INDUSTRY STUDIES 2000

Electronics

ABSTRACT

As the 21st century begins, the electronics industry continues its strong growth worldwide. Semiconductors are emerging from a 3-year decline as new applications for their use emerge on the market. Increases in wireless communications, Internet storage capacity, and personal computing devices underpin the ongoing boom. Current challenges are in part a consequence of government policy. Immigration quotas, for example, have contributed to a critical shortage of skilled workers, and export licensing policies relative to high-speed processing capability have hampered U.S. industry exploitation of global markets. Moreover, the short life cycles of today's electronic products translate to difficulty in obtaining replacement parts, and the growing dependence of some domestic market sectors on foreign suppliers tends to jeopardize U.S. market share. The U.S. electronics industry continues to outperform other industrial sectors, however, due to its propensity for innovation, firm commitment to strong capital investment, and substantial funding for research and development.

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PLACES VISITED

Domestic

Advanced Micro Devices, Sunnyvale, CA

Auspex Systems, Santa Clara, CA

Dominion Semiconductor, Manassas, VA

Litton Electron Devices, San Carlos, CA

Lockheed/ Martin, Crystal City, VA

LSI Logic, Milpitas, CA

National Semiconductor, Santa Clara, CA

Northrop Grumman, Linthicum, MD

Oracle, Reston, VA

Palm, Inc., Santa Clara, CA

Sensytech Industries, Newington, VA

Stanford Global Supply Chain Management Forum, Palo Alto, CA

TRW, Reston, VA

United Defense, San Jose, CA

Varian Medical Systems, Palo Alto, CA

Virginia Semiconductor, Fredericksburg, VA

Xilinx, San Jose, CA

International

Advanced Micro Devices, Dresden, Germany

Center for Technology, Dresden, Germany

DaimlerChrysler Aerospace, Unterschleissheim, Germany

Federal Office of Defense Technology and Procurement, Koblenz, Germany

Fraunhofer Gesellschaft, Dresden, Germany

Fujitsu-Siemens Computers, Augsburg, Germany

Infineon Technology, Dresden, Germany

Office of the European Commission, Information Society Technologies Program, Brussels, Belgium

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U.S. Mission to NATO, Brussels, Belgium

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INTRODUCTION

With an insatiable appetite for electronic devices, the United States is the high-technology Titan of the world and the master of innovation. The United States holds a commanding lead globally in development, production, and consumption in virtually every electronics sector except wireless telecommunications; there, Europe leads the way. The electronics industry can be conveniently divided into semiconductors, computing devices, and telecommunications. Unique to this industry is the speed at which it develops. Breakthroughs that take years in other industries require only months or weeks in the electronics sectors, and the market growth is phenomenal. According to *U.S. Industry & Trade Outlook 2000*, the top four fastest growing industry sectors in the United States relate to electronics, a trend that can be easily extrapolated worldwide.

Industry momentum, however, poses some significant global challenges, and research has exposed striking parallels between the European Union (EU) and U.S. industries in this regard. While not comprehensive, the following list comprises points deemed crucial to an understanding of the characteristics of, and challenges facing, this integral industry:

- The global electronics labor market is the tightest of any industry.
- Technology changes so fast that spare parts are frequently out of production and older equipment is no longer supported.
- The Department of Defense (DOD) has little influence on the direction of the commercial market.
- The defense electronics industry is barely staying afloat, and is shifting to commercial products for badly needed revenue.
- Virtual companies and enterprises without fabrication facilities (i.e., "fabless") are on the rise.
- Trans-Atlantic corporate mergers have confirmed the value of transnational ventures in avoiding a "Fortress EU" vs. "Fortress U.S." mentality.
- Export controls hinder profits in both the European Union and the United States.
- Research and development (R&D) costs are the highest of any industry.
- Dresden, Germany—the "Silicon Saxony"—is becoming a center of excellence in technical education and R&D.
- Innovation and minimum time to market are the sine qua non of the electronics industry.
- Intellectual property is the most valuable company asset.
- Moore's Law may be limited as much by toolmakers as chip designers.
- The education system, cost of labor, level of taxation, and level of automation

are chief differences between the EU and U.S. industries.

- The United States chooses to let industry define electronics standards—in the EU, the government assumes this role.

THE ELECTRONICS INDUSTRY DEFINED

Semiconductors

Current Situation. Semiconductors are the lifeblood of the electronics industry. The manufacturing process for semiconductors, better known as integrated circuits (chips), consists of layering chemicals onto wafers made of silicon or other semiconducting material to form hundreds of integrated circuits on each wafer.

Measured in sales, semiconductors are the nation's largest manufacturing industry. United States–based companies enjoyed a 51 percent share of the world market of $149 billion in 1999. While exports made up 56 percent of U.S. companies' sales,[i] North and South America also provided the largest global market for semiconductors, with a third of all purchases.[ii]

The semiconductor industry includes both small and very large firms (Table 1) that are not necessarily direct competitors with each other because of the myriad variations in their products. Some companies, like Intel, Advanced Micro Devices (AMD), and Motorola, produce large quantities of microprocessors or chips in enormous "clean room" fabrication facilities ("fabs"). Others produce special-order wafers, sensors, or integrated circuits in smaller quantities for defense or other specialized uses. A few key players like Intel and NEC dominate the industry at the high end. At the low end, semiconductors are treated almost like commodities, with Asian producers dominating global sales. The Taiwan Semiconductor Manufacturing Company, for example, is the biggest semiconductor foundry in the world.

Table 1. Top Ten Chipmakers In 1999[iii]

Firm	*Market Share (%)*	*Sales ($ billions)*
Intel	15.9	26.80
NEC	5.5	9.21
Toshiba	4.5	7.61
Samsung	4.2	7.13
Texas Instruments	4.2	7.12
Motorola	3.8	6.39
Hitachi	3.3	5.55
Infineon	3.1	5.22
STMicroelectronics	3.0	5.08
Philips	3.0	5.07

Enormous capital investment requirements create high barriers to entry into semiconductor manufacturing. New fabs cost at least $2 billion to build and equip, and technological obsolescence could occur within 2–3 years. In 1999, the U.S. industry spent 19 percent of its sales revenue on capital investment and another 14 percent on R&D. Few other high-technology industries (e.g., pharmaceuticals, software) reinvest such a high proportion of their revenues in R&D.[iv]

Labor costs in the industry are also high. Heavy demand for software and computer engineers as well as other highly skilled workers created shortages and caused worldwide wage appreciation. North American labor expenses per employee were twice the offshore average in 1998.[v] Constrained in their ability to fill gaps by hiring foreign workers because of limits on the number of H–1B visas permitted each year, U.S. companies are forced to pay higher wages to less skilled employees and bear the costs of additional training.

Outlook and Challenges. To continue to compete, some companies are entering strategic alliances to share R&D costs. Others are gaining funds for capital investment by limiting their U.S. activity to designing and marketing semiconductors and other components while contracting the manufacturing, testing, and assembly overseas. In this way, they focus capital expenditures on R&D within the United

States, and limit their expenses for skilled labor and for the retooling of production facilities in response to demand changes. Strict U.S. environmental regulations also play a role in offshore manufacturing. Ten percent of all U.S. semiconductor production takes place in foreign fabs, a percentage that is increasing even among traditional producers.[vi] A notable exception to this trend is the manufacture specialized electronics for the military.

High capital and labor costs notwithstanding, both U.S. and foreign firms continue to invest in new plants and equipment in the United States, Europe, and Asia. Favorable incentives from national and local governments, as well as the availability of qualified workers and a base for research appear to be the prime motivating factors. To attract jobs, for example, the German government provided a quarter of AMD's start-up costs for building a $1.9 billion fab in Dresden. A technology center even when it was part of East Germany, Dresden also offers AMD skilled workers and an excellent research base.

Robust growth in the semiconductor market is expected to continue for the near future. The total market is predicted to grow by 12–20 percent per year to $234 billion by 2002.[vii] Worldwide 1999 revenues were led by a comeback surge of Asian dynamic random access memory (DRAM) chips.[viii] While overall demand is expected to increase, the patterns of demand for specific device types are more difficult to predict. According to recent articles, the personal computer (PC) is declining in importance as a driver for the semiconductor industry because PC profit margins are down and sales growth has slowed.[ix] The communications sector is pulling ahead as an engine of sales. This change may mean that faster, more powerful microprocessors—i.e., the gigahertz battle in processing power between AMD and Intel—may no longer be the hottest contest in the industry. In PCs, the microprocessor is a large stand-alone chip, the most expensive part of the electronic system. In consumer and communications electronics, such as advanced cell telephones and digital set-top boxes, processors are smaller, specialized pieces of systems-on-a-chip. Some companies, like Texas Instruments, have repositioned to focus on the production of digital signal processors and analog chips for the communications market.[x] Demand for flash memory—e.g., for digital cellular telephones, cameras, local area network (LAN) switches, PC cards for notebook computers, and digital set-top boxes—is expected to skyrocket in the next few years, up from $4 billion in 1999 to some $16 billion in 2003.[xi] Many firms are gearing up to try to fill the expected demand for flash memory, which could lead to a temporary overcapacity reminiscent of the DRAM glut in the 1980s.

If high-end chips go through the "commoditization" process, as DRAMs and others did, profitability will continue to be squeezed. According to the Semiconductor Industry Association, logic devices and microprocessors have seen production costs stabilize or increase, while prices have dropped. Although the drops are not as dramatic as those for DRAMs (average 30 percent per year from 1982 to 1998), they are of concern to the industry nonetheless.[xii] In addition, Asian firms want to move up the technology curve to profit from burgeoning demand for more sophisticated chips and, with strong investment, could give U.S. firms a run for their money.[xiii]

With U.S. firms exploring everything from hybrid semiconducting material to nanotechnology, U.S. technological leadership for the next generations of chip technology will continue, given sustained high levels of R&D investment. United States domination of the global semiconductor manufacturing equipment market, as well as in R&D and in the design side of semiconductors, indicates that U.S. companies will continue to profit even if production moves increasingly overseas.

Government Goals and Role. The global reach of the semiconductor industry and the force of commercial demand for its products tend to limit government's role in the United States. Department of Defense applications no longer drive technological development as they once did. European and Asian governments take more active stances than the United States to help their companies compete and provide jobs for their citizens. Government support for basic and applied research having economic implications is evident in Germany. In the United States and elsewhere, government policies concerning immigration, taxation, and education adversely affect the investment climate for semiconductors.

Computing Devices

Current Situation. Today, some form of computing device is involved in nearly every institutional activity. Whether making financial transactions to stemming hostilities around the globe, businesses and governments have become increasingly dependent on the electronics value chain as an enabling force.

The United States is currently the global leader in the development, production, and consumption of computing devices. A German electronics industry association has reported the extent of U.S. dominance, citing its 30 percent share of the $2.2 trillion global electronics industry in 1998 (Table 2). This same association predicts that the world electronics market will grow at an 8 percent rate for the next 30 years. Maintaining the U.S. lead in market share will require strong leadership, extensive R&D investment, and supportive government policies. Proactive businesses and innovative ideas will also be important.

Table 2: Market Shares in Computing Devices Worldwide, 1998

Country/Region	*Market Share (%)*
United States	30
Japan	11

European Union	20
Rest of world	39

Market growth in computing devices between 1998 and 1999 was remarkable. According to the U.S. Electronic Industries Alliance, shipments of electronic components climbed to $244 billion during the first half of 1999, up by $20 billion (9 percent) from the $224 billion for the same period in 1998. The explosive global growth of business-to-business contact on the Internet and consumer desire to remain "connected" added to the sales of electronic components. These sales rose 12 percent to $75.5 billion in the first half of 1999. Sales of associated telecommunications electronics, including infrastructure equipment, soared 18 percent to $41.6 billion.

Because global interdependence is the rule for computing devices and other electronic products, a healthy balance between imports and exports is essential to U.S. industry vitality. Therefore, given the competitiveness of Asian and European markets in both labor quality and costs, coupled with a surging domestic demand (nearly $450 billion in 1999), computing devices are destined to have a significant impact on the U.S. economy.

Outlook and Challenges. Members of the electronics industry in the United States and Europe have identified two emerging trends in computing devices: (1) an increase in reliable, cost-effective data storage and retrieval, and (2) the introduction of net-centric software.

The growth of global Internet business-to-business transactions demands new and expanded data storage capabilities. According to the International Data Corporation, capacity requirements for installed servers double each year. In 1998, for example, Unix system managers added 110 percent more storage capacity than in 1997. This growth is certain to continue, owing to a decline of 40 percent per year in the price per megabyte of disk-based storage systems while performance increases and prices remain fairly constant.[xiv] The ability to store and retrieve vast quantities of data requires solutions such as network attached storage (NAS) or a storage area network (SAN). Coupled with the increasing capacity and availability of bandwidth, NAS and SAN will reduce the islands of computing by scaling storage and server resources across the enterprise. The market is predicted to be in the $20–$25 billion range by 2002 and to increase thereafter.

On the software side, current wireless devices do not contain enough memory capacity to run common office automation suites. Oracle and Sun Micro Systems are introducing net-centric software that offers relief from the limitations inherent in hand-held wireless devices. Such software not only can facilitate wireless applications, but also can absolve office employees of burdensome software application updates, as the updates will be maintained on a centrally accessible system. The advent of wireless and low-bandwidth burst cache capabilities, through improvements in processor capability, memory storage, and programmable logic devices, will allow expanded portable wireless communication via the Internet. With improved network storage, a hand-held device becomes a network tool that can be customized for businesses and consumers. This can be regarded as a promising market for the consumer, commercial, and defense industries.

Government Goals and Role. Internet security is a significant policy issue facing governments in the United States and Europe. The object of an intense technology-versus-policy debate, a privacy/security capability is required to ensure that transactions via the Internet remain protected from those with the right technology, but the wrong intentions. Protecting the security of e-commerce transactions and general purpose government use of the Internet is crucial to increased consumer confidence in information technology, but it requires a suitable, sophisticated encryption capability. The policy tension centers on the strength or quality of encryption that businesses and governments require. The United States is a leader in the field of encryption, but export policies restrict U.S. firms from gaining market share, even as foreign competitors market comparable encryption software. A sizable worldwide market (in the $20–$25 billion range) exists for encryption products. The current Administration recently relaxed controls on some forms of encryption technology transfers to permit the exploitation of this market; however, national security and privacy issues will continue to be an issue of debate among governments, law-making bodies, and industry. Adequate security protection is vital to maintaining public confidence in the use of the Internet for business and government transactions.

The United States must maintain an active role in encouraging increased innovation and productivity in the electronics industry. United States domestic and export policies with regard to electronic devices must at once be consistent with national security requirements and supportive of international business development programs through the Departments of Commerce and State. Clearly, the EU is working to encourage growth of the computing devices industry in member countries through development of strong business, education, and government relationships. The German state of Saxony, for example, is well situated technically, benefiting as it does from the close cooperation of educational, government, and business organs. This cooperation is conducive to significant innovation and to the attraction of new industry to the region. For the United States to maintain its technological advantage and market share in the electronics industry, the combined power of business, education, and government must likewise be brought to bear.

Telecommunications

Current Conditions. Over the past half-decade, the popularity of the Internet has precipitated an explosive growth in the communications equipment sector of the electronics industry. The ever-increasing demand for data communications bandwidth strains a telecommunications infrastructure built for telephone traffic. A continuing demand for new equipment and software to expand or replace this infrastructure drives the market to seek increased efficiencies in telecommunications.[xv]

Unfortunately, the infrastructure change to date has been asymmetrical. The emergence of fiber optics as the infrastructure backbone and the rapid performance increases in digital switching technology have led to massive growth in the bandwidth capacity of long-distance point-to-point and network communications links. However, consumer access to the larger network is for the most part slow and limited. The expense of high-speed connection has tended to restrict access to commercial business markets. Accordingly, local service providers, primarily the Regional Bell Operating Companies (RBOCs) have had a virtual monopoly in this market for years. The Telecommunications Act of 1996 was designed to increase competition by allowing cable companies, long-distance service companies, and local service providers to compete in each other's markets. However, thus far this competition has been slow to develop because of regulatory requirements and the large investments needed to build alternative infrastructures.[xvi]

Three segments in the communications sector are experiencing rapid growth. Breakthrough products in all-optical switching equipment in 2000 will begin to allow optimal exploitation of the communications capacities of fiber-optic networks. At the same time, the cost of optical networking equipment is decreasing, enhancing the economic feasibility of bringing fiber-optic capacity closer to actual users. Pioneer Consulting of Cambridge, Massachusetts, predicts that optical switching systems will create a 5-year, $31 billion market opportunity, growing at an annual rate of 121 percent during that time.[xvii]

The wireless communication segment is also experiencing phenomenal growth. Voice communications still drive the majority of spending on wireless communications infrastructure, while cellular systems continue to represent the largest portion of wireless communications networks in the United States. However, the growth of personal communications system applications, as well as the emergence of de facto standards such as the Wireless Application Protocol (WAP), indicates that data communications will eventually dominate the wireless sector.[xviii] Lacking inexpensive broadband access at the user level, wireless technology drives the need to build high-capacity enterprise networks.[xix] The lack of a single standard inhibits U.S. industry penetration of the world wireless market. European firms, operating under a single European standard called Global System for Mobile Communications (GSM) lead the world in the application of wireless communications.

Although wireless technology is making inroads as a stopgap measure for local broadband access, cable is the primary competitor emerging in the local subscriber market. Cable television providers have a deployed infrastructure that reaches many of the same users (local subscribers) as the telephone companies. High-speed cable modem Internet access rose from 300,000 subscribers in 1998 to more than 1 million in 1999, and is expected to exceed 4 million by 2002.[xx] In response, the RBOCs have rolled out digital subscriber line (DSL) technology, which enables greatly increased bandwidth access over existing telephone lines. It appears that the long-delayed competition in the local subscriber market is under way.

In contrast to these segments, the satellite communications segment experienced setbacks with the bankruptcy of Iridium and ICO Global communications. The provision of personal communications systems from satellites faces competitive challenges from terrestrial wireless networks. On the other hand, the demand for satellite service for developing countries is on the rise, primarily because of the lack of terrestrial telecommunications infrastructure in those countries. In addition, demand continues for satellite services in broadcast, specialized services for business (very small aperture terminals), and for mobile terminals, in particular global positioning system applications.

While leading-edge technology developments in optical and wireless networking have spawned numerous start-ups, the communications industry as a whole remains dominated by a few players. Also, well-publicized mergers and acquisitions among long-distance service providers, cable providers, and media content firms, as well as vertical and horizontal integration of "nuts-and-bolts" companies, leads to a consolidation of infrastructure providers.

Outlook and Challenges. Optical technology will increase its domination in central and wide area networks (WANs); no other technology can effectively compete. Long-haul technologies, such as microwave and satellite systems, will remain substantial markets in geographical areas where optical infrastructures are too expensive or difficult to implement. In addition, as all-optical switching equipment gains efficiencies and prices fall, more optical fiber links will reach residential and business customers. More likely, however, is increasing competition between RBOCs with DSLs and long-haul services with cable modems over the next several years to provide broadband access for users.

The wireless market should experience huge gains in market value and penetration worldwide as greater data communications and bandwidth become available for mobile users. Wireless technologies should also make significant inroads for stationary users, primarily in LANs and interconnects to WANs, at least until optical fiber goes the "last mile." Bandwidth access will necessarily be limited by the density of users, bandwidth availability, and cell size; physical limitations are such that per user bandwidth can grow to at most a few hundred kilobits per second.[xxi]

The need for uninterrupted, inexpensive broadband data communications access for both fixed and mobile users will continue to drive the market. Given the multiplicity of technological, economic, and regulatory factors, it is difficult to predict with any precision how the communications infrastructure will evolve to meet this challenge. It is essential that firms in this industry operate in a competitive environment—i.e., across all segments of the domestic and international markets.

As a communications user, the U.S. government's primary challenge will be to leverage commercial technology and infrastructure to the maximum extent possible, while guaranteeing secure access to required bandwidth in times of crisis. In most cases, it may be desirable for the government to lease communications services from a commercial vendor, rather than to own and operate its own communications equipment. This will require a paradigm shift within the government, especially in the military.

Government Goals and Role. The U.S. government should allow market competition and industry standards efforts to continue without interference, with two exceptions. First, the government must ensure that fair competition develops at the local subscriber level. Since RBOCs control wired telephone access to the end user, adequate competition can exist only if there is equal access to the end users. Cable providers currently provide the only serious competition to the RBOCs for Internet access; their market penetration is nowhere near complete.

Second, U.S. industry must be able to influence new generations of wireless communications standards in Europe. Given past history, mandated European standards are likely to spread across most of the world, and could effectively constrict U.S. firms' competitiveness. The Department of Commerce is working with the European standards organizations for U.S. industry access; those efforts should continue.

CONCLUSION

Electronics is a $2.2 trillion industry worldwide and by some projections is expected to grow by more than 8 percent annually for the next 30 years. Noteworthy is the fact that the DOD represents less than 3 percent of this market, and although once a driver in electronics, it now lacks the influence to substantially affect market conditions. From semiconductor to computer, the electronics industry is defining everyday life and laying the pathway to the future in terms of quality of life, increased productivity, more transnational partnerships, and increases in national defense capabilities.

Like most industry sectors, electronics has its share of challenges. There is, for example, a critical shortage of qualified workers worldwide that must be remedied, and short electronic product life cycles are plaguing commercial and defense industries with out-of-production parts problems. Moreover, a growing trend for key U.S. suppliers to develop sole dependency on offshore semiconductor manufacturers leaves U.S. markets at risk. The rapid expansion of wireless technology, which will add to the already strained bandwidth worldwide, is another area of great promise and needed science. And lastly, the U.S. export licensing process is slow, resulting in delayed or lost sales overseas and a reduced worldwide market share for U.S. firms. Addressing these challenges will require national attention and response from a government system designed for a different pace and already lagging behind.

ESSAYS ON MAJOR ISSUES

The following are four essays representing major points in the electronics industry that deserve additional focus. The personal digital assistant essay describes one of the major trends in the industry: the wireless Internet. The remaining three focus on issues important to U.S. economic growth and national security.

PERSONAL DIGITAL ASSISTANTS

J. J. Blessing

Hand-held computing devices, personal digital assistants (PDAs) are a key enabling agent for the wireless Internet. They leverage the productivity and thus enhance the competitive advantage of all who use them. No single industry is untouched by the PDA, and employment is expanding worldwide. Significant challenges remain, however, in the areas of architectural standards, bandwidth, and software development.

In only 8 years, the PDA has grown from an "electronic scratch pad" to a comprehensive personal information manager (PIM). Although the PIM functions are essential, the focus must now shift to applications that increase productivity and thereby make business, government, and the DOD more efficient. The United States easily enjoys the lead role in developing the Internet; however, Western Europe is the pacesetter in the wireless area.[xxii] The successful merging of these two markets will determine the new technology leader.

Tomorrow's PDA will be a compromise between maximum functionality and minimum size and weight. It will be judged by how well it wirelessly connects to networks and the Internet, and by how much it enhances productivity. Wireless consumer growth is forecast to be phenomenal. According to the International Data Corporation, there were 7.4 million wireless subscribers pulling data off the Web in 1999, and it expects this number to grow 730 percent to 61.5 million over the next 3 years.[xxiii]

Three major challenges will confront this market: (1) establishing a single architectural standard; (2) increasing the speed of existing and future bandwidth; and (3) developing the software that will uniquely enable PDAs to be productive assistants, operating seamlessly around the world without breaking the "link." Companies have already achieved enormous breakthroughs in some of these areas, but the final problems will not be resolved without serious additional work.

Standards and Architecture. Many wireless standards and architectures are available today. The Europeans lead the way in seamless connectivity, using a single system, GSM, from Finland to Spain. However, there is some movement toward adopting Code Division Multiple Access (CDMA) as the global standard. Even the Europeans (i.e., the EU) have agreed to build compatibility with CDMA into all future technologies, because it permits faster wireless data transfers. With its further expansion as a standard into East Asia, CDMA now commands about 10 percent of the world market, and one research group expects this number to grow to 30 percent by the year 2005. [xxiv]

A working group of the Internet Engineering Task Force is developing an architectural standard known as Mobile Internet Protocol (Mobile IP) that will give mobile users a great degree of freedom across private and public networks. Mobile IP will allow a node to change its point of attachment from one link to another while using the same IP address. Users will be able to remain "plugged in and productive" from any device anywhere in the world. One of the major challenges facing the implementation of Mobile IP is network security. Firewalls currently obstruct all classes of incoming data from mobile users that do not meet specific criteria (e.g., they contain an unknown IP address), and this obstacle must be resolved to ensure truly mobile access.[xxv]

Bandwidth. The downloads may be slow today, but Qualcomm has already developed chips that can carry the Internet to wireless devices three times faster than existing dial-up modems, and much faster chips are on the way. A system known as High Data Rate, due out next year, delivers Internet connections to wireless devices at speeds more than 40 times faster than is possible today.[xxvi] Working to solve the problem of bandwidth and screen size, about 300 companies have bought into WAP to provide a standard way of bringing Web sites to different wireless devices.[xxvii] Air2Web will soon announce its wireless infrastructure technology, which will allow two-way or interactive data exchange over any digital device using any carrier technology. If this technology delivers, WAP may not be required.[xxviii]

Software. With fast connections already on the way, the key to unleashing the power of wireless computing will be in writing the software for these applications, just as it was for the Internet revolution.[xxix] The two most limiting characteristics/challenges facing wireless Internet devices, however, are screen size and data input. Users want their devices to be as small and light as possible, their screens to be big enough to read, and their input pads to be big enough to fit their fingers on—but that is what they want today. A potential future solution is voice operation. Voice operation requires more powerful processing power, but overcoming this limitation may not be that far off, given the doubling of processing power every 18 months, as described in Moore's Law.[xxx] Moving toward net-centric software by conducting all the powerful computing on a central server (leaving resident on the PDA only what is required for remote operation) is another possible solution. This would help overcome memory and bandwidth constraints on the current generation of PDAs.

In summary, the evolution of the PDA has been nothing short of miraculous, and prospects for its applications and contributions to productivity appear boundless. What began as a PIM-capable "gadget" is now merging with wireless Internet technologies that will eventually combine the best features of the PDA, the cell telephone, and the two-way pager. Though some significant challenges for the development of this technology still exist, progress is steady toward a standard architecture capable of providing seamless connectivity for the wireless PDA.

WORKFORCE

George Allen

The electronics industry faces its stiffest challenge trying to recruit and retain highly skilled engineers for its workforce. The Information Technology Association of America has reported that employers will create a demand for 1.6 million new high-technology positions this year. About half of these positions—843,000 jobs—will go unfilled.[xxxi] One sector of the electronics industry, the computer and office equipment industry, is projected to be the fastest growing industry in the nation through the year 2006, with an annual growth rate of 15 percent.[xxxii] One of the main drivers of this challenge is the current national employment trend. Unemployment stands at 3.9 percent nationwide—the lowest in 30 years. A tight labor market in many business sectors is also reflected in these unemployment figures; worker shortages are found in almost every industry.[xxxiii]

Within the electronics industry, those companies that depend primarily on defense contracts have even greater difficulty finding and retaining engineers. Government spending on defense contracts has decreased significantly since 1990; firms reliant on those funds can no longer provide the job security that they once did.[xxxiv] The competition in this already tight market economy for highly skilled engineering talent continues to be won by the "dot-com" companies, which offer stock options, profit sharing, employee tuition reimbursement, exceptionally large starting salaries, and other attractive employment incentives.[xxxv] In its electronics industry study last year, the Industrial College of the Armed Forces cited these labor shortages as one of the most significant challenges facing the electronics industry, and those shortages are expected to worsen.[xxxvi] Data from other studies confirm this worsening trend. An aging workforce of baby boomers reaching retirement age in the next 10–15 years compounds the dilemma. The Defense Contract Management Agency also predicts that the number one difficulty as the workforce ages and retires will be finding enough skilled workers in the design and industrial areas.[xxxvii] Easing of immigration limits and educational improvements have become essential to filling many of the jobs that will be created in the next 25 years.[xxxviii]

Forester Research reports that the short-term answer for the electronics industry is to import offshore talent through the issuance of high-technology work visas (H–1B visas).[xxxix] Congress increased the limit on H–1B visas from 65,000 to 115,000 in 1998 on condition of a return to the previous level of 65,000 by 2002.[xl] Technology leaders such as Texas Instruments and Sun Microsystems have repeatedly lobbied Congress not only to recant the required return to the previous level of 65,000, but also to increase the annual level to around 200,000.[xli] Without sufficient H–1B visas, many skilled foreign nationals that graduate from the nation's universities will not be able to obtain U.S. employment authorization.[xlii] Also, as foreign economies improve, the willingness of foreign engineers to immigrate could decline.[xliii] Correction of the visa problem, however, will have little long-term significance; much more will be needed to adequately address the ever-increasing problem of finding the qualified engineers required to ensure continued electronics industry support of the national security strategy.

With a diminishing pool of young recruits in the United States, the need for an educational system capable of developing the requisite technical skills grows even more critical. The nation's future security depends on it. There are not enough trained people in the education pipeline to meet the high-technology engineering requirements of the electronics industry. From 1985 to 1995, the number of bachelor's degrees in the mathematics or computer science field dropped 29 percent, from 54,510 to 38,620. A drop of 37 percent occurred in the number of bachelor's degrees in the electrical, electronics, and communications engineering fields, from 23,742 to 14,929.[xliv] To solve this problem, a variety of industry-sponsored efforts are under way. Some electronics industry firms offer summer hire programs for high school and first- and second-year college students, high school industry seminars, grants to colleges in mathematics and the sciences, specific school partnerships, and funding to colleges for specific engineering programs. General Electric and Intel each spend about $1 billion annually on education and training programs.[xlv] Raytheon sends its female engineers to Girl Scout meetings to promote the engineering field for women. The defense-electronics section of Northrop Grumman has a mentor program for underprivileged high school students in Maryland that includes free college tuition.[xlvi] Although many private firms have generously invested in school systems, others remain reluctant to collaborate with the federal government for fear of additional regulation and oversight. Pressures from global competitors may also dampen enthusiasm for long-term investment. These educational initiatives are in reality a fragmented and piecemeal strategy at best; they do not shape, mold, and prepare the workforce for the decades ahead.

Unless fundamental changes occur in the nation's education system, the future economic prosperity and national security of the United States could be at risk. Developing and maintaining necessary science and mathematics skills for engineering will require coordinated and sustained efforts by government, industry, and the education establishment. One long-term approach is to create a national electronics intellectual capital plan. Such a plan would identify the core competencies required to meet the nation's projected electronics skill sets, with emphasis on mathematics and science. This strategic planning document would constitute the basis for revising national achievement tests designed to assess mastery of mathematics and science skills.

A commission formed to define the competencies and related standards becomes a logical step in this overall strategy. Membership could include representatives from the Department of Education, the electronics industry, and local school systems. Additionally, a federally mandated (reviewed by the Board of Governors) increase in teacher pay to attract and retain the country's best and brightest in the education field deserves consideration. Teacher salaries were raised significantly in Vermont in 1995 in an effort to attract and retain the best teachers for the state school system. The results of the last nationwide tests showed a marked improvement in student scores and increased teacher retention.

Also worthy of attention is establishing a national clearinghouse for corporate and government grants to promote equitable distribution of donated corporate resources across educational institutions and communities. Businesses and vendors have invested time and resources through school partnerships, but such gifts must be equitably allocated and focused on achieving the target goal: meeting the specific education standards stipulated in the national electronics intellectual capital plan. The clearinghouse could be a nonprofit organization co-sponsored by the federal government and industry.

Granting of more than 200,000 H–1B visas appears reasonable for the government's role in the short term. Essential for the long-term health of the electronics industry, however, is a federally mandated focus on strategies such as the aforementioned:

education improvements in the mathematics and engineering disciplines, a national electronics intellectual capital plan, a national clearinghouse for student grants, an active partnership with business, and higher salaries to attract and retain highly skilled teaching professionals. Absent such a focus, the education system would almost certainly fail to meet the needs of the industry, with serious consequences for effective industry support of the national security strategy.

SEMICONDUCTOR SECTOR

Bob Bostiga, Mike Carroll, and Terri Robl

Two major issues affect the competitiveness and health of the semiconductor sector of the U.S. electronics industry and thus have implications for U.S. national security: export controls and the move toward “fabless” companies.

Export Controls. United States export control policy denies foreign adversaries (or rogue states or individuals) access to leading-edge technologies that could allow them to develop sophisticated weapons. The Departments of State, Commerce, and Defense have the major roles in developing that policy. During the Cold War, the collaborative processes used by these Departments generally kept pace with the changing technological landscape, while international agreements limited alternative sources for sensitive items. More recently, and particularly in electronics, federal export controls have lagged increasingly far behind industry advancements. Some computer products that are mass-marketed globally still require an export license in the United States. Industry claims billions of dollars in sales losses due to export controls, enabling foreign competitors with less rigid export control regimes to seize market share at the expense of leading-edge U.S. products.

This loss of sales limits U.S. companies’ ability to invest aggressively in R&D and capital equipment required to remain competitive in the worldwide semiconductor market. Given the strong role that electronics plays in the U.S. economy, a weaker U.S. electronics industry would have serious economic consequences.

A second problem is the licensing process itself. Licenses can take up to a year or more to obtain. Foreign customers are often reluctant to deal with U.S. companies because of the bureaucracy and delays that they experience when applying for export licenses.

The Semiconductor Industry Association and individual firms have argued strongly for the government’s loosening export controls on electronic goods and streamlining the administrative process for reviewing and approving license applications. Both can probably be done without jeopardizing U.S. interests. On the policy side, new criteria should be developed to better distinguish between sensitive high-technology and mass-marketed products. Web-enabled collaboration and analytical tools might facilitate the policymaking process by bringing diplomatic, economic, and military interests together more quickly and effectively. On the process side, improvements are under way. The State Department has received funding to computerize and add positions to its staff to deal with the 48,000 annual applications, and to further streamline the process for exports to trusted allies. Establishment of a fee-for-service operation, similar to that used by the State Department for passport and consular services, could generate additional revenues and tie staffing levels directly to the workload. Industry would likely agree to a fee-for-service model if it improved responsiveness.

Fab vs. Fabless Companies. Although most U.S. semiconductor companies still operate their own fabs, many are turning to overseas contractors for at least part of this capability. About 10 percent of all production for U.S. semiconductor companies is being done offshore, and that percentage is rising. "Fabless" companies like Qualcomm, ATI Technologies, and Xilinx concentrate on design, development, and marketing, and they leave manufacturing entirely to offshore foundries. In this way, they avoid the high labor and capital costs involved in building, maintaining, and upgrading manufacturing capacity. The Fabless Semiconductor Association has 115 member firms and claims that their profit margins and revenue growth are well above the average for semiconductor makers.[xlvii]

The recent earthquake in Taiwan had a profound effect on semiconductor availability worldwide. Supplies dwindled, prices rose, and U.S. original equipment manufacturers were unable to meet delivery schedules due to significant parts shortages. Two Taiwanese foundries, Taiwan Semiconductor Manufacturing Company and the United Microelectronics Corporation, provide two-thirds of the offshore production for fabless companies.[xlviii] This gave pause to fabless companies that depend on Taiwanese fabs and raised concerns about relying on foreign sources. Fortunately, the U.S. military was not involved in a major conflict for which electronic component shortages would have been significant.

If unforeseen natural disasters or hostilities did develop in a specific area, other sources would likely be available. United States semiconductor firms have production facilities in Germany, Ireland, and other friendly countries, and they are making additional investments to respond to growing demand. If shortages became particularly acute and a national emergency demanded it, the Administration could invoke the Defense Production Act of 1950 to obtain needed components from U.S. fabs. In any case, military needs are minimal compared with the normal commercial demand.

While the current percentage of offshore semiconductor manufacturing is not alarming, the DOD should monitor developments in this sector. As with any critical commodity, the United States should try to avoid a dependence on semiconductor-manufacturing capability in one region.

DIMINISHING MANUFACTURING SOURCES AND OUT-OF-PRODUCTION PARTS

Orville Prins and Don Wussler

Issues. Both the commercial and defense electronics industries continue to face major issues in the areas of diminishing manufacturing sources (DMS) and out-of-production parts (OPP), although from different angles.

The DMS situation occurs when vendors of key parts and subsystems go out of business, leaving no provider of these key parts. The DOD was exposed to this situation when Optical Imaging Systems, Inc. (OIS), the defense industry's key supplier of flat-panel display glass, went out of business in 1998. This departure from the market affected the F–16 *Fighting Falcon*, F–18 *Hornet*, F–2, AH–64D *Apache* helicopter, and the M1A2 Abrams tank. On the commercial side, the failure of OIS directly affected Boeing production or modification of 727, 747, 777, and DC–10 aircraft.

The OPP situation occurs when vendors produce only new versions of parts or subsystems and no longer produce or support previous versions. The DOD and its suppliers were given a wake-up call when Intel announced on December 30, 1996, that it would no longer produce military-specification products after December 31, 1997. The company had decided to depart the military products market for the more lucrative commercial marketplace. Intel products were pervasive in the U.S. defense establishment, and this announcement affected ongoing development and production as well as the sustenance of fielded weapons systems. Intel's departure will be extremely costly to the DOD; billions of dollars will be spent for new suppliers, redesigns, and life-of-service buy-outs.

The defense industry, confronted with extremely long development and production cycles and system lifetimes, struggles to maintain currency in many of its key subsystems, including central computers and signal processors. The desire to maintain as few configurations of a given weapons system in the field as possible is a strong one, and users sometimes mandate no more than two different configurations at any one time. With vendors producing new systems every 18 months and supporting perhaps only one previous version, the DOD continually finds itself behind the electronics modernization curve. As an example, the Air Force was forced to undertake a computer replacement program for the E–8C Joint Surveillance and Target Recognition System (Joint STARS) because the original Joint STARS central computer would no longer be available for the second half of the procurement program.

Commercial companies must fight the battle from both sides, as a supplier and as a customer. As a customer, they must worry about their suppliers either not providing parts or not supporting the parts of the products they produce and the equipment they use to produce them. As a supplier, they must craft a balance between forging ahead to new products and supporting their customers' needs.

Solutions. Government and industry customers pursue several similar strategies to address these serious challenges. Customers always try to have multiple sources for key parts to avoid the dilemma of a sole source's going out of business. Life-of-system quantity procurement of parts is also a common strategy, although in some cases the government must seek congressional approval to deal with full-procurement rules. Sometimes both government and industry customers must bring production of a given part in-house to ensure source viability.

Commercial companies tend to have one major advantage over their government counterparts: most are usually chasing the same product life cycle as their suppliers—i.e., the 1- to 3-year time frame. Hence, they are geared to replacing parts and equipment on cycles closer to those of their suppliers. From an OPP perspective, their parts go out of production at the same pace as their suppliers' parts; thus, the cost of OPP is a essentially a "normal" cost of doing business.

Commercial vendors will usually support, if not produce, at least one previous version of their products. Some aggregate several pieces into a module and treat the module as the "part." As long as the output of that module looks the same with new pieces (form, fit, and function), the replacement of parts is transparent to the customer.

There are no "silver bullets" for DMS or OPP; these issues will challenge industry suppliers and customers well into the future.

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