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Information Technology Management from 1960-2000

Evolving from the earlier periods of electromechanical ADP (Automated Data Processing) technologies the modern digital computer came into its own form of information technology during the period from 1960 to 2000. Heralded by the advances of the digital computer, Europeans are thought to have introduced the acronym IT, which stands for Information Technology.[1] This term, which Americans rapidly adopted, signified digital convergence in data, voice, and video. Also during this time the organization continuously reinvented and assigned new functions to the computer as dictated by improved economics and organizational learning. Eventually these changes accumulated so as to become an information revolution that changed the way companies structured and managed themselves.

Stages Theory of IT Management

The Stages Theory, first proposed in 1973,[2] has been widely used as a normative theory for the management of IT. The theory is based on the notion that the complicated nature of computer technology would produce a body of knowledge on the effective management of IT within an organization. As a result, the assimilation of computer technologies, and more broadly, information technologies, required bold experimentation, out of which emerged four stages of organizational learning.

These four distinct stages of organizational learning formed an "S-shaped" curve. Initially limited investment and contained experimentation for proving the value of the technology in the organization characterized Stage I: Initiation. Following initiation, the steep part of the S-shaped curve (Stage II: Contagion) represented a period of high learning in the organization whereby the technology proliferated in a relatively uncontrolled manner. Uncontrolled growth eventually led to inefficiency, which created a demand for controls that slowed the growth to a more manageable rate—Stage III: Control. In Stage IV: Integration, the curve flattened, and ultimately the accumulated learning led to a balance of managed controls and growth. At Stage IV, organizations mastered the dominant design of the technology, providing a foundation for the next order of magnitude of progress (i.e., the next S-curve era) to be introduced through a major improvement in the dominant design.

The main dominant designs[3] experienced include mainframes, minicomputers, microcomputers, and networked client/servers. **Figure A** illustrates these three eras, described as the S-shaped

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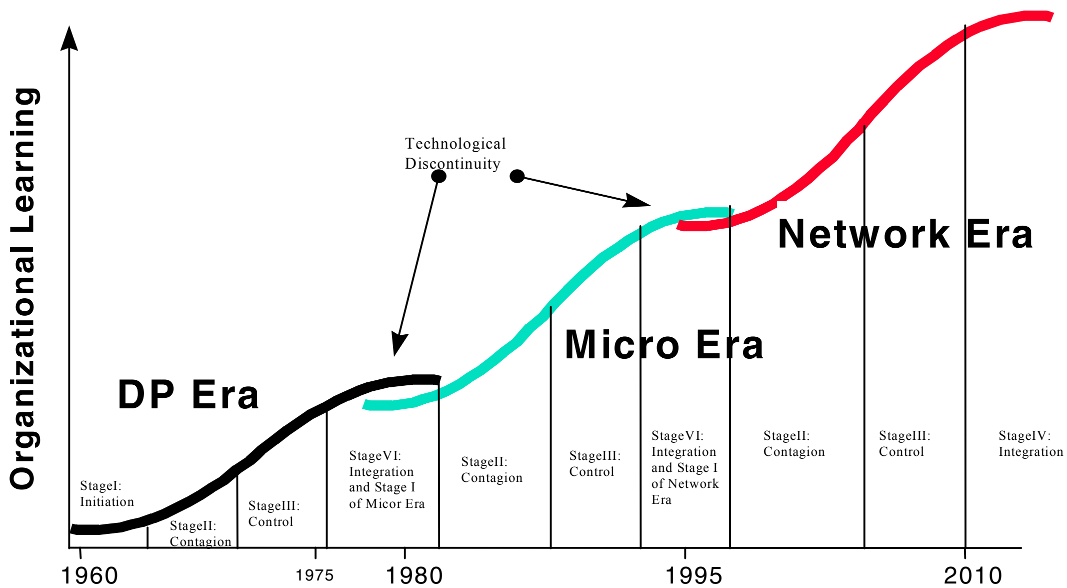
Professor Richard L. Nolan prepared this note as the basis for class discussion. This technical note was derived from a chapter written by Professor Nolan in "A Nation Transformed by Information", edited by A.Chandler, Jr, J. Cortada, Oxford University Press, 2000.

organizational learning curves, in which the three dominant designs of IT have been and are being assimilated into organizations. The Data Processing (DP) Era dated from 1960 to 1980, the Microcomputer (Micro) Era dated from 1980 to 1995, and the Network Era, which had begun around 1995, was expected to continue until 2010. History showed that each industry, and each organization within an industry, experienced a few years lead or lag in their learning of associated technologies. The senior level and IT management in each organization within an industry directly influenced the pace.[4]

Figure A The Stages Theory of Growth



Source: created by the writer

The S-shaped curves of the eras overlapped during a period of "technological discontinuity."[5] During this period in the organization further growth of the mature dominant design of the old technology directly conflicted with the vigorous growth of the emerging dominant design of the new technology. Management and IT workers who had mastered the old dominant design struggled to retain their knowledge power in the organization against those who were proposing to replace it with the new. This struggle was a familiar one in history, and one where with few exceptions the new technology won. Ironically, those who won the struggle in one round would lose it in the next. And, with the rapid growth of the IT industry, most management and IT workers faced "a diet of continual change."[6]

Relationship between Organizational Structure and IT Architecture

The dominant designs of IT related to the dominant designs of organizations.[7] The dominant form of organizational structures at the period of rapid commercialization of the digital computer during the 1960s and 1970s was the familiar multidivisional (M-form) functional hierarchy.[8] M-form corporations were centrally administered industrial groups where corporate offices administered autonomous integrated operating enterprises that produced for different markets. Each divisional operating unit (e.g. plastics, chemicals) would include a hierarchy of line (e.g. manufacturing, marketing) and staff (e.g. accounting, purchasing) functions. The first mainframe computers with their hierarchically structured database systems (e.g., IBM's IMS (Information Management System)) reflected this organizational hierarchy. The advent of the Micro Era introduced a "chicken and egg" proposition whereby lower costs enabled wide dispersal of computers in the organization, and organizations simultaneously became more networked, thereby breaking down barriers between middle management and upper management. This process continued to evolve as the networked infrastructures of the now familiar Internet and intranets linked consumers, vendors and suppliers—at times blurring the boundaries not only between various functions within a single company, but between one company and the next.

There has always been two types of customers for computers in the organization: (1) engineers and scientists (scientific computing), and managers and administrators (commercial computing). Scientists and engineers wanted computers to help them conduct product research and solve problems associated with the design and manufacture of products. Their needs generally required collaboration and intensive computation to solve mathematical problems.

Managers and administrators wanted computers to help them run their large, hierarchical organizations more efficiently. Their needs involved massive amounts of data processing of sequential files such as paying payrolls and keeping track of payments by customers. Commercial data processing had lots of input and output data, and rather simple arithmetical calculations.

In the very early history of computers (before mid-1950), scientists and engineers were the dominant customers of computers. With the decision by IBM to get into computers and its market dominance from the mid-1950s through the 1970s, dominant customers were shifted to commercial customers. However, Digital Equipment Corporation was founded to meet scientific and engineering customer needs, and grew to be the second largest computer company in the 1970s.

Table A shows the evolution of scientific and commercial computing through the eras of IT management along with key product introductions by the major industry players. One can see that overtime what started out as two streams of computing serving different customers in the organization has converged by 1995 to network computing. The highlighted boxes in the middle of the figure are key events influencing the convergence.

The Data Processing Era

By 1960, M-form large businesses with revenues ranging from $100 million to multi-billions dominated the U.S. economy. Sophisticated information and communication systems supported the management of these larger organizations. For example, essential modern accounting and budgeting systems controlled the resource allocation process necessary for these organizations to sustain steady annual revenue and earnings per share (EPS) growth.

Early information resource leadership was conceptualized within the context of the functional hierarchy of the operating divisions of a multidivisional enterprise. Early computer systems were large and had significant electromechanical components including peripheral devices for input, output and storage. As a result, organizations generally viewed technology as "machine-oriented" because these early computer systems both looked like large machines and were used like the mechanically driven business machines of the Industrial Age whose evolution is described in Chapter 4.

Table A The Two Paths of Computing

Era	Scientific Computing	Shared Technologies	Commercial Computing
The Data processing Era 1960–1979			**1953**: IBM shipped 701, its first electronic computer.
			1954: IBM's 650 quickly takes over the commercial market. It leases for $3,250 a month.
	1957: Ken Olsen and Harlan Anderson found Digital Equipment Corporation.		
		1959: IBM's 7000 series mainframes are the company's first transistorized computers.	
	1960: The precursor to the minicomputer, DEC's PDP-1 is introduced.		**1960**: A team drawn from several computer manufacturers and the Pentagon develop COBOL, Common Business Oriented Language.
	1965: DEC introduces the PDP-5, the fifth model in its line of minicomputers.		
		1963: Finalization of the ASCII code (American Standard Code for Information Interchange) permits machines from different manufacturers to exchange data.	
			1964: IBM announces System/360 a family of six mutually compatible computers and 40 peripherals that could work together.
	1965: DEC introduces the PDP-8, the first major, mass-produced minicomputer; It is sold for $18,000.		
	1969: Data General introduces its minicomputer, the NOVA.		
	1969: AT&T Bell Laboratories programmers Kenneth Thompson and Dennis Ritchie develop the UNIX operating system on a spare DEC minicomputer.		
		1969: ARPANET, the precursor to the Internet, is started.	
			1970: Amdahl Corporation founded to produce clones to IBM's 370.
	1972: HP branches into business computing with the HP 3000 minicomputer.		
	1973: Robert Metcalfe devises the Ethernet method of network connection at the Xerox Palo Alto Research Center.		
	1974: University of California at Berkeley obtain a UNIX tape. The system is soon running on several PDP-11s. Bill Joy arrives at UC Berkeley and begins working on UNIX.		
	1974: Researchers at the Xerox Palo Alto Research Center design the Alto--the first workstation with a built-in mouse for input. It is used for local networks and is not commercialized.		**1974**: The Altair personal computer kit is introduced. It is built by hobbyists for hobbyists
			1975: Amdahl installs its first mainframe produced by Fujitsu in Japan.
			1975: Bill Gates and Paul Allen found Microsoft.
		1975: Telnet, the first commercial packet-switching network and civilian equivalent of ARPANET, is born.	

	1977: DEC introduces a new product line, the VAX 11/780, to compete with the larger IBM 3031 and 3032. This enhanced minicomputer quickly makes impressive inroads in the low end of IBM's mainframe markets.	**1977**: Radio Shack (Tandy), Commodore and Apple introduce microcomputers. The Apple II becomes an instant success.
	1977: TCP/IP is being used by other networks to link to ARPANET.	
	1979: 3Com Corp. is incorporated by Robert Metcalfe	
	1979: DEC, Intel and Xerox joined to establish the Ethernet as a standard, with DEC using it for the VAX.	
The Microcomputer Era 1980 – 1994	**1980**: RISC (Reduced Instruction Set Computer) architecture is introduced by John Cocke of IBM. It greatly boosted computer speed by using simplified machine instructions for frequently used functions.	**1980**: CompuServe, financed by H&R Block, begins aggressively to develop online technology.
	1980: ARPA throws its support behind Berkeley UNIX as a common system the agency could recommend for all its clients. It also adopts the TCP/IP protocol.	
	1981: Apollo Computer unveils the first workstation, its DN100, offering more power than some minicomputers at a fraction of the price.	**1981**: IBM introduces its PC, making possible a computer on every desktop. The new PC includes MS-DOS (Microsoft Disk Operating System) and the Intel 8-bit chip. Its open-standards allow a flood of new PC-clones. It reveals a multi-billion dollar market.
	1981: 3Com makes and ships its first transceivers.	
	1982: Sun Microsystems is founded by Andreas Bechtolsheim, Bill Joy, Vinod Kholsa, and Scott McNealy. By May of this year, it introduces its workstation combining UNIX, a Motorola chip and the Ethernet, making Sun the industry leader.	**1982**: Mitch Kapor develops the spreadsheet program Lotus 1-2-3, greatly stimulating sales of the IBM PC and its clones.
	1982: Introduces HP 9000 technical computer with 32-bit "superchip" technology -- its first "desktop mainframe" -- as powerful as room-sized computers of the 1960s	**1982**: DEC introduces three personal computers. They were incompatible with the VAX machines and not fully compatible with the IBM PC.
		1982: Compaq is founded by Rod Canion.
		1983: Ray Noorda takes over Novell and focuses on producing local area networking software (network operating systems). In October, Novell introduces its Sharenet X (eventually renamed NetWare) network operating system.
		1983: Apple introduces its Lisa. The first personal computer with a graphical user interface, its development is central in the move to such systems for personal computers.
		1983: Compaq Computer Corp. introduces the first successfully commercialized IBM-PC clone.
	1984: Cisco is founded.	
	1984: DEC introduces the VAXstation I, the company's first 32-bit single-user workstation.	**1984**: IBM, Sears and CBS form Prodigy. Originally called Trintex, the venture is conceived as a home banking and shopping service.
	1984: MIPS Computer Systems, Inc., is founded in order to market the RISC chip it has developed.	**1984**: Michael Dell begins his computer business which is based on his innovative marketing techniques.
		1984: Microsoft enters the LAN networking software arena with its MS-NET product.

1985: The modern Internet gains support when the National Science foundation formed the NSFNET, linking five supercomputer centers at Princeton University, Pittsburgh, University of California at San Diego, University of Illinois at Urbana-Champaign, and Cornell University.

1985: IBM devises token-ring technology to control LAN traffic (between printers, workstations and servers) more effectively.

1985: Microsoft announces the retail shipment of Microsoft Windows, an operating system, which extends the features of the DOS operating system.

1986: Cisco ships its first product, the AGS router.

1986: IBM with MIPS release the first RISC-based workstations, the PC/RT and R2000-based systems. They are a commercial failure.

1986: HP introduces broad new family of computer systems based on the RISC architecture.

1987: Sun launches "The network is the computer" campaign. It also introduces a workstation with a RISC chip called SPARC.

1987: The National Science Foundation (NSF) begins to manage the backbone of the Net (taking over from the government).

1988: Microsoft and Ashton-Tate announce the Microsoft SQL Server, a relational database server software product for LANs.

1988: IBM introduces the AS/400, a mid-range system.

1989: Sun's new SPARCstation 1 has more power and functionality than any other desktop computer in the world: 12.5 mips, RISC-based, and less than $9,000.

1989: America Online (AOL) is formed.

1989: Novell introduces a "multithread" SMP system that works with major operating systems, including IBM's OS/2, UNIX, and Apple's Macintosh, to run different tasks or applications simultaneously.

1990: IBM introduces the RS/6000, its first successful exploitation of the RISC technology.

1990: The World Wide Web is born when Tim Berners-Lee, a researcher at CERN, the high-energy physics laboratory in Geneva, develops HyperText Markup Language.

1990/1991: Programmers at the University of Minnesota create Gopher which allows students and faculty to query campus computers for information.

1991: DEC moves into to the production of mainframes with the VAX 9000.

1991: Apple and IBM join forces with Motorola to produce a RISC microprocessor called PowerPC, which they hope will topple the Intel 8086 family. It becomes the processor for Apple's Macintosh computers.

1993: Microsoft formally launches Microsoft Windows NT.

1993: Early versions of the Mosaic web browser written by Marc Andreesen and Eric Bina (written at the University of Illinois) are available over the Internet. It is first written for UNIX, with versions for the MAC and PC platforms following.

1994: Andreesen's Netscape introduces its version of the browser.

		1995: The NSF backbone becomes commercially supported and business by the thousands begin active work to move their IT architectures to the new network architecture. **1995**: Sun introduces Java, the first universal software designed from the ground up for Internet and corporate intranet developers to write applications that run on any computer, regardless of the processor or operating system.	

Sources: 3Com's Timeline of Successful Innovation (http://www.3com.com/inside/investor/timeline.html); Amdahl Corporate History (http://www.amdahl.com/about/timeline.htm); Cisco Systems Corporate Timeline (http://www.cisco.com/warp/public/750/minor_invest6.pdf); The Computer Museum timeline (http://www.tcm.org/html/history/timeline/);Data General (http://www.dg.com/about/html/generations.html); Dell Computer Corporation Corporate History (http://www.dell.com/corporate/access/dellstory/index.htm); Digital Equipment Corporation Corporate History (http://www.digital.com/timeline/); Hewlett-Packard Corporate History (http://www.hp.com/abouthp/history.html); IBM Corporate History (http://www.ibm.com/IBM/history/timeline.nsf/); Microsoft Corporate History (http://library.microsoft.com/mshist/1985.htm); MIPS Corporate Overview (http://www.mips.com/whoWeAre/index.html); Anonymous, "IBM PC XT Local-Network Scheme," *Byte* (October 1983): 593; Paul E. Ceruzzi, *A History of Modern Computing* (Cambridge, MA: The MIT Press, 1998); Sun Microsystems Corporate History (http://www.sun.com/corporateoverview/who/html_history.html); Alfred D. Chandler, "The Computer Industry: The First Half-Century," in David B. Yoffie (ed.) *Competing in the age of digital convergence* (Boston, MA: Harvard Business School Press, 1997): 37-122; Kenneth Flamm, *Creating the Computer: Government, Industry, and High Technology* (Washington, DC: The Brookings Institution, 1998); Matt Kramer, "MS-Net paves the wave for LAN applications," *PC Week* (November 13, 1984): 1. Bruce Sterling, "Short History of the Internet," *Fantasy and Science Fiction* (February 1993).

In 1952, John Diebold coined the term "automation"[9] as it applied to computer technology. This new computer technology "based on a mathematical formulation of a basic theory of communication and control, made possible the construction of self-regulating and self-programming machines." These new machines could automatically perform a sequence of logical operations, correct errors that occurred in the course of their own operation, and choose according to built-in criteria between several predetermined plans of action. Significantly, automation allowed such advances as a single machine being used for more than one process by the simple switching of a magnetic taped program. Each taped program contained a different series of instructions that the machine would follow allowing for slightly different products to be produced—the innovation of the stored program. The end result was not only fewer personnel, but fewer machines required to do the multiple tasks in organizations. A year later, Diebold published an article in the *Harvard Business Review*, which widely publicized this concept of the computer to managers.[10]

Early Scientific Computing Influenced Commercial Computing

The first applications of computers were in the scientific domain for national defense purposes, where they have a robust history of their own.[11] Scientific and engineering departments in large organizations such as Boeing had a long history of computer use, and in the 1960s used both analogue as well as digital computers for simulation and calculations.[12] During the 1960s it even looked like hybrid computers, which integrated both analog and digital computer components (by interconnection of digital to analog converters and analog to digital converters), might evolve into a major type of technology in scientific computing.[13] Hybrid computers combined the advantages of a digital computer's data storage, time sharing and logic capabilities with an analog computer's speed, lower cost, and easier programming.[14] However the more complex hybrid computers died out with the arrival of the IBM 360 computer series in the mid-1960s, which bridged scientific computing and commercial computing.[15]

IBM's introduction of the 360 computer series in 1964,[16] spurred the major growth in commercial computing, which had begun to emerge in the mid-to-late 1950s and early 1960s. IBM became the primary supplier of IT and the DP manager became the major buyer—a common adage among these managers in that era was "you never get fired for buying IBM." Although IBM dominated the market during the 1970s with an average market share of 68%,[17] serving geographically dispersed operating units with centralized computing was expensive and provided the market environment for new entrants. Digital Equipment Corporation (DEC) innovated the minicomputer and became the second largest computer company in the 1970s by successfully concentrating on serving the engineering-oriented factory and laboratory markets.

Minicomputers were medium-scale computers, which functioned as multi-user systems for up to several hundred users. The minicomputer industry was launched in 1960 after Digital introduced its PDP-1. However it wasn't until Digital's introduction of the PDP-5 in 1963 and the PDP-8 in 1965, that minicomputers entered the market in strength. Following Digital's successful launch, Hewlett-Packard, Data General, Wang, Tandem, Datapoint and Prime all introduced similar successful systems.

It was while working on a spare DEC minicomputer, that AT&T Bell Laboratories programmers Kenneth Thompson and Dennis Ritchie developed UNIX.[18] UNIX was not a complete operating system. Rather, it was a set of basic tools that allowed users to manipulate files in a simple and straightforward manner. One of the major benefits of UNIX was that although it was developed on DEC computers, UNIX could run on any machine that had a C compiler. This was one of the first steps towards open standards and contrasted sharply with the traditional computer vendor's strategy of keeping its code secret. In version 4.2 of Berkeley UNIX (named as such because Bill Joy refined UNIX while at Berkeley before becoming one of the founders of Sun Microsystems), support for the networking protocol TCP/IP[19] was added. As Paul Ceruzzi noted, "this protocol, and its bundling with Berkeley UNIX, forever linked UNIX and the Internet."[20]

Another important development in the initial stages of networking also occurred during the DP Era. In 1973 Robert Metcalfe devised the Ethernet method of network connection at the Xerox Palo Alto Research Center, Based on Hawaii's ALOHAnet, the Ethernet used cheap coaxial cable that allowed computers to send and listen for radio signals. These signals would then be gathered back together and delivered to the appropriate computer. The Ethernet, with its speed of three million bits per second, was unheard of at the time. As Ceruzzi noted, "Those speeds fundamentally altered the relationship between small and large computers. Clusters of small computers now, finally, provided an alternative to the classic model of a large central system that was time-shared and accessed through dumb terminals.[21]

Ethernet's first big success came in 1979 when Digital, Intel and Xerox joined to establish it as a standard, with Digital using it for its VAX.

First Commercial Applications in Vertically Integrated Hierarchies

Responsibility for these early computers was grafted onto the functional organization within the M-form enterprise, and there remained a sharp distinction between commercial computing and scientific computing. Commercial computing was usually grafted onto the accounting function, and scientific computing (if it existed in the firm) was grafted onto the engineering or research function. The information resource manager in the firm typically used the title of EDP (electronic data processing) or DP (data processing) manager.

The DP manager—often referred to as a "benevolent dictator"—became a relatively powerful manager of a centralized function because command and control were central to the management of multi-product functional hierarchies during the DP era.[22] The mantra for these managers during the DP Era was "manage DP as a business within a business."[23] General managers of single product companies and of divisions in multi-product companies viewed the computer as a technology that supported an established way of doing business. These general managers charged DP managers to support the business, and apply the tenets of how the organization traditionally managed its business to managing the computers—not to use computers to innovate in new ways of running businesses.

A major source of competitive viability was the large-scale, efficient factory—regardless of whether that factory was a traditional car manufacturing plant, or a paper-processing factory of an insurance company or bank. Vertically integrated corporations facilitated control by owning suppliers to ensure sources of supplies (e.g., car manufacturers owning steel mills), or owning distribution channels to ensure customers would continue to buy at the rate of production (e.g., oil companies owning gas stations).

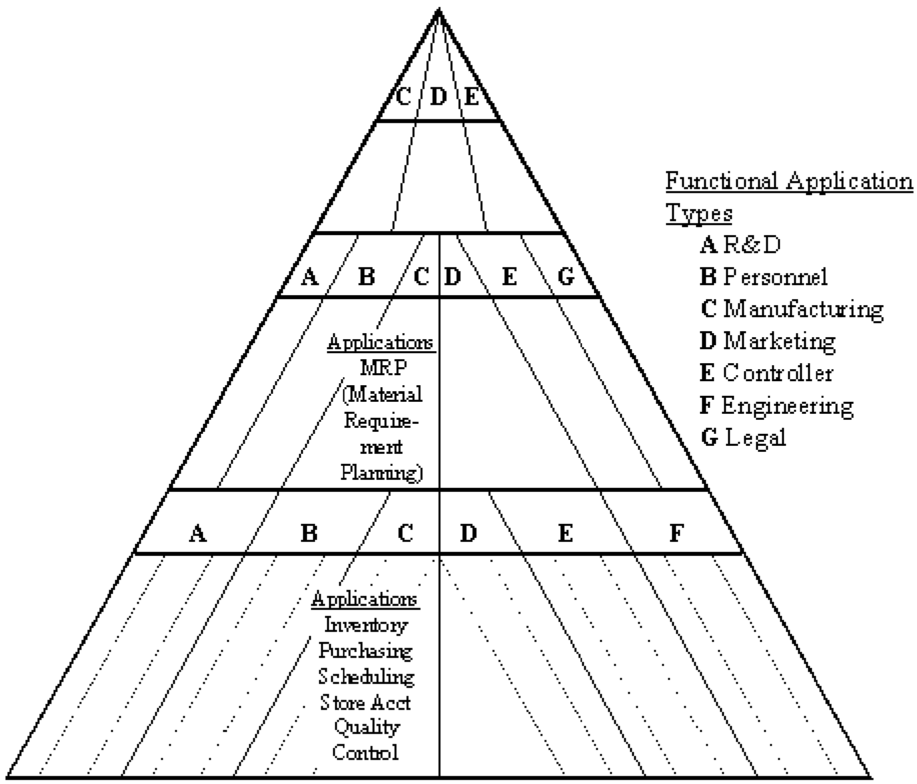
As a result, the first commercial applications generally included accounting, and automated tasks such as payroll processing and general ledger. As Cortada explained in Chapter 6 these applications were often coded in low level assembler programming languages, although Cobol, a higher level language, rapidly became the preferred programming language for commercial applications during the 1960s. Remarkably, in the late 1990s, Cobol remained the most-used language in software and development.[24]

Figure B shows a typical graphic illustrating an applications portfolio for a functionally organized manufacturing company or a product division of a multidivisional company. The familiar pyramid icon is divided into three hierarchical levels. Within each level, there are functional application groupings such as manufacturing and accounting. Finally, within each functional application at each level, there are individual applications representing opportunities for use of the computer.

The applications portfolio evolved by first automating low level operational support tasks within a function such as inventory control, shop floor control, and scheduling in manufacturing; or plant, cost, and general accounting in controller. After sufficient automation of low level operational support tasks within a function, the organization integrated automated tasks within a functional department (i.e. R&D or Engineering) by automating management control activities such as production operations management, accounting management, and human resources management. More difficult cross-functional automation to support management control activities within the firm laid the groundwork for the third and most difficult level of automation. At this level, automation supported strategic five year plans though the integration of department profit plans, and corporate-wide human resource planning. Throughout this process, the organization moved up the S-shaped curve as it learned more and more about how to apply IT and tap into its potential.

As illustrated in **Figure B**, given a computer technology and its associated economics, parts of the business functions or processes could not feasibly be automated at any point in time. Research conducted by Nolan, Norton & Co. during the 1980s determined that approximately 50% of all operational support functions and 47% of management control functions could be automated within an organization. Because of an overall lack of structure, the higher level strategic planning functions were more difficult to automate than either operational support or management control functions. Nevertheless continued improvements in the technology, increased the overall number of business functions that could be automated.

Figure B Applications Portfolio of a Functionally Organized Manufacturing Company



Source: *A Nation Transformed by Information*, Oxford University Press, 2000

Corporate-level Financial and Management Accounting

While the product divisions of multidivisional organizations focused on automating tasks from the ground up, the corporate offices focused on tying their divisions together. Indeed, accounting applications of the computer contributed to efficiently managing the complexity of M-form, command and control organizations. In this structure, two main types of accounting control tools played major roles: annual budgeting and capital budgeting. The first controlled expenditures aimed at generating revenue during the calendar year; and the second controlled expenditures that generated multiple year revenues.

Annual budgeting The annual budgeting process for the large M-form hierarchical organization usually based itself upon an incremental growth model of 10% to 15% growth per year. Once the company became large, the planning process intended to maintain consistent year-to-year incremental growth in revenue and profit. The line-item general ledger and the codified hierarchical organization chart formed the foundation of the accounting model. The line item general ledger typically consisted of thousands of objects of expenditures. The organizational chart typically consisted of hundreds of boxes, each associated with a similar group of general ledger accounts. For example, most of the boxes on the organization chart included types of overhead expenses such as paper and office equipment. Before the computer, summarized profit-center accounting was done at a high-level and infrequently during the year. After the computer, which largely enabled the process, complex divisional and profit-center accountability evolved.

Accountants categorized the assets and equities of the firm into general ledger accounts and then structured these accounts into a Balance Sheet, which defined the financial position of a company at a point in time. Another set of accounts referred to as "temporary" accounts recorded the inflows (revenue) and outflows (expenditures) of assets intended to generate annual profit. At the end of the year accountants closed out the revenue and expense accounts to their respective General Ledger permanent asset and equity accounts, resulting in a Profit and Loss (P&L) Statement, and a new end-of-the-year Balance Sheet. Comparing the beginning Balance Sheet with the ending Balance Sheet determined the profit or loss for the company's operations during the year.

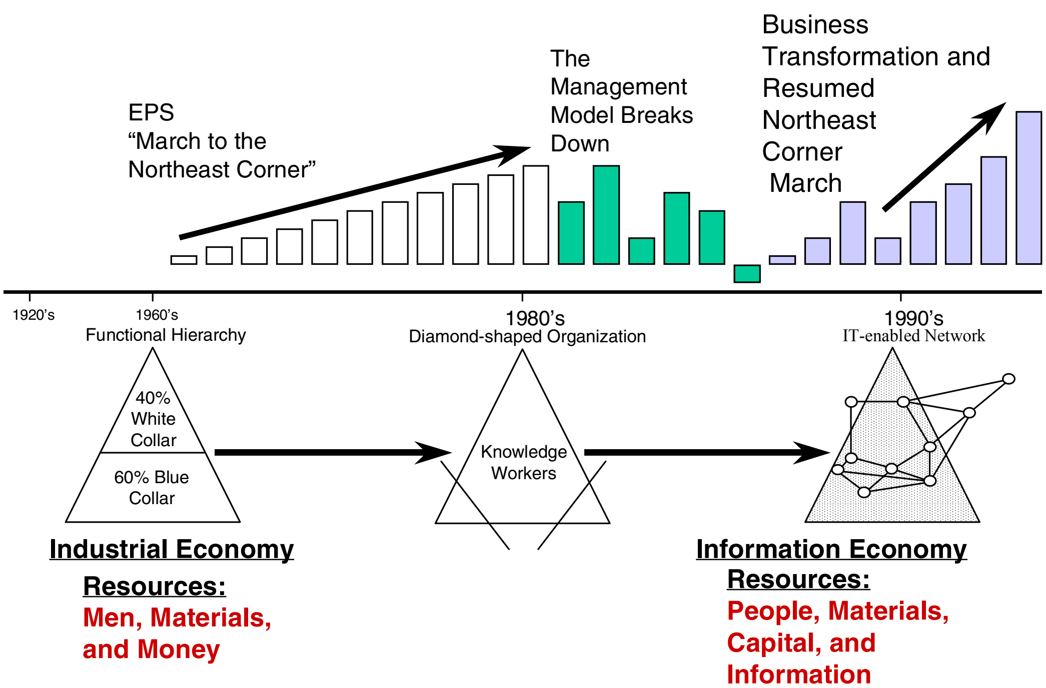
IT, first in the form of electromechanical data processing devices, and later in the form of computers, enabled this very powerful accounting process to be driven down to the divisional "lines of business" of the organization for decentralized P&L accountability, as well as accountability for Return on Investment (ROI). By assigning each box on the hierarchical organization chart a number code, the annual budgeting process could be conducted at very low levels in the organization. The boxes could be assigned a group of expense accounts and revenue accounts, and, for each box, revenues and expenses could be budgeted for activities during the calendar year. Then at any level of the organization chart, the planned revenues and expenses could be summarized and compared with the actual revenues and expenses at a point in time. Further, managers of the departments, lines of business, regions, and other such combinations could be assigned budget responsibility, budget performance could be summarized by the computer, and managers rewarded or penalized for financial performance. During the electromechanical period, most large firms struggled to conduct the annual budgeting process and the closing of the books efficiently. However, the computer made it easy to do the process monthly or weekly, and in some financial institutions (e.g., Morgan Stanley) in the 1990s the "closing of the book" was done around the world on a daily basis—almost in real time. With efficiently managed computers, organizations routinely produced multitudes of P&L statements by levels in the organization, regions, and even to the detailed level of individual customer profitability.

Capital budgeting The capital budgeting process was as important as the annual budgeting process in enabling the M-form company to achieve consistent financial performance. The capital budgeting process was a methodology for analyzing the financial returns and risks of capital expenditures that spanned multiple annual accounting periods, such as construction of a new building or acquiring a new machine. Organizations used this methodology to work out the inflows and outflows of cash for the life of an expected multi-year expenditure. Then managers applied a variable discount factor that would discount the net value of the flows to the present to equal zero. The discount factor that did this was equal to the expected ROI. Companies used various "hurdle rate"[25] discount factors (typically 15% to 20%) to account for risk and to screen potential investments to ensure that they used their scarce capital resources most effectively.

While organizations found the computations for capital budgeting during the electromechanical period long, tedious, and expensive, the computer made these computations trivial, and by the 1990s virtually all companies routinely used sophisticated capital budgeting techniques at almost zero cost.[26] Firms extended command and control accountability from divisional P&L responsibility to divisional ROI responsibility. In many ways, just as farmers and engineers of the Industrial Age applied steam engine technology to mechanize the farm, and make the farm more efficient, engineers and computer programmers applied computer technology to the traditional command and control, M-form functional hierarchy to make it more efficient.

This sophisticated use of accounting in the M-form hierarchy enabled managers to control complex operations and to support their goal of consistently increasing revenues and earnings per share (EPS). As a result, shareholders regularly saw annual bar charts in the first or second pages of company annual reports showing unbroken 10% to 15% growth rates in revenues or EPS for long periods of 10 years to 15 years. People termed this phenomenon the "march to the northeast corner," because the sequence of bars for each year seemed to march to the upper right corner of the graph. The "march to the northeast corner," is illustrated in **Figure C**.

Figure C Business Transformation Summary



Source: *A Nation Transformed by Information*, Oxford University Press, 2000

IBM and AT&T, two companies considered to be widely successful in the 1970s had 13.2% and 11.6% compound annual growth rate for the 1970s.[27] EPS growth, which was also reflected by the "march to the northeast corner," generally represented the increasing return that an investor realized from investing in the stock. In the case of IBM and AT&T, the average EPS rates for the 1970s were $1.70 per year and $5.65 per year.[28]

Figure C also illustrates that the DP Era and the "march to the Northeast corner" corresponded with a period when organizations did not usually challenge the M-form functional hierarchy and the Industrial Age management model of managers managing scarce resources of "men, materials, and money." However, as the computer penetrated deeper and deeper into organizations, learning transpired to the point that organizations understood the role of the computer to be much broader than its use to support the efficient transaction processing in organizations. Many manual and clerical functions were totally automated eliminating the need for blue collar and clerical human resources. As illustrated in **Figure C**, layoffs and downsizing began to mutate the symmetrical pyramid organization structure. This major mutation of the functional organization challenged management in many ways, and often led to disruption in the "march to the northeast corner."

Batch processing on standalone mainframe computers was extended through communication lines to input devices such as punched card readers. Then card readers were refined to permit direct keyboard input to computers through the use of "dumb terminals".[29] The next refinement was the timesharing of a mainframe computer by a number of users. The mainframe computer could carry out computations so much faster relative to the manual typing of input characters of a user, the illusion was that the users had the exclusive use of a computer.

After the initial automation, management began to realize that computers could be networked together permitting a greater sharing of the data that were contained in the various computers used by the company. As a result, the ability of workers to rapidly obtain and manipulate figures, previously available to only select individuals in the firm, increased the knowledge of the firm as a whole and further blurred the lines between the various levels of management. Businesses transformed themselves, and with the help of their new information resource, namely the microcomputer, many businesses began their "march to the northeast corner" once again.

Transition to the Micro Era

By 1980, just before the IBM PC and its clones began to transform the industry, most of the administrative functional tasks of the organization had been automated. The minicomputer had also largely completed its automation of factory tasks such as bill of materials, inventory control, and production scheduling. Databases emerged as an important technology for managing the data used in integrated applications, and data administration also evolved to identify the activities necessary for rudimentary information resource management.

In October 1981, IBM introduced its personal computer and industry pundits began to predict that soon everyone in a business would be able to have a "mainframe" on their desktop.[30] In order to expediently develop its radically new and different product, IBM had to turn from its policy used in the production of its existing mainframes and minicomputers of developing and manufacturing all the necessary components. It set up a standalone microcomputer business, and gave the management team freedom to go outside to Intel to develop the CPU, to Microsoft to develop the operating system, to Tandun to develop the internal disk storage unit, to Matsushita to develop the monitor, and to Epson to develop the printer.[31] IBM units made the board assembler and keyboards. In addition, in order to market its mass-produced consumer product, IBM began to sell its first PC through Sears Roebuck's new business machine stores and through Computerland.[32]

IBM's introduction of its PC profoundly transformed the computer industry in five years. The result was a new horizontally integrated IT industry with many competitors in each tier, great levels of innovation and severe price competition. Within two years, Compaq (which had been founded in 1982) introduced the first commercially successful PC clone and others soon followed.

Novell, which was taken over by Ray Noorda in 1983, was quick to realize that companies would need help and software, in the form of local area networks (LANs) and network operating systems (NOSs), permit a number of personal computers within an office or business unit to share the same peripheral devices such as printers and disk drives. In October 1983 it introduced its Sharenet X (later renamed NetWare) which allowed as many as 255 IBM PC XTs to share up to 320 megabytes of storage.[33] In response to Novell's success other corporations also entered the LAN market. 3Com Corporation, formed in 1979 by Robert Metcalfe, the inventor of the Ethernet, began to compete in

1981 using Metcalfe's new technology. 3Com became one of Novell's major competitors. In 1984, Microsoft entered the market when it introduced its MS-NET. The server portion of MS-NET ran general file servers and controlled the use of printers, plotters and other shared network resources.[34] However, both IBM and Microsoft had little success in challenging the two pioneers until the appearance of Microsoft's Windows NT in 1993.[35]

While PCs were proliferating among the general corporation in the commercial market, many computer makers were developing a microprocessor-based product, the workstation, for their scientific and engineering markets. From the start, as workstations were networked systems by which high-powered "servers" stored and transmitted information to "client" desktop computers within a department corporation or other operating unit. Workstations were typically powered by RISC-based[36] microprocessors, ran on UNIX operating systems and were often linked together using Ethernet technology.[37]

The workstation industry got its start when William Poduska and much of the top management left the minicomputer maker Prime Computer to start Apollo in 1981.[38] That year, Apollo unveiled the industry's first workstation, its DN100. Once again, others soon followed and Sun Microsystems, which was incorporated at the beginning of 1982, became the industry's technological innovator. Sun was founded by four 27 year-olds, three Stanford graduates and Bill Joy, Berkeley's UNIX expert. It became the industry's progenitor by connecting a Motorola chip to Joy's version 4.2 of Berkeley UNIX and the TCP/IP protocol.

In 1984, a group of Stanford students, who had been further refining the RISC chip (initially introduced by Joe Cocke of IBM in 1980), formed MIPS Computer Systems to market their product.[39] In 1986 Hewlett-Packard and IBM both introduced MIPS developed RISC chip-based lines. Hewlett-Packard's was a great success, while IBM's was a failure. The next workstation was Sun's powerful SPARC system, introduced in 1987. In 1989, DEC made its shift to the RISC microprocessor, while in 1990 IBM began to market its RS/6000 computer.[40]

PC Adoption in Firms in the Commercial Market

Although the workstation client-server technology came to play a central role in the development of corporate, university and institutional intranets, and their connection to the larger Internet, the scientific engineering market was much smaller in terms of revenue than the commercial markets. During the early years of the Micro Era, the PC dominated. However, like many new technologies, not all employees readily adapted the PC. Moreover, the switch from the mainframe to the microcomputer did not occur overnight. Many DP managers felt (rightly) that PCs threatened their positions; similar to Yates' discussion on the impact that the decentralization of vertical files had on the approach of filing managers, microcomputers directly challenged the conventional centralized management approach of IT activity. DP managers feared PCs threatened their effective control of the computer in the organization. First, because PCs cost relatively little (IBM suggested that the typical system used for business—including color graphics and a printer—would cost about $4,500),[41] many departments in the business had the budgetary authority to purchase them directly. Second, the proliferation of many computers throughout the company resulted in the replication of accounting and reporting functions carried out on large mainframe computers threatening a loss of data integrity control. Further, the organization lost a great deal of time in confusing arguments about whose numbers were the "right" ones. Finally, wide dispersion of desktop microcomputers presented a real risk of breakdowns in maintaining the security of corporate data, and computer applications.

Control efforts by DP managers tended to constrain the movement of computers into the organization as well as how they would be used, to the point that PCs went underground. Users began dealing directly with PC vendors and introducing PCs into the various parts of the organization either without the knowledge or in direct defiance of the DP manager. Vendors specialized in selling to the end user of microcomputers who used the machines for word processing, graphics (desktop publishing), and computer aided design (CAD). The success of their tactics were such that penetration of PCs in the organization became ubiquitous. The end result was an organization for IT that was fragmented; centralized mainframes and minicomputers coexisted with multiple pockets of decentralized user-managed PCs.

In order to get their information systems back under control, senior management of organizations realized that more emphasis had to be put on the importance of IT. During the Micro Era, Bill Synnott, then VP of Information Systems at Bank of Boston (now BankBoston), coined the term CIO, which stood for Chief Information Officer. The term, which Synnott defined as the "senior executive responsible for establishing corporate information policy, standards, and management control over all corporate information resources,"[42] was intended to reflect the expanded role of IT leadership, and focus on "information" as the key resource to be managed.

Once DP managers had accepted the ubiquitous nature of PCs within organizations, the use of PCs set off new levels of organizational learning and experimentation. Industrial Age organizational structures and management principles were challenged in part because command and control was so institutionalized in the management of the M-form functional hierarchy that it was difficult to move beyond to risk management and flexible response—skills required for effective competition in the Information Age. The Total Quality Movement (TQM) demonstrated that the sharing of information among workers led to higher efficiency and fewer product defects. The realization that with computers a company could accomplish the same amount of work with significantly fewer workers led to downsizing. As shown in **Figure C**, by the mid-1980s organizations were beginning to treat information as a resource, hierarchical structures were undergoing creative destruction, knowledge workers were emerging, and the hoped for consistency of the "march to the Northeast corner" was breaking down.[43]

As a result of these technological changes, organizational learning reached a level in which it viewed the computer as more than a machine to automate low-level tasks within a function. It viewed the computer as a technology that could make managers and workers more productive. Shoshana Zuboff conducted a seminal study during this period and introduced the term informate (instead of automate) as a more appropriate term to describe the potential of computers in the firm.[44] The idea was not to simply replace workers with computers, but to leverage workers with computers. Through time, the idea formed into thinking about workers as "case workers" where the computer facilitated work.[45]

The Beginnings of the Internet

While organizations utilized and learned about mainframes, minicomputers and eventually microcomputers, the defense department and universities quietly developed another technology. In 1969, ARPANET,[46] the precursor to the Internet, started.[47] As part of the ARPANET project, in 1971 computer scientists linked four university supercomputers enabling scientists to share information with one another. Throughout the 1970s, the Internet continued to evolve as new languages and technical enhancements emerged. By 1984, the term Internet started to emerge, although few outside the community of scientists, educational institutions, the military and computer hobbyists knew of its existence. Andrew Zimmerman, chairman of the Telecom & Media industry group at Coopers & Lybrand, writing in 1997 noted that

> this procedural change—this great renaming—marked an evolutionary turning point: one from a straight back-and-forth communications network to a new form of media, one with content and context and seemingly unlimited possibilities. Expanded addressing technology enabled thousands of "broadcasters" to take to the Net. The Net began to resemble a complex and highly adaptive life form, with a personality composed of many different interests and motivations. With each advance in technology and each new use that was found for the Net, the whole of the thing adapted and grew.[48]

Throughout the late 1980s and early 1990s a series of events laid the foundation for the now familiar Internet: in 1987, the National Science Foundation (NSF) began to manage the backbone of the Net; in 1990 the World Wide Web was introduced as a system in which vast amounts of information could be linked; in 1991, scientists introduced hypertext markup language (HTML) which made it possible to switch relatively rapidly among all the files and directories of the Internet. And in 1993, the introduction of the first widely used browser at the University of Illinois (NCSA Mosaic) made accessing the Internet both easier and faster. Individuals, organizations and governments began to build web sites offering information, files and programs that could be downloaded. Zimmerman noted that "the Web was growing at 340% annually. The number of host computers on the Internet rose from 80,000 in 1989 to 1.3 million in 1993 to 2.2 million in 1994." This number continued to soar. A survey by Bellcore indicated 14.7 million host computers in September of 1996 and 26 million in September of 1997.[49]

Transition to the Network Era

The uncoordinated management of the exploding PCs by user groups in the organization rapidly led to inefficiencies and costly situations leading senior management to intervene and trigger searches for better solutions. The natural and obvious solution integrated centralized mainframe/minicomputer applications and databases with decentralized PCs. Unfortunately, the way that mainframe/minicomputer applications had evolved over time, along with the explosion of PCs and their myriad of software approaches and vendors, made the integration easier said than done. Nevertheless, client/server concepts and implementation, which had begun to appear in the Micro Era, emerged in full force as the new dominant design in which the client was designed for direct user access to computing (similar to the PC), and the server provided direct access to databases and other facilities required by the user. Thus, the notion of network centric computing evolved and was embraced by the IT industry.

Makers of workstations such as Sun Microsystems,[50] Hewlett-Packard, IBM, Digital and Microsoft (with its Windows NT) provided specialized server capabilities to thousands of workers in companies who were hooked up to networks of hundreds of thousands of computers. The complexity of interconnected networks reached a point that necessitated simplification and led to renewed interest in "open standards." The Internet had proven itself as a reliable network of thousands of interconnected computers, and its IT architecture (UNIX, HTML) and protocols (TCP/IP) were quickly seized upon as internal client/server standards for companies. The term "intranet" emerged to describe the adoption of Internet architecture standards for internal networks. Once intranets were developed inside companies, it was an easy step to hook them directly to the outside by hooking into the worldwide Internet. These intranets hooked to the Internet vastly increased the capability of companies to communicate with outside suppliers, customers, and even competitors.

Internet Phenomenon

A number of authors have reflected on the nature of the Internet, and its attributes of self-management and the role of open standards versus a "control-oriented" development philosophy.[51] In a similar manner, the development of intranets required more coordination and promulgation of open standards than traditional use of controls and fixed long range plans. Organizations also maintained focus by rationalizing key IT decisions that were based on delivering value to customers.

The CIO now faced an environment of building an IT architecture that consisted of many partners, strategic alliances and outsourcers. It was a very different environment than that of the 1960s and 1970s in which the IS manager could get most of their products and services from one or two vendors. In the Network Era, there was a constantly changing, large number of vendors that the CIO had to manage.

By 1998, Information Age companies in the IT industry had become exemplars for companies in other industries. Fourteen-year old Cisco, had become the fastest company ever to reach a market value exceeding $100 billion.[52] All of its manufacturing of the physical routers was outsourced to strategic partners, and coordinated through its computer network: its intranet. Cisco's gross margins, which exceeded 70%, were primarily the result of building and selling intangible knowledge assets.[53]

Cisco, and Information Age companies like it, had adopted open Internet standards (TCP/IP and HTML), which provided workers access to the company's databases. Companies like Cisco realized internal efficiencies by making their benefits information directly accessible to their employees through client computers and the use of web browsers (i.e., Netscape's Navigator and Microsoft's Internet Explorer). Sometimes leading and sometimes following, a company integrated its external web site with its internal intranet which enabled its customers to "self-serve" themselves through their own computers within their organizations. In 1998, 70% of Cisco's $800 million of service revenue was provided over the Internet by connecting customers to their intranet. In addition, more than 50% of Cisco's product revenue of $8 billion was shipped over the Internet directly to customers.[54] The cost advantage as well as the robust customer service enabled by IT, set a new competitive standard in Cisco's industry. Similar IT leveraging of networks began in other industries as well, and likewise established new competitive standards.

The Internet demonstrated that a network architecture was scaleable to the point that large organizations could operate their thousands of PCs in a robust network environment (TCP/IP) and transfer information among the networked computers in an efficient and timely manner. In response, when the NSF backbone became commercially supported in 1995, businesses by the thousands began active work on moving their IT architectures to the new network architecture, which proved that e-mail and multimedia documents could be easily sent around the world over the existing telecommunications infrastructure. In 1995 the *Economist* suggested that "the Internet will almost certainly have a stronger impact than the PC … a reasonable guess might put it ahead of the telephone and television but behind the printing press."[55] At the end of 1995, there were approximately 90,000 sites on the web, about half of which were commercial.[56] As of July 1998, approximately 36.7 million sites (every online host and individual machine connected to the Internet) existed on the web, about one third of which were commercial.[57]

Gilder proposed "Metcalfe's[58] law of the telecosm"; Metcalfe's law of the telecosm is based on the idea that interconnecting n number of computers results in a potential value of n squared.[59] For example, the network of roads for n number of cars results in a potential value of n squared. The idea applies to telephones, fax machines, and computers. The explosion of the Internet in business can be attributed to its potential value as projected by Metcalfe's law of the telecosm. The Internet is the fastest technology ever to achieve 50 million connected users; as of July 1998, approximately 130 million people used the Internet; about 70 million were in the U.S. and Canada.[60] IntelliQuest, a provider of information services to technology companies, suggests that the number of American users online has doubled between 1996 and 1998.[61]

Similar to Moore's Law,[62] Gilder ordained that: "the total bandwidth[63] of communications systems will triple every year for the next 25 years." He went on to predict that within the first decade of the 21st Century, the all-optical network would be thousands of times more cost effective than electronic networks.[64]

Not only was the bandwidth expanding, the underlying economics of computers and telecommunications had made it possible to process and transmit massive amounts of information around the world more cheaply the next year, the year after that, and so on for as long as we could foresee. Starting with the processing of binary coded alphanumeric data on the computer, and proceeding through fax, voice, graphics, and video digital coding, protocols and standards had emerged, enabling the power and declining cost of information technologies to be applied to organizational activities. The overall phenomenon became known as "digital convergence."

The fusion of computers and telecommunications led to deregulation of telecommunications in the United States and the 1984 breakup of AT&T.[65] The introduction of competition produced a deluge of new products, and created the environment for the rise of the Internet. The ultimate result was a huge, vibrant IT industry that drove the U.S economy through the 1990s and into the 2000s. In the spring of 1998, Ira Magaziner, Senior Advisor to President Clinton for Policy Development noted that "over the past three years over one third of the real growth of the economy has been accounted for by information technology industry growth and that has been primarily driven by the building out of the Internet."[66] Familiar examples included

- Wal-Mart used store level point-of-sale data to efficiently drive supplier replenishment[67]
- Amazon.com efficiently sold books over the Internet cutting out the need to physically house all the books that they sold. Amazon's average inventory holding periods of five days to six days, plus accounts payable terms of up to 180 days, reduced working capital levels.[68]
- Edmunds and Microsoft's CarPoint provided buyers with automobile dealer invoice information equalizing the power of the car dealer and the customer for more efficient car purchasing transactions.[69]

Digital convergence was playing a role in the restructuring of all industries and the IT industry enabled businesses in general to more efficiently manage information resources to the extent that new economies of organization resulted (e.g., virtual organizations, vast reductions in the use of expensive paper communications),[70] and information was incorporated into products and services to create more value for customers (e.g., automatic diagnostics and call back to repair facilities from elevators around the world greatly reduced elevator breakdowns in buildings).[71] The more that corporations reengineered the business processes to take advantage of information technologies, the greater their opportunities to improve the economics of the business and value to the customer.[72]

Challenge of System Management in the Network Era

Information resource leadership continued to evolve through the three eras of the management of the changing dominant design of IT, and through the increased influence of IT on the economics and strategy of the organization. Just as the Industrial Age IT architectures of the 1960s and 1970s mirrored the functional hierarchical organization structures, the Information Age IT architectures of the 1990s and beyond mirrored the highly organic, flexible network organization structures that emerged in the Information Age.[73]

These flexible network structures challenged all organizations in the Network Era to coordinate the thousands of computers that made up the their internal networks, as well as the tens of thousands of computers with which the organizations communicated through the various connections with other intranets[74] of suppliers and customers and the overall Internet. This challenge was one of coordination rather than control, and required new, emerging approaches to management. Not surprisingly, both senior management of the organization as well as the leaders responsible for IT throughout the eras struggled with this new model for information resource leadership. John Sifonis and Beverly Goldberg noted that "the technology leader of tomorrow must be a business leader with all the management skills of any other senior executive. The CIO has gone from being a corporate god in the 1980s to the chief blame taker in the 1990s, when IT initiatives often have failed to deliver their promised productivity gains."[75]

Indeed, it appeared that the importance of the CIO's role diminished in the early 1990s. A survey of 300 CIOs conducted by Heidrick and Struggles Inc. in 1997 found that only 2% of those CIOs surveyed were on their corporate boards, just 7.7% reported directly to the CEO and/or the president of the corporation, and just 40% were on one or more senior management committees.[76] In contrast, in 1974, Robert J. Greene looked at some 300 firms and found that 10% of the DP managers reported directly to the president, 2% reported directly to the chairman of the board and 7% reported to the executive vice president. A full 14% of the DP managers in Greene's study reported to the controllers.[77]

This struggle has been reflected through high turnover rates: Gomez Advisors found that 34% of the CIOs in their study reported having less than 10% of their IT employees turnover annually, 42% said that 10% to 20% left annually, and the remaining 24% reported that 20% to 30% of their IT staff left the firm each year.[78] Further, Deloitte & Touche found that in 1991 the CIO turnover rate was 14%, it peaked in 1993 at 18.8% and in 1996 (latest available data) the turnover rate was 17.7%.[79]

Information Resource Management

The fundamental difference between Industrial Age companies and Information Age companies was the formal recognition of information as an important resource, and the incorporation of new management principles to manage information effectively and explicitly as a resource.[80] Further, management viewed IT as the underlying technology of the information resource. They used IT to exploit information directly as a resource to add value to the product or service, and as a result, management attention shifted from the technology itself to what the technology could produce through the extraction of value from information resources.

Impact on "Work"

The recognition of information as a resource had a dramatic impact on managing "work"—that is, the activities that people did to create value in the firm. In the Industrial Age, organizations divided work into its smallest elements and then assigned the work to small groups that repetitively and consistently carried out their tasks. Organizations coordinated successive modules of the output of tasks across functions and integrated the components into a finished product. Each product was the same as the other—mass production. Therefore, employees accessed codified and consistent information for producing a product. The management principle "need to know" governed the distribution of information in the organization.

In contrast, the Information Age organization moved from mass production to highly tailored products or services for the customer. The concept of a static system to produce a static product was replaced by a dynamic, interactive system to produce rapidly changing products. Also, the ability to continue to coordinate activities and sort out how to better or more efficiently produce a product or service led to a continuously changing production process. The concept of work and the role of information shifted from a "need to know" environment to one where information generation, flows, and use were incorporated into the concept of work itself. For example, in the Network Era, workers use knowledge gained from networked computers to leverage the creation of customer value. Concepts such as the "shadow partner" appeared to describe the emerging IT network architectures whereby the dominant role of the knowledge worker was leveraged through easy to use, but highly robust computers facilitating access of information.[81]

Real Time Resource Allocation and Management

An important tenet of management in the pre-computer period was the annual budget cycle for major resource allocation. In the M-form functional hierarchy, upper management completed change and resource allocation once a year, and then for the rest of the year the organization focused on execution and actions to correct deviations from the plan. This cycle time seemed long by the 1980s, but it facilitated the coordination of many workers doing many tasks required to mass-produce products and services in an economical manner.

The computer enabled companies to obtain performance information rapidly that before was both hard to get and took a long time to process. As noted earlier, first firms completed monthly "closings" to summarize performance, and take correct action, then weekly summaries appeared, and finally daily closings emerged in some industries like Financial Services. Accordingly, real time resource allocation—using real time messaging IT architectures—was possible, which permitted organizations to be extremely responsive to changing market conditions, to pursue newly discovered opportunities swiftly and to allocate the resources of the firm dynamically.

An integral component of these real time resource allocation systems was relational shared databases, which permitted knowledge workers to obtain current information on the results of operations, and to take actions necessary to correct variances from objectives. For example, State Street Corporation developed a global architecture system that was designed to deliver information and investment services to their customers on a near real time basis.[82] The phenomenal growth of ERP (Enterprise Resource Planning) systems[83] was likewise fueled by the strategic advantages of information transparency among customer and supplier organizations.

From "Make and Sell" to "Sense and Respond"

IT-enabled network organizational structures facilitated the adoption of more sophisticated competitive strategies that extended beyond "making and selling" products and services to "sensing and responding" to individual customer needs in real time.[84]

One of the ways that corporations sensed customers needs was to use information technology to electronically connect to their customers. Examples included:

- use of scanning data in retail stores—Levi Strauss & Co. used consumer database information and regional market-demand characteristics revealed by geodemographic data to match supply and demand in each store.[85]
- use of geographical information systems (GIS)—Isuzu used GIS applications to identify the optimal locations for new dealerships.[86]
- use of network computers in a car—Intel designed a high-performance, highly integrated microchip for engine- and transmission-control systems that monitored and continually adjusted engine performance.[87]
- use of wireless in the automotive industry—Siemens Automotive released a wireless Traveler Information System (TIS™) which used cellular communication to retrieve information related to traffic conditions along a specific route.[88]
- use of search agents in electronic commerce—Excite's Jango 2.0 agent searched the Web and returned a consolidated list of prices and availability for the item the user had requested.[89]
- Not only did corporations use IT to strategically sense customer needs, they also strategically used IT to respond electronically to fulfill customer needs. Examples included:
- use of knowledge management software—Corporations such as Fidelity Investments, AT&T and Allied Signal used BackWeb technology to push items such as software updates, company directories, news from the Net and data from corporate databases to their employees' desktops.[90]
- virtual manufacturing—By the time Netscape Navigator was officially released in August 1996, it had been through six beta versions. Each of these beta versions had gradually and systematically improved the end product by incorporating user feedback about features and bugs.[91]
- supermarket replenishment—H.E. Butt Grocery Company (HEB) first teamed up with Procter & Gamble (P&G) to employ Continuous Replenishment (CRP) in 1989. CRP allowed P&G to supply HEB with products based directly upon warehouse shipment and inventory data rather than upon receipt of HEB-generated purchase orders. This reduced order cycle time by six to ten days and dramatically reduced inventory levels in the store. By mid-1997, 65% of warehouse cube volume was on CRP.[92]

By the late 1990s IT-enabled "sense and respond" strategies had made a strategic impact on most if not all industries. IT innovation became an integral part of almost every company's strategy formulation process. More often than not, however, a particular IT breakthrough surprised companies, and they found themselves in a position of strategic jeopardy—that is, the breakthrough forced a company to match a competitor's IT initiative just to keep their customers. Further, by the late 1990s, vertically integrated structures in most industries had already been weakened and replaced by more horizontally integrated structures. IT had facilitated these changes by lessening coordination costs, and permitting more efficient, but more complex outsourcing and strategic alliance relationships.[93] Thus, it was easier for specialists to penetrate various parts of the value chain of industries. Product and service development cycles continued to be shortened, and innovative ways developed to sense and respond to customers' needs. The strategic role of the computer, in turn, brought line management directly into the management of IT through both capital and annual budgeting processes.

Impact on Product and Services

Much of an ongoing controversy about the value of IT investments resided in the inherent robustness of IT. IT could be applied to increase efficiency in order to reduce the price of products and services, and IT could be used to add unique features to products and services. However, unless organizations directly managed the investments in IT so that the investments increased profits in the firm, the measurements of investments were elusive and hard to quantify.

Halving the cost The economics of information as a declining cost resource relative to the increasing costs of scarce resources resulted in a phenomenon over time where organizations increasingly substituted information for scarce resources in the production of goods and services. As the mix of resources continued towards information and away from scarce resources, the cost of the product or service declined—firms eventually passed these savings onto the consumer. Once senior managers recognized the strategic importance of the substitution, they often rallied their organizations with goals to halve the cost of the product or service over time without reducing its quality.

Doubling the quality The information resource was much more robust than just impacting the cost of the product or service of the organization, organizations also used it to increase the quality. Similarly, once senior management realized how information could be used to increase the value to the customer through increased levels of service (e.g., easy to use information on how to effectively use the product or service) or increased levels of performance of the product (e.g., substituting electronic fuel systems for mechanical fuel systems in automobiles to improve the overall performance and reliability of the car), goals were often set to double the "quality" of the product or service while holding cost constant.

Adding heretofore impossible features Closely aligned with increasing the quality was using IT to add features to the products or services that had not before been possible. For example, car manufacturers incorporated ABS (computer-based anti-lock braking systems) into vehicles. The way that ABS worked to sense and respond electronically to the friction of the wheel on the road incorporated unique features of computer technology not previously available in other technologies.

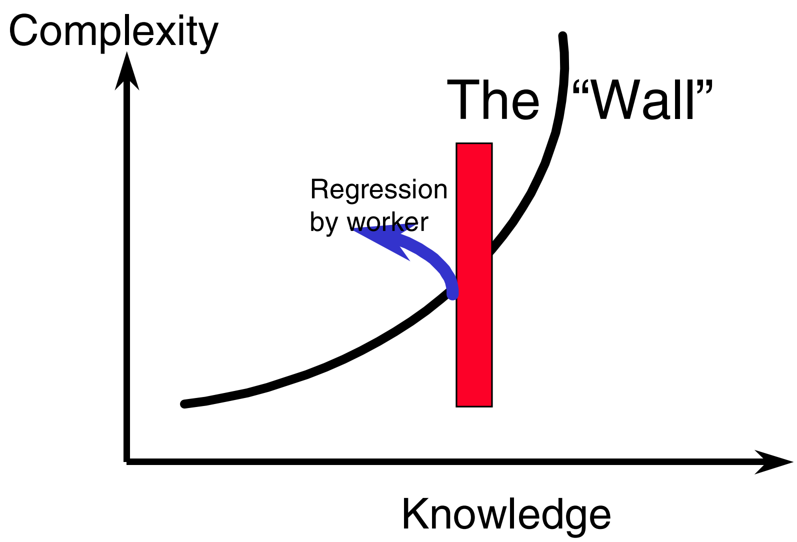
By the late 1990s, the application of computer chips that cost only dollars per chip had made the computer ubiquitous. More than a trillion chips were embedded in millions of products. Automobiles had up to 150 embedded computer chips doing everything from the aforementioned ABS based upon road conditions to communicating the location of the vehicle to the driver through accessing GPS (Global Positioning System). Networking of computers through the Internet had come of age, and set off a new wave of computer applications promising new IT-enabled benefits for customers.

Rise of the Caseworker

In the Industrial Age, companies divided work into work done by two classes of workers. Companies differentiated classes by the amount of their education: white-collar workers usually were college educated consisting of managers and professionals such as accountants and engineers; blue-collar workers usually had graduated from high school. The overall business model was such that white-collar workers designed the way that work would be carried out as codified through task definitions, job responsibilities and policies. White-collar workers also supervised blue-collar workers to ensure that they carried the work out properly. When firms detected variances in a plan, the white-collar workers "managed" by taking corrective actions.

In the Information Age, the line between white-collar and blue-collar workers broke down as the sharp distinction between designing work and carrying out work blurred. Also contributing to the breakdown was that serving customers with "sense and respond" strategies required workers to operate as caseworkers and cope with a much more complex work environment. Consumers further complicated the new work environment with their new demands for faster product cycles and service times, which in turn required access to more knowledge faster than ever before. The combination of these factors is illustrated in **Figure D**.

Figure D The Caseworker Paradox



Also illustrated in **Figure D** is the barrier that workers incurred as complexity and access to knowledge reached a point where the they could not perform without effectively leveraging IT. As noted previously, the role of IT in leveraging the capabilities of a worker had been conceptualized as providing a "shadow-partner" to a caseworker that enabled the caseworker to quickly access databases and networks that contained the knowledge necessary for the worker to carry out their value-added activities.[94]

The IT-enabled caseworker promoted the paradigm of client/server computing. The caseworker used a "client" computer to directly interact in real time to other computers (servers) to access customer information and product databases. Rapidly, the interaction began to expand to networked computers of suppliers, outsourcers, and others that might provide information to enhance the service to the customer.

New Benchmarks of Organizational Performance

While during the latter part of the DP Era the broader role that computers could play in the organization began to emerge, the impact of the Micro Era made apparent that computers were much more than transaction processing machines. New benchmarks began to emerge pioneered by the innovative, high growth companies in the Information Age, which aggressively led the way in applying computers. As shown in **Table B**, IBM ranked number one in market value[95] during the DP Era and most of the Micro Era. However, by 1997 both Microsoft's and Intel's market values were greater than IBM's. And in July 1998, Cisco, a mere 14 year-old company who started by making switches and routers[96] for networks, also surpassed $100 billion in market value.[97] Cisco not only pioneered the use of the intranet in its own business demonstrating the strategic value of networking, they built the hardware/software products required by other companies to move towards an integrated network, and strategic intranets.

Table B Market Value and Sales per Employee

Market Value Rank				Sales per Employee		
1978	**1986**	**1997**	**Company Name**	**1978**	**1986**	**1997**
5	3	1	General Electric	$49,012	$98,081	$320,797
16	16	2	Coca-Cola	120,164	309,259	639,593
NA	577	3	Microsoft	NA	171,304	510,885
3	2	4	Exxon	464,112	685,176	1,503,490
17	9	5	Merck	69,040	134,492	439,348
273	216	6	Intel	36,690	69,506	393,564
27	8	7	Philip Morris	82,814	186,315	369,171
1	1	8	IBM	64,747	127,011	291,348
2	4	9	AT&T	50,969	169,391	401,557
54	39	10	Pfizer	58,038	111,900	254,146
11	18	11	Procter & Gamble	147,267	208,635	337,396
53	26	12	Bristol-Myers Squibb	75,167	138,564	311,586
467	17	13	Wal-Mart Stores	51,446	84,461	142,979
25	30	14	Johnson & Johnson	52,199	90,829	250,044
70	41	15	American Int'l Group	11,026	315,842	762,217

Source: Standard & Poor's Compustat. Market value ranks and SPE reflect calendar year-end values.

Sales per Employee (SPE) Before computers became ubiquitous, SPE remained around $50,000 to $100,000. Employers considered labor fungible and measured it in hours. When sales increased, planning factors automatically increased proportionately all other resources required to produce the increment in sales, thus maintaining the "march to the northeast corner." As noted, during the Micro Era overall organizational learning about how to use and exploit the potential of IT exploded. SPE became a variable, and leading companies achieved SPE that grew to levels between $250,000 and more than $1,000,000. **Table B** illustrates the top 15 U.S. companies in terms of market value at the end of 1997 and their respective SPE. Five of these leading companies had SPE that were more than one and a half times that of their industry's average, and all but two companies had SPE that were higher than the industry average.[98] While not conclusive, these numbers provided evidence that SPE correlated with computer leveraged revenue generation activities in the firm—as companies transformed from DP Era practices (1978) to Micro Era practices (1986) to Network Era practices (1997) their SPE increased at rates of 1.5 times to close to 29 times their previous era's SPE.[99] Organizations who paid more attention to mining customer databases, building intellectual assets, and knowledge management, appeared to have higher SPE.

Market value Market value of companies went a long way to replace sales as a benchmark of successful companies. In the Industrial Age, sales generally correlated with market share, and companies with a large market share could more easily control prices and protect margins. Market value of companies was a rough measure of what investors expected would be the long-term return for their investments in a company. The suspicion was that market value also reflected the overall capacity of the company to innovate in maintaining their competitive position.

In **Table B**, the 1978 and 1986 ranks of the market values for the top 15 companies in 1997 are also shown. As noted earlier both Microsoft's and Intel's market value in 1997 exceeded that of IBM's. However, both of those companies had vastly smaller sales (IBM, Microsoft and Intel had 1997 sales of $78.5 billion, $11.4 billion, and $25.1 billion respectively).[100]

Summary

The management of IT has passed through three eras during which long periods of organizational learning have transpired. Management of the computer as an Industrial Age machine characterized the DP Era. Engineers installed massive-sized computers, which consisted of room-sized cabinets and whirling tape drives, in specially designed machine rooms. Technicians were recruited to tend to the machines. People associated the large size of mainframe computers with the power of the machine to do work. It is amusing to know that as computers were miniaturized into minicomputers, some DP managers placed the smaller minicomputers into larger cabinets because of the belief that senior managers would not think that the smaller computers were powerful enough to do the work of the larger ones.

But with the cumulative experience of applying computers, DP managers began to discover that computers were much more than the electric mechanical machines of the Industrial Era. They discovered that not only could paper-based transactions be automated, but the paper-based processes could be redesigned to be much more efficient through electronic processing. Further, they discovered that transaction processing could be integrated across the traditional functions: simultaneously an order could be taken from a customer, inventory reserved, the order scheduled for production in the factory, and an invoice sent. Attempting to implement these types of applications put the DP managers on the fulcrum of complex, hard-to-do organizational changes. Failures to consummate the required organizational changes effectively resulted in less than optimal use of computers, and in turn, the turnover of DP managers increased to 30% to 40% during the mid-1970s,[101] and remained high through the 1990s. Nevertheless, the opportunity to continuously change and improve business operations and customer service through IT became the hallmark of managing Information Age organizations.

The Micro Era formally began with IBM's introduction of the Personal Computer (PC). The term connoted that the computer was not necessarily a large, high cost machine, but something that could be used by individual workers to do more work efficiently. The innovation of the desktop PC was so radical in its time that most centralized DP or IS departments either ignored them, or attempted to rid the organization of them. But, the PC makers went around the DP departments and sold PCs directly to users in the various functional areas: spreadsheets for financial and accounting departments, word processing to secretaries, and graphic systems to graphic arts departments. The result was a bifurcation in the management of IT in the firm: the central DP department centrally managed mainframes for transaction processing, and the users managed their PCs individually.

While IBM introduced the low cost PC to the commercial organization, Apollo Computer invented a more expensive microcomputer to appeal to the scientific customer; it called this computer the workstation. Sun Microsystems followed close behind, and became the industry's innovator, by introducing a workstation that included the UNIX operating system, the Ethernet and the TCP/IP protocol for efficiently networking computers.

The first shifts towards the convergence of scientific and commercial computers could be seen during the Micro Era. In 1986. Cisco shipped its first product, the AGS router which facilitated the integration of computers in the organization into networks. And corporations such as Novell and

Microsoft were developing software that would help corporations to link their microcomputers with workstations that acted as servers.

By the 1990s, the fragmentation resulting from the proliferation of computers in the organization reached a point where many began to question the overall return from IT investments, and the impetus for networking clients and servers was greater than ever.[102] Then, in the mid-1990s, the Internet was discovered by many businesses. The dawn of the Network Era once again changed the paradigm from managing individual computers to managing networks of computers. Broadening the management paradigm to networks shifted the focus from managing technology to managing information resources enabled by IT. Accordingly, refinements such as knowledge management, creating and maintaining intellectual assets, providing self-service to customers over the Internet, and even directly distributing products over the Internet have become emerging areas of study. A major shift in the organizational concept of a computer as a machine to automate work, to an enabler of a new information resource that could be leveraged by workers to create value has occurred.

Endnotes

[1] Harry Newton, *Newton's Telecom Dictionary: 13th Ed.* (New York: Flatiron Publication Co., 1998): 378.

[2] The Stages Theory was first published in Richard L. Nolan, "Managing the computer resource: a stage hypothesis." *Communications of the ACM* 16 (July 1973): 399-403. This original stages theory of computer growth was based on the learning curve reflected through the data processing budget. Subsequent publications focusing on the Stages Theory as applied to organizational learning include Cyrus F. Gibson and Richard L. Nolan, "Managing the Four Stages of EDP Growth," *Harvard Business Review* 52 (January-February 1974): 77-88, and Richard L. Nolan, "Managing the crises in data processing," *Harvard Business Review* 57 (March-April 1979): 115-126.

[3] For a discussion of the emergence of "dominant designs" in technology see William J. Abernathy and James M. Utterback, "Patterns of Industrial Innovation," *Technology Review* 80 (June/July 1978): 40-47; and James M. Utterback, *Mastering the Dynamics of Innovation* (Boston: Harvard Business School Press, 1994): 23-55.

[4] Richard L. Nolan "Managing the advanced stages of computer technology: key research issues," in Warren F. McFarlan (ed.), *The Information Systems Research Challenge: Proceedings* (Boston: Harvard Business School Press, 1984): 195-216 lists various corporations that have applied the stages theories to their information systems. Several Harvard Business School cases have applied the stages theory to a particular industry or company. These include: Linda M. Applegate, "Frito-Lay: The Early Years (A)," 9-193-154 *Harvard Business School Case* (1993); Linda M. Applegate and Donna B. Stoddard, "Xerox Corp.: Leadership of the Information Technology Function (A)," 9-188-113 *Harvard Business School Case* (1988); Linda M. Applegate, "Xerox Corp.: Leadership of the Information Technology Function (B)," 9-191-024 *Harvard Business School Case* (1990); Linda M. Applegate and Ramiro Montealegre, "Eastman Kodak Co.: Managing Information Systems Through Strategic Alliances," 9-192-030 *Harvard Business School Case* (1991).

[5] See Louis A Girifalco, "The Dynamics of Technological Change," *The Wharton Magazine* 7 (Fall 1982): 31-37. Also, Edwin Mansfield, *Economics of Technological Change* (New York: W.W. Norton., 1968), Richard N. Foster. *Innovation: The attacker's advantage* (New York: Summit Books, 1986), Clayton M. Christenson, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail (Management of Innovation and Change Series)* (Boston: Harvard Business School Press, 1997), and Philip Anderson and Michael L. Tushman, "Technological Discontinuties and Dominant Designs: A Cyclical Model of Technological Change," *Administrative Science Quarterly* 35 (1990): 604-633.

[6] Anonymous. "Institutionalizing change." *Crossborder Monitor* (April 1, 1998): 1.

[7] James I. Cash, Robert G. Eccles, Nitin Nohria, and Richard L. Nolan, *Building the Information-Age Organization: Structure, Control and Information Technologies* (Chicago: R.R. Donnelley & Sons Company, 1994).

[8] Alfred D. Chandler, Jr. "The M-Form: Industrial Groups, American Style." *European Economic Review*. 19 (1982): 3-23; also refer to Alfred D. Chandler, Jr. *The Visible Hand : the Managerial Revolution in American Business* (Cambridge, Mass. : Belknap Press, 1977)

[9] In his note on automation in John Diebold, *Automation: the Advent of the Automatic Factory* (New York: D. Van Nostrand Company, Inc., 1952): ix, Diebold mentions that Mr. D. S. Harder, Vice President in charge of manufacturing of the Ford Motor Company, had for some time previous to Diebold's introduction of the term, used the word "automation" to describe the automatic handling of materials and parts in and out of machines.

[10] John Diebold, "Automation—the new technology," *Harvard Business Review* 31 (November-December 1953): 63-71.

[11]See for example, James W. Cortada, *The Computer in the United States: From Laboratory to Market, 1930 to 1960* (Armonk, New York; M.E. Sharpe, 1993): 64-101; Kenneth Flamm, *Creating the Computer: Government, Industry, and High Technology* (Washington, D.C.; The Brookings Instituition, 1988): 29-79.

[12] George McDaniel (ed.) *IBM Dictionary of Computing* 10th Edition (New York: McGraw-Hill, Inc., 1994) describes an analog computer as one whose operations are analogous to the behavior of another system and that accepts, processes, and produces analog data, which is data in the form of a physical quantity that is considered to be continuously variable and whose magnitude is made directly proportional to the data or to a suitable function of the data. A digital computer is a programmable functional unit that is controlled by internally stored programs and that uses common storage for all or part of a program and also for all or part of the data necessary for the execution of the programs. A digital computer operates on discrete data represented as strings of binary digits.

[13] Anonymous, "More hybrid computers become available," *Chemical and Engineering News* 42 (May 4, 1964): 51-52.

[14] Anonymous, "New hybrid computer system a product of joint agreement," *Chemical and Engineering News* 41 (July 1, 1963): 43.

[15] For a brief history of the IBM System 360 see James W. Cortada, *Historical Dictionary of Data Processing: Technology* (Westport, Connecticut: Greenwood Press, 1987): 212-220.

[16] For a brief history of the IBM System 360 see James W. Cortada, *Historical Dictionary of Data Processing: Technology* (Westport, Connecticut: Greenwood Press, 1987): 212-220.

[17] Standard & Poor's Compustat.

[18] The discussion on UNIX and Ethernet is summarized from Ceruzzi's chapter "Workstations, UNIX, and the Net, 1981-1955" in Paul Ceruzzi, *A History of Modern Computing* (Cambridge: The MIT Press, 1998): 281-306.

[19] TCP/IP stands for Transmission Control Protocol/Internet Protocol. Thomas G. W. Keen, Walid Mougayar, and Tracy Torregrossa, *The Business Internet and Intranets: A Manager's Guide to Key Terms and Concepts* (Boston: Harvard Business School Press, 1998): 253-255 explain that TCP/IP, the procedures and formats that create, transmit, and receive messages on the Net, is the Internet's core. TCP/IP allows any computer anywhere to talk to any other computer anywhere, even if they are completely dissimilar in hardware, operating system, and applications software.

[20] Paul Ceruzzi, *A History of Modern Computing* (Cambridge: The MIT Press, 1998): 284.

[21] Paul Ceruzzi, *A History of Modern Computing* (Cambridge: The MIT Press, 1998): 292.

[22] Richard L. Nolan, "Plight of the EDP manager," *Harvard Business Review* (May-June 1973): 143-152.

[23] Richard L. Nolan, "Business needs a new breed of EDP manager," *Harvard Business Review* (March-April 1976): 123-133.

[24] Robert L. Glass, "Cobol—a contradiction and an enigma," *Communications of the ACM* 40 (September 1997): 11.

[25] A "hurdle rate" is the minimum return on investment that a proposed investment must yield in order to be considered for funding my the corporation. For further information about hurdle rates see Clyde P. Stickney and Roman L. Weil, *Financial Accounting: An Introduction to Concepts, Methods, and Uses* (Philadelphia: The Dryden Press, 1994): G-32, G:47 define hurdle rate as the required rate of return in a discounted cash flow (DCF) analysis. A DCF uses either the net present value or the internal rate of return in an analysis to measure the value of future expected cash expenditures and receipts at a common date.

[26] By the 1990s, every electronic calculator costing $10 or more embedded these complex present value calculations into their logic enabling the calculations to be done by entering some basic data, and pressing a button.

[27] Standard & Poor's Compustat.

[28] *Ibid.*

[29] "Dumb terminals" were input devices that did not have a computer CPU that enabled the terminal to carry out computations in a standalone environment. Later on PCs were used for both standalone use, and for input to mainframes.

[30] Anonymous, "A mainframe on three chips." *Business Week (Industrial Edition)* (March 2, 1981): 116.

[31] Richard N. Foster, *Innovation: The attacker's advantage* (New York: Summit Books, 1986).

[32] Ron Scherer, "IBM unveils new home computer line," *The Christian Science Monitor,* (August 21, 1981): 5.

[33] The Sharenet operating system provided the file server with support for multiple DOSes sharing network and file space, a means for managing the functioning of multiple computers in the same directory simultaneously, file security, and support of spooled printers and station-to-station pipes. The network protocol was CSMA/CD (Carrier Sense Multiple Access) and the data-transfer rate was 1.43 megabits per second. For an additional fee, electronic mail could be incorporated into the network operating system. Source: Anonymous, "IBM PC XT Local-Network Scheme," *Byte* (October 1983): 593

[34] Matt Kramer, "MS-Net paves the wave for LAN applications," *PC Week* (November 13, 1984): 1.

[35] *International Directory*, vol. 6. (1992): 269; *Hoover's Guide to Computer Companies* (1996): 26-27, 164-165.

[36]RISC (Reduced Instruction Set Computer) architecture was introduced by John Cocke of IBM. It greatly boosted computer speed by using simplified machine instructions for frequently used functions.

[37]For a discussion of broader technological developments of the workstation, refer to "Workstations, UNIX, and the Net, 1981-1955" in Paul Ceruzzi, *A History of Modern Computing* (Cambridge: The MIT Press, 1998): 281-306.

[38]Alfred D. Chandler, "The Computer Industry: The First Half-Century," in David B. Yoffie (ed.) *Competing in the age of digital convergence* (Boston, MA: Harvard Business School Press, 1997): 70, 89-94.

[39] Paul Ceruzzi, *A History of Modern Computing* (Cambridge: The MIT Press, 1998): 289

[40]Alfred D. Chandler, "The Computer Industry: The First Half-Century," in David B. Yoffie (ed.) *Competing in the age of digital convergence* (Boston, MA: Harvard Business School Press, 1997): 92-93.

[41] Ron Scherer, "IBM unveils new home computer line," *The Christian Science Monitor,* (August 21, 1981): 5.

[42] William R. Synnott and William H. Gruber, *Information resource management: opportunities and strategies for the 1980s* (New York: Wiley, 1981): 66.

[43] In addition to the proliferation of computers, the march had broken down in the 1970s and 1980s for a wide variety of macro-economic reasons—recession, oil crisis, breakdown of international financial arrangements, foreign competition, etc.

[44] Shoshana Zuboff, *In the Age of the Smart Machine: the Future of Work and Power* (New York: Basic Books, 1988): 9-11.

[45] See Maryam Alavi. "KPMG Peat Marwick U.S.: One Giant Brian," 9-397-108 *Harvard Business School Case* (1997) and Robert G. Eccles, and Julie Gladstone, "KPMG Peat Marwick: The Shadow Partner," 9- 492-002 *Harvard Business School Case* (1995).

[46] The ARPANET was named for and sponsored by the Defense Department's Advanced Research Project Agency.

[47] The information about the history of the Internet, presented in the following paragraphs of this chapter, is taken from Andrew B. Zimmerman, "The evolution of the Internet; Internet/Web/Online Service Information," *Telecommunications* 31 (June 1997): 39; Barry M. Lerner, et al., "The past and future history of the Internet; The next 50 years: our hopes, our visions, our plans," *Communications of the ACM* 40 (February, 1997): 102; and Katie Hafner and Matthew Lyon, *Where Wizards Stay Up Late: The Origins of the Internet* (New York, NY: Simon & Schuster, 1996). For a more detailed history of the Internet please refer to these sources.

[48] Andrew B. Zimmerman, "The evolution of the Internet; Internet/Web/Online Service Information," *Telecommunications* 31 (June 1997): 39.

[49] Anonymous, "Host computers almost double within the year," *New Media Age* (October 9, 1997): 16. Bellcore's survey classified host computers as centralized server computers, work stations and each modem in the modem back of Internet Service Providers.

[50] For a further discussion of the simplification of corporate networks see Mark Cotteleer and Robert D. Austin, "Network Computing at Sun Microsystems: A Strategic Deployment," 9-198-007 *Harvard Business School Case* (1997).

[51] See various articles by Mary Cronin published in *Fortune*; John Hagel III and Arthur G. Armstrong, *Net Gain: Expanding Markets through Virtual Communities* (Boston : Harvard Business School Press, 1997).

[52] Lee Gomes, "Cisco passes significant milestone, topping $100 billion in market value," *Wall Street Journal Interactive Edition* (July 20, 1998): http://interactive.wsj.com.

[53] Richard L. Nolan and Kelley A. Porter, "Cisco Systems, Inc.," 9-398-127 *Harvard Business School Case* (1998).

[54] *Ibid*.

[55] Anonymous, "The accidental superhighway," *The Economist*, (July 1, 1995): S3.

[56] Andrew B. Zimmerman, "The evolution of the Internet; Internet/Web/Online Service Information," *Telecommunications* 31 (June 1997): 39.

[57] Values are based on "The Internet Domain Survey," *Network Wizards* (July 1998): http://www.nw.com/zone/WWW/dist-bynum.html. Commercial sites reflect the percentage of total domain names that end in .com. The survey methodology is described at http://www.nw.com/zone/WWW/new-survey.html.

[58] Robert Metcalfe is the inventor of Ethernet. The idea of Ethernet was outlined in Metcalfe's Harvard Ph.D. thesis in 1993, and now is used to network more than a 100 million computers. Metcalfe went onto found 3Com Corporation.

[59] See George Gilder, "Metcalfe's Law and Legacy," *Forbes ASAP*, September 13, 1993.

[60] Numbers are from Nua Internet Surveys (http://www.nua.ie/surveys/how_many_online/index.html).

Each month, this firm looks at the many published surveys on Internet users and makes an educated guess of the best number of people who are online.

[61] Anonymous, "Latest IntelliQuest Survey Reports 62 Million American Adults Access the Internet/Online Services," http://www.intelliquest.com/press/release41.asp (February 5, 1998).

[62] Gordon Moore, chairman emeritus of Intel Corporation, observed that the technology for cramming transistors on a fixed size silicon chip doubled approximately every 18 months. His theory was first published in Gordon E. Moore, "Cramming more components onto integrated circuits," *Electronics* (April 19, 1965): 114-117.

[63] TechWeb Technology Encyclopedia defines bandwidth as the transmission capacity of an electronic line such as a communications network, computer bus or computer channel. It is expressed in bits per second, bytes per second or in Hertz (cycles per second). Source: (http://www.techweb.com/encyclopedia/defineterm?term=bandwidth)

[64] George Gilder. "Fiber keeps its promise," *Forbes ASAP* (April 7, 1997): 2.

[65] Stephen P. Bradley and Jerry A. Hausman. *Future Competition in Telecommunications* (Boston: Harvard Business School Press, 1989); Peter Temin and Louis Galambos, *The fall of the Bell system: a study in prices and politics* (New York: Cambridge University Press, 1987).

[66] Ira Magaziner, "Call to Action," *Second International Harvard Conference on Internet & Society* (May 29, 1998).

[67] Stephen P. Bradley, Pankaj Ghemawat and Sharon Foley, "Wal-Mart, Inc.," 9-794-024 *Harvard Business School Case* (1996).

[68] Pankaj Ghemawat and Bret Baird, "Leadership Online: Barnes & Noble vs. Amazon.com (A)," N-798-063 *Harvard Business School Case* (1998).

[69] John J. Sviokla, "Edmund's—www.edmunds.com," 9-397-016 *Harvard Business School Case* (1997).

[70] Donna B. Stoddard, Anne Donnellon, and Richard L. Nolan. "VeriFone (1997)," 9-398-030 *Harvard Business School Case* (1997).

[71] Warren F. McFarlan and Donna B. Stoddard. "Otisline (A)," 9-186-058 *Harvard Business School Case* (1990).

[72] Michael Hammer and James Champy, *Reengineering the corporation: a manifesto for business revolution* (New York, NY; HarperBusiness, 1993) was an important book in triggering the campaign to reengineer business processes rather than simply use computers to automate the existing business functions and tasks.

[73] Nitin Nohria and Robert G. Eccles (ed.), *Networks and Organizations: Structure, Form, and Action* (Boston.: Harvard Business School Press, 1992).

[74] Thomas G. W. Keen, Walid Mougayar, and Tracy Torregrossa, *The Business Internet and Intranets: A Manager's Guide to Key Terms and Concepts* (Boston: Harvard Business School Press, 1998): 231 state that intranets are networks build on Internet-based technology that limit access to people within the originating organization and others who have been granted permission to access the internal networks. The intranet may or may not link to the external Internet.

[75] John G. Sifonis and Beverly Goldberg, "Changing role of the CIO," *InformationWeek* (March 24, 1997): 69-82.

[76] *Ibid. 79*

[77] Robert J. Greene, "The DP manager's status," *Datamation* (June 1974): 66-67.

[78] Ivy Schmerken, "Hail to the Chiefs," *Wall Street & Technology* 16 (January 1998): 40.

[79] Chuck Nunamaker, "CIO Profile," *Leading Trends in Information Services: Ninth Annual Survey of North American Chief Information Executives--1997* (New York, NY: Deloitte & Touche Consulting Group LLC, 1997): 15.

[80] For a more detailed discussion on the new management principles that evolved, refer to Richard L. Nolan and David C. Croson, *Creative Destruction: A Six-Stage Process for Transforming the Organization* (Boston: Harvard Business School Press, 1995): 14-17.

[81] Robert G. Eccles, and Julie Gladstone, "KPMG Peat Marwick: The Shadow Partner," 9- 492-002 *Harvard Business School Case* (1995).

[82] Chiara Francalanci and Donna Stoddard. "State Street Corporation: Leading with Information Technology," 9-195-135 *Harvard Business School Case* (1994).

[83] TechWeb Technology Encyclopedia (http://www.techweb.com/encyclopedia/defineter?term=ERP) defines ERP as an information system that integrates all manufacturing and related applications for an entire enterprise. An ERP implies the use of advanced information technologies, including GUIs, CASE tools, 4GLs, client/server architecture and open systems.

[84] Stephen P. Bradley and Richard L. Nolan (eds), *Sense and Respond: Capturing Value in the Network Era* (Boston: Harvard Business School Press, 1998).

[85] *Ibid.*, p. 132.

[86] *Ibid.*, p. 129.

[87] Anonymous. "New Intel chip for autos; Intel Corp. introduces high-performance microchip." *Ward's Auto World* (December 1995).

[88] Anonymous. "Siemens' access to 'real-time' driver information can help reduce symptoms of road rage." *PR Newswire* (May 6, 1998).

[89] Megan Loncto. "Bots Search for Best Prices." *Computer Shopper* (April, 1998).

[90] Rochelle Garner, "Barkat's big leap," *Upside* (March 1998).

[91] Stephen P. Bradley and Richard L. Nolan (eds), *Sense and Respond: Capturing Value in the Network Era* (Boston: Harvard Business School Press, 1998): 184.

[92] Theodore H. Clark, David C. Croson, James L. McKenney and Richard L. Nolan, "H.E. Butt Grocery Company: A leader in ECR Implementation (Abridged)," 9-196-061 *Harvard Business School Case* (1997); Robert D. Austin and F. Warren McFarlan, "H.E. Butt Grocery Company: A leader in ECR Implementation (B) (Abridged)," 9-198-016 *Harvard Business School Case* (1997).

[93] T. W. Malone, J. Yates, and R.I. Benjamin, "Electronic Markets and Electronic Hierarchies," *Communications of the ACM* 30 (1987): 484-497.

[94] See Maryam Alavi. "KPMG Peat Marwick U.S.: One Giant Brian," 9-397-108 *Harvard Business School Case* (1997), for a discussion of the history of knowledge management at the firm and the facilitating role of the Internet and intranet technologies in executing the firm's knowledge management strategy; Robert H. Buckman, "Knowledge sharing at Buckman Labs." *Journal of Business Strategy* (January/February 1998), for a discussion the implementation of a "knowledge management culture" at Buckman Laboratories; and Jeff Moad, "The working web," *PC Week* 14 (March 17, 1997): 125, for a discussion on the roll-out of intranets to non-traditional knowledge workers at companies such as Delta, Levi Strauss & Co, and Tektronic Inc.

[95] Approximate market value is calculated by multiplying the value of a common share (as reported on a stock exchange) by the number of common shares outstanding.

[96] Thomas G. W. Keen, Walid Mougayar, and Tracy Torregrossa, *The Business Internet and Intranets: A Manager's Guide to Key Terms and Concepts* (Boston: Harvard Business School Press, 1998): 195 defines that routers as a key component of all networks; as their name suggest, they handle the routing of traffic across a network, interpreting destination addresses and managing traffic jams among their many other communication, coordination, and management functions.

[97] Lee Gomes, "Cisco passes significant milestone, topping $100 billion in market value," *Wall Street Journal Interactive Edition* (July 20, 1998): http://interactive.wsj.com.

[98] Sales per employee numbers were compared with the industry averages presented in "1998 *Fortune* 500," *Fortune* (April 27, 1998). General Electric was the only company presented in Table 2 that had sales per employee more than double that of its industry average (2.09 times). At the other end of the spectrum, IBM had sales per employee that were only 0.85 times that of its industry's average and Johnson & Johnson had sales per employee that were 0.99 times that of its industry's average.

[99] Rates of increase were based on the difference in SPE between each of the eras for the firms listed in **Table B**. The average rate of increase between 1978 and 1986 (not including International Group's 28.63 rate of increase) was 2.00; the average rate of increase between 1986 and 1997 was 2.60.

[100] Standard & Poor's Compustat.

[101] Richard L. Nolan, "Business needs a new breed of EDP manager," *Harvard Business Review* (March-April 1976): 123-133.

[102] See Paul A. Strassman, *The Business Value of Computers* (New Canaan, Connecticut: The Information Economics Press, 1990).