The Semiconductor Industry's Role in the Net World Order

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The global chip industry has seen a number of remarkable changes in the decades since it came into being with the initial diffusion of the technology in the 1960s (Tilton, 1971). These transformations include not only technological advances but also changes in the competitive landscape. This paper examines new forces that are reshaping the industry once again. The central force is the emergence of distributive networks as the leading application for the electronics industry. New forms of network communication and information flows have given rise to what we call the "Net World Order." Other forces feeding into the current evolution of the semiconductor industry include the maturation of the manufacturing services industry and the development of an organizational infrastructure for system-level chip design. Our analysis of the industry focuses on how chip makers are creating and capturing value within the emerging Net World Order.

The 1960s and 1970s saw the rise of semiconductor producers in the United States, Japan, and Europe, spurred by breakthroughs in the United States, including the development of the integrated circuit and the creation of the microprocessor. Despite its history of technology leadership, the United States semiconductor industry's *market* leadership had diminished by the mid-1980s when Japanese firms displaced their U.S. counterparts largely on the strength of their manufacturing prowess applied to "commodity " chips – primarily DRAM. The 1990s saw a "reversal of fortune" as U.S. firms responded with both improved manufacturing capabilities and more sophisticated designs (Macher, Mowery, and Hodges, 1998).

The key application for semiconductors during the 1990s was the personal computer (PC). Intel was selected in 1980 as the supplier of the microprocessor for the initial IBM PCs, and by 1992 it had grown to become the single largest supplier of integrated circuits to the world market.[1]

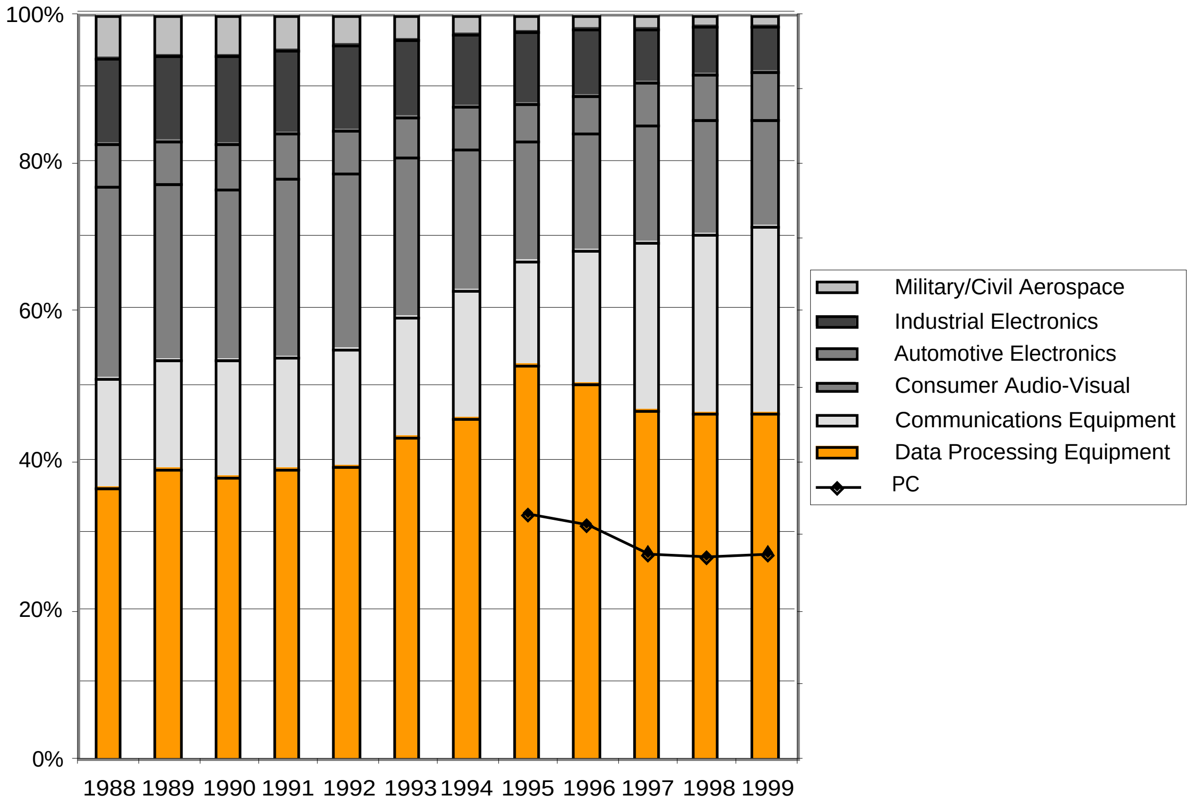
At the beginning of the current decade, Intel is still in the number one position, but it no longer appears as unassailable as in the past. Not only does it face credible competitors in its key microprocessor market, but it is also scrambling to capture share in important new markets where it does not enjoy a standards-based advantage. This shift in the electronics industry has been widely heralded[2] as the dawn of the "Post-PC era" in which the central application is the Internet, along with the home, office, and wireless networks connected to it – a phenomenon collectively known as "distributive networks."

Figure 1 illustrates these changes. During the early 1990s, the share of semiconductor sales to products in the data processing sector climbed steadily to peak in 1995 at more than 50% of all semiconductors sold. Subsequently, this share – about 60% of which is accounted for by personal computers alone – has fallen, while chip sales to the communications sector (both wireline and wireless) have expanded.

[1] based on data from Dataquest.

2 In a telling example, albeit one that was perhaps driven in part by the dot-com bubble, Ziff-Davis changed the name of its venerable "PC Week" magazine to "eWeek" in May 2000.

Figure 1: Sales of Semiconductors by Final Product Market, 1988-1999



SOURCE: DATAQUEST

As noted above, a key change in recent years has been a shift in the status of manufacturing. Intel's dominance of the semiconductor market has been built in part on its commitment to manufacturing excellence. Rapid successive introductions of new generations of process technology enabled the creation of faster microprocessors. Few companies could match the technology level or the volume of Intel's production.

Yet manufacturing has become less of a differentiator among semiconductor firms for two reasons. First, many products that used to require specialized manufacturing processes can now be fabricated in the industry's most common process, known as CMOS. Second, providers of chip manufacturing services – foundries that design and sell nothing of their own – have achieved technical levels in CMOS manufacturing that rival even Intel and have built up formidable capacity (Macher, et al., 1998). Thus, cellular telecom company Qualcomm, whose CDMA technology first appeared in the market in 1995, was able to rapidly expand foundry production of chip sets for its phones and basestations to become the largest "fabless" chip company with sales of roughly $1 billion by 1998. Such fabless companies now account for about 10% of the chip industry's sales,[3] and chip firms that own fabs are increasingly turning to the foundries for part of their output.[4]

This paper examines product innovation by chip firms in the Net World Order, and how innovation (value creation) translates into revenue (value capture). To what extent are the chip

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[3] Based on data from the Fabless Semiconductor Association reported in "Order Up?" *Electronic Business*, November 1999.

[4] "Getting In Line At The Fab," *Electronic Business*, August 2000.

makers capturing a share of the value they create? What determines their share? How have the rules of the game changed as the industry expands its focus from personal computers to distributive networks?

To research these questions, we have conducted over two dozen anonymous interviews with semiconductor firms and their customers in the United States and Europe. Our research also exploits the rich store of publicly available information in trade journals and company reports.

This paper provides preliminary answers to our research questions. Section 1 provides a quantitative introduction to the role of semiconductors in the Net World Order and presents a simple framework of value creation and value capture. Section 2 briefly recounts the history of the "PC World". Section 3 describes the ways in which chip firms create value in the Net World Order, through both innovation and cooperation. Section 4 describes the strategies of chip firms for capturing value in the Net World Order. Section 5 takes a look at the preceding issues from a regional perspective. Section 6 concludes.

1. Chips In The Net World Order

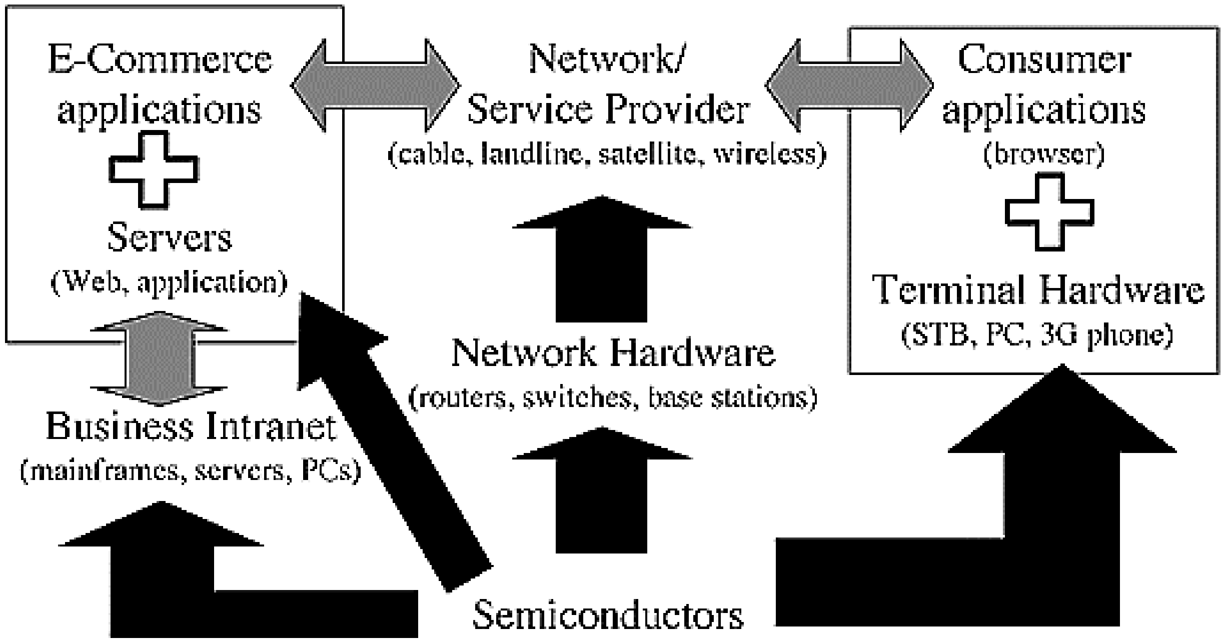
The diffusion of the Internet and related applications has given rise to new markets and new business relationships for semiconductor companies. We examine this emerging Net World Order by characterizing the markets and relationships across three segments of Internet-related applications: business, consumer, and infrastructure. Integrated circuits, or "chips," lie at the heart of all Internet-related devices, but their importance in terms of value-added contribution varies across these segments.

Figure 2 illustrates the pathways by which chips move into the business, consumer, and infrastructure segments of the Net World Order. Dark arrows represent physical goods (chips and systems) moving into the Internet economy, and gray arrows reflect data exchanges between parts of the Internet. The left-hand side of Figure 2 depicts the distributive networks employed by businesses for internal and commercial purposes. Internally, businesses use the Internet to maintain contact with remotely located employees such as field sales or engineering staff. Businesses also access the Internet to conduct external transactions and to provide or locate information.

The right-hand side of Figure 2 places end-consumers in the Net World Order. Consumers interact with the Internet for a variety of purposes such as communications (e-mail and chat), entertainment (music and games), information gathering, and shopping. Consumer access to the Internet is still predominantly via PC, but a range of new "Internet Appliances" are appearing on the market that offer simpler access and/or a more task-specific experience.

At the center of the diagram lies the Internet infrastructure. These are the "pipes" over which data flows. The principal owners are telephone companies and the largest service providers who in turn lease bandwidth to downstream access providers and large businesses.

Figure 2: The Macro Value Chain Of The Net World Order



1.1 By The Numbers

Table 1 provides a rough quantitative characterization of these three branches, which amounted to about 41% of all chip sales in 1999. Dataquest forecasts that their weighted compound annual growth will actually be somewhat less than that of the semiconductor market as a whole, but it is also possible that many products that we excluded from our networking categories, such as cars, household appliances, and industrial robots, will be connected to the network by 2004, which would raise the share of the Net World Order.[5] Communications-related chip sales into these new markets could eventually resemble the historical growth of chip sales to the digital (but not yet Internet-enabled) cellular handsets, which grew at nearly a 60% annual rate from $2 billion in 1995 to about $20 billion in 2000, just under 10% of all chip revenues.[6]

[5] The Net World Order is also worthy of study because it includes the applications, such as network infrastructure and computers, for which chip companies generate significant process and product innovations that diffuse to the rest of the chip industry and to the economy as a whole (Jorgenson, 2001).

[6] Dataquest data – the 2000 number is from a Fall 2000 forecast.

Table 1: The Three Chip Markets Of The Net World Order

	BUSINESS NETWORKING	NETWORK INFRASTRUCTURE	CONSUMER NETWORKING	ALL ELECTRONICS
REPRESENTATIVE PRODUCTS	PC, server, network interface cards, 3G cell phone, workstation	router, switch, cellular basestation	PC, 3G cell phone, set-top box, Internet appliance	Networked products plus non-networked goods such as faxes, TV sets, automotive
SHARE OF CHIP MARKET REVENUE IN 1999	30%	3%	8%	100%
FORECAST CAGR* TO 2004	11%	9%	17%	14%

*CAGR: compound annual growth rate
SOURCE: calculated from Dataquest reports issued in Spring 2000

Business networking is currently the largest market for Internet-related chips with about a third of chip sales. The leading business application of chips is, by far, personal computers (PCs). The lion's share of revenues from the chips in PCs is reaped by Intel, which earned 82% of the revenue for all microprocessors (not just those in PCs) in 1999, as well as about two-thirds of the revenue from the logic chips that connect the processor to the rest of the PC.[7]

In 1999, the consumer networking market, including about 30% of PC sales, was less than one-third the size of the business market, but Dataquest predicts that it has the highest growth potential of the three Internet-related markets. A number of factors have impeded the growth of the non-PC consumer market to date, including regulatory complications, intellectual property concerns, and consumer confusion in the face of multiple standards, but projections are optimistic that the "broadband revolution" – with flashy services such as video-on-demand – will lead to rapid growth as the industry players overcome these impediments.

The third Internet market – infrastructure – is smaller still at about 3% of all chip sales. As will be discussed later, however, products such as routers and switches constitute a relatively profitable opportunity for IC companies.

Table 2 shows the chip content of specific types of Internet-related systems, which are listed in the order of the size of chip sales into each market.

In 1999, PCs accounted for more than a quarter of all chip sales (70% of chip sales for networked systems), and Dataquest does not expect this dominant position to be significantly eroded for at least the next five years. In short, the "Post-PC era" has so far *not* been characterized by the displacement of PCs by other devices. Instead, the main characteristic is a return to more "normal" (i.e. low-margin) competition in the PC market as increasing price pressure is brought on by efforts to mine the consumer market for continued PC growth and to compete with non-PC devices for accessing the Internet. These changes undermine the fundamental features of the PC World (high volume combined with high margins) as chip and system companies are forced to explore a broad variety of growth opportunities in search of a new high-volume application to justify the large fixed costs associated with the design and manufacture of integrated circuits.

After PCs, the weight of any single Internet-related product market in the chip industry falls off precipitously. The next-highest shares of the chip market in this list goes to three other

[7] Semico Research data reported in "Sector to Return to Double-digit Growth," *Electronic Buyers' News*, April 10, 2000.

types of computers (Entry-Level Servers, Workstations, and Midrange Computers) with about 2% each. In other words, no single consumer or infrastructure application looms large in the chip maker's current view of the Net World Order apart from the PC, which was split about 70:30 (in unit terms) between the business and consumer markets consumers in 1999.[8]

Table 2: Chips In The Net World Order, 1999

System Type	1999 IC Revenue ($ Million)	ICs As % Of System Wholesale Price	As % Of All IC Revenues	IC Revenue CAGR* forecast to 2003
PCs	$49,079	38%	28.36%	15%
Entry-Level Servers	3,348	41%	1.93%	17%
Workstations	3,275	37%	1.89%	6%
Midrange Computers	3,028	18%	1.75%	11%
Central Office Telecom Equipment	2,105	7%	1.22%	6%
LAN Switch	1,518	15%	0.88%	10%
Digital WAN	1,175	13%	0.68%	11%
Analog Modems	1,125	24%	0.65%	-9%
Mainframe/Supercomputers	1,076	7%	0.62%	-4%
Routers	852	12%	0.49%	11%
LAN Cards	850	20%	0.49%	11%
Fiber Optic Transmission Equipment	679	10%	0.39%	10%
Remote Access Equipment	514	19%	0.30%	23%
LAN Hub	465	24%	0.27%	-10%
Handheld Computers	447	25%	0.26%	36%
ISDN Terminal Adapters	307	26%	0.18%	1%
Broadband Local Loop Systems	203	17%	0.12%	52%
DSL Premises Equipment	134	26%	0.08%	38%
Cable Modem Premises Equipment	92	21%	0.05%	11%
Internet Audio Players	56	33%	0.03%	57%
Internet-Enabled Set-Top Boxes	45	41%	0.03%	76%
Internet-Enabled Wireless Infrastructure	24	9%	0.01%	195%
ALL NETWORKED SYSTEMS	$70,398	27%	40.68%	15%
ALL SYSTEMS	$173,027	17%	100.00%	17%

*CAGR: compound annual growth rate
SOURCE: calculated from Dataquest reports issued in Spring 2000

[8] This Dataquest estimate is for branded PCs only. The unbranded market (e.g. custom-built machines by small shops and do-it-yourselfers) may be as high as one-third of total shipments, but is hard to track.

Although this situation will not change radically in the near future, several new categories of Internet-related products are expected to grow fairly rapidly. Table 3 shows Dataquest's near-term forecast of chip sales into two such markets – Web-access cell phones and video game consoles. These are just two of several new gateways, including a host of Internet appliances just now coming to market, that will link consumers to the Internet in the years ahead and for which demand patterns are naturally very difficult to forecast.

Table 3: Selected Chips in the Net World Order, 2002

System Type	2002 IC Revenue (forecast)	ICs As % Of System Wholesale Price	As % Of All IC Revenues
Internet-Enabled Wireless Handsets	657	28%	0.21%
Video Game Controllers	4,912	80%	1.54%

SOURCE: calculated from Dataquest reports issued in Spring 2000

The third column in Tables 2 and 3 provides data on the relative scale of the contribution of chips to the value of the systems in which they reside. For each type of system, the statistic shows semiconductor purchases as a percentage of the wholesale system revenue. The average for all systems is 17%, while the weighted average for the Internet-related products listed in Table 2 is 27%, primarily because of the prominence of PCs at 38%. Infrastructure products, such as routers, and large-scale computers are close to 10% both because relatively more of the value in the final product comes from the associated software and because these low-volume but technically complex products require higher margins to be profitable. In contrast, chips constitute a larger-than-average share of wholesale prices for consumer products (Internet audio players, Internet-enabled set-top boxes) because of low levels of non-chip content and higher-volume, more competitive end markets.

1.2 A Framework For Analysis

Our analysis of the diverse markets of the Net World Order begins with a simple framework that incorporates the major determinants of the competitive position of chip companies based upon their innovation activities (value creation) and their marketing and distribution strategies (value capture). The following lists are not comprehensive, but rather include those elements that our research has suggested most distinguish the emerging Net World Order from the competitive situation of the past 20 years.

Three competencies are particularly relevant for semiconductor product innovation because they are difficult for competitors to imitate.[9] Successful firms will generally not excel in all three but rather focus on one or two:

[9] Rumelt (1987) provides a general discussion of such "isolating mechanisms," defined as "impediments to the immediateex post imitative dissipation of entrepreneurial rents" (p.145).

- Process Skills: Does the firm use specialized or “bleeding-edge” (best-in-class) fabrication processes?
- Integration Skills: Does the firm command system-level knowledge necessary to the design of integrated hardware-software platforms?
- Intellectual Property: Does the firm own specialized design (as opposed to process-related) IP?

The five primary characteristics of the marketing and distribution channels of semiconductors are:

- Standards: Do products need to meet critical standards set by regulatory or industry bodies?
- Market size: Is the market unusually large (or unusually small)?
- Adoption: Is the market subject to network effects?
- Infrastructure: Does the product require that a network be in place for the product to operate?
- Branding: Are the final customers likely to be swayed by brand image at the chip level?

The combination of innovation competencies, marketing/distribution channels, and firm-level strategy will produce a particular configuration of the value chain in which a chip firm participates. As a result, the role of semiconductor companies in the Net World Order will lie on one of several possible paths through Figure 2, where the major players in the supply chain are the chip firm (IC), the system house (S), and the carrier (C). Of the combinatorial possibilities, three that are shown in Table 4 provide a representative selection.

Table 4: Development Pathways in the Net World Order

#1	IC ↔ C -> S
#2	C ↔ S -> IC
#3	IC -> S -> C

KEY: ↔ = strategic partnership
-> = arm’s length supply relationship
(arrow’s origin indicates source of authority)

The arrows in the table represent the source of control (e.g. who is placing an order), and a double-headed arrow indicates a strategic partnership. The structure of these control pathways has definite implications for the bargaining power of the chip maker.

Pathway #1 represents the most powerful bargaining position for the chip company. Here the semiconductor company has direct access to the carrier and knows the carrier’s projected needs in order to develop a chip with specific functionality for high-end products. The system company that build the final product is an arm’s-length contractor to the carrier rather than a strategic partner.

Pathway #2 represents the opposite situation, which is also the least powerful bargaining position for the chip company. The system firm and carrier are strategic partners, while the chip company must competitively bid for the right to supply inputs.

Pathway #3, in which no strategic partnership appears, represents a middle position for the chip company in terms of bargaining power. In this case, the semiconductor company may have some unique functionality (proprietary intellectual property) that it can sell to the system house. However the price (and profit) that the chip company can command from the system house is dependent upon the system house's ability to bargain with the carrier and then its willingness to share the proceeds.

The following sections use this conceptual framework to analyze the PC World and the Net World Order.

2. The Evolution of the PC Market

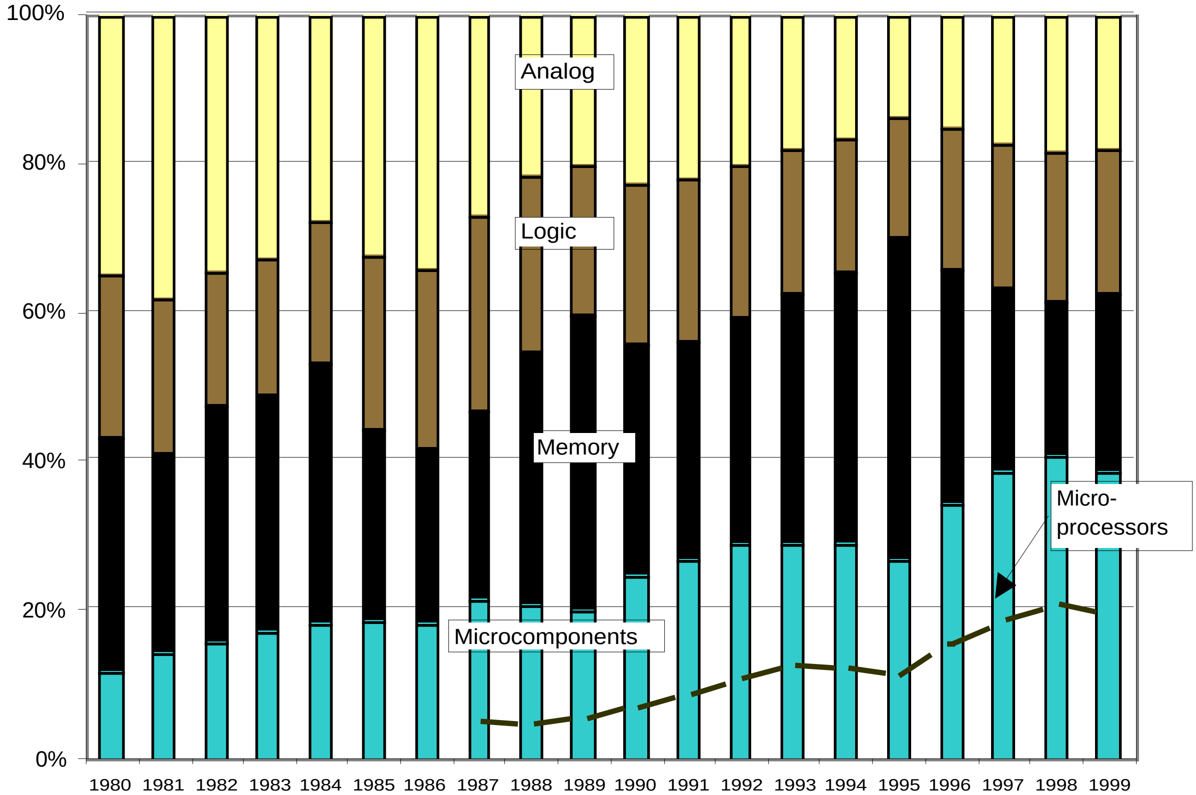
In order to provide a context for understanding the significance of the Net World Order for the semiconductor industry, this section provides a brief history of the "PC World," which we might date from the 1979 introduction of the Apple II+, the first personal computer to appeal to a broad audience. The PC World is still an important paradigm in the electronics industry, but is of declining relative importance, as shown above (Figure 1). At the chip level, the most significant features of the PC World are a long expansion of the market for microprocessors and a large but volatile market for memory chips.

The personal computer industry as it exists today, with current sales of more than $150 billion per year, began to take shape after the introduction of the first IBM PC in 1981. That PC, for which the operating system could be licensed, became a *de facto* standard on the strength of network effects relating to DOS-, and later Windows-based applications. Because the operating system was tied to Intel's x86 architecture, Intel had nearly as much bargaining power as Microsoft.

Figure 3 shows the evolution of the market for integrated circuits from 1980 to 1999 with the share of each of the four major categories of chip: analog, digital logic, memory, and microcomponent.[10] The share of microcomponents has steadily grown over the period, from 12 to roughly 40%. The dark line on the lower right of the figure shows the share of microprocessors alone starting in 1987 (the earliest date at which Dataquest separately estimated this value). That share has grown slightly faster than microcomponents as a whole, to reach almost 20% of all integrated circuits by the end of the period.

[10] "Microcomponents" include microprocessors, microcontrollers, microperipherals, and digital signal processors.

Figure 3: Integrated Circuits by Type, 1980-1999 (% of industry revenue)



SOURCE: Dataquest

Figure 3 tells a second story about chips in the PC World, namely the considerable volatility of the market for memory chips (the majority of which are of the well-known DRAM type used as the primary memory in PCs). The visible rise and fall of the memory chip share reflects underlying movements in the price of memory chips. Because of steady competition in this commodity market, profit margins moved with market conditions much more so than for microprocessors, where Intel was able to keep its competitors at bay. The harsh market conditions for memory chips have led to the exit of all but one U.S. producer. Notable exits from the market include those of Intel in the mid-1980s and, more recently, Texas Instruments, which sold off its global DRAM operation in 1998 to concentrate on building a franchise in digital signal processors, a key component in many of the latest electronics products, from cell phones to anti-lock brakes.

Microprocessors thus constitute the single biggest *success* story of the PC World, and Intel, the company whose processor set the standard for the dominant PC design, was the company that most benefited from this.

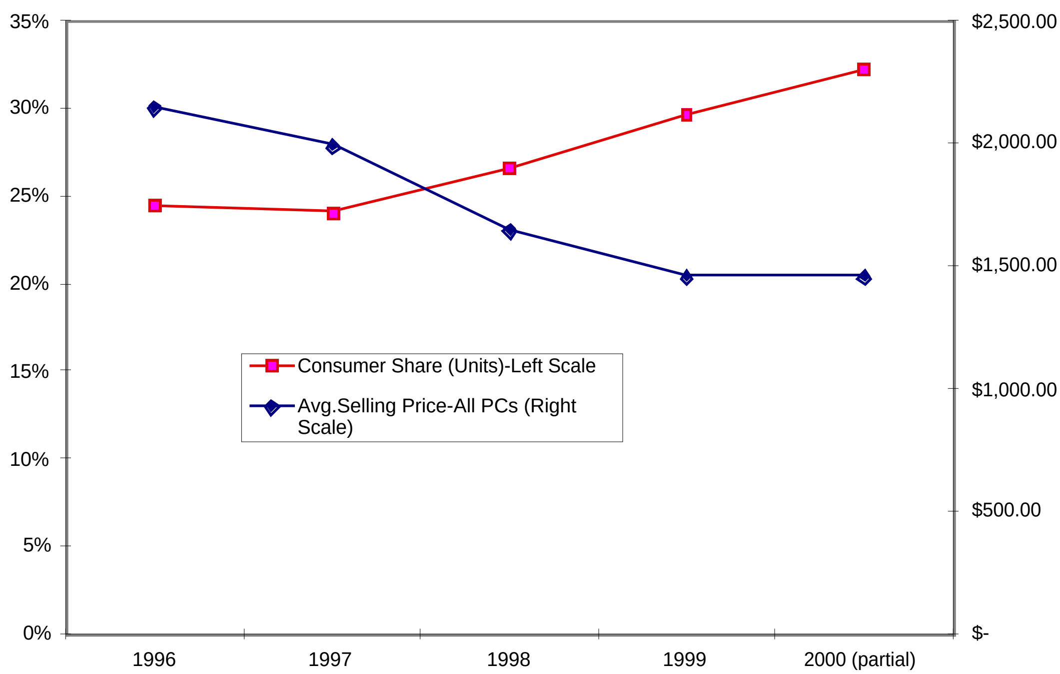
Intel successfully executed several strategies to defend its franchise. One such strategy was breakneck innovation enabled by relentless shifts from one process generation to the next. The average product life cycle (i.e. the time before a new PC model is introduced) dropped from about five years in the very early years of the industry to less than two years in 1989 (Wesson, 1994). By 1997, the length of time a new model commanded the highest price before being superceded by a better model had fallen to three months (Curry and Kenney, 1999).

Another successful element of Intel's strategy was the establishment of a brand in the mind of end users. This was a big break from the standard anonymity of chip suppliers and successfully increased Intel's bargaining power with its customers. The "Intel Inside" program was introduced in 1991 and continues today.

Intel's strategy, however, could not stop the tides of change. Although many consumers were willing to buy high-powered computers at a high price, a "value" segment of the market was waiting to be served that opened up opportunities for competitors. By late 1996, personal computers selling for less than $1,000 – a previously unbreakable barrier – had come to market (Curry and Kenney, 1999), and many of these low-end machines no longer had Intel inside. The lowest price for personal computers continued to fall until, in 1999, PCs were sometimes literally given away in exchange for entering contracts with internet service providers.

Figure 4 recaps this evolution with two intersecting lines spanning the period 1996 to the first nine months of 2000. The downward-sloping line is the average selling price of all PCs, which fell from about $2,150 to $1,460 – a drop of more than 30%. The upward-sloping line shows that the steady price reductions expanded the market in part by attracting relatively more consumers, whose share of total unit purchases grew from 24 to 32%.

Figure 4: Evolution of PC Market, 1996-2000(1st nine mos.)

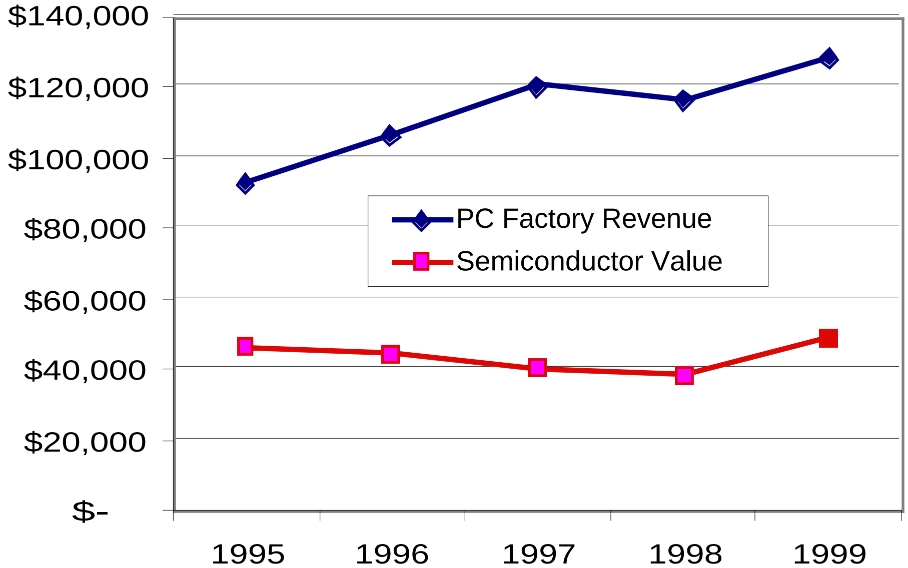


SOURCE: Dataquest

Figure 5, which extends the story down to the chip level, shows the total wholesale value of PCs from 1995 to 1999 and the sales value of the semiconductors consumed in those PCs. The increase of microprocessor competition at the low end of the market after 1996 helped drive down the value of chips as a share of the cost of the PCs from 50% to 38% over the period.[11]

[11] The breakdown of chips in PCs by value is nearly 50% for the microprocessor, about one-third for memory, 4% for core logic, and the balance for miscellaneous semiconductors (estimated from Dataquest data on total semiconductor sales into the PC market for the period 1996 to 1999).

Figure 5: Semiconductors Shrinking as Share of PC Cost

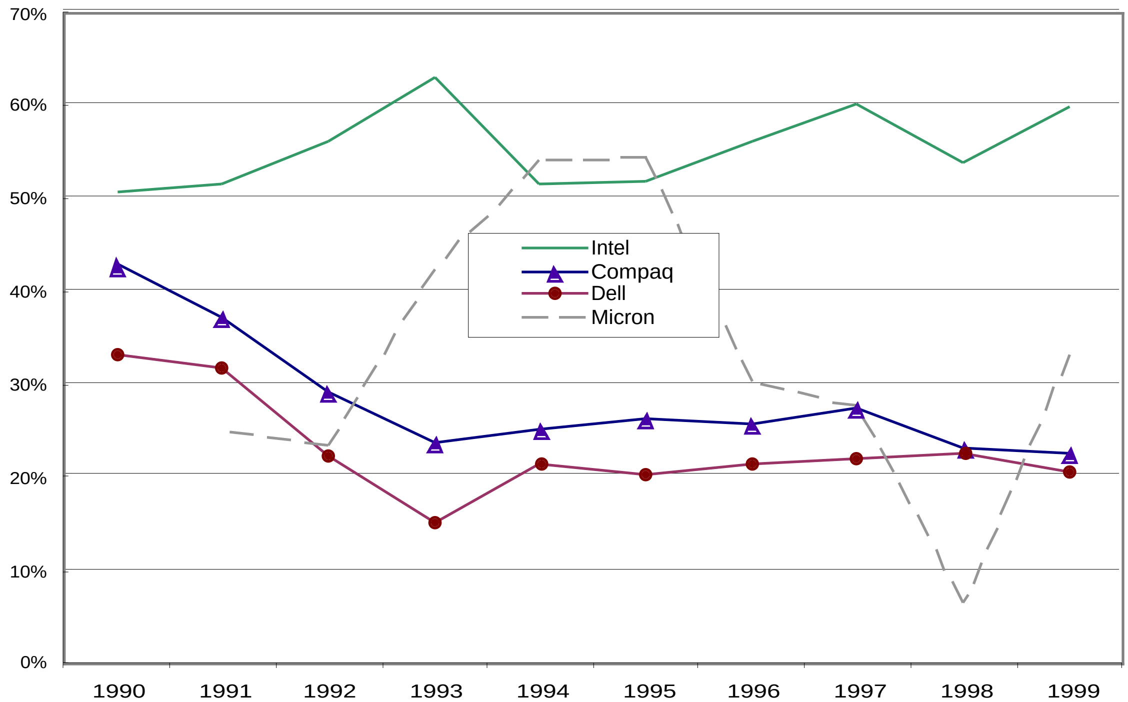


SOURCE: Dataquest

What is perhaps surprising, however, is that Intel seems to have suffered far less than its customers from the expansion of the “value” segment of the PC market. Figure 6 shows the gross profit rates (before overhead, depreciation, non-operating items, and taxes) of Intel and two of its key customers plus Micron Technology, whose primary product is DRAM.[12] Micron’s gross profit clearly reflects the volatility of the DRAM market. Intel, meanwhile, maintained a fairly steady high level of gross margin, whereas Dell and Compaq saw their gross profit rates decline and then stagnate.

[12] Companies were chosen for their emphasis on a single product type for most of the period. The use of Net Income data yields a similar picture.

Figure 6: Gross Profit Rates in the PC World, 1990-1999



SOURCE: Primark Corp. (Global Access Database)

The seeming immunity of Intel from the changes in the PC market can be explained by its delay in addressing the low-price segment. By continuing to push its process and design capabilities at the high-end, Intel successfully maintained its profitability in a difficult market. Although this created a low-end opening for Intel's competitors, particularly AMD, Intel eventually provided strong competition in all ranges of the market and earns the continued benefit of its brand-awareness premium.

However, even Intel no longer believes that the PC will maintain its privileged position in the electronics industry. Intel has moved into the infrastructure and consumer markets of the Net World Order. These new efforts include the development of portable devices such as an Internet music player, around a non-Intel processor architecture;[13] an aggressive entry in the small but lucrative market for chips in switches and routers;[14] and the pursuit of a proprietary digital signal processor in partnership with Analog Devices, with a likely first application in Internet-capable cell phones.[15]

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[13] "Facing Computer Slowdown, Intel Hopes New Consumer Devices Will Boost Growth," *Wall Street Journal Interactive*, January 2, 2001. The StrongARM processor architecture used in the digital audio player is licensed from ARM, a British firm that licenses designs and sells no chips of its own.

[14] "Intel's New Network ICs Target Enterprise-Class Applications," *Electronic Buyers' News*, May 1, 2000. Intel's "IXP" networking chips also use the StrongARM architecture.

[15] "ADI-Intel DSP Core Appears Ready For Prime Time," *Electronic Buyers' News*, December 1, 2000.

3. Value Creation in the Net World Order: Firm Competencies and Market Attributes

This section compares the major product markets of the Net World Order from the standpoint of innovation in the semiconductor industry. The markets discussed here are the PC; wireless (mobile) Web applications; consumer multimedia (fixed) Web appliances; and Internet infrastructure. The consumer/business market distinction for Web appliances is replaced here by the wireless (both consumer and business) and fixed multimedia (consumer)product markets, since they represent two major and competing markets. Although certain products can be sold in both the business and the consumer market, the distinction is important because the competitive dynamics of the sub-markets are different for chip companies. The key customers in the business market are corporate procurement departments, which tend to be relatively conservative with respect to new technologies because of legitimate concerns about reliability and enterprise-wide compatibility. Intel's awareness of the importance of an image of reliability in the corporate market was part of its impetus to launch its own "Intel inside" branding campaign, and the company maintains a sales force in the thousands to keep in close touch with corporate technology buyers.[16] Not surprisingly, the recently successful competitors to Intel have made their greatest inroads in the more price-conscious consumer PC market.

The first part of the framework from Section 1 consisted of relevant competencies in process, integration, and design in which a semiconductor firm could choose to specialize. This section asks: which competencies are most relevant to a given product market of the Net World Order? Table 5, which summarizes the answer, shows that the competencies needed by chip firms in the markets of the Net World Order differ markedly from those that have been relevant to the PC World.

Table 5: The Relevance of Competencies in the Net World Order

	Personal computers	Wireless applications	Consumer multimedia	Networking infrastructure
Process skills	Yes	No	No	No
Integration skills	No	Yes	Yes	No
Intellectual property	Yes	Varies by application		

Process has been a critical part of the story in the PC World. The PC, and especially the microprocessor that drives it, required innovation based upon both architecture and process improvements. To create a competitive wedge between itself and its rivals, Intel has remained in the forefront of process technology and has maintained its own manufacturing capability for microprocessors rather than using contract manufacturing services. Process skills are also vital to competitiveness in the manufacturing of DRAM.

Process tends to be less important in the other major product markets. In wireless, for example, Qualcomm was able to grow rapidly to account for more than 7% of the market for digital cellular chips while owning no fab of its own. Qualcomm's strength is the intellectual property that it owns, along with the system-level knowledge needed to successfully design a highly integrated chip set. Many successful companies in the consumer broadband and network

[16] "Newly Competitive AMD Prepares To Battle Intel in Corporate Market," *Wall Street Journal Interactive,* December 27, 2000.

infrastructure markets, such as Broadcom and PMC-Sierra, are also fabless, competing on the strength of their intellectual property and fast time-to-market.

Integration has become a critical skill in the Net World Order for several reasons (Linden and Somaya, 1999). A reduction in the number of chips in a system brings several benefits including increased reliability, greater speed, lower unit manufacturing cost, lower power consumption, and smaller size. Lower cost is very attractive for consumer markets, where high price is often the biggest barrier to the adoption of new technologies such as digital set-top boxes and personal digital assistants (PDAs). Small size and low power are particularly important for wireless applications where the products are portable.

Integration also provides the means for chip companies to offer their customers faster time to market by providing a ready-made system. This requires complete integration of both software and hardware, with the system firm able to customize and differentiate the final product by choosing from a menu of optional functions that are already part of the package.

For the chip company, a high level of integration means that all the necessary hardware and technologies must be brought together at one time either through internal efforts, licensing, or acquisition. Horizontally diversified firms that already own much of this intellectual property will tend to have an advantage in these markets because they do not need to negotiate agreements and pay royalties to third parties. For example, the firms that had announced system-on-a-chip solutions for digital set-top boxes by 1999 were Motorola, IBM, LSI Logic, STMicroelectronics, and Matsushita Electric Industrial. Each of these firms carries an extensive product portfolio and has sufficient system engineering expertise in-house to design system-level semiconductors (i.e. one or a small number of chips that perform all the functions that would previously have been executed by a much larger number of components).

Even larger firms, however, may be missing pieces of the system. This need has given rise to a growing market for the exchange of "intellectual property (IP) blocks" – partial chip designs that can be integrated in a single mega-design. Intellectual property can also be acquired rather than licensed. An example on a large scale was the $800 million purchase by Philips of the Netherlands, a major consumer electronics company and also one of the world's top ten semiconductor producers, of a U.S. company, VLSI Technology, in 1999 for its strong portfolio of communications-related intellectual property that Philips needed to pursue new applications such as home networking.[17]

Integration is also increasingly important in the PC market as it confronts the Net World Order. Specialized niches in the PC, such as graphics chips, are being absorbed by the ever larger microprocessor or its closely connected logic chip set. The first microprocessor, introduced by Intel in 1971, took two engineers nine months to design and had 2,300 transistors.[18] The Pentium 4, introduced by Intel in 2000, had a five year development cycle during which hundreds of engineers worked in teams for nearly the entire period to develop the 42-million-transistor chip.[19] In the case of graphics, Intel chose to acquire the necessary know-how by purchasing a graphic chips supplier called Chips & Technologies in 1997.[20]

The importance of the third competence – design-related intellectual property (IP) – has already been discussed for its importance in the PC World. Intel owned, refined, and defended

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[17] "Philips' Bulging Portfolio Poses Integration Problem," *Electronic Buyers' News*, November 1, 1999.

[18] "The History Of Intel, 30 Years Of Innovation," 1998, accessible at http://www.intel.com/pressroom/archive/backgrnd/cn71898a.htm as of January 2001.

[19] "Comms Held Pentium 4 Team Together," *Electronic Engineering Times*, November 1, 2000.

[20] "Intel Quits Discrete Graphics-IC Market For Integrated Approach," *Electronic Buyers' News*, August 19, 1999.

the x86 architecture so that rivals had to invent around it yet ensure compatibility with it. Specialized IP is important in some other parts of the Net World Order. Philips, for example, developed a TriMedia processor for consumer multimedia applications including set-top boxes and ultimately decided to spin-off the TriMedia business into a separate company.[21] Companies specializing in network infrastructure, such as PMC-Sierra also boast a large portfolio of patented technologies.[22] An example in wireless is Qualcomm, discussed above. But in other cases, integration of existing technologies is the key to competing.

The second part of the framework from Section 1 identified five attributes of marketing and distribution channels that affect the ability of semiconductor firms to capture value commensurate with their innovative contributions. Table 6, which summarizes these attributes by product, shows how the characteristics of the marketing and distribution channels for semiconductors have changed between the PC World and the Net World Order.

Table 6: Market Attributes in the Net World Order

	Personal computers	**Wireless (mobile) applications**	**Consumer (fixed) multimedia**	**Networking infrastructure**
Standards	Stable/Owned	Stable/Shared	Unstable	Stable/Public
Market Size	Very large	Large	Potentially large	Small
Adoption	Network Effects	Individual	Individual	Individual
Infrastructure	Independent	Dependent	Dependent	Not applicable
Branding	Important	Important	Important	Not important

Standards for PCs have been relatively stable. Although the underlying technology for PCs has evolved dramatically over time, the market's dominance by a duopoly – Intel and Microsoft – has kept the development path predictable. Intel has tremendous bargaining power because it owns its de facto standard.

Standards for wireless applications and network infrastructure are also fairly stable, but for a very different reason, namely that they are determined by negotiation within international committees. The underlying intellectual property may still be owned by firms, as in the case of the wireless industry, but they must be available for licensing to become *de jure* standards. A public standard, in sharp contrast to proprietary standards such as Intel's, reduces the bargaining power of chip firms because it places them all on a level technological playing field and increases the likelihood that systems firms will be able to multiple-source their components. The equipment comprising the Internet infrastructure must meet strict requirements for interoperability set by official bodies like the International Telecommunications Union and the Internet Engineering Task Force, the key voluntary industry organization. Because of this predictability in technical standards, the primary challenge for chip companies serving the Internet infrastructure market is to be first to market with the newest generation, such as a faster router or an Ethernet chip.

In sharp contrast, standards in the emerging market for Internet-related consumer products are quite fragmented. First, there is wide variety of machine types that consumers can potentially adopt to access the Internet. In addition to PCs – still by far the largest means of access – consumers may also choose from among a box on the television set, a cell phone or

[21] "Philips Spins Off TriMedia Processor Technology As Separate Company," *Semiconductor Business News*, March 29, 2000.
[22] "CEO of the Year: PMC-Sierra's Bob Bailey," *Electronic Business*, December 2000.

PDA, and a host of counter-top “Internet appliances” such as a dedicated e-mail device. The set-top box could be designed to handle cable, satellite, or broadcast transmission. Each type of product requires mastery of a different type of technology (e.g. radio transmission and power management for cell phones, or video processing in the case of set-top boxes). In each instance, the relevant standards are likely to be some combination of public, proprietary, or even unsettled, as in the case of high-definition television in the United States.

The second attribute, market size, has been significantly greater for PCs than for other Net World Order (and most electronics) products (see Section 1). At the other extreme, the market for Internet infrastructure products is relatively small because the total number of routers and switches that can be sold in any one year is necessarily limited. Wireless and consumer multimedia applications are an intermediate case. No high-volume market has yet emerged, but the industry is in the early stage of product development and acceptance. But Internet-enabled devices have shown the potential for tremendous growth. An early-generation Web-access cell phone introduced in Japan (NTT DoCoMo’s “i-mode”) expanded its subscriber base from zero at its introduction in February 1999 to more than 5 million by March 2000.[23]

The third attribute is whether adoption relies upon individual choices made in isolation or if the technology exhibits network effects. The IBM-standard (sometimes known as “Wintel”) PC is a classic case of network effects because software development and the ability to share files depended upon people using the same platform, i.e. the attractiveness of adoption to one individual increases with the total number of users.

In most cases, Net World Order products are unlikely to exhibit network effects. Chip customers are very wary of allowing another Intel-style standard to emerge that gives a single supplier undue market power. Cable companies, for example, are promulgating an open standard (DOCSIS) that will ensure them the availability of multiple, interchangeable suppliers in the interactive set-top box market.[24] More fundamentally, the Internet’s success is built on the notions of interconnectivity and interoperability at the hardware level, which will likely prevent the cumulative phenomena of the PC World from recurring.

What is true for hardware need not be true for services, however. The tremendous growth of DoCoMo’s i-mode service reflects network effects because DoCoMo’s strict veto power over which services have access to its proprietary portal can keep some functions out of the hands of its rivals.[25] Issues of access were also addressed in the legal negotiations that allowed the AOL-Warner merger.

The fourth market attribute is the importance of infrastructure. Infrastructure dependency can have a major impact on the ability of chip companies to earn rents. All Web access devices, whether fixed or wireless, require an extensive and specific infrastructure (e.g. cable, DSL, satellite) before the device can be used by customers, and many devices (e.g a DirecTV satellite receiver) are network-specific. Network dependence tends to increase the bargaining power of the network operator, particularly since the number of networks is usually limited in any given location for economic or regulatory reasons.

In a similar way, the fifth attribute – branding – can increase bargaining power, usually in favor of a system firm. Corporate and private buyers distinguish between brands based on perceived quality or fashionability. A network might have some brand cachet as well if it is

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[23] “NTT DoCoMo's i-mode Subscribers Exceed 5 Million,” *Asia Biz Tech*, March 21, 2000.

[24] For pre-digital equipment, cable companies have been locked in to proprietary end-to-end deals with either General Instrument (now part of Motorola) or Scientific-Atlanta.

[25] “NTT DoCoMo-Style Business Model Includes a Few Pitfalls,” *Asia Biz Tech*, December 11, 2000.

believed to be, for example, more reliable than its competitors. It is much more difficult for component suppliers to compete by establishing a brand. The Intel case is an anomaly in this regard – a component of central importance in a market large enough (and profitable enough) to justify the high fixed cost of a national ad campaign that risked alienating some of its customers. The infrastructure market is probably the least susceptible to the influence of branding because of the importance of technical issues such as speed and the technical focus of those making purchasing decisions.

4. Value Capture in the Net World Order: Configuring the Value Chain

The last part of our framework described pathways through the Net World Order – configurations of the value chain. The creation of value involves not just the harnessing of technology, but also the production of goods for which there will be sufficient demand to provide a return on the fixed costs of product development. To this end, chip firms in the Net World Order benefit from working closely with their customers. Table 7 summarizes the primary and secondary pathways by product market.

Table 7: Value Chain Configurations of the Net World Order

	Personal computers	Wireless applications	Consumer multimedia	Networking infrastructure
Primary Pathways	IC -> S	C ↔ S -> IC	C ↔ S -> IC	IC ↔ S ↔ C
Secondary Pathway (if any)		IC ↔ C -> S	IC ↔ S -> C	

KEY: ↔ = strategic partnership
-> = arm’s length supply relationship
(arrow’s origin indicates source of authority)

The PC World has a simple configuration because of the absence of carriers from the value chain. As shown earlier, Intel has commanded enormous bargaining power with systems (i.e. PC) manufacturers with resulting high profits.

Wireless devices, as described in the previous section, are infrastructure-dependent in that they must be compatible with an available network. The compatibility can be limited to the interface, as in the case of a handheld computer with an interchangeable modem, or network features can be tightly integrated, as in upcoming third-generation cell phones that will exploit network-specific features such as music downloading or global positioning services.

In cases where the integration is tight, chip companies may work directly with carriers. For example, Qualcomm developed a multimedia software suite known as Wireless Internet Launchpad to run on its CDMA chip set. In order to enable adoption in Japan, Qualcomm had to first work with the local CDMA network providers to enable the software to run on their systems before striking deals with individual handset manufacturers.[26] The strategic partnership between Qualcomm and the carriers greatly increased the chip company’s bargaining power vis-à-vis the system (i.e. handset) manufacturers. Although the chip company must maintain good relationships with the system manufacturers in order not to undermine future business

[26] “QUALCOMM CDMA Technologies Announces Widespread Adoption of Compact Media Extension Software in the Japanese CDMA Market,” Qualcomm Press Release, July 17, 2000.

opportunities, the chip company can exert some leverage over the system house by having possibly the only chip that meets specific functionality required by a carrier.

The more common arrangement, however, is for the carrier to work with a system firm to design a new handset and then to let the system firm decide which chips to use. This primary pathway, which would also apply in the case of wireless connections for handheld computers, reduces the bargaining position of chip suppliers.

System-level packages of chips and software are also becoming more common in the consumer multimedia market. The chip company packages its chip set with software and development tools so that system companies can bring new products rapidly to market. Because of the ability to choose different feature sets from the software packages, system companies can still differentiate their products.

Strategic partnerships between chip and system firms are a major coping mechanism for chip makers in the face of the unstable standards of the consumer market, and one of the major exponents of this approach is STMicroelectronics, a Franco-Italian joint venture created in 1986. In the words of Jean-Phillipe Dauvin, the company's chief economist: "System-on-chip means the silicon must be developed in a very tight linkage to the final users. . . The winning companies will be the companies that form strategic alliances with customers."[27] In the words of a stock analyst that follows the company, STMicro "works with leading manufacturers in principal sectors on the next-generation products so they get locked into the design cycle."[28] STMicro's strategic partners include Nokia, Ericsson and Alcatel.

In an extreme example of chip maker initiative, National Semiconductor created a coalition around a design for a "Webpad" to be based on a specialized processor for which it saw a need to jump-start the market. National worked with Taiwan's Acer for manufacturing, a company called Merinta for software and integration, and Internet Appliance Network for marketing and a link to the Prodigy network.[29] The initial customer was Virgin, a retail company interested in exploring a new business model. In this scenario, the carrier was probably in the weakest bargaining position.

Probably the more common product development path in the consumer market is for a design to be agreed on between a system firm and a network operator. Thus a set-top box specification might be promulgated by a cable company to several potential suppliers. These system companies will, in turn, work with potential semiconductor suppliers to develop the proposed product. The carrier then selects one or more system suppliers, only indirectly selecting the chip suppliers at the same time. America On-Line, for example, chose Philips to produce its initial cable set-top box, and Philips in turn chose a reference design from a communications company called Boca Research, that was based on a processor from National Semiconductor.[30]

The network infrastructure market is characterized by a two-way strategic partnership with systems companies at the center. The system firm works closely with network operators to develop a network architecture and also with chip suppliers to coordinate technology roadmaps. The bargaining power of the semiconductor companies is enhanced because of the small volumes involved and the need of the system houses to ensure that they have a steady and reliable supply. Interestingly, two major producers of telecommunications equipment – Siemens

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[27] "ST Micro execs see chip market driven by 'e-society,'" *Electronic Buyers' News*, December 12, 2000.
[28] "It's Europe's Turn," *Electronic Business Asia*, March 1999.
[29] "Virgin Territory," *Electronic Business*, September 2000.
[30] "Boca Research's Design Chosen for Philips' Co-Branded AOL TV Set-Top Box," Boca Research Press Release, May 11, 1999.

and Lucent – have opted to spin off their semiconductor operations (as Infineon and Agere, respectively) which suggests that the benefits of coordination across this interface have definite limits relative to the need for both parties to be able to work with others outside the relationship.

In most cases, the chip company is dealing directly with a system manufacturer. However their relative bargaining power depends upon if they are strategic partners in development, or if one of them is in the driver's seat. Besides the bargaining power discussed above, the price (and profit) that the chip company can command from the system house is dependent upon the system house's ability to earn rents and then its willingness to share the proceeds.

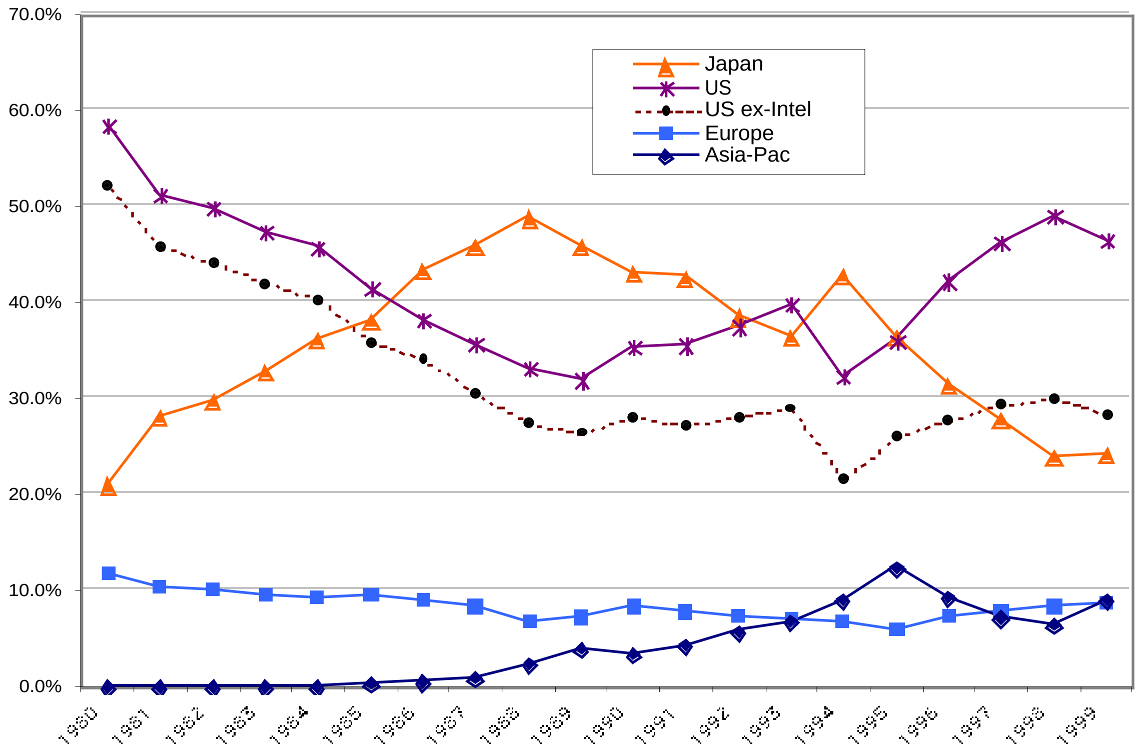
System manufacturers have several strategies to retain rents for themselves. Even where system companies have a close relationship with their chip suppliers, negotiations are likely to take place at regular intervals (e.g. quarterly) to demand that the supplier drop prices in line with the regularly productivity improvements that take place in the semiconductor industry. Systems firms frequently employ former employees of chip firms to assure that they will have intimate knowledge of how low they are likely to be able to drive the price.

Another way system companies capture rents is by competing with their suppliers. The attractiveness of the fabless model has also lowered the barrier for systems companies to design some of their own chips, which most of them are starting to do – beginning with simpler, high-volume chips. This forces chip companies to either retreat to more R&D-intensive products or to try to underbid the in-house design program.

5. Regional Differences in the Net World Order

This section examines the differential outcomes of countries and regions in the Net World Order. First we look at the regional distribution of chip companies in order to identify regional patterns. Figure 7 shows the respective shares of the global chip market over a 20 year period for Top-40 suppliers based in the United States, Japan, Europe, and Asia-Pacific (i.e. Taiwan and Korea). The well-known rise and subsequent decline of the Japanese share is shown, along with the resurgence of the U.S. beginning in 1990. The growing distance between the U.S. share and the "ex-Intel" (dashed) line beneath it make clear what a huge role Intel has played in the U.S. "comeback." Without Intel, however, the U.S. share has been almost stagnant since 1990, while Intel's expansion came mostly at the expense of the Japanese share. At the end of the 1990s, U.S. firms had almost one-half of the market, while Japanese firms had a quarter of the market and Europe and Taiwan/Korea each had one-tenth.

Figure 7: Share of Top 40 Semiconductor Firms By Region, 1980-1999



SOURCE: calculated from Dataquest data

A possible interpretation of the relative strength of the U.S. semiconductor sector is that Japan and Europe were relatively slow to embrace first the personal computing revolution and then the networking phenomenon that built on it. U.S.-based chip firms reaped a considerable advantage because of the rapid adoption of PCs in the U.S. by both businesses and households. However the underlying forces are not clear. The empirical relationship between domestic adoption and company performance presents us with a chicken-and-egg problem, as well as the accompanying task of identifying important institutional forces that may be driving both adoption and performance. For example, did rapid adoption of computers by the business community give a competitive advantage to U.S. chip firms, or did rapid adoption occur because the U.S. firms were instrumental in convincing the business community by example and advertising of the value of using computers? In addition, we must ask what was the role of the university system in the U.S. in the adoption process, both in terms of creating the educated management users (and later the educated consumer users), the semiconductor engineers, and the technology itself. What was the role of the Federal government (and the NSF in particular) in disseminating Web use throughout the university and the public educational system? The answers to these questions, which we do not address in this paper, would help us understand the relationship between the regional markets and local companies that we observe here.

Let us look at the underlying data more closely. Tables 8 and 9, which present data on the geographic dispersion of non-memory chip sales by source company, show the close relationship between non-memory chip sales and headquarters location throughout the 1990s. Non-memory chips are selected for two reasons. First, they are the more design-intensive chips and most likely to be linked to specific applications (Linden, 2000). Second, the DRAM market has undergone a well-known regional shift as U.S. firms exited in favor of Asian producers. The market for these commodity chips may be more fully globalized than that for non-memory chips, which would dilute the statistics in the table.

Table 8 shows the shares of non-memory chip sales *from* firms based in the United States, Japan, Europe, and non-Japan Asia-Pacific *into* each of these four markets in 1992. Table 9 shows comparable data for 1999. In both tables, the diagonal shows sales from firms to their home market – and these numbers are noticeably larger than the others in the same column.

This home-market specialization shows that the geographic dispersion of non-memory chip sales clearly has nothing to do with market size. The tables cannot show, however, whether the home-market specialization occurs because system companies prefer to work with locally-based suppliers or because chip firms understand local applications best.[31] Either way, the data suggest that regional markets are important in determining semiconductor sales, and the market cannot be thought of as strictly global.

Table 8: Shares of Non-Memory Sales by Headquarters Location, 1992

FROM / TO	US Companies	Japan Companies	European Companies	Asia-Pacific Companies
US Market	**52%**	8%	17%	8.1%
Japan Mkt.	10%	**71%**	2%	4.9%
Euro.Mkt.	21%	5%	**63%**	3.5%
A-P Mkt.	17%	16%	18%	**83.5%**

SOURCE: calculated from Dataquest data

Table 9: Shares of Non-Memory Sales by Headquarters Location, 1999

FROM / TO	US Companies	Japan Companies	European Companies	Asia-Pacific Companies
US Market	**45%**	9%	21%	14.4%
Japan Mkt	9%	**62%**	3%	3.2%
Euro.Mkt	21%	7%	**50%**	4.6%
A-P Mkt	25%	22%	27%	**77.8%**

SOURCE: calculated from Dataquest data

Just as the PC World contributed to a realignment of global market shares toward U.S. producers and away from their Japanese counterparts, so too may the Net World Order. For one thing, the PC World was, and to a large extent still is, U.S.-centric. However if we look at the potential use of wireless Web appliances, we see that the rest of the world is more reliant upon cell phones than the U.S. and presents potentially large markets for wireless appliances. Tables 10 and 11 show the number of computers and the number of cellular subscribers per 1,000 population in 1999, respectively. The computer value for the U.S. (538.9) is much larger than that for Japan (325.5) or the large countries of Europe such as the United Kingdom (379), France

[31] It is unlikely to have anything to do with the location of production because a majority of chips are assembled (a process that follows fabrication) in Asia and shipped worldwide.

(318.9) and Germany (317.4). For cellular subscribers, the U.S. ranks only 24th at 314.87, behind Japan (382.57), the United Kingdom (409.3), and France (350.07).

Table 10: Computers per 1,000 People, 1999

Rank	Country	Value
1	**USA**	**538.9**
2	SWEDEN	510.4
3	FINLAND	507.8
4	ICELAND	507.3
5	NORWAY	506.8
6	AUSTRALIA	492.0
7	DENMARK	476.6
8	CANADA	475.8
9	NEW ZEALAND	416.9
10	SWITZERLAND	408.3
11	NETHERLANDS	400.6
12	SINGAPORE	390.9
13	**UNITED KINGDOM**	**379.0**
14	HONG KONG	360.2
15	IRELAND	352.6
16	AUSTRIA	344.0
17	BELGIUM	343.8
18	**JAPAN**	**325.5**
19	**FRANCE**	**318.9**
20	**GERMANY**	**317.4**

SOURCE:
World Competitiveness Yearbook, 2000

Table 11: Number of cellular subscribers per 1,000 People, 1999

Rank	Country	Value
1	FINLAND	678.10
2	NORWAY	627.03
3	SWEDEN	590.08
4	HONG KONG	551.02
5	**ITALY**	**521.56**
6	AUSTRIA	512.61
7	DENMARK	506.04
8	KOREA	499.04
9	LUXEMBOURG	497.62
10	TAIWAN	493.60
11	ISRAEL	479.25
12	PORTUGAL	473.90
13	SWITZERLAND	441.65
14	NETHERLANDS	424.61
15	**UNITED KINGDOM**	**409.30**
16	AUSTRALIA	397.41
17	**JAPAN**	**382.57**
18	SINGAPORE	381.45
19	SPAIN	381.22
20	ICELAND	378.20
21	GREECE	365.16
22	IRELAND	360.59
23	FRANCE	350.07
24	**USA**	**314.87**
25	BELGIUM	312.33
26	**GERMANY**	**283.13**

SOURCE:
World Competitiveness Yearbook, 2000

The world of the Internet is still largely U.S.-centric. Table 12 shows the number of Web host computers per 1,000 population. The U.S. is again ranked first at 136.65, even farther ahead of Japan (16.65) and the large European countries (28.4 in the UK, 17.61 in Germany) than was the case for computers in general. The absence of network effects in many Net World Order applications, however, may prevent the U.S. from benefiting from its large market, i.e. de facto standards (should any arise) will not necessarily move outward from the United States.

Table 12: Number of Internet Hosts per 1,000 People, 1999

Rank	Country	Value
1	**USA**	**136.65**
2	FINLAND	117.25
3	ICELAND	93.69
4	NORWAY	76.72
5	CANADA	66.49
6	HONG KONG	66.40
7	SWEDEN	64.89
8	DENMARK	54.92
9	AUSTRALIA	50.34
10	NEW ZEALAND	47.81
11	NETHERLANDS	44.71
12	AUSTRIA	36.26
13	SWITZERLAND	32.11
14	**UNITED KINGDOM**	**28.40**
15	BELGIUM	27.15
16	ISRAEL	25.53
17	SINGAPORE	22.19
18	LUXEMBOURG	22.10
19	TAIWAN	20.04
20	**GERMANY**	**17.61**
21	**JAPAN**	**16.65**

SOURCE:
World Competitiveness Yearbook, 2000

The data on cellular penetration, combined with the earlier evidence on the home-market specialization of chip firms, provide the first indication that the Net World Order may lead to different outcomes in the semiconductor industry than those of the 1990s. In most Net World Order applications, Japan, Europe, and the United States are pursuing somewhat different technology trajectories that reflect a combination of differences in regulation, legacy infrastructure, and consumer preferences. In Japan, for example, the leading cellular carrier, NTT DoCoMo, adopted a relatively low-tech interactive cellular standard ("i-mode") that became a huge success while most other providers waited for more technically advanced systems before rolling out Internet access. This gave DoCoMo a lead in terms of developing services and a business model, which it is now trying to export by investing in cellular companies in Europe and the U.S. The Japanese phone and chip companies that are DoCoMo's primary suppliers are hoping to piggyback on their customer's global expansion.[32]

The strong adoption by European countries of cellular telephony is due to a combination of Europe's uniform adoption of GSM cellular technology and the relatively high cost of wireline telephone service. This high adoption rate is considered to have given the well-known European handset producers – Ericsson and Nokia – an advantage in world markets, where they command a combined share of more than one-third. At the chip level, European dominance at the system level has not translated to a similar outcome, but the field is considerably more balanced. The leading chip vendors in the cellular market, according to Dataquest, are Motorola (itself the second-largest handset producer) and Texas instruments (on the strength of its early commitment to digital signal processor technology). But the list of leading vendors includes the three main European chip makers – STMicroelectronics, Infineon, and Philips (albeit largely on the strength of its acquisition of a U.S. company, VLSI Technology) – as well as three Japanese producers – NEC, Fujitsu, and Hitachi. Two more U.S. companies – Qualcomm and Lucent – round out the top ten, in which the ratio of the largest to smallest is less than 3-to-1. To summarize the case, the strong local markets for cell phones may have helped European and

[32] "Panasonic Looks to Expand Its International Cell Phone Reach," *Electronic News*, November 6, 2000.

Japanese chip firms compete globally, but the reverse proposition does not hold, i.e. U.S. chip firms do not appear to have been hindered by a relative slowness in the local adoption of cellular technology.

Time will tell if continuing differences at the regional level will undermine the current global dominance of the U.S. chip industry.

6. Summary and Conclusions

Our research examines the transformation of the semiconductor industry that began in the late-1990s with the consumerization of the personal computer industry. The relative shift toward sales into the market for networking and communications products – what we call the Net World Order – will likely leave its stamp on the global chip market for the next 20 years much as the emergence of the PC industry did in the early 1980s.

This paper marks the first presentation of our findings, which are only preliminary. In comparing the PC World and the Net World Order, we find the following important differences:

- Technological innovation shifts from being focused on process and architecture to being focused on integration and specialized design IP.
- Manufacturing is no longer an important part of competitive advantage, and software talent has become central to the company. Semiconductor companies can be fabless and focus on design activities.
- The product market in the Net World Order is much more diversified and fragmented than in the PC World.
- Net World Order markets are characterized by more open standards and often require an infrastructure. Because of its central requirement for product compatibility, the carrier plays an important role in the Net World Order.
- In high-volume markets, chip companies may benefit from being able to sell specialized system-level designs to multiple system houses. In this case, a chip company would be hurt by being part of a vertically-diversified company that is be a competitor to other customers for the chip.
- In developing integrated system chips, a chip company benefits from being part of a horizontally-diversified company that already owns, and has the capability to produce, the intellectual property for the various chip functions required.

In the PC World, we see that the performance of firms is related to product adoption rates within their local market. Although the underlying causes are unclear, this relationship appears to hold in the Net World Order, where standards and infrastructure are more important. Already we see the potential for wireless adoption of Web appliances to be more important in markets outside the U.S., and this may give foreign chip companies an important competitive advantage.

One of the conclusions that emerges from our analysis is the low probability that the chip industry will ever be dominated by a single company in the way that Intel has done for nearly a decade. System firms and network operators are wary of permitting any supplier to own a standard in the same way that IBM empowered Intel. The PC market is also unusually large, unlike the fragmented emerging markets for most Internet-related products. These markets have distinctive regional characteristics, which we expect to become even more important as Web appliances, both mobile and fixed, become more widely used by both consumers and businesses. Because an infrastructure is required, we believe that the bargaining power of the semiconductor companies will depend to a large extent on their informational and relational ties to the carrier so that the chip company can influence, or at least anticipate, the product innovation that will be highly valued.

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