ACT
Protecting Small Business Innovation

Future of Computing

User Experience and Integration

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Executive Summary

The computing industry is going through a mobile revolution as svelte, powerful, and power-sipping devices are freeing users from their power cords. On the heels of the smartphone, notebook, and netbook booms, tablet computers are changing the dynamics of the computing industry. And now we have ultrabooks emerging, combining some of the best attributes of tablets and small form computing devices. Innovation will not stop until we achieve a computing continuum with multiple, interoperable devices optimized for specific uses.

Yet, the success of all of these devices has to do with taking full advantage of recent trends in computer design:

- **TREND #1: User Experience Design Processes** – Be they desktops, laptops, or servers, computers have traditionally been designed as general purpose computing platforms. Increasingly, however, the design of computing devices and components is being guided by User Experience (UX) design research in order to better understand user expectations and behavior and deliver devices that match them. Most major tech firms employ UX researchers today, including Apple, Intel, Google, and Microsoft.

- **TREND #2: Integration of Computing Components** – Chip companies have been moving toward increased integration of components since the first days of the industry. AMD, Apple, ARM, and Intel have all been pushing more components (Central Processing Units, Graphical Processing Units, Memory, Input/Output interfaces, etc.) on the same piece of silicon. These integrated designs reduce the cost, size, complexity, and power consumption of systems while increasing performance per square inch of silicon, which makes customization for specific user experiences more feasible.

These trends represent the future of computing, and they are helping the industry create incredibly powerful and portable devices that are easy to use and inexpensive to own. In order to meet the evolving needs of users, computing devices (particularly mobile computing devices like tablets and smartphones) are becoming more like consumer electronics devices than traditional general purpose computers. The trade-off is that these devices are less flexible than a general purpose computer. Apple's iPad, for example, does not perform some traditionally basic computing operations, nor does it allow you to easily swap out the graphics processing unit (GPU), the memory, or the camera the way you can on your desktop PC.

While some have raised concerns about these tradeoffs and what they mean for competition and openness, those fears have proven to be overblown. First, both of these trends are proven to improve the experience for users and to lower costs. Second, the increasing popularity of devices like the iPad and Kindle demonstrate that many customers are comfortable with making these tradeoffs. Third, competition in the chip market is evolving as Apple, Intel, Qualcomm, Nvidia, Samsung, and others are increasingly competing head-to-head with fully integrated system-on-chip designs. Finally, the reality is that an increasing number of customers will own a

multitude of interconnected devices that they use for specific tasks and environments. Despite the recent success of more specialized devices, general purpose computing platforms will continue to play a large role in the computing landscape for the foreseeable future, ensuring that those customers who demand that ultimate level of flexibility will continue to have the option.

Future of Computing: Lessons from The Tablet Revolution

Apple officially announced the iPad in January of 2010 and began selling them in April of 2010. At that time, tablet-style computers had been widely available in business and consumer channels for a decade, yet few of them were met with anything more than moderate interest and none became mass-market products. Sales of tablets lagged despite Bill Gates's bold pronouncement way back in November of 2001 that within five years tablets would become the most popular form of computers sold.[1]

Over the past 15 months, however, the tablet market has taken off. In the wake of the iPad, Asus, Barnes & Noble, HP, HTC, Research In Motion, Motorola, and Samsung have all released tablets into the marketplace. In fact, more than 15 million tablets were shipped in Q2 of 2011.

Consumers loved the fact that tablets enabled them to play HD video for 10 hour stretches and surf the web with effortless swipes and touches - all in an almost impossibly svelte package that cost around $500. Previous generations of tablet computers weighed two or three times as much as an iPad and cost three or four times more. Netbooks, the pinnacle of mobility in the pre-iPad era, generally cost the same, weighed between 2.5-4 lbs, only had two or three hours of video playback, and were regularly criticized for lack of responsiveness.

Perhaps the most amazing aspect of these devices is that all these improvements in performance were achieved without any radical new innovations in chip design or battery design. For example, the chip Apple is using is based on a relatively common ARM Cortex-A8 chip and its batteries are basically standard rechargeable lithium-ion polymer (LiPo) batteries similar to those used in Amazon's Kindle, Microsoft's Zune, and Apple's MacBook products. Instead, Apple and the other tablet manufacturers have fully embraced two of the most important

[1] "Comdex: Gates foresees 'digital decade'" CNN.com: November 12, 2001 http://archives.cnn.com/2001/TECH/ptech/11/11/comdex.gates.keynote/index.html

trends in the computing industry to impressive effect: *User Experience Design* and *Integration of Computing Components*.

These devices are not designed to be replacements for general-purpose computers, but the design methodologies used to produce them will benefit the entire spectrum of computing devices. The use of *User Experience Design* and *the Integration of Computing Components* will be critical in mobile phones, notebooks, and even high-end servers.

Expanding User Experience Design to PC Development

User Experience Design (UXD) provides a holistic approach to design that includes everything from human factors, to engineering and usability, to ergonomics and accessibility. It is a relatively new design discipline that emerged organically as information technologies became more intertwined in the daily lives of people. As computers left the office and found their way into our pockets, traditional approaches to industrial design like "human interface design" and "ergonomics" reached the limits of their effectiveness.

While the concepts of User Experience Design began in the computing industry with consumer-facing companies like Apple and Microsoft, its influence has more recently expanded into PC component companies like IBM, Intel, and Nvidia. In particular, Intel has been a leader in this area. Last year, Intel launched its Interaction and Experience Research (IXR) division which is dedicated to changing how people experience computing in the future. While Intel's design decisions were previously driven by the engineer's quest to keep pace with Moore's Law or demands from customers like Dell and HP, the company's embrace of UX research means designs are now being shaped by the needs of the end users rather than original equipment manufacturers or its first line customers. Recently, this research has led Intel to focus on creating "context aware" platforms for devices that can mute themselves automatically in a church or stop your stream of Facebook updates while you're in an important meeting[2].

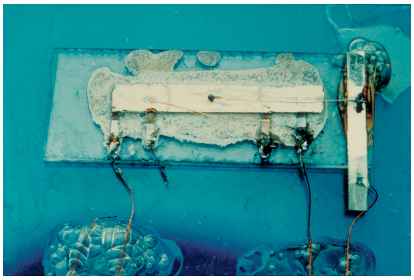
In the case of the iPad, Apple's implementation of User Experience Design enabled Apple to start from scratch and reimagine the device as being more akin to a consumer electronics device than a general purpose computer. Whereas previous mobile computing devices were designed to be tiny personal computers, capable of doing anything a computer user might do, the iPad was designed to sacrifice some of that power and flexibility to deliver 10 hours of HD movie watching and a great web browsing experience in a very small device.

[2] Intel Blog. http://blogs.intel.com/idf/2010/09/contextual_continuity_across_t.php?wapkw=%28genevieve+bell%29

Integration By Design

In many ways, the increased focus on UXD has provided added fuel to a second major trend, integration of computing components, which has been a driver for change in the computer industry since its inception.

History of the "Integrated Circuit" Industry



Since the beginnings of the computer industry, there has been a constant and ever-increasing move toward the integration of computer processing components. In fact, the issues of size, cost, and power consumption led Texas Instruments' Jack Kilby to invent the first "integrated circuit."

Until the 1950s, the electronics industry relied almost exclusively on vacuum tubes, which were "fragile, bulky, unreliable, power hungry, and produced considerable heat." Creating even modest computational machines required soldering thousands of these devices together into an incredibly complex system with thousands of points of potential failure. This was termed the "tyranny of numbers" and it's what Kilby solved with his creation of the integrated circuit.

The overall trend toward integration of computational components has continued ever since. Throughout the past 25 years of the PC era, new functionality has been added directly to the central processing unit with each new generation of technology for the same reasons. Here are a few examples, each of which became standard components in nearly all CPUs that followed.

Intel's 486 Chip (1989) | Integrated Math Coprocessor and Memory Cache

In order to improve overall performance, the Intel 486 integrated several components onto the chip that were previously only available as separate components. Most notably, Intel added a Floating Point Unit (FPU), also known as a "math coprocessor," directly to the chip. FPUs are used to carry out basic mathematical functions including addition, subtraction, multiplication, and division and are now integrated into every modern chip to enhance processing speeds and save money. Additionally, Intel added 8kb of on-chip SRAM memory cache directly onto the chip resulting in much faster results than the off-chip cache solutions used with 386 chips.

AMD's Opteron Chip (2003) | Integrated Memory Controller

AMD's Opteron processor was groundbreaking on several levels, but it was also the first x86 PC chip with an integrated memory controller. Integrating the memory controller reduced the latency penalty for accessing the main RAM and eliminated the need for a separate memory controller chip.

AMD Fusion and Intel Sandy Bridge (2011)

Following AMD's purchase of the Graphics Processing Unit (GPU) maker ATI, AMD's CTO announced in 2006 that the company would be integrating its CPUs with ATI's GPUs in order to "bring supercomputer performance to the desktop[3]." AMD launched the result of that vision, the Fusion platform, in early 2011. Also in 2011, Intel launched processors based on its Sandy Bridge architecture that includes an integrated GPU.

System on a Chip

Nearly every major chip designer has deployed or is deploying System on a Chip (SoC) designs today, and they power most smartphone and tablets today. SoC architectures are the next step in integration, pulling together nearly all the computational resources, memory, external interfaces, and power management functions onto a single chip. SoCs have long been considered the best option when size, power consumption, and reliability are the most important aspects of the decision.

As mobility becomes a key factor in more computing decisions, SoCs are evolving beyond their traditional roots as processors of choice for embedded devices like cameras and feature phones. Today, SoCs are increasingly being used in more general purpose computing devices, like smartphones, tablets, and netbooks.

ARM-based SoCs

The ARM Holdings Corporation is a spinoff of British firm ACORN Technologies and Apple computers that was created in 1990 as the two firms were collaborating on Apple's first tablet computer, the Newton. Today, ARM mostly does research and design of new ARM-based chip technologies and licenses them for manufacture by companies like Apple and Samsung. NVidia's Tegra chips, Qualcomm's Snapdragon, and Apple's A4 & A5 processors are all built on the ARM platform.

As of 2007, almost 98 percent of the nearly 1 billion mobile phones in use included at least one ARM processor, but the company and its licensees have been increasingly focused on more complex systems. Variations of ARM chips have powered nearly every major smartphone including Apple's iPhones, Motorola's Droid, Samsung's Galaxy S, and HTC's EVO. Additionally, ARM SoCs are becoming increasingly popular for tablets and netbooks like the Apple iPad, the Amazon Kindle, Barnes and Noble's Nook eReader, the Blackberry Playbook, and the Motorola Xoom. Dell has already used ARM SoCs for some low-end laptops and netbooks, and Microsoft has already announced that its newest version of Windows, Windows 8, will run on ARM SoCs.

[3] http://www.telegraph.co.uk/finance/newsbysector/epic/arm/8243162/History-of-ARM-from-Acorn-to-Apple.html

Intel-based SoCs

With the market for small, low power, high performance chips growing rapidly, Intel is moving into the market for SoCs. With a background in producing chips focused first and foremost on performance, Intel is only recently entering the market for low power chips. With battery life and "instant on" responsiveness becoming key factors for this platform, …?

While Intel has been experimenting with SoC designs for years, in May 2011 the company announced two new SoC platforms, Cedar Trail and Medfield. Cedar Trail is the successor to Intel's first system on a chip for tablets and netbooks, Oak Trail, which includes processors like the Atom processor Z670 and hit the market in 2011, powering the upcoming Lenovo Ideapad slate among others.[4] Medfield is Intel's first significant foray into providing SoCs for smaller devices like smartphones and tablets.

Microsoft Xbox SoC

Even Microsoft is getting into the SoC game in an effort to remove any potential over-heating issues with its Xbox 360 gaming console. Gamers are among the most demanding computer users out there and game consoles are often pushed to the brink of overheating by graphics-intensive gameplay. Throughout the Xbox's history, Microsoft has moved toward more integrated processors with each generation, culminating in Xbox 360 Slim, codenamed "Valhalla," which uses the Microsoft Xbox CGPU SoC.[5] "The goal of the consolidation was, of course, to lower the cost of making the console by reducing the number of different chips needed for the system, shrinking the motherboard, and reducing the number of expensive fans and heatsinks."[6]

The undeniable trend in computing is toward continued integration of increasing numbers of computing components onto a single piece of silicon. This trend has been going on since the very first days of computing and is being driven by consumer demands for better performance, with longer battery life, at lower costs.

The Future of Computing: A Policy Approach

The trends outlined above and exemplified by modern tablets are set to guide the long-term evolution of the computing industry. From the perspective of government policymakers and regulators, the reasons for encouraging these trends are pretty clear.

[4] http://newsroom.intel.com/docs/DOC-1976

[5] http://www.anandtech.com/show/3774/welcome-to-valhalla-inside-the-new-250gb-xbox-360-slim

[6] http://arstechnica.com/gaming/news/2010/08/microsoft-beats-intel-amd-to-market-with-cpugpu-combo-chip.ars

The entire purpose of UX design research is to create products that better meet the actual needs of consumers. This research has guided the development of some of the most successful technologies in history including the smartphones, tablets, electronic readers, and the Microsoft Xbox Kinect. UX design methodologies enable companies to maximize the benefit to consumers per dollar spent on technology and leads to the kinds of innovative technologies that can create new jobs and improve lives.

The computing industry is moving rapidly toward more integrated components in order to meet the demands of consumers for more mobile and less power-hungry computing devices that still have great, or even improved, performance. In order to meet the growing appetite for mobile computing devices, the industry is using integration and SoC's to shrink sizes, lower costs, remove noisy fans, and increase battery life with no impact to performance. Smartphones like the Motorola Droid and iPhone as well as tablets like the iPad and the Samsung Galaxy Tab are just scratching the surface of what is possible with SoC chips. Integration is also proving critical to the development of industry-specific solutions in medicine and hospital care. Additionally, integration has been taking place in the desktop PC and server markets in order to boost performance, reduce size, and to make less power hungry/greener computers, particularly for the servers that make cloud computing possible. Perhaps the best example of this trend is in area of supercomputing, where computers the size of buildings have been reduced to a single SoC[7].

Figure 2 World's First TeraFlop Super Computer (Sandia's ASCI Red - 1996)

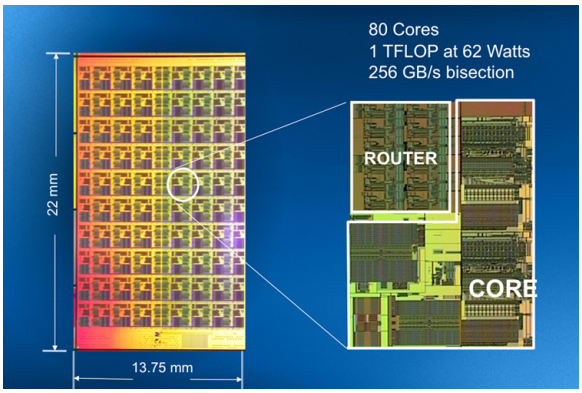


Figure 1 World's First TeraFlop Super Computer ON A CHIP (Intel's TeraFlops Research Chip - 2007)

Despite the clearly beneficial goals and outcomes of these two trends, however, some have expressed concerns and argued that the government should intercede. Generally, these concerns fall into two categories: the potential for less competition in the chip market and less openness and innovation on these platforms.

[7] "An Overview of Intel's Teraflops Research Chip." Legit Reviews. February 13, 2007. http://www.legitreviews.com/article/460/1/

Competition in the Age of SoC's

The continued integration of computing components onto a single piece of silicon has raised some concerns about competition in the computing industry. Companies that have emerged to provide discrete chip solutions for processing graphics (GPUs) and handling newer input/output devices face an uncertain future as the need for discrete solutions declines. Given this reality, some have argued that chip integration is a form of anti-competitive tying that is illegal under Section 1 of the Sherman Antitrust Act.[8]

Regulators are concerned that this integration could harm competition and, eventually, consumer choice. The existence of dominant players in the market only heightens their concern and requires them to review these arrangements closely. They are usually worried that this integration will create a market with fewer competitors, lower incentives to innovate in the areas of integration, and eventually higher prices for less innovative products. However, a closer look at the chip market, its history, and the law suggests that these concerns can easily be dismissed:

- **Modern Antitrust Law Recognizes that Most Tying is Competitive** – Economists and courts have recognized that most tying arrangements, even those by dominant firms, are pro-competitive and improve consumer welfare. Economists have written extensively about the pro-competitive effects of many forms of integration (or tying arrangements). [9] Additionally, the US Supreme Court has found that competitive markets and tying arrangements are compatible.[10] If there is potential harm, then the regulator should weight the pro-competitive benefits of the tie against the harm it produces in order to determine whether to act. Even if we assume the potential for harm given the role of dominant players like ARM and Intel, the weighing of the equities are overwhelmingly positive for consumers and competition.

- **Integration is Being Driven By Consumer Demand and It's Creating Immense Benefits –** As discussed at length above, the trend toward integration of previously discrete computing components onto a single piece of silicon has been going on since the early days of the computer industry. In every instance, these decisions were made in order to deliver benefits to consumers, either through better performance, lower prices, smaller sizes, or better battery life. Moreover, the benefits have been extraordinary. For a few hundred dollars, you can now carry around the equivalent of a mini supercomputer in your pocket that can connect wirelessly to broadband Internet and run all day long without needing to be plugged in.

- **Competition in the Chip Market is Evolving, Not Disappearing** – To begin with, the market for high-end notebooks, PCs, and servers that utilize discrete CPU's and GPU's is not going away. Those markets will continue on well into the future as [[scientific researchers, medical professionals, video editors, gamers, and animators]] continue to prioritize computing power above power consumption, price, or size. In the mobile computing space, however, competition is evolving into an even more dynamic market than it ever was before. The rapid growth of the mobile market has meant that the previously distinct market for SoC processors for embedded devices and smartphones is merging with the market for PC processors for netbooks, notebooks, and tablets. Increasingly, Intel and AMD are competing with ARM-based chips from Qualcomm, Samsung, and others. Additionally, NVidia, which previously

[8] In the U.S. Federal Trade Commission's 2009 complaint against Intel, the regulator argued the practice amounted to "unlawful bundling or tying of Intel's GPUs with its CPUs resulting in below-cost pricing of relevant products."
http://www.ftc.gov/os/adjpro/d9341/091216intelcmpt.pdf
[9] David Evans & Michael Salinger, Why Do Firms Bundle and Tie? Evidence from Competitive Markets and Implications for Tying Law, 22 Yale J. on Reg. 37 (2005).
[10] Ill. Tool, 126 S. Ct. at 1292; see also infra note 21 and accompanying text.

focused solely on discrete GPUs, is now producing its own SoC based on the ARM platform and competing head-to-head in the mobile market. This merging of the market will be accelerated further as Microsoft Windows 8 is released and computer makers will have their choice of dozens of processors from AMD, Intel, Nvidia, Qualcomm, Samsung, and others.

Generativity & Openness in Age of UX Design

In some academic circles, there is concern about the success of devices based on UXD that are somewhat less open and "generative" in comparison to general purpose computers. In 2008, Harvard Law School professor Jonathan Zittrain published a book entitled "The Future of the Internet And How to Stop It." In many ways, "The Future of the Internet" is actually an anti-UX Design screed. Zittrain's central premise is that "A lockdown on PCs and a corresponding rise of tethered appliances will eliminate what today we take for granted: a world where mainstream technology can be influenced, even revolutionized, out of left field."[11] Zittrain's essential worry is that consumers' understandable fears about the security of fully generative systems (like a PC) could lead toward "locked-down" appliances like iPhones, Tivos, Blackberries, and Xbox's dominating the future of computing, and he's asking government and industry players to do something about it.

One core problem for Zittrain's argument is his assumption that "fear" is leading consumers toward Tivo's and iPhones. He dismisses the concept that users might actually prefer the simpler, more elegant solutions that are produced via UX design practices to be optimized for specific uses. Instead, Zittrain argues that concerns about security of open platforms (they don't offer the safety of curated application stores, for example) scare people away from general purpose computing devices and toward more closed platforms. In essence, he thinks everyone would prefer a single Swiss Army knife instead of a kitchen full of Henkel's knives, a Rabbit corkscrew, and full size forks and spoons. Yet, from the research being done by UX researchers around the world, it is clear that UX methodologies work incredibly well to produce the kind products that make users more productive and happier.

Even more problematic for Zittrain's theory is the fact that his predictions have largely been proved false. In the three years since his book was published, even the platforms that he criticized for being "sterile" and lacking "generativity," have proved incredibly innovative.

Zittrain rightfully understands that the community of users and developers that emerges around a platform technology is often as innovative as the company that produced the technology in the first place. Therefore, he argues, the ideal computing device is left intentionally "unfinished" in its design to allow for a more open platform for innovation. However, the iPhone and Xbox, who play the villains in Zittrain's story, have built up massive, generative innovation communities around them. Apple's App Store now contains more than 350,000 apps for the iPhone and iPad [12] and the incredible innovations in robotics, 3D imaging, and medical technology that are being created using Microsoft's Xbox Kinect are simply astounding.[13]

Why were the concerns about a lack of openness and generativity on these platforms misplaced? First, these concerns represent an underestimation of human creativity. The imposition of some limitations on a platform technology rarely prevents innovation, and usually spurs innovators and creatives to find ways around those

[11] Zittrain, Jonathan. The Future of the Internet: And How to Stop It. Yale, 2008. Pg 5.
[12] http://www.apple.com/iphone/features/app-store.html
[13] http://spectrum.ieee.org/automaton/robotics/diy/top-10-robotic-kinect-hacks

limitations or to embrace them and find innovative ways to solve their problems within that framework. Second, these concerns underestimate platform technology providers like Apple, Intel, and Microsoft. Despite Zittrain's fears, these companies all fully understand the importance of generativity and creating vibrant developer communities around their platform technologies. Efforts to build information appliances and create a more structured system is not a betrayal of those principles, but rather an attempt to combine the benefits of an open platform with the ease of use and security of more closed ones.

Conclusion

The hardware side of the computing industry is being increasingly driven by trends toward User Experience Design processes and the increasing integration of computer components onto a single piece of silicon. These trends represent the future of computing, and they are helping the industry create incredibly powerful and portable devices that are easy to use and inexpensive to own. In order to meet the evolving needs of users, computing devices (particularly mobile computing devices like smartphones and tablets) are becoming more like consumer electronics devices than traditional general purpose computers. The trade-off is that these devices are less flexible than a general purpose computer. You can't buy an iPad and easily swap out the graphics processing unit (GPU), the memory, or the camera the way you can on your desktop PC.

While some have raised concerns about these tradeoffs and what they mean for competition and openness, those fears have proven to be overblown. First, both of these trends are proven to improve the experience for users as well as lower costs. Second, the increasing popularity of user specific mobile devices like the Kindle demonstrate that many customers are comfortable with making these tradeoffs. Third, competition in the chip market is evolving as Apple, Intel, Qualcomm, Nvidia, Samsung, and others are increasingly competing head-to-head with fully integrated system-on-chip designs by designing SoCs for specific uses. Finally, general purpose computing platforms will continue to play a large role in the computing landscape for the foreseeable future, ensuring that those customers who demand that ultimate level of flexibility will continue to have the option.