Intel Corporation – Intel Labs Europe: Open Innovation 2.0

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ABSTRACT

Around the world, the name Intel is synonymous with personal computers. Since the early 1980s nearly all personal computers, and more recently servers, are designed with a microprocessor based on Intel's x86 architecture. Over the last decade, however, the industry has seen many changes, and current trends send strong signals to Intel that it must continue the evolution of its own internal corporate innovation process—one that has driven Intel's success for many years—or suffer potential negative consequences.

The reality is that for almost 40 years, personal computers have remained relatively the same; all had the same open modular architecture originally designed by IBM in the early 1980s. However, the past few years have seen a wave of evolution that includes embedded computing driven by the growth of digital devices like tablets and smartphones.

These changes are of major importance to Intel. Instead of using the workhorse standard x86 processor, digital devices today have a chipset optimized for that device's specific application. This hardware change is further complicated by the shift to cloud computing and data centers. Change within the semiconductor industry, and specifically for Intel, is requisite and inevitable.

Today, the firm is investing heavily in its future. Part of this investment is an initiative called Open Innovation 2.0, undertaken in Ireland under the umbrella of Intel Labs Europe. This innovation demonstrates Intel's commitment to evolving its corporate innovation processes to meet the needs of today's customers as well as future customers, markets, and industries. It must be said, however, that some technology-based innovation luminaries and academics believe Open Innovation (OI) is nothing new but merely the latest repackaged fad in innovation.

In this thesis I evaluate how Intel developed its OI initiative and then assess the levels of success achieved to date and planned for the future. History will show if OI is a useful innovation tool and whether Intel can maintain its reputation in the volatile field of digital computing.

Thesis Supervisor: John Van Maanen
Title: Erwin H. Schell Professor of Management

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To my partners in the thesis experience — Julian Andres Herman Rodriguez, Kan Yamamoto and Isaac Cronkhite—what a journey. Finally to Gil Maria Campos, You Me Ko, Mitsou Kosaka, Sophia Dhas, and Bob Little, thank you for showing me day after day that giving to others and serving a greater good is truly the right path we should all work hard to attain.

I owe enormous thanks to my wife, Angela. She has been more than supportive during my time at MIT as a Sloan Fellow. I am truly blessed to have her in my life, along with our wonderful daughter, Audrey Jane.

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Finally, I would like dedicate this year to my mother, Jane, and the memory of my father, D.W. (Jack), who taught me how to persevere in the worst of times, to always value knowledge, and always strive to be the best person I can be.

Thomas W. Mills
Cambridge, MA
May 8, 2015

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CHAPTER 1

INTRODUCTION

The seed for this research grew out of a 2009 MIT case study on the subject of corporate innovation process, authored by Rebecca M. Henderson.[1] She was working with Corning Inc., where she was part of the collaborated effort with the firm's executive management to develop a corporate product innovation process for Corning.

At the time Henderson conducted her research, I was working at Corning as a program director in the office of the chief technology officer. As her work continued, the combination of industry and academic best practices inspired me to spend a year as an MIT Sloan Fellow, where I dove deep into the academic side of technology innovation while researching best practices and processes for technology-driven *Fortune 500* corporations.

Research and data collection were coordinated under the auspices of Intel Corporation, Intel Labs Europe, and my sponsor Martin Curley (Vice President, Intel Labs Director, Intel Labs Europe, and Senior Principal Engineer). I conducted an extensive literature review of academic and business publications and journals. I also interviewed key business and engineering professionals at Intel Corporation as well as faculty at MIT (see Appendix A for a list of interviews).

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[1] "Corning Inc.: The Growth and Strategy Council," #08-056.

1.2 THESIS STRUCTURE

Chapter 1 - Summarizes the idea behind the research and interest in corporate innovation.

Chapter 2 - Summarizes the literature review in order to convey an understanding of the basics of technology innovation. It provides a background into how academics define and set best practices in the product innovation process, and concludes with a summary of literature that discusses several open innovation frameworks.

Chapter 3 - Shares a brief summary of the semiconductor industry, highlighting its business dynamics, business models, and product categories.

Chapter 4 - Maps the history of Intel innovation and how Intel became one of the most important technology companies in the world.

Chapter 5 - Introduces the story of Intel's Open Innovation Initiative. I use the case-study approach to highlight the complexity in this real-life example of how Intel Labs Europe not only uses best practices but also leverages Open Innovation to harness and direct its future product innovation process.

Chapter 6 – Presents an argument for Intel's continued use and growth in using Open Innovation as a competitive advantage.

Chapter 7 – Concludes the thesis research with recommendations for future options for Intel Labs Europe OI2 initiative.

CHAPTER 2

A REVIEW OF INNOVATION

History has shown that even successful and established companies sometimes lose their "edge" when it comes to realizing the timely need for or development of radical product innovation. Instead, they focus on processes to optimize business rather than exploring possibly disruptive but necessary innovative solutions. At the same time, those companies seek to stay ahead of their competitors and to meet the expectations of Wall Street and the company's shareholders.

One definition of innovation is a new idea and or a more effective device or process. According to Schumpeter (1934), the "process of creative destruction" (p. 37) allows incumbents to hold monopoly power only temporarily until a more innovative product or service—usually delivered by fresh entrants—disrupts the market and replaces the incumbent. Even large firms find that they must embrace "creative destruction" or disappear.

A prime example of innovation is the explosive boom of Silicon Valley startups in the Stanford (California) Industrial Park. Beginning in 1957, employees left one company behind, taking with them their own unique ideas to build new enterprises Then employees from those firms left to start their own companies. Over the next several decades, this snowball process launched the momentous growth of the information technology (IT) industry.

Three key words define innovation: newness (or novelty), adoption, and value. Of course, an idea does not have to be completely new, just new to a user, organization, focus area, or society. Many successful innovations are adaptations of existing ideas, products, or services that have already been adopted and become successful in some other sphere. Innovation is also about value creation, and unless value is sustained, innovations will fall away. Knut Holt (1978) said: "Innovation is the fusion of a user need and a technological opportunity. Ultimately there is only successful innovation when a user, organization and society perceives and receives value" (p.52). Morten Hansen and Julian Birkinshaw (2007:1) describe the process of innovation as going through three phases: idea generation, idea development, and the diffusion of developed concepts. Most innovations fail in the diffusion or adoption phase.

2.1 LITERATURE REVIEW

It would be impossible to track and understand every single innovation introduced in the last 50 years. Fortunately, there is an established body of academic work that can help one to understand the intricacies of innovation. I will discuss some of the preeminent theories below, which I also will apply to my research on innovation at Intel.

2.1.1 Three Phases Of Innovation

William Abernathy and James Utterback (1978) developed what is today regarded as one of the most important models for framing innovation. Known simply as the Abernathy-Utterback model (see Figure 1-1), it characterizes industry innovation as going through three successive phases: the fluid phase, the transitional phase, and the specific phase.

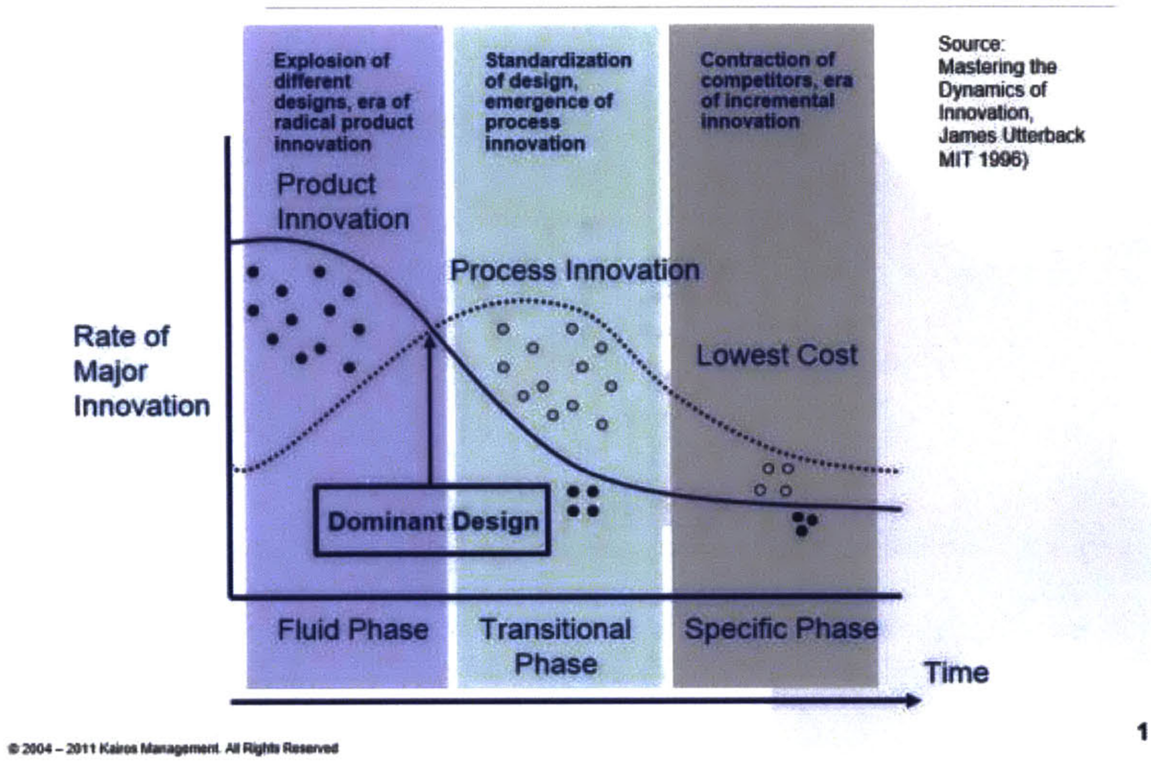

Figure 2-1. Utterback's Three Phases of Innovation

Source: httpl://kairosmanagement.files.wordpress.com/2013/12/utterback-v2.jpg

During the Fluid Phase, product design and operational characteristics experience enormous experimentation, many questions, and considerable contention even while the process remains relatively untouched. In general, high-technology companies are more caught up in understanding and designing what customers will buy than in the process of how the product will be manufactured.

Eventually, the Fluid Phase gives way to the Transitional Phase, where the product becomes standardized due to market forces, but the evolution of the process for making that product changes greatly. Standardized products emerge that often combine several technologies in unique ways.

At this point, an industry may enter the Specific Phase, where both the speed of product and process innovation slow, and the industry becomes stable. Because the company is producing a product that is considered a dominant design, the firm can now focus on driving costs down and scaling operations to increase unit volume and capacity instead of embarking on costly development programs in an attempt to increase performance.

The Abernathy-Utterback model recognizes that the three phases strongly influence the structure of a technology-based organization. For example, individual entrepreneurship is common in the Fluid phase, while project teams and task groups are more common in the Transitional phase. Companies in the Specific phase are characterized by highly structured and rigid organizational structures.

The product(s) that emerge from this process often become dominant designs, typically created by combining several technologies together in a unique way, and the outcome of all the product innovation(s) that occurred in the fluid phase. By definition, a dominant design "wins the allegiance of the marketplace" (e.g., Microsoft Windows, automobiles with combustion engines), and once it emerges, such a design makes it increasingly difficult for firms to compete solely through product differentiation. Taking the automobile example, its dominant design was the internal combustion engine, and all the standard features on cars today (e.g., windshield wipers, electric starters, seatbelts) are dominant designs (Utterback, 1994). It is important to note that a dominant design is not necessarily the product with the highest performance or greatest amount of functionality. It is determined by a combination of technological and market forces, but also influenced by factors such as standards, regulations, and government influence.

2.1.2 Disruptive Innovation

Taking a different perspective on innovation, Clayton Christensen discusses "low-end disruptive innovation" in his book *The Innovator's Dilemma* (1997). He describes a framework where incumbent organizations (such as Intel), that are well into the Specific phase, make all the correct business decisions yet are still overtaken by smaller companies or lower-performing technologies.

The concept of disruption is complex, but it begins with understanding that products with unique enabling technologies have performance vectors. These lines start to vector upward, but over time their slope flattens as the performance of competitive products improves year after year. High-technology product examples include: new generations of semiconductors with more transistors; hard drives with added storage; projection systems that output more lumens, and so on. Companies increase revenue, market share, and stock price when these lines continue to vector upward—and when the market and/or customer pull is driven by product performance. Increasing product performance allows companies to expand into new market segments and regions while reaping the benefits of having performance advantages over their competitors.

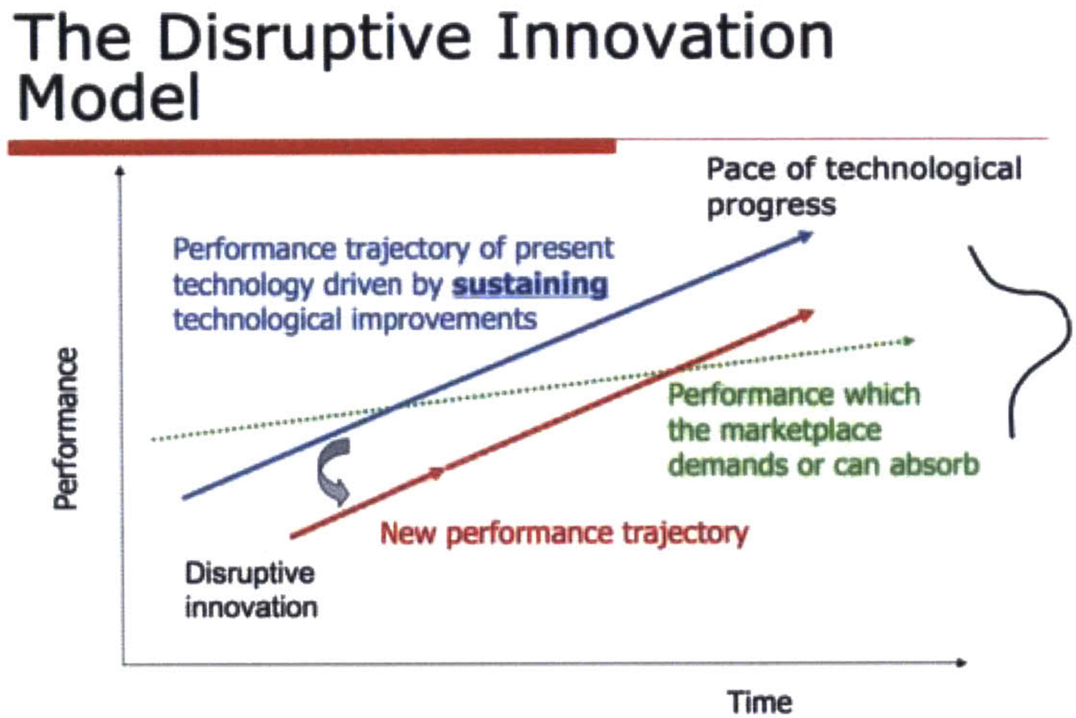

Figure 2.2 Christensen's "low-end disruptive innovation" model

Source: Christensen, p. xvi.

This brings us to Christensen's idea behind disruption: the market supply of performance can overshoot customer demand. Christensen points out how product performance can actually outpace the performance realistically required or even sought by the customer. Although there are plenty of demands for faster operating systems and software, sometimes users find they just do not need a new version of a high-performance technology, such as a new ultrabook laptop, if, for example, all they want to do is edit a document or read e-mail. Certain applications, like video and voice technology, help increase market demand for higher-performance semiconductors, but in the end today's chips are often a case of overkill in some of today's applications.

Innovation disruptions sometimes catch companies by surprise; nevertheless, such disruptions can be difficult to avoid even if they are seen coming. The reason for this is the value network, which establishes feedback mechanisms to keep companies focused along existing performance vectors. For this reason, innovation disruptions can be very dangerous to incumbent firms.

2.1.3 Open Innovation

The term "open innovation" refers to the use of both inflows and outflows of knowledge to improve internal innovation and expand markets for external exploitation of innovation (Cheng and Huizingh, 2014). Open innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas to create internal and external paths to market as the firm seeks to advance it technology. Alternatively, it is innovating with partners by sharing risk and sharing reward (Chesbrough, 2003). The boundaries between a firm and its environment become more permeable, allowing innovations to easily transfer both inward and outward.

Henry Chesbrough's book, *Open Innovation* (noted above), discusses the new imperative for benefiting and profiting from technology commercialization based on open innovation. He believes that companies are increasingly rethinking the fundamental ways they generate ideas and bring them to market, harnessing external ideas while leveraging in-house R&D outside their current operations.

He observes paradigm shift from closed to open innovation. In a closed model, successful innovation requires control. He defines open innovation as "a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology" (Chesbrough, 2003: 93) In a world of distributed knowledge, the paradigm stipulates that innovation should move more freely into and out of the company. A company cannot rely entirely on its own R&D and should buy or license innovation from others. Moreover, innovations that are not useful to the company should be taken outside the company through licensing, joint ventures, or spinoffs. Innovation networks can include users, rival companies, and academic institutions.

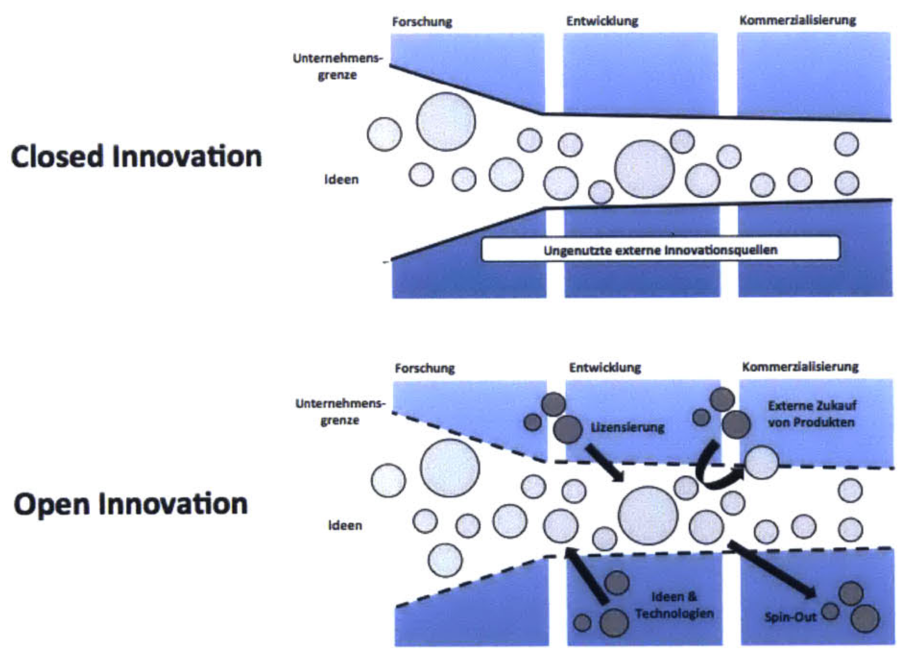

Figure 2-3 Open vs. Closed Innovation

Source: Chesbrough, p.31.

Chesbrough cites the example of Xerox PARC, which produced a number of high-potential technologies (e.g., GUI interfaces using a mouse, Ethernet) which Xerox management ultimately deemed unusable because they did not fit the company's business model. Some of these innovations were subsequently sold either to growing Silicon

Valley high-technology firms (such as Apple) or spun off by PARC engineers. These examples illustrate the potential loss of value, both for the company and for shareholders because there were no processes in place to harness and manage promising technologies.

Eric von Hippel offers another viewpoint in the democratization of innovation. When innovation is being democratized, users of products and services—both firms and individual consumers—are increasingly able to innovate for themselves. User-centered innovation processes have a number of advantages over manufacturer-centric innovation development systems, which have been the mainstay of commerce for years. Users that innovate can develop exactly what they want rather than rely on manufacturers to act as (often very imperfect) agents.

There are several highly publicized examples of how open innovation has met success. One of the more unique examples is from Citroen Car Company. Featuring the slogan "You like it, we make it," Citroen collaborated with Facebook on an app that sought public input into the design of a special edition of one of its popular vehicles. The app was launched in April 2012, and Citroen urged the 81,000 members of its Facebook community to participate. They were asked to determine the model's look, equipment, and details from among a range of possibilities. This included options for the number of doors, interior and exterior colors, and communications equipment including a satellite navigation system. This virtual automobile designer application was available online for just one month, but over 24,000 configurations were submitted (Grobler, 2012).

Another example of open innovation is Lego, the maker of colourful, interlocking plastic bricks. The company has an online open innovation platform that lets members of the public submit product ideas which, if they come to market, will give them a percentage of the sales royalties. Users can create a page outlining their new concept and then share it with others to see what they think. Once the project receives 10,000 supporters, it is reviewed by the Lego team to see if it meets the company's standards for playability, safety, and support of the Lego brand. If these criteria are met, then Lego will move forward with production (Grobler, 2012).

CHAPTER 3

THE SEMICONDUCTOR INDUSTRY

The semiconductor industry has changed the world in more ways than perhaps any other industry. The pace of innovation in the semiconductor industry fuels today's world. The world would be lot slower without semiconductors. The semiconductor industry supplies to diverse markets: data processing, communications, consumer electronics, industrial accounts and the automotive industry. It is a growing industry. The global semiconductor industry achieved sales totaling $335.8 billion in 2014, a 9.9 percent increase from the 2013 total of $305.6 billion.[2]

The semiconductor industry has distinct characteristics that position it uniquely in the economy and in the global competitive arena:[3]

- *Key economic growth driver*: From a worldwide base semiconductor market of $213 billion in 2004, the industry enabled the generation of some $1,200 billion in electronic systems business and $5,000 billion in services, representing close to 10% of world GDP.[3]
- *High innovation and flexibility*: The semiconductor industry is marked by a fast pace of change: products with short life cycles, changing technology and constant price-performance improvements. Incumbents can lose their stronghold in a flash.[3]

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[2] See: <http://www.semiconductors.org/news/2015/02/02/global_sales_report_2014/ global_ semiconductor_industry_posts_record_sales_in_2014/>.

[3] Semiconductor industry. See <http://en.wikipedia.org/w/index.php?title= Semiconductor_ industry&oldid=653651179>.

- *Continuous growth with cyclical high volatility*: Semiconductor companies face constant booms and busts in demand for products. When times are good, companies like Intel and Toshiba cannot produce microchips fast enough to meet demand. When times are tough, it can be brutal. Slow PC sales, for instance, can send the industry—and its share prices—into a tailspin.

3.1 BUSINESS DYNAMICS

Market analysts categorize the semiconductor industry into the following product types: Discrete, Opto, Sensors, Analog, Micro, Logic, and Memory (see Figure 3-1).

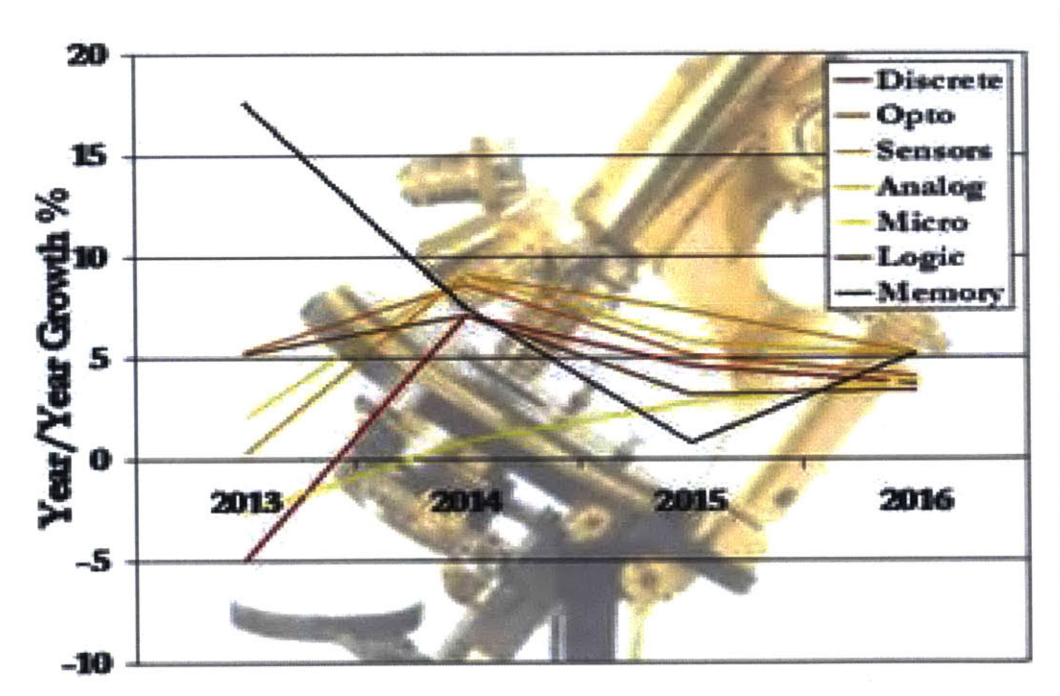

Figure 3-1: Year/Year growth of semiconductor market (%)

Source: <http://www.forbes.com/sites/jimhandy/2014/06/26/wsts-updates-semiconductor-forecast-325-billion-in-2014>.

Furthermore, semiconductors can be broadly divided into discrete semiconductor components and integrated circuits that connect these components to give enhanced functionality. To simplify things, I defined integrated circuits (ICs) into the following product categories: memory, microprocessors, and logic devices (see Figure 3-2).

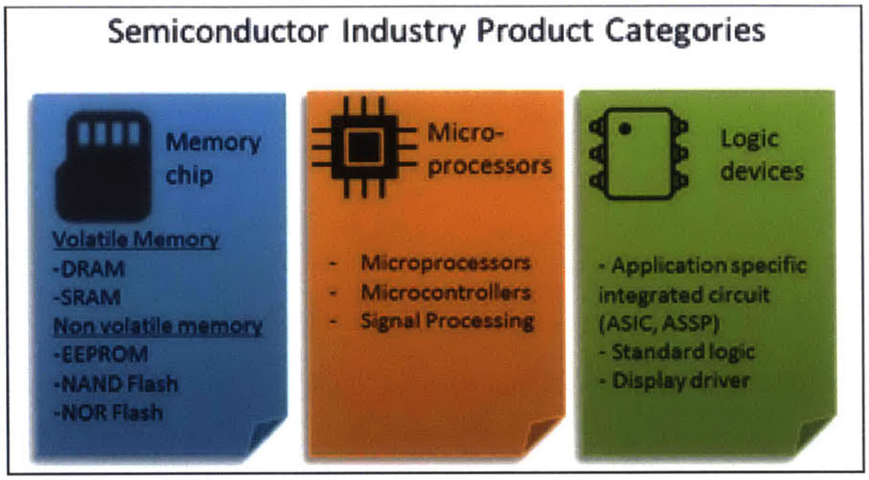

Figure 3-2: Semiconductor industry product categories

Source: <http://maltielconsulting.com/Semiconductor_Industry_After_Economic_Upheaval_maltiel_semiconductor.pdf>.

- **Memory**: Because of continuing consolidation in the memory market, memory prices are so low that only a few established long-term big players like Toshiba and Samsung have managed to stay in the game.
- **Microprocessors**: Intel leads the microprocessor segment. It has forced every competitor, except Advanced Micro Devices, out of the mainstream market.
- **Logic Devices**: The market grew at a CAGR of 12.9 percent over the period from 2012 to 2015. One of the key factors contributing to this market growth is the increasing focus on reducing power consumption. The market has also witnessed the increasing adoption of programmable logic devices in various sectors.

Revenues of some of the major companies in this industry are shown in the table below. For 23 consecutive years, Intel has maintained the number one market share position.[4]

Rank 2013	Rank 2014	Vendor	2013 Revenue	2014 Estimated Revenue	2013-2014 Growth (%)	2014 Market Share (%)
1	1	Intel	48,590	50,840	4.6	15
2	2	Samsung Electronics	30,636	35,275	15.1	10.4
3	3	Qualcomm	17,211	19,194	11.5	5.6
5	4	Micron Technology	11,918	16,800	41	4.9
4	5	SK Hynix	12,625	15,915	26.1	4.7
6	6	Toshiba	11,277	11,589	2.8	3.4
7	7	Texas Instruments	10,591	11,539	9	3.4
8	8	Broadcom	8,199	8,360	2	2.5
9	9	STMicroelectronics	8,082	7,371	-8.8	2.2
10	10	Renesas Electronics	7,979	7,249	-9.1	2.1
		Others	147,883	155,679	5.3	45.8
		Total	314,991	339,811	7.9	100

Figure 3-3: Revenue details of Top 10 semiconductor manufacturer (2013 and 2014)

Source: Gartner, 2015.

3.2 BUSINESS MODELS

In the old business model, semiconductor companies owned and operated their own research, design, testing, production, and manufacturing. However, as chips became faster, so did the sophistication of their circuitry. Companies needed to continually update machinery to keep up with production demands and newer circuits. As costs increased

[4] See: <http://www.gartner.com/newsroom/id/2955617>.

and competition grew fierce, many companies could not sustain both design and fabrication. This led to the adoption of different business models, as described below.

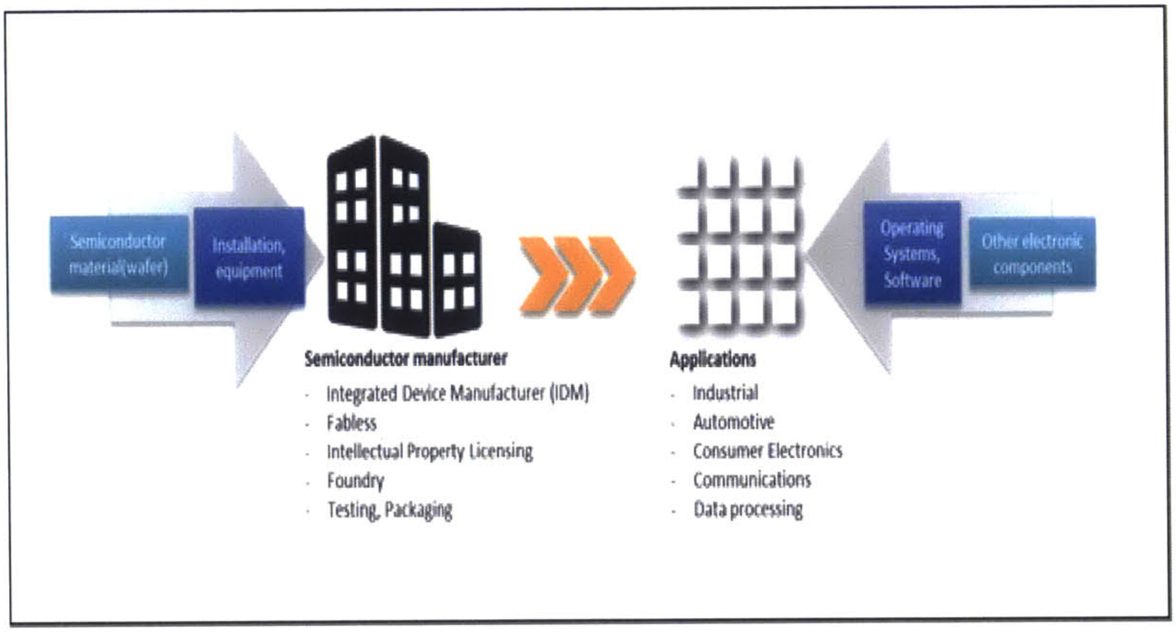

Figure 3-4: Semiconductor manufacturer business models

Source: <http://maltielconsulting.com/semiconductor_industry_after-economic-upheaval-maltiel-semiconductor.pdf>.

- **Integrated device manufacturer (IDM)**

  An IDM is a semiconductor company that owns the complete chain from fabrication to design, marketing and sales of ICs (e.g. Intel). Some IDMs (Integrated Device Manufacturers) such as IBM and Intel,[5] sell their unused production capacity to fabless companies.

[5] IDMs. See<http://en.wikipedia.org/w/index.php?title=Integrated_device_manufacturer&oldid=660264118>.

- **Fabless**

  A fabless is a semiconductor company that uses all its resources for designing, marketing, and sale of its devices. Production of those devices is outsourced to manufacturers called *fabs* or *foundries.*

- **Foundries**

  They manufacture devices for fabless companies. These fabs focus solely on handling bulk orders that came from fabless businesses.

- **Silicon intellectual property**

  Silicon Intellectual Property (SIP or Silicon IP) is a business model where the company licenses its technology to a customer as intellectual property. This type of semiconductor company is fabless. It does not provide physical chips to its customers but offers certain functional blocks/IPs to help the customer with the development of its chips. The most successful Silicon IP companies include ARC International, ARM Holdings, Rambus, and MIPS Technologies.[6]

- **Back-end processing**

  There are strong ecosystem of companies that focus on the back-end processing like testing, characterization and packaging.

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[6] See: <http://en.wikipedia.org/wiki/semiconductor_intellectual_property>.

CHAPTER 4

INTEL'S HISTORY OF INNOVATION

Intel is the world's leading semiconductor chip maker and the inventor of the x86 series of microprocessors—the processors found in most personal computers and servers that shaped the PC ecosystem. Intel's success is attributed to the genius of its visionaries, as well as its marketing and pricing strategies that set trends not just for product innovation but also business innovation and a commitment to its philosophy (based on Moore's Law) that made it a pioneer in two of the building blocks of modern technology: memory chips and microprocessors.

As portrayed by Malone (2014), the Intel story had its beginnings in 1957 when a handful of employees at Shockley Transistor Company quit their jobs to strike out on their own. Robert Noyce and Gordon Moore were among them, and their new company was Fairchild Semiconductor. It was not long before the world would witness the disruptive power of this young team. By 1958, they produced and shipped their first transistor, the 2N696 double-diffused-base transistor which was a breakout technology. With this invention, Fairchild became not just a major player but the leader in the transistor industry because their product instantly rendered almost every other transistor in the industry obsolete.

Fairchild leadership firmly believed in an aggressive product development process and a vision of market dominance. They believed in getting their transistors built and bring them to market quickly. They also believed in finding new low-cost ways of fabricating transistors to improve profitability.

Malone (2014) also captured the culture at Fairchild under Robert Noyce, who was known for his innovative experimentation and explorative techniques, such as setting teams in competition with each other to drive alternative solutions or innovative fabrication processes.

It was not just his management prowess that he was known for. In 1959, Fairchild's rival, Texas Instruments (TI), announced its pending patent for a new type of multiple-transistor device: a complete circuit on a single chip. This threatened to make Fairchild's 2N697 planar transistor obsolete. But Noyce produced his own solution to the transistor miniaturization problem—the integrated circuit. His design had more advantages than TI's design, could be manufactured in huge volume at a low price, and was functionally reliably in the real world. As we now know, the integrated circuit changed everything, dooming the transistor industry, as transistors would never again dominate the tech world. TI lost the battle to Fairchild.

Shortly after production began, in a major strategic move, Noyce licensed the technology to the semiconductor manufacturing companies that Fairchild had just edged out when Fairchild's new product made every other transistor obsolete. This helped Fairchild earn revenues not just from its transistors but also from licenses.

Noyce was indifferent to corporate hierarchies and the trappings of power. That created a level work environment at Fairchild that had few precedents in American business (Malone, 2014).

In 1968 Noyce and Moore left Fairchild to start Intel Corporation, a portmanteau for integrated electronics. As a young company, Intel was determined to manufacture low-cost, mass-produced semiconductor memory devices.

4.1 PRODUCT HISTORY

4.1.1 SRAM and DRAM – Dominating Memory Markets

Intel had predicted that the older generation computer memory technology, the magnetic-core memory would be phased out with the introduction of newer, faster, more reliable, and more powerful semiconductor memory technology. Intel saw this as a major opportunity to replace the magnetic-core for read-only memory (ROM) and for random-access memory (RAM). (ROM was used to store the computer program's permanent data, whereas RAM was used as a temporary storage in computers.)

Intel's first product, released in 1970, was a memory chip called Static Random Access Memory (SRAM), a 64-bit memory chip that achieved speeds twice as fast as the Fairchild 64-bit SRAMs already on the market (Malone, 2014). Within a few years of its introduction, the magnetic core memory was completely obsolete. Intel then introduced a Schottky bipolar ROM, with an industry-leading 1024 bits, which was the highest capacity semiconductor memory at the time, soon followed by the 1101 SRAM, in the metal-oxide semiconductor (MOS) technology. MOS was not as fast as bipolar, but it made up for that limitation by being much easier to design and fabricate, and it could be made much smaller and denser. The existence of two separate manufacturing processes for the transistor was characteristic of the Intel product development philosophy under

Noyce. He set the MOS and bipolar teams in competition mode with each other in order to identify every possible solution to a problem and maintain Intel's commitment to being the industry leader and catalyst.

Toward the mid-1970s, the demand for a special type of memory chip called dynamic random access memory (DRAM) was rising due to the popularity of mainframe and personal computers and a need for faster memory (Malone, 2014). Intel once again pioneered an innovative design, fabrication, production, and pricing that soon made Intel the top semiconductor company in the world. DRAMs set the performance pace for every other device in the business, and have been the centerpiece of almost every graph of Moore's Law (Malone, 2014), which I will discuss in section 4.1.3.

4.1.2 X86 Processors and IBM PC: Dominating the PC Industry

Another breakthrough came with the Intel 4004 microprocessor. As explained in Malone (2014):

> Using MOS technology, Intel designed and fabricated one chip on whose surface different regions could be dedicated to logic/calculation, read-only memory (ROM), a cache of random-access memory (RAM), input/output management, and power control. These regions were linked together on a chip resulting in a single chip that could perform all of the tasks on the multichip motherboard of say, a calculator. This came to be known as a microprocessor or a CPU-on-a-chip. (p. 144)

Intel's microprocessor, the 4004 and its successors the 8008 and 8080, were not major revenue contributors. However, with the advent of Intel's newer and faster 16-bit 80286 microprocessors and Intel's ability to manufacture the chips in volume, IBM chose the Intel microprocessor to feature in their PC products. With the PC revolution that followed, Intel positioned itself as a key component supplier for PC-compatible systems.

In 1985, Intel released the 386 processor, with a new 32-bit architecture and 275,000 transistors. The chip's performance was more than 5 million instructions per second (MIPS). Compaq's DESKPRO386 was the first PC based on the new microprocessor.[7]

In 1989, Intel's 486 processor came to market, with 1.2 million transistors and a built-in math coprocessor. This chip was 50 times faster than the original 4004, equaling the performance of powerful mainframe computers.[8] In 1993, Intel introduced the Pentium processor, setting new performance standards in the chip industry. The Pentium processors were five times more powerful in terms of performance compared to the 486 processor. With 3.1 million transistors in the chip, it clocked at 90 MIPS (EU Open Innovation Strategy and Policy Group, 2013).

In 1995, Intel scaled its Pentium processors, introducing the Pentium Pro microprocessor using 5.5 million transistors with a high-speed memory cache to accelerate performance. With Pentium Pro's performance clocking at 300 MIPS, it was a popular choice for servers and high-performance workstations. In 1998, Intel's Celeron processor was introduced, catering to the PC users segment. Figure 4-1 illustrates the history of microprocessors at Intel.

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[7] See: < http://www.landley.net/history/mirror/intel/cn71898a.htm>

[8] See: < Intel, http://en.wikipedia.org/w/index.php?title=Intel&oldid=660318758 >.

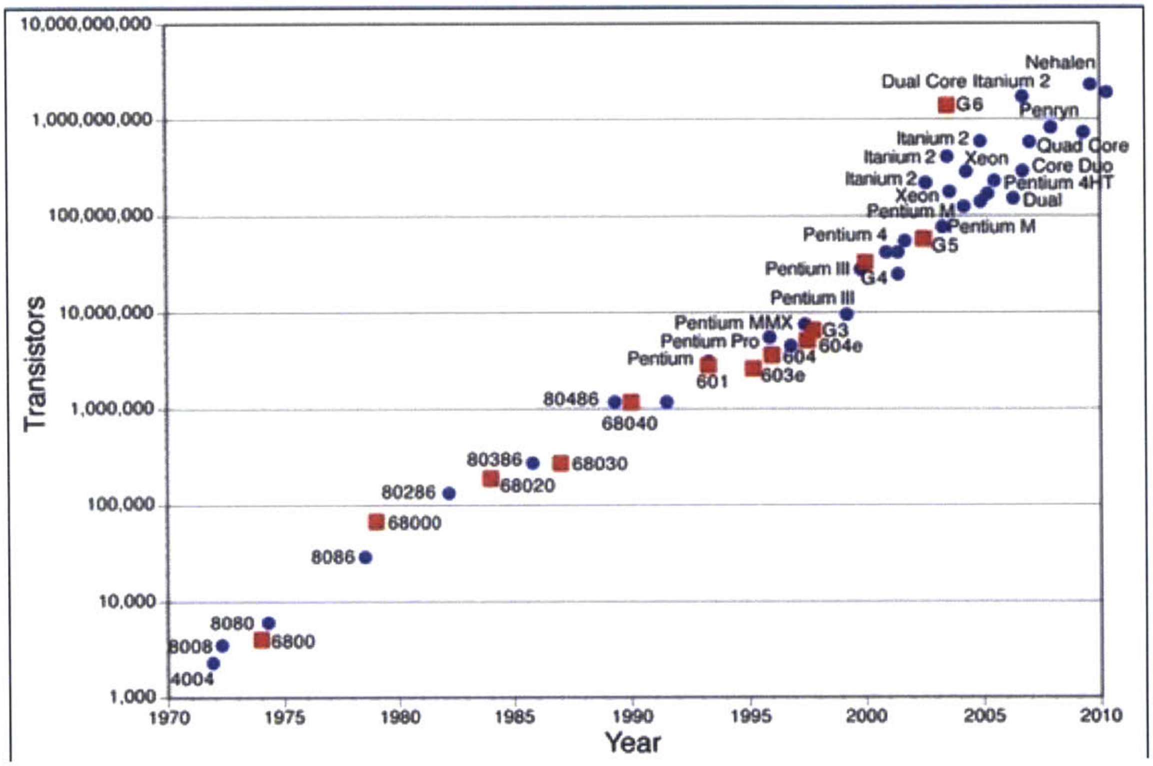

Fig. 4-1. History of Intel microprocessors

Source: <http://pointsandfigures.com/2015/04/18/moores-law/>

4.1.3 Commitment to Moore's Law

Intel's identity is inseparable from innovation, and has been since the mid-1960s when the company's co-founder, Gordon Moore, declared: "The speeds of computers will double every 18 months." This meant it was possible to double a chip's computing power every 18 months without raising its cost. This observation, now known as Moore's Law, became the guiding principle in the semiconductor industry, spurring numerous technological innovations and changing the shape of the technology world.

Testifying to the Moore's Law, a comparison shows that the speed of 1970s processors ranged from 740 KHz to 8MHz and in 2009 the processor speed clocked around 1.3 GHz[9]. The transistors in the chip rose from 16k per chip to 2bn per chip (Gawer and Cusumano, 2002). Ethan Mollick (2006) notes:

> The accuracy of Moore's Law is credited with being the engine of the electronics revolution, and is regarded as the premier example of a self-fulfilling prophecy and technological trajectory in both the academic and popular press. Predictions made using the law becomes the basis for future production goals. (p. 30)

4.1.4 Missing the Mark

Reduced Instruction Set Computing[10] (RISC) and Complex Instruction Set Computing[11] (CISC) are two ways to design microprocessors. CISC is the older approach; RISC is a newer technique. CISC designs required many more transistors to achieve the same result that RISC chips can accomplish with fewer transistors. Intel's chips were based on the older CISC scheme, and its processors at that time were the 386 and the 486. At that point, other companies began to pursue RISC techniques (Grove, 1997). He recounts that while some Intel scientists considered RISC technology to be a major improvement over CISC, it had a major drawback: it was not compatible with most software available in the market. To deal with this divide, Intel decided to go both ways, designing and manufacturing its much-awaited 486 microprocessors based on CISC and simultaneously releasing the i860 microprocessor based on RISC. In a sudden change of heart, however, Intel abandoned the i860 and decided to pour all its effort and resources into what it was good at—the CISC-based microprocessors. The ramifications of this

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[9] See: < http://www.mooreslaw.org/>.

[10] Reduced instruction set computing, See<http://en.wikipedia.org/w/index.php?title=Reduced_instruction_set_computing&oldid=653642367>.

[11] Complex instruction set computing, See <http://en.wikipedia.org/w/index.php?title=Complex_instruction_set_computing&oldid=648587413>.

decision caused Intel to miss the smartphone and tablet wave, as I discuss in the next section.

Smartphone and tablet wave eludes Intel

Opting to pour its resources into CISC-based processors instead of RISC, Intel deviated from one of Noyce's early strategies. Under Noyce, Intel was known for developing competing techniques or processes and releasing them simultaneously. This experimentation and explorative strategy saw many competing technologies being invented and refined. By opting to continue its commitment to Moore's Law and to CISC, Intel paid a huge price when smartphones and tablets arrived. Powerful but power-hungry CISC processors were no longer in demand. RISC architectures, perfected by ARM, swept across the market,[12] and Intel has been playing catch-up ever since.

Itanium: Losing the server war

Itanium[13] is the name of a family of 64-bit Intel microprocessors that implements the Intel Itanium architecture (formerly called IA-64). It was developed for enterprise servers and high-performance computing systems. However, it did not meet expectation regarding running legacy x86 code and failed to compete with x86-64 architecture. In 2008, Itanium was the fourth-most deployed microprocessor architecture for enterprise-class systems, behind x86-64, Power Architecture, and SPARC. X86-64[14] is a 64-bit

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[12] See <http://www.economist.com/blogs/schumpeter/2013/05/intel-v-arm>

[13] Itanium, See <http://en.wikipedia.org/w/index.php?title=Itanium&oldid=659748224>

[14] X86-64, See<http://en.wikipedia.org/w/index.php?title=X86-64&oldid=657155514>

version of the x86 instruction set originally conceived by Intel's rival, AMD. SPARC[15] and Power Architecture[16] employ RISC instruction sets for microprocessors contrary to Intel's CISC instruction set, and was developed by Intel's competitors.

Slowing demand

The growth in demand for high-end microprocessors slowed in the 2000s. During this time, competitors such as AMD (focused on low-end and mid-range processors) garnered considerable market share, eventually across the entire product range. Intel's dominant position in its core market was greatly reduced. Intel regained momentum in 2007 after the unveiling of its Core micro-architecture. The product range was perceived as an exceptional leap in processor performance.

The failure of Ultrabook

The Ultrabook is a class of high-end sub-notebooks featuring less bulk without compromising battery life. It uses low-power Intel core processors and solid-state drives. Intel expected to piggyback on the success of Windows 8 to achieve its own success. However, that strategy failed due in part to generally unenthusiastic reception of Windows 8, and to Intel's inability to regain traction in the declining PC sales market. The Ultrabook competes directly with other subnotebooks, such as Apple's MacBook Air, and when the tablet market exploded, it spelled the end of a big market for Ultrabook.

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[15] SPARC, See<http://en.wikipedia.org/w/index.php?title=SPARC&oldid=660110170>

[16] Power Architecture, See<http://en.wikipedia.org/w/index.php?title=Power_Architecture&oldid=647042237>

4.2 INTEL'S CORE BUSINESS STRATEGY

4.2.1 Platform Leadership

In the 1990s, demand began to slow for PCs, caused in part by sweeping innovations in the semiconductor industry and the consequent computer science advances caused the continual obsolescence of PC architecture (Gawer, et al., 2002). The ecosystem constituents of the PC market were broadly classified as software and hardware companies. However, it was never clear which software or hardware firm would take the lead in bringing new architectural standards to PCs. This lack of platform leadership in the industry severely dented the scope of innovation at the system hardware level. From Intel's point of view, the PC platform was not moving at the pace at which Intel was accustomed to developing processor power. Intel Architecture Lab (IAL) was established in 1991 as a response to fill this leadership void and to serve as a catalyst in innovation.

Figure 4-2: Intel's growth strategy

Source: Gawer, 2002. Adapted by thesis author.

IAL identified three key areas of the PC ecosystem that could spur overall platform growth:

- *Drive architectural progress on PCs*: In the 1990s, Intel developed Peripheral Component Interconnect (PCI), which was a so-called *bus* technology that linked the internal pieces of the PC system. Intel enabled the entire industry to use this as a new standard, revolutionizing the internal architecture of the PC. In the mid-1990s, Intel developed the Universal Serial Bus (USB) technology to provide a common interface linking PCs to external devices such as keyboard, scanner, and printer.
- *Motivate and facilitate innovation of its complementary products and technology:* Intel created business possibilities for companies that adopted the new USB interface for their peripherals. This benefited both the peripheral manufacturers as well as Intel as a technology driver of PCs.
- *Drive development of new system capabilities:* Intel inspired the spirit of innovation outside of Intel through Open Source initiatives, which I will discuss in section 4.5.2.

4.2.2 Intel's Open Source Commitment: Spirit of Innovation

Linux, arguably the world's most important Open-Source project, was initially started by Linus Torvalds on an Intel x86 machine.[17] After Linux was established, Intel became a strong supporter of its development. Intel is also a top contributor to other

[17] See < Linux, http://en.wikipedia.org/w/index.php?title=Linux&oldid=660240737 (last visited May 3, 2015)>.

important Open Source projects like Linux Graphics, Linux Bluetooth, and the Linux Kernel. It is also one of the top contributors to popular projects such as Webkit, Chromium, and Android. Intel supports everything from enterprise and Big Data to the Internet of Things, because its management believes that open source is the driving force behind innovation that advances the software and hardware industries. As a result, Intel aggressively promotes the use of its architecture as the foundation for developing open-source-based solutions. Intel works with software leaders, like SuSE, Google, Red Hat, SAP, Oracle, SAS, Canonical, IBM, Mozilla, to ensure their hardware is strongly supported by proprietary software.[18]

In 2004, Intel established its Open Source Technology Center (OTC) to work with open communities. Through this channel, Intel produces quality code that optimizes the latest in Intel platform features while driving software reliability, accessibility, security, and performance. It unlocks the potential of Intel hardware and creates new software business opportunities through innovation in complementary products.

4.3 EMERGING PRODUCT DEVELOPMENT STRATEGY

Today, Intel microprocessors are essential components in many products. Its position in the microprocessor business is generally unrivaled. At the same time, Intel must fend off threats from larger products or ecosystems that could render micro-processors obsolete or create entirely new/different demand profiles for microprocessors that are better met by competitors' offerings. This is where Intel found itself when it embarked on the Open Innovation 2.0 Initiative, which I discuss in the next chapter.

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[18] See <https://01.org/about>.

4.3.1 Keeping Moore's Law Alive

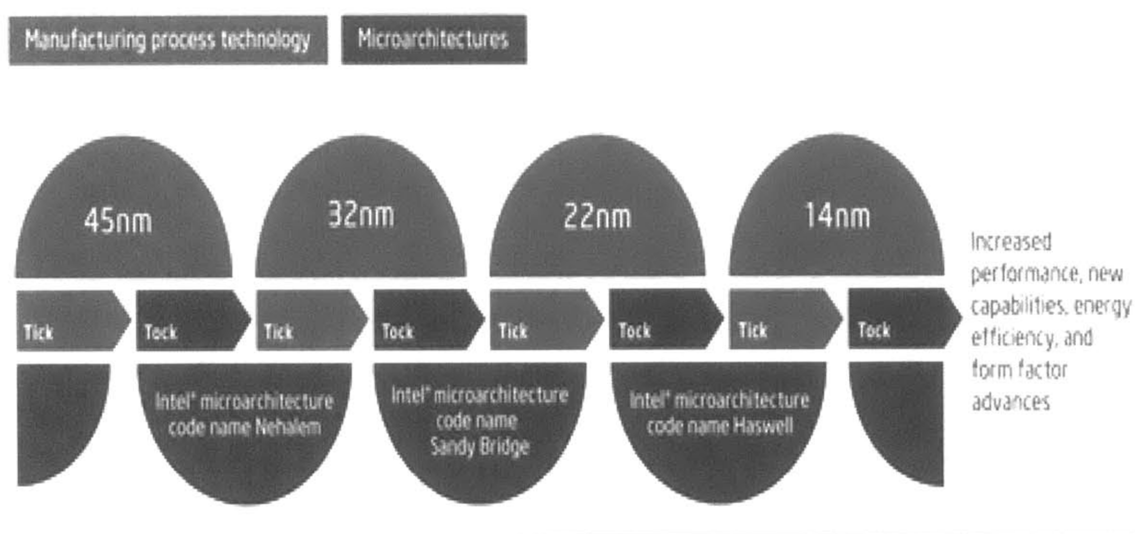

Figure 4-3: Intel's Tick Tock Model[19]

Source: <http://www.intel.com/content/www/us/en/silicon-innovations/intel-tick-tock-model-general.html>

Despite formidable challenges, Moore's Law remains at the heart of the company's strategy nearly 50 years after Intel co-founder Gordon Moore first observed the phenomenon. To that end, Intel believes that 14nm transistors will improve performance and reduce leakage of power; also that this technology will be used to manufacture a wide range of high-performance and low-power products, including servers, personal computing devices, and products for the Internet of Things.[20]

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[19] See <http://www.intel.com/content/www/us/en/silicon-innovations/intel-tick-tock-model-general.html>.

[20] See <http://www.intel.com/content/www/us/en/silicon-innovations/intel-14nm-technology.html>.

Intel's latest chip, Broadwell, was fabricated with 14nm technology based on Haswell micro-architecture.[21] In 2016, Intel will follow up with Skylake, which is also a 14nm chip but designed with a completely new microarchitecture designed to be low power but giving greater GPU performance.[22] Intel expects the trend to continue at 10nm and even at 7nm using its advanced lithography tool, Extreme Ultra-Violet (EUV), a tool which is still under development. Furthermore, Intel is now on its third generation of chips using FinFET transistors, while competitors TSMC and Samsung/Global Foundries are still making 28nm and 20nm chips with planar transistors, and will not start production with FinFETs until mid-2015. That means Intel now owns a lead in process technology and manufacturing of 3.5 years.[23]

4.3.2 Maintaining Market Leadership and Market Share

An aggressive desire for market dominance is a core characteristic of Intel. After falling behind rival chipmakers in the mobile and tablet markets, Intel is now charting a bold comeback by paying tablet manufacturers some of the initial engineering cost to develop tablet devices using its chips, rather than the competitive chip architecture from ARM. Intel is intent on gaining back market share by using this pricing strategy. Figure 4-4 illustrates the model.

Meanwhile, Intel is aggressively pursuing a comeback with its low-power 14nm microchip technology for its mobile platform, SoFia LTE 2, which is due to be shipped in

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[21] Broadwell (microarchitecture), See <http://en.wikipedia.org/w/index.php?title=Broadwell_(microarchitecture)&oldid=659674034>.

[22] Skylake (microarchitecture), See <http://en.wikipedia.org/w/index.php?title=Skylake_(microarchitecture)&oldid=660176215>.

[23] See <http://www.zdnet.com/article/what-we-learned-about-intel-this-week/>.

2016 (Oliver, 2011). Intel never gives up. It is resilient and always ready for a head-on-head battle for market leadership.

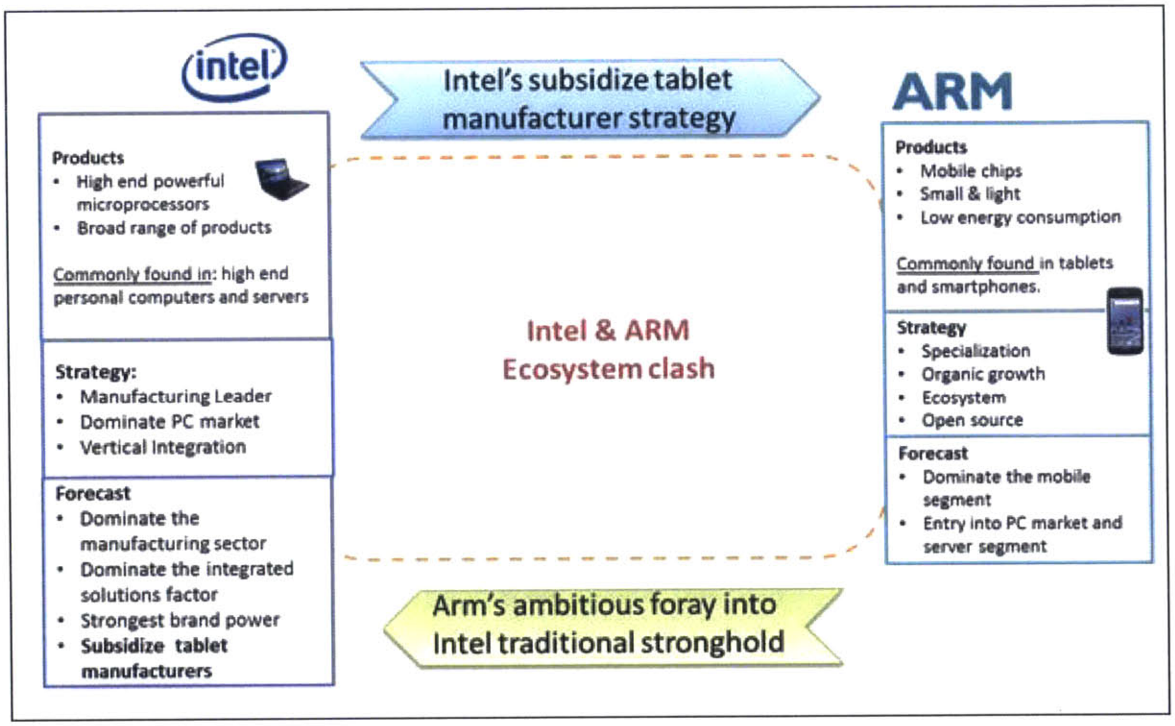

Figure 4-4: Intel vs. ARM strategy

Source: <http://www.slideshare.net/TobyAllen1/ibm-arm-strategic-comparison>.

4.3.3 Cloud and Data Centers

Today the real growth for Intel is in data centers, which is already a $14 billion business and expected to grow an average of 15 percent a year until 2018. Enterprise IT hardware is also important. The growth drivers are the cloud architectures, software-defined networks (SDN), and network-functions virtualization (NFV) for communications, high-performance computing, and Big Data and analytics.

4.3.4 Internet of Things (IoT)

Concerned that it does not make the same mistake with IOT as it did with the tablet market, Intel has jumped aggressively into the IoT market. It has set up numerous innovation centers across the globe for research and development of IoT. Aiming to become the platform leader in this domain, Intel is aggressively pursuing alliances and acquisitions to stay on top. It wants to provide end-to-end IoT solutions to quickly connect, manage, and protect consumer devices. Intel's open, scalable, and reliable platforms deliver state-of-the-art technology for trusted product lines such as Quark, Atom, Intel Security, and Wind River. Intel has left no stone unturned in its drive to remain on top in the IOT space, thus exhibiting once again its founders' spirit of innovation.

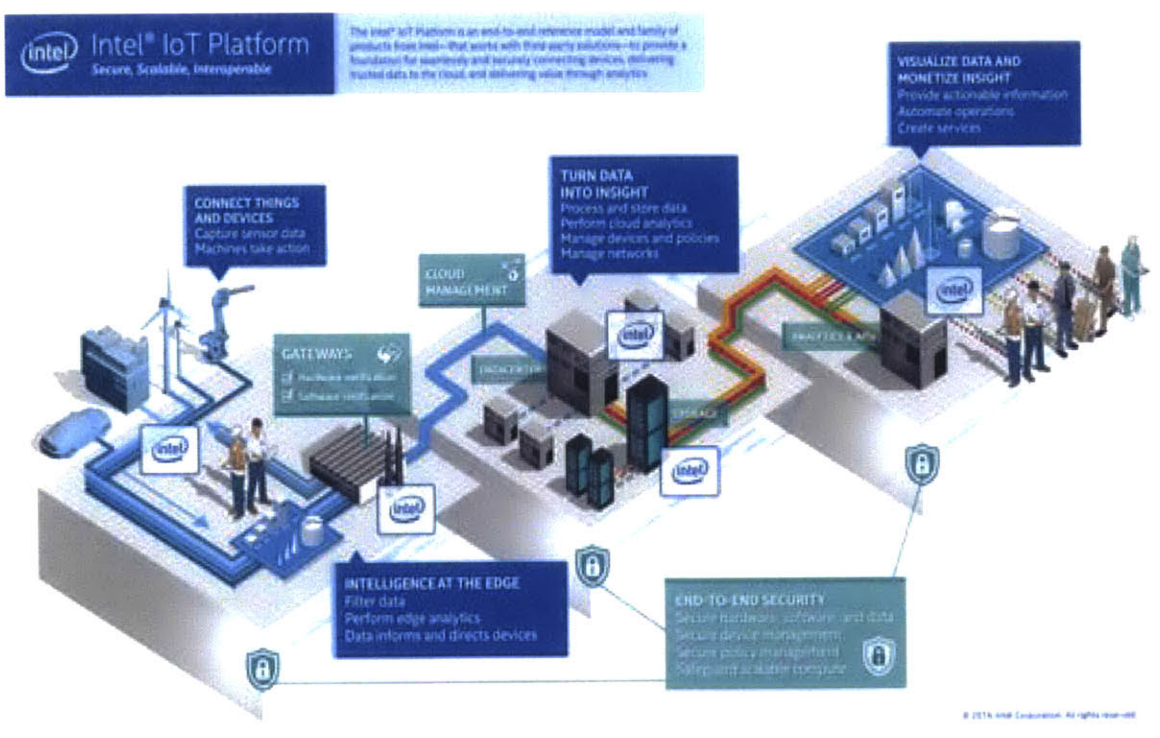

Figure 4-5: Intel's IoT platform

Source: Intel. See: <http://ww.intel.com>.

CHAPTER 5

THE OPEN INNOVATION INITIATIVE

Sooner or later, every technology company faces this question: "What is next"? In today's business environment, where many companies have interlinking and overlapping commercial offerings from which consumers pick and choose, the answer to this question is even more complicated because innovations from other firms that may not be direct competitors could have a major impact and change the competitive dynamics of the ecosystem within which they all participate.

In the last decade, Chesbrough (2003) developed the idea of open innovation, where ideas pass back and forth between organizations. Today, the success of innovation can be characterized by how well innovation ecosystems, assembled from a multitude of participants, create novel products and services that are quickly adopted — a process that is important from the market perspective as well. Chesbrough stresses the importance of creativity beyond a company's organizational boundaries as essential for creating valuable innovations—a co-creation process that benefits all stakeholders.

5.1 THE BEGINNING OF OPEN INNOVATION 2.0

In February 2015, I interviewed Martin Curley (Vice President, Intel Labs Director, Intel Labs Europe and Senior Principal Engineer), who told me about the Leixlip facility, his team, and how innovating is part of daily life for everyone at Intel. At that point, Intel had invested more than $12 billion to transform a 360-acre former horse farm in Ireland into a global manufacturing center. Located just west of Dublin, in Leixlip, County Kildare, this Intel campus employs over 4,500 technical professionals, and is Intel's largest manufacturing plant outside of the United States, with two semiconductor wafer fabrication facilities.[24]

Intel has always been known as a company that not only reinvents itself through breakthrough product innovation, but also creates its own markets with technology advancements in semiconductors. Intel's identity is inseparable from innovation.

Following our discussion, I wondered what Curley and his manager (Wen-Hann Wang, Intel's Corporate Vice President and Managing Director of Intel Labs) would discuss about OI2 when they were behind closed doors. I think Curley would have explained that his team had worked successfully with Intel's business units to develop and expand what he called Open Innovation 2.0 (OI2) initiative. As Curley told me, he saw OI2 as a collaborative ecosystem initiative with Intel as the primary organizer in a joint collaboration between Intel and the European Commission (EC). Together Intel and the EC would bring thought leaders from industry, academia, and government to work on new innovation approaches for Europe. This vision and organization would be driven by Intel Labs Europe under Curley's direction.

I believe Wang, who is responsible for Intel's global research efforts in computing and communications (including six major labs and hundreds of programs), would think about how to support this OI2 initiative. He would schedule regular meetings to obtain first-hand updates from his colleague who has spent the last ten years moving the initiative forward. When we met, Curley described the progress, challenges, and

[24] Intel website: see <http://www.intel.com>.

achievements, and how this OI2 initiative will enable new product opportunities within Intel's various business units.

For Wang, Curley's OI2 initiative relative to everything else Wang managed, was probably just another initiative in a portfolio of hundreds of programs, each moving with varying speeds and complexities. I think Wang would worry, as I did, if this initiative could work on a larger scale. Could it be formally introduced within the Intel Labs global corporate innovation process and succeed? Could adding another layer of process within what made Intel so successful really be a catalyst for future growth—or just the opposite? Could OI2 be the missing component in Intel's innovation process that would keep the firm from missing the next market opportunity, as it did with smartphones and tablets? Could OI2 be replicated in other regions of the world within Intel, or did Curley and Intel Labs Europe have something unique that would only work there?

5.1.1 Open Innovation Strategy and Policy Group (OISPG)

The Open Innovation Strategy and Policy Group (OISPG), led by Martin Curley, unites industrial groups, academia, governments, and private individuals to support policies for open innovation at the European Commission. OISPG has published ten substantive reports on different aspects of OI2. This new paradigm is based on principles of integrated collaboration, co-created shared value, cultivated innovation ecosystems, unleashed exponential technologies, and extraordinarily rapid adoption. Curley told me (and he has written) that he believes innovation can be a discipline practiced by many rather than an art mastered by just a few.

OI2 represents the second significant paradigm shift in the recent history of thought about innovation (Kuhn 1962). Everett Rogers (1962) set the stage with his insights into the diffusion of innovation leading to adoption. Approximately forty years later, the paradigm shifted to Chesbrough's definition of open innovation. Now, ten years beyond that, the innovation paradigm is shifting again—to Open Innovation 2.0. This is consistent with Kurzweil's law of accelerating returns (1999), which predicts that paradigm shifts will occur more rapidly, especially in technology domains.

The OI2 innovation paradigm is based on extensive networking and co-creative collaboration between all actors in society, spanning organizational boundaries well beyond normal licensing and collaboration schemes. According to Curley, with OI2 in place, the sharing and co-generation of innovation options will give Intel a significant competitive advantage and help it achieve broad-scale innovation benefits for a larger number of stakeholders. In OI2 there is also a cultural shift away from resisting change and toward innovation and the creation of shared value.

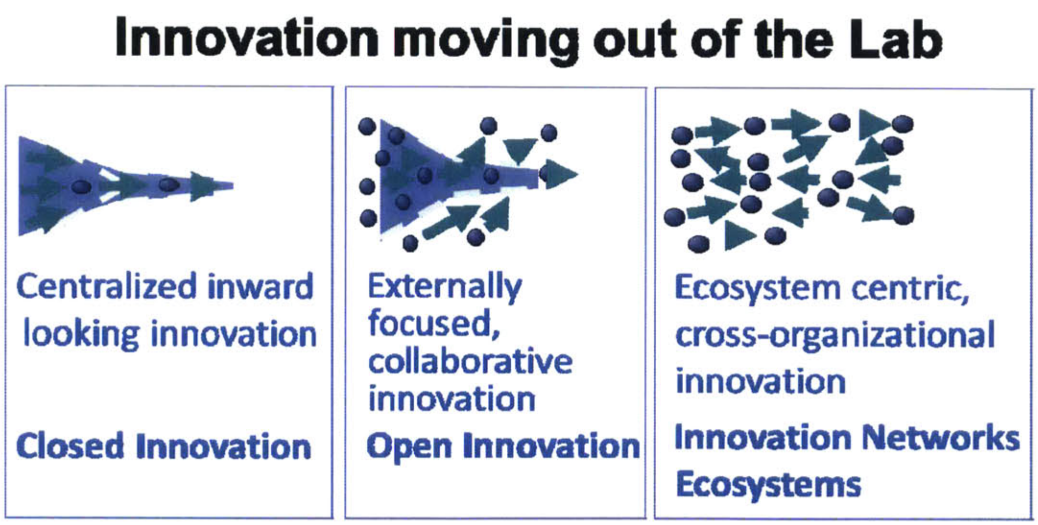

Figure 5-1 The Evolution of Innovation

Source: Intel Labs Europe OI2 2013 Conference.

Curley (2013) defined two key characteristics of the OI2 paradigm:

(1) Telecommunication networks deployed in the service of increased social interaction. According to Karl-Erik Svieby (1997), greater bandwidth and accelerated trust lead to the creation of more innovative options as more shared ideas are activated. George Gilder observed in 1993, when analyzing the power of Robert Metcalfe's Ethernet design, that the value of telecommunication networks grows as an exponential function of the number of intercommunicating nodes (Shapiro & Varian, 1999:184). Recent experiments, such as the creation of wikis, demonstrate how powerful communication networks can be when enabling large groups of individuals to collaborate.

(2) Use of the quadruple helix model. Four entities—government, industry, academia, and civil participants—work together to co-create the future and drive structural changes far beyond the scope of what any one organization or person could do alone (see Figure 5-2). According to Curley, this approach is most successful when there is a shared vision and shared value is created. OI2 can unite academia, industrial groups, governments, and private individuals to support policies for open innovation. A brief perspective of the four groups is given below.

Figure 5-2 Quadruple Helix innovation

Source: Intel Labs Europe OI2 2013 Conference

5.1.2 Academic Perspective on Open Innovation

Central to the success of OI2 is the concept of shared value and shared vision. Michael Porter and Mark Kramer (2011) espouse the idea of shared value, where companies shift from optimizing short-term financial performance to optimizing both corporate performance and social conditions, thus increasing the value shared by both the corporation and the society in which it is embedded. The thinking of these two academics has had profound implications on the topic of how to deal with the challenges facing Europe today.

OI2 is also a paradigm concerned with creating shared value, sustainable prosperity, and improvements in human well-being. Many people recognize that innovation is not just an imperative for economic and social progress. Rather, it is a composite of mindset, art, skill, and societal capability that underpins the survival and progress of the human species. Hence it is a key tenet that OI2 aims to enhance simultaneous value creation for civil, business, academia, and government markets (Curley & Formica, 2013).

MIT's Michael Schrage commented in an interview: "Innovation is not innovators innovating, but customers adopting." This statement perfectly characterizes the shift in mindset that is a hallmark of OI2. In the interview, Schrage further stated: "The real story of American innovation is [about] the folks who adopted inventions and thereby transformed them from mere inventions to full-scale innovations." Innovation happens when a customer becomes a co-creator of value, an active subject of the innovation process, and not merely a passive object. In Schrage's terms:

Invention + adoption = innovation (Schrage, 2008).

5.1.3 Industrial Perspective on Open Innovation

With advances in global information and communications technologies, the processes and practices of innovation are evolving at a rapid pace. Innovation as a discipline has shifted from being something invented by a brilliant researcher to an ecosystem-centric view in which the ecosystem is often the distinguishing unit of success, not individual companies or universities.

Justin Rattner, Intel CTO, is quoted in the 2013 OI2 conference proceedings as strongly supporting the concept of 21st century industrial research, characterized by visioning, inventing, validating, and venturing.[25] Instead of innovation being driven by a brilliant individual researcher, he says, innovation success is driven by teams of boundary spanners that possess multidisciplinary skills. Methodologies, such as the Intel Labs Joint

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[25] Martin Curley and Bror Salmelin. OI2 Conference, May 20-21, 2013.

Pathfinding process, create mechanisms that can span the so-called "valley of death" that lies between research and product adoption, thus enabling greater returns on research investments. Joint pathfinding occurs when research laboratories and business groups jointly share resources, risks, and decisions. The eclectic at Intel works together to build product roadmaps that identify pathways from research to results (Curley, 2013).

5.1.4 Government/Political Perspective on Open Innovation

The political perception of innovation is changing throughout the world. A primary tenet of Intel's OI2—that successful innovation is accelerated when a wider spectrum of stakeholders participates—is heard frequently from world leaders. In his 2013 State of the Union speech, U.S. President Barack Obama said: "Innovation does not just change our lives; it is how we make a living" (Obama 2013).

When speaking at the opening of a newly expanded innovation facility in May 2013, Obama said:

> We are seeing the pooling of research, of risk, and the potential for breakthroughs in manufacturing technology that only happen when we bring everyone together. No company alone would have the incentive to [make this investment] on its own, but together companies are willing to move forward. (Robinson, 2013)

Maire Geoghegan Quinn, EU Commissioner for Research, Innovation, and Science, spoke about the continual need for a model of innovation. In a 2011 interview, Quinn said: "To transform research into genuine innovation and to strengthen the whole chain from research to retail, a close working relationship with other commissioners, with member states, with research institutions, and with business will be necessary" (Quinn, 2011).

In a 2012 interview, George Osborne, UK Chancellor of the Exchequer, warned:

> Innovation is not a sausage machine. . . . You don't get [innovation] by a plan imposed by government, and you can't measure it just by counting patents or even just spending on R&D. It is all about creative interactions between science and business. You get innovation when great universities, leading-edge science, world-class companies, and entrepreneurial start-ups come together. (Solon, 2012:1)

Political perspectives like these help to ensure that policy decisions accelerate the creation of both business and societal value through innovation.

Curley commented that the role of the public sector is to create a setting for open innovation where the combination of needed components can happen in a "frictionless environment." The public sector provides not only a framework but also fuels the innovation processes, for example, by procuring innovative products and sharing RD&I risk. It is also important to create efficient political and legal environments to catalyze innovation and experimentation.

5.1.5 User Perspective on Open Innovation

OI2 is a paradigm-breaker for users. Instead of the user being a research object, and innovations being showered upon them, in fact users become an integral part of the innovation process (Curley, 2013). Over the last decade, innovation has moved from open innovation, through networked innovation, and now to participative innovation, which, in Curley's view, is a core characteristic of OI2.

User experiences are new drivers for innovation. Instead of focusing on a product or service feature, developers focus on the user experience. Paying attention to the user's experience of an innovation is crucial to ensuring that a happy user will influence further adoption of the innovation by spreading the word (see Figure 5-3).

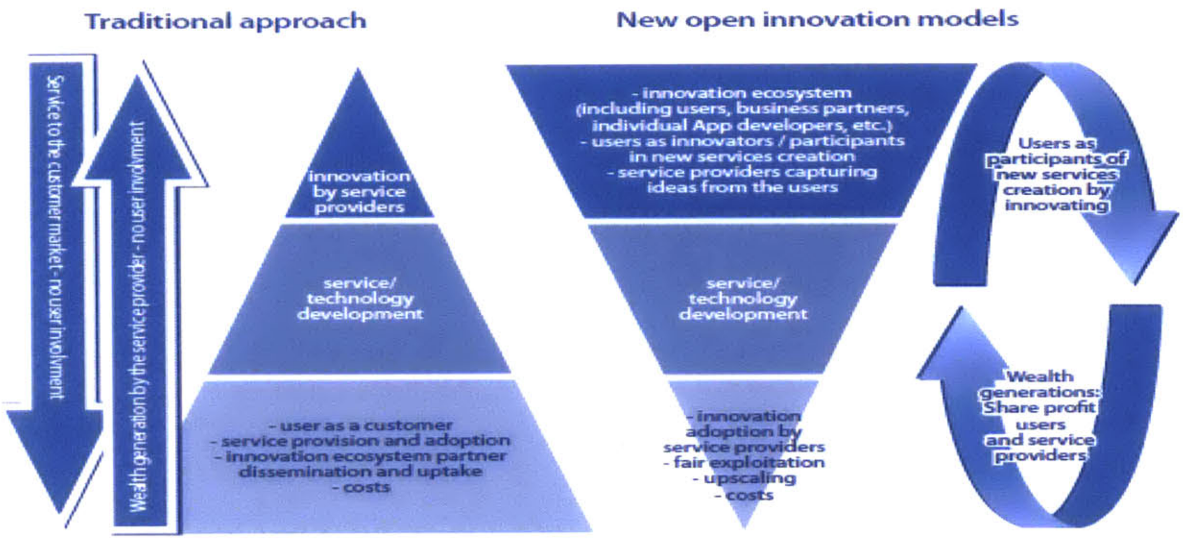

Figure 5-3 Open Innovation business models

Source: EU OISPG, Intel Labs Europe OI2 Conference, 2013.

From the OI2 perspective, Curley said the Intel team knows it needs to go beyond monolithic cluster thinking to multidisciplinary ecosystems, while incorporating one of Europe's unique assets: perhaps the most advanced and demanding users of the ideation and innovation process. In this case, users are academics, industrialists, members of government, and the citizens themselves.

5.2 OI2 SUMMARY

According to Curley, Open Innovation 2.0 is not a panacea for the innovation process that all companies struggle with, but it adds an essential component to traditional innovation approaches while accelerating collective learning and value creation. By harnessing the OI2 frameworks, and by using the collective and collaborative potential of people in Europe and beyond, Intel Labs Europe OI2 team hopes it can work with others to create a brighter, more sustainable future. With the Open Innovation 2.0 paradigm, Curley said he believes there is a new opportunity for an entrepreneurial renaissance.

CHAPTER 6

ROADMAP FOR THE FUTURE

As part of the Open Innovation 2.0 Sustainable Economy & Society Conference in Dublin, Ireland in May 2103, Martin Curley wrote that the adoption of the new OI2 paradigm will be the catalyst that "unleashes a virtual Cambrian explosion of innovation in Europe" (Curley, 2013). Instead of gravitating to the lowest common denominator of society, Curley believes that Europeans will leverage all the talents and resources of European society. OI2 is all about an openness to innovation that does not resist change, but embraces it. OI2 requires a new mindset focused on teams, collaboration, and sharing. Only with this focus will it be possible to tear down the walls that form separate silos of civil, academic, business, and government innovation. Silos will be replaced with creative commons, shared societal capital, and the systematic harvesting of experimental results. Information technology will play a special role because IT can supply the necessary connectivity and enable social networking among innovators and the communities they serve (Curley, 2013).

6.1 INTEL OI2 – YESTERDAY AND TODAY

6.1.2 Finding the Value

A key decision that has an enormous effect on determining the profitability of a company is the allocation of resources among many promising projects. To minimize cost, maximize profit, and remain competitive, all companies need to monitor and adapt to changing industry and market conditions on a continuing basis. Resource allocation for IT investment, in conjunction with the business planning process, is critical to an enterprise's ability to meet its business requirements (Curley, 2004).

In 1999, IT departments around the world were struggling with how to drive and create value in their corporate entities. The same was true for Intel, and this effort became the foundation of the OI2 initiative. Curley explained in his book *Managing Information Technology for Business Value* (2004), that Doug Bush, then Vice president and CIO of Intel, brought Curley into his organization to address the problem of managing the IT functions so as to realize maximum business value. "Curley and his team developed a systematic approach to identifying and prioritizing opportunities, reducing cost, and optimizing the business value of IT investments" (Curley, 2004: xiv). It was a long road between this initial Intel IT value-capture program and today's OI2 initiative that focuses on creating increased social capital, enabling broader boundary spanning, and the creation of new activation triggers for innovation options.

6.1.2 Finding the Future

What started as an IT value program in 1999 is now a world-class Innovation Open Lab in Ireland. The lab is home to a research team that engages in open research and innovation opportunities in Europe that have all the earmarks of value-driven technology solutions.[26]

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[26] See: <http://en.Wikipedia.org/w/index.php?title=Intel&oldid=660318758>.

Intel did not stop, however, with just opening up a new R&D lab in its Ireland facility in hopes of developing new solutions to complicated problems. Instead, Intel moved to the next level by partnering with Imperial College and University College of London to find real-life applications for technology that would enhance life in a major city. This new initiative aims to solve problems related to the environment, as well as the social and economic issues faced by growing cities. What Intel did was turn a city into a laboratory—a laboratory that is part of its OI2 initiative

Increased urbanization means that cities will have to find smart solutions to ensure they run smoothly and have minimal impact on the environment. This means anthropologists will work alongside computer scientists and city planning professionals to ensure that the social needs of the population are taken into account. Other projects could include a network of sensors to monitor air quality, traffic flow, and water supply.

One of the most important tasks for the researchers will be extracting meaning from the huge amounts of data created by the project. Analyzing the data to see which systems worked and which did not—this is a great experiment around big data analytics.[27]

6.1.3 Smart City

In Dublin, university scientists, city officials, and residents are collaborating with Intel Labs OI2 researchers to use infrastructure and Big Data to detect and predict events that could affect the well-being of city residents and the local environment: air quality, energy leaks, droughts, and traffic jams, to name a few. The list could also

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[27] See: <http://www.bbc.com/news/technology-18189986>.

include real-time experiments ranging from 21st-century robotics, smart vehicle safety and the privacy of big data. Intel Labs is also working with the Dublin City Council and Trinity College to develop and test citizen-centric services and solutions that could become a template for the sustainable connected cities of tomorrow.

Intel is trying to take the "quadruple helix" of interaction between knowledge institutions, enterprises, government and civil society; out of the lab and into the real world. This is part of the plan that may help set Dublin apart and propel it on a path to becoming a sustainable city while also helping Intel to understand customer needs and problems before it is too late to make changes.[28]

With more than 50% of the world's population now living in cities (and projections showing this figure will grow to more than 70% by 2050), the need for an adaptive and responsive infrastructure is paramount for achieving and maintaining the capacity, prosperity, sustainability, and livability of our future connected cities.[29] The build-out of smart infrastructures that will allow cities to utilize technology to adapt to their environment, will enable Intel to play a central role in achieving the future capacity of cities to grow and support sustainable living (see Figure 6-1).

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[28] See: <http://www.greencity-event.com/intel-squeezes-into-smart-and-crowded-sustainable-cities-space/>.

[29] Ibid.

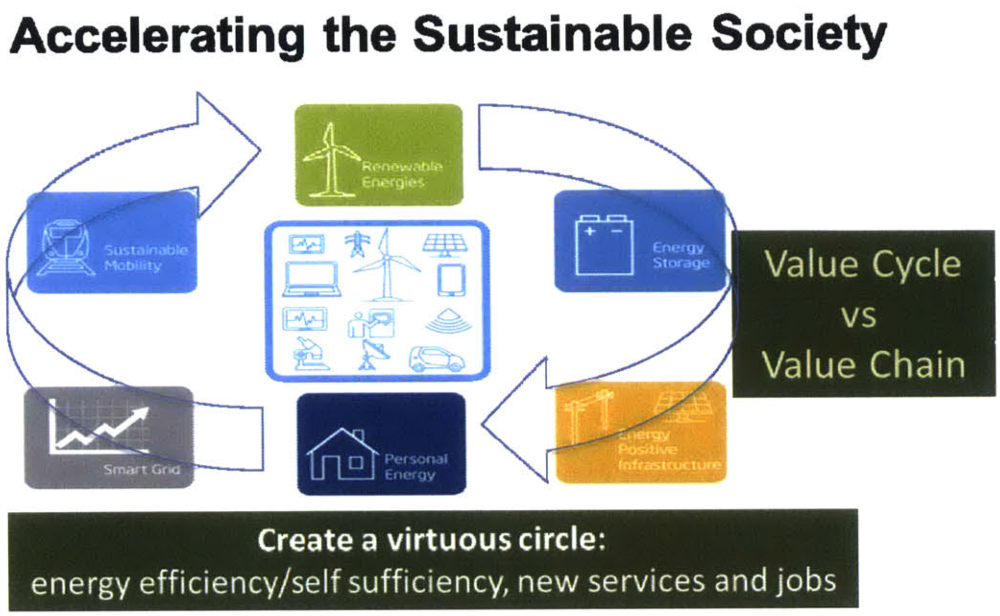

Figure 6-1. Accelerating a sustainable society

Source: Intel Labs Europe

6.1.4 A Strategic Inflection Point

As microprocessors become faster and more powerful, an long list of new applications develops, while existing applications will spread worldwide. It is predicted that there will be further integration of audio, video, and conferencing capabilities via the Internet. The increase in computing power will make computers easier to use. Voice and handwriting recognition, local control of complex Internet-based applications, and lifelike animation demand considerable computing power—all available in future Intel microprocessors.

As discussed earlier, Intel's OI2 team identified key examples of open innovation that highlight the new paradigm, while also leveraging diverse concepts and practices, including shared value, open innovation, co-creation, entrepreneurial experimentation, and quadruple-helix innovation. The Intel team believes that the effective collaboration of government, academia, industry, and civil individuals working together can drive structural change and improvement far beyond the scope of what any one entity could achieve on its own. Their observations indicate that we are perhaps witnessing a "strategic inflection point" in the practice and impact of innovation.

CHAPTER 7

OPEN INNOVATION 2.0: MOVING FORWARD

This thesis reviewed some of the major frameworks in technology innovation strategy. It also reviewed key problems specific to the semiconductor industry, as well as Intel's competitive position in the semiconductor market. Then the focus shifted to Open Innovation 2.0, an important initiative at Intel Labs Europe, chosen because it had specific implications for the future planning of Intel moving forward.

Industry analysts and competitors alike have regularly predicted the end of Intel's dominance for years. The world is indeed changing, technologies and business models evolving, and customers sometimes shifting away from the dominant Intel design. Yet, after my interviews with Intel's OI2 team, I believe that as it has done in the past, Intel will continue to evolve within the industry.

The Intel OI2 initiative is enabled by the convergence of three mega-trends: digitization, mass collaboration, and sustainability. Across the world, examples of Moore's Law in action can be seen in virtually every domain. Industries that have taken centuries to mature have been dramatically reshaped in less than a decade (e.g., music, book and magazine publishing). Many more industries are ready for this transformation: the emergence of smart electrical grids, Tesla's April 2015 announcement of its new Powerwall,[30] and other energy solutions as prime examples.

[30] Powerwall is a home battery that charges using electricity generated from solar panels to power homes and businesses in the evening. See: <http://www.teslamotors.com/powerwall>.

As illustrated in Figure 7-1, OI2 is a paradigm that assumes that firms can and should use external as well as internal ideas to create internal and external paths to market, even as the firm advances its technology (Chesbrough, 2003). Utilizing the quadruple helix model of the four entities—government, industry, academia, and civil participants—all working together, this process will co-create the future and drive structural change far beyond the scope of what any one organization could do alone.

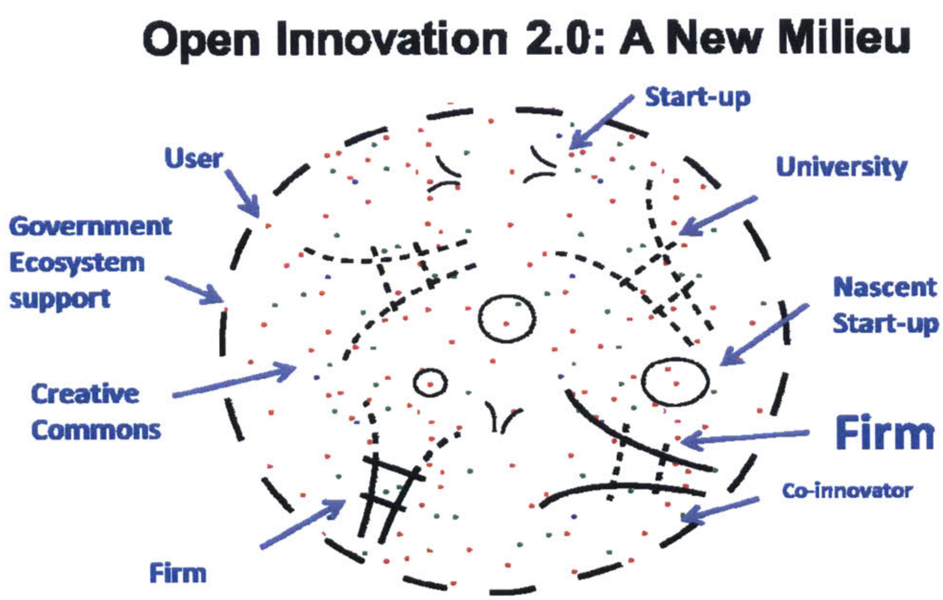

Figure 7-1 Open Innovation 2.0: A New Milieu

Source: Intel Labs Europe

What is Intel's path forward? I believe the company is taking the right steps with its OI2 initiative. Although many high-technology companies have developed their own forms of open innovation, Intel has built an open innovation initiative that demonstrates not only true customer pull, but true value throughout the ecosystem.

Considering the benefits that Intel is receiving from OI2, it makes sense for Intel to take steps to globally formalize the OI2 processes and push OI2 into other regions of the world where Intel's presence is already established and where specific markets are important regions for new growth (e.g., China, India, North America).

As OI2 evolves, its goal will be to help practitioners and academics achieve results that are probable, predictable, and profitable. In the real world, OI2 will increase the velocity and success rate of innovation due to its co-creative and experimental nature. At the OI2 2013 conference, Martin Curley cited Neils Bohr's good-humored cautionary quote: "Prediction is difficult, especially about the future." The future of OI2 is bright and promising, as its application will increase the probability of making significantly better choices and creating profitable new markets as a consequence.

APPENDIX A

LIST OF INTERVIEWS

Intel Labs Europe
Dublin, Ireland (February 2-3, 2015)

Martin Curley	VP & Intel Labs Director, Intel Labs Europe, and Senior Principal Engineer
David Fleming	Technology Manager, Intel Labs Europe
Brain Quinn	Director, Strategic Programs Intel Labs Europe
Charles Sheridan	Director, Intelligent Cities Labs, Intel Labs Europe
Dave Boundy	Director, Intel Labs Europe
Jim Kenneally	Principal Investigator, Intel Labs

MIT Meetings (Cambridge Massachusetts)

James Utterback	Professor of Management and Innovation and Professor of Technological Innovation, Entrepreneurship, and Strategic Management
Fiona Murray	Professor of Entrepreneurship, Associate Dean for Innovation; Co-Director MIT Innovation Initiative; Faculty Director, Martin Trust Center for MIT Entrepreneurship; Legatum Center; Member of UK Prime Minister's Council for Science and Technology (CST)
Pierre Azoulay	Associate Professor of Technological Innovation, Entrepreneurship, and Strategic Management

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