inc. v. Warner Chilcott Public Limited Company, et al., 2:12-cv-03824 (E.D. Pa. April 16, 2015).

*In Re. DAP Antitrust Litigation*, Expert Report, The Antitrust Litigation Course, American Bar Association (Antitrust Section), Mock Trial in U.S. District Court for E.D. of Pennsylvania, MDL Docket No. 1999, (October 4-5, 2007).

Amicus Brief from Group of Industrial Organization Economists to the U.S. Supreme Court, filed August 24, 2006, regarding *Weyerhaeuser Co., v. Ross-Simmons Hardwood Lumber Co., Inc.*, 411 F.3d (9th Cir. 2005).

Amicus Brief from Group of Industrial Organization Economists to the U.S. Supreme Court, filed March 24, 2006, regarding *William Twombly, et al., v. Bell Atlantic Corporation*, et al., 313 F. Supp. 2d 174 (S.D.N.Y. October 7, 2003); *William Twombly, et al., v. Bell Atlantic Corporation, et al.*, 425 F.3d 99 (2d Cir. 2005).

Amicus Brief of Antitrust Economists in *People of the State of NY v. Actavis plc and Forest Laboratories, LLC* (14-4624), filed January 15, 2015; matter on appeal for the U.S. District Court for the SDNY (Civil Action No. 1:14-07473).

“Bank Privatizations in Central Europe and Russia,” Davidson Institute Report to the U.S. Department of Treasury, (March 1996).

“Director's View,” The Davidson Window, vol.1, (Winter 1994), pp. 1-2; vol.1, (Summer 1994), pp. 1-2; vol. 1, (Spring 1995), pp. 1-2.

“Transitions in Expertise,” The Journal of the International Institute, (Winter 1994), (July/August 2017), pp. 6-8.

Crisis Resolution in the Thrift Industry: Beyond the December Deals. (Co-authors: Roger C. Kormendi, Victor L. Bernard, S. Craig Pirrong), Report of the Mid America Institute, (March 1989).

Popular Press:

- “Statistics and Sports: Deflategate,” Analysis Group, 2015 Year in Review.
- “Dean Of The Year: The Three-Peat Change Agent,” *Poets and Quants*, December 16, 2015).
- “10 Business Schools to Watch in 2016,” *Poets and Quants*, (December 16, 2015).
- “Faculty and students call for calmer tone in campus protests,” *Wall Street Journal*, (December 3, 2015).
- “IIM-B students can opt for lessons from Yale, Berkeley, and other top Business schools,” *Prep Sure* (November 19, 2015).
- “Research top priority for IIM-B”, *Live Mint* (December 2, 2015).
- “Global meet for business students concludes,” *Hindu*, (November 18, 2015).
- “IIMB Students to Gain Global Exposure,” *New Indian Express*, (November 18, 2015).
- “Berkeley Haas becomes 28<sup>th</sup> school in Yale’s Global Network,” *Financial Times*, (November 5, 2015).
- “How Yale is beginning to crack into the elite B-school ranks,” *Fortune*, (December 17, 2014).
- “Businessweek’s 2014 Winners and Losers,” *Poets and Quants*, (November 14, 2014).
- “Is Michigan State Really Better Than Yale?,” *New York Times*, (August 7, 2012).
- “Yale Redefines What It Means to Be Global,” *Wall Street Journal*, (June 7, 2012).
- “Can ‘Ted’ Snyder Work His Magic on Yale’s School of Management?”, *Poets & Quants*, (February 8, 2012).
- “Yale’s Big, Audacious Global Bet,” *Poets and Quants*, (February 8, 2012).
- “Q&A with Edward Snyder, Dean, Yale School of Management” *Business Standard, Mumbai*, p. 12, (November 8, 2011).
- “If You Get the People Right, They Build the School,” *Financial Times*, (October 17, 2011).
- “Turnaround Specialist to Take on Yale,” *Wall Street Journal*, (June 3, 2010).
- “The Subtle Strategist,” *Financial Times*, (April 11, 2010).

- “Student ≠ Customer,” *Nytimes.com, Room for Debate*, (January 4, 2010).
- “2016 Olympics,” *Chicago Tribune*, (September 17, 2009).
- “The Party’s Over: The Coming Business School Shake-out,” *BusinessWeek.com*, (April 2, 2009).
- “Global Learning for a Truly Integrated MBA,” *Financial Times*, (February 19, 2009).
- “Driven Mad by Traffic Congestion,” *Business Week Chicago*, (April 2008).
- “The Market’s Place,” *Chicago Tribune*, (August 12, 2007).
- “Advocating a Carbon Tax,” *CNBC Europe*, (February 19, 2007).
- “Are B-Schools Slacking Off?” *Business Week*, (February 11, 2007).
- “The Quiet American?”, *Global Focus*, Vol. 1, No. 2, (2007).
- “Dean’s Column: The Toughest and the Best Advice,” *Financial Times*, (May 15, 2006).
- “On MBAs,” *Financial World*, London, (September 2005).
- “Are Business Schools Becoming Global,” *India Times*, (August 2005).
- “Global Challenge,” *The Guardian*, London, (August 4, 2005).
- “Vigorous Competition Better than any Oath,” *Handelsblatt.com*, (September 4, 2003).
- “Playing the Game the American Way,” *Budapest Business Journal*, (July 9, 1993).
- “An English Reform of American Law,” *Wall Street Journal*, (August 9, 1991).

Business School Cases and Class Materials:

- “Alternative Tools to Influence Market and Non-Market Behavior.”
- “W.R. Grace Co.’s Zonolite Licensee Program: How to Exploit Two Related Monopolies and Improve Economic Efficiency.”
- “Job Risk.”
- “Pricing Decisions: Custom Limousines.”
- “The Choice of Technologies.”
- “Mimicking the S&P 500.”

“Human Capital, Work, and Leisure.” Co-author: Scott E. Masten.

“Sugar Quotas.” Co-author: Edward J. Mitchell.

## GRANTS AND FELLOWSHIPS

Grants from University of Virginia Darden School’s Batten Institute and University of Chicago Booth School of Business for major extension of previous research, 2009-10. Resulted in “Napsterizing Pharmaceuticals: Access, Innovation, and Welfare” (January 2011).

Grants from Aventis Pharmaceuticals, University of Chicago Graduate School of Business, University of Virginia Darden School, and Bates College 2000-01. Resulted in “Napsterizing Pharmaceuticals: Access, Innovation, and Consumer Welfare,” NBER Working Paper (October 2002).

BT Grant of funds and equipment to the University of Michigan Business School to deliver educational modules using new technologies (November 1995).

U.S. Department of Treasury Grant to the Davidson Institute to study bank privatizations in Central Europe and Russia. Co-investigator: Roger C. Kormendi (June 15, 1995 – December 31, 1995).

Bradley Foundation Grant to study contract mechanisms to protect non-patentable innovations. Co-investigator: Scott E. Masten (July 1, 1989 - June 30, 1990).

RGK Foundation Grant to study contract mechanisms to protect non-patentable innovations. Co-investigator: Scott E. Masten (July 1, 1989 - June 30, 1990).

University of Michigan Office for the Study of Public and Private Institutions Research Grant to study contract mechanisms to protect non-patentable innovations. Co-investigator: Scott E. Masten (Summer 1989).

Robert Wood Johnson Foundation Grant to study the effects of tort reforms on medical malpractice litigation. Co-investigator: James W. Hughes (June 1, 1987 - December 31, 1988).

Earhart Foundation Grant to study the effects of the Supreme Court's *Brunswick* decision on private antitrust litigation (Summer 1986).

University of Michigan Business School Summer Research Grants to study private and public antitrust enforcement and other law and economics issues (1984, 1985, 1989, 1990, 1992, and 1993).

University of Chicago, Committee on Public Policy Studies Fellowship (1978).

## INVITED PAPERS, CONFERENCE PRESENTATIONS, PUBLIC TESTIMONY\*

\* In this section I include information regarding my testimony and briefings in public settings. Please refer to [edwardasnyder.com](http://edwardasnyder.com) for information regarding my consulting testimony in various litigations.

- “Global Innovation: China and the World,” Remarks at Fortune Brainstorm Tech International panel, (December 5, 2017).
- “The Anti-Globalization Narrative: Implications for Business Schools”, Keynote speech at Deusto Business School’s Centenary Celebration, (January 17, 2017).
- “The Anti-Globalization Narrative”, Keynote speech at the 6<sup>th</sup> International Business School Shanghai Conference, hosted by Antai College of Economics and Management, Shanghai Jiao Tong University, (October 17, 2016).
- “Crafting Strategic Relationships”, panel at the 2016 AACSB International Conference and Annual Meeting (ICAM) (with Kai Peters, Chief Executive, Ashridge Business School), (April 5, 2016).
- Remarks at the Yale Law School’s Corporate Law Center Advisory Board Dinner, (March, 8, 2016).
- “Global Antitrust Enforcement”, Keynote at the Annual New York Antitrust, New York State Bar Association (NYSBA), (January 28, 2016).
- “Past, Present, and Future of Business Education”, Keynote speech at Fudan University School of Management’s Partnership Deans Gathering, (November 5, 2015).
- Keynote Speaker at the 6<sup>th</sup> Indian Management Conclave, (July 29, 2015).
- “Globalizing Business Schools: The New Frontier”. Closing Keynote speech at the Graduate Management Admission Council (GMAC) Leadership Conference, Fort Lauderdale, Florida, (January 24, 2014).
- Keynote Speaker at The Rotman School’s Future of Business Education Conference, Toronto, Canada, (November 5, 2013).
- “American Law and Economics Association, invited paper (with Pierre Cremieux), “Antitrust Enforcement in the EU and US: An Empirical Assessment of the Influence of Protectionism”, Vanderbilt University Law School, (May 17, 2013).
- “Emerging Markets and Business School Strategies”. Invited moderator, International Conference and Annual Meeting for The Association to Advance Collegiate Schools of Business, (April 9, 2013).
- “Turkey as a Pivotal Country in the Global Economy”. Presentation to DEİK, Foreign Economics Relations Board, Istanbul, Turkey, (November 30, 2012).
- “Management Challenges in the Global Economy”. Presentation to faculty, students and staff at Renmin University of China School of Business. Beijing, China. (March 2012).
- “The Management Education Industry.” AACSB Annual Deans Conference Plenary Session with Deans Christine Poon, Joseph Thomas, and Andrew Policano) Phoenix, Arizona, (February 20, 2011).
- “U.S. Business Schools and the MBA: A Long Perspective.” EFMD Annual Meeting of Deans and Directors, Lyon, France, (January 25, 2011).

- “Proof of Common Impact in Antitrust Litigation: The Value of Regression Analysis.” George Mason 13th Annual Symposium on Antitrust Law, February 4, 2010; Analysis Group Seminar, New York, NY, (October 20, 2010).
- “Digging Out of the Deficit.” Executive Roundtable Panel Discussion with Governors Tim Pawlenty (MN), Donald Carcieri (RI), Mark Sanford (SC), Robert McDonnell (VA), and John Kasich, Candidate for Governor (OH), Cincinnati, Ohio, (September 20, 2010).
- “Corporate Governance.” Inside Counsel’s 10<sup>th</sup> Annual Super Conference, invited panel. Chicago, IL, (May 25, 2010).
- “The Future of §2 Enforcement.” Antitrust Section of the New York State Bar Association, Annual Meeting, (January 28, 2010).
- “Global Antitrust Enforcement.” Center for Public Studies, Santiago, Chile, (September 2009).
- “Globalization of Management Education.” Plenary Speaker at AACSB Annual Deans Conference, San Francisco, CA, (February 5, 2009).
- “The Role of Economic Experts in Class Certification in the United States.” The American Bar Association Section of Antitrust Law Trial Practice Committee, (June 17, 2008).
- “How to Use Economics.” Illinois Agricultural Leadership Seminar. Chicago, IL (August 2006).
- “Are Business Schools Becoming Truly Global?” with Dean Santiago Iñiguez. AACSB Dean’s Conference, San Diego, CA, (February 6, 2006).
- “Strategic Choices in a Global Environment.” Presentation with Dean Santiago Iñiguez. European Foundation for Management Development Deans’ Conference, Rotterdam School of Management, The Netherlands, (January 26, 2006).
- “How to Use Economics.” Distinguished Alumni Presentation, Colby College, (October 2005).
- “Hatch-Waxman and Public Policy Toward Pharmaceuticals.” Presentation at Summer 2002 Conference for Western Attorneys General (2002).
- Congressional Briefing, “Hatch-Waxman Reconsidered: How Best to Promote Prescription Drug Innovation and Affordability,” sponsored by the Alliance for Health Reform and supported by the National Institute of Health Care Management, (June 13, 2002).
- Combined Federal Trade Commission and Department of Justice Hearings on Competition and Intellectual Property Policy. Presentation of testimony on Hatch-Waxman and Public Policy Toward Pharmaceuticals, (March 2002).
- Graduate Business Conference, Johnson Graduate School of Management, Cornell University, invited panel, The Future of Management Education, (March 2001).
- “Economics and Government Policy.” Panel Discussion with Edward P. Lazear, Randall S. Kroszner, and Lawrence H. Summers, Honoring Gary S. Becker: A Conference, Chicago, IL, (February 11, 2001).

New York State Bar Association, invited panel on Indirect Purchaser Litigation in Antitrust, New York, NY, (January 2001).

University of Virginia, E-Summit's Plenary Session, (November 1999).

European Association of Comparative Economics, Annual Conference, invited panel, Bank Privatization, Grenoble, France, (September 1996).

University of Chicago, Conference on Tort Reform, Commentator for Steven Shavell, (June 1996).

U.S. Department of Treasury, Davidson Institute, "Banks in Transition: Investment Opportunities in Central Europe and Russia," New York City, (May 1996).

U.S. Department of Treasury, Davidson Institute, "Bank Privatization in Central Europe and Russia," Budapest, (April 1996).

American Law and Economics Association, invited paper (with Greg Niehaus), "Damage Schedules in the Products Liability System and the Efficiency of Consumption Choices," (May 1994).

American Economics Association, invited paper (with James W. Hughes), "Litigation under the English and American Rules: Theory and Evidence," (January 1994).

University of Michigan Presidential Forum on *Constituting International Expertise: Who, What, Where Why, How?*, "Transitions in Expertise," (October 1993).

American Law and Economics Association, invited paper (with James W. Hughes), "Litigation under the English and American Rules: Theory and Evidence," (May 1992).

Western Economic Association, 100 Years of the Sherman Act, invited paper (with Thomas E. Kauper), "Misuse of the Antitrust Laws," (June 1990).

Western Economic Association, Applied Microeconomics, invited paper, "Aftermath of the *Sealy* Antitrust Litigation," (June 1990).

Law and Society Association, invited paper (with James W. Hughes), "The English Rule for Allocating Legal Costs: Evidence Confronts Theory," (June 1989).

Duke University, Conference on the Law and Economics of Contracting, invited paper (with Scott E. Masten), "The Design and Duration of Contracts: Strategic and Efficiency Considerations," (April 1988).

U.S. Senate Banking Committee, testimony based on research paper ("The Origins and Resolution of the Thrift Crisis"), (February 1988).

Georgetown University, Conference on Private Antitrust Enforcement, invited paper (with Thomas E. Kauper), "An Inquiry into the Efficiency of Private Antitrust Enforcement," (November 1985).

Hoover Institution, Conference on Antitrust and Economic Efficiency, invited paper, "Efficient Assignment of Rights to Sue for Antitrust Damages," (August 1984).

## SEMINARS AND OTHER PRESENTATIONS

Yale School of Management

Problems with Global Antitrust Enforcement (2/16).

Vanderbilt Law School, American Law & Economics Association (5/13).

University of Chicago

Applied Price Theory Workshop (4/84, 10/84, 10/02).

Economics and Legal Organization Workshop (10/90, 1/92, and 5/92).

University of Virginia, e-Summit (11/99).

U.S Treasury (2/96).

Davidson Institute Research Seminar Series (4/95).

University of Michigan, Center for Chinese Studies (10/94).

Young Presidents Organization, Asia Region Meetings (2/94).

Confederation of Indian Industries, CEO Forum (2/94).

Harvard University Law School, Law and Economics Seminar (4/93).

George Mason University Law School, Law and Economics Seminar (10/92).

University of Illinois, Industrial Organization Workshop (4/92).

Georgetown University Law School, Law and Economics Workshop (11/91).

Cornell University Law School (4/91).

University of Southern California, Applied Micro Workshop (10/90).

University of California at Los Angeles, Industrial Organization Workshop (10/90).

Virginia Polytechnic Institute, Economics Department Seminar (11/89).

Ohio State University, Industrial Organization Seminar (5/88), Microeconomic Theory Workshop (10/86).

Federal Trade Commission (10/88, 10/92).

Western Economic Association (7/87, 7/88, 6/90, and 7/96).

Duke University, Center for the Study of Business Regulation (11/86 and 12/92).

Colby College (5/85, 2/92, 3/96).

U.S. Department of Justice, Antitrust Division (5/85, 5/86, 5/87, 11/89, and 5/91).

Washington University, Industrial Organization Workshop (3/85).

University of Michigan,

Industrial Organization Workshop (2/84, 4/85, 9/86, 1/88, and 3/88).

Law and Economics Seminar (10/89, 4/90, and 1/92).

#### PH.D. THESIS COMMITTEE SUPERVISION

Alowin M. Th. L. Moses, “A Model of Voucher Privatization” (University of Michigan, 1996).

Vijay Singal, “Efficiency Versus Market Power in Mergers: Evidence from the Airline Industry” (University of Michigan, 1992).

David E. Weinstein, “Essays on Japan's Trade and Industrial Structure” (University of Michigan, 1991).

Debra J. Holt, “Understanding Strategic Choice: The Statistical Analysis of Experimental Games” (University of Michigan, 1990).

David J. Denis, “Asymmetric Information and the Market for Seasoned Equity Offerings: Theory and Evidence” (University of Michigan, 1988).

Amy J. Broman, “The Impact of Federal Income Tax Policy on the Charitable Contributions Behavior of Households” (University of Michigan, 1987).

James W. Hughes, “Tort Reforms and Medical Malpractice Litigation” (University of Michigan, 1986).

Barton L. Lipman, “Delaying or Deterring Entry: A Game-Theoretic Analysis” (University of Michigan, 1985).

#### OTHER

Trustee, Colby College

International Advisory Committee, School of Business, Renmin University of China

Member of American Law and Economics Association

Member of the Committee for Economic Development of the Conference Board (CED)

Member of MIT Corporation Visiting Committee for the Sloan School of Management

Member of the 3<sup>rd</sup> Advisory Board of Antai College of Economics and Management, Shanghai Jiao Tong University (Term: November, 2015 to October, 2018)

Chair or Member of AACSB Accreditation Review Committees, including University of

California Berkeley (Haas), University of California Los Angeles (Anderson), MIT Sloan, Wharton, Columbia Business School, Georgetown (McDonough), HEC Paris, Fudan School of Business, and Stanford GSB.

**APPENDIX B**

**EDWARD A. SNYDER  
RECENT EXPERT TESTIMONY**

1. United States District Court, Northern District of California  
*In re: Transpacific Passenger Air Transportation Antitrust Litigation*, Master File No. C 07-05634 CRB, MDL No. 1913  
Report and deposition 2018
2. United States District Court, District of New Jersey  
*In Re: Lamictal Direct Purchaser Antitrust Litigation*, Master File No. 12-cv-995-WHW  
Report and deposition 2018
3. United States District Court, Middle District of Florida  
*In re: Disposable Contact Lens Antitrust Litigation*, Case No. 3:15-md-2626-J-20JRK  
Reports and depositions 2017 & 2018
4. United States District Court, Eastern District of Virginia, Richmond Division  
*Steves and Sons, Inc. v. JELD-WEN, Inc.*, Case No. 3:16-cv-00545-REP  
Reports, deposition, hearing, and trial testimony 2017 & 2018
5. United States District Court, Northern District of California  
*In re: Optical Disk Drive Products Antitrust Litigation*, Master File No. 3:10-cv-2143-RS; MDL No. 2143  
Reports and depositions 2017
6. United States District Court, Northern District of California  
*Cathode Ray Tube (CRT) Antitrust Litigation*, Master File No. 07-5944-SC, MDL No. 1917  
Reports and depositions 2014
7. United States District Court, Eastern District of Pennsylvania  
*King Drug Company of Florence, Inc. et al., v. Cephalon, Inc., et al.*, Case No. 2:06-cv-1797; *Vista Healthplan, Inc., et al., v. Cephalon, Inc., et al.*, Case No. 2:06-cv-1833; *Apotex, Inc., v. Cephalon, Inc., et al.*, Case No. 2:06-cv-2768; *Federal Trade Commission, v. Cephalon, Inc.*, Case No. 2:06-cv-2141  
Reports and depositions 2011 & 2014
8. United States District Court, District of Massachusetts  
*Kirk Dahl, et al., v. Bain Capital Partners, LLC, et al.*, Case No. 07-cv-12388-WGY  
Reports and depositions 2014
9. United States District Court, Northern District of California  
*TFT-LCD (Flat Panel) Antitrust Litigation*, Master File No. M-07-1827-SI, MDL No. 1827  
Reports, depositions, and trial testimony 2013 & 2014