The Future of Computing: Technology Trends and Forecasts

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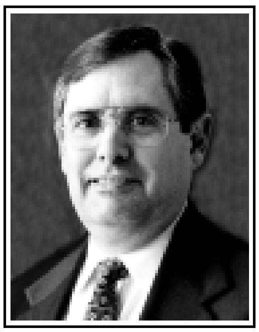

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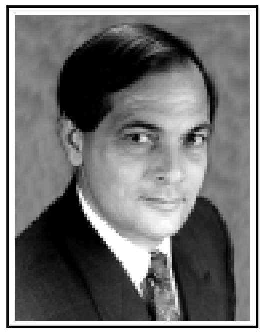

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This article reviews the implications of technology change on computers, including the competition among the various computer platform types. Following the review of the technology, forecasts and analyses pertaining to the economic valuation of computer technology are developed. These are designed to support financial depreciation decisions on computer lives.

Computers are constantly evolving and changing as the various platforms and technologies compete with each other for market share. What was once the sole province of mainframe computers for business is being challenged by micro- and mid-range computers, whose power is only beginning to be tapped by distributed networks. Together, they are becoming more powerful than the ubiquitous mainframe. At the same time, mainframe manufacturers are restructuring their products to integrate into the very networks that challenge their supremacy.

In the early years of the Information Age, computers were mainframe-based, and use was primarily confined to business and research. However, the 1980s and 1990s have seen the migration of the computer to minis and micros, which has led to an ever-growing number of users in the office and, more recently, the home. As we approach the next millennium, consumers are expected to sign up in record numbers for information, education, and entertainment services provided over networked computers.

Computer Platforms

The "computer platform" is the medium upon which computing functions are carried out. Included for discussion in this article are mainframes, mid-range computers, microcomputers, and servers. There are several trends which have impacted the evolution of computer platforms away from mainframes. These include:

- Integration of platform types.
- Competition between platforms.
- Microprocessors.
- Interactivity via networked PCs, workstations, and servers.

Of these developments, microprocessors—and their implications for all platforms—are rapidly becoming *the* driving force in computer technology. Sales of the various platforms are projected to continue to favor microcomputers for the next few years. From 1996 to 2002, projections are for microcomputers to grow from 47.6% to 55% of all computer revenues. Mid-range computers are expected to drop from 24.2% to 20%, and mainframes from 28.2% to 25% during the same period.[1]

Mainframe Computers

In spite of the many inroads made by other computer platforms, mainframes continue to be the mainstay in computing for major enterprise systems in large companies. A number of changes, however, are affecting mainframe technology. Current state-of-the-art for mainframe computing employs massively parallel processing (MPP) using RISC processors, many with CMOS technology, or SMP (symmetrical multi-processing) systems provided by the PC/mid-range manufacturers for smaller systems.[2] This architecture, using multiple Pentium or RISC processors with UNIX operating systems to accomplish performance comparable to mainframes, is breaking into the niche previously reserved for mainframes.

The trend in large computer applications is toward merging the processors and architectures among all levels of computing, blurring the distinctions between these traditional categories. Using identical or similar processors in parallel, and using the same operating systems, mainframes are interfacing with servers running integrated high-end applications. The servers, in turn, interface with personal computers and workstations which do the processing.

While both mainframe and other platforms evolve, there will be some cost advantages to retaining the old technology—at the sacrifice of developing more modern systems and re-engineering processes. However, the long-term future of traditional mainframes is limited. This is due to technologies being brought to bear through other platforms and the relatively low rate of development for mainframes. Mainframe technology could become a classic case of substitution as it rapidly approaches a crossroads that could eliminate most traditional large processor mainframes. We project that, by around 2002 at the latest, mainframe computer applications for businesses will be essentially replaced, either by client/server applications or new language software on SMP/RISC-based mainframes or mid-range computers, which will be significantly faster and more economical. The likelihood is that this will occur very rapidly. It is entirely possible that mainframes will be completely replaced by the lesser categories of mid-range computers, workstations, and powerful PCs.

Another view of the future for the mainframe is that network computing will diminish a company's need to make large investments in mainframes, already behind other categories especially microcomputers. This could result in computer clusters employing multiple nodes in a single system, with capacity for incremental growth and better price/performance than large stand-alone computers. The mainframe may not disappear as quickly in this scenario, since it will be able to act as a repository for large databases and is being redesigned to be integrated into networks. The continued success of mainframes will likely depend on the functionality they bring to the distributed computing environment.[3]

Mid-range Computers

As might be expected, mid-range computers (a.k.a. mini-computers) are between mainframes and microcomputers in terms of size, functionality, and cost. The same technology implications for the other classifications are also pertinent to mid-ranges. As mid-range computers increasingly vie for the mainframe market, their viability in the intermediate range of applications is being challenged by PCs.

Mid-range computers are based on 32- and 64-bit processors, and are relatively small, multiple-user computers dedicated to specific tasks. The microprocessor is also affecting mid-range computing. Since many new applications are based on microprocessors, it is becoming more and more difficult to distinguish between mid-ranges and micros. The new mid-range computers are basically micros, with parallel processors capable of supporting multiple users on PCs to run solutions previously requiring mainframes. The cost savings for the computers themselves can be tremendous, and primary considerations become networking, software, and training costs. Ultimately, the new technology will overcome the old, as the complexities of its applications and benefits of networking overcome the embedded base of legacy systems using large mainframe computers. These changes are occurring throughout the business world today.

Microcomputers

This category is comprised of personal computers, including laptops and smaller devices and workstations. Microcomputers are used for an individual's information requirements, and can be configured to serve multiple users. Technology developments in microcomputers are the driving force behind many of the changes occurring in the general computer market. The reasons include:

- Nearly 99% of worldwide computer shipments, constituting 80% of revenues, are derived from microprocessor-based computer sales.[4]
- Constantly increasing programming costs are driving companies to pre-packaged, PC-based software, even for larger systems.
- Microcomputers are becoming increasingly powerful, allowing enterprise-level functions to be accomplished in lieu of mainframe computing.
- The microcomputer is becoming ubiquitous in the culture of modern business, with increasing familiarity among employees. Other trends, such as telecommuting and networking, also promote its use.

Personal Computers

The current technology base of microcomputers includes the Intel Pentium and Motorola 68040 microprocessors. Currently, the 32-bit processors, led by Intel's Pentium chip, dominate the market, with Macintosh technology currently experiencing reduced sales due to the financial and operational problems at Apple. The ready availability of software packages for the PC also gives it an advantage over current Apple offerings. However, a recent move by Apple to license its operating system to other manufacturers to clone their line of personal computers should provide lower prices and increased competitiveness for the overall market.[5]

An alliance between IBM, Motorola, and Apple was formed several years ago to develop and manufacture the PowerPC chip. It was expected to outperform Intel processors since it would combine two operating systems, thus providing effective competition for the Microsoft/Intel "duopoly." The chips could then be used in PCs for both manufacturers. This particular initiative has not worked out as planned, and Intel still holds a decided edge in the PC market.[6]

Future characteristics for the microcomputer market are summarized as follows:[7]

- The CD-ROM will become standard on desktop models in 1996.
- Digital signal processors for voice and video input will become standard on most PCs in 1997.
- The standard PC configuration beginning in 1996 was the 90 MHz Pentium with 16 MB of RAM and 1 GB hard disk. (PCs are currently being sold at 120-133 MHz, 16 MB RAM, and 1.6 GB hard drives, with high-end machines at 166 MHz, 32 MB RAM, and 2 GB hard drives.)

Workstations

A workstation is similar to a personal computer in that it normally has one user, but it is more powerful and used for high-performance, high-end technical applications. Workstations typically use RISC-based microprocessors and the UNIX operating system.[8] The recent introduction of the PowerPC will allow the IBM/Motorola partnership to make significant inroads into the workstation market.

Servers

Servers are computers which are built in all sizes, and are configured to be used in a number of applications, primarily for the benefit of multiple users. These include database (storage of shared data), e-mail, work group, and communications applications. The main uses are in client/server configurations, LANs, and Internet/Intranet services. Servers can be based on three different computing platforms: mid-range, workstations, and PCs. Typically, PC servers cost in the range of a few thousand dollars. From a competitive technology perspective, PentiumPro-based servers, using WindowsNT, have been introduced on the low end for use as servers for smaller networks, resulting in less costly applications.

Servers also distribute applications, including database and e-mail, to "clients," which enjoy much quicker and more satisfying access to the information compared with mainframe experiences. High-end servers are even challenging the mainframe's traditional place at the top of the computing pyramid. Servers are also important in the client/server environment, providing the storage and some of the processing needs. This application, in which the server runs the database, is called a file or network server.[9]

As servers proliferate among the networks, alternatives are becoming available in the form of increasingly powerful "smart" storage devices. With integrated microprocessors to facilitate requests for data, this is critical, as data storage and retrieval requirements become increasingly complex and sophisticated. In many cases, storage devices will be able to replace servers in Intranets/Internets. IBM, by far the largest manufacturer of these storage subsystems, is developing a dedicated storage/server for 1996 production.[10]

Distributed computing is becoming a driving force in creating a rapidly-growing market for servers. They are becoming a primary option for enterprise applications, either in support of, or as a replacement for, mainframe systems—a trend which is expected to continue.

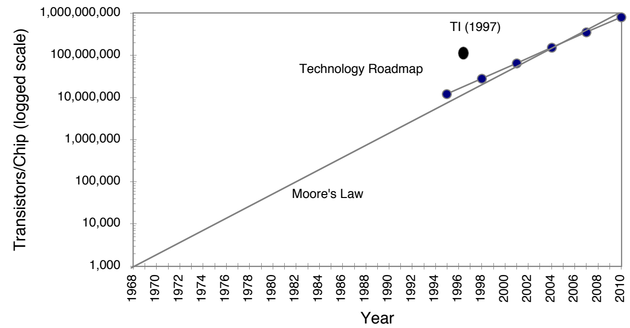
Implications for Computer Technology

The integrated chip has contributed greatly to the continuing trend of increased power and speed that the computer industry has experienced since the 1970s. Chip components comprise a major portion of computer costs, especially for microcomputers. Technology measured in density of transistors per chip is continually increasing, with a resulting decrease in size.

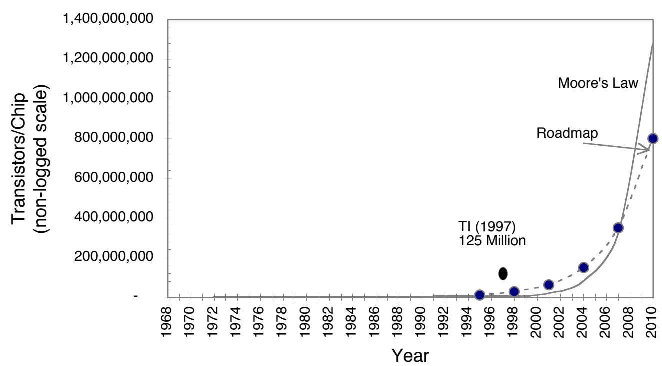
Moore's Law, formulated by Gordon Moore, Intel's chairman in the early 1960s, stated that "the number of transistors integrated onto a piece of silicon would double every 18 months or so."[11] This has largely held true for 30 years. For example, the number of transistors per chip, 3,500 in 1972, has grown to 5.5 million today for the Intel Pentium Pro. *The National Technology Roadmap for Semiconductors*, developed by the Semiconductor Industry Association, defines the common vision for the future of semiconductor technology. By developing technology needs and forecasting manufacturing capabilities, the *Roadmap* projects state-of-the-art standard technology characteristics. Figure 1 is a comparison of Moore's Law and *Roadmap* forecasts for transistors per chip through 2010.[12]

Indications are, however, that chip technology may be approaching the limits of Moore's Law. The physical capabilities associated with the ability to pack increasing numbers of transistors on a chip are expected to be approached around 2010 when critical dimensions of .07 microns are projected. This is not to say that further progress may not be achieved, but it may have to be achieved through other parameters. It should be noted that Texas Instruments' recent announcement of the availability of a chip with 125 million transistors in 1997 (with undetermined commercial availability) is a strong indication of the continuation of the trend to increase transistors per chip.[13]

Figure 1
Moore's Law Versus Projected Transistors per Chip



Roadmap Compared with Moore's Law



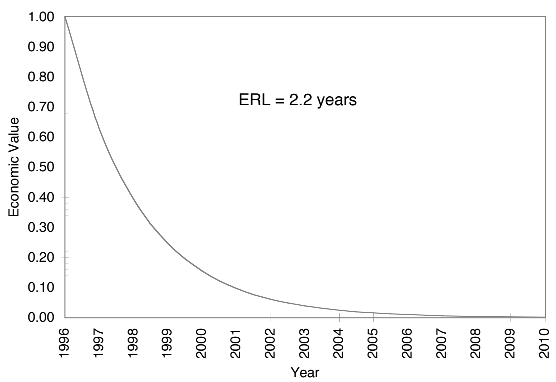
Source: National Technology Roadmap

Valuation Based on Price/Performance

Based on the implications of Moore's Law, Figure 2 forecasts the diminishing value and economic remaining life for PCs. From this curve, we can determine the economic remaining life for PCs by determining the pace at which their value is reduced each year due to the continuing technological improvements predicted by Moore's Law. This life analysis assumes that the cost of a PC will remain relatively constant over time (in actuality, prices have been substantially reduced), in spite of the continually increasing power and an interim retirement rate of 5%.

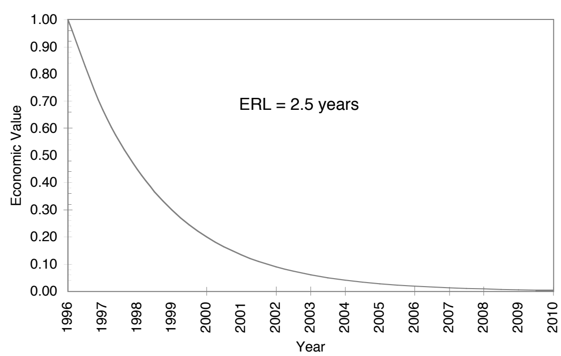
Figure 3 develops the same type of life analysis based on the projected diminishing value for PCs under the assumptions of the *Roadmap*. This slightly reduces the rate of technology advance compared with

Figure 2
Economic Value and Economic Remaining Life Based on Moore's Law



Source: Technology Futures, Inc.

Figure 3
Economic Value and Economic Remaining Life Based on the Roadmap



Source: Technology Futures, Inc.

Moore's Law, producing a slight increase in the economic remaining life.

The price/performance effects of technology improvements are best demonstrated by the pace of change in the PC market in the current year (1996). Rapidly-dropping costs of major components have contributed to price reductions in recent models by many manufacturers from 40% to nearly 50% in the last year. Improvements such as larger hard disks, more powerful CD-ROMs, and faster modems with higher processor speeds have been incorporated. Examples of these trends include drastic price reductions for DRAM, Pentium processors, CD-ROMs and hard disk drives during 1996.[14]

Salvage Value

Our determination of salvage value for computer assets consisted of a variety of assessments, including a review of companies' experience and market surveys. The salvage value of used computer hardware is primarily dependent on its relationship with state-of-the-art technology, and it is a key indicator of asset value over time. Frequently, when new products are introduced, the prices of predecessor technologies are dramatically cut to reduce inventories. This allows the slower adopters to upgrade their equipment and prepare the market for the latest developments. In computers, the technology which has just been superseded then becomes almost valueless. Rapid advances and proliferation of computer technology in more recent years has caused salvage values to diminish over time.

A survey of firms which purchase and resell used computers resulted in the following conclusions:

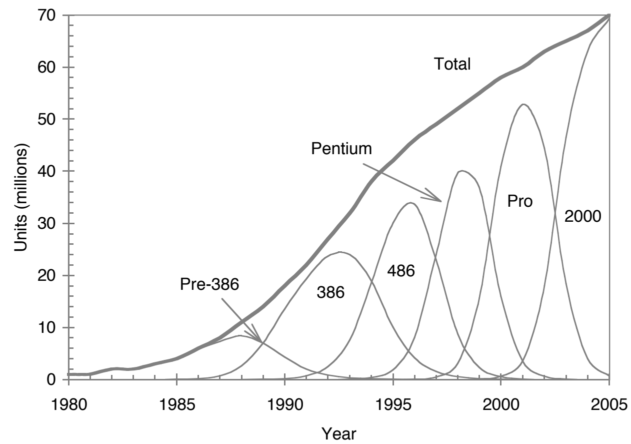
- Most companies seeking used computers are interested only in recent technology in excellent condition.
- For PCs, any technology older than 486/Pentium levels is valued only for scrap. This means that the maximum value would be less than 5%.
- Computer resale vendors were reluctant to discuss the values or percentages they are willing to pay for more recent technology, but we conclude that a range between 10% and 25% of the original purchase price for PCs less than three years old is reasonable.
- A primary factor in valuing used computers is the current price of state-of-the-art Intel microprocessors, which tends to establish the amount buyers are willing to pay for old technology. High-end PCs sell on the used markets for only 30% to 50% of original cost within a year or so of purchase.

We conclude from our review that salvage values for used computers are closely linked to the obsolescence of the technology, and that appropriate levels for salvage should range from 0% to 3% of original equipment cost. This assumes that current generations of computer investments will continue to become rapidly obsolete.

Technology Forecasting Life Cycles

Semiconductor technology, including processor and memory components, continues to be the major driving force behind the price/performance of computers. The effects of technology change on the microcomputer market from its inception around 1980 to 2005 are illustrated in Figure 4. The total desktop workers PC market is illustrated, along with the estimated market share of each successive technology and its corresponding life cycle. Implied remaining lives resulting from these life cycles are one year for 386s, 1.4 years for 486s, and 3.5 years for Pentiums, with a composite average of 1.8 years.

Figure 4
Desktop Workers PC Technology Market Shares



Source: Technology Futures, Inc.

Summary of Recommended Lives for Computer Assets

Based on our research, we conclude that the lives of computer investments should be closely evaluated to ensure that proper economic and obsolescence factors are considered. The pace of change experienced in the past is likely to continue. Lives developed for PCs using Moore's Law and *Roadmap* considerations are key influencing factors for all computer platforms. We recommend that computer assets in the aggregate be depreciated over lives not to exceed three to five years.

The rapid obsolescence and economic value loss of computer technology should be considered as significant components of investment and financial decisions regarding computers. Employment of optimal technology will be essential in competitive markets, and the computer will be integral to that effort. NTQ

[1] CBEMA, *The Information Technology Industry Data Book, 1960-2002* (1992).
[2] RISC = reduced instruction set computer; CMOS = complementary metal-oxide semiconductor.
[3] Standard & Poor's Corporation, *Industry Surveys, Computers* (September 28, 1995).
[4] Price Waterhouse, *Price Waterhouse Technology Forecast 1996* (October 1995), p. 107
[5] AmCoEx Home Page (May 20, 1996) [On-line].
[6] *Ibid.*
[7] Price Waterhouse, p. 122.
[8] P. Norton, *Introduction to Computers* (New York: Macmillan/McGraw-Hill, 1995), p. 32-33.
[9] Norton, pp. 215-217.
[10] A. Choi, "Storage Devices Take Spotlight in Computer Industry," *Wall Street Journal* (April 22, 1996):B4.
[11] C. R. Barrett, *Microprocessor Evolution and Technology Impact* (Intel Corporation, 1993), p. 7.
[12] Semiconductor Industry Association, *The National Technology Roadmap for Semiconductors* (1994), p. 11.
[13] Texas Instruments, "Editorial Background," *Texas Instruments Home Page* (May 1996) [On-line].
[14] S. Chan, "Now PC Buyers are Getting More for Even Less," *Wall Street Journal* (June 18, 1996):B1.