perfectly the first time they are built. The design process has become inextricably tied to production. Data is fed directly from the design process to the machines that fabricate the tools that build the circuits. In some recent cases even tools aren't required: IBM, for example, has used electron beams to directly write patterns on wafers the same way images are painted on television screens.

With the virtualization of the semiconductor business it is now possible to build electronic systems on a chip in a few weeks for a few thousand dollars. A small silicon chip can replace a room of electronics that would have taken years to build just four decades ago.

Scheduling the Skies

Much of the focus of this book has been and will be on products. But virtual services are of equal importance. One obvious example is money. As has been much reported, we are moving toward a cashless society that depends upon a virtualized monetary system. Money already races around the world at the speed of light. Each day $----billions change hands in informational transactions which require neither gold nor currency nor printed documents.[20]

Another service industry to benefit from virtualization has been travel. Travelling has never been a simple process. From ships, coaches and ferries to bullet trains and supersonic aircraft, each new technological breakthrough has brought with a host of service challenges, many of them in ticketing and reservations.

Perhaps the most extreme example of this has been in the airline industry. With scores of airline companies and thousands of planes in the air crowding major lanes and runways, traffic control and airport management have required ever more sophisticated computers, software and communications networks to keep up.

In 1989, for example, throughout the world ________ people booked seats on ________ flights.[21] Just keeping track of that information, when combined with lay-overs, connecting flights and seating assignments is difficult enough. Add to this special meals, multiple timed connections, frequent flier miles, and myriad discounts. Without powerful computer software, dealing with these millions of permutations would be impossible.

The story of how ticketing system for airlines, at first a carry–over from passenger trains, evolved into a virtualized service is a remarkable one. Many of these examples are a result of the research of ___________.[22]

The story of the airline ticketing begins in the 1920s with the comparatively simple task of filling the solitary spare seat on airmail planes. Ticketing was simply a matter of taking down the name of the passenger who had paid for the flight on a given day.

The rise of multi-passenger airliners in the early 1930s made the task more complicated. Now to handle reservations required keeping track of available seats and recording passenger names. By the end of the decade, new young airlines such as American were developing ways to overcome reservation confusion and overbooking by centralizing control at a flight's point of departure. This led to the so-called Request and Reply systems which required the customer to contact the ticketing agent at the departure point and then wait for a return confirmation call.

The end of WWII brought with it the modern age of air travel and an explosion in demand that outstripped the supply of available flights. As individual seats became more valuable, so did the importance of quickly returning cancellations to the available pool for sale. The immediate solution to this was to install availability display boards in reservation offices so that agents could quickly scan flights for seat openings or, if booked, seats on alternative flights. Soon, however, explosive demand outstripped even this technology, until life as an airline ticketing agent took on an element of sheer absurdity.

This was American Airline's office in Chicago office:

> A large cross-hatched board dominates one wall, its spaces filled with cryptic notes. At rows of desks sit busy men and women who continually glance from thick reference books to the wall display while continuously talking on the telephone and filling out cards. One man sitting in the back of the room is using field glasses to examine a change that has just been made high on the display board. Clerks and messengers carrying cards and sheets of paper hurry from files to automatic machines. The chatter of teletype and sound of card sorting equipment fills the air.[23]

In 1945, American Airlines set out to revamp its entire ticketing and reservation system. The push was directed by American's president, C.R. Smith, who had seen the power of new technologies to manage aircraft during his wartime stint as deputy commander of the Military Air Transport Command. He announced, "We're going to make the best impression on the travelling public, and we're going to make a pile of extra dough just from being first."[24]

Smith's ally in the project was Charles Ammann, head of American's Advanced Process Research Department, who had spent the war determining the need for such a system to remove the onus from ticketing agents, maintain an accurate running inventory, reduce the need for chaotic reservations offices, and automatically advise all offices of flight sell-outs.

In visiting data processing vendors, however, Ammann soon found that while all were adept at building solutions for accounting applications (that is, one person needing access to thousands of records), few had any experience -- or interest -- in inventory control (hundreds of people needing access to a single record). So Ammann set out to build a system of his own.[25] One of his early prototypes used metal tubes to represent flights, holding marbles, representing seats. Each time a seat sold an electrical trip would drop one marble. Another, seemingly more practical prototype used resistive networks in a crude electrical system.

After many prototypes, the system that Ammann finally presented to Smith used a matrix of relays (columns were dates, rows were flights) in which shorting plugs could be manually inserted to indicate a sell-out. Called the Reservisor System, and built by Teleregister Corp., it was installed at American's Boston reservations office in February 1946 and represented the "first time any airline had adapted current electronic discoveries to reservations handling."[26]

Within a year, the Boston office was handling an additional 200 passengers daily with 20 fewer agents. The remaining agents worked at electrical 'sets' in which they keyed in their requests, saw a light blink if it was accepted, or remain dark if not.

The Reservisor was a considerable improvement over what came before, but it was still slowed by the time it took to physically transfer Passenger Name Record (PNR) cards and insert the shorting plugs. Maintaining records remained a sizable problem..

The next refinement to the system was the Magnetronic Reservisor, installed by American at LaGuardia Airport in 1952. It used the new magnetic drum computer memory as a low-cost storage system. By 1956, a more sophisticated version, capable of handling 2,000 flights for 31 days and which cut response times to one-half second, was installed at

American's New York West Side Terminal. For the time being, the reservation inventory obstacle was overcome.

Now Ammann and his group attacked the challenge of passenger information. The result, first tested 1956, was the Reserwriter, a computer that read punched cards filled with passenger data, converted them to paper tape and transmitted the data over teletype. By 1956, the Reserwriter systems were linked into a nationwide network.

Despite obvious performance improvements, American's reservation system was still error-prone. An estimated 8 percent of all transactions were in error, and to process a single round-trip reservation between New York and Buffalo required 12 people, 15 procedural steps and 3 hours elapsed time. Furthermore, through most of the 1950s, productivity per reservations employee fell nearly forty percent. Misplaced PNR cards too often led to overbooked flights and angry customers.[27] American knew that the pending jet age, with its greater seating capacity and shorter time windows, would only make the situation worse.

The solution, though American didn't yet know it, was already in the works. IBM, looking for new markets for its primarily military computers, had been eyeing Teleregister's success in airline reservations for years. The code name for Big Blue's search for consumer applications for its computers, terminals and disk drives, was SABER and it was as part of this effort that the company approached Ammann at American. In 1956 a combined task force defined the needs of a state-of-the-art reservations system, and beginning in mid-1958, IBM set out to build it.

By the end of 1959, American had accepted IBM's proposal -- though not without some trepidations about an untried telecommunications system that would cost $16,000 per agent set, had installation costs of $2.1 million and threatened hardware expenditures over the next decade of $37 million. Making the decision easier were predictions of annual savings of as much as $5 million by 1970, and for reservation processing times to fall from 45 minutes to just seconds.

After a fitful start, due to inadequate software, SABRE (as it was now called) came on-line in November 1962. It proved to be an extraordinary success; so much so that other airlines attempted to imitate it. The first, and most successful was Eastern Airlines, with its APOLLO system, also IBM based. Similar attempts by United and TWA to install Customer Reservation Systems with other computer vendors initially failed, so by

1970 both acquired Eastern software and set up their own APOLLO-type systems.

In 1975, American made the crucial decisions to adopt the Joint Industry Computerized Reservation System (JICRS) standard and to move SABRE into the heart of its corporate business strategy. In doing so, adding the instantaneous delivery of a customized product (airline reservations) to its traditional business of air transportation, American Airlines became one of the first firms to move toward virtualization.

Soon American discovered that, having paid for the initial start-up cost, the incremental cost of additional services was marginal. SABRE quickly turned out to be an extraordinary money-making machine: planned return on investment, with all the incremental revenues, was forecast at 67 percent. Instead it turned out to be more than *500 percent.* Soon SABRE was handling other travellers' needs, such as rental cars and hotel reservations, and thus extending its reach beyond the actual flight itself.

One of the most interesting effects of SABRE was that it moved the 'factory' closer to the customer. Older ticketing techniques had worked to the advantage of larger travel agency chains, which could implement their own computerized record keeping, and because of their size, get better treatment from the airlines. But with SABRE, even the tiniest agency, if armed with a network terminal, could quickly order the right ticket and an array of ancillary services.

With all of these advantages, it is should not be surprising that Computer Reservation Systems (CRS) continue to grow in influence and value. In 1988, American's SABRE had revenues of nearly one half billion dollars. That year, for example, American earned $134 million of its $801 million in profits from SABRE. And despite the fact that SABRE represented only 6 percent of the airline's revenues. In 1989, SABRE was valued at $1 billion; or 25 percent of American Airlines.

By 1990, according to Business Week, 93 percent of America's 35,000 travel agents were plugged into Customer Reservation Systems (CRSs), 12,443 of them with SABRE and SABRE has continued to expand its services. One new offering is SABREvision, designed to put CD-ROM players at its member agencies to link with their SABRE PCs and provide full color images about vacation packages.

One unexpected result of SABRE and the other CRSs is that greater control is placed in the hands of the user -- not just travel agencies, but corporate clients and even individual consumers. As travel agencies gain the capacity to schedule and book entire vacation packages, and even to print out the tickets, the ability to perform the basic task of making ticket reservations is moving further down the pyramid. According to Calvin L. Rader, CEO of WorldSpan, currently the third largest CRS, his firm wants to become "a true information company," by allowing corporations to use their own desktop computers to perform ticketing transactions.[28] Similarly, software is now available for individuals to use their home computers to reserve airline tickets.

An interesting sidelight to all this, and a glimpse into another impact of the virtual revolution, is the customer's reaction to these systems. While CRSs may have begun offering their services to other airlines for covering overhead, in the process they raised customer expectations for a non-biased presentation of information. Thus, when SABRE and others were accused of internal bias, of diverting users to their airlines or unfairly measuring stop-over times for international flights, the result was an extraordinary hue and cry about a breach of public trust. The U.S. Congress investigated and a bill was introduced (though it failed) to force all carriers to divest their CRSs. American Airlines and the others discovered to their surprise that in virtualizing they had also created a whole new business environment.[29]

Recently the Wall Street Journal reported on new software for travel agencies that more efficiently navigates through CRSs in search of the best ticket prices and even 'sits' on the phone line tracking the status of fully-booked flights waiting to pounce on the first cancellation.[30] With this announcement, the SABRE system, which had originally been American Airline's scheme to capture customers and give it a competitive advantage in the way it presented data on flights, had now become part of a network that would yield control to the customer.

The story of SABRE is a dramatic example of how services can be virtualized and in the process become essential to the conduct of business. Control of the reservation systems has provided American with numerous competitive advantages. Not only has it been a source of great profits, but it has given the company a gold mine of information which has enabled it to run its business more effectively.

For example, the Sabre system can predict (based on historical reservation patterns) whether a flight is going to be full. Obviously, the objective is to carry as many passengers as possible at as high a fare as the airline can demand. Therefore, airlines want to save some seats for last minute business travelers who pay three to four times as much for many tickets as vacationers do. The trick then is to use real-time information on reservations to adjust fares at the last possible moment to fill the planes. If it looks like there are going to be lots of empty seats the airline can increase the number of low-priced seats available on the flight.

Using this technique, airlines currently make more 200,000 fare changes each day; a number that will only increase with the new travel agency software programs waiting to pounce on the latest fare change.[31] Not only would all this be impossible without powerful information processing equipment, but the competition is so great and pace of change is so fast that the performance of these systems must be perpetually updated. The airline with the best information has the greatest chance of filling the seats on its flights at the highest prices. . . and over time a few percentage points in load factor can make the difference between profitability and Chapter 11 in an industry that makes less than --% on sales. For these firms, information and virtualization means survival.

Along a Wide Front

The examples selected for this chapter span a wide range of industries. That fact alone provides some important clues on the nature of the virtual revolution.

The breadth of the examples suggests the eventual pervasiveness of this new business model. If the virtual process can affect everything from the manufacture of guns to computer chips, it is easy to envision it affecting a very broad range of discrete manufacturing processes.

There are also trends to be gleaned from the examples in this chapter. For example, the virtual engineering processes described for the semiconductor industry are also being used by other industries, such as in the design of electronic equipment. Mechanical design automation packages from software firms such as Autodesk and Intergraph now enable engineers and architects to design homes, buildings, and airplanes in a fashion similar to that used with electronic devices. And finite element analysis tools permit the performance of mechanical structures to be simulated on a computer just as one does with electronic circuits.

The American Airlines SABRE story suggests how virtualization will change the information-sensitive portions of other service industries. The story of printing also offers clues to the similar changes that will take place in information services. Combine this with the virtualization in financial services mentioned earlier, instantaneous mail order fulfillment, and the demand-responsive merchandising systems at companies such as Benetton, K-Mart, and Wal-mart described later in the book and it should be apparent that the virtual revolution is already having considerable impact on traditional service industries.

Another feature of virtualization, an increasing role for the customer as a co-producer, can be seen in the semiconductor, printing, and airline examples. In each case, the customer, by becoming more competent in the products and services, can not only better control the result, but in the process develops strong and enduring ties to the provider.

The Beretta example offers a telling history of the evolution of the modern corporation and the changes required at each step along the way. Ultimately, it provides a glimpse at the type of manufacturing processes the virtual corporation will employ. The Beretta example also suggests how total quality control and computer integrated manufacturing will have broad implications in the future of the corporation; as will the creation of a highly-trained, involved workforce. The Remington story complements this by showing how the virtual revolution offers the possibility of not only advancing the power of manufacturing, but enriching it by regaining some of what has been lost in two centuries of mass production.

In the industrialized world, the virtual business revolution will be all-encompassing. Companies will be moving forward along a wide front, not only by changing themselves, but, through interaction over common needs, other businesses as well. And making the advance smoother will be the engine that will propel these companies forward: information technology. Information processing drives the virtual revolution.

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[3]Wilf Corrigan, interview, March 1991

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[17]James Burke, The Day the Universe Changed, Little, Brown, 1985, pp 111-112

[18]Dirk Hanson, The New Alchemists, Little, Brown, 1982, pp 59-60.

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[22]Unless otherwise noted, the history of the Sabre System comes from "American Airlines SABRE System", by ________, presented to the History of Computing Conference on June 24, 1991.

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Chapter 3: Powers of Information

The words, 'power of information' are used so frequently they have become at best a cliche, and at worst an advertising slogan. In the process, the phrase has been so inflated into science fiction -- the omnipotent and dangerous supercomputer peering into our lives -- that information seems some priceless and enslaving commodity.

The truth is, extraordinary advances in information processing will serve as the dynamo of the virtual revolution. Further, in the years to come, incremental differences in the ability of companies to acquire, distribute, store, analyze, and invoke actions based on information will determine who wins and loses the battle for customers.

For those who could not identify with the implications of 'the power of information' the events of the Persian Gulf war must have been a revelation. After all, solely in terms of manpower, the Iraqis held a 20 percent edge. On top of that, most military texts of the last 200 years have argued that to be successful an attacking force must be twice to three times the size of an entrenched defender. So, by all traditional measures, the Iraqis should have been able to put up a good fight.

Yet, the war itself, first over Baghdad and then on the ground in Kuwait, was among the most one-sided in history. The Allies lost less than 100 of their 450,000 troops in the war zone. As has been much remarked since, American troops were statistically safer on the front than they would have been on many city streets at home.

Why the rout? The answer was obvious to anyone watching television during the brief course of the war. The Allied troops had far superior information about their enemy and then managed that information more effectively. In strategic command and control, the Allies used satellite and reconnaissance information to learn just about everything they needed to know about Iraq's static defenses. Tomahawk cruise missiles, using reconnaissance information stored in their memories, were so well programmed that they actually followed roads and streets to their targets. Further, because the Allies appreciated the importance of information, they also knew the value of denying it to the other side. They either destroyed or negated the ability of the Iraqis to deliver commands or identify attackers -- a plan made unforgettable by the image of Baghdad anti-aircraft fire filling the air long after a Stealth fighter had passed.

In battlefield tactics, the power of information was even more striking. While some Iraqi commanders were reduced to using runners to carry messages, Allied solders used handheld digital devices to pick up satellite transmissions and locate themselves accurately within a few yards in the trackless desert. Minicomputers quickly calculated complex artillery trajectories, put shells dead on target and wiped out the enemy before it could mount a counterstrike. M-1 Abrams tanks used their on-board computers to fire accurately 'on the fly' and wreak devastating damage to Iraqi armor with only a handful of losses in return.

With the Persian Gulf war, the value of information reached a zenith; bytes became more important that bullets. The case was made, with brutal clarity, that information could become the foundation for devastating destruction.

If there was one piece of Allied hardware that captured and held the world's attention during the short course of the war it was the Patriot anti-ballistic missile. For several days at the height of the air war, the cities of Israel and Saudi Arabia were held hostage to Iraqi Scud missiles. Like the German V-2 before it, the Scud threatened the unstoppable horror of a ballistic missile aimed at a civilian population. The jerry-rigged Patriot, though only partially effective, saved the day.

Historically, ground defense against airborne attack has always been exceedingly difficult, from anti-aircraft fire over Berlin to SAM missiles launched over Hanoi. The intercept times are so short that any deviance in the path of the incoming object is usually enough to guarantee defensive failure. Drop a ballistic missile in from the ionosphere and the population is essentially left undefended and paralyzed in fear.

The Patriot changed that. In some instances, Allied satellites detected launch backfires as the Scuds left Iraq, transmitted the data to groundstations in the United States and elsewhere, where it was processed and then relayed to Patriot batteries in Israel and Saudi Arabia. There, the surprise gone, the skies could be scanned by radar for the incoming missile, the lock-on information conveyed to the Patriot's own guidance system and the missile launched. In flight, intercepting at a closing speed of several thousand miles per hour, the Patriot would make the final real-time trajectory adjustments to adapt to the flight path of the often-tumbling Scud. The result was seen in the skies over Tel Aviv and Riyadh.

What enabled the Patriot to accomplish this remarkable task was that it continuously changed its flight behavior to adapt to evolving circumstances. It did this by using sophisticated (though hardly state-of-the-art) computational equipment. But more important than that was the information this equipment processed: information that not only captured the nature of the attacking ordinance, nor just its overall trajectory, but the second-by-second 'behavior' of the Scud as it descended through the turbulent atmosphere.

In many ways, the ability to predict -- whether it was the path of ballistic missiles or the movements of ground troops -- and then quickly react was the decisive factor for the Allies in the Gulf War. In the process, time seemed to accelerate, such that the real ground war, expected by many experts to drag out for months, in the end essentially lasted only 48 hours. Because the Allies knew so much about the deployment and behavior of the enemy, they could encircle and destroy the Iraqi troops with certain knowledge there would be no significant resistance.

Getting the Information Right

That is war, with its unique intensities and skills. Can information really be of comparable importance in business?

The answer is a qualified yes. Certainly better information won't allow American Airlines to annihilate US Air overnight. Sears won't vanish tomorrow because Wal-Mart and K-Mart use information more effectively. Motorola won't destroy its Japanese semiconductor competitors because it has a better information gathering network. However, over time better information *can* translate into a decisive competitive advantage. It can be said, with certainty, that if two competitors are equal in other respects, the one making the best use of information will undoubtedly win . . . sometimes with stunning speed.

Consider how Toyota, the world's most successful automobile company, sells cars in Japan. Toyota has shown the competitive power that can be gained by adding electronics to an efficient, low-tech, information reporting system. The Machine that Changed the World describes how Toyota also used computer intelligence to amplify an established information reporting program in its distribution system.

Like many Japanese auto companies, Toyota long sold automobiles door-to-door. It is an unusual process outside Japan, but it has also led to a tight relationship between company and customer. In doing so, Toyota has probably learned more about its buyers than any U.S. or European car company:

"Toyota was determined never to lose a former buyer and could minimize the chance of this happening by using the data in its consumer data base to predict what Toyota buyers would want next as their incomes, family size, driving patterns, and tastes changed. . .[1]

"[Sales] team members draw up a profile on every household within the geographic area around the dealership, then periodically visit each one, after first calling to make an appointment. During their visits the sales representative updates the household profile: How many cars of what age does each family have? What is the make and specifications? How much parking space is available? How many children in the household and what use does the family makes of its cars? When does the family think it will need to replace its cars? The last response is particularly important to the product-planning process; team members systematically feed this information back to the development teams."[2]

It should be noted that in recent years, as door-to-door selling has grown too expensive, Toyota has begun a gradual shift toward dealerships in Japan. But even these dealerships are nothing like their U.S. counterparts. Because Japanese car makers are increasingly virtualized -- that is, automobiles can be custom ordered and delivered in a matter of days -- dealerships are often little more than storefronts, with a few sample cars.

A typical experience for a Japanese automobile customer:

"The first thing a consumer encounters on entering a Corolla dealership today is an elaborate computer display. Each Corolla owner in the Corolla family has a membership card that can be inserted in the display, just as one would insert a card in a bank machine. The display then shows all the system's information on that buyer's household and asks if anything has changed. If it has, the machine invites the owner to enter new information.

The system then makes a suggestion about the models most appropriate to the household's needs, including current prices. A sample of each model is usually on display in the showroom immediately adjacent to the computer display."[3]

That's not all. Using the same terminal, potential customers can also access information on insurance, financing, even parking permits. They can even learn about used cars, if they so wish.

Record keeping on processes inside the firm has been equally extensive. There Toyota uses its famous production system, centered around *kanban*.[4] Kanban is a simple system of cards attached to part bins that track the progress of those parts through the production process, serving as both a tracking tool and an order form for new parts. In the past, with kanban, Toyota could use information management to obviate the need for warehouses and high inventories, escape the roller coaster of over- and under-production by its suppliers and implement the first 'just-in-time' production system . . .and do it all without computers.

When computers did come to the Toyota factories they were smoothly integrated into the process, because Toyota already understood the flow of information in its production areas. Just as important, Toyota workers were committed to making both the kanban and automated information processing systems work. Labor and management worked as a team. This second lesson was lost on many companies, most famously General Motors, which rushed to install computers and robotics before it fully understood the information-worker culture in its plants, and the relationship between its factories and dealers.

Within the GM factories, the environment was poisonous to the notion of teamwork and shared information. Says Maryann Keller in Rude Awakening, ". . .the workers wanted to do their jobs well, wanted to be competitive, but all too often they were fighting against unbeatable odds to get their jobs done. Every problem became a confrontation; since there was a basic mistrust between labor and management, it was hard to establish a cooperative environment where problems could be solved."[5] Fittingly, it took a joint venture with Toyota, the Nummi plant in Fremont, California, to show GM how far it had fallen behind in the business it once dominated.

General Motors suffered a similar breakdown in information transfer in its relationship with dealerships. Like other U.S. car makers, GM expected its dealers to accept unsalable cars they didn't want, often by tieing them in with delivery of more desirable models. According to The Machine that Changed the World, in describing the Big Three U.S. auto makers:

"To make matters worse, coordination between the sales division and the product planners in the big mass-production companies is poor. While the product planners conduct endless focus groups and clinics at the beginning of the product-development process to gauge consumer reaction to their proposed new models, they haven't found a way to incorporate continuous feedback from the sales division and the dealers. In fact, the dealers have almost no link with the sales and marketing divisions, which are responsible for moving the metal. The dealer's skills lie in persuasion and negotiation, not in feeding back information to the product planners."

"It's sobering to remember that no one employed by a car company has to buy a car from a dealer (they buy in-house through the company instead, or even receive a free car as part of their compensation package). Thus, they have no direct link to the either the buying experience or the customer. Moreover, a dealer has little incentive to share any information on customers with the manufacturer. The dealer's attitude is, what happens in my showroom is my business."[6]

These weaknesses in information management may not be fatal for General Motors, but the resulting lack of understanding of the needs of the market has contributed greatly to the firm's loss of market share. The danger of this lack of information becomes even more obvious when one considers that the design cycle on Japanese cars is, on the average, more than a year faster than the five year cycle of U.S. car makers.[7] This puts the Japanese manufacturers in a far better position to track changing market tastes and then quickly design new models to meet them.

The Toyota story shows that computer technology can be used to reinforce already-efficient manufacturing and direct-sales information systems. This access to the market in turn acts as an early warning system for the company about any sudden shifts in customer attitudes. As much as any company in the world, Toyota understands the power of information.

One U.S. company that *did* appreciate the Toyota story was Hewlett-Packard Co. When HP decided to bring computer power to the organization and control of its manufacturing it chose this as its charter:

Getting the right information to the right people at the right time to achieve our business objectives.[8]

What makes this statement remarkable is that Hewlett-Packard is one of the world's largest manufacturers of computers used in design, process control, and inventory management. Yet, there is no mention of computers in the statement, only of the efficient use of information. The implicit message is that any effective means of information transfer is acceptable.

If hand-written notes can do the job, use them; if it means the fully networked data processing hierarchy known as computer integrated manufacturing, use it, too -- as long as it gets the right information to the right people at the right time to achieve Hewlett-Packard's business objectives.

Bolts of Information

Another example of the way information can transform a business, this time in distribution, is the "Quick Response" (QR) movement in the U.S. textiles industry. QR has been driven by fabric giants Milliken and DuPont and by such retailers as J.C. Penny, K Mart, and Wal-Mart.[9]

Challenged by off-shore competition, Milliken set out to obtain the maximum advantage from its proximity to U.S. customers. This meant bringing technology to bear to slash the time between the appearance of a new fashion and its arrival in volume at retailers.

A model for these firms was the Italian company, Benetton, which had made its mark delivering knitted goods in the hottest new colors seemingly overnight. One way Benetton did this was to invert the traditional method for manufacturing sweaters. Instead of dying the yarn and knitting the sweaters, it knitted sweaters with a neutral yarn and then dyed them to meet market demand. That way, should the market go from blue to green overnight, Benetton could not only quickly respond but also not be stuck with obsolete inventory.[10]

A study of the U.S. garment industry had determined that it took an average of 66 weeks to complete the process of converting raw materials to textiles to apparel and then moving it through the distribution channel to the retail consumer. In the fast-moving world of fashion this was slow enough to cost the industry an estimated $25 billion per year in lost potential business. Most of this damage occurred at the retail end, where an estimated $16 billion was lost each year from markdowns, lost potential sales on out-of-stock items and excess inventory.

The problem, in part, resulted from a breakdown in the means for passing newly obtained information backwards through the supply chain. Information about a decline in sales of a particular style would slowly worm its way back from the cash register to the buyer; then to the garment manufacturer and from there to the textile firm and then on to the fiber manufacturer. As orders were cancelled at each point along the supply chain, valueless inventory would pile up.

The obvious solution -- that of simply hustling the goods through the system faster -- turned out to be inadequate for the situation. There would still be too much waste. Instead, a two-way system was needed, in one direction speeding the apparel down the distribution channels, and in the other direction feeding back results to each upstream participant.

To see if this theory was right, a research firm set up three pilot runs. The results were staggering. One quick response chain involving Belks and Haggar (jackets and slacks) saw sales jump 25 percent, gross profits up 25 percent and inventory turns leap 67 percent. A pilot QR chain in tailored clothing involving J.C. Penney, Oxford and Burlington not only saw sales up 59 percent and inventory turns climb 90 percent, but cut forecasting errors by more than half. Similar results were seen by Wal-Mart, Seminole, and Milliken in tests with slacks.[11]

The QR system, with its overlapping feedback loops of information, had proven itself. Just as important, the participants in the program had learned to trust one another with what was once proprietary information, such as sales, orders and inventories. Reports Joseph D. Blackburn of Vanderbilt University: "The first step in a quick response program is to find willing partners. As in other industries, finding partners is challenging because, as an industry spokesman states, 'In your traditional relationships, what's out there today is lack of trust. Nobody trusts anybody. Breaking down those barriers is not easy, but that is the key to quick response. There's got be a lot more communication. In quick response programs or any other program where change must be made, it is harder than the old way of doing business. A lot harder'"[12]

Blackburn adds: "Adversarial relationships block communication and inhibit the unfettered flow of information needed for effective supply chains. . ." As with Toyota, only when the informational and cultural systems were in place could electronics be inserted into the program to amplify its strengths.

The key technologies of QR proved to be computer networks, bar code systems, and scanners. Wal-Mart alone invested one-half billion dollars in QR point of sale equipment.[13] Now a retailer could scan the bar code on a given item being sold and instantly pass the information on that sale all the way back through the chain to the textile maker. Not only was the style of the product recorded, but also information on color and size, and that information served as the underpinning of a fast just-in-time inventory system along the distribution chain.

By the end of the 1980s so efficient had the QR system become -- and so high the level of trust amongst its participants -- that different players began to use additional technology to tighten the system even further, and in the process approached delivering the virtual product. One such example is described by Blackburn:

"In this case, Milliken supplied the finished product, an oriental rug-design area rug to a major retailer. Milliken made the following offer to the retailer: 'You send us the daily orders that you get from the consumer, we will manufacture the rugs and ship UPS directly to the consumer's home.' This meant that the retailer could eliminate not only his entire distribution center for that product, but all of his inventory except for display items in the showroom. The retailer responded, 'That will work only on regular sales, but commercial sales are such a spike [in demand] in our sales pattern that we've got to carry inventory to cover the spikes.' Milliken responded by asking, 'What percent are the spikes?' It turned out that two-thirds of their sales were promotional. If they guessed wrong on those two-thirds of their sales, they had excess inventory. Milliken then said, 'It's all or nothing. It's either quick response or it's not quick response; we will satisfy your orders. Now you have to tell us when these big spikes are coming. We have got to share that kind of information.' The retailer agreed and now Milliken is taking orders on a daily basis and shipping directly to the consumer. The system responds much faster than through the traditional [distribution center] channel and with a fraction of the inventory. Moreover, the retailer's costs were slashed by 13 percent."[14]

Coordination and Control

This pivotal role of information management in the corporation is something that has occurred within our lifetimes. In The Visible Hand, a history of the management of American business from 1850 to 1930, author Alfred Chandler argues that the modern corporation was built on capital, management, and energy (and with it, material) intensiveness. [15]

The advent of the virtual corporation will add information to that list. The success of a virtual corporation will depend on its ability to gather and integrate a massive flow of information throughout its organizational components and intelligently act upon that information. In the process, the very nature of this information-intensity will make the virtual corporation *less* capital, management and energy intensive. This represents one of the fundamental breaks between the virtual corporation and contemporary business enterprises. The virtual corporation will significantly alter the traditional internal balance of individual businesses and of the economy as a whole.

It is Chandler who noted that the first management hierarchies appeared in the railroad industry in the 1850s in response to a need to provide and analyze the information needed to run these complex enterprises.

"No other business enterprise, or for that matter few other non-business institutions, had ever required the coordination and control of so many different types of units carrying out so great a variety of tasks that demanded such close scheduling. None handled so many different types of goods or required the recording of so many different financial transactions."[16]

As corporations in other industries began to experience the same complexity of size and scope in their businesses, they too moved to adopt multiple level hierarchies of management. General Motors in its heyday boasted of nearly twenty levels of management, as did IBM and General Electric.[17]

As these and other companies have struggled to boost efficiency and become ever more market responsive, they have stripped out layers of management and broadened the span of control of the managers that remain. For example, in June 1991, GM restructured its giant Chevrolet-Pontiac-Canada Group, by itself one of the 20 largest businesses in North America, by turning three engine groups into one, cut 13 free-standing parts making operations to just eight, in the process "pruning away several vice presidencies" and expanding the responsibilities of the rest.[18]

Today the trend in management is to delegate ever more decision-making and control to the employees doing the actual work. Computers now gather and supply the information that was once provided by management hierarchies. In the process, training has had to be substituted for supervision. The modern employee is expected to use the information gathered by computer networks and know what to do instead of having to be told. One proven way of doing this has been through quality circles, groups of employees that regularly meet to discuss how to improve product quality and workplace productivity. Such programs teach employees how to analyze and solve quality problems with minimal management supervision.

In some cases, the lines between worker and middle manager essentially disappear. Rosabeth Moss Kantner of Harvard has written, "As work units become more participative and team oriented, and as professionals and knowledge workers become more prominent, the distinction between manager and non-manager begins to erode. . .Position, title, and authority are no longer adequate tools, not in a world that encourages subordinates to think for themselves and where managers have to work synergistically with other departments and even other companies."[19]

T.J. Rodgers, CEO of Cypress Semiconductor, has taken a technological approach to the challenge of removing layers of bureaucracy. Starting Cypress with the goal of maintaining a flexible, adaptive organization no matter how large the company grew, Rodgers from the beginning refused to allow a middle management to form. Instead, he installed a computer system to track the daily objectives of every company employee. Such a system, wrote Fortune:

> . . .allows him to stay abreast of every employee and team in his fast-moving organization. Each employee maintains a list of ten to 15 goals like 'Meet with marketing for new product launch,' or 'Make sure to check with Customer X.' Noted next to each goal is when it was agreed upon, when it's due to be finished and whether it's finished yet or not.
>
> This way, it doesn't take layers of expensive bureaucracy to check who's doing what, whether someone has got a light enough workload to be put on a new team, and who's having trouble. Rodgers says he can review the goals of all 1,500 employees in about four hours, which he does each week. He looks only for those falling behind, and then calls not to scold but to ask if there's anything he can do to help them get the job done. On the surface the system may seem bureaucratic, but it takes only about a half-hour a week for employees to review and update their lists.[20]

At one manufacturing company after another, middle management, the most populous of industrial professions a quarter century ago, is fast becoming an endangered species. Some executives have even grown vehement in their desire to root out what it sees as an impediment to success. Industry Week, quotes Richard C. Miller, founder and vice president of Aries Technology, as assigning middle managers much of the blame for American industry not adapting quickly enough to new technology. Says Miller: "I'm not real impressed with middle managers. Many are [just] hiding out until they retire. There are times when I would like to take middle managers by the necks, bang them against the wall and ask: 'Don't you realize the company is going to be out of business in five to ten years if you take that attitude?"[21]

Similar opinions can be heard these days in services as well, such as in banking, accounting, and government. Not surprisingly, given this attitude, business is becoming less and less management intensive and increasingly dependent on competence at the worker level.

This is because, as computers gather and provide the information that was at one time the product of middle management and as employees have become better trained and empowered to make decisions, the role of management in the business of the future is bound to decline. Information and the power it provides will flow to the worker.

As for the energy intensity of business that Chandler identified as one of the cornerstones of the modern corporation, evidence of its decline is no further away than your Sony Walkman. Increasingly, the value of the products we purchase is determined by their sophistication and information content and less and less by their material/energy content. Nowadays, more powerful products don't necessarily weigh more, they just do more. Their value is a function of their information processing features.

For example, the items that boost the price on today's automobiles include sophisticated audio systems, anti-lock breaks, electronic controls for fuel, ride adjustment, traction, air bags, and electronic transmissions; and automatic control of temperature, seat and mirror position. All are highly prized features and important profit-makers for car companies. All are also highly information dependent and add little to the material content of the car.

Home electronic equipment has become ever higher in performance and capability and ever lighter in weight. The nineteen inch remote–controlled, 82 channel stereo color TV of today weighs only 20 lbs compared with its 60 lb. black and white, 13 channel dial, monaural predecessor of 1960. Today's mid-size color TV sells for about $20 per pound. A 386-type laptop computer weighs only about 12 pounds and sells for about $200 per pound. This compares to just $5 or $10 per pound for an automobile like the Ford Escort. The complexity of the information content is the defining factor.

Much of the added information value in modem products comes from semiconductors. And the semiconductor industry itself is one of the most impressive example of the energy conservative nature of information-intensive industries -- which is one reason why it is so important to a resource-poor nation such as Japan. A typical semiconductor manufacturing plant that produces $1 billion of output consumes just --- watts of energy. By comparison, a steel plant consumes ---, and an aluminum plant a remarkable--- watts for the same level of output. This makes semiconductors --- times more efficient that steel plants and --- times more efficient than aluminum ones in terms of dollars of output per watt.

In an information intensive world, supplying information and providing the capability to process it can add billions of dollars to the value of products without requiring much, if any, additional energy use. For example, the business of supplying financial information is a --- billion industry. The value of software annually sold with computer systems currently is ---. Information publishing is a worldwide industry of ---. Yet all three consume relatively little energy other than that required to cool, warm or light the offices of their employees. In just this way, the virtual corporation will depend upon the power of information, not electricity, to create value.

One can make a good case that the virtual corporation will be significantly less capital intensive as well. Lean production is 'lean' because it uses less of everything compared with mass production -- half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also, it requires keeping far less than half the needed inventory on-site, results in many fewer defects, and produces a greater (and ever-growing) variety of products."[22]

When companies successfully implement such systems they make more efficient use of capital equipment, reduce the need for much working capital, and increase the output per square foot of their factories. The "Quick Response" experiment of the textile industry demonstrates how virtualizing production, distribution and retailing can boost inventory turns and thus reduce the need for working capital.

Taiichi Ohno, inventor of the Toyota production system, has been quoted saying that his current project is "looking at the time line from the moment the customer gives us an order to the point where we collect the cash. And we are reducing that time line by removing the non-value added wastes."[23] By squeezing wasted time out of the system, as goods speed their way more quickly through production and into the customers' hands, sizable amounts of working capital will be saved.

That is the impact on manufacturing. One can also add that the generation of information intensive products is less capital intensive as well. One of the purest examples of this is software, and there the quintessential case is Microsoft, the dominant supplier -- $1.8 billion in sales -- of software for personal computers. Microsoft has grown to its present size with one of the fastest growth rates in American business history, while still generating the capital it needs internally. The company's public stock offering was primarily just to create liquidity for its owners.

Businesses that add value to their products by using information generally enjoy very high gross margins. Take a data base company, such as Lexus/Nexus, a supplier of information to the legal profession. Once it has incurred the cost of installing the computers and collecting the core data, that information can be sold repeatedly with little additional expense. By the same token, the variable costs associated with handling more reservations on an airline reservation system such as SABRE are practically zero.

One of the best examples of information-intensive products are the Intel Corp. microprocessors that power most of the world's personal computers. Intel enjoys an estimated 80 percent gross margin on each microprocessor it sells. Obviously, the value of these products rests not in the cost of their production but in the value of their information processing power to customers.

Levels of Understanding

So pervasive and fundamental is the role of information -- from the words in this book you are holding down to the strands of DNA in each of the trillion cells of your body -- that we often look right past it.

Most of this information is clustered into data bases, collections of information that range from the information in a Rolodex to the memories in a human brain to the banks of billions of bytes of data supporting a Cray supercomputer. The virtualization of society can be seen as the interlinking of relevant data bases into ever more extensive and integrated networks.

The data base we most often use during a typical day is stored in our own memory. In it we carry patterns of behavior, records about our friends and business associates, and rules about how to deal with the vagaries of daily life.

We augment this body of information with a growing number of other data bases. For example, there are the notes we write to ourselves, 'to do' lists, address books, calendars, and computer data bases. We also transmit this information to others via written and spoken word, physical delivery systems such as the postal system and Federal Express, and by electronic means such as fax and the telephone.

Not only are we receptacles of information, but also generators of information that induces and controls the action of others. To see that, take an average workday. An engineer generates designs that encode information in the form of specifications that are transported to others to define the nature and form of a manufacturing process. An architect does the same thing in the blueprint for a building. A stockbroker transmits information and its analysis to clients about market behavior to induce buy and sell orders.

In fact, in modern life, a significant portion of the population that works in service industries does little else but process and manipulate information. Consider the work of lawyers, accountants, advertising account managers, newspaper reporters, and thousands of other service careers.

Here at the end of the 20th century, four decades into the computer age and at the threshold of the virtual revolution, it is increasingly obvious that the very nature of business itself is information. Many of the employees in any corporation are involved in the process of gathering, generating or transforming information.

In a typical modern automated industrial firm only a small fraction of the workers are actually involved in physical work -- perhaps less than 5 percent, according to ______. But even among that tiny population, information has revised the workplace.[24]

In the age of numerically controlled machines and robotics, manufacturing has become yet another information process where machine instructions stored in computer memory describe how a piece of metal should be rolled, lathed, stamped, welded, bolted or painted. Fewer and fewer human beings are actually involved in the production process. Instead, most workers in manufacturing companies are now involved in producing services. They deal mostly with information. They sell products to customers and service their needs; they are involved in manufacturing overhead processes to assure that the right products are produced and that the proper materials required are readily available; they administer and control the operation; develop plans and strategies; and they design the products and services they have determined the customer desires. This is as true in the most traditional of industries — steel, automobiles, railroads, tool and die, and construction -- as it is in the most modern, such as computer workstations and bioengineering.

In service industries as well, major portions of the work force engage in processing information. In a typical airline just --% of the work force are involved in flying the planes, feeding the passengers, handling the baggage, or maintaining and servicing the planes. Most are involved in generating and using the information required to run the business. Similarly, the vast majority of the employees in a typical financial services firm are involved in information gathering, processing, and generating customer services based on information. The same is true for newspapers, television, and advertising.

All of this suggests to us the following:

The rate of progress of modern business depends on its ability to generate and process information.

It is important to ask: what kind of information? Accuracy aside, all information is not equal. In fact, the information of use to a corporation falls into four distinct categories. Until recently, only the most elementary one has been available to industry in any systematic and manageable way. Obtaining or generating the other three has only become economically feasible in recent years. Learning how to acquire and work with these other information forms not only will be important, but will be the basis of the virtual corporation.

These four forms of information are classified as *content*, *form*, *behavior*, and *action*.

Content information formed the basis for the modern corporation, as described by Chandler.[25] It is information about quantity, location, and types of items. For example, a simple inventory system includes information about the number of parts of a particular type and where they are located. Other related files may describe the specifications of these parts. Databases on personnel can contain addresses, employment and salary history, and some personal data on employees. Customer files contain data on credit, past activity, orders, credit history, etc.

Content information is historical in nature, a record of what has happened. It records what an employee has done and when an individual was born or where inventory has been stored or what a customer has ordered. Content information is what typically used to reside in a file cabinet, and then was transferred to punched cards and now fills the memory of a personal computer in a personnel department or on a loading dock.

Until the 1980s, the computer industry was built on the ability to process content information for business. IBM's dominance of the commercial computer business was a direct result of the fact that it did a better job of processing and integrating content information for business than any of its competitors.

Form information describes the shape and composition of an object. In comparison to content information, form information can be quite voluminous. The content information about a Ford Sable might describe its color, the type of options installed in the car, the price, and where the vehicle is located in the distribution system. The form information on the same car would describe the shape of every component in the system. It would contain data on the precise shape of a piston, the materials and processes used to manufacture it, and the acceptable tolerances. Millions of bytes of data are required to store the form data for the same automobile that would be described by a few hundred bytes of content data.[26]

A good illustration of the differences between content and form information can be found in the data associated with a typical American home. The content information on such a house -- lot size, square footage, tax burden, mortgage payable -- constitutes a few hundred bytes on a tax roll or in the computer at a title office. But to describe the form of that house on a computer system using, say, Autodesk software, would require _____ million bytes of storage and ___ million computer operations.[27]

Billions of computer operations are often needed to generate the huge databases that describe form. Twenty years ago this data might have taken weeks, even months to generate. As computers have become faster it has been possible to generate comparable form data in a matter of hours, even minutes. That compression of time, and its commensurate reduction in processing cost, has made the use of form information feasible for a growing number of businesses.

Content information is a record of the past. Form describes shape. Neither offer much of a glimpse into the future -- and successful forecasting is a hallmark of business competitiveness. Successful forecasting requires the ability to simulate, often in real time, how a system is going to perform. That would enable us to understand each system's behavior.

Behavioral information often begins with form information and usually requires massive amounts of computer power. To predict the behavior of a physical object a computer must be able to simulate its motion in three dimensional space through numerous discrete steps in time. To simulate the performance of a microprocessor circuit containing one million devices and operating at 100 megahertz (millions of cycles per second) for a single second means the computer must determine the states of one million devices for every one hundred millionths of a second of simulated time. The computers and information processing techniques required to perform these kinds of computations are only now coming within reach.

Powerful workstations supplied by companies such as Sun and Silicon Graphics make it possible for engineers to do this type of analysis at their desks. Computer simulations have also proved to be an extremely effective tool for molecular design. The simulation of a complex organic molecule on a Molecular Simulations Inc. system may require anywhere from 18 billion to two trillion computer operations.[28] In an example closer to the lives of most readers, Boeing uses sophisticated simulation information to study the behavior of aircraft wing designs under stress.

The usefulness of behavioral information as an alternative to expensive, destructive or even dangerous real-life testing has even been recognized in more mainstream industries. "We're at a turning point because of the drastically reduced prices of these [new computers]," George Dodd, head of computer science at General Motors' research labs told The Wall Street Journal. According to Dodd, engineers will soon be doing tasks that they once only dreamed of, such as crash-testing cars on desktop computers, instead of smashing into concrete walls. And, possibly, designing car parts entirely by computer.

With accurate simulations it is often possible to build a flawless or fail-proof device the first time. Of course this is only practical if the cost of simulating the result and the time to perform the simulations are much less than the cost of building the prototype in the first place. The extensive use of behavioral information in the last few years, has become possible as computer processing power and memory storage prices have fallen within range.

The paradigmatic example of this for our time is the Boeing's design of its new 777 airliner, the largest project ever undertaken by computer alone. Costing an estimated $5 billion, it requires 7,000 specialists in 200 'design-build teams' linked together by seven mainframe computers and 2,800 workstations. The plane will even be 'electronically pre-assembled' long before it reaches the manufacturing floor. Despite this mammoth production, Boeing believes computer design will cut the total project cost by 20 percent.[29]

With behavioral information, many design disasters of the past might have been averted, reduced to mere laboratory curiosities. Using behavioral information, a potential and unforeseen future tragedy can be replaced with a successful and predictable conclusion.[30]

Even more opportunities to use behavioral information are waiting in the wings -- the so-called "grand challenges". These include the prediction of weather, analyzing atomic structure to create new materials, understanding how drugs affect the body, locating and extracting oil, and understanding the interplay of substances in combustion systems.[31]

According to Kathleen Bernard of Cray Research, "Problems such as these can require a trillion [operations] per second and billions of words of memory" — power only a thousand times greater than is available today.[32]

The final triumph of the information revolution will be the use of a fourth type of information: information that instantly converts to sophisticated Action.

As computing power grows inexorably cheaper, compact, and more powerful, it is possible to build machines that not only gather and process information, but act upon the results.

Needless to say, simple feedback machines capable of basic action have been around for years. The standard home thermostat is a good example: it senses temperature and then turns on or off the heat to maintain the house at a constant temperature.

Today's action information machines are vastly more sophisticated. As industrial robots, they can accept information and use it to shape mechanical parts, inspect and pick and place parts, or, in a scenario right out of science fiction, build the next generation of industrial robots.[33] In other incarnations, they can evaluate requests for money at an ATM, laser cut a metal shape to order, understand and execute human voice instructions, or build dishwashers at General Electric's celebrated $300 million Louisville plant.[34]

These are but early applications of action based information. Just as form information and behavioral information need both cheap storage and inexpensive processing power, managing action information requires all that came before it, plus inexpensive interfaces to the natural world. This means analog-to-digital converter chips, man-machine interfaces, inexpensive sensors, and sophisticated machine vision systems.

Most of these technologies are already in development. For example, Synaptics Inc. is experimenting with techniques to provide machines with human-like vision -- a process that will require not only massive amounts of computing power, but also organizing that power into brain-like 'neural networks.'

These advances suggest that our lives will increasingly be dominated by machines that perform tasks for us. In many cases this will be a less personal world; the first clues can be experienced now whenever we deal with an ATM rather than a human teller, or when our phone calls are answered by a voice mail machine. Not all of the changes will be so obvious, of course: when we step on the anti-lock breaks in our car, it is a computer that tells the system how rapidly to apply and release the pressure.

Work life will also feel the change. More and more factories will operate with 'lights out', devoid of humanity except for the occasional passing guard or visiting repairperson. One likely effect of this will be a kind of corporate future shock.. For hundreds of years, businesses operated using only one type of information. Each generation found new and more effective ways of gathering, processing and using this information. Now, in just a single generation, three new kinds of business information will be available. Learning to use these new forms will require cognitive changes in both management and the workforce.

As resistant to this change as they might be, many companies may find no alternative but to use form, behavioral, and action information -- if only because the edge they might give a competitor would quickly be decisive. With form information, that competitor might be able to eschew the cost and time of prototyping; with behavioral information it might better predict the future; and with action information it can run automated factories and provide customers with adaptable products. That is simply too much of an advantage in a competitor for even the largest firm to withstand for long.

While any precise vision of the future may be clouded, it is obvious that the virtual corporation will increasingly rely on devices that harness, integrate, and effectively use these new types of information. Information will be the core of the virtual corporation. A company's ability to operate and create products and services will be dependent on its information gathering, processing, and integration skills. Content information will continue to determine the state of the business. Form information will make it possible to define the products to be produced. Behavioral information will test those models in use. And action information will pull it all together into the actual manufacture, testing, and distribution of the finished goods and services. A virtual corporation will be defined by its ability to master these new information tools.

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[1] The Machine That Changed the World. James P. Womack, Daniel T. Jones & Daniel Roos, Rawson Associates/MacMillan 1990. pg. 67

[2] ibid, pg 182

[3] ibid, pg 189

[4] Toyota Production System. Taiichi Ohno, Productivity Press, Inc. English Edition 1988.

[5] Rude Awakening, Maryann Keller, Harper Perennial, 1989, pg. 127

[6] The Machine that Changed the World, pg. 173.

[7] ibid, pg 118.

[8]

[9] "The Quick Response Movement in the Apparel Industry: A Case Study in Time-Compressing Supply Chains" by Joseph D. Blackburn, in Time-Based Competition, Business One/Irwin, 1991, Chapter 11.

[10]

[11] ibid.

[12] ibid, pg. 254-5

[13]

[14] ibid, pg258

[15] The Visible Hand, Alfred D. Chandler, Jr., Belknap Press/Harvard University, 1977. pg. 280.

[16] ibid, pg. 94

[17]

[18] "GM Will Run Big Car Group Like Japanese," The Wall Street Journal, June 10, 1991. pg A3.

[19]

[20] "The Bureaucracy Busters," by Brian Dumaine, Fortune, June 17, 1991. pg. 46.

[21] Factory Automation, special report, Industry Week, June 20, 1988. pg 44.

[22] The Machine that Changed the World, pg. 13.

[23] Ohno, Taiichi, Toyota Production System, Productivity Press, English translation 1988. From the Publisher Forward by Norman Bodek, pg ix

[24] Bill, not in Scientific American article, nor in Manufacturing Matters. Suggestions?

[25] Chandler

[26]

[27] Autodesk is calling back with these numbers.

[28] Source: Barry D. Olafson, PhD. of Molecular Simulations Inc.

[29] "Change is in the Air as Boeing Builds New 777" by George Tibbits (AP) San Francisco Examiner, October 6, 1991, pg. E3 and "Picture Perfect" photo essay, Business Week/Quality 1991. pg. 96.

[30] See the Tacoma Narrows Bridge story in chapter 6.

[31] "Ordering Chaos," by Kathleen Bernard, Technology 2001, pg. 82.

[32] ibid.

[33] This appears to be what is going on at the very secretive Japanese robotics firm, Fanuc.

[34] Factories of the Future, special section, Industry Week, March 21, 1988, pg. 44.

Chapter 4: The Upward Curve of Technology

The sudden and sweeping transformation of business through technology is nothing new. The locomotive, automobile, airplane, transistor and integrated circuit, just to name some well-known examples, have each in their time overturned the status quo. Historically, whenever important technological innovations have caused an order of magnitude (that is, a ten times) improvement in the existing order, the result has been a revolutionary change in the way people live their lives and conduct their business.

Easily the most famous example of such a change was the industrial revolution. The traditional date for the beginning of the industrial revolution is 1770, with the construction of the first textile machines and the first general industrial usage of steam power in England. From that date to 1851, the time of the International Exposition in the Crystal Palace, the productivity of the textile, iron, and steel worker increased by a factor of about 300 -- or just over two orders of magnitude.[1]

This jump, greater than the combined productivity improvements of the previous fifty generations, was made possible by an efflorescence of inventions, everything from steam power to simple punched card Jacquard loom programming to the Bessemer process for creating steel. Not only did each of these inventions make a profound change, but their interaction and cross-fertilization rewove the social fabric. As the great British naturalist D'Arcy Thompson wrote in 1895, "Strike a new note, import a foreign element to work and a new orbit, and the one accident gives birth to a myriad. Change, in short, breeds change . . ."[2] Much of the world in which we live is the result of these early Victorian industrial and social transformations.

Order of magnitude advances and their dramatic effects also can be clearly seen in the history of transportation technology. Early man could only carry small loads. Because of that, his principal activities were confined to hunting or gathering food and constructing shelter. In the ages that followed, the wheel was invented, powerful animals such as the horse, camel, and elephant were tamed and crude boats constructed. With those advances, it became practical to carry not just 50 pounds, but 500 or even 5000 pounds. The resulting surplus made primitive forms of trade possible. By the time of Christ, merchant ships with 500 tons dead weight were not uncommon. Ancient histories record Hiero II of Syracuse having built a warship weighing 4200 tons by 250 B.C.[3] and, perhaps apocryphally, in 332 B.C. of Ptolmey Philopator constructing a type a catamaran -- a 4,000 rower tesseraconter -- capable of transporting 2,800 soldiers.[4]

Trade, made possible by improved transportation, was responsible for the growth of great cities such as Carthage and Rome. Improved methods of transportation enabled farmers to transport necessary grain to dense population centers which otherwise would have been incapable of supporting themselves. The free flow of goods permitted cities to specialize production, leading to the development of skilled work and guilds. Inevitably, countries once widely separated came into contact and felt the need to protect their spheres of influence.

The ability to move large groups of material and equipment over great distances changed the nature of warfare. War was no longer an event that took place almost exclusively between local tribes on a small scale. As early as 490 B.C. it was possible for the Persian fleet to transport 100,000 soldiers across the Aegean Sea to Marathon to fight the Greeks.[5] Order of magnitude advances in shipping made possible regional commerce and regional war.

For the next 2300 years, however, advances in maritime technology would be incremental, such as with square rigging and the compass. From the trireme to the galleon to the man-of-war, the change would be one only of degree. The next great order of magnitude change on the sea would come during a twenty year span in the mid-19th century with the arrival of steamships. As one writer put it, "The great three deckers of 1850 were no different from the carracks of 1450 except for slight modifications in hull shape, a few sail changes, and a certain amount of improvement in the making of firearms. By contrast, a three-decker of 1850 was a completely different vessel from an ironclad of 1880-1890 . . ."[6]

Much the same thing occurred on land. From the chariot and wagon to the Wells Fargo stagecoach and the Conestoga wagon, the rate of progress of land transportation remained glacial for nearly four millennia. Perhaps the only real order-of-magnitude breakthrough during all those years was the canal, a hybrid of land and water transportation with considerable advantages but only limited application. Otherwise, advances in land transportation were limited to improvements in axles, wheels and suspension, and to roads.

This changed with the invention of the steam engine and its use in locomotives. According to Chandler, rapid, predictable, reliable, rail transportation made the modern corporation possible.[7] The railroads changed the economic destiny of America. But that change was nothing compared to the transformation that took place in society when the speed of personal transportation advanced from the six or so miles an hour of a horse drawn buggy to the sixty miles an hour of an automobile. The 'car culture' that emerged redistributed the population, and reorganized the family.

The airplane brought another order of magnitude advance in transportation speed. The image of the airplane shrinking the world is a cliche derived from everyday experience. With time no longer a constraint, the average citizen could visit more remote places in the world in a week than a Columbus, backed by a national treasury, could see in a lifetime.

It is important at this point to note that the first order of magnitude advance in the speed of travel -- from horse to automobile -- took more than four millenia to consolidate. The second -- from automobile to passenger jet -- took less than a century.

In our time, a most dramatic, and certainly the most unpleasant, jump in technological capability occurred with the development of the atom bomb. Man's ability to deliver explosive terror on his enemy went from about 2,000 pounds of TNT per bomb dropped during World War II to 10,000 times that during that war's last week.[8] On August 6, 1945, the Enola Gay dropped the Little Boy atomic bomb on Hiroshima. It exploded with an estimated force of 12,500 tons of TNT.[9] This was enough to end the war with Japan in a matter of days, reorder world power, and grip the world in terror of eminent destruction for a half-century. All this came from an overnight advance of about four orders of magnitude in destructive power.

The historical examples cited above both illuminate and strongly suggest the status quo can be dramatically altered by order of magnitude changes. If indeed, order of magnitude advances can occur quickly and unexpectedly, then we should be both vigilant and prepared to react to extremely rapid rates of change.

In fact, there is one area of technology where order of magnitude changes occur regularly not every century, but every few years, have been doing so for decades, and promises to continue at this pace, or better, well into the next century. The field is information and communication sciences -- computers, mass storage, software, and telecommunications. And as if that weren't enough, these stunning advances can be easily integrated with other emerging technologies to multiply their force. It is this perpetual transformation, achieving a technological leap comparable to the forty century path from horse cart to bullet train about once per decade, that makes the virtual revolution inevitable and immediate.

As discussed in the previous chapter, the virtual corporation needs vast amounts of low-cost information storage and processing at its disposal to deal with form, behavior, and action information. On top of that, it must transmit this information quickly and inexpensively around the world.

The best way to appreciate how all this happened so quickly is to begin with Moore's Law and its implications for business. During the early 1970s, in preparation for a conference speech on the future of memory chips, Silicon Valley pioneer Dr. Gordon Moore sat down and plotted on logarithmic paper the capacity of each past generation of computer memory chips.[10] He then also plotted the same features for future chips of this type (random access memory, RAM) planned by his company, Intel Corp.

To Moore's amazement, the graphed points made a straight line. It seemed that every two years, the complexity of these memory chips doubled. He knew his industry had been advancing quickly, but even to Moore this graph was a surprise.

Extending the line still further, Moore predicted that it would take only the twenty years to 1991 to go from the 1000 bit dynamic RAM of 1971 to volume production of 1 million bit memory chips. At the time, the very idea of such a powerful chip was fabulous . . .but history proved Moore correct.[11]

Says Denos C. Gazis of the IBM Research Center, "The net result is that we are able to quadruple the density of memory chips roughly every three years. And progress is accelerating."[12]

As it turned out, Moore's Law applied to other integrated circuits as well. Ultimately, this insight has permanently shaped the vision of the electronics industry.

To fully appreciate the sweep of Moore's Law requires a little history. Shockley, Brattain, and Bardeen invented the single circuit transistor in 1947. In the forty-five years since, that single transistor has been miniaturized and packed with others of its kind into single integrated circuits containing a total of more than *30 million* transistors and capacitors. The resulting sixteen million bit dynamic RAM represents more than a seven order of magnitude increase in capacity. And that is just the beginning. The *billion* bit single chip semiconductor memory is already waiting just beyond the beginning of the 21st century, representing a nine order of magnitude jump in just over a half century.[13]

Thanks to the advances suggested by Moore's Law, by the early 1970s, semiconductor memory had become cheap enough to replace magnetic core memory, the principal storage device in computers. At the time this occurred core memory cost about five cents per bit. Twenty years later semiconductor memory was available for one-thousandth of a cent per bit, a four order of magnitude improvement.[14]

Improvements in semiconductor price/performance have always had a ripple effect upon computers. As Kenneth Flamm, of Brookings Institute told Datamation, "It's always been the cost of computing power that has driven computers and their applications, at the low end as well as the high end. Every time the prices tumble like a rock, there's a huge expansion in demand for computers and new applications."[15]

Plotting the price/performance of computer central processing units, internal memory, disk storage and complete systems between 1957 and 1978, Flamm found all showed a nearly straight line improvement of 25 percent per year in real dollars -- a 1,000 times improvement in just two decades. And Flamm believes the annual gains have been even greater since.[16]

How far the process has gone in forty years can be seen in UNIVAC I, the 1950 descendent of ENIAC. It weighed 16,000 pounds, had 5,000 vacuum tubes and performed 1,000 calculations per second. UNIVAC I was the first commercial computer, though only six were built, three of which were sold to the U.S. Census Bureau at $250,000. [17] By comparison, a contemporary computer at the same price, the MIPS 6000, is about the size of a file cabinet and races along at 55 *million* calculations per second.[18]

The ripple effect of these gains spread throughout the computer industry, touching all. For example, in 1991, Gazis would estimate that "my own personal computer has about 5 times as much power and storage capability as IBM Research provided to our entire Yorktown laboratory when I joined the company in 1961."[19]

The computer's information storage underwent a similar leap. A good measure of that advance can be found in comparing a General Electric disk drive of 1961, with its 25,000 bits per square inch, with a Hitachi drive announced in late 1991 featuring 151 million bits per square inch -- a 6,000 times improvement in just 30 years. [20]

Comparable improvements have taken place in power consumption as well. That might not seem important until you look inside your home computer and see a power supply about three inches on a side. If it had to be one million times larger, that power supply would be twenty five feet on a side. With that, the world's current installed base of ___ million microcomputers would be on the verge of sucking dry the world's electrical power grid. It is the miserly use of power by integrated circuits that makes it possible to pack computer intelligence just about anywhere -- on a desk top, in a Patriot missile, or in a video game.

Riding a Tidal Wave

Moore's Law is the most sweeping elucidation of the pace of invention in the electronics era. But there were other, lesser-known, jumps in performance in other areas. One of the least known, but perhaps most important of these, has been improvements, by many orders of magnitude, in system reliability.

ENIAC in its day, was almost perpetually out of commission: its thousands of tubes cooked the interior of the building that held it at 120 degrees F. "Search-and-replace teams combed the machine for blown tubes while other engineers scurried about rewiring major portions of ENIAC to conform to the dictates of each new trial run."[21] By comparison, modern 'fail-safe' transaction computers built by Tandem and others are designed for trillions of computations between breakdowns. This remarkable improvement in reliability has made it possible to use computers in critical automation processes, such as life-support, factory operation, and airplane flight control, without the fear of frequent failure.

Strictly speaking, one cannot add all the advances together because there would be double counting. It can be said, however, that in forty years computing has experienced a combined improvement in five dimensions -- mass storage, reliability, cost, power consumption and processing speed -- of thirty orders of magnitude.[22]

A thirty orders of magnitude change is a factor almost beyond human compass. The jump from a single atom to the Milky Way galaxy is only a 27 order of magnitude change. And, as we noted above, it took just a two order of magnitude change to spark the Industrial Revolution and only a four order of magnitude change in explosive power to end a World War and redirect human history.

As remarkable as it seems, it will take every one of these 30 order of magnitude improvements in the world of computing to deal with the form, behavior and action information required by the virtual corporation. The fact that we are almost there is one of the miracles of the age.

Inventions and their interactions will be the engine of the virtual revolution. A recent study by the Wharton School of Business set out to look at the changing nature of business competition in the 21st Century and the technologies that would be critical to that competition.[23] Determining that high speed capital and technology transfer, access to cheap labor and collapsing product and life cycles would bring about a radical change, the study concluded that "continuous corporate renewal" will be required to remain competitive -- and that wealth will no longer be measured in terms of ownership of fixed physical assets, but in ownership (or access to) knowledge-intensive, high value-added, technology-driven systems.

"This 'paradigm shift' in management strategy," the report concludes, "will require concomitant shifts in both management structure and operations."

There is a striking similarity between this prediction and the nature of the virtual revolution. The study goes on to combine U.S. Commerce and Defense Dept. studies to produce a list of more than 20 critical technologies needed for the United States to stay competitive in the next century. Nearly all depend in some way upon information and communications technology.[24]

Most of the inventions in information and communications have occurred and will occur in within several basic fields: semiconductors, computer hardware, data storage, software, system integration, and data communication. Advances in other technologies, such as laser, xerography, numerical control, speech recognition, computer vision, liquid crystal and plasma displays, etc. also will play an important role.

Semiconductors are obviously vital to virtualization. Within that industry, microprocessors should continue their seemingly endless march up the performance-cost curve. Memory chips will continue to get faster and denser, although the rate of progress in this field has begun to fall behind Moore's Law. Application Specific ICs, such as gate arrays, will steadily grow larger, faster, and easier to design -- and in the process serve as the building blocks for future generations of computers, numerical control machines, communication networks, FAX's, copiers, cameras etc. . .and thus maintain their role, in chip pioneer Jerry Sanders' phrase, as 'the crude oil of the information age.'[25]

In computers, several new generations of **hardware** will be needed to make the virtual corporation a practical reality. RISC (Reduced Instruction Set Computing), parallel processing (which will let thousands of computers work together on the same problem) and other architectural innovations will make important improvements in cost, size and processing power.[26] By the year 2000, these developments should permit computation speeds to reach __ millions of instructions per second--- in machines costing about $__________. That's $___ per mip, compared with the current $____ per mip, or yet another change of several orders of magnitude. Armed with this kind of power, designers will at last be able to use behavioral information more extensively in their simulations -- a key to accurate long-term forecasting.[27]

Another area where this processing power will be important is in the presentation of processed information. The human mind can comprehend numerical information more easily as images or graphs than as columns of figures. For that reason, a great deal of the computational power of modern computers is devoted to the visual presentation of information. If the computations can be done quickly enough, this information even can be presented so as to appear three dimensional and in motion. Industrial Light and Magic Inc. uses precisely these processes to create the visual effects in science fiction movies such as the *Star Wars* trilogy.

The ability to view form and experience behavior is dependent not only on bringing massive amounts of computer performance to bear on the problem, but also requires huge amounts of **data storage**. Even if dealing solely with content-type information, these files can be massive. For example, each year the IRS deals with more than 100 million tax returns, 1 billion special information forms and mails out nearly 4 million letters requesting additional tax payments.[28]

Early computers contained magnetic data files capable of storing information on magnetic surfaces at very low densities. The first IBM drum memory, introduced in 1951, was composed of magnetically-coated rotating cylinders containing 58 tracks, with 100 characters per track. The company's first hard disk drive, the RAMAC 350, introduced in 1956, stored 4.4 megabytes on 24-inch platters in a box the size of a washing machine.[29]

Today it is possible to store as much 1 billion bytes on a disk drive the size of a shoe box. Most personal computers now even come equipped with paperback book-sized forty megabyte discs tucked inside them. While useful, data files even of this size are not large enough to let users work effectively with extensive amounts of form or behavioral type information -- for that, tens, even hundreds of billions of bytes, of data storage are needed

For that, an alternative is already on the scene. Optical data storage, which can store as much as two billion bytes of reference data on a single surface, represents yet another multiple order of magnitude jump in information storage.[30] It combines laser and semiconductor technology to store massive amounts of data on plastic disks similar to music grade CDs.The optical disk (or its cousin, the CD-ROM) can also store still or video images that can be combined with text in multi-media presentations that represent a further improvement in ease of use.

The notion of billions of bits of inexpensive information at the fingertips of every employee in an organization has dramatic implications for the virtual corporation. For one thing, high speed manipulation and control of this kind of mass of information is crucial to 'custom mass production', which in turn makes the virtual product possible. Only with the ability to store and then process the huge volumes of behavioral and action information will it be possible to understand and track the changing needs of each and every customer, or locate and capture prospective new customers.

The impact of this new storage technology may be even more pronounced in the service industry. For example, a single compact disc would not only hold all the information currently found in any retail catalog, but likely everything else in that firm's year-round inventory. Not only that, but the photos could move, or represent the product in three dimensional color, be mixed and matched with other items, or even modified to match the customer's size. They could then be purchased over a computer network for next day delivery by air.

Currently, the library of these disks only amounts to a few hundred volumes, mostly scientific data bases, computer software and reference works, such as encyclopedias. Nevertheless, the maturing of the industry has begun. And the corporate world is beginning to take notice: Sun Microsystems, for example, says it plans to distribute all its software in the future on compact discs. Other companies have announced plans to do the same thing with product catalogs and data sheets. Logic Automation, which catalogs vast libraries of behavior information to help clients simplify electronic system design, is moving to put on a single CD-ROM what it used to send to its customers as a sheaf of floppy disks.[31]

Thinking Straight

The typical computer user, when he or she 'talks' with a computer is, in reality, dealing with layer upon layer of **software**, each in turn converting the user's language into something closer to the cryptic language the computer understands. Were it not for this that buffer the user from the workings of the system, computers would still be the province of only computer scientists.

Early computers had to be programmed in their own internal 'machine language'. Programmers wrote single instructions on programming pads using alpha-numeric codes that were then converted into computer instructions. The process was so long and laborious that it was essentially impossible to write the long programs required for sophisticated applications.

To improve this frustrating situation, engineers began writing programs, such as Fortran (1957) and Cobol (1960) to translate simple English-like programming commands into computer instructions. The success of these early-generational languages and operating systems, led to an explosion in the potential uses for the computer -- and, as every computer owner knows, that led in turn to an insatiable demand for more and more computing power and memory. As the amount of data stored in a typical system grew, new techniques had to be found to deal with it, from early flat filing systems to the modern relational data base.

With languages, operating systems and data management in place, programmers could now begin work on applications programs, software that would bring the power of the computer to bear on specific needs. What followed was an explosion of word processing, spreadsheet, personal information management, and desktop publishing software -- and communications networks to link machines together -- that continues to this day.

With local area networking came a need to integrate the data generated by one source and combine it with that from another; an engineer working on a design might want to feed the information in a schematic circuit diagram to the person doing the layout of a printed circuit board -- who might want to forward the results on to the manufacturing department so that its people could purchase the parts and program the production equipment.

New Computer Aided Software Engineering (CASE) tools have made it possible to produce these new applications faster and with a high level of reliability. As a result, the modern computer user has literally millions of line of code at hand from which to select thousands of different applications programs. In the words of Esther Dyson, "CASE makes it easier and faster to build software, and makes the programs that result higher in quality, more consistent, and easier to change later on."[32]

On the horizon are new generations of software to take full advantage of the increasingly powerful computers of their time. Among the features of this new software, like that being developed by the new IBM-Apple joint venture, will be object-oriented operating systems, data bases, and program languages. These and other advances will make it possible for both professional programmers and consumers to harness the millions of mips about to reside on their desktops.

But even that will not be sufficient. An immediacy of useful information will be a hallmark of the virtual corporation. Thus, computers will have to reach out to other data sources, and their owners will need to pass ideas swiftly back and forth. To reach out beyond the employees of a company to suppliers, retailers and most of all, customers themselves, will require a much better **data communications** infrastructure in this country than we now have -- not just low-speed voice–grade telephone lines linking personal computers, but a network of satellites and broadband fiber optic cable capable of bringing multi-media into every American home. This would be an expensive task -- $100 billion, according to one estimate[33], twice that according to some others -- but the technology is already available. Says William R. Johnson, Jr. of Digital Equipment: "Today fiber optic technology, with a speed of 100 million bits per second, is beginning to be implemented. Continuing this pattern of ten-fold improvements, the next development [before 2000] promises 1 billion (1 gigabit) per second).[34]

That would be an enormous and expensive task. This is one place where the virtual revolution will move into the public sphere; when business decisions depend upon political ones, and the entire nation must make some important and far-reaching choices (see Chapter 10).

Technology and Virtuality

The technologies discussed in this chapter, as well as others still to emerge, will make possible the creation of a panoply of virtual products and services. Some of these offerings -- desktop publishing, electronic photography, field programmable gate arrays, desktop shopping and airline reservation systems -- will be almost pure technological creations; empowering the user to create his or her own custom creations.

In other cases, the technologies will be almost invisible to users, tucked inside of corporations to implement fast-response/mass customization manufacturing systems; used to build guns to order, cars in 72 hours, or quickly refill a retailer's shelves.

Thus, it can certainly be said that technological invention underpins virtualization. But it alone is not sufficient. Desktop publishing and electronic photography, for example, are not new electronic industries. In fact, they are established industries -- printing and image making -- that have been revitalized and transformed by electronics . . .just as the ATM is still banking, and Beretta, for all its computers and milling machines, is still a gun manufacturer. Computer integration and flexible manufacturing got Remington to the point where it could explore new business options, but it took inventive marketing for the company look to its own past for future products. All, despite improvements and productivity leaps associated with the new technologies, remain subject to the unique characteristics of their businesses.

In nearly every case, the virtual revolution will be led by companies in established industries that have recognized the potential of using some or all of the four kinds of information to reconstruct their business; or that are observant enough to spot a technological cross-over threat emerging in some distant industry and race to incorporate it; or that develop these multi-disciplined inventions themselves. In every case, technology will be subordinate to, not a substitute for, a complete understanding of the market and the business.

But, because many virtual products of the future will be almost solely the creation of technology, there is a danger that businesses executives will become overly reliant on it. One early victim of this kind of thinking is General Motors, which has wasted its billions on automation and new facilities in the belief that technology is the sole driver of the virtual process.[35]

The purpose of this chapter has been to show as convincingly as possible that technology has advanced to the point where the virtual corporation is now feasible. In fact, most of the virtual processes we see going on around us in the United States are a direct result of technology.

But, if technology is no longer an impediment to virtualization, neither is it sufficient to create a virtual corporation. The Japanese and Europeans, more than Americans, appreciate that fact. The virtual processes in many of their factories were created *not* with technology but rather through organizational innovations and redefined business relationships.

There is a danger in believing that technological supremacy is enough to capture the power of the virtual revolution. The journey to this new industrial paradigm requires more than just engineering. It will challenge us to re-think the role of every office, every laboratory, and every factory workstation in the company. This time, technical innovation alone will not save us.

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[13]
[14]
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[17]ibid, pg. 36.
[18]MIPS Computer Systems, Inc. prospectus, November 7, 1989. pg. 23.
[19]Technology 2001, pg. 44.
[20]"The Drive for Capacity," by Terry Costlow, Electronic Engineering Times, October 14, 1991. pg. 1.
[21]The New Alchemists, pg. 60.
[22]
[23]"Management of Critical Technologies", by D. Bruce Merrifield, Walter Bladstrom Professor of Management, Wharton School of Business, 1991. pg. 1
[24]ibid. appendix A. Here is the complete list:

- Materials
  - Materials Synthesis and processing
  - Electronic and photonic materials
  - Ceramics
  - Composites
  - High-performance metals and alloys
- Manufacturing
  - Flexible computer-integrated manufacturing
  - Intelligent processing equipment
  - Micro- and nanofabrication
  - Systems management technologies
- Information and Communications
  - Software
  - Microelectronics and optoelectronics
  - High-performance computing and networking
  - High-definition imaging and displays
  - Sensors and signal processing
  - Data Storage and peripherals
  - Computer simulation and modeling
- Biotechnology and Life Sciences
  - Applied molecular biology

Medical technology

Aeronautics and Surface Transportation

Aeronautics

Surface transportation technologies

Energy and Environment

Energy technologies

Pollution minimization, remediation and waste management

[25]Jerry Sanders, quoted from the Ben Rosen Technology Conference, New Orleans, June 1980.

[26]Interview the president of Masspar Jeff Kalb

[27]Interview with Richard Shaffer, editor of Technologic Computer Letter

[28]"Why April 15 is Getting Worse and Worse", Forbes, March 18, 1991, pp 84-85.

[29]"Paper, Magnets and Light", by Robert R. Gaskin, Byte, Nov. 1989, pp. 391-392.

[30]ibid. , pg. 399.

[31](Call Bill Lattin, President, at 503-690-6900)

[32]"Computers Programming Computers", by Esther Dyson, Forbes Magazine, _____.

[33] "Why the Highway Won't Reach Home Just Yet" by Peter Coy, Business Week, September 16, 1991, pg. 112.

[34]"Anything, Anytime, Anywhere," by W.R. Johnson, Jr., Technology 2001, pg. 153.

[35]Rude Awakening, pg. 204.

Chapter 5: The Future By Design

In 1894, the Honorable Evelyn Henry Ellis, a wealthy member of English Parliament, set out for Paris to buy a car. His destination was Panhard et Levassor (P&L), then the world's leading automotive manufacturer.[1]

Despite that title, P&L's primary business was as a manufacturer of metal cutting saws. It was a classical craft production operation. The workers in the plant were skilled craftspeople who understood mechanical design and the materials with which they worked. The owners of the company, Messrs. Panhard and Levassor, first talked with a customer, developed specifications for the car, then assumed responsibility for ordering parts and building the final product. Much of the design and engineering of the component parts took place in individual craft shops scattered throughout Paris. When the parts arrived at the shop skilled fitters finished the design job with metal files to assure a proper fit.[2]

Almost a century later, when the scientists working on the virtual reality project at the University of North Carolina became involved in the design of their new offices, Sitterson Hall, the experience was quite different. They decided to simulate on a computer system the experience of living in a building that did not yet exist.

"When Sitterson Hall was in the planning stages, the VR (Virtual Reality) researchers who were going to work in the multi-million-dollar building after it was completed converted the architect's plans to a full-scale 3D model--that existed only in cyberspace. When the people who were going to spend their days in the building "walked" through the model, many of them felt that one particular partition in the lobby created a cramped feeling in a busy hallway. The architects didn't agree until the future occupants of the building used the 3D model to give the planners a walkthrough. The partition was moved. The building was built."[3]

A few years later author Howard Rheingold visited the newly finished Sitterson Hall, stepped onto a treadmill and took a virtual walk through the same building:

"I put the cybergoggles over my my eyes, then entered the virtual building and walked through the virtual lobby. . .I was able to stroll the corridors of an entire building while physically never leaving one small room.[4]

The scientists, architects, and Rheingold had all been using behavioral information to duplicate -- even modify -- the experience of reality. Similar, though less dramatic, version of the virtual experience are increasingly being used by engineers to 'visit' their new product designs. This process, call it *virtual engineering*, offers one likely solution to the challenge of ever–shorter product cycle times that will characterize the virtual business revolution. To experience the physical form, even operate, a product that as yet resides only on the drawing board, holds the prospect of all-but eliminating the prototype and test run phases of product development.

Virtual engineering will, in fascinating ways, combine the century-separated experiences of Rheingold and Ellis. What Ellis encountered at P&L in 1894 was an older form of what today would be referred to as simultaneous or *concurrent engineering*. By definition, this means that everyone affected by design decisions becomes involved in the design process to make sure that the multiplicity of downstream needs (manufacturability, serviceability, market demand, etc.) are met. In Ellis' case this was pretty simple since the craftsperson who produced the parts also designed them; making it very easy to coordinate manufacturing and engineering. In the Sitterson Hall story, many of the people who would eventually work in the building had a chance, albeit somewhat limited, to redesign the building based upon their virtual experience of its use.

The Honorable Evelyn Henry Ellis, M.P. also did something that not many car buyers have done since: he played a central role in the design of his own car. He, not some design shop in Dearborn, Tokyo, or Turin, decided upon the features he wanted and made the compromises and trade-off decisions about which would be included in the finished product. He enjoyed, like wealthy men and women in all ages, the luxury of control.

Customer control lies at the heart of the virtual corporation, and that control is most fully realized in the virtual products produced by such enterprises. Some of this, of course, is going on today. The customer who buys a programmable ASIC from leading American producers Actel or Xilinc designs the desired product, then programs the virtual product. Otis Elevator has discovered by providing architects with design terminals it can make it easier for the architect to specify the elevators used in the buildings they are designing. In this way Otis links the architect into its design process.[5]

The objective of virtual engineering is to compress product development time; shrinking the interval between the identification of the need for a new product and the beginning of its manufacture. Accomplishing this can be a demanding and expensive process. But the motivation is clear: corporate survival. Bill Schroeder, vice chairman of Silicon Valley's Conner Peripherals, one of the fastest growing companies in history -- zero to $1 billion in four years -- explains it this way.

"The first guy cleans up, the second does OK, and the third guy barely breaks even. The fourth guy loses money."[6]

While this may be a slight oversimplification, there are enough companies who have experienced the pain of being late to the market that they have decided to do every thing within reason to cut development time. They find products with short design cycles are more successful, they can be designed to respond to competitive threats more quickly, they more closely match the needs of the market, and their development costs are less. That is why Intel, to maintain dominance in the microprocessors, has chopped the average development time for its new products by more than 50%, from 108 weeks to 48.[7] It is also why the Japanese have cut the design time for a new car to just three years, compared to five years for U.S. auto makers, and are working to make even greater reductions.[8]

Today product design is performed by the majority of companies throughout the world using a feed forward or *serial engineering* process. Information is gathered from customers on their needs and a product specification is developed. Engineering then designs the product and passes it on to manufacturing to build. The product is then sold to the customer and the service organization is given the responsibility for repair when the product breaks down. The process is linear; each step along the path awaits completion by all those that precede it.

Besides the wasted time, another serious problem with serial engineering is often the upstream participants in the process have little appreciation of the growing wedge of downstream consequences created every time they make a simple decision. The problems caused by this process were evident at Cadillac while it used serial engineering:

" . . . Cadillac used a disastrous serial-design method. The designer of the car's body would leave a hole for the engine, then the power-train designer would try to fit the engine into the cavity, then the manufacturing engineer would try to figure out how to build the design, and finally the service engineer would struggle to invent ways of repairing the car. The results were predictable. On one model, the exhaust manifold blocked access to the air-conditioning compressor, so seasonal maintenance meant removing the exhaust system. On another model, the connection between the spark plugs and the spark plug wires was so tight that mechanics tended to break the wires when they pulled them off to check the spark plugs."[9]

At networking equipment maker Cisco Systems Inc., one of Silicon Valley's fastest growing new companies in the late 1980s, serial engineering created a series of disastrous problems just at the time when the company was doubling sales annually. Poor communications about the specifications for a communication chip caused low yields and field failures. Inadequate test programs forced the company to ship four interfaces to customers who wanted just two interfaces, because it was impossible to test the two interface system. Reported IEEE Spectrum:

"Then there was the manufacturing 'bone pile' -- the stack of circuit cards that had failed tests during manufacture. Engineering had created only meager diagnostic tests for these rejects. As a result, manufacturing could not find the cause of many of the failures and could not correct them — and the bone pile got bigger.[10]

Cisco solved the problem, and escaped it altogether in a subsequent product by moving away from serial design to a more cooperative relationship between design and manufacturing.[11]

Obviously there has to be a better way. Too much is at stake. As noted, one study has estimated that the potential gains from improving a company's development process are between 40 percent and 60 percent.[12] Another suggested that 75 percent of a product's cost was decided at the conceptual design stage; that a 50 percent cost overrun on development would cut profitability by 3.5 percent, and that a six month delay in getting a product to market would slash profitability by 33 percent.[13]

Numbers like these are a powerful incentive to rethink engineering and design. The result has been concurrent engineering. Some observers have suggested it is less a new methodology than the simple application of common sense.

The central notion behind concurrent engineering is that all of those affected by design — engineering, manufacturing, service, marketing, and sales as well as suppliers and customers -- should participate as early as possible in the design cycle. Through this communication, trade-offs can be made, and consensus reached, that will reduce product cost, improve manufacturability and serviceability, and assure that the product has features that match the market's desires. By predicting and eliminating problems before they appear, and, as the word 'concurrent' suggests, carrying out activities in parallel, months can frequently be cut off the design cycle.

Not surprisingly, among the components of concurrent engineering are continuous improvement (*kaizen*), just-in-time delivery and total quality. To this are added such processes as statistical process control, the Ishikawa cause-and-effect fishbone diagram and design for manufacture and assembly. The last is especially interesting because it calls upon designers to constantly keep the needs and limitations of the factory in mind; to produce 'robust' designs that manage to achieve better product performance while being easier to manufacture with high quality.[14]

Using a concurrent engineering approach, the Japanese have reduced the time it takes to produce production-ready dies from two years to one. The way dies used to be designed in the automotive industry was to wait until product designers could provide the die makers with complete specifications for the stamped part. Then the steel blocks would be ordered and the production of the dies begun. In the Japanese system, close communication between the designers and the die makers allows the latter to begin die production while the body design is still in the works. This is possible because the die makers have a rough idea of the size of the new panels. So, they can make the rough cuts early -- and then follow-up with the final machining as soon as the designers are ready. This pragmatic approach shaves one year off the cycle.[15]

Chrysler learned from the Japanese model when it set out to create the Viper. Using concurrent engineering, a development team of just 85 people created the sports car in only three years -- two years faster than the typical Chrysler -- and with a development that, at $70 million, was nearly half that of the Mazda Miata.[16]

General Motors also has adopted a form of concurrent engineering for its new Impact electric car, forming a team of young design engineers, manufacturing people, marketing specialists, and even production workers, working alongside one another in an attempt to design the car in just four years.[17]

When teams work in parallel and communicate well they can often begin working before other upstream groups have finished the design work. To add to this many of the mistakes which so frequently plague development programs can be avoided. Many of the gains come from avoiding errors and doing things right the first time.

When the consulting group Pittiglio, Raabin Todd & McGrath surveyed several hundred mid-level managers and others involved in product development, they came up with some surprising results. Among their findings were that forty-seven percent of all product development is repeated, fifty-one percent of development activity consists of "fire fighting" or unplanned activity, and that project hand-offs are often botched because of poor communication.[18]

There are of course other benefits to concurrent engineering. Among these are that it leads to products that are easier and less costly to manufacture. One remarkable example of this can be found at Volkswagen's Hall 54 assembly plant. As a result of simultaneous engineering, an extra frame part was added so that the front end of VW Golfs and Jettas under assembly could be temporarily left open. This permitted engines and shock absorbers to be installed by robotic hydraulic arms. Until then, this operation had been the bottleneck of the assembly line, requiring as much as one minute and several workers to complete. Using the new assembly process, the time was cut to twenty-six seconds, unattended, thus enabling the entire production line to run more efficiently.[19]

In another example at the same plant, the assembly management convinced the purchasing department to buy cone-point screws, even though they cost eighteen percent more than the standard flat–tip versions. The reason was that the new screws would insert easily into holes even if not precisely aligned -- crucial to the application of automatic insertion tools.[20]

The end result of these and a number of other decisions was that Hall 54 was able to use robots or special machines to perform twenty-five percent of it operations whereas in the past, five percent had been the best achieved.[21]

As this suggests, the design of a product has a definite influence on whether it can be flexibly manufactured. A well conceived design will support mixing of models in production by using large numbers of common parts and by identifying subassemblies that express the model differences, by concentrating model differences in as few parts as possible, and by designing assembly sequences that permit the product to be made in modules.[22]

Often computers play a decisive role in making these improvements. The greater the capacity to visualize the finished product, the more likely problems can be spotted early. It is estimated that only 20 percent of product-quality defects come from the production line -- and 80 percent "are locked in during the design phase."[23]

Using a computer to attack design problems with an eye on the ultimate manufacturing, can yield remarkable results. For example, NCR Corp.'s Cambridge, Ohio facility used 3-D computer-aided design software to develop a new point-of-sale terminal. After a review team critiqued the design for shortcomings, the final product had 85 percent fewer parts, 65 percent fewer suppliers and 75 percent less assembly time.[24]

Digital Equipment Corp. used the same technique in designing a three-button computer mouse -- cutting assembly time by 65 percent and materials cost by 42 percent. In a similar program with a new computer storage system, DEC found it had increased the product's reliability by 50 percent over its predecessor and reduce its cost per million bytes by 50 percent.[25]

Thanks to simulation, consistency and the sharing of data between concurrent work teams, computer-based design can also lead to unprecedentedly high levels of quality, even as performance undergoes manifold improvement. In 1988, Intel Corp. instituted its (PDQ)2 (Perfect Design Quality, Pretty Darn Quick) program to accelerate design cycle times. In three years, thanks to computer-based concurrent engineering and improved communications between design teams, Intel was able to reduce design-to-sample times in half, while still doubling product complexity. Most important, the company achieved a 95 percent success rate on the first silicon fabrication of new products. One result was that, in the face of a dozen Japanese competitors, Intel retained 95 percent of the so-called 'flash' memory market, its devices ten times more reliable than any other on the market. [26]

Clever design has been used in many fields to get great product variety simply. In electronics, many 'new' products are merely program steps put into programmable memory for a microcomputer to execute. Change the memory and you change the features.

By the same token, clever design can also keep high volume products cost–competitive. For example, in the early 1980s, Sony automated its Walkman assembly plant by first redesigning the products so they could be assembled from only one side -- then built assembly machines to do it.[27]

The future promises to bring multi-media computing to the design process, enabling concurrent engineering to truly live up to its title. The first of these products are just now being introduced. For example, CIMLINC, an Illinois software firm, has designed a product that enables diverse engineers and manufacturing people to interact on computer screens by sketches, full motion video, data base texts, and even make balloon notes or arrows on existing on-screen design drawings.

In 1991, one user of this system, a Raychem machining plant in Richmond, British Columbia, was awarded the *ComputerWorld*-Smithsonian manufacturing award for producing zero-defect products nearly four times faster than a jobshop and for having reduced set-up times from two hours to just fifteen minutes. Said the general manager of the plant, "There"s only one piece of paper in the entire operation: a shipping tag."[28]

Thinking Ahead

If the design of the product and the manufacturing process used to produce it are well thought-out from the start, it is much easier to achieve incremental product development. This in turn lets companies get new products to the market with less work and effort. As one might expect, the Japanese have adopted this philosophy quite broadly in their design efforts. Incremental product development fits quite neatly with kaizen.

"In fact, most Japanese companies start their product development cycle with a product already in hand, then set out to add relatively minor improvements. 'Over 90% of the product development work in Japan is of the incremental type,' explains Tatsuo Ohbora, a principal at McKinsey & Co.'s Tokyo office. What sets Japanese product development apart from that of other countries is the fact that this improvement is constant and always strives to tailor the product to individual needs."[29]

A remarkable example of incremental development can be found in the 13 year story of a humble three horsepower residential heat pump manufactured by Mitsubishi.[30]

As Stalk and Hout describe it, when Mitsubishi introduced the first of its models in 1976, the United States was far and away the world's largest maker of residential heat pumps. For three years, Mitsubishi made few changes in its product besides some variations in sheet metal. Then, beginning in 1979, the company began a process of making at least one major improvement in the pump *every year* through 1988. In 1979, it was the addition of remote control. Then, in 1980, the major breakthrough of adding integrated circuitry for control and display. A year later, the company added microprocessor control and quick connect freon lines -- not to improve performance but to cut costs of circumventing distributors and selling directly through appliance stores.

Each year, relentlessly, the improvements continued: a rotary compressor, expanded electronic control, optical sensor control, handheld remote control for temperature and humidity, 'learning' circuitry so the product can learn when to defrost itself, electronic air purifiers. By 1989, without a single technological breakthrough, Mitsubishi was building a residential heat pump with twice the performance of its 1976 ancestor and offering a panoply of extra services. Meanwhile, its U.S. competitors were still just beginning to install integrated circuitry. Finally, the leading U.S. heat pump maker gave up and began sourcing from its Japanese competitors.[31]

Perhaps the most most fascinating aspect of the virtual revolution in engineering deals with the automation of the design process. The key to the automation of design has been the improved performance of computers and the ingenious software that has taken advantage of these new performance levels -- most notably in dealing with form and behavioral information.

The big, lumbering computers of the 1960s were used principally in data processing applications, such as accounting, payroll, materials requirements planning, and production scheduling -- that is, content information. They could be used to maintain parts lists and records on what was built, but were ill-equipped to play much of a role in design.

Even without computers, engineering design has dealt with form information for many years, through drawings, clay models, and engineering prototypes. A typical engineering bullpen at an aircraft company during the Second World War consisted of row upon row of draftsmen hunched over boards drawing cross-sections of aircraft fuselage and wings, like slices in a loaf of bread The assumption was that the surfaces being described varied smoothly between these slices. A similar process was used in the design of automobiles.

Unfortunately it is difficult to visualize finished products by looking at engineering drawings. Key features are often missed and the paths of parts moving in three-dimensional space are rarely described adequately.

The way firms of the era dealt with this problem of translation was by creating physical simulations (usually to scale) of the planned products. For example, automotive designers carved full-sized clay models to see how the final product would look. Some type of prototype was almost always built before production began. With any luck, this would enable designers to discover problems with designs and modify them before it was too late. A typical process would consist of drawing a design, building a prototype and testing it, building a pilot run of a number of units on the manufacturing floor and then testing those units as well to make sure the design could be fabricated and would work as planned. In the case of airplanes, this meant brave test pilots risking their lives trying out new designs.

An important process running parallel to all this was engineering analysis. Here even the early computers could help. Engineers would describe as much of the design as they could using equations, and then run those equations through a range of variables to see if the design held. While this type of analysis was capable of identifying many problems, it was in general not very accurate and was inadequate for most of the complexities of the real world.

Despite these limitations, the market pressure for ever-higher levels of performance perpetually forced designers to be more aggressive in their designs. And sometimes, when the limits were pushed too hard, the results were disastrous. The engineers who designed the Lockheed Electra did not reinforce the wings enough and when the plane encountered turbulence, harmonic vibrations would cause the wings to rip themselves right off the plane. This euphemistically named 'flutter problem' caused several horrible crashes before it was identified and fixed.

A similar harmonic vibration problem caused the collapse of the Tacoma Narrows Bridge. Built in 1940, this 2,800 foot span was so delicate in design that it was called by some critics 'the most beautiful bridge in the world.' The motorists who had to drive it however called it Galloping Gertie for the way it rocked in even light breezes. Sometimes the car ahead might even disappear momentarily from sight as the bridge bounced in the wind.

Four months after it opened, a 40-mile per hour wind came up and the bridge began to sway and writhe with increasing severity until it simply tore itself apart and fell into the water below.[32]

The Tacoma Narrows bridge had been designed using the state-of-the-art engineering analysis tools of its time. Unfortunately, they were inadequate to task of dealing with massive and complex computations need to predict the performance of the bridge in a storm.

One of the common ways of the era for coping with the lack of precision was to simply overdesign products. A classic example of this was the DC-3, statistically the safest and most durable airplane ever built. The plane was constructed with such a large safety margin (notably in the multi-spar wing and tail construction) that it had to compromise both performance and payload. On the other hand, the plane could fly 70,000 hours without being rebuilt -- and many of the nearly sixty year old planes are still in daily service throughout the world.[33]

Until the advent of high performance, low cost computers, design analysis was necessarily crude. Engineers frequently used what was called worst case analysis techniques which studied the performance of designs at the most extreme limits. While these techniques often led to reliable designs they also often unduly restricted the flexibility of the designer. Worse, even with this defensive technique, it was nevertheless impossible to imagine, much less explore, all the potential worst case scenarios. The only real answer was to build a prototype and then test it to destruction in hopes of finding some undetected or unconsidered flaw.

About the only thing working to advantage of those early designers was that the products were far simpler than they are today. When first introduced, the DC-3 carried only twenty-one passengers, flew just 192 mph, and had two 900 horsepower Wright Cyclone engines.[34] That is a far cry from the modern 400 passenger Boeing 747 or supersonic Concorde.

By the same token, the most sophisticated integrated circuits of the early 1970s contained five thousand transistors. Today, that density approaches five million transistors. It was difficult enough to coordinate the efforts of a small team doing the design and analysis of that earlier device. For the modern integrated circuit to be designed the same way would require the coordinated efforts of thousands of engineers, truly a Herculean task. Fortunately, thanks to advances in computers and software, it is possible to design a five hundred thousand transistor device today faster than its five thousand transistor ancestor.

In fact, the virtual design process probably has advanced further in electronics than in other engineering field. This is partly because electrical circuits are comparatively well-behaved and obey simple rules. It also helps that the history of computers and semiconductors are so intimately linked, the resulting interaction creating considerable synergy. Electrical engineers who designed chips for computers understood a lot about the potential of those computers to help them do their work.

The first work on a computer–driven display on a CRT took place in the early 1950s on the Whirlwind I computer at MIT. By 1962, in a doctoral dissertation, Ivan Sutherland, introduced the concept of interactive computer graphics, and within a few years designers at General Motors had turned that idea into a reality. Leading that team was Dr. Patrick Hanratty, who, in the early 1970s, wrote the first mechanical drafting software that is the philosophical core of many CAD systems today.[35]

One of the first uses of computers in design was in the automation of the drafting process. It was easy to have computers draw lines, rectangles, and circles under the direction of a draftsmen. If a dimension needed to be changed or a line moved, the computer did this easily. It merely erased the form data stored in its memory associated with the old shape and replaced it with new. Just a few years before the electric eraser had been the considered an innovation in drafting; now, with the computer, almost overnight the drafting table, t–square and paper became superfluous.

As in most applications of computers, what began as a replacement for traditional methods soon expanded into heretofore unimagined new uses. For example, since many of the shapes drawn were used over and over again, it was a simple matter to store them in a computer. The draftsmen could then point to a screen at the place where he or she wanted the shape to appear and the computer would draw it. By the same token, the computer could also enlarge and shrink the object on the command.

"Since this was the first wave of automation to hit design engineering, the results were spectacular. For example, productivity ratios (which compare the time needed to do something the new way versus the old way) were reported at 4:1 to 20:1."[36]

The first systems automated the more mechanical processes in electrical engineering. They helped the draftsman a great deal but did little to leverage the skill of the engineer. The next step then was to develop computer aided engineering (CAE) tools.

At the time, engineers would prepare schematics or abstract representations of what they wanted the draftsmen to draw for them. The draftsmen would then take these ideas and translate them into the form information they drew with on their computers. Automating this process was straightforward: enable the engineer to enter the schematics directly into the computer and then have the computer automatically draw the physical representation of the design.

Engineers of course knew they frequently used certain structures over and over again. So, almost immediately they began to store on their computers libraries of frequently-used structures. Consequently, if an engineer wanted to use an 'adder' design in a project it was a simple matter to access a copy of the adder from the computer's library and insert its schematic into the design. If a microprocessor needed to be integrated into the design it was simply a matter of borrowing one from a schematics library and dropping it into its proper place. As computer power grew, designs consisting of thousands or even tens of thousands of transistors could be used over and over again. The designer now merely had to use a mouse to point at an icon representing, say, the circuitry for a modem, click on it and then 'place' that design into the system, making all the necessary interconnects. A process that once would have taken months, now could be accomplished in minutes.

Reusable engineering, as this type of phenomena came be to called, was a boon to designers. But serious questions remained, most notably: How could you be sure the design really worked the way you thought it did? In such complex structures it was easy to make a mistake in the interconnections and severely compromise the resulting product. The only way to guarantee this wouldn't happen was to build prototypes and then test them under a wide range of operating conditions.

Needless to say, this defeated the purpose. For one thing, building prototypes was a slow and expensive process. In a traditional manufacturing facility, it could take months and thousands of dollars just to build the prototypes. Then the engineering test set-ups would add even more time and cost -- and still be only capable of testing the devices in a limited number of situations.

The obvious answer of course was to let the computer do it, let it create realistic models and put them through their paces. A great idea, but only if the computer ran fast enough and was cheap to use. That didn't occur for general business use until the 1980s and the arrival of engineering workstations from firms such as Sun and Apollo.[37]

With workstations, high speed simulators could be built that reproduced the actual electrical characteristics of devices in different configurations. These simulations were used to build models of even more complex collections of devices, adding to an ever-larger library for designers. At the same time, the continuously improving performance-cost ratios of computers, combined with new engineering software from companies such as Autodesk and Versacad made workstation-like activities possible even in personal computers. Wrote Industry Week, "Before PC packages, a mainframe implementation could mean $70,000 per [engineering station], but now the total cost — PC plus software -- can be less than $10,000. Even a deluxe PC system would be hard pressed to exceed $20,000."[38]

The Silicon Compiler

One of the keys to virtual design is the empowerment of engineers to deal with higher and higher levels of abstraction. In practice, this means that the computer must simultaneously be able to present the designer with intuitive, menu-like choices, while at the same taking care of all the tedious details of translation. For example, an engineer might point on the computer screen to an icon representing a microprocessor, a high level abstraction, and the computer would in turn generate the tens of thousands of rectangles and polygons needed to implement the design.

The answer to this need came from another corner of computer technology: the *compiler*.

Compilers are programs that greatly increase the productivity of software engineers by generating many lines of recondite machine language code for each line of English-like compiler code written by the engineer. Compilers of this type have been around since the 1960s. The great design breakthrough in silicon engineering came at a conference in 1979, when a CalTech graduate student, David Johannsen, working under Prof. Carver Mead, announced the first *silicon compiler*, software that made it possible with simple language requests from the user to pull together complex integrated circuit design components into larger structures.

Silicon compilers are extraordinarily complex structures. Author George Gilder compares the process to designing a complete town -- buildings, homes, streets, water and power -- for several thousand people:

"The crux of compiler design is to partition the overall job into a group of problems of manageable size, in which each part consists of a countable and intelligible number of entities. Making one brick, or one brickmaking machine, or one room design, or one house design, or one town's street design, are all manageable problems. So is designing a transistor, a logic gate, a functional block, a computer architecture.

". . .Silicon compilers perform the crucial function of allowing the designer . . . to avoid the multifarious intricacies of lower-level implementation . . .Freed from the details, the programmer can address the specific needs of the user."[39]

Silicon compilers and other related tools have made it possible for engineers to take advantage of the tremendous complexity that can be placed on a single silicon chip. It is now possible to design circuits containing millions of transistors, accurately predict their performance, release complete production tooling, and get a part working perfectly the first time -- all in a matter of months.

When Moore's Law first forecast the future of the semiconductor industry as a doubling of complexity every two years, there was much hand wringing in the business because no one could envisage how to cope with the design complexity required for this rapid rate of advance. But with silicon compilers, computer-aided design and engineering software, ever more powerful computers and increasingly sophisticated graphics, the design tool industry has managed to close the gap.

A glimpse of what this will mean in the virtual revolution can be found in some of the more sophisticated ASICs companies. For example, here is daily life at LSI Logic:

"We've now got this extraordinarily rich computing environment, all on $20,000 computers networked together ten or fifteen in a group. . .And, of course, software methodology and technology has matured greatly and now we are able to create almost astounding virtual reality on these computers -- we literally now are capable of modelling and designing and developing complex circuits where the interactive design is performed between the software and the engineer in such a way that can predict the circuit's performance behavior. . .

"[That's how] we've been able to design something like ninety products in less than two years -- we're building at the same time we're designing. And virtually all of them work the first time. It's the methodology now that's exciting. Products are a fleeting thing. They come and go in nanoseconds compared to the old paradigm of products living for three years.

". . .We redesigned the MIPS R2000 [RISC processor chip] from the ground up, and it took only ten months from definition to working silicon. That's 700,000 transistors. Ten engineers, ten months, and the exciting thing is that today we're still shipping Revision A, with no known bugs. The first silicon that came out of the fab worked.

". . .The biggest savings in time to market is in verifying that the thing's going to work before you commit to silicon. That's because you take a 12–week hit automatically when you start over. You also get greater reliability this way. We had a major customer here recently. Silicon Graphics. They called us up -- this was November -- and said, 'You know those prototypes of ours you've got coming out? Well, go ahead and just ship them to us in volume, because we can make a million dollars a day if we can ship those boxes before the end of the year.

"And we said, 'But you haven't signed off on the prototypes.'

"And the guy said, "Hey, your stuff always works. Just go ahead and ship.'

"The bottom line is the parts did work and Silicon Graphics came over here in eight stretch limousines and took the whole group out to a fancy dinner as a show of appreciation."[40]

Higher Levels of Abstraction

Virtual engineering will not be the plaything of electrical engineers alone. Designing mechanical entities is not from fundamentally different from designing electrical ones. Virtual engineering teams already work on the design of airplanes, automobiles, and buildings. Finite element analysis tools enable designers to predict the behavior of mechanical structures in the same way electrical engineers can forecast the performance of electrical ones.

One of the most widely used computer programs for mechanical design is produced by AutoDesk. This inexpensive software, which runs on a personal computer, can be used in everything from the design of office space to simulated racquetball games. The company's Cyberspace program, in which the operator wears helmet and glove, "puts the designer in space with the parts he is designing. By moving his head, he changes the view, and his gloved hand gives him an ability to grasp and move parts of the design and grab commands in the heads-up command system."[41]

Few other human activities are as clearly defined as architecture. But even in these areas, computers and virtual design, though more limited, can still be a great aid to human creativity. One such field is that of molecular design. This field is highly dependent on the advances made in computational chemistry and empirical data gathered through x-ray studies of molecular structures and many other techniques. Here, virtual designs might seem out of place — yet one project, at the University of North Carolina, involves using virtual reality to enable chemists to actually "see" molecules floating before their eyes, hold them and feel their attraction and repulsion with other molecules, and even "bond" them together according to the rules of physics to produce new hybrid designs.[42]

Similar research is being conducted in performing simulated surgery on 3D X-ray images, and even, not surprisingly, on manipulating the flow of electricity through integrated circuits.

All of this suggests that the automation of the engineering process has just begun.

In Japan, since 1986 a hush-hush project backed by 200 businesses and led by such firms as Nissan, Hitachi and NEC has been at work on a 'robust' design system that would automatically adjust the dimensions of all the parts in a device to compensate for a single one not conforming to specifications -- thus achieving perfect quality.[43]

According to Peter Drucker, some Japanese firms also are taking advantage of the time and cost savings of computer assisted design to take concurrent engineering to a new, higher level -- that of developing three new competing products at the same time. The first product uses kaizen to improve an existing product through improved performance, greater reliability and reduced cost. The second "leaping" program attempts to create a new product out of the old, as the Sony Walkman did out of the tape recorder. Finally, a third program searches for a genuine, breakthrough innovation.

Says Drucker:

"Increasingly, the leading Japanese companies organize themselves so that all three tracks are pursued simultaneously and under the direction of the same cross-functional team. The idea is to produce *three* new products to replace each present product, with the same investment of time and money -- with one of the three then becoming the new market leader and producing the 'innovator's profit.'"[44]

In the United States, where reusable engineering was first developed, researchers such as E. I Feigenbaum and R. S. Engelmore of Stanford University now envision the day when each design engineer will have his or her own electronic *associate*.

Such an associate would consist of a powerful set of tools and data bases that would raise engineering to ever-higher levels of abstraction while increasingly simplifying and automating the process. Included in this vision are massive data bases containing not only textbook facts but empirical knowledge related to design, reliability, safety, manufacturing process, etc.; as well as suites of seamlessly integrated engineering tools. Ultimately, Feigenbaum and Engelmore envisage virtual design teams in which some of the members may by computers instead of people.

"[The Engineer's Associate (EA) would] contain a model of the engineering process from one or more perspectives, and know how to access the knowledge bases and the tools for assisting the various members of the engineering team. In the short term, the EA would mediate among the human designers, help resolve conflicts, and transform perspective, the EA would include automated systems as members of the engineering team.[45]

It almost goes without saying that with the arrival of the Engineer's Associate and comparable artificial intelligence systems, the very nature of the design process will change. With expertise transportable, it will become possible for customers, acting as co-producers, to assume more of the design process themselves. By speeding the process, engineers will be able to evaluate many more alternatives before selecting a solution.

This is precisely what happened at Canon when it installed the OPTEX system for designing zoom lenses. By cutting design time by over an order of magnitude, from three hours to fifteen minutes, the designers were able to investigate and test many new ideas that had previously been too time-consuming and costly to consider.[46]

The world of the virtual engineer will be one powered by high-speed computation and all its wonders, of organizational innovation in which concurrent engineering and common sense will be responsible for much of the innovations. The result of all of these advances will be the ability of companies to rush products through the design cycle and into the market with breathtaking speed. The powerful tools will also simplify the design process, making it possible for customers to be more deeply involved in the design process itself.

There is a symmetry to all this, a racing into the future in order to regain some of the splendors of the past -- only this time not just for the select few. It seems likely in the not-to-distant future customers may just find themselves in the role of the Honorable Evelyn Henry Ellis M.P., designing a car to fit their own unique desires and seeing it delivered in a matter of weeks. In T.S. Eliot's words, "And the end of all our exploring/ Will be to arrive where we started/ And know the place for the first time." [47]

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[44]"Japan: New Strategies for a New Reality," by Peter Drucker (editorial), The Wall Street Journal, October 2, 1991, pg. A12.
[45]"Toward the Engineer's Associate: A National Computational Infrastructure for Engineering", white paper prepared by R.S. Engelmore and J.M. Tenenbaum, Sept. 1990, pg. 3.
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Chapter 6: The Machinery of Change

The ultimate goal of virtual manufacturing is to provide high quality product instantaneously in response to demand.

This concept violates many of the truths that traditional manufacturing managers have held sacred. For years the manufacturing floor was dominated by dogmatism on the part of managers and inflexibility on labor's side. It began with Taylor's stopwatch and the notion of the *one best way* and quickly deteriorated into a deep labor-management hostility that survives in many U.S. industries to this day.

Labor responded to the deskilled, routinized, boring Modern Times world of the interchangeable worker with defensive demands for rigid and inflexible work rules that made responsiveness to change almost impossible. At the same time, Fordism and mass production saw the construction of factories set up and tooled to build only a limited variety of products at very low cost. With these inflexible factories it necessarily followed that that marketing should sell what the factory could economically produce. Manufacturing managers with little confidence in workers believed the only way to achieve productivity was drive for high output using performance to standards as the sole motivating tool. The accepted way to meet quality goals was to inspect after the product had been produced and rework defective production. Not surprisingly, over time management learned to assume that low cost came at the expense of both quality and flexibility.

Companies also began to accept poor quality and poor performance of suppliers as a necessary cost of doing business; a problem to be endured, not corrected. And, since suppliers shipped poor quality product and did not deliver when they said they would, manufacturers learned to build large inventories of raw materials and components. Since capital equipment broke down frequently, companies planned for failure and learned to order redundant equipment. A "just in case" manufacturing philosophy took up residence at the heart of American industry. It was now okay to have too much inventory and banks of idle machinery.

When, after first experiencing the superiority of Japanese products during the 1970s, customers began to demand higher quality U.S. products, manufacturers most often responded by adding more and more inspection steps to the just-in-case model. They created so-called 'inspection-oriented' plants in which the cost of finding and reworking products was as much as 50 percent of production costs. . .hardly competitive with the low-cost Japanese counterparts.[1]

Faced with this, in recent years the accepted dogmas have come under close scrutiny and the conventional wisdom has changed. As researcher Earl Hall has written: "The decade of the 1990s promises to provide a wealth of information and experience for establishing the modes of competitive manufacturing in the 21st century. Indeed, much of the restructuring of the last quarter of the 20th century, and industry's response to that restructuring, is prologue to the next century."[2]

Much of this change has come from unlearning the rules of the past. For example, companies have learned to strive for nearly perfect quality. As a case in point Motorola has set quality goals for its products at just *three* defects per million parts.[3] As U.S companies have studied the successes of 'lean production' in Japan, they have come to realize that teaming up with suppliers can lead to the predictable delivery of reliable components; and that by working closely with capital equipment producers they can come to expect dependable machinery. And when this occurs, just-in-case becomes an anachronism, an embarrassing memory.

The differences between the "just in case" factory of yesterday and the lean production facilities of today are striking. When researchers Womack, Jones and Roos, visited the Toyota Takaoka facility right after touring the GM Framingham, Mass. plant they were stunned by the difference.[4] Whereas the GM plant's wide aisles were crammed with indirect workers ("workers on their way to relieve a fellow employee, machine repairers en route to troubleshoot a problem, housekeepers, inventory runners") adding no value to the actual product, the Toyota plant's narrow aisles were almost deserted. "Practically every worker in sight was actually adding value to the car."

At the individual workstations, the difference was equally obvious. In Framingham, weeks' worth of inventory were piled up, with defective parts "unceremoniously chucked in trash cans." At Takaoka, no worker had as much as one hour's worth of inventory at his workstation -- and when a defective part was discovered it was immediately tagged and sent to a quality control area for replacement.

Despite the fact that only senior managers could halt the line at Framingham, the line regularly stopped anyway -- thanks to machinery breakdowns and parts shortages. At a given moment, some workers would be buried in work, while others waited with nothing to do. The work area was filled with defective cars, the paint area backed-up with numerous car bodies awaiting work, and outside, railway cars sat filled for days with parts awaiting unloading into the giant parts warehouses.

By comparison, at Toyota-Takaoka there were no bottlenecks, no warehouses (when asked how many days of inventory were at the plant, the Toyota executive thought it was a mistranslation of *minutes*), and despite the fact that any worker could stop the line at any time, almost no work-stoppages. As for defective cars awaiting rework or repair . . .there were none.

The reader will probably not be surprised to learn that the visitors found the Toyota workers, though the pace was greater, to be purposeful and self-motivated. As for the workers at Framingham, the only word Womack, Jones and Roos found appropriate was "dispirited."

At the same time companies began to wean themselves from a just in case mentality, they were also discovering that responsiveness and flexibility did not have to be traded off against low cost. As Stalk and Hout have pointed out: "Demanding executives at aggressive companies are altering their measures of performance from competitive costs and quality to competitive costs, quality, *and* responsiveness."[5] Reducing the time from design to tooling, combined with the flexibility to make short product runs with minimum plant downtime in-between, results in short product cycle times. And that in turn gives the manufacturer the ability to more quickly respond to changing customer interests.

A growing number of examples how cost, quality, and responsiveness are compatible can be found throughout U.S. industry, from mini steel mills to application specific integrated circuits manufacturers to clothing makers. So numerous have these cases become that not even the most hidebound industry executive can argue the conventional 'wisdom' with much conviction.

Ford Motor Co., for example, has invested in a new flexible manufacturing plant in Romeo, Michigan that will break with the traditional pattern at U.S. automobile engine factories of producing a half-million copies of a single engine type each year. According to Business Week:

> Ford thinks it has a better idea. First, design V-8 and V-6 engines around a basic building block -- in this case, a combustion chamber designed for maximum fuel economy. Then, equip factories with machinery flexible enough to build several different models. Ford now plans as many as six new V-8s and V-6s in the 1990s -- everything from cast-iron workhorses to high-performance aluminum thoroughbreds.
>
> At Romeo, flexible manufacturing equipment and modular design will permit production of more than a dozen engine sizes and configurations on one line. Then engines will share about 350 parts. That will give Ford unprecedented freedom to match the plant's 500,000 engine capacity with customer demand.[6]

General Electric, often lauded for its early jump into flexible manufacturing, proved the power of this system a few years back at its locomotive works in Erie, Pa. These works were among GE's first successful attempts at virtualizing manufacturing. The test came when the locomotive business began to dry up. Could GE adapt to a changing market? As Industry Week later reported, ". . .the line was switched to motor frames without missing a beat."[7]

Cohen and Zysman have called this kind of manufacturing responsiveness *static flexibility*, which they define as "the ability of a firm to adjust its operations at any moment to the shifting conditions of the market -- to the rise and fall of demand or the changes in the mix of products the market is asking for." They argue that this flexibility can be technological (the use of new programmable machine tools), political (the worker buy-out of a steel plant in Weirton, West Va. that results in lower wages in exchange for the workers' stake in the firm) or organizational (the reduction in the number of job categories at the GM-Toyota NUMMI plant from 183 at other GM plants to just four). "Static flexibility decreases the risk that the firm won't be able to adapt to changes in the number and types of goods demanded in the market; it increases the ability to adapt to changed conditions.[8]

The idea of manufacturing responsiveness is tightly bound with that of *total cycle time*, the interval between when the market desires a product and when a company answers that need; in Stanley Davis' phrase, "from conception to consumption."[9] Davis, like many observers of industry, believes that anything more than marginal (10-20 percent) reductions in total cycle time are only possible with revolutionary change; in his words, "reconceptualizing the production, distribution, and/or delivery processes themselves."[10] These changes must take place because of shrinking product life cycles. In order to compete effectively companies are being driven to flood the market with new products which take advantage of new technologies as soon as they are available.

The idea of time as a competitive advantage is not new, but has always been an important consideration in business. As Chandler has written, many of the advances of the industrial revolution in America that have been credited to the economies of scale and distribution "were not those of size but of speed. They did not come from building larger stores; they came from increasing stock turn. . . It was not the size of the manufacturing establishment in terms of numbers of workers and the amount and value of productive equipment but the velocity and throughput and the resulting increase in volume that permitted economies and lowered costs and increased output per worker and per machine."[11]

What has changed is that time-reduction has become a conscious program in most forward-looking companies, a component like any other that can be improved, reduced and even eliminated through intelligent planning and the judicious use of technology.

The Japanese discovered this, with stunning results. In the automotive industry, as we have already shown, the Japanese coupled the adaptability of lean production with short design cycles to blanket the market with new products. One very visible result is that the average model age of Japanese car models is now about two years -- compared with five years for North American and European manufacturers.[12]

None of this has been lost on companies in competitive high technology markets. They experience it every day. In early 1991, a survey by Technologic Partners and Ernst & Young found that for technology company executives, "the main cause for alarm . . .lies in expectations for further acceleration in product life cycles, which are already turning out new products faster than most customers can absorb them . . .Where more than half of the systems companies saw product life spans of 36 months or longer five years ago, most now expect their products to survive for less than three years. And the overwhelming majority expect average product life span five years from now to be less than 18 months. Software companies don't go that far, but the same trend is at work."[13]

The recognition of this fact has led to a focus on time, more precisely on its reduction, as a key factor in business success. Says Stalk and Hout, who pioneered this field of study, "Today's innovation is time-based competition."[14] Former electronics industry executive Philip R. Thomas has written, "It is important to recognize that the big do not out-perform the little; the fast most frequently out-perform the slow."[15]

The only way companies can compete at this kind of pace and still turn an adequate profit, will be to race down the path towards virtual manufacturing. Some firms have already begun the process and their examples serve as models to industry of what can be accomplished.

One much-reported story is that of General Electric's circuit breaker business. Challenged by Siemens in that market, GE concluded that what it needed was quicker response times to customers. "We had to speed up or die," said William Sheeran, general manager of GE.[16] To achieve that acceleration, the company consolidated all of its production into a single North Carolina plant and installed automated flexible manufacturing systems, reduced its 28,000 different components by more than 90 percent, yet still left its customers with more than 40,000 different product choices[17]

The impact of these changes was dramatic. As Fortune reported, the time it took GE to fill orders fell from three weeks to three days. Costs fell 30 percent, while productivity jumped 20 percent, in the same year. The plants return on investment rose to more than 20 percent and, in what was considered a tired market, GE actually gained market share.

Blackburn has reported on a similar effort by the Allen-Bradley Co. to retain its market dominance in industrial controls and industrial automation. Installing a high-volume, flexible manufacturing facility that could take, manufacture and ship orders in just 24 hours, the company saw its costs per unit fall to the lowest in the world while at the same time its product offerings jumped from 125 to 600.[18]

Milwaukee's Badger Meter Inc., a maker of flow meters for everything from private homes to city water mains, was an early convert to flexible manufacturing, installing its first two-machine work cell in 1986 to replace six stand-alone machines. The impact has been extraordinary. Says

Industry Week: "'Today,'" according to John J. Janik, vice president of operations, 'all of the cast water-meter housings machines at Badger are automatically inspected and have to come out right the first time through. Each set of castings in a cluster is completed in six minutes . . .with the six stand-alones, production of a group took twelve weeks, given all the fixturing and setups.'"[19]

Just as important as this jump in performance has been Badger's use of it to improve customer response. Said Janick: "Each morning the production manager simply keys into the program which and how many of the 110 different housings of brass, bronze, steel or aluminum he wants for the day based on orders received the day before."[20]

DuPont, once enjoying a 90 percent market share with its rubbery plastic Kalrez, found itself losing market share to Japanese rivals. The company responded by shortening cycle times from 70 days to 16 days, reducing lead times from 40 days to 16 days and improving on-time deliveries from 70 percent to 100 percent. Sales jumped.[21]

Each of these examples, and there are scores more throughout industry, suggest the power of virtualizing manufacturing. Be it merely the linking together of a few milling machines into a flexible manufacturing system or the ultimate step of a fully computer integrated factory, the challenge for companies is to gain control over the time component of their manufacturing -- the average factory takes an estimated ten to fifteen times too long to pass a product through according to The Economist[22] --and then make the crucial next step to converting and consolidating that new-found advantage into a customer service.

A Distant Trumpet

The fast responsiveness of virtual manufacturing eliminates many of the errors caused by poor forecasting. In turn, short cycle times attenuate what business analysts call "the trumpet of doom". The trumpet is a plot of forecasting error versus time. What it implies is the further a person must forecast into the future, the greater the possibility of error.

The trumpet of doom plagues the clothing and apparel industry where clothes are ordered months before they are sold. The inability to know in Spring what the consumer will want in the Autumn continually leaves retailers with shelves stocked with the wrong product and a seemingly endless parade of seasonal sales. Retailers lacking virtual suppliers have come to accept their fate much as the manufacturer's of yesterday dealt with similar problems with a just-in-case philosophy.

There is a better way, as Badger Meter has shown. By being able to set production each morning and reprogram the factory machinery in minutes, Badger spares itself the waste that comes from sudden cancellations or order revisions. Worker time is no longer wasted on production doomed to become scrap. This is similar to Benetton, with its custom dyeing to track changing consumer taste and to reduce waste.

The ability to respond better to customer needs enables the company to command premium prices. When one considers that the manufacturer is already enjoying increased profits from smaller inventories, less scrap from quicker production cycles, and lower costs, the chance to command higher prices as well comes as a happy bonus.

This is possible for two reasons. First, the product reaches the market sooner, increasing its perceived value to potential customers. Second, because of its better 'fit' of features to the needs of those customers, as well as its greater quality and reliability, the product can carry a higher initial price. This is what Stalk and Hout were talking about when they said time-based products enjoy higher profits and faster growth than their tardy competitors.[23]

That's at the beginning of the learning curve. In time, as competition increases, these products should still be better able, thanks to strong customer perception of quality, to hold their prices. And when at last prices do begin to fall, these products have a deeper cushion of profitability to fall back upon.

Finally, at the end of the product's life cycle, the company has a greater ability to predict where the market's changing needs will lie and a greater capacity to develop, build and deliver a follow-up product to start the process all over again.

Virtual manufacturing is based on lean production (and all that it implies) and on a continuing flow of new technology that has made possible flexible and computer integrated manufacturing and low-cost capital equipment. These, in turn, often makes it practical to produce products in the distribution channel and at the customer's site.

Lean production is the name given to the Toyota production system by John Krafcik of the IMVP (International Motor Vehicle Program), a five million dollar study by the Massachusetts Institute of Technology study of the future of the automotive industry. The study concluded that "Lean production is 'lean' because it uses less of everything compared with mass production -- half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires far less than half the needed inventory on site, results in fewer defects, and produces a greater and ever growing variety of products."[24]

Benjamin Coriat of the University of Paris has pointed out that lean production is much more an organizational innovation than a technological one.[25] It depends not so much on computers and automatic machinery as it does on worker skills, organization on the factory floor, and relationships between manufacturers, suppliers and customers. It requires suppliers to deliver near-perfect product precisely when it is required and manufacturers to have production machines that are almost always available and working correctly whenever they are needed. [The former is one reason why Japanese manufacturers prefer to stick for decades with proven suppliers rather than risk even the most appealing new sources.]

The IMVP study contrasts lean production with craft and mass production in the following way:

"The craft producer uses highly skilled workers and simple but flexible tools to make exactly what the consumer asks for--one item at a time. Custom furniture, works of decorative art, and a few exotic sports cars provide current-day examples. . . Goods produced by the craft method -- as automobiles once were exclusively -- cost too much for most of us to afford.

"The mass-producer uses narrowly skilled professionals to design products made by unskilled or semiskilled workers tending expensive, single-purpose machines. These churn out standardized products in very high volume. Because the machinery costs so much and is so intolerant of disruption, the mass-producer adds many buffers -- extra supplies, extra workers, and extra space -- to assure smooth production. Because changing over to a new product costs ever more, the mass-producer keeps standard designs in production for as long as possible. The result: the consumer gets lower costs but at the expense of variety and by means of work methods that most employees find boring and dispiriting."[26]

Lean production appears to do the impossible. It delivers the great product variety once associated only with craft production at costs that are often less than those associated with mass production. These benefits are provided along with products of extraordinary quality.

But lean production also has been widely misunderstood. It not a solitary event but the continuous application of a process. A company becomes 'lean' by making gradual improvements in each step of the manufacturing process. In fact, the creator of the Toyota Production System, Taiichi Ohno, arrived at lean production as a result of his efforts to eliminate *all* waste.[27] His goal was to make the most efficient use of all of the resources available to the company--human, capital, and supplier. In the process he adopted total quality control methodologies and developed the just-in-time (JIT) system of manufacturing. Although technology has an important role to play in lean production--flexible tools, work cells, and computer integrated manufacturing--it is not fundamental. What is fundamental is teamwork between production workers and management. General Motors found this out in its efforts to install the lean production methodologies at two of its factories.

In the words of Maryann Keller, describing the successful arrival of lean manufacturing at the GM/Toyota NUMMI plant in Fremont, California: "At the core of [lean manufacturing] were two premises -- both new for GM. The first was that the average worker is motivated by the desire to do a job that enhances his sense of self-worth and that earns the respect of other workers. The second premise was that the worker is inspired by an employer who places value in the worker's input. Under the system in Japan, every worker is encouraged to think — to use brainpower an find ways of improving products and processes and eliminating wastes -- and is rewarded for improvements."[28]

Compare this with Keller's description of life at GM's traditional-style plant in Van Nuys, California:

". . .the workers wanted to do their jobs well, wanted to be competitive, but all too often they were fighting against unbeatable odds to get the job done. Every problem became a confrontation; since there was a basic mistrust between labor and management, it was hard to establish a cooperative environment where problems could be solved . . .workers operated in a vacuum; they did the job they were told to do without relating it to the final outcome. . . [It] was an environment where workers were not partners in the task of building cars. Often they did not know how their jobs related to the total picture. Not knowing, there was no incentive to strive for quality — what did quality even mean as it related to a bracket whose function you did not understand? Workers were held accountable through a system of intimidation: Do your job and your supervisor won't yell at you. That was a pretty thin incentive!"[29]

Lean manufacturing violates so many of the traditional beliefs that have grown up over the years around mass production that it can be hard to believe it will work at all. Ohno for example believed the key to efficient production was not long runs of identical product but rather short runs of a wide variety of products. In order to do this, he had to discover ways to eliminate the waste associated with long set-up time for production equipment in the manufacturing areas.

Among the tricks he found were working directly with tool and equipment manufacturers to make the process easier, training the production workers to do the job, and storing the tools on the production floor rather than in tool cribs so they would be instantly accessible to the worker. In order to be able to make such a system work effectively, Ohno had to train and trust his workers. All had to understand how to perform the changeovers and Ohno on his part had to trust those worker with tools that manufacturers traditionally stored in secure areas for fear they'd be lost, damaged, or stolen.[30]

The results achieved by Ohno were astounding. For example, between the late 1940s and late 1960s, tool change times dropped from as much as three hours to just three minutes -- a nearly two order of magnitude chance that provided a clue to the dramatic changes to come.[31] Once it was possible to reduce set-up times to the point that they were insignificant, it became practical to vary production almost at will and dramatically reduce in-process invenstories. Workers could produce the parts needed by assemblers for the next hours' production and then change their set-ups to be ready for the production of a different product. This is why Woomack, Jones, and Roos found the workers at Toyota's Takaoka factory had one hour or less inventory at their workstations.[32]

But if the worker was going to produce just what was needed by the person he or she was supplying, or if a supplier was going to supply parts just when they were needed, an efficient way had to be found to coordinate everyone's efforts. In 1947, when Ohno began his work the Toyota production system, the Japanese did not have vast amounts of inexpensive computer power at their disposal. But even if they had it is not obvious that a computerized system would have been nearly as efficient as the way Ohno discovered for doing the job.

Just In Time

To meet the challenge of delivering parts when they were needed, Ohno developed the *kanban* system. The system has since been adopted in many different forms and has come to be known as just-in-time or 'stockless' production.

Kanban/Just In Time has become synonymous with Japanese industry, so it is shocking to learn where it came from. As Ohno tells it:

Kanban [is] an idea I got from American supermarkets.

Following World War II, American products flowed into Japan -- chewing gum and Coca-Cola, even the jeep. The first U.S.-style supermarket appeared in the mid-1950s. And, as more and more Japanese people visited the United States, they saw the intimate relationship between the supermarket and the style of daily life in America. Consequently, this type of store became the rage in Japan due to Japanese curiosity and fondness for imitations.

In 1956, I toured U.S. production plants at General Motors, Ford and other machinery companies. But my strongest impression was the extent of the supermarkets' prevalence in America. The reason for this was that by the late 1940s, at Toyota's machine shop that I managed, we were already studying the U.S. supermarket and applying its methods to our work. . .we made a connection between supermarkets and the just-in-time system.

. . .A supermarket is where a customer can get (1) what is needed, (2) at the time needed, (3) in the amount needed . . .From the supermarket we got the idea of viewing the earlier processes in the production line as a kind of store. The later process (customer) goes to the earlier process (supermarket) to acquire the required parts (commodities) at the time and in the quantity needed. The earlier process immediately produces the quantity just taken (restocking the shelves). We hoped that this would help us approach our just-in-time goal and, in 1953, we actually applied the system in our machine shop at the main plant.[33]

Just-in-time systems have been defined as those which "Produce and deliver finished goods just in time to be sold, subassemblies just in time to be assembled into finished goods, fabricated parts just in time to go into subassemblies, and purchased materials just in time to be transformed into fabricated parts."[34] Or, more simply: "the idea of producing the necessary units in the necessary quantities at the necessary time."[35] The term is sometimes used in ironic contraposition to 'just-in-case', the mass production philosophy of keeping massive inventories on hand to cover any eventuality.

The kanban system as conceived of by Ohno was brilliant in its simplicity. Kanban in Japanese means visible record. Basically, each lot of parts had a kanban card attached to it. When the parts were passed down the assembly process, the kanban was attached to them. When more of the part type was required, the card was passed upstream, the worker set up the machine to produce the part, and production commenced. The same system was used with suppliers as well. Most of them were located in close proximity to the Toyota plant, so kanban cards could be easily delivered.

When suppliers produce product of extremely high quality and deliver in exact quantity in response to kanban requests, much of the cost and overhead associated with mass production vanishes. There is no need for incoming inspection, raw material inventories, or sophisticated billing, ordering, shipping, and receiving procedures. The kanban card, for example, becomes the purchase order and a copy of it (or the actual card itself) can be sent to the accounting department and serve as the bill from the supplier. In the process, lots of manufacturing overhead, and accounting complexity, vanishes. Production becomes lean not only on the factory floor but in the factory office space as well.

One of the authors, when he was responsible for a factory, remembers reviewing a six inch thick stack of paper work associated with the payment for the purchase of 1,000 floppy discs. As he dug into the pile, he asked his controller why it was so difficult to figure out how much money was owed. The answer was simple. The quantities shipped were different than the quantities ordered. If fifty units were supposed to arrive on a particular day sometimes fewer did, and other times more. Seldom did the right quantity arrive at the right time. Of course, a large percentage of what was shipped had to be returned as faulty -- and that meant even more paper work associated with returning the material and tracking its replacement. Hours of work were expended on what would have taken minutes with a kanban system and reliable supplier. On top of that, the company had to maintain large amounts of just-in-case inventory.

Of all of the new virtualized manufacturing processes, just-in-time is probably the most pervasive. In 1985, Purchasing magazine polled 400 of its readers and determined that 20 percent had a JIT program in place, and 10 percent more were planning one. Two years later, with 1,000 respondents, the sum of the two responses had jumped to 72 percent.[36] The great preponderance of these JIT implementors (more than 75 percent) reported improvements in quality and productivity.[37]

One reason for this jump is a recent recognition of the benefits of the JIT system for both high and limited volume production. Western companies, watching the Japanese use this methodology to produce limited selections of high quality, low-priced products, often concluded that JIT was useful only in high-volume, long production run manufacturing. The firms decided that the greater product variety of job-lot production often found in Western factories would be the best defense against Japanese competitors armed with JIT.

As we all now know, the truth was just the opposite. Writes Richard J. Schonberger: "Growth spawns variety. The company that has gotten rich making 'basic black' will then build a plant to make some other model or product. In time, the company ends up with a full line of models, all produced and sold in volume and manufactured more or less repetitively — the present situation at Nissan, Sony, Canon, and other top Japanese companies. The Western job-lot competitor no longer has even the advantage of more product variations."[38]

Not that implementation of JIT will come easily. While U.S. industrial companies have jumped on JIT as a solution to many of problems, their suppliers have proven far more resistant. Said Vaughn Beal, president of one of the most famous JIT success stories, Harley-Davidson, "The easy half of the job of implementing JIT is doing it inside. The tough one-half is doing it with suppliers." A study in the Journal of Purchasing and Materials Management found that 50 percent of automotive JIT users reported that poor supplier quality was a problem; and that while the 85 percent of these respondents had implemented JIT, only 39 percent of their first-tier suppliers had.[39]

One reason for supplier resistance to JIT is a fear that manufacturers will use it a means for shifting blame up the chain and loading suppliers with inventory they once carried themselves. Smart companies have moved to assuage this concern by creating stronger supplier-manufacturer ties through shared information and even manufacturer training and investment in supplier JIT systems. Needless to say, it is precisely this sense of co-destiny, of shared participation in product creation that is a precursor to virtualization (see Chapter 7).

It is easy to see how, in the virtual corporation, JIT will play an important role. Affordable volume production of custom products will require strong control over inventories and production to maintain both competitive pricing and the ability to make nearly-instantaneous product shifts to meet changing market demand. This can only occur if the manufacturer is not burdened with expensive and soon-to-be obsolete inventory. The reduction of inventory in the system also eliminates the shockwaves of frantic orders and cancellations that paralyze the supplier network as suppliers struggle to control their inventories while being whipsawed by violent changes in customer demand.

For the just-in-time process to work, everything must be right. Machines must function when they are needed and not break down unexpectedly. Parts must be right when they arrive. If they are out of specification and cannot be used, the line will stop. One of the beauties of the just-in-time system is that it does stop whenever there is a problem. It therefore provides tremendous motivation to fix problems permanently so they will not occur again. By the same token, it would be a mistake to install a just-in-time system in a facility plagued with quality problems.

The virtual corporation is likely the most fertile environment for implementing JIT. A company built on the efficient and rapid gathering, processing and distribution of information is one that can take JIT to new levels of precision. The ability to predict market changes takes just–in-time out of a reactive mode into a anticipatory one.

Nevertheless, it still seems likely that the dream of a perfect Just-in-Time production system will remain just that even in the virtual corporation. Pure JIT, devoid of inventories altogether, will be a rare event in 21st Century. Even the Japanese have found that in most situations, supporting pure JIT is simply too expensive.[40] Rather, each industry is likely to find a optimal mix of JIT and some inventories. This mix, which will change dynamically with the shifting operations of the virtual corporation, will depend upon such factors as type of product (or component), production facilities, organization and location.[41]

Total Quality Control

Hand in hand with Just-in-Time goes the race for perfect quality. When there is no margin for error, there can be no tolerance for performance short of perfection.

Emphasizing quality as a production methodology was an American invention, the life's work of such men as W. Edwards Deming and J. M. Juran. It was the Japanese, however, who put it to use to establish an almost-unassailable reputation in the world marketplace. As Ohno has written: "Imitating America is not always bad. We have learned a lot from the U.S. automobile empire. America has generated wonderful production management techniques such as quality control and total quality control and industrial engineering methods. Japan imported those ideas and put them into practice."[42]

One important aspect of total quality control is that it shifts major portions of the responsibility for quality from the staff operations of a firm to the manufacturing line. That is to say, obtaining ever-higher product quality is no longer solely the task of the quality organization, pre-production design or post-production inspection, but an inextricable part of the manufacturing process itself. As such, a product is not considered built unless it performs to specifications.

Juran himself has consistently refused to give a simple definition for *quality*, arguing that any such definition would be a trap. Instead, he opts for a multiplicity of meanings, of which two have critical importance. The first is *product performance/product satisfaction* [he adds that 'product' includes both goods and services] and *freedom from deficiencies/product dissatisfaction*. The first deals with characteristics of the product that lead users to become satisfied that they made the purchase -- features such as ease–of-use, gas mileage, promptness of delivery, etc. The latter deals with those factors that make the customer unhappy with the purchase and leads to complaints, repairs and returns. Juran stresses that the two meanings are not opposites to one another. Rather, the goal of product performance is to be better than competing products; the goal of freedom from deficiencies is perfect quality.[43]

The key to achieving total quality is getting everyone in the organization from the president on down involved in the process. All of the external suppliers must buy into the process as well. The goal is to eliminate all defects. In the process, employees, not just quality control specialists, are taught how to identify problems and analyze their source using a variety of diagnostic tools such as quality dispersion charts, defect frequency rates and trends, process control charts, and the so-called Ishikagawa 'fishbone' diagram, which charts the causes and effects in a particular manufacturing process.[44]

Organizations which have gone on to achieve high levels of quality have sometimes claimed to not have any quality organizations at all. Quality, they say, has become such a part of the company culture that everyone knows that it is his job to eliminate all defects. These advanced organizations further support and maintain these high quality levels through management example and on-going training programs.

The value of quality came as a surprise to many American manufacturers and service suppliers. Many were stunned by the realization that quality was in fact free. An early voice, Philip Crosby estimated that the cost of poor quality could be as great as 20% and that with processes that eliminated defects and waste most of that money could be saved.[45] He went on to list his four commandments of product quality:

1. Definition: Quality is the performance to requirements.
2. System: The prevention of defects.

3. Performance standard: Zero defects.
4. Measurement: The price of non-conformance to perfect quality.[46]

The combined effects of lean production systems, JIT methods and TQC processes are stunning. For example, in studying the impact of combined JIT/TQC programs, authors Charles O'Neal and Kate Bertrand found a wealth of success stories, including:

-- Harley-Davidson reducing manufacturing cycle times for motorcycle frames from 72 days to just two, while increasing final product quality from 50 percent to 99 percent.

-- Digital Equipment, at its Albuquerque computer workstation pilot line reducing overall inventory from 16 weeks to three, while reducing the defect rate from 17 percent to 3 percent.

-- 3M's Columbia, Missouri plant, that saw a *seventy times* reduction in critical defects, appearance defects and packaging problems.[47]

Other observers have located similarly spectacular case studies throughout American business. For example, *Business Week* found at yet another 3M plant, this one in St. Paul, a quality program in the production of two-sided industrial tape cut waste by 64 percent, reduced customer complaints by 90 percent and increased production by 57 percent . . .all in two years.

One of the most remarkable of these stories is in Kodak's manufacture of plastic tips for blood–analyzer machines. In ten years the company cut defects from 2,700 per million to just two. And the only reason those two were bad was because someone had closed the package improperly.[48]

Other firms throughout the world have experienced similar results. In the early 1980s Philips Electronics, one of the world's most successful automobile headlamp makers, tried to sell its products to Toyota -- only to find the Japanese firm deeply disappointed with the quality of the lamps. Philips adapted Toyota's TQC measurement system and discovered its product quality "was devastating", according to a company executive, "Our old wisdom was not valid anymore." Philips perservered, pursuing the elusive Toyota goal, and improved packaging, manufacturing, and transportation. The result was, by 1990, the firm enjoyed considerable savings in wasted material, saw defect levels fall 100 times, doubled its exports to Japan and captured 60 percent of that market.[49]

The differences on the bottom line were easy to identify in the MIT study of the automotive industry. At the Toyota Takoaka plant in 1986, it took 16 hours to build a car in 4.8 square feet of workspace per vehicle per year with .45 defects. At Framingham, it took nearly 31 hours in 8.1 square feet, with 1.3 defects. Toyota was responding to the market more quickly, using half the labor hours, getting more output from every square foot of expensive plant space, using its capital equipment more efficiently and *still* producing a higher quality product with lower warranty costs because it had fewer problems.

If this didn't make the point, the NUMMI plant did. In 1987, using American UAW workers, the plant built a car in 19 hours in 7.0 square feet and, most important, matched Takaoka with .45 defects per car. Inventories, which averaged 2 weeks in Framingham, fell to just 2 days at NUMMI Fremont -- still short of the two hours at Takaoka, but certainly a decided improvement which cut the need for millions in working capital.[50]

The Toyota Production System was transferrable to U.S. suppliers as well. *The Wall Street Journal* reported on Bumper Works Inc., a small Danville, Illinois manufacturer of pickup truck bumpers that Toyota targetted as a test case for its system in the United States. Bumper Works, which already had an excellent reputation for quality, still managed to increase productivity by 60 percent and reduce defects by 80 percent.[51]

A warning, however: TQC, lean production, and just-in-time processes are so attractive there is a tendency on the part of results-oriented American manufacturers to go for broke. In the process, they have moved too fast and reached too far and the results have often been disastrous.

General Motors tried to cure its productivity, worker, and quality problems with automation. It ended up with a technological nightmare.

The GM Hamtramck plant, opened outside Detroit in 1985, was designed to be the pilot for the company's Saturn line as well as a showcase for GM's new commitment to technology. According to Maryann Keller, the plant had 260 robots for welding, assembling and painting cars, 50 automated guided vehicles to serve the assembly line; "and a battery of cameras and computers that used laser beams to inspect and control the manufacturing process."[52]

"But, instead of a showcase, Hamtramck became a nightmare of technology gone berserk. The stories of robot breakdowns and miscues read like a 1950s B movie that might have been titled *Robots from Hell*...

-- Robots designed to spray-paint cars were painting each other instead.

-- A robot designed to install windshields was found systematically smashing them.

-- Factory lines were halted for hours while technicians scrambled to debug the software.

-- Robots went haywire and smashed into cars, demolishing both the vehicle and the robot.

-- Computer systems sent erroneous instructions, leading to body parts being installed on the wrong cars.[53]

Meanwhile, as this debacle was taking place at Hamtramck, a research team from MIT found that a Ford plant producing comparable cars using far less technology was showing the same productivity. And as if that wasn't enough, in 1987 Toyota opened a plant in Kentucky that used little robotics at all . . .and quickly had *twice* the production rate of Hamtramck.[54]

The GM story is unfortunately not unique. Americans have tended to focus on short-term results and posting the best possible numbers on the next quarterly report. The Japanese, taking a longer view, have believed the best way to achieve results was to perfect the processes upon which they were based. They have also approached the process of improvement in a very conservative way, becoming great believers in taking small incremental steps and pursuing the goal relentlessly over extended periods of time. The Japanese have a word for this approach: *kaizen*.

Kaizen

Author Masaaki Imai calls kaizen "the single most important concept in Japanese management -- the key to Japanese competitive success." His definition:

"KAIZEN means *ongoing* improvement involving *everyone* -- top management, managers, and workers. In Japan, many systems have been developed to make management and workers KAIZEN-conscious.

"KAIZEN is everybody's business. The KAIZEN concept is crucial to understanding the differences between Japanese and Western approaches to management. If asked to name the most important difference between Japanese and Western management concepts, I would unhesitatingly say, 'Japanese KAIZEN and its process-oriented way of thinking versus the West's innovation- and results-oriented thinking...

'In business, the concept of KAIZEN is so deeply ingrained in the minds of both managers and workers that they often *do not even realize* that they are thinking KAIZEN."[55]

Kaizen can also be seen as Cohen's and Zysmun's second form of manufacturing responsiveness, *dynamic flexibility*, which they define as "the ability to increase productivity steadily through improvements in production processes and innovation in product."[56]

For Imai, kaizen is the philosophical underpinning not only of all Japanese business methods, but also of the society itself. Specifically in manufacturing, it is a customer-driven process "in which it is assumed that all activities should eventually lead to increased customer satisfaction." This is accomplished by different kind of management thinking that rewards people's "process-oriented efforts for improvement", and not just results alone.

It's not hard to see the relationship between quality control and kaizen -- in most applications, kaizen, as a system of communicating ideas for improvement up and down the corporation hierarchy, is the most efficient vehicle yet found for improving quality. Kaizen, with its different system of motivation and reward, is vital to the success of quality control circles. It is kaizen that enables some Japanese firms to now look beyond 'quality that is taken for granted' (*atarimae hinshitsu*) to the extraordinary notion of 'quality that fascinates' (*miryokuteki hinshitsu*) and the confluence of technology and aesthetics that marks the virtual corporation. [57]

Kaizen is one of the few well-developed business improvement philosophies. In use, it shifts the corporate orientation away from the bottom-line (results–orientation) and the fitful starts and stops that come from dependence on product breakthroughs (innovation-orientation) towards a continuous, gradual slope of improvement in products, quality, and cycle times. As Cohen and Zysmun see it, "American firms tend to produce product innovations periodically, moving from one plateau of best practice to another. The Japanese, studies suggest, move through continuous and interactive product innovation, steadily improving the production process."

One result of this difference in philosophy, they add, is the "Japanese system, with its greater dynamic flexibility, has achieved greater productivity gains over the last few years than the more rigid American one."[58]

One of the greatest strengths of kaizen is the speed with which it can incorporate the latest technological advances -- an important factor when one considers that many studies of economic growth since World War II have concluded that technology, more than capital or labor, has been the dynamic force behind economic development and improvements in productivity. One reason a kaizen-driven company can do this so efficiently is that its entire workforce is oriented towards locating new ideas and swiftly and effectively putting them to work. In essence, every employee becomes a management consultant.

Different companies have different techniques for implementing kaizen. One of the most interesting comes, not surprisingly, from Taiichi Ohno. It is called the "five whys" and it operates just like its name. When a production problem is encountered at Toyota, one is expected to ask why it happened five consecutive times, each with a greater level of precision, until eventually the symptoms are overcome and the root cause emerges.[59]

To illustrate the power of kaizen in action, Imai offers the example of Nissan Motors' Tochigi plant, which in the decade after the 1973 introduction of its first welding robot, increased its automation rate to 93 percent and its robotization rate for welding work to 60 percent -- while at the same time reducing standard work time by 60 percent and improving efficiency by as much as 20 percent. This remarkable metamorphosis occurred, according to a Nissan executive, through a series of kaizen campaigns that searched for plant improvements in increments as tiny as *six-tenths of a second.* Imai quotes one staff engineer as being told by his boss on the first day on the job: "There will be no progress if you keep on doing the job exactly the same way for six months."[60]

Through the use of kaizen the Japanese have chipped away at their manufacturing problems. They have improved quality here, reduced a set-up time there, replaced a poor supplier with a better one, worked with capital equipment suppliers to get them to produce equipment that was more reliable, easier to maintain, and faster to set-up, trained their components suppliers to do a better job . . . and in the end improved quality and JIT performance to the point where lean production became possible. Needless to say, by definition, none of this happened overnight. Taiichi Ohno started his pursuit of lean manufacturing in the late 1940s and only felt he had the process working reasonably well by the early 1970s.

This suggests that companies cannot achieve virtuality overnight in their factories through some kind of massive re-organization or design project or capital equipment investment. Quite the contrary: building a virtual factory requires changing almost every brick in the corporation. Do that too quickly and the structure will collapse. The only practical way to is through *kaizen.*

An interesting story illustrating this point is told by Masaaka Imai:

Back in the 1950s, I was working in the Japan Productivity Center in Washington, D.C. My job mainly consisted of escorting groups of Japanese businessmen who were visiting American companies to study "the secret of American industrial productivity."

Toshiro Yamada, now Professor Emeritus of the Faculty of Engineering at Kyoto University, was a member of one such study team visiting the United States to study the industrial-vehicle industry. Recently, the members of his team gathered to celebrate the silver anniversary of their trip.

At the banquet table, Yamada said he had recently been back to the United States in a "sentimental journey" to some of the plants he had visited, among them the Rouge River steelworks in Dearborn, Michigan. Shaking his head in disbelief, he said, "You know, the plant was exactly the same as it had been 25 years ago."[61]

The lesson of Imai's story is that while a heavy reliance upon masterstrokes has been the bane of U.S. manufacturing, so has inertia, an acceptance of the status quo. Kaizen and the route to virtual corporation lies in-between. No doubt in the rapidly changing business environment to come some companies will speed ahead too fast with reckless disregard for what is practical. Others will remain wedded to the past. But the ones who take the message of JIT, TQC and kaizen seriously will effectively confront the challenge.

The Illusion of CIM

The virtualization of manufacturing and the information processing revolution have occurred simultaneously. So, it is not surprising that there has been an on-going interest, and sometimes pressure, to put the latest electronic miracle to work on the plant floor.

In some instances, this process has worked beautifully. There are a number of examples of numerical control machines, basic robotics, and a host of other techology-driven tools and systems having had a very positive effect upon manufacturing.

With the tools proving themselves so useful, there has been a subsequent drive to integrate them into clusters to assume ever--greater production responsibility. The first few levels of this integration, such as seen in the Remington arms, Ford engines, and GE circuit breakers examples, are usually described by the phrase 'flexible manufacturing system', or FMS.

More specifically, FMS is defined as a "computer controlled manufacturing system using semi-independent numerically controlled (NC) machines linked together by means of a material handling network."[62] FMS was the next logical step in a process that had begun with very high volume, low complexity transfer lines containing dedicated machines and had progressed, with the use of computers and NC machines, to the automation of more sophisticated processes. FMS was targeted at bringing cost-effectiveness to what was described as "mid-volume/mid-variety" applications.[63]

In application, FMS places a series of NC and other machines under the control of a computer system that controls the sequential or random production of a family of parts. The machines are physically linked together by a material handling system. The computer's role is "to continuously monitor the activities of the equipment and provide supervisory and engineering reports. Simulation can be used effectively to predict the behavior of system components and, therefore, provide for appropriate corrective behavior when needed."[64]

Implemented properly, FMS can be a potent tool. It lends itself neatly to all the other components of virtualized manufacturing -- JIT, total quality control, kaizen and innovation -- and in the process helps the manufacturer achieve many of the goals of virtualization, including shorter cycle times, a smaller/smarter labor force, smaller lot sizes and improved short run responsiveness/long-term adaptability.

Unfortunately, FMS is often not properly implemented. And doubly unfortunate, but certainly in keeping with Imai's claim that whereas kaizen "is people-oriented, [American-style] innovation is technology- and money-oriented"[65], many U.S. firms, convinced that computerization is the universal key to manufacturing success and have leap-frogged basic FMS into what is called "manufacturing cell" or, more popularly, Computer Integrated Manufacturing (CIM). CIM takes the flexibility of FMS to another level of integration, one that perpetually finds the optimum match between labor and automation to achieve the maximum value of both.

CIM is wonderfully appealing in theory, often for the wrong reasons ('lights out" factories, no more labor troubles, a quick edge on the competition). That's why CIM, touted as the big manufacturing breakthrough of the age, has, at many companies, turned into a disaster. And the reason is simple: to implement computer integrated manufacturing requires the kind of sweeping organizational changes towards virtuality that many companies investing in CIM have yet to make.

Clues to this costly fiasco could already be seen with FMS. A survey by Jaikumar in 1986 found that American flexible manufacturing systems exhibited an "astonishing" lack of flexibility, sometimes performing worse than the equipment they were designed to replace.[66] One example was Ford's St. Louis minivan plant, which had to go with a less–appealing and heavier floor plan for one of its vehicles because the computer-controlled line was too inflexible to handle a better design. [67]

Poorly implemented FMS systems result in a poor use of machine tools, increased lead times, increased in-process inventories, and inefficient use of floor space.[68] And this was only *medium* complexity manufacturing; CIM, designed for high complexity, only took the failure to another level of magnitude. The most notorious case, once again, is General Motors, with its estimated $40 billion investment during the 1980s in computers and robotics to little apparent positive effect.

Tellingly, the companies that did succeed with CIM were often those companies (such as IBM) that needed it least. For those firms, CIM was merely the next step in a program of continuously improvement in efficiency that began with first understanding the flow of parts and information through the factory, then bringing on increasingly information intensive tooling and reporting systems. Wrote researchers at Touche Ross: "There is a necessary progression from quality to dependability to cost to flexibility."[69]

In the words of an Association for Manufacturing Excellence report on flexibility:

> The strategy of flexibility cannot take root unless the environment for it is right. There are a number of assumptions about the conditions necessary for flexible organizations. One is that, for practical purposes, companies are regarded as the network of people who compose them. Flexibility cannot be purchased by acquisitions or merger. Flexibility is something that people *do*. Organizations of people may be combined or dissociated, but flexibility itself is not attainted through things, financial or physical.[70]

Searching through the rubble of failed or failing CIM programs and then comparing what they found with successful programs, managers and academic researchers made some important discoveries.

The most important of these was that the term CIM itself was a dangerous misnomer. It was not computers that were being integrated into the manufacturing environment, but people . . .hence the growing use of the replacement phrase Human Integrated Manufacturing (HIM). According to Earl Hall, unlike CIM, HIM recognizes that it is crucial to determine the most efficient manufacturing practices *before* automating them, that software and communications network require greater resources for development and maintenance than was thought, and most of all, that computer-based manufacturing systems must "be designed for the total manufacturing environment, including the important human interface, and not as only productivity enhancements replacing the human being."[71]

Similar sentiments were heard elsewhere. "The early focus [mostly technological] has been broadened to include cultural [people-oriented] issues and an emphasis on communications," says Peter C. Graham, CIM market-development manager for Digital Equipment. Adds Jack Conaway, DEC's manager of CIM strategic programs: "In CIM, doing the right things in the acquisition or implementation step must proceed from an understanding that the content of CIM is 80 percent cultural and only 20 percent technological. And unless an organization structures itself for an integrated operating mode, the acquisition process will fall short of the success hoped for."[72]

What does this mean is daily business life? One obvious fact is that HIM demands a better trained workforce. Wrote one observer: "If the human factor behind all this slick new technology is ignored or poorly managed, even the best physical and technical changes will fail miserably."[73]

American workers have traditionally resisted any form of automation on the not wholly-inaccurate assumption that companies want to use it to displace them. The irony for both management and labor is that an effective HIM program not only usually increases the role of direct labor on the factory floor, but also its influence throughout the organization. The so-called "Wisdom of the Shop" plays an important role in the virtual corporation.[74]

One person who has long understood the real role of computers in manufacturing as the facilitator of labor is, the always prescient Taiichi Ohno. In his book Toyota Production System, Ohno makes the astonishing comment about the structure of a manufacturing firm.

> A business organization is like a human body. The human body contains autonomic nerves that work without regards to human wishes and motor nerves that react to human command to control muscles. The human body has an amazing structure and operation; the fine balance and precision with which body parts are accommodated in the overall design are even more marvellous . . .
>
> At Toyota, we began to think about how to install an autonomic nervous system in our own rapidly growing business organization. In our production plant, an autonomic nerve means making judgements autonomously at the lowest possible level; for example, when to stop production, what sequence to follow in making parts, or when overtime is necessary to produce the required amount.
>
> These discussions can be made by factory workers themselves, without having to consult the production control or engineering departments that correspond to the brain in the human

body. The plant should be a place where such judgements can be made by workers autonomously.[75]

Ohno continues the metaphor even further, suggesting that businesses succeed because of their reflexes, their ability to react to the slightest change, and that "the larger a business, the better reflexes it needs." He also adds that companies can stiffen and slow with age just as people do.

Finally, this latter-day Hobbes turns to the mind of his corporate leviathon. Over the millenia, mankind has, he suggests, developed an 'agricultural' mind, an attitude about time and resources that has often been at odds with the industrial world. Now, says Ohno, some wish to go to a 'computer' mind in one jump. That would be a mistake, he says, because we must pass through the intermediate step of the 'industrial' mind. "The industrial mind extracts knowledge from working people, gives the knowledge to the machines working as extensions of the workers' hands and feet, and develops the production plan for the entire plant including outside cooperating firms."[76]

He goes on to note that American mass producers now use computers extensively. So too does Toyota, says Ohno, "but we try not to be pushed around by it . . .We reject the dehumanization caused by computers and the way they can lead to higher costs."[77]

In the United States, where business imagery typically deals with organized sports or warfare, such an anthropomorphic view of the corporation would be inconceivable . . .until recently. Consider this quote from a well-known Harvard Business Review article:

The manufacturers that thrive into the next generation will compete by bundling services with products, anticipating and responding to a truly comprehensive range of customer needs. Moreover, they will make the factory itself the hub of their efforts to get and hold customers— activities that will now be located in separate often distant, parts of the organization. Production workers and factory managers will be able to forge and sustain new relationships with customers because they will be in direct and continuing contact with them. Manufacturing, in short, will become the cortex of the business. Today's flexible factories will become tomorrow's service factories."[78]

Listening to these arguments, Coriat's statement that lean production was more a organizational invention than a technological one becomes all the more cogent. The factory of the future will be more humanistic (and humane) than many people think.

While technology will not solve all of manufacturing problems facing the virtual corporation, it will certainly present it with a host of opportunities. One of them is an unprecedented degree of flexibility in where to locate production facilities. With instantaneous world wide communications it is theoretically as easy to control a factory in Asia as it is one which is right next door. The ease with which production can be integrated around the world will mean companies will have greater flexibility than ever in selecting plant locations.

As Hall has written: "The 21st century manufacturing company will extend the concept of the integrated production line to include the wide area transportation and communication network which supports that production line."[79]

The virtual corporation, however, will abhor distance. If it can find a friendly environment close to customers, it will want to locate there. Being close will enable it to be more responsive. There will be more opportunities to deal face-to-face with customers, to understand their problems, and to design products that precisely meet their needs, and there will be less chance of something going wrong as the product moves from the factory to the customer. One likely result of this will be a repatriation to the U.S. of production operations moved overseas a generation ago.

Speed has as well turned the world upside down. Flexible factories, in many cases, don't have to be as large as mass production ones in order to be cost-effective. The inflexible machines of the mass production factory had to produce massive number of units in order to justify their existence.

Thanks to the rapid pace of technology it is now possible to build sophisticated factories at very low cost. This means factories will be located centrally in some cases, in the distribution channel in others, and at the customers site in some instances. The location of the factory will be a function of the capital intensity of the process and the skill level required to effectively operate it.

Thus, automobiles, steel, aluminum, paper, dynamic RAMS, synthetic fibers, and pharmaceutical products will still for the most part be made in remote central locations. The capital intensity of the processes, the skill to achieve satisfactory results, and desirability of locating these facilities in certain geographic areas dictates this. But many other products and processes do not face similar constraints.

Low cost and highly automated systems make it possible to process color film in one hour in low volume at numerous points around the country. Prescription glasses which used to take weeks to have made are now commonly available in one hour. The machinery to grind the lens is simple enough to use and low cost enough to manufacture making it possible to place the factory in the distribution channel.

If the production process can be made simple and inexpensive enough, it becomes possible to move it to the customer's plant, even into the consumer's home. Camcorders have made it possible for just about anyone to produce his or her own movies. Individuals can measure their own cholesterol levels, blood sugar and pressure, and determine whether they are pregnant without ever getting a doctor or clinical laboratory involved. By the same token, an engineer can program an ASIC at his desk creating an integrated circuit in minutes that would have taken a year and thousands of dollars just a few years ago.

If virtual products can be put into the customers hands, why not virtual services? Of course they already exist. Companies and individuals using computers are already doing banking transactions from their homes and offices. Thousands of ATMs have put virtual banks on every street corner. It is now possible, thanks to computerized airline reservation systems, to make reservations and print tickets easily and inexpensively at remote locations -- making it possible to locate a travel agency almost anywhere. Then there are the virtual libraries. Vast amounts of information has been stored in data bases in remote computer systems. These data bases can be searched at computer speeds to find key word references in millions of documents, thus rendering obsolete old card files and dog-eared Reader's Guide to Periodicals. In much the same way lawyers can use Lexus to find legal precedents and authors can search though years of the New York Times clipping morgue from their homes using the Source.

Of course, though we become so accustomed to it as to forget, all of us are living with virtual stores in our own homes. Flip on the TV and you can buy products from Home Shopping Network. Open the mail box and discover Fifth Avenue's best stores at your finger tips -- and use Federal Express to get products you order delivered the next day. The suburban shopper can now get products from the virtual Tiffany's faster than he or she can from downtown stores, the latter being an onerous journey that often must be planned weeks ahead.

The virtual production facility is highly responsive and mobile. As technology moves ahead, it will be possible to put more and more of it in the customer's hands, anywhere in the world.

The virtual factory may seem too good to be true. Custom products produced faster and at lower prices than mass produced ones? It would be a preposterous notion if we weren't already seeing it happen. For once, both the producer and the consumer win.

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Chapter 7: Shared Dreams

Xerox was once the most secretive of American companies. But in the late 1970s, faced with copier costs 30 as much as 50 percent greater than its Japanese competitors, and watching its once dominant market share dwindle, Xerox set out to regain its competitiveness.

To do that, Xerox knew it had to make severe cuts in production costs. That it turn meant it had revise the very nature of its relationship with suppliers. In the words of James Sierk, group vice president for quality, "To get ten times better, you have to change the process."[1]

The first step was slash away at the supplier lists. Xerox set a goal of reducing the number of suppliers from 5,000 to 500. The company reasoned that it would have to work closely with its suppliers to manage their performance and 500 was the maximum it could handle. Said Sierk, "We could never have trained 5,000 suppliers."[2] At the same time, the company announced a goal of just 1,000 parts rejected per million on its assembly lines -- compared to as much as 25,000 rejects per million being delivered at the time by some suppliers.

Ultimately, Xerox cut back to just 325 suppliers, a number that in time stabilized at 400. With this manageable group, Xerox embarked on an intensive training program, including instruction in statistical process control, statistical quality control, just-in-time manufacturing, and total quality commitment. [3] Those suppliers that didn't keep up were dropped, sometimes en masse.

The result was that between 1981 and 1984 net product cost was reduced by nearly 10 percent per year; rejection of incoming materials by 93 percent. New product development time and cost were cut by 50 percent and production lead times fell from 52 weeks to 18 weeks.[4]. By 1989, the defect range was just 300 per million and the company's Business Products & Systems Group won the Malcolm Baldrige National Quality Award.[5]

Xerox had reduced its supplier base by over 90%. Nine out of ten companies who were doing business with Xerox at the beginning of the process were no longer receiving purchase orders. The remaining suppliers saw their business grow.

Reshuffling the Deck

The Xerox story is a harbinger of the future. So is the 1991 agreement between those two historical antagonists, IBM Corp. and Apple Computer. And so are the General Motors supplier councils; and Genecor, the joint venture of Genentech Inc. and Corning Glass Works. So is Sematech and other industry or regional consortia. So too is the investment of Ford and Volvo into Hertz; Ford, Tenneco and Kubota into Cummins Engine; and Boeing and GE into United Air Lines.[6]

Like all business transformations, the virtual revolution is forcing a revision of traditional business arrangements towards what Harvard professor Benson Shapiro calls "the new intimacy". As the rapid gathering, manipulating and sharing of information moves to preeminence and as company boundaries grow increasingly fluid and permeable, established notions of what is 'inside' and what is 'outside' a corporation become problematic, even irrelevant.

So too do the once-obvious differences between *supplier, manufacturer, distributor, retailer, customer*, even *competitor*. At one time or another, an enterprise or an individual may play multiple roles. For example, manufacturing can be moved up the chain and placed into the hands of the traditional supplier, as with semiconductor companies assuming much of the work once done by computer makers. Or it may move downstream to distributors (such as value-added resellers of computer networks), retailers (photo processing) and even consumers (the creation, from components, of home computer and audio-video entertainment systems). By the same token, suppliers can by-pass the putative manufacturer to become distributors; or they can obtain market information directly from customers, as with Burlington.

Customers too have been enlisted into the virtuality campaign, helping to design their Japanese cars, performing diagnostics and simple repair work on their Xerox machines, and by-passing the retailer and distributor at warehouse stores and manufacturer's outlets. Why involve customers so deeply? Because often the customer is in a better position to design the products he wishes the supplier to produce than the supplier is.

In the words of Derek Leebaert of Future Technology, Inc.:

"In the future, there will be continuous anticipated feedback to the producer from the eventual customer. The "end" of a transaction will be defined far closer to the real end. A new degree of control, by the hours rather than by the months, will change our notion of a finished product. At present, making changes in a major industrial process is like turning a supertanker. Like Alexander Pope's spider 'living along the line,' all parts of the process will be inter-feeling."[7]

Some industry observers have also predicted a rise in 'dynamic multi-venturing': multiple-player joint ventures, sometimes even between erstwhile competitors, in which teams from the different companies come together to work on a common technology or product goal. Certainly, the Apple/IBM (and Motorola) arrangement suggests such a possibility, as did the AT&T/Marubeni/Matshusita Safari computer project. But it remains to be seen if this is will develop into a broad trend, or if companies will be willing to move beyond an arms-length relationship to actually surrendering sovereignity.[8]

Needless to say, this widespread reconfiguration of business relationships is likely to create complementary internal reorganizations. There are also appears to be no universal template for such a corporate structure. On the contrary, the constant shifting of roles by the players involved suggests that the virtual corporation may exist in a state of perpetual transformation. As BRIE research suggests, the future structure of successful businesses may even change with differences in national culture -- from Japanese mega-corporations to the assemblages of small factories in Northern Italy -- adapting to different forms of organized labor, management styles, laws, social mores, even familial relations.

Yet, at the same time, from another perspective, virtual corporations will also be more stable and unchanging than their contemporary counterparts. This will be due to the nature of the relationships themselves, resulting from the stronger and more enduring ties that will come from a shared destiny with a small group of both suppliers and customers.

Thus, seen up close, the virtual corporation will appear amorphous and in perpetual flux; but from afar, it will seem permanently nestled within a tight network of relationships.

In studying the nature of that network, it is best to look beyond the old categorizations and instead evaluate the flow of information, goods and services to suppliers and through the distribution channel to end-users.

A common future and mutual support will be the hallmarks of relationships between suppliers and customers. Virtual products and services will have a very large service component, much higher than that associated with conventional products and services. Customers and suppliers will increasingly share the same fate. For either to succeed, they both will have to prosper. The term *co-destiny* captures the spirit of buyer and seller relationships of the future. Each will be locked into the destiny of the other.

Mutual dependence will characterize the virtual business relationship. Customers will be very dependent on suppliers. They will have invested very heavily in their supplier relationships. They will have shared their business secrets with them. They will have trained them in their needs, and integrated them into their design processes. Not surprisingly, the excellent supplier will be viewed as irreplaceable.

Suppliers will view customers in an identical fashion. A good customer will be a precious asset. Hundreds of hours of management time will have been spent to secure key relationships with the customer. Suppliers' businesses will be restructured to meet the needs of the customer base. Plants may even be relocated to better respond to customer needs. Losing a good customer will be a business crisis.

Companies are going to increasingly structure their businesses around the market segments they serve. The products they design will be tailored to the markets they serve. The service infrastructures they put in place will have to meet the needs of specific customer groups. For all but the most basic commodity products, companies will find themselves increasingly bound to market segments and the customers who belong to them.

The Virtual Supplier

The implications for new types of interactions between suppliers and manufacturers has been a hot topic for discussion in recent years.

Authors Michiel Leenders and David Blenkhorn have identified the need for customers to do a better job of getting suppliers involved in assuring the success of their customers.

". . .supply is part of the competitive edge and of continuing top management concern . . .The greatest contribution potential for supply stems from early involvement in the development of new projects, products, services, and organizational strategies.[9]

. . .A good supplier lives up to the deal made with respect to quality, quantity, delivery, price, and service. A better supplier goes well beyond this minimum by taking the initiative to suggest ways and means whereby the customer can improve products, services, and processes. An exceptional supplier places the customers' needs first and is in tune with the long-range objectives and strategies of the customer. The exceptional supplier has the mission to make the customers prosper. Good, better, and exceptional suppliers are scarce. Therefore, supply management can be called the battle for good suppliers."[10]

What Leenders and Blenkhorn argue is that as competition becomes more global and as product cycle times shorten, the traditional arms-length relationship between suppliers and buyers must end. Buyers will depend ever more upon their suppliers not only for fast and reliable delivery, but also to play an even greater role in the design and manufacture of the finished product.

Leenders and Blenkhorn advise companies that if they wish to get high levels of involvement from suppliers they have to sell them on the benefits of being an exceptional supplier. They have given this process a name: *reverse marketing*.

They aren't alone in calling for this change. Dr. Brian Joiner, president of Joiner Associates Inc. business consultants, has said, "There are many places where close relationships between customers and suppliers solves problems. Nowadays I think a long-time close relationship between customers and suppliers is critical to survival."[11]

Adds Prof. Robert Spekman of the USC School of Business:

"It has become obvious to many manufacturers that their ability to become world-class competitors is based to a great degree on their ability to establish high levels of trust and cooperation with suppliers. . .those who subscribe to the partnership approach to vendor management argue that the gains far exceed the potential risks."[12]

For a virtual corporation to succeed it must be so closely linked with its suppliers as to create a shared destiny; a co-destiny relationship. To achieve that, many of the established barriers between buyer and supplier must be removed. Ultimately, even the boundaries between the two will become indistinct. For example it will not be unusual for suppliers have offices on their buyer's premises, share trade secrets, cross-license patents, provide one another with cost information, and include the other in long-range planning.

But building such bridges between manufacturers and their suppliers does not come easily. It isn't simply a matter of sitting down with the supplier and announcing that 'we need to work together more closely.' Rather, it requires unprecedented levels of trust and commitment to place the fate of a company in the hands of people who *aren't even employees* .

The nature of this heightened trust can be great enough to make even the most open-minded CEO wince.

Writes Industry Week:

"The road to world-class supply chain management meanders through a series of cultural changes -- to a new plateau of trust. To achieve true partnership, customers and suppliers must share information -- on new product designs, internal business plans, and long-term strategy — that once would have been closely guarded."[13]

Suppliers are no more likely to accept this new openness than their customers. S. Charles Zeyncl, director of quality at Union Carbide's Chemicals & Plastics Group in Danbury, Connecticut, got just such a reaction when he proposed supplier-customer joint teams: "[Managers] were concerned that if you [include] customers on a joint team the customers would learn all your secrets, your weak points, and problems."[14]

The demands of just-in-time delivery make it almost impossible for suppliers and buyers not to share both tactical and strategic information. But it is very difficult for companies to engage in information sharing unless they trust the motives of one another. Joseph A. Bockerstette of Coopers & Lybrand has observed, "Many suppliers feel just-in-time is a way for Fortune 500 companies to dump on them."[15] As long as suppliers feel this way it is very unlikely they will give their full support to such a program.

Nowhere will this be more painful than in the sharing of cost information. This violates one of the deepest taboos in all of business. It will require an act of trust far greater even than sharing proprietary technology. Yet, in a virtualized environment this may be required of both supplier and manufacturer so each may help the other reduce process steps, set realistic tolerances and in any other way contribute to their mutual success.

Making the Cut

As manufacturers begin scrutinizing their supplier lists and reducing them to a manageable size, they are likely to keep those with the most reliable offerings and closest relationships and cull out the rest. This narrowing of supplier lists will characterize business at least through the end of the century. As Fortune has written, "Suppliers had better learn fast. Most large U.S. manufacturers are reducing their number of vendors in order to control quality."[16]

A survey by Grant Thornton of 250 mid-sized manufacturers found that 69 percent had imposed stringent quality improvements on their suppliers, and that 76 percent had dropped at least one supplier as a result. Control Data's Cyber division, for example, dropped 650 of its 800 suppliers. Sun Microsystems not only cut its suppliers from 450 to 150, but gave 80 percent of its business to just twenty of the remaining firms. Dell Computer not only demanded that its suppliers meet a specific certification requirement, but that the suppliers of those suppliers do the same.[17]

And this isn't true only in the United States. After tough audits of its suppliers, BMW dropped 100 that did not measure up -- and regularly audits the rest.[18]

Unfortunately, the firms most likely to suffer from this selection process are the small suppliers. Many are insufficiently capitalized to make the requisite investments being demanded by their customers. For others, installing the flexible manufacturing system required to support a virtual customer may represent too much of an operational leap from the current struggle just to get products out the door. Still others may not have a sufficiently broad product line to be a valuable sole source. And, says Prof. L. Joseph Thompson of Cornell, "Small companies are less likely than large companies to have made improvements in productivity. They're concerned about meeting the payroll and not about the longer term."[19]

Big or small, suppliers will have to scramble to make the cut with their increasingly virtualized customers. In some cases, this will lead to considerable pain as relationships of many decades end in lapsed contracts and even bankruptcies.

For the big supplier this heightened competition may mean not only upgrading manufacturing and improving information processing, but even cementing the relationship through equity investment. Recent years have seen a number of cases where major suppliers have bought debt and stock in key customers in order to guarantee future contracts. That's what Ford did when it put $1.2 billion into Hertz's $1.3 billion buyout . . .after all, Hertz, which began buying Fords in 1918, is that automobile company's largest customer.[20]

When the United Airlines parent Allegis Corp. faced a takeover in 1987, Boeing helped by buying $700 million of Allegis preferred stock. Soon thereafter, Allegis placed a $2.1 billion order with Boeing.

Investment can even help suppliers buy into new business relationships. "We'd been trying to do more business with Payless for years," John C. Nicholls Jr. of Masco Corp. told Business Week in explaining why Masco and a sister firm had purchased $209 million of new Payless debt and preferred stock. Masco soon enjoyed a multi-year contract with Payless. "It's our expectation they will become an even bigger customer," said Nicholls.[21]

Small suppliers, without such resources, must look for other ways to assert their irreplaceability. One method is to simply outperform larger rivals in terms of quality, flexibility, and delivery speed. Also working in their favor, at least in the near-term before technology closes the gap, is that customers, as they narrow their sources, will increasingly give preference to suppliers that are physical nearby. Researchers have found that customers visit suppliers in inverse proportion to their distance. Says Russell W. Meyer, chairman of Cessna, "We spend a lot of time with subcontractors. It's a lot easier to work with someone in Wichita than with someone in Los Angeles."[22]

Thus, it will not be surprisingly in years to come to see some suppliers actually packing up and moving near their biggest customer in exchange for long-term commitment. Some Japanese auto parts suppliers already have done this, setting up shop near the Nissan plant in Tennessee.

The New York Times reports that a number of garment makers are returning to the U.S. from Asia for the same reason:

"Many American retailers have adopted 'just-in-time' inventory controls to improve efficiencies and reduce costly inventories That has made ordering and shipping from Asia cumbersome, especially when consumer moods swing sharply or goods arrive with flaws and need to be returned for corrections. . .The Gap, in fact, has found that it can buy American-made men's pants for about the same price as those from Hong Kong."[23]

In certain cases, small suppliers can take advantage of restrictive labor and government policies in order to succeed. The most famous example of this is the collection of hundreds of small factories in Northern Italy. Many of these operations are family-owned, having spun out of the larger customer. These firms survive by being both nimble and by sparing their customers some of the tax and labor problems that come with doing the work in-house. As Cohen and Zysman describe it:

"Manufacturers, facing increased labor costs and restricted ability to manage flexibly inside their plants, took to subcontracting production of some components. . .The subcontractors, being small, used less capital-intensive technology and processes than those employed within the large firms, and also, for reasons particular to Italian politics, fell outside the regulations that affected the giant companies. . .

"These subcontractors often began to innovate themselves and to produce new production equipment and products. An entire sector made up of smaller firms sprang up. Public policy supported these developments by creating institutions to support these small entrepreneurial operations and to encourage vertical disintegration of production. . . Eventually, these small producers broke loose from their subcontracting role to begin a different pattern of dynamic flexibility. They have become innovative suppliers in world markets."[24]

Companies within certain industries are forming aggregations of buyers and sellers in order to remain competitive. For example, the American semiconductor equipment manufacturers and their domestic customers have formed SEMATECH. This research consortium, backed by both the Federal government and the largest U.S. independent and captive chip makers (IBM, Intel, etc.), is chartered to support the development of future generations of process equipment to keep the U.S. competitive. Implicit in the program is the linking of American chipmakers to their domestic suppliers in a co-destiny relationship.

One way both small and large suppliers have found to bind themselves more closely with buyers is to add a new value-added *service* to their product offerings. Industry Week found an example of this strategy at the General Motor's Buick Reatta plant, where PPG Industries not only provides the paint for the cars but actually runs the factory paint shop. Ironically, one of PPG's tasks there is to reduce the use of its own paint. Service programs can range from repair programs (such as Caterpillar Tractor's guarantee to customers that it will deliver a part anywhere in the world in 48 hours) to buyer training, even to design itself.

It is important for buyers not just passively cut supplier rolls, but to actively involve themselves in, to use a phrase by author David N. Burt, "Managing suppliers up to speed" because in many cases of apparent poor supplier performance the real problem is the buyer itself. Thus, to drop a supplier for tardy deliveries may in fact mean both losing a good supplier and perpetuating a flawed purchasing program.

Hewlett-Packard uncovered just such a problem in its own supplier network. According to Dan Marshall, an HP manufacturing specifications manager, in 1987 only 21 percent of deliveries to the companies 50 manufacturing divisions were on time. "We wasted many hours firefighting, trying to determine which parts would be late and devising schemes to keep production lines going anyway. Early deliveries, meanwhile were costing us a fortune in inventory storage and control."[25]

Instead of doing the usual thing -- that is, blaming the suppliers -- HP took a hard look at its own supplier relations. The company was amazed at what it found. A survey discovered that HP and its suppliers were clear upon their agreements only 40 percent of the time. Furthermore, HP found that suppliers had frequently shipped on-time by their own criteria, but had in fact been confused by the buyer as to whether the assigned date was for shipment or delivery.[26]

"Our study clearly revealed that *communications* was the chief culprit in on-time delivery failures -- hardly a popular conclusion since it made us a primary cause of the trouble. We set out to take corrective action. . . We changed the purchase order, labeling each date clearly.

"We have tried to solve the [hodgepodge routing problem] with uniform routing guides. Finally, suppliers were manually subtracting the transit time from the delivery date to calculate the ship date. We have tried to preempt such errors — and other data entry errors -- by installing electronic purchase orders that flow directly from HP's computers to the supplier's open-order management systems."[27]

Within two years, 51 percent of supplier deliveries to Hewlett-Packard were on time, production was stopped less often and inventory expenses had been cut by $9 million.

Like all types of management in the virtual era, the management of suppliers must be built upon trust. And nowhere is that trust more complete than in a manufacturer allowing its supplier to actually assume the task of component design. This has long been a standard procedure in the semiconductor ASICs business, but now it can even be found pockets of America's smokestack industries. As Design News has written:

"Times have changed. Today, progressive companies view their suppliers as important allies in the increasingly bitter struggle for survival and prosperity. The idea is to take full advantage of talented engineers who work for suppliers. Those skilled people effectively expand the size of your firm's design team. . ."[28]

These words are echoed by automotive analyst Arvid Jouppi in describing why Chrysler was investing $800 million into a technology center and nearby supplier park outside of Detroit: "Chrysler doesn't have an engineer who can be dedicated to each and every component that goes into its autos . . .By having suppliers close-by to work with Chrysler's engineers and technical people, Chrysler can continue to be an assembler of cars and use the brain trust of its suppliers."[29]

The first example of Chrysler's new strategy is the Viper sports car. Chrysler's supplier engineered many of the car's most important components, including the transmission. Ultimately, more than 90 percent of Viper's parts came from suppliers -- compared with just 70 percent for the typical Chrysler vehicle.[30]

Balancing the Equation

The advantages to buyers of joining virtualized supplier relationships should be apparent: fewer and more skillful suppliers, higher quality/lower cost components arriving in a more timely manner, even a body of free design engineers to help out when needed. Add to this the less obvious advantage of being able, through greater outsourceing, to share the capital investment required to build a new product, and this new type of supplier relationship looks like a terrific deal for the manufacturer.

Less apparent at first glance are the advantages to a supplier. First it has to run a gauntlet with its competitors to see which will be winnowed out. Then it has to speed up production, consistently deliver on time and have near-perfect production quality. On top of that, Big Brother Buyer will be regularly making inspections, telling it how to operate, tapping into its computers and picking the brains of its most talented people. Finally, the supplier may have to drop its other customers and even change its location, all to cater to its most important customers.

This is, of course, a one-sided view of what should be a balanced relationship. Enlightened suppliers realize that by reducing cycle times, improving deliveries, and building high quality products, they are reducing their own costs and making themselves more valuable to their customers. They also know that when customers invest in tying computers together so they can share information and become dependent on suppliers to develop products for them, they are also guaranteeing a long-term source of revenue to those suppliers. Some companies, such as BMW, even sweeten the deal by rewarding their best-performing suppliers with higher margins.[31]

It is also important to understand that buyers often must make one huge sacrifice when entering a virtual relationship with a seller: the loss of privacy. Very often, virtualization demands that suppliers be made privy to company product strategies. Writes Industry Week, "To achieve a true partnership, customers and suppliers must share information — on new product designs, internal business plans, and long-term strategy — that once would have been closely guarded."[32]

Most difficult of all to the buyer, but most important to the supplier, is that the typical sub-contractor relationship of the future will be single source and governed by extended contracts. This last, anathema to most contemporary manufacturers, is emblematic of the new level of trust in business relationships that will be demanded by the virtual revolution. Co-destiny means exactly what it says. The buyer shows its trust in the supplier by frequently giving it exclusive production rights. Conversely, the supplier puts itself in a position of extreme dependence upon the buyer for business. It is an image with considerable appeal, certainly an improvement over the historic melodrama of the itinerant, disloyal, and price-slashing buyer and the antiquated, low-quality and unresponsive supplier. Now both, concerned for each other's welfare, at last march in step into the future.

But one must not forget that a shared destiny also means a shared fate. Sometimes these new relationships may turn out to be an exchange of scores of small miseries for one large disaster. The supplier that hitches its wagon to a falling star, or the manufacturer that builds its business upon an incompetent sole source supplier will find itself part of a larger debacle, one that inflicts serious damage on both parties.

This is just one more reminder that for all of its blessings, the virtual revolution also brings with it a whole new set of dangers. The selection of partners is among the most important tasks facing the virtual company. When contracts are sole source and long-term, choosing a supplier takes on all of the gravity of a joint venture -- which in many ways it is.

Companies moving towards such sophisticated supplier arrangements already have begun to recognize this vulnerability. That's one of the reasons Xerox so heavily trains its suppliers. At Ford, according to Burt, the evaluation of potential suppliers is both detailed and, to be sure nothing is missed, multi-disciplinary:

". . .product development teams invite two or three qualified suppliers to compete on the design of new parts. Ford analyzes these suppliers' designs, quality plans, and price proposals. Then purchasing, with assistance from other team members, conducts a cost analysis and proceeds with negotiations. The successful proposal must satisfy a number of objectives: function, quality, aesthetics, price. The successful supplier normally becomes the only source of supply for the life of the product."[33]

Needless to say, in this scenario the supplier is also strongly motivated to help its key customer succeed. One way to do this is to make sure it is supplying that customer with exactly the product it wants. A graphic software system, called Quality Function Deployment (QFD), has even been devised to help with that analysis. It tracks the material qualities the customer desires through a series of test methods to determine if the supplier's product achieves the proper parameters.[34]

It is not hard to imagine a next step, still far in the future, in which the supplier begins to look far downstream to the distribution channel and even to the final consumers themselves. A supplier might even conduct its own market research, offering its own service guarantees, even solicit design advice from those consumers . . .anything to support its customer's success.

For its part, the customer/manufacturer must reward this supplier support with trust. Until now, such firms have protected their interests by lining up multiple suppliers that could fill in for one another in case of failure. Second sources were identified in case a primary supplier failed to perform. By the same token, suppliers were proud of pointing out in annual reports how widely distributed their business was. Being dependent on a narrow customer base was considered to be a great risk.

In the business model of the future, customers will have far fewer suppliers. The just-in-case supply philosophy will be increasing obsolete. Failure of a supplier to adequately support a customer will be a serious problem. On the other hand, suppliers will be dependent on fewer customers. Failure of a customer will be extremely damaging to the supplier's business.

Customers and suppliers will have few options. They will have to risk dependency in order to reap the benefits of virtual relationships. Co-destiny is a price that will have to be paid in order to buy a ticket into the virtual business world of the future.

Holding On To The Customer

In a highly competitive business environment featuring abbreviated product lifecycles, profits come from holding customers through several product generations. Robert Reichheld of Bain & Co. estimates that retaining 2 percent more customers has the same effect on the bottom line as cutting costs by 10 percent. As a case in point, he found that for regional banks a 20 year customer is worth 85 percent more profits than a 10 year one. Dallas Cadillac dealer-magnate Carl Sewell has estimated that one of his lifelong customers will buy a third of a million dollars in cars.[35] Thus, it becomes vital for the virtual corporation to capture customers and pull them as much as possible into a co-destiny relationship.

This cuts both ways. Consumers of all but the most basic commodities are equally motivated to establish a long-term relationship with a narrower supplier base in exchange for better service.

As Robert Williams of Travelers Home Equity Service told the American Banker Conference, "people are no longer buying just products or services . . .they are buying *relationships*."[36] To use Schonberger's phrase, "the customer is *in* the world class organization, not outside it." [37]

The binding of consumer to manufacturer is especially acute with complex electronics products. For example, the new owner of an Apple Computer quickly becomes very dependent on the manufacturer. That owner depends upon Apple to teach him or her how to hook up the hardware and become proficient with the software.

Part of this can be accomplished by Apple through manuals and tutorials, but the company must also depend upon its channels of distribution to carry much of the load, such as the repairman at the local computerstore. On top of that, the trade press also helps, at arm's length, through magazines, newsletters and electronic bulletin boards dedicated to Apple products. Community colleges and trade schools also do their part by offering courses in Apple computers. Needless to say, there are similar programs for IBM-compatible computers -- but, underscoring the binding process, it is rare that members of the Apple 'world' know much about IBM computers or vice versa.

The users, in turn, by investing dozens of hours in these various forms of training, by buying or creating their own software programs for that particular machine, develop a strong emotional and financial stake in its future.

High tech isn't the only place where consumers are developing tight, long-term relationships with suppliers. Consider the travel industry. Here data bases play a key role in the kind of service customer receives. Because it has become so simple to keep track of who the repeat customers are, it is easy to give the good ones preferential treatment. American Airlines does this with its Advantage program; as does United Airlines with Mileage Plus. The good customers of these and other airlines get better seats, greater access to first class upgrades, and more free trips. By the same token, hotels keep track of their good customers and make sure they get a no smoking room if they want one, the right size bed, a room on the quiet side of the hotel, as well as on the right floor.

The credit card companies are increasingly virtualizing their product offerings. By tracking customers' purchase and payment patterns, they are able to offer flexible credit limits that assure more credit is available to customers that typically have seasonal fluctuations in their credit needs.

In the automotive world, Toyota maintains up-to-date records on its customers. Using this information, the company is able to track the needs of their customer base -- crucial to achieving its sworn objective of never losing a customer. [38]

Toyota carefully tracks the demographics of the customer base and makes sure it has the right models to meet the needs of 'its' consumers. This means making a major investment in gathering the data and tracking the tastes of customers -- and then being committed to designing products that match those preferences.

For his or her part, the consumer is also making an investment in Toyota: Time spent supplying personal data, in learning and analyzing the company's new products. This time-investment is an important factor when that consumer is ready to buy a new car. After all, because Toyota probably has a model that matches that consumer's needs, and because the trade–in value of a Toyota is higher to a Toyota dealer than it is to others, what is the likelihood of that consumer going anywhere else?

Playing the Quality Card

One of the best tools companies can use to exceed customer expectation is quality. This has been borne out by the PIMS studies of market strategy conducted during the last two decades by the Strategic Planning Institute. These surveys of thousands of businesses have consistently shown that quality may be the most important factor in business competition, with high product quality directly correlating to improved return on investment, profit, productivity, market share, capacity utilization and employee morale.[39].

Quality, according to author Keki R. Bhote is:

"The engine that drives a company to the bank. . . It can be categorically stated that:

- -- There is no more powerful cost reduction tool than quality improvement.
- -- Quality is an absolute prerequisite to cycle time reduction.
- -- Quality is an essential step in reducing design cycle time, which is becoming one of the distinct competencies of a company in the global wars between corporations.
- -- Quality is one of the most important elements of - indeed a short cut to - customer satisfaction."[40]

But the PIMS researchers go to great pains to note that successful quality is not that which is in conformance to design specifications, but what is *perceived* as quality by the customer.[41] Ultimately then, after all the mean-time-between-failures measurements and the net-defects-per–million assembly rates, quality comes down to a subjective consideration by the customer. And that suggests that not only must the customer be in the company, but that the company must conversely find a way to be in the mind of the customer.

To be a leader in customer satisfaction will be doubly difficult -- especially when competition by other virtual corporations pushes that satisfaction threshold even higher. That is why virtual corporations will require massive information gathering systems, enlisting suppliers, distributors, wholesalers, retailers, service contractors, independent market researchers and even the customers themselves into an insatiable quest for understanding.

Says Rosabeth Moss Kanter, "The potential exists for collecting, analyzing, and using data to meet customer needs not just once but over and over again -- to serve the customer without having to ask."

Such a massive (and expensive) program of information gathering will, by necessities of resources and time, have to be narrow in scope. This suggests that, as with its dealing with suppliers, virtual corporations will have to also narrow their customer lists. It will simply be too difficult to attempt the traditional strategy of selling hundreds of different product lines through scores of different channels to millions of different consumers. The amount of information that would be required to be competitive in all those business would be overwhelming.

Barbara Bund Jackson, in her book Winning and Keeping Industrial Customers, suggests one way this selection process will occur. She argues that there are two kinds of customers, as defined by attitude: the *lost for good* customer, who "is either totally committed to the vendor or totally lost and committed to some other vendor"; and the *always a share* customer who "holds little vendor loyalty and can be temporarily lost or regained at any time."[42]

The primary marketing task of a virtual corporation is to identify which members of its customer base belongs to the first group and then do what it takes not to lose them. Non-virtualized companies will be left to fight for the dwindling population of 'always a share' customers.

The Production of Service

Virtual products and services have a very rich service component. Much of the value of virtual products results from the ability of suppliers to produce the product 'instantly' in response to demand or to custom design the product so that it precisely meets the needs of the customer. Instant delivery and custom design are both services.

Services also have a service component of their own. The core service of an airline is that of getting a customer from one location to another safely and on time. The airlines augment this service with numerous other services, such as frequent flyer upgrades, executive waiting lounges, special meals, and shorter check-in lines for important customers. Unfortunately, though probably not surprisingly to consumer, a recent survey found that only 10 percent of U.S. service companies have a quality program in place.[43]

There has been much, often sophistic, academic debate about what differentiates a product from a service. Perhaps the best definition is Leonard Berry's: "A good is an object, a device, a thing; a service is a deed, a performance, an effort . . . it is whether the essence of what is being bought is tangible or intangible that determines its classification as a good or service."[44]

Some of the other important characteristics frequently identified include:

> *Services are intangible.* It is often not possible to taste, touch, or experience a service before it is purchased.
>
> *Services are produced and consumed almost simultaneously.* An obvious example of this is a meal in a restaurant. But is also holds true for, say, the service an attorney renders to a client in court.
>
> *Services cannot be inventoried.* A hospital cannot produce in advance the treatment it wishes to render to patients.
>
> *Customers are involved in the production of the services they receive.* A customer must be present and willing to ride on an airplane before an airline can carry that customer from one city to another.

Given this, virtual products seem very service-like. With such products, Berry's "essence of what is being bought" will often be intangible. For example, commodity products such as integrated circuits and fasteners are often identical in performance, quality, and price. What will determine whether or not a customer will buy from a supplier may be such things as the ability of the supplier to meet the customer's just-in-time delivery requirements. In such an instance, the essence of what is being purchased is responsiveness to customer requirements.

The goal of the virtual supplier will be to produce products instantaneously in response to customer demand. The virtual customer will attempt to use the purchased products as soon as they are delivered. To the degree possible, virtual products will be consumed as they are produced, just like services. Similarly, the goal of the virtual supplier will be to operate with as little inventory as possible. The ideal virtual producer will have no finished goods inventory -- again, just like a service producer.

Since the virtual producer will not produce for inventory, the output of its plant will be lost when there is no demand. The same is true for an airplane when it takes off with an empty seat or when a hotel room is not rented for a night. In all these cases the revenue producing capability of the provider is lost and cannot be recovered. That's why information on customers is so important.

Because virtual products are service-like, one would expect that many of the features that characterize the relationship between service producers and their customers would be true of virtual manufacturers and consumers as well. Two of the most important of these are the ability of the consumer to act as a co-producer of the services he or she is to receive and the mutual competence of provider and consumer in producing the service the consumer desires. In both, an educated consumer/customer is vital.

When a virtual customer enters into a relationship with a manufacturer, that customer takes on a great deal of responsibility to assure the supplier's success. Perhaps the best example of this is provided by the custom integrated circuit business. Here, customers are given the engineering tools that enable them to design the custom products they desire.

Customers who wish to receive just-in-time support from their suppliers must be intimately involved in the production of the service. That is because just-in-time support requires suppliers to produce products that are nearly perfect.

To do this, one must first define what perfection is. This of course varies greatly from customer to customer. For example, one customer may be happy with components that work up to 120 degrees F. and another may require parts that work to 150. Once that hurdle has been crossed it is important to understand the supplier's manufacturing process. The customer must understand how quickly the supplier can respond to changes in demand. It must then provide the supplier with sufficiently stable forecasts that the supplier has the chance to respond.

Equally, the consumer of a virtual product will play a far more active part in that product's creation than at any time in recent history. In the more static environment of the past, what was purchased was that which the manufacturer was willing to produce in its mass production factory. The most famous example of this was Henry Ford's remark about Model Ts being available in any color so long as it was black. Options were rare and there was little opportunity for customer involvement in product design. Now, if the consumer is going to achieve the true benefits from the products purchased, he or she is going to have to make an investment in learning how to be an effective co-producer. This level of investment made by the purchaser in the supplier is in fact one of the distinguishing characteristics of the relationship between a virtual supplier and its customer.

A lesson to be learned from the service industries about this process is: *It is easiest to provide good service to the most competent customer.* Every doctor knows that the patient who follows directions is the easiest to treat. Every microcomputer maker knows that the most competent customers have fewer problems installing and using the equipment. Customers willing to read manuals rarely call the manufacturer for help.

Thus, one of the most important roles the virtual manufacturer plays in the customer relationship process is that of creating a competent customer. Customers have to be trained in how to use virtual products and how to interact with virtual manufacturers. One would therefore expect the virtual corporation to make large investments in not only making products easy to use but in training the customers to use them.

Much of this training will happen in the normal course of business. This is another reason why stable long-term relationships are important. They provide a great deal of time for both customers and suppliers to train one another in their needs.

There is no doubt that computers and networking will play an important role in this training process. Computer-aided instruction will make it possible for customers (and consumers) to perform a considerable amount of self-instruction. Already, much of the software currently sold with personal computers comes with computer programs that train the operator on their use. The multi-media systems of the future will take this process to even higher levels of interaction.

Spreading the Word

In 1991, the most popular advertising campaign in American was for Pepsi-Cola and featured Ray Charles singing "You've got the right one baby, uh-huh." By traditional rights, the success of this campaign should have increased Pepsi's market share against its nemesis, Coca–Cola. After all, Coke's ad campaign, it was generally agreed, had been lackluster.

And yet, according to most analysts, Coca-Cola actually *gained* market share from Pepsi. Something had definitely changed, and its importance could be found in the words of Coke's CEO to effect that he would rather win new customers than advertising awards.

During the virtual revolution it is hard to imagine any corporate function that will undergo as great a change as that of marketing communications -- that is, advertising and public relations.

Modern advertising was created by the conjunction of mass production and mass media. Its task was to convert individual tastes into a desire for the generic fruits of mass production. That it often accomplished this through appeals to individuality, snobbishness and uniqueness is a testament to its cleverness. Public relations assumed a similar role, only its target was the press and its task to convince reporters to write favorably about the company's products or business. Even with the rise of niche-oriented trade magazines, advertising and public relations retained this philosophy, rooted in individual products and their appeal to potential customers.

It is hard to imagine how these practices can continue as effectively in the future. Virtuality signals the end of most mass-produced commodity products and the arrival of mass customization -- not the stuff of mass marketing. Further, while virtual corporations will always be looking for new customers, they will be more selective about the ones they take. Far more important will be serving the customers they already have. Finally, these established customers, often trained as co–producers, will be unlikely targets for advertising hype, and will probably know as much about the product as any reporter in the trade press.

This is not to suggest the death of advertising or PR. There will always be some mass market consumer products — beverages, perfumes, pharmaceuticals — that will lend themselves to mass marketing techniques. But elsewhere, these two professions will have to adapt to revolutionary change.

There are already some clues as to what these changes will mean. In the ASICs business, for example, companies such as LSI Logic seldom advertise individual products. After all, such ads would be worthless, as each product is customized to the customer. Instead, these companies use advertising to tout their capabilities, to explain what they can do for potential customers. The companies then often supplement this with personal contacts at the highest levels. Says LSI Logic's Wilf Corrigan:

> "In this relationship, the ties that bind are not made exclusively at the purchasing agent-salesman level. The relationship I'm describing involves an interface of top technologists as well as top corporate management. There is too much at stake to devote less firepower to the relationship."[45]

Some services firms already have caught on to this change. Already by the end of 1990, Citicorp was selling market information on 2.3 million users of special ID cards in Chicago, Dallas, Los Angeles and other major cities. This information is being used by manufacturers, service companies and their advertising agencies to custom-target specific customers. Arbitron and A.C. Nielsen are each spending as much as $125 million to institute nationwide computer networks to gather information directly from supermarket checkout scanners for use by their clients. As Laurel Cutler, vice chairman of ad agency FCB/Leber Katz told Forbes, by using such technology she would soon "know the name and address of everybody who buys my products", enabling her to "target an individual message" for each customer.[46]

Regis McKenna has long argued that as products grow more complex and competition more intense, both industrial customers and consumers increasing look to key opinion makers for advice. In any given industry, these opinion makers, respected for their knowledge and objectivity, rarely number more than a handful. Their judgements can make or break a product, rendering worthless the millions spent on product advertising. As an example, he points to the IBM PCjr., which died despite an expensive advertising campaign because the key analysts, columnists and technologists in the personal computer industry gave it poor reviews. [47]

His argument is echoed by Business Week, which, in calling the 1990s the decade of 'value marketing', suggested that companies "use your advertising to provide the kind of detailed information today's sophisticated consumer demands", as well as offer "frequent buyer plans, 800 numbers and membership clubs [that] can help bind the consumer to your product or service."[48]

Another clue to the future of marketing communications can be found in the writings of Guy Kawasaki. Kawasaki, a former Apple executive, argues that in a world of informed consumers who see through most advertising hype the sole remaining course for marketing is passionate sincerity -- *evangelism*, as he calls it:

"Evangelism is the process of convincing people to believe in your product or idea as much as you do. It means selling your dream by using fervor, zeal, guts and cunning.

"In contrast with the old-fashioned concept of closing a deal, evangelism means showing others why they should dream your dream. . .Evangelism is the process of spreading a cause."[49]

Kawasaki's 'shared dream' may be the best description yet of the new business relationships that will emerge from the virtual revolution. If advertising and public relations are to find a place in this new business environment, they too must share the dream -- and convince potential customers to do the same. To accomplish that, these professions must also virtualize their services, moving ever-further away from product-oriented mass market promotions towards creating more customized messages through more select media.

Sharing a Destiny

For many American businesses, the 1991 Christmas season served as a painful harbinger of the new business world to come. As the Wall Street Journal reported, many retailers, faced with the prospect of depressed sales, were "keeping tight control of inventories and forcing suppliers to swallow more risks and costs."[50]

The result, the story continued, was to force "suppliers to swallow more risks and costs . . .swell their own inventories, speed up production cycles and stick to traditional products -- or risk losing business. . ."[51]

As difficult and expensive as this was for the manufacturers, the Journal concluded, "some of the new pressure is good medicine. It forces them to reduce their own costs by speeding production cycles and honing their just-in-time inventory techniques. The faster response times also helps American-made goods beat imports, which can't be delivered promptly without stockpiling."[52]

Thus, many firms, for survival in the middle of deep economic recession, reluctantly began moving towards virtualization. This placed them at an advantage over their competitors that had not made the change -- but behind those that had voluntarily virtualized before feeling the crush.

A good example of the latter was Levi Strauss & Co., which had installed a "LeviLink" computer network with its major customers that enabled the jean maker to poll retailers and replenish their inventories without even recieving an order. This quick response system enabled Levi's to cut production and delivery times for a pair of jeans from 44 days to just 22.[53]

Similarly, Rubbermaid, in order to avoid what its president Wolf Schmidt called the "dead periods" between consumer purchases and retailer replacement orders, began tracking inventories by tapping into retailer's point-of-sale systems.[54]

Such strong business relationships will be among the most important competitive advantages the virtual corporation will possess. Unfortunately, in a confrontational, competitive, and litigious society like our own, it is hard to see how the requisite level of overall trust can be achieved.

Nevertheless, despite the odds, such relationships are slowly being constructed. This will not be an overnight process. Nor will it probably ever occur to the degree an idealist would desire. After all, what purchasing agent, knowing a supplier's costs will be able to resist trying to drive down that supplier's profits? And what supplier, knowing it is a sole source, is not going to try to exploit the situation?

But the idea is to begin the process, push it forward, and let time and mutual experience slowly raise the level of trust. It will rise too, if only because customers, having narrowed their supply base, will have fewer suppliers to choose from; and suppliers will have fewer customers to whom to sell. The very limitation of alternatives will lead to interdependence. Over time, as the linked customers and suppliers (or manufacturers and consumers) feel increasingly comfortable with the idea of co-destiny, relationships of trust are likely develop. The degree to which they do will determine the ability of both parties to profit.

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Chapter 8: Rethinking Management

Virtual or not, the function of management is results--quarterly, yearly, and long range. Results which satisfy the needs of customers, employees, shareholders, and the communities in which they live. Managements incapable of delivering on the expectations of these widely divergent groups will not survive and neither will the institutions for which they are responsible.

In this sense there is no difference between the management we know today and the virtual management of the future. What will be different is the structure and methods virtual managers will have to use to achieve their goals. Perhaps the most fundamental change is the shift management will have to make from directing action to insuring the smooth functioning of processes. A second transition will occur in the very structure of management itself. It will become less hierarchical, and in the process much of middle management will vanish.

We know the companies that build the highest quality products in the most efficient factories have relied on techniques such as total quality management and lean manufacturing. These techniques are in turn dependent on worker skills in problem-solving and teamwork. Management's role becomes one of facilitating the processes; supporting the efforts . . .and taking a back seat when it comes to giving orders. The people doing the work direct their own activities. For example, Donald Peterson, the former CEO of Ford, relied on teamwork, driving responsibility down in the organization, tapping the creativity of all employees, and managers who were more coaches and cheerleaders that autocrats to revitalize troubled operations.[1] In the process, Ford dramatically improved the quality of its products and the productivity of its factories.

We know the same type of management techniques are at work in the companies providing superior services to customers. Here managers have discovered that employees who have direct contact with customers must be empowered to respond directly to the customers needs. Indeed, one of the keys to the service turn around at SAS airlines was Jan Carlzon's determination in giving front-line employees the authority to meet customers expectations without constantly seeking approval from superiors.[2]

If employees are making the decisions about what they should do and are trained to do the right things, then there is less need to have middle management directing their activities. Also much of the function of middle management has been both to serve as an information channel through which top managers can view events and to relay orders from the top down to the individuals doing the work. These functions are less needed as well. In the first place, computer networks can carry much of the information about the status of operations more efficiently and effectively than can people. In the second, top managers who are coaches and cheerleaders will give fewer orders because they are committed to letting the processes work and permitting the employees doing the work to decide for themselves.

Of course it easy to criticize these ideas as both naive and idealistic. We are so used to doing things differently that the concept of a kinder and gentler management system will undoubtedly be viewed with much skepticism. So it is perhaps a good time to stop and reflect on how we got to where we are. In the process, we will build a vision of today's hierarchical and directive management systems as ones which were designed to control the railroads and the mass production factories of the late 19th and early 20th century. Today's systems are a legacy of the past designed in an era when computers did not exist and were used to control a static mass production process. They are as obsolete for modern flexible and responsive environments as the buggy whip and horse drawn carriage.

Says Derek Leebaert, "The computer's pervasive effect works endlessly to force 'authority' to prove itself."[3]

A View of the Past

In early 1896, at the suggestion of his boss Fredrick Taylor, Stanford Thompson constructed a special book for his research into piece rate assembly times.[4]

What made the book unusual was that it was actually a guise. A hole had been cut into its right-hand pages to hide a stopwatch for surreptitiously timing the activities of the workers. Great pains had been spent by Taylor in developing a stopwatch that could be operated with one hand, and Thompson showed equal care in reducing the record forms on the book's left hand side "so that the case containing them and the watch will not attract attention."[5]

Using the stop watch and the book, Taylor studied the various methods for performing work. His objective was to discover the "one best way" to do a job. Once the best method was discovered productivity standards could be set. Workers could be instructed in the most efficient methods. Foremen could use the standards to drive the work force to higher and higher levels of productivity.

Using Taylor's scientific management techniques it was possible to direct worker activity down to the second. The directive style of management which is so prevalent throughout much of industry was born.

Maintaining such secrecy was important for Taylor and his associates because they'd found workers didn't trust them, that the factory rank-and-file believed the American Plan (as the Taylor method was called) was just another way to squeeze more work out of them.

Taylor, a former worker himself, sensed this deep hostility: "It's a horrid life for any man to live not being able to look any workman in the face without seeing hostility there, and a feeling that every man around you is your virtual enemy." He would add later, several years after having a nervous breakdown, "I have found that any improvement is not only opposed but aggressively and bitterly opposed by the majority of men."[6]

Of course the workers fought back, especially after labor realized that the manifold increase in production under the American Plan would not be matched (as Taylor had advised) with increases in salary. In the hands of business executives who saw only greater profits by speeding up production, Taylor's scientific management, with its dream of improving the lot of both employer and employee, often became a nightmare for the latter.

John Dos Passos wrote of factory life in the factory just after the First World War in the following fashion:

At Ford's production was improving all the time; less waste, more spotters, strawbosses, stool-pigeons (fifteen minutes for lunch, three minutes to go to the toilet, the Taylorized speedup everywhere, reach under, adjust washer, screw down bolt, shove in cotter pin, reachunder, adjustwasher, screwdown bolt, reachunderadjustscrewdownreachunderadjust) until every ounce of life was sucked into production and at night the workmen went home grey shaking husks.[7].

[In some companies, little has changed. Rivethead, published in 1991, tells a modern version of the same story:

"As for the guy who smashed his hand, the aftermath was both sad and ridiculous. Within ten minutes of the mishap, Henry Jackson was over at the scene of the accident rantin' his fat ass off to all within earshot about how he was gonna put this individual on notice for 'careless workmanship in the job place.'. .Here a man had just been permanently maimed and Henry's only concern was to see that the guy was properly penalized."[8]]

The American Plan was the first attempt to bring the tools of science and technology to the management of production. It resulted in a great increase in productivity, but it also created worker alienation. In its wake grew the schism which has set worker against management and destroyed the spirit of labor/management teamwork that will be essential for the virtual corporation.

To this manufacturing strategy, the railroads brought with them the second major component of today's corporate management: hierarchies.

To manage the railroads, management had to have information. It had to know where the locomotives and railcars were, whether they were functional or not, where the freight was that needed to be picked up and where it was to be transported to and thousands of other bits and pieces of information. This required a management reporting structure which gathered the information, summarized it, and reported it to the next level of management. The next level would go through much the same process and pass the information on. Finally the data reached a decision maker who decided on a transportation strategy and gave the orders as to how to operate the system. The orders were passed back down through the layers of management and orders were given that directed worker activity.

The railroads of the late 19th and early 20th century often functioned with up to -- levels of management. There were managers at the --- center who reported to managers at the -- office who reported to managers--- at a distant location using the telegraph system. Management hierarchies made it possible operate the railroads effectively just as scientific management made it possible to run the factories efficiently. Combining these systems created a management system which was ideal for the control static and inflexible mass production systems.

These management techniques were so effective that within a short time the United States was populated with the world's greatest industrial corporations. So dominant was industrial might of our country that Servant Schreiber? in his 1970? book The American Challenge presented a vision of the industrialized world totally dominated by giant American corporations that would crush at will the industrial midgets of Europe.[9]

The great business schools in our country studied the successful industrial paradigms of the early twentieth century. The managers enshrined their successes in books and management bureaucracies. Soon thousands of managers were trained in the techniques. Generations of companies grew in the shadows of the great industrial institutions of our country using the same methods and techniques.

A hierarchical and directive system of management might have been the ideal industrial paradigm for managing mass production in the first half of the twentieth century but it has proven to be ineffective in directing the efforts of today's modern corporation. Many of the reasons for the industrial failures in the United States in steel, automotive, and consumer electronics can be directly traced to these structures. Similarly, much of the renaissance of companies such as Xerox and Ford can be directly related to the efforts of these companies to throw off the shackles of the these 19th century systems.

Hierarchical and directive management, which has proven to be ineffective for many of today's corporations, will turn into a management fiasco for the virtual corporation. The system of the past which was so effective for a static environment of mass production will be a disaster in the fast-moving world of the virtual corporation.

The principle reason for this is that levels of management mean levels of approval. Levels of approval take time. The more levels of approval, the more time and the more the approvers are divorced from the market.

Time is the virtual corporations most valuable resource and the one commodity it cannot afford to waste.

On top of this; the virtual corporation will have many products with short life cycles. The decision to respond and how to respond to a rapidly changing market can best be made by the individuals closest to the action. Attempts by managers who are removed from the day to day turmoil of the market to direct the activities of the worker are condemned to failure.

Times have certainly changed since the late 19th century. One of the most fundamental changes has been the invention of the computer. Networks of computers have assumed much of the traditional role of management hierarchies. For example, railroads today mark their railcars with machine readable symbols and feed the information directly into computer systems which track the location of the rolling stock. Computers can as well analyze demand and work out strategies for moving the railcars to the right locations in order to carry the freight. Thus computer networks today are capable of replacing middle management functions of the past.

If employees doing the work direct most of the work and computers carry the information middle managers used to transmit, the question becomes "What does management do?" The answer is that it sets the goals, measures the results, directs the strategy, puts in place the processes, and establishes the environment that ensures the processes will work effectively.

For example, the management in a virtual corporation must establish an environment in which concurrent engineering can function. It must put in place training programs, provide recognition systems, and empower employees so that total quality control can work. It must establish the relationships of trust with suppliers so that just-in-time systems will function effectively. It must raise the level of competence so that the individuals doing the work can be trusted to do the right things -- in the words of management futurist Dick Cornuelle, not only do what they are told, "but to do what they are *not told*, or even what they *can't be told*."[10]

Getting Flat

Much has been written in recent years about how corporate organization will change in the face of new communications and manufacturing technologies, global competition that demands ever-faster cycle times, and a diminishing workforce.

One such shift is towards a flatter organization; one in which much of middle line management and most of staff management will have disappeared.

Peter Drucker has noted that "from the end of World War II until the early 1980s, the trend ran toward more and more layers of management and more and more staff specialists. The trend now goes in the opposite direction.

"Restructuring the organization around information -- something that will, of necessity, have to be done by all large businesses -- invariably results in a drastic cut in the number of management levels and, with it, the number of 'general' management jobs.[11]

Others see the same effect: "New and flatter management structures become possible as more information within an organization comes on line. Organizations will no longer be forced to choose between centralization, for tighter control, and decentralization, for faster decision making. On-line technology will make it possible to have centralized control with decentralized decision making."[12]

Predicts John D. O'Brien, vice president for human resources at Borg-Warner Corp., "I think the term 'staff function' will become extinct sometime in the 1990s."[13]

Executive search executive Dave Flansbaum is even more severe: "Middle managers are a dying breed and can, in fact, be a tremendous impediment to organizational change."[14]

Examples of this 'flattening' of the organization chart can already be found throughout American industry. Franklin Mint, for example, has cut the number of management layers from six to four, while still doubling sales.[15] Drucker predicts that by the mid-1990s even General Motors will have "only five or six management levels, as against the 14 or 15 it has now."[16] At one time, thirteen levels of management lay between Eastman Kodak's general manager of manufacturing and the factory floor -- now there are just four.[17] Intel, already a lean company, has cut management levels in its operating groups from ten to as little as five.[18] And organizational consultant Jewell Westerman claims that his typical corporate client can cut the number of management layers between the

CEO and front-line supervisors from twelve to six -- and sometimes even to five.[19]

One of the most impressive examples of how quickly a company can be rewarded for flattening its organization is Hewlett-Packard. In 1990, the firm, historically among the premier performers in American business, was suffering from slowing sales, dwindling profits, hurt morale and what CEO John Young called "a flawed organization mechanism."

HP, said the *Wall Street Journal*, "was suffering the classic symptoms of corporate gigantism: slow decision-making, sparring fiefdoms and an uncontrolled cost structure. In the fast-moving [Silicon] Valley, HP increasingly resembled a dinosaur watching fleet–footed mammals steal its nest eggs."[20]

In a tough self-appraisal, HP found that it had begun to bury itself in layers of bureaucratic red tape. Even the smallest decisions were sometimes sent all the way up the management chain to Young's office. "To start a rebate program . . .a group manager in the laser–printer operation needed eight signatures, including those of two executive vice presidents."[21]

In just a year, through a hard-nosed reorganization, reduction of management approval layers, the shifting of greater control to product development teams and a more aggressive approach to the market, HP managed to turn itself around. It introduced several important new products in record time, restored its historic profit margins, and as a result, watched it stock price climb.

One obvious result of flattening the corporate organization is that those managers that remain will be forced to assume a much greater span of control. Many will have more employees reporting to them than ever before.

How many? The traditional military squad model argues that the optimum number of people that can be effectively led by one officer is about six. According to Professor J. Brian Quinn of Dartmouth, in the future, the span of control for one manager may reach *two hundred*.[22] This has led Drucker to argue that the corporation organization of the future will not resemble any current business models, but be structure more like "the hospital, the university, the symphony orchestra."[23]

Such expansion in span of control is simply not possible using traditional management techniques. There are not enough hours in a day for a manager to gather the requisite information and make informed decisions on the activities of the 50 or 70 employees Tom Peters has suggested as the typical future span of control. Rather, new schemes of reporting and responsibility must be devised.

One of these, computer-based Management Information Systems (MIS), have been a part of most large businesses for several decades. It now has become vital to coping with the flattening organization. Says Prof. Michael Tracy of MIT's Sloan School of Management, "A sizable percentage of any organization's staff is not producing something, but coordinating something. They are in fact information conduits, types of people networks. In many cases, technology can do it better, faster. With layers of management condensed and the system dispersed throughout the corporation [MIS] offers flexibility and market--response times that preserves options. And in a time of business and general economic uncertainty, that can be a priceless edge."[24]

Technology will help with some of the challenges in coordination and performance measurement. Some companies are already implementing networks for just such a purpose. One example of this, as noted earlier, is Cypress Semiconductor, which uses a company-wide computer system to set 10-15 weekly goals for each of its 1,500 employees -- all of which are reviewed weekly by CEO T. J. Rodgers. Crucial to this program, as even the brash Rodgers will admit, is to not let the system become oppressive and act as an Orwellian Big Brother looking over every worker's shoulder.[25]

But technology alone is not enough to deal with the problems associated with a greatly expanded spans of control and fluid organizational structures. In fact, in one crucial area, management technology can be dangerously limiting. This is in the area of "thick" information. As defined by Henry Mintzberg of McGill University, thick information is knowledge — irrational, subjective, intuitive -- that transcends what can be categorized on an MIS report; "information rich in detail and color, far beyond what can be quantified and aggregated. It must be dug out, on site, by people intimately involved with the phenomenon they wish to influence."[26]

Mintzberg's most telling example is that of the 'thin' information on body counts used by Secretary of Defense McNamara to pursue the Vietnam War versus 'thick' knowledge obtained by U.S. ground troops merely by looking into the faces of Vietnamese peasants. Corporations, and their managers, that become too dependent upon information system surrogates for the reality of daily business life risk falling fatally out of touch. Instead, they must thicken their empirical knowledge with regular experience in the trenches with their people -- yet another task on the back of the increasingly-burdened manager in the virtual corporation.

[It should also be noted that there is another danger with information systems as well. That is the tendency to become overwhelmed by data -- to not have the necessary software tools to sift through the mountains of figures produced by corporate information gathering networks. Given the increasing demands on a manager's time, most will likely find themselves content to operate from summaries of summaries — and there too lies another risk, that of reductionism, of summarizations that don't properly capture the true message of their source material.]

To many managers, spans of control of 50 to 200 direct reports sounds more like anarchy than Drucker's symphony. It is difficult to see how any manager working in such an environment could acquire the thick information Mintzberg suggests is necessary. It is impossible to envision a manager with 100 direct reports being truly knowledgable about the achievements of his subordinates and capable of writing meaningful performance appraisals. How could a manager who is spread so thinly deal with the personal problems of his subordinates or give the kind of personal recognition which is so necessary?

Whether one believes spans of control can reach these extremes or not, it is certainly practical to control extremely large organizations with relatively few levels of management. For example organizations with seven to nine direct reports at each level can reach sizes of tens of thousands of employees with five levels of management, thousands with four, and hundreds with just three. Interestingly, an organization with the fifteen levels of management which General Motors is reported to have and eight direct reports at each level could control a worker population of more than thirty billion employees, or about triple the world's population.

Traditionally a means of quickly getting sales, inventory and production information to decision makers, MIS now must expand until it integrates the entire corporation, using electronic technology to transfer useable data back and forth between sales offices, the finance department, factories and the corporate headquarters. Unless the computer can shoulder some of the work, managers will never be able to deal with the load placed upon them by the wider reporting structures. This evolution, already underway, has been reflected in nomenclature changes, as MIS (Management Information systems) becomes simply IS (Information Systems) to show that the passage of information is no longer unidirectional; and as portions of the MIS systems are referred to as ESS (Executive Support Systems) to portray its role in top management decision processes.

EDI (Electronic Data Interchange) with both customers and suppliers can do much to lift the burden of managing the interaction with suppliers, customers, and other groups within the same organizations from the managers shoulders.

"Specifically, EDI can benefit many departments within an organization. In accounting, for instance, EDI impacts invoicing, data control, payments, electronic funds transfer, and contract progress, among others It also enhances purchasing effectiveness through decrease in selection costs, integration with JIT inventory management, efficient order processing, and monitoring of suppliers' delivery, quality and price performance.

"In manufacturing, distribution, and logistics, implementing EDI can reduce inventories, foster JIT management, promote engineering data exchange, and improve work scheduling, warehouse and transport planning, and delivery notification and acknowledgement. And, in sales and marketing, improvements can be seen in product awareness, market feedback and research, reduced promotional and distribution costs, and streamlined distribution networks."[27]

Not surprisingly, IS managers have been among the first to recognize the impact of information on the corporation. Tellingly, they are among the first executives to append the word *virtual* to their activities. ______ speaks of 'Virtual MIS' as the goal of bringing crucial information instantly to the right decision maker, and then transmitting the resulting decision back through the network just as quickly.[28] Robert Morison of the Index Group writes about how corporate IS networks can find the balance between centralized, corporate-level information processing and the information needs of outlying small business units -- a process he calls 'virtual centralization.'[29]

IS makes possible wider management spans of control only if delivers the right data to the right decision maker. It must, in the words of Michael Hammer, "Organize around outcomes, not tasks."[30] Historically, that has not always been the case. Says Debi Coleman, the chief information officer of Apple Computer:

"Can you imagine building the wrong product? Or finance paying the wrong set of taxes? Yet, too often IS has gotten away with following its own compass rather than contributing to the needs of the company it was created to serve. . .Too many companies have spent millions of dollars on the latest networking equipment and software to gather unnecessary information with an absurd degree of accuracy — only to have the CEO walk in one morning muttering, 'Why can't I get today's sales data?'[31]

In the virtual corporation, the blisteringly fast cycle times and the need for instant adaptability to market changes will not allow this kind of error. Drucker is quite right when he speaks of the "information corporation", the notion that the company of the future will be organized around knowledge rather than specific products. But if that information is wrong, or gathered on the wrong subject or sent to the wrong people, the company is worse off than if it had no IS at all.

Researchers into the history of IS have found a pattern in the development of information systems.[32] The implementation of a corporate information system, they found, typically goes through three stages:

-- *The Initial Shift in Infrastructure:* "A change is made in how the organization fundamentally works. Initially costs go up, but as the system gains acceptance and attains its critical mass costs begin to drop and capacity expands."

-- *The Marketing Phase:* "The firms use the new infrastructure to bring out new products and services at a rate faster than their competition."

-- *The Information-based Organization:* "Information becomes a vital management support system as the application of information technology is expanded to support strategic thinking, operational decisions, exception reporting, intelligent screening procedures, and other management control processes."[33]

The most progressive American companies are racing to implement this final stage. At Apple, for example, Coleman's team is developing IS system that reach beyond the company out to distributors to gather what she calls "channel information", data that the company needs but cannot gather by itself. She has also experimented with new kinds of presentational software, such as the 'Slicer Dicer', to enable Apple executives to easily navigate through mountains of raw data.[34]

The computer industry is helping as well. Numerous software firms are developing IS system software that spares companies from having to devise their own from scratch. And most hardware firms offering networking equipment for their machines.

There are a growing number of cases of companies using information systems to improve quality and cut overhead and cycle times. For example, DEC saved $2 million in capital equipment costs at one pilot plant by installing an EDI system, yet still reduce inventory on select line items from $800,000 to $43,000 and cut lead time from twelve to eight weeks.[35] HP implemented an IS system for its sales force and found an estimated 10 percent improvement in the number of purchase orders, a 35 percent increase in productivity, a cut in travel time for internal company meetings and a jump in customer contacts.[36] At Security Pacific Bank, the MIS system not only made possible new services (including, in a joint venture with local auto dealers, a fast financing program for car purchases) but proved so efficient that it "is now a profit center selling its services inside and outside the bank."[37]

The ultimate scenario for such an information-based, virtual organization has been described by the Index Group's John Thompson. The fully integrated firm, he says, is:

> "like a spreadsheet in which, when the contents of a single cell are altered, the changes automatically ripple out through the entire organization. Thus, when a customer places an order, all the related operational systems adjust accordingly: inventory, logistics, distribution plans, all the way back up the value chain into manufacturing, scheduling and beyond out to suppliers, so that the necessary parts are ordered. At the same time the systems of all the lateral functions, R&D, marketing and market research, are informed of the changes and they too 'recalculate' accordingly.[38]

Even if the computer tools prove far less effective than the pundits of information technology believe, they will still enable managers to accomplish far more and deal with an ever-greater scope of responsibilities. They will provide management with a powerful arsenal of weapons with which to blast away the middle management hierarchies that add little value to the overall management process.

Holding Back the Tide

Thompson's image of the adaptive, virtualized corporation is an appealing one in theory, but in practice it collides with the twin obstacles of management resistance to change and unwillingness to delegate control.

Effective integration of a corporation-wide information system requires that management both understand the flow of data through the firm beforehand and be comfortable using technology afterwards. There is considerable empirical and anecdotal evidence that many corporate managers are unwilling to do either.

A survey by Industry Week in 1988 found that while 85 percent of its readers believed that the top management of their firms would have to become more acclimated to technology in the years to come, only 54 percent thought their present management would be capable of doing that.[39] A private 1988 study of middle managers by Arthur Young Management Consulting Group found that executive management "appears out of touch with reality and very unimpressed with technology."[40]

As for understanding -- or trusting -- the flow of information in their firms, the same Arthur Young survey found a great divergence between the opinions of top and middle management over their company's implementation of technology: the execs believed the company was at the cutting edge, the middle managers knew differently. One McKinsey consultant:

". . .visited 50 of the best U.S. manufacturing sites and asked CEOs if they believed in their accounting systems. We asked them if, when numbers came up for an investment in automation, they believed in those numbers. Not <u>one</u> of the 50 said yes. They said, 'If it gets here, somebody smart looked at it, and they massaged the numbers to be what they wanted them to be. What I make my decisions on is my gut, not the numbers."[41]

An unwillingness to believe the information emerging from their information systems, a false belief in the quality of their technology, and an inadequate understanding of how their organizations really operate. . . is it any wonder companies spend vast funds on IS systems that don't work? Or that they are deeply threatened by the prospect of a flattened organization and expanded spans of management?

But there is an even greater threat to the ability of contemporary American corporations to make the transition to lean, adaptive, information-based organizations. And that is, implicit in everything said so far, the unwillingness of management to surrender its control.

'Knowledge is Power," said Francis Bacon, and no one in contemporary life knows that better than the corporate manager. We have tried in this chapter to use the term 'decision maker' rather than 'manager' for the individuals who will make the quick choices required by fast cycle times. That is because for the flattened organization to succeed, many, if not most, of those decision makers will have to be non-managerial employees. Increased employee responsibility is crucial to the extended span of control as well, if only because it will be physically impossible for a supervisor to make all of the business decisions for a large number of direct reports, all of them with increasingly specialized skills.

The resulting independence of the employees will, predicts some observers, lead to their coalescence into temporary work groups created ad hoc to deal with particular problems. Says Fowble of Eastman Kodak, "As the span of control widens, natural teams form."[42]

One of the great challenges for business in the years to come will be finding ways to make those teams work. The problem for the present is how to keep management from making those teams fail.

To allow non-managerial personnel to make decisions, even to temporarily form quasi-operating groups demands that the flow of information in the company move bi-directionally. Not just up the corporate hierarchy, but down as well. Here we enter into the murky world of management/employee trust that frustrated Fredrick Taylor a century ago.

Peter C. Graham, CIM market development manager for Digital Equipment Corp., has observed:

"Unfortunately, two factors still hinder the potential of networks in manufacturing. First, networking is not well understood. Our research indicates that senior management still doesn't understand the implications. The second factor is the threat that networks pose to established power bases in a company. 'Where will the database reside?' 'Who will have the power to make changes?' 'And who will have what access to what information?'

"For [data networks] to be successful often depends on structural changes that permit managers to transcend their old ideas of self-interest."[43]

Others share his view. "The prevalence of resistance is a real and unfortunate fact," says John Leibert, president of consulting firm MDSS, "Changing operations has a major emotional impact on some managers, especially when they must allow the users to enter and maintain the data that the managers had controlled."[44]

Ed L. Abt of Western Steel describing his experiences installing an corporate information system:

"At one place where I installed a package, there was active opposition from managers who were not about to change. They had thrived on putting out fires and were highly praised by the top management for being able to do so. They really didn't want to stop being heroes.

"It was almost like sabotage. They would, for instance, not mention that not all incoming materials from suppliers were inspected. The programmer, following general industry procedures, would schedule inspection for all, a needless task in this instance. Or the managers would concoct flimsy excuses not to show up for meetings."[45]

The concern of managers is not unfounded, especially in the face of statements like: "Since managers are no longer the guardians of the knowledge base, we do not need the command-control type of executive."[46] After all, many have staked their working lives on playing the corporate game by long-established rules and are now enjoying the pay-off. . .only to be told that the rules have changed and rewards disappeared. "It's gut wrenching," Xerox CEO Paul Allaire told Fortune, "The hardest person to change is the line manager. After he's worked like a dog for five or ten years to get promoted, we have to say to him or her, 'All those reasons you wanted to be a manager? Wrong.'"[47]

Learning Management

What then is the new model for management in the virtual corporation? Allaire has observed: "You cannot do to your people what was done to you. You have to be a facilitator or a coach and, by the way, we're still going to hold you to the bottom line."[48]

Professor Kim Clark of Harvard has written, "Executives who have thus been concerned primarily with capital investment and its return or who have put their faith in systems and procedures they thought would last forever now have to concentrate on creating a dynamic environment in which their most creative people can work hard in concert."[49]

This will be even more difficult than it sounds. For one thing, the new manager's 'people' in the virtual corporation will not only include traditional subordinates, but also employees that have temporarily moved over from other departments to be part of a task force, part–time employees, even men and women who aren't even employed by the firm but work for suppliers or distributors.

Setting goals for this heterogeneous collection and making sure they are met; knowing when to lead and when to stay out of the way; and merely keeping up with the group's range of interests and responsibilities, will be extremely challenging.

A growing number of industry watchers are beginning to tackle the question of how to effectively manage in a virtualized corporation. One popular new theory is that of *participative management*, the notion that employees become co-equals with their managers in planning and decision-making. With participative management all the fears and hopes of both managers and those they manage converge in a sort of nexus. The very notion of participative management can strike terror in the hearts of managers who relish their power and employees who aren't interested in the burden of command. It can also, as many have noted, lead to a chaos in which every participant holds to his or her particular opinion and no one is in the position to make a final decision.

Participative management can also be perverted into a power grab by the powerless, or conversely, into yet one more simulacrum of authoritarianism. Says Dick Cornuelle about the latter, "Many managers still think that participative management is like sandlot football where the quarterback sends *everybody* out for a pass."[50]

One individual who has closely studied the changing nature of management-employee relations is Rosabeth Moss Kanter, editor of the Harvard Business Review. She has written:

> "As work units become more participative and team oriented, and as professionals and knowledge workers become more prominent, the distinction between manager and non-manager begins to erode. . . [Managers] must learn to operate without the crutch of hierarchy. Position, title, and authority are no longer adequate tools, not in a world where subordinates are encouraged to think for themselves and where managers have to work synergistically with other departments and even other companies. Success depends increasingly on tapping into sources of good ideas, on figuring out whose collaboration is needed to act on those ideas, on working with both to produce results. In short, the new managerial work implies very different ways of obtaining and using power. [51]

Such a change, says Kanter, will force managers to find new methods for motivating their people. She has identified five such sources of motivation:

-- *Mission*: Inspiring people to believe in the importance of their work.

-- *Agenda Control*: Giving people the opportunity to be in control of their own careers.

-- *Share of Value Creation*: Rewarding employees for their contribution to the success of the company, based upon measurable results. [Note that this can mean skilled employees earning larger salaries than their putative superiors.]

-- *Learning*: Providing people with the chance to learn new skills.

-- *Reputation*. A chance to make a name for oneself in terms of public or professional recognition.

Kanter concludes by saying, "Commitment to the organization still matters, but today managers build commitment by offering project opportunities. The new loyalty is not to the boss or to the company, but to projects that actualize a mission and offer challenge, growth and credit for results."[52]

In the Eye of the Storm

But what of the manager himself? Stripped of many of the traditional perquisites of power and authority (including sometimes even title), coping with an expanded and nearly impossible span of control after having lost many of their peers, 'managing' a fluid group of employees who are "speaking up, challenging authority, and charting their own course"[53] and perhaps even earning a higher salary -- it seems reasonable to ask what will motivate these men and women.

That's is one of the most challenging questions facing the virtual corporation. The answer lies with the top management of each company . . . and most of all with the Chief Executive Officer.

The office of the chief executive of a virtual corporation is the pivot around which the entire organization will turn. Here decisions *will* be made. One will be to establish and preserve a reward system for managers that will keep them as motivated as their subordinates. Such a system likely will resemble Kanter's proposal for employees, keyed to the special needs of management professionals, including a greater self-identification with the success of the corporation. Such a program would necessary involve shifting ever-greater power and independence down through the management ranks. And that will most likely create a chain reaction upwards right to the CEO's office door, depriving him or her of much of the power a chief executive once possessed.

This will be a crucial moment for the CEO. After enforcing an apparent loss of authority and control at every step down the corporate hierarchy, can he or she make the same sacrifice? As the penultimate manager in the firm, the CEO almost by definition has the most to lose and the most zealous about not losing it. Can a typical CEO countenance paying one or more subordinates a comparably higher salary than he himself earns?

One of the unfortunate features of the American culture is that it rarely celebrates as role models the types of individuals that meet these criteria. One can think of managers and coaches of professional sports teams as one of the rare examples of this type of management style. In military history perhaps the nearest example is Dwight Eisenhower as Supreme Commander of Allied Forces/Europe. But neither are arresting archetypes -- which, of course, is the point. Japan, by comparison, is famous for its 'invisible CEOs' at the top of giant corporations.

This is not to suggest that the CEOs of virtual corporation must be anonymous figures. On the contrary, they must be *very* well-known to their employees. Nor can they shrink from the responsibilities of command. However, they can no longer solely lead the charge into the battle; but rather must devote themselves to developing the campaign strategy, leaving battlefield tactics to the smaller fighting units at the front.

At the same time, the CEO cannot start up the machine of the corporation and then sit back and let it run by itself down a predetermined path. The markets of the future will be too changeable for that. Furthermore, left to its own devices, the virtual corporation, with its diffused decision making, risks imploding, exploding or, most likely, careening down the wrong path. It is the job of the CEO to set the corporate vision, the corporate ethos, and to judiciously and sparingly use his or her power at the right pressure points to almost invisibly cause change.

The nature of such a CEO has been the focus of a number of researchers and analysts. Common themes emerge from these writings.

The CEO must define the corporate vision and skillfully convey it to all employees at every level. "In the future," says David Luke III of Westvaco Corp. "Nothing of any consequence will be accomplished without a vision that extends the entire length and breadth of the corporation."[54]

Says management consultant Fred G. Steingraber: "the principal responsibility for fostering [the] new organizational philosophy, including seeing the future of the company along with the customer, can only come from the CEO -- from his or her values, communication, style, and way of measuring performance."[55]

Adds Ronald Walker of Korn/Ferry International:

"[One quality that] will distinguish the 21st century executive. . .is the ability to communicate. Although he probably will come up through the ranks with operational experience, when he reaches the top he will have to be an effective communicator. . .He will have to be able to tell his company's story to his employees if he wants to retain and motivate them. . ."[56]

The CEO must symbolize the company. To customers, suppliers and other constituents, the one constant reference point in a perpetually changing virtual corporation will be its CEO. That's one reason why Steingraber predicts that "the succession of a new CEO increasingly will be a once-in-a-generation event at most companies. . . Lone Rangers who move from company to company, increasing their earnings and stock options at each move, will not be the pattern." [57] A.T. Kearney researchers found that among the top-performing Fortune 500 firms, the CEOs had an average tenure with the company of 16 years -- while at the lesser performing firms, the average was just 6.9 years.[58]

Says Walker:

"The second key quality that the 21st-century executive must possess and be able to communicate is integrity and ethics. That will be the challenge of the company's greatness. The effective executive must be able to discuss with all his constituencies what is good and bad about the company. Through his leadership, he must be his company's symbol of integrity and ethics.[59]

The CEO must be the company's premier generalist. This is the other reason why executives of virtual corporations will typically come from within the firm and will rarely jump ship. As software consultant Kenan Sahin told Fortune, "Before, when markets were slower, leaders had time to absorb information from experts. Now markets and technologies are becoming so complex, the experts will have to do the leading."

In truth, with decision-making moved down the corporate hierarchy and the company moving rapidly to cope with changing customer needs and market conditions, it will take everything the CEO has just to keep up with change, much less propel it. And keeping up is vital, because the CEO must be sufficiently prepared to make the crucial, company-wide decisions when they appear. That means the CEO must consciously place himself in frustrating position of being at the center of the corporate information system -- "You've got to stay on top of the information flow," says Wilf Corrigan of LSI Logic -- while refraining most of the time from using that knowledge."

The CEO must trust the employees of his firm. Says Donald Petersen, former CEO of Ford:

"It's tough for a boss to tell his subordinates that they know more about something than he does and to run with their instincts on something. He has to have the self-confidence to trust and empower people below him in the company heirarchy. Managers who lack this confidence are reluctant to give away power, because it means they're letting go of their ability to exercise control over other people as well as what they see as proof of their personal value."[60]

With this we come full circle to the problem that has lurked at the corners of American business since the days of Fredrick Taylor and decades before that. The virtual corporation is built upon unprecedented levels of trust. Between the company and its suppliers and customers. Between management and labor. Between senior and middle management.

Ultimately it comes to this: The chief executive of a virtual corporation must be able to trust employees in the firm to make responsible decisions. Those employees in turn must trust in the vision for the corporation as devised by the CEO. This is what Walker implied when he said the top executive must be the model of integrity. And it is what John W. Gardner has meant in his writings on leadership when he says that leaders cannot maintain authority unless followers are prepared to believe in that authority; that "executives are given subordinates; they have to earn followers."[61]

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In the virtual corporation, where almost every employee is to one degree or another a leader, the requirements for belief and trust are greater than ever before.

The exact form virtual management will take is of course in doubt. We can however be certain that it will be different from the management practices in most of today's corporations. The prescriptive management style of scientific management which gave minute to minute direction to the efforts of workers is dead. The towering management infrastructures born in the railroads in the 19th century are obsolete. Taking their place will be more self-management by worker, computer networks and flattened management structures, and managers focused on making processes work and establishing a vision for the company.

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[54]"Just Managing Won't be Enough" by Mark Goldstein, Industry Week, April 18, 1988. pg. 21.
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Chapter 9: The Virtual Worker

In many ways, the General Motors plant in Oklahoma City is a perfect example of what critics find wrong with the U.S. auto industry. It builds retrograde car models using outmoded techniques. For example, most welding is still done by hand. As for automation: there are 5,300 employees and only 40 robots.

By comparison, the GM plant in Orion Township, Michigan is technologically just what futurists would want. Its 5,600 workers build value-added luxury cars using the latest manufacturing equipment, including 170 robots.

So, as the Wall Street Journal asked in 1991 after studying both plants, "Guess which builds cars better?"[1]

It is the Oklahoma City plant, one product of which, the Pontiac 6000, was the highest ranking U.S. car on the J. D. Power & Associates list of the 10 most trouble-free cars. By comparison, the Cadillac Fleetwoods and Oldsmobile Ninety-Eights that roll out of Orion Township sometimes have as many as six defects per car -- three times GM's own quality goals.[2]

What's the difference? Why does the less-sophisticated plant produce the better cars? The *workers*. GM Oklahoma City has implemented many Toyota production techniques including just-in-time and lean manufacturing. But more important, its line employees exhibit a level of cooperation, identification with the quality of their work and an esprit de corps not found at Orion Township.

For example, the Journal reporter was amazed to find during one visit that on any given day as many as 100 of the Oklahoma City plant workers were in class receiving training on new equipment, computers and basic literacy skills. What's more, these courses were "taught by union instead of management personnel, unlike the practice at most GM facilities."[3]

At Orion Township, by comparison, the reporter found a situation of seething worker-to-worker and labor-to-management animosities. In the previous few months, one employee had attacked a supervisor with a knife ("a lovers' quarrel" said management) and a worker had hit another with a power tool. Local police bitterly complained about perpetual calls to the plant to deal with similar problems.

As for the union role at Orion, the words of UAW's local chairman were guaranteed to send chills through every progressive manager: "What is quality? I mean, I have a hard time getting my arms around it." Needless to say, when it came to reading the plant's daily update on production and defect levels, the union chairman admitted to never having done so.[4]

Beyond the fast cycle times, the lean production techniques, the implementation of new communications and data processing; after the new supplier/manufacturer/customer relationships, the adaptive organizations and the revolutionary products, the virtual corporation comes down to the individual worker. If that man or woman has not signed on to the virtual revolution, has not ratified its philosophy and accepted its terms of lifelong training, perpetual change and greater responsibility, then -- as the Orion Township plants shows -- no amount of new equipment or management posturing will make the slightest difference. Without the virtual worker, the virtual corporation cannot even be created, much less endure.

That ratification cannot be impelled or induced. It must be voluntary. It must occur as part of a larger redefinition of the relationship between workers, management, and, where it still exists, organized labor. This redefinition constitutes a *new social contract,* one that not only redistributes power, but also demands an unprecedented level of cooperation, and, once again, trust.[5]

Propelling this revolution in the workplace is the recognition that change has made past practices irrelevant, even destructive. For example, as other arenas for competition -- such as location -- diminish in the face of the new technologies, the role of workers becomes central. "How we manage people is going to be one of the most significant competitive advantages a business can have," says Dr. Edward E. Lawler III at the USC Center for Effective Organizations, "because the traditional competitive advantages -- where you manufacture and where you are headquartered -- have eroded. Using people as a competitive edge is more sustainable over a longer period of time."[6]

Wrote researchers at LeHigh University, "Agile manufacturing enterprises are able to manage unpredictability by maximizing the scope for human initiative."[7]

Another reason for change is that the modern worker has begun to develop a different set of priorities relating to work. "The old motivational tools have lost their magic," according to Jude Rich Of Sibson & Co., "The great challenge that lies before us is to restructure how we do work and reward people."[8]

Just as important, the change also is occurring for conservative reasons. American workers enjoy some of the world's highest wages. In the face of global competition from foreign companies with far lower labor costs, worker skills must be more efficiently leveraged for their employers to remain competitive. Says Lawler, "Business must ask more of the U.S. workforce. We have to let workers contribute more and add value to the business in proportion to their wage."[9]

His view is supported by BRIE's Michael Borrus, who; in his studies of the semiconductor industry, estimates that only 70 percent of Japan's advantage in chip making comes from better organization and 30 percent from better employee training. He says, "Better technology alone won't solve the problem."[10]

"The winners in the next few decades will be the companies with the most empowered work forces," says Michael Dell, CEO of Dell Computer Corp.[11]

What will daily work life in the virtual corporation look like? Tellingly, the impending changes for employees have not received the same attention as have the comparable changes for managers.

Several changes do, however, appear inevitable, given the increasing technological orientation of corporations, the distribution of decision making out to the rank-and–file, the less distinct boundaries between the company and its suppliers and customers, and the perpetually accelerating cycle times. These changes include:

-- More sophisticated training that will continue through employee's career.

-- Cross-disciplinary organizations, such as work teams, that will have extensive decision-making powers.

-- Hiring policies by corporations that select for adaptability to change.

-- An unprecedented emphasis on retaining existing employees in a shrinking labor pool.

-- Unions (where they still exist) and management entering into different, mutually dependent relationships.

-- A redefinition of the traditional notion of a 'career.'

-- The potential for a different form of worker alienation.

The Advancement of Learning

Throughout most of American history, the unwritten definition of 'worker' included the *lack* of education. The educational system was organized around this philosophy. High schools were two-tracked, with basic education and vocational training for those who would enter the working world upon graduation, and college preparatory classes for those who would continue on to earn college and university degrees and enter management or a profession.

"A century ago, a high school education was thought to be superfluous for factory workers and a college degree was the mark of an academic or a lawyer. [Now] for the first time in history, a majority of all new jobs will require postsecondary education.[12]"

A recognition of the failure of this model has been growing in industry for several decades, until we now find ourselves in what is generally acknowledged as a crisis in American education. At a time when U.S. corporations have an unprecedented need for a well-trained workforce capable of dealing with current technologies and with the study skills needed to quickly adapt to new ones, these companies find themselves faced with hiring new employees that, after 12 or more years of schooling, are still functionally illiterate or in other ways unprepared for corporate life.

A survey by the American Business Conference of its members, primarily mid-sized growth companies, found that 41 percent of the firms believed that worker competence had declined -- and of those respondents, 71 percent said they had become more dependent upon mechanization in response.[13] Motorola, in the first years of its celebrated employee training program, found that it had to stop and rethink the program because it had seriously overestimated the educational level of its employees. According to William Wiggenhorn, Motorola's vice president of training, in a survey of employees at a key division, only "40 percent passed a test containing some questions as simple as 'Ten is what percent of 100?'"[14]

"Let me dwell for a moment on the full drama of those results. The Arlington Heights work force was going to lead the company into global competition in a new technology, and 60 percent seemed to have trouble with simple arithmetic. We needed a work force capable of operating and maintaining sophisticated new equipment and facilities to a zero-defect standard, and most of them could not calculate decimals, fractions and percents.

It took us several months and a number of math classes to discover that the real cause of much of this poor math performance was an inability to read or, in the case of many immigrants, to comprehend English as a second language. Those who'd missed the simple percentage question had been unable to read the words. . .[15]

Documenting installations one by one, we concluded that about half of our 25,000 manufacturing and support people in the United States failed to meet the seventh grade yardstick in English and math."[16]

And the situation is expected to only get worse. Even if the educational system was to remain unchanged, demographic influences would continue to increase the general unpreparedness of the new arrivals in the workforce. The population bulge of the Baby Boom that swelled the ranks of the workforce in recent years has now, for the most part joined the ranks of the employed This is the last group in our lifetimes to fit the stereotype of the average American worker -- that is, white and male. Most future employees will have to come from other groups.

Among the 25 million new workers in this decade, only 15 percent will fit this profile. By comparison, 42 percent will be women, a group that historically has not migrated to technical careers; 20 percent native non-white men and women; and 22 percent immigrants, many of whom will have to learn English. The fastest growing group in the workplace will be Hispanics, an ethnic group with one of the highest high school drop-out rates in American society.[17] In an aging population, none of these potential sources of labor can be ignored.

Combined, these statistics suggest a monumental challenge. On the positive side, these groups have proven to be capable workers. For example, the same people who did so miserably on the Motorola test had also managed to increase productivity at their plant *ten-fold*.[18] What might they have accomplished had they not needed supervisors to translate everything that appeared on their computer screens?

"People," says Ko Nishimura, president of Selectron, "are much more capable than they think they are, and they are willing to do more than you think they will."[19]

The most progressive American corporations already assume that the average new employee will not only be unprepared to handle the special requirements of the job, but probably the basic skills of reading, writing and office interpersonal relations. Already, U.S. companies spend $30 billion each year on education. [20] Hewlett-Packard estimates it spends $100 million each year on employee training and an equal amount on lost worktime doing so. Similarly Motorola invests a combined $120 million, up from just $7 million a decade ago.

Unfortunately, much of the huge training sum spent nationwide is spent elsewhere than on the rank-and-file. Fortune estimates that just 12 percent of the workforce receives any formal on-the-job training. So, who is being trained? Management. A survey conducted by the Rand Corp. found that while more than 60 percent of men and women professionals and nearly 50 percent of managers said they had been trained by their current employers, only a quarter of machine operators and assemblers said the same.[21]

By comparison, one of the reasons for the huge international success of German *Mittelstand* companies is a sophisticated two to four year worker apprenticeship program. At $18,000 per year, this program may be as expensive as tuition at a top-notch U.S. university, but it also creates a highly skilled workforce.[22]

Learning to Learn

The sort of executive privilege in training found in the U.S. is not only contrary to the philosophy of the virtual corporation, with its empowered employees, but worse, at a time when workers have the greatest need for both basic education and job skill training, is self–destructive.

What is needed instead is continuous training for all company workers, in basic literacy and mathematics (algebra) where needed, team building, and continuing education in the new technologies appropriate for the job. "The whole work force must be trained," says Sue E. Berryman, director of the National Center on Education & Employment, "and it must be continuous training, not a little splat here and there, like an injection. . .The old idea was that the schools cooked you until you were done, and then you went to work. Now, you've got to be constantly cooking."[23]

In the words of IBM-Rochester's personnel manager Joanne McCree, "People must be 'enabled' as well as 'empowered' for this to work."[24]

A number of firms have already begun to develop career–long development programs for its workers. Probably the best known of these is Motorola Corp. and its Motorola University. According to Wiggenhorn, who is president of the University, until 1980, Motorola, like most companies, "hired people to perform set tasks and didn't ask them to do a lot of thinking" -- and when it did train employees, "we simply taught them new techniques on top of the basic math and communication skills we supposed they brought with them from school or college."[25]

Dwindling competitiveness and experiences like the math test at the Arlington Heights plant, taught Motorola differently:

> "Then all the rules of manufacturing and competition changed, and in our drive to change with them, we found we had to rewrite the rules of corporate training and education. We learned that line workers had to actually understand their work and their equipment, that senior management had to exemplify and reinforce new methods and skills if they were going to stick, that change had to be continuous and participative, and that education — not just instruction -- was the only way to make all this occur."[26]

As Motorola's CEO George M.C. Fisher succinctly put it, "We find it necessary to continually train all of our workers."[27]

Discovering just how to conduct this training was not a straightforward process. As Wiggenhorn says, the company started out with some inaccurate premises about the educational sophistication of its workforce and had to backtrack quickly to make up the difference. Crucial to the survival of the program, during this difficult period, was the sustained support of chairman Robert Galvin, right down to personally answering complaints from employees about the training program -- thus underscoring the vital role played by top management in the success of any corporate training program.

At the heart of the Motorola training program was a philosophical credo: that every employee had a right to training . . .and retraining when technology changed. From this credo came two corollaries. One, the carrot, was that if this training failed with an individual employee because of poor pedagogy or the employee's own learning disability, it was the company's responsibility to find another way that worked. The other, the stick, was that if an employee refused the retraining when it was needed, he or she could be fired. "In fact," says Wiggenhorn, "we had refusals from 18 employees with long service, and we dismissed all but one. That sent another strong message."[28]

In practice, Motorola has 1,200 people in some way involved with training and education. Of these, Motorola University employs 110 full–time and 300 part–time staffers. Twenty three product design engineers serve as the equivalent of department chairs, and the senior product manager as a sort of dean. The University specializes in the teaching of interpersonal skills, and in recent years has worked with local community colleges and technical schools to offer courses in basic business and technical skills such as mathematics, electronics, accounting, computer operation, and statistical process control. The program also stresses teambuilding skills and the inculcation of the Motorola corporate culture.[29]

Wiggenhorn likes to quote Cardinal Newman's nineteenth century view of the ideal university -- that of creating individuals who can "fill any post with credit" and "master any subject with facility" -- but more pragmatically speaks of raising the average literacy of company employees from seventh to ninth grade by 1995.[30]

Says Wiggenhorn, "We not only teach people how to respond quickly to new technologies, we try to commit them to the goal of anticipating new technologies . . .We not only teach skills, we try to breathe the very spirit of creativity and flexibility into manufacturing and management."[31]

Adds Susan Hooker of Motorola University, "We now need to keep everyone in the company going upward in terms of skill levels. The 1990s will be the decade for improving the quality of people."[32]

Motorola's is only the most celebrated of the new corporate training programs. Other corporations, recognizing changing demographics and the pressing need for a better educated workforce, have also begun to install company-wide training programs. At General Electric Aircraft Engines, for example, nearly one-third of its 38,000 employees have taken a two-day course in problem solving -- leading one twelve-year employee, a carpenter, to tell Fortune, "Before, the hourly people felt like every time we walked through the gate, we checked our brains at the guard shack. So this is starting to tap into untapped resources, which is neat."[33]

Levi Strauss,in converting one of its factories to modular manufacturing is giving each of its workers there 100 hours of training in such areas as reducing labor costs and laying out equipment on the shop floor. The company feels this is necessary because in the future, each employee will have as many as three different jobs.[34]

In Silicon Valley, Solectron, faced with a quarter of its 2,000 employees being non-native American, and many not even speaking English, created Solectron University, with courses in basic electrical assembly, American culture, and English. Said vice president Bill Yee, "The university is part of the company's cultural transformation."[35] Not far away, Intel, faced with coordinating a huge workforce, spends more than $2,000 per employee each year on skill development and inculcating both workers and managers in the company's basic values regarding work ethic, risk--taking and customer orientation.[36]

One established myth is that employee training can only be afforded by large corporations because of their economies of scale. But in an age of computer terminals, VCRs, educational data bases and thousands of community colleges, those traditional barriers no longer exist -- a good thing too, as smaller companies will often need employee flexibility the most in the virtual revolution.

Amplifier maker Peavey Electronics in Mississippi found one method for training its employees: it has implemented the U.S. Army computerized Job Skills Education Program (JSEP) in conjunction with a nearby community college. Peavey embarked on the program because it recognized that its workers were not up to the demands of modern manufacturing techniques. Said Karl Haigler, special advisor to the state governor, "No one is going to take someone right off the street to run a half-million dollar robot. So this type of program is life or death for industrial expansion in Mississippi."[37]

The results of the project were staggering. Of the original 64 employees who took the JSEP program, a third have been promoted at least once. A second class of 13 jumped three math grade levels in just 56 hours — compared with one grade level in 60 to 80 hours in traditional adult education.[38]

Plumley Cos. of Tennessee, a family-owned automotive supplier, set out to train its workers in statistical process control, paying 500 of them to attend a course at the local junior college. Like the executives of giant Motorola before him, CEO Richard Plumley was amazed to find "that over 50 percent of our workers could not add, subtract, multiply or divide. And here we were trying to teach them a first-year college course."[39]

Plumley Cos. now employs two full-time instructors, offers basic courses in reading, writing, problem-solving, arithmetic and reading comprehension; as well as free classroom instruction taught each month in everything from geometry and computers to three different levels of Japanese and German.

In the first seven years of the program, 55 employees earned their GED. More important for the company was the improvement in the bottom line: productivity (in sales per employee) increased 50 percent and defective products and waste dropped by more than 35 percent. Most of this, the company believes, can be credited to training.[40]

"The investment in education has more than paid for itself," concluded Plumley. "It would have been a greater cost not to make the investment.

"There are many people in the workforce with outstanding work ethics. But many of them also need a radical change in their own self-esteem to be able to achieve their full human potential. We need to educate workers so they can respond with their heads, not their gut."[41]

One company that has set out to do just that is Lenscrafters. This half-billion dollar division of U.S. Shoe operates nearly 500 outlets, each a factory for the real-time production of prescription eyeglasses in less than one hour. To do this, Lenscrafters has to move most daily decision-making out to its geographically dispersed employees.

In the process, Lenscrafters has discovered a hidden obstacle to virtualization: that of the organization as a whole never learning from mistakes made at individual sites — and thus repeating them over and over.

Says David E. Browne, Lenscrafters' 32 year-old CEO:

"One of the dangers in our approach -- in terms of being very decentralized and empowering -- is that if we aren't capturing the key learning from the different parts of the organization, we may face a lot of redundancy. In a lot of situations, people will face a problem for the first time. As a company, we may have faced it 20 times and figured out four different ways to attack it. . . there's a major efficiency to be had by having everybody understand what we've learned to date."[42]

The Lenscrafters dilemma is a reminder that the virtual revolution, before and after everything, is about learning. The virtual product itself is a learning machine, gathering information to be used in the design of its successor. By the same token, the virtual corporation is a learning entity, struggling to understand its mercurial operating environment so as to successfully adapt to it.

The individuals who make up the virtual corporation -- employees, contractors, even suppliers and customers — more than anything else, must also be full-time *learners*.[43] This doesn't mean 'trained'. Simple skill development is not enough for the continuous and radical changes of virtualized business. Any such skill would quickly be rendered obsolete or irrelevant. Rather, participants must learn how to learn. They must be equipped with the conceptual skills required to deal with perpetual change. And they must be armed with the technology needed to put this ability to work.

One way Lenscrafters helps this learning process along is by making the acceptance of mistakes one of the company's 'core values.' Says Browne, "It's OK to fail in our [corporate] culture as long as you try ideas and have something not work, as long as you learn from it and the company learns from it . . .accepting mistakes is important. It removes fear. It encourages innovation. There's a lot of room for folks to tailor-market, to tailor merchandise, to tailor their operations approach."[44]

Progressive European companies are also pursuing employee education. BMW, for one, regularly sends its foremen to 'Study City' to learn total quality production skills.[45]

A non-traditional European company that has tapped into this learner market is The Body Shop Corp., a British natural cosmetics firm with franchises throughout the world and with annual revenues predicted to reach $1 billion by 1995.[46]

Despite its countercultural airs and founder Anita Roddick's sworn hatred of "Harvard MBAs", The Body Shop has long recognized the importance of training and information as employee motivators. The company's training center in London is open to any employee, not only of the parent firm, but of every franchiser around the world. As Roddick told Inc., other cosmetics companies "train for a sale. We train for knowledge."[47]

The New Breed

One striking feature of the manufacturing and office floors of the virtual corporation will be how little the employees will *look* like their counterparts of our time.

At the turn of the century, 45 percent of the U.S. workforce will be white males, down from 47 percent in 1990. But the types of white males will be quite different. [48] The most eligible of the Baby Boomers have already been picked, as will all the subsequent 'X' generation, or Baby Busters, as soon as they leave school.

That leaves those white males who for some reason or another -- low intelligence, physical disabilities, criminal record, emotional disfunctionality — have opted out or been excluded from the workplace. It also leaves the perpetual have-nots of American work life, black males for example, who for a number of reasons -- high drop-out rate, lack of workplace experience and racism -- actually risk seeing their presence in the work force recede. In the labor crunch that will come from an aging population, companies will be forced to take a second look at these groups and find ways to accommodate them in the workplace.

One group that will show an increasing presence in the workforce will be women. Native white women will represent the fastest growing fraction of the labor force, contributing an estimated 42 percent of the new workers between 1985 and 2000. Native non-white women, especially black women, will also hold a larger fraction of jobs in the years to come. These figures, combined with those of immigrant women, suggest females in the labor force will, for the first time approach the percentage of men on the job and contribute almost two-thirds of the new workers in the near future.[49] This constitutes a powerful interest group that may force many hungry companies to adopt 'women's policies' such as extended maternity leave, sick child leave, part-time and home work and on-site day care as recruiting tools.

Immigrants will remain one of the most dynamic components of the labor force, with more immigrant men (13 percent) and immigrant women (9 percent) added to the workforce before the end of the century than native non-white men (7 percent). Immigrant workers present their own unique problems, most notably in the inability to speak English, cultural confusion, and, for many refugee–type immigrants, a lack of training in the tools of everyday modern life.[50]

In the past, corporations might have chosen to ignore these groups, arguing that their job was to make a profit for investors, not subsidize social change. That strategy is increasingly untenable. In accepting the challenge of hiring from less-adapted groups, companies must also accept that many established mores of the office and factory must also go by the wayside.

Barbara Shimko of Widener University offers a glimpse of the magnitude of this task:

"It is understandable that recruiters want to hire persons from identifiable mainstream groups who in the past have proven to be successful, easy-to-manage employees. The applicants that recruiters are attracting these days do not belong to those desired groups. These include, among others: minorities, females, older people, handicapped, disadvantaged, and those lacking work experience. In addition, some applicants will have the added burden of a major personal problem such as a discordant home life (if they have a home), a prison record, or a history of alcohol or drug abuse. In all likelihood, if you hire someone and then decide to fire him or her because things are not working out the way you had hope they would, the person you bring in as a replacement is going to seem very much like the one you just let go."[51]

Unfortunately, of many hiring criteria used by American corporations, many are more social tics than anything else, designed -- unconsciously or not -- precisely to keep out these potential sources of labor. For example, Shimko and her group surveyed 38 general managers of fast food restaurants to determine what these managers felt were crucial factors in the hiring or not hiring of job applicants. Beyond the usual matters of attitude, prior experience and honesty, Shimko found that 20 percent of the managers (tied for the highest percentage with 'attitude') considered appearance a factor in the decision not to hire. In particular, this meant hairstyles, jewelry, and brightly colored or unusual clothing the manager found objectionable — characteristics that might simply signal a different cultural upbringing.[52]

But most amazing to Shimko was that nine percent of those receiving a negative hiring decision were turned down for inappropriate eye contact.

"To give a firm handshake and look someone straight in the eyes is a very important lesson taught by Dad to every middle class male at a tender age. Not only do non-mainstream groups miss the lesson from Dad, some are taught that direct eye contact is rude or worse. Girls are frequently taught that direct eye contact is unbecoming in a female. In reality, having averted or shifty eyes may indicate mostly that the job applicant is not a middle class male."[53]

Psychological researchers in the mid-1970s found that many of these new types of hires had not had a proper job as an adult and thus misread as threats what were in fact standard business practice. For example, to some workers, a dressing down by a supervisor might be seen as abuse or prejudice, thus some employees may respond with deep distrust and resentment and fight back with petty theft, surliness, or idleness. This employee then is labelled a 'behavior problem' and the cycle spirals down to angry termination or even violence.[54]

Needless to say, this behavior isn't unique to non-traditional hires. Still, it is more likely to be discovered beforehand among individuals with an established employment record. And, as with appearance and office behavior, a little pre-emptory training can preclude workplace tension or even tragedy.

All of these caveats aside, the new, non-traditional workers often turn out to be important contributors. For example, non-traditional employee groups often show a dedication, loyalty, and even special skills, not typically found in traditional employee groups. Marriott Corp., suffering from a 105 percent annual turnover rate among its workers, initiated a program to hire physically and mentally disabled workers. Though the program had its costs -- special social and job training courses, as well as teaming the new hires with company managers -- the turnover rate of this group is just 8 percent.[55]

In Philadelphia, Project Transition trains welfare recipients specifically for the fast food industry, as it is not only one of the fastest growing U.S. industries, but also has one of the worst turnover rates -- and thus would be more receptive to hiring Project Transition graduates. Given the dangers of manager prejudice, one of the things the Project teaches its participants is how to 'impersonate' mainstream job applicants during interviews. To help the newly hired deal with their unpreparedness for work culture, Project graduates are also helped with eight weeks of on-the-job coaching.[56]

Team Work

The volatile nature of the virtual corporation will be reflected throughout its organization. If this is true in the ranks of management, with its shifting spans of control, it will be even more so among workers.

The empowerment of employees, combined with the cross-disciplinary nature of virtual products, will demand a perpetual mixing and matching of individuals with unique skills. These individuals, as their talents fit, will coalesce around a particular task; and when that task is completed will again separate to reform in a new configuration around the next task. The effect will be something like atoms temporarily joining together to form molecules, then breaking up to form a whole new set of bonds.

In the virtual corporation it will not be unlikely for a task force to form, almost spontaneously, around a common task. Such a group might contain representatives from the research lab, the manufacturing floor, a sales office, even from suppliers, distributors, academia -- and the customer. This group might physically gather on a regular basis, but often would be geographically dispersed and would communicate using telephones, computers, and electronic mail.

In recent years, the most discussed example of this sort of group activity is the *work team*.

In Fortune's description, work teams:

". . .typically consist of between three and 30 workers -- sometimes blue collar, sometimes white collar, sometimes both. In a few cases, they have become a permanent part of the work force. In others, management assembles the team for a few months or years to develop a new product or solve a particular problem. Companies that use them -- and they work as well in service or finance businesses as they do in manufacturing -- usually see productivity rise dramatically. That's because teams composed of people with different skills, from different parts of the company, can swoop around bureaucratic obstacles and break through walls separating different functions to get a job done."[57]

The magazine went on to note that a survey by the American Productivity & Quality Center found that half the 476 Fortune 1000 companies it had surveyed planned to use work teams in the future -- but that, as of 1990, only half had done so. But among those that had organized around work teams, the improvements have been impressive:

-- So successful have teamwork programs been at the Defense Systems and Electronics Group at Texas Instruments that management announced the goal of having every employee in a 'self-directed workteam' by the end of 1992.[58]

-- The General Mills Lodi, California cereal plant runs during the night shift with no managers present; work teams at the plant have increased productivity 40 percent;

-- A Federal Express work team identified a billing problem that was costing the company $2.1 million per year;

-- Aetna Life & Casualty reduced the ratio of middle managers at its home office from 1:7 to 1:20 while still improving customer service;

-- Work teams at Johnsonville Foods in Wisconsin convinced their CEO to make a major plant expansion, and the result has been a 50 percent improvement in productivity.[59]

-- Corning Glass took the bold step of organizing 70 percent of its 1,200 scientists and engineers into quality workteams, an unheard-of notion in R&D. The result in the first four years was savings of more than $21 million, faster new product creation, and a doubling of Corning's return on equity. [60]

There are several obvious advantages to work teams. For one thing, they reduce the need for layer upon layer of middle management. They also move control down to the people with the most obvious, hands-on experience with the process.

In the factory, some managers believe that with work teams the costly creation of individual labor standards can be dropped in lieu of estimates of required labor for the total operation. It also increases efficiency. For example, "when one operator on the line is done earlier than the others, he helps the assemblers in the adjacent positions complete their required tasks." And, the process is self-motivating and self--disciplining, as the team begins to develop an esprit de corps and pulls along its laggards.[61]

It is important to note that work teams in themselves are not a solution. In fact, one survey of the auto industry found that teams can actually reduce productivity. The real gain in productivity, these researchers found, was when team organization was linked with greater participation in shopfloor decision-making.[62]

Another survey found that team members themselves listed as the three most important benefits that of improved involvement and performance, positive morale, and "the sense of ownership and commitment to the product that teams create."[63]

Work teams are a prelude to the kind of ephemeral organizational structures that will be found in the virtual corporation. The aforementioned survey found that the typical team size is six to ten members and that three–quarters have been in existence less than three years, and a little more than half less than two years.

From a team of five assembly line workers in a factory to a product design team of fifty scientists, graphic designers, production experts and customers spread throughout the world in a dozen different time zones is not an easy jump. The great challenge to teams in the virtual corporation will be overcoming the limitations of both geography and time. Team members may not always be able to communicate directly, much less in person, so systems must be in place that support collaboration through other means, such as computer data bases. Apple Computer is currently working on just such a program, an 'electronic campus' that would allow team members to interact through common data bases that organize contributions not sequentially, but thematically.

Developing productive teams, even of the simplest variety, is not simple. First, not every job merits a team approach. Simple, solitary tasks usually don't benefit from this type of reorganization. Secondly, as writer Michael Schrage explains in Shared Minds, bringing people together in a team structure does not guarantee fruitful collaboration:

"When it comes to human communication, there's a factor more influential in everyday life than most people care to admit . . .It's our ability to deceive ourselves. . . This self deception runs through most organizational communications. It's why people think meetings are a waste of time, and it helps explain the frustration most people feel when they try to collaborate.

"Most people kid themselves into thinking that they're collaborating with someone when, in reality, they're just saying words. Traditional modes of discourse in no way capture the subtleties, the power, and the degrees of interaction necessary for effective communication."[64]

Students of work teams have discovered them to be far more complex in their behavior than one might expect. Researcher Glenn Parker found that a successful team typically exhibits a dozen different traits, from a clear purpose, to ruthless self–appraisal. He also identified four types of team player: the 'contributor', who is information and performance focused; the 'collaborator', who is the source of the team's vision; the 'communicator', who is the facilitating heart of the team; and 'the challenger', who serves as the team's devil's advocate. Every team member exhibits one or more of these traits and "a really good team has members who make sure that all four of these roles are being exhibited in the correct proportions."[65]

Allan Cox, takes this one step further, defining an effective work team in the image of a living organism, "a thinking organism":

" . . .[a team] is a thinking organism where problems are named, assumptions challenged, alternatives generated, consequences assessed, priorities set, admissions made, competitors evaluated, missions validated, goals tested, hopes ventured, fears anticipated, successes expected, vulnerabilities expressed, contributions praised, absurdities tolerated, withdrawals noticed, victories celebrated, and defeats overcome."[66]

Obviously, this is a much more sophisticated vision of a work group than a glorified quality circle or a task force to determine employee vacation schedules. Add temporal and geographic elements to Cox's definition -- that such a team may be ephemeral or nearly permanent, that it may have a handful of members or dozens, that its participants might not all be employees, and that they may be dispersed over the globe -- and we have an image of work organization in the virtual corporation.

Learning Together

Reaching this more sophisticated level of teamwork will require not only more advanced hardware and software, but also much more training of the individual team member.

If this chapter has a single dominant message, it is that in the modern business world, the world of the virtual revolution, employee training becomes paramount. This means training in the basic educational and social skills where they are lacking. It means, as the corporation of the future will be built on information, training in the tools that control and manipulate information will be necessary. And, because team work will be the primary work mode, it means training in consensus-building, group dynamics and problem-solving is essential.

This is not an inexpensive process. Unfortunately, most companies simply march into a work team organization without the requisite employee