Chapter 2
New Product Development

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2.1 New Product Development Introduction

Since the industrial revolution, the global industrial economy continues to expand rapidly. The automotive industry enabled people to live outside of cities and commute in. The aerospace industry has linked not only states but entire countries. Henry Ford's assembly line revolutionized the way things were manufactured. At the heart of every successful design and manufacturing company is an efficient new product development process. This process allows engineers to understand their customers' desires and make quantitative and qualitative decisions about what features to design into their product. Companies that can rapidly innovate, deploy product development strategies, and integrate tooling suppliers are likely to gain and maintain market share.

The semiconductor industry is at the heart of the expanding digital world. The world's demand for silicon is on a steep positive trajectory. Silicon has many applications within the average consumer's life. From personal laptops, to data centers, the demand for more efficient processing and memory is continually growing. Intel Corporation is a major player in the semiconductor design and manufacturing industry. In order to stay competitive in the semiconductor manufacturing industry, Intel must focus on customer integrated design, accelerated innovation,

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product development strategies, tooling supplier integration, and understanding the technology life cycle of its products.

2.2 Intel's Background

Founded in 1968, Intel changed the world dramatically with its revolutionary products, from the first microprocessor to miniaturized personal computers (NUC). Intel remained competitive in the semiconductor industry through clever marketing, high-quality research and development, superior manufacturing proficiency, an open corporate culture, and legal proficiency. Its wide range of products power not only computers, but also data servers, cloud services, memory systems, graphics, microarchitectures, media interfaces, and more. In addition, Intel has stayed on top of the changing world of technologies by accumulating acquisitions and partnerships in multiple industries over the years. One key aspect of Intel's continuous growth is its progressive, customer-oriented approach to product development, as discussed in this paper.

2.3 New Product Development Analysis and Discussion

2.3.1 Accelerated Radical Innovation

Intel has taken the lead in the semiconductor industry since day one. The innovator invented the world's first metal oxide semiconductor chip, replacing magnetic-core memory chips. In 1971, Intel released their first microprocessor, Intel® 4004, which was also the first general-purpose programmable processor on the market. At the time, the concept of microprocessors was still new to the general public. The 4004 was mainly for engineers to customize with software to perform different functions in a wide variety of electronic devices. After just 1 year, Intel released Intel® 8008, which was 8-bit instead of 4-bit, supporting significantly more random access memory (RAM). The 8008 was a tremendous success; it became widely used in hundreds of products in addition to the first microcomputer in the market, including traffic lights, cash registers, industrial machines, etc.

Starting the 1980s, personal computers (PCs) became common and without much knowledge of the product, people were focused on the software, specifications, or recommendations rather than the central processing unit (CPU) inside. Intel's market share was also eroding as manufacturers preferred upstart competitors for lower costs during the recession. This prompted Intel to launch a worldwide brand marketing campaign to help users identify PCs based on Intel's valuable processors. Intel Inside® became a label everyone looked for. One important aspect of radical innovation is the creation of new knowledge and commercialization of completely novel products and ideas. Intel no longer wanted to be seen as a highly technical company whose work only engineers or scientists could relate to, but also a prevalent name in every household. Prior to the campaign, Intel had been advertising the next chips or products or partnering with other companies such as HP, Dell, etc. Using their chips, Intel started a marketing strategy known as ingredient branding, which no other company had used. Intel invested in hundreds of millions of dollars in this incredibly novel approach of rebranding itself over a period of several years, with sales of only $500 million at the time. Its devoted efforts included half of the computer manufacturers' advertising costs, elaborate and immersive exhibits at the annual CES (International Consumer Electronics Show) and high-profile TV campaigns. Within just a few years following the campaign, Intel became the largest semiconductor of the world.

From the Intel 8008, the 10 μm process to Intel's latest released chip codenamed Coffee Lake, the 10 nm process, the company made amazingly significant progress. This progress follows the model of its co-founder, Gordon Moore, who predicted that the number of transistors in a chip double every 2 years. Rather than a force of nature of any sort of scientific law, this was Intel's commitment to continual progress due to their dedication. Moore's law went on to become the widespread business model of the semiconductor industry. With radical innovation defined as improvements in known performance features of five times or greater that could take decades, Intel's incremental increase of transistors on a chip 1000 times smaller after merely 40 years was an impressive feat. Its transistor density and chip size reduction have outperformed its competitors in the market. Intel has truly achieved what many other companies strive for—accelerated radical innovation. Intel has accomplished its innovation leadership since its very first processor and has been consistent throughout the years through meticulous analysis of scientific knowledge and telecommunication tools to precipitate the diffusion of its products in the market.

Rising to the top of a cutthroat competitive market is not merely about outperforming competitors, but also the company itself. Consumers must have the desire to not only stay loyal to the brand but also spend on an upgrade from the product's predecessor. A close evaluation of Intel's last two generations of microprocessors in the market indicates how the company is still able to be ahead in the market by attaining accelerated radical innovation. A comparison test amongst a pair of Acer Swift 3 notebooks, powered by eighth Gen Core i5-8250U CPU and a seventh Gen Core i5-7200U chip and a pair of Dell XPS 13 s, powered by eighth Gen Core i7-8550U CPU and a seventh Gen, Core i7-7500U processor, reveals that eighth Gen is ~80% faster than seventh Gen on average. In sub-areas like excel spreadsheets, video transcoding, and app load times, the eighth Gen is better than its predecessor by ~65, ~60, and 56%, respectively. Intel proves its commitment and propels its innovation forward by significantly boosting product performance with powerful enhancements from generation to generation.

Intel strived to achieve accelerated radical innovation from its first microprocessor with the Intel Inside® household name. Becoming an ingredient in someone else's recipe was never appealing to ambitious companies, however, Intel leveraged this opportunity and quickly established itself as a trusted brand with assured quality. The company made the endeavor to deviate from its traditional approaches, favor long-term benefits over short-term, consider its whole network of suppliers to manufacturers to consumers, and ultimately rewarded itself with a large, global consumer base. Intel products are incorporated in not only computers nowadays, but also in numerous other cutting-edge technologies, spanning from the semiconductor industry to entertainment, business, automotive, software, and more.

2.3.2 Product Development Strategies

Product development at Intel is multifaceted, employing multiple strategies to yield a plethora of product designs and increase manufacturing capability. These strategies include leveraging internal development/manufacturing capabilities to optimize Intel's product portfolio and acquisition of startups to enhance products in their portfolio and expand into high-growth markets.

As Intel's bread-and-butter PC market matured, Intel has been on the hunt for the next big market and finding related markets to expand into. Intel coined IoT (Internet of Things), opening doors for the company to grow into novel/high-growth market segments. IoT products encompass embedded electronic packages for a broad range of applications. Intel's decisions have begun to expand past the core silicon-based product focus, however, product offerings from Intel are still stayed true to the core integrated electronics focus and established R&D structure cultivated by manufacturing. The acquisition of companies such as Alterra and Mobileye demonstrates this divergence from the core silicon business while still staying true to the mission of selling silicon. The purchase of Altera has justifications in accelerating the product development process while mutually enhancing both companies' product lines. The acquisition of Mobileye demonstrates the acquisition strategy as a way of substantially accelerating product development through the purchase of a key player to gain foothold in a desired market segment.

2.3.2.1 Identifying Core Competency

Intel is an established international company with strong technical strengths. Intel was founded in 1968 and has been in the microprocessor industry since 1985. The company currently employs approximately 102,700 employees. Intel has nine major manufacturing and R&D sites and seven test assembly sites internationally with presence in 46 countries. Research and development expenditures reached over $13 billion in 2017. Intel took the fourth position for the number of US patent assignments over 2016 as well as 2017.

These core competencies integrate together in a model Intel calls "Virtual Cycle of Growth," meaning involvement of Intel projects in all parts of a system from data center devices to end-user devices of all kinds (PC, mobile, and IoT devices) can impact the company as a whole.

Intel is organized into five broad groups: Client Computing (CCG), Data Center (DCG), Internet of Things (IOTG), Non-volatile Memory Solutions (NSG), and Programmable Solutions (PSG). Each of these groups specializes in a related microelectronics related market focus.

The Client Computing Group has been responsible for designing and manufacturing Intel's Core-branded processor families, supporting Intel's notebook and desktop product lines as well as wireless and wired connectivity products.

Data Center Group specializes in data center platform advancement and supporting Intel's Xeon Scalable processor line for enterprise, cloud, and communication infrastructure market segments.

Internet of Things Group includes all IoT platforms for automotive, industrial, retail, and other markets with embedded applications.

Non-volatile Memory Solutions Group focuses efforts on developing and manufacturing memory technologies such as 3D NAND and Optane. These technologies have been implemented in the memory market in the form of solid-state drives.

Programmable Solutions Group is focused on programmable semiconductors such as field programmable grid arrays (FPGA) and related products for markets such as industrial, military, automotive, and communications.

Moore's law has been a major reference in semiconductor technology cadence since Gordon Moore, an Intel co-founder, published the observation in 1965. Moore's law states that transistor density should double approximately every 2 years. This is a cadence that Intel has aimed to achieve with every new iteration of transistor design, vastly changing the way the semiconductor industry has operated.

A less obvious analysis of Intel's position in the market is defined by the barrier to entry in semiconductor manufacturing. While the dense IC market prescribes to Moore's law on transistor density doubling, the trend for required resources in achieving this level of technological advancement in the last decade has been an opposite trend, requiring more and more R&D, test, and manufacturing cost. This observation of increasing the capital cost of semiconductor fabrication increasing over time has been dubbed Moore's second law or Rock's law. The rising cost creates a prohibitive wall around the manufacturing industry, limiting competitors to a select few: Samsung, Taiwan Semiconductor Manufacturing Company (TSMC), and GlobalFoundaries (GF); fewer which offer full-stack design-to-manufacturing capabilities similar to Intel.

2.3.2.2 Leveraging Core Competency

Intel utilizes its technical design and manufacturing capabilities with internally designed products as well as externally designed product manufacturing. Production manufacturing facilities are designed with a "copy exactly" method, which enables smooth technology transfer between manufacturing sites through the creation of a virtual fab environment. This design allows for better cost control and production capacity.

Product manufacturing process R&D on similar product lines are carried out concurrently. For example, referencing the transistor density, product R&D of 14 and 10 nm process nodes are stagger start but have periods of overlap in development to facilitate product release at the desired cadence described by Moore's law. This enables the company to have a fluid release of products by initiating technology research early enough to allow the technology to mature before releasing into retail products.

Leveraging internal resources has led to an expanded product portfolio outside of microprocessors. Intel has expanded to auxiliary microprocessor products such as motherboard sockets, thermal solutions, and motherboard reference designs as well as server products and assemblies, although manufacturing of some of these products is not done internally. Intel employs a multi-source strategy for supply chain to manufacture certain components such as connectivity, FPGA, networking, and memory products. These subcontractors help to augment internal production capability and capacity.

Taking advantage of the decades of technical experience, advanced production capabilities, and robust validation methodology, Intel offers custom foundry manufacturing for external design firms (known as Intel Custom Foundry (ICF)). The foundry business capitalizes on the fabless model employed by many other electronics design firms. This model is built upon design firms that do not have manufacturing capabilities to outsource production to an external foundry. The technology Intel offers to their foundry clientele capitalizes on performance-relevant matured process technologies. Intel is quiet about the success of ICF, however, ICF demonstrates a product optimization by leveraging Intel's technological lead over competitors with mature technologies and manufacturing resources of the company.

2.3.2.3 Enhancement of Core Competencies

A position Intel has taken to enhance their core competencies is through the acquisition of companies in target market segments supplemental to current Intel technologies and companies which are positioned in critical industries destined for future exponential growth. These companies provide Intel with the ability to foster growth within existing product lines as well as gain access and a technical foothold into new industries. Two recent purchases exemplify these different variations of this strategy: Altera and Mobileye.

Altera specializes in programmable logic devices, with their largest deliverable being field programmable gate arrays (FPGA). These devices are integrated circuits that can be configurable by the end user to cater to their product needs. FPGAs find purpose in integration in IoT devices: an industry that encompasses a broad range of products and applications such as data center sensor monitoring systems and health care monitoring systems. FPGAs function as sensor controllers and data acquisition tools which enable IoT systems to be developed and integrated into data analysis systems for connectivity.

Intel's purchase of Altera is a beneficial one that enhances its core competency while positioning Intel as a key player in the IoT device market. Intel has had prior experience with Altera's main product line, Stratix-10 FPGA, with a fostered relationship and familiarity through Intel Custom Foundries. Intel's expertise in microprocessor design and manufacturing coupled with Altera's market position as a major player in the FPGA market and designs enable mutual benefit to both organizations. Additionally, referencing the client-to-cloud strategy, the success of Altera would directly impact Intel's IoT market. As Altera establishes itself further as the choice for FPGAs by IoT device developers, Intel sees advantages directly through Altera sales while indirectly seeing demand increase in many related technologies also supported by Intel (data centers, wireless technologies, etc.).

The acquisition of Mobileye demonstrates a product strategy that diverges from the traditional silicon-based business Intel has pursued. Mobileye is a company that focuses on camera recognition software to enable autonomous driving vehicle abilities along with collaborations with governments and crowdsourcing for road data collection. The company has had its technologies implemented into over a million vehicles on the road today, spanning from Audi to Honda. These commercial technologies currently do not enable fully autonomous driving capabilities, however, it is the goal of the company.

This market has been identified by Intel to be a substantial growth market. Intel estimates the market can be worth up to $70 billion by 2030. The benefits, however, are mutual between the two companies. Mobileye brings to Intel new technologies and a leading position in the autonomous driving automobile market while Intel is able to supplement Mobileye's hardware efforts with their System-on-Chip (SoC) and FPGA product lines. Indirectly, Intel expects to see farther-reaching impacts into its data center market through an increase in demand for cloud computing resources. This purchase stands as staking a claim in a novel growth market that has benefits that span multiple business units within the organization.

2.3.3 Integrating Tooling Suppliers

The new product development process has many multivariable decisions embedded within it. When each one of these decisions arises, engineers and managers must hold design reviews to determine what the best solution is. Typically a decision matrix is used to decompose a decision. Key variables are assigned weightings, and the solution with the highest score is selected. This static method of decision support has its limitations. For one, this method is unable to account for uncertainty within weighting. Each weighting in reality is a stochastic random variable, taking on a range of values. Dynamic decision support is needed to understand the variability in the new product development process.

Thus managers and engineers can define probability distributions for the sub-variables and link them to the final variables. Monte Carlo simulation can be utilized to understand the probability of success of a product proposal. It should be noted that at Intel, many sub-variables are determined by their tooling suppliers. Product cost and available resources and affected by the wafer fabrication equipment used. The window of opportunity is affected by how quickly new manufacturing equipment can be developed. Product quality and margin rate are directly affected by the performance and quality of wafer fabrication equipment. Because of the importance of these sub-variables, it is vital that Intel integrates their tooling suppliers in its new product development process.

An important aspect of Intel's new product development strategy is understanding its suppliers of wafer fabrication equipment. Intel's corporate structure is designed to develop and manufacture new products. They act as a central integrator of new products and technologies. The wafer fabrication equipment used for etching and deposition processes is designed by tooling suppliers such as Lam Research, Tokyo Electron, ASML, and Applied Materials. Companies hold the majority of the wafer fabrication equipment market share. This competition between suppliers is advantageous for Intel because it promotes innovative design, and competition between companies to keep pace with Intel's innovation.

Intel and companies like Lam Research must have an ongoing dialog about the capabilities of the wafer fabrication equipment. For example, when Intel is developing a new advanced memory chip with copper interconnects, they are more than likely to purchase a Saber electrochemical deposition machine. The Saber machine can be used by Intel for "High-throughput, void-free fill with superior defect density performance for advanced technology nodes" Lam. The exact performance parameters of the Saber would need to be understood by Intel design engineers prior to finalizing their processor design. If an Intel engineer determines that small additional features are needed, often times they can be quickly added to the wafer fabrication equipment. However, for larger innovations, Intel will need to integrate their tooling supplier months, if not years, ahead of production to ensure the design criteria can be met. If Intel fails to align on a proper timeline with its tooling suppliers, they are setting up their new product launches for production failure.

2.3.4 Technology Life Cycle

2.3.4.1 Computer Processing Unit (CPU)

Intel's iconic microprocessor began with the first commercial 4004 processor in March of 1971. The release for the 33 years would be consistent and provide a prime life cycle of roughly 2–3 years per CPU. After the release of the next generation, CPU production of the last CPU will slowly be ramped down and prices will be cut. Driving the short relevant life cycle is the steadily increasing number of transistors available on every newer processor. This short life cycle makes the time an incredibly valuable asset in the release of microprocessors and establishes a barrier to entry to the industry. Each generation of microprocessors that reduces critical dimensions results in faster performance, reduced energy consumption, and a lower cost per transistor. These three items are the key performance indicators that PC and data center customers desire in processors. The expectations for the product development of the next generation of chips has been predictable for the research and development team.

This traditionally predictable product life cycle is simple in principle and heavily dictates every decision made in the industry about product life cycles. It offers the benefit of giving the industry leader a dominant market share but demands consistent innovation to retain market share. Intel maintained the improvement at consistent intervals with a “tick tock” model to vary the focus on each generation of microprocessor. The Tick model would represent a new manufacturing process resulting in a smaller critical dimension. The Tock model after would be the same gate size as the last Tick model but have a different microarchitecture on the chip. The new microarchitecture would squeeze the gate closer together to fit more transistors on the chip without shrinking the gates themselves. In the last decade, the thermal properties of silicon have reduced the gains expected in the clock speed of the chips. This forced companies to seek creative options in order to improve performance and resulted in more cores available in many consumer PC microprocessors. By sharing the workload in parallel across multiple cores the performance of the chips would increase with compatible software.

2.3.4.2 Internet of Things (IoT)

The IoT market is a new field for Intel where many different smart connected devices to provide innovation in a variety of fields. This field will require custom-built processors called Field Programmable Gate Arrays (FPGAs) in the devices and large data centers to interpret the information received. The data center side of the business will have predictable new product development expectations just like the rest of the CPU industry while the IoT devices themselves will vary. Countless devices will be connected to the internet and together they will solve engineering problems that currently seem impossible. Intel’s business justification can be broken down into securely dealing with IoT devices, building an intelligent system, and providing customers end to end analytics. Developing IoT can provide Intel revenue directly from the services they provide and indirectly from the cloud analytics that will require additional server processors to review data.

Some IoT devices will power cheap sensors that monitor temperatures of homes, the humidity of rooms, and weather fridge doors are open or closed. Many of these devices will be cheap and have a low importance if they do fail. Certain IoT devices will be responsible for saving lives and require large amounts of validation and testing. Security will be a top priority for almost all data as companies and advertisers will view the data as valuable IP that may contain insight on consumers.

Autonomous driving is an incredibly new technology that will present unique challenges to product development and life cycles. The technology will continue to improve drastically over the next decade which will require consistent improvements in performance to remain competitive. The validation of the hardware will require external validation to ensure that the products are safe for the consumers. Cars themselves are driven for a long time after they are purchased with the average age of a car on the road in the USA being 12 years. Certain consumers will pay for the latest technology while others will use older technology to reduce the cost of the devices in their affordable cars.

FPGAs were a $6 billion industry in 2017 and are expected to grow to $10 billion by the year 2023. They represent a growing need for purpose-built chips that can efficiently, securely, and cost-effectively to accomplish device-specific tasks. Intel's acquisition of Aletra for $16.7 billion on December 28, 2015 help Intel gain the intellectual property needed to enter portions of the FPGA market. Companies want FPGAs that have a lower fixed initial design cost and a lower variable cost associated with manufacturing each. Having extra features on generic FPGAs can cost extra money per unit and result in poor performance. Generic FPGAs fail to do a very specific task well that certain devices need resulting in longer computational times and higher battery usage. Technology life cycles of FPGAs will vary greatly depending on consumer adoption habits and the demand of the device itself. Meaningful improvements in battery life, features, and security will drive demand for the latest model of FPGAs. The usable lifetime of specific devices will likely dictate how long the FPGAs will be expected to last. Cars may need reliable performance for 25 years while mobile.

2.3.5 *User-Centered Design of Products*

Companies' success is largely dependent upon the user-centered design of products and Intel is no exception. According to Intel company values, customer-centric work is based upon three pillars: why they do it, how they do it, and what they do. Intel believes "Design thinking" is the future of work. These kinds of design innovations can play an integral role by making human-to-device interactions more intuitive, individualized, and convenient. Creating superior user experiences can ultimately translate into a competitive advantage.

2.3.5.1 User-Centered Design Methods

Intel employs several methods in user-centered design of new products which include research studies, the Intel User Experience Lab, and various business acquisitions.

Intel was one of the first companies to research consumer acceptance in the self-driving car industry. In March 2017, Intel announced plans to purchase Mobileye, an

Israeli developer of autonomous driving systems. General acceptance of autonomous vehicles is low. This data is based upon two independent surveys conducted by Morning Consult in 2018. The polls show that mistrust in autonomous driving increased following two fatal accidents involving autonomous vehicles in March of 2018.

Even without technological flaws, acceptance, and adoption of technology are impossible if people are afraid to use the technology. Intel is an advocate for the social integration of self-driving cars. Intel conducted acceptance testing, a type of trial that is becoming more common in the food and software industries that analyzes consumer feedback on new products. Currently, no product in these industries is launched without extensive feedback from testers. In turn, developers are able to make products more user-friendly. Intel conducted this type of study to analyze consumer trust in self-driving cars. In general, people are wary of safety levels, surrendering control to a machine, and many must overcome psychological discomfort. Intel Autonomous Driving Group investigated whether participants who had never ridden in a self-driving car would change their mind after experiencing it first-hand. In the study, passengers were interviewed before, during, and after riding in an autonomous car in order to track any change in opinion. The cars used were Ford Fusion sedans that have a minimalist addition of a camera on the top roof of the vehicle. The following results were found: passengers reported that seeing the steering wheel moving without a driver contributed to anxiety; voice control between humans and machines eases feelings of lack of control; and passengers expressed concerns over the special needs of small children, the elderly, and those with disabilities. At the time, it was one of the first studies of its kind, but more research is to be done. Currently, there is no standardized testing model for self-driving cars, but one may be developed in the future to standardize testing methods.

In the Intel User Experience Lab, Intel products are researched with the consumer in mind; using technical equipment, the consumer experience is replicated by stimulating the senses of sight, touch, and hearing. Display testing is conducted using a variety of tools. A consistent pattern indicates a consistent picture, whereas a non-uniform pattern indicates an inconsistent picture.

Touch is analyzed using a robotic arm and display testing. The robotic arm lets researchers conduct tests in a repeated and controlled fashion, with the ability to simulate fast, slow, and erratic movements. A camera captures a video of the robot arm's actions. The footage is fed into a spreadsheet and analyzed to help researchers understand what needs to be improved to satisfy the user.

Sound is analyzed using a hemi-anechoic chamber, where in-depth testing is conducted on speech recognition, audio, and voice quality testing. A head-shaped device can measure pressure on the ear and distance from the mouth to understand ways that humans react with audio devices. Different voice types are simulated as well as background sounds such as forest environment, elementary school playground, and train stations among others.

Through numerous business acquisitions, Intel is capable of developing more user-centric products. In 2013, Intel acquired Omek Interactive, a company that develops gesture-based technologies; through this acquisition, Intel hoped to increase its capability of delivering more immersive perceptual computing experiences. In 2013, Intel acquired Indisys, a Spanish natural language recognition startup that developed artificial intelligence technology in the form of a human image that converses fluently in multiple languages across different platforms. In 2015, Intel purchased a 20% stake in Vuzix, a smart glasses manufacturer. In 2015, Intel purchased cognitive computing company Saffron Technology. In August 2016, Intel purchased deep-learning startup Nervana Systems.

2.3.5.2 Intel's User-Centered Products

In addition to fostering a creative, human-centered culture, Intel develops products that cater to the needs of consumers and industries alike.

Intel offers a wide range of CPU products suitable for different devices with their scalable processors. Intel Core processors can be chosen depending on the type of device and whether the customer prioritizes performance or mobility. Collectively, Intel Quark, Intel Atom, Intel Core, and Intel Xeon processors each support a wide range of performance points with a common set of code.

Intel has also worked to improve the user experience of virtual reality (VR) gaming. Intel designers worked to optimize the user experience and performance of Code51—the first worldwide mech arena VR game supporting Oculus Rift, HTC Vive, PSVR, and Pico VR platforms. The game has been released in over 3000 VR arcades in China and is targeted for release in PlayStation Store, Oculus Store, and Steam in Q2 of 2018. Intel enhanced visual and audial aspects of the game through the use of its Intel Core i7 processors and included features such as 3D audio, object destruction, enhanced CPU particles, and additional background objects. Intel achieved this improvement by utilizing seven design points of immersive VR games. First, they determined the choice of immersive motion tracking system to drive player movements in the virtual world of a game by comparing the tracking system's pros and cons with the game's mechanics. For instance, for Code51, the virtual cockpit tracking system was chosen for the ability to move continuously in VR, compatibility with current premium VR helmets, alignment with the "sitting down" style of the arena game, and to permit longer gameplay. Intel designers also worked to alleviate VR motion sickness through UI design, level design, rendering performance, reducing acceleration and angular velocity, and dynamically reducing the field of view. Steps were also taken to enhance the spectator viewing experience for e-sports. Another issue that was mitigated was the low sharpness of current VR HMDs compared to conventional displays. CPU performance was also optimized to prevent stalling the VR scene rendering. Lastly, the user experience of the VR game was improved by utilizing all available computational resources on a hardware platform as much as possible, resulting in a deeper immersive experience. These features significantly increased the immersion of Code51 on high-end CPUs without a performance drop, since most of the computation was offloaded to idle CPU cores.

Internet of Things (IoT) refers to the network of devices, vehicles, and home appliances embedded with electronics, software, sensors, and connectivity which enables these items to connect and exchange data without human interaction, resulting in many benefits such as improved efficiency, saved time and money, and reduced human exertion. This network of devices reinforces user-centered design by catering to the individual need of the user. Intel IoT products are present in every consumer and industrial application imaginable: retail digital signage and kiosks; retail analytics and operations; healthcare analytics, infrastructure, and products; financial services; smart cities, buildings, and homes; automotive and connected transportation; industrial automation; and energy. IoT devices cannot operate independently; significant data analysis—using servers—is necessary to run IoT systems. For instance, a self-driving car generates 4 TB per day and a plane generates 40 TB. Each of these systems needs to be connected in a feedback mechanism that can generate actionable intelligence, through AI or high-level data analytics. These IoT systems cannot run without powerful back end processing services. Smart homes, autonomous driving, industrial systems, and energy are utilizing an increasing number of sensors, but they cannot be enabled without a system to collect and analyze this data to make informed decisions. The recent restructuring of the Intel IoT group has shifted its focus to higher end and more compute-intensive applications such as autonomous vehicles, drones, and healthcare, with Atom, Core, and Xeon chipsets. Though this area is lower volume than "gadgets," it has better margins that better fit into Intel's strengths. These are areas where Intel has significant intellectual property to exploit: CPU, GPUs, storage, and connectivity for analytics, AI, ML, big data processing, and network operations.

2.4 Conclusion

This case study has identified five perspectives within the topic of new product development in which to analyze Intel Corporation. Intel focuses on accelerated radical innovation by meticulously investigating the product development process from initial concept to commercialization, adoption, and societal impact. Product performance increases substantially from generation to generation as a result of regimented innovative research process and implementation. Intel has defined product development strategies that include leveraging internal development/manufacturing capabilities to optimize Intel's product portfolio and acquisition of startups to enhance products in their portfolio to expand into high-growth markets. On the manufacturing side, Intel focuses on integrating tooling suppliers in their development process to ensure they have the manufacturing technology required. Collaboration between Intel and tooling suppliers allows for customer interactions and inputs in tooling supplier product design. This allows for improved product functionality custom catered to client needs.

Intel always understood where its products are in their respective technology lifecycles to understand the engineering expectations of their devices. User-centered product focus from the conception of a product is a key component of the methodology Intel employs in product feature design. Maintaining close ties to end users allow Intel to create products that better cater to customer needs. By employing these five strategies Intel has secured their place as a leader in the semiconductor design and manufacturing industry.

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