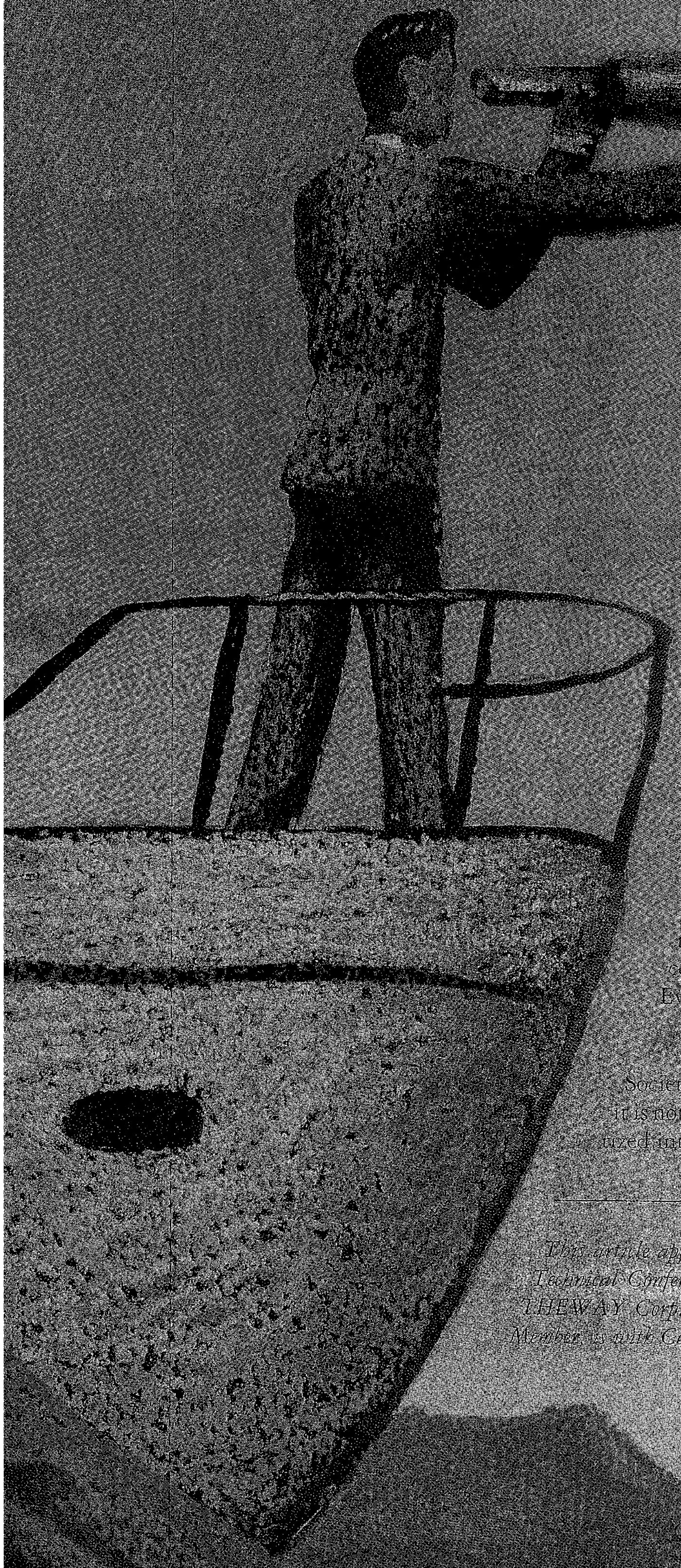


Changing Paradigms for Engineering

Marcus O. Durham and Robert A. Durham

A paradigm is a set of rules that define the boundaries of a system and provide the description of the operation within the boundaries. The basic philosophy of a culture or corporation is a paradigm for that particular time.

In many systems, a paradigm may be an unconscious technique. As an example, the traditional paradigm for success was go to school, work hard, and keep your integrity, and you would reap financial reward. This was not a written formulation, but was so accepted by society that anything different was little more than heresy. Even while promoted, that maxim was proven to be full of holes [1].

History

Societal expectations are influenced by advances in technology. Although it is not a complete description, the major technological eras can be summarized into four groups [2].

This article appeared in its original form at the 1996 Petroleum & Chemical Industry Technical Conference in Philadelphia, Pa. Marcus Durham, an IEEE Fellow, is with THEWAY Corp. and the University of Tulsa, Tulsa, Okla. Robert Durham, an IEEE Member, is with Central & Southwest, Tulsa, Okla.

1077-2618/98/$10.00©1998 IEEE

Nomad independence: In a nomad society, the technology needs are basically limited to tools for hunting, herding, and gathering and to erecting a temporary shelter.

Agrarian economy: Tool requirements extend to cover farming and storage and to erecting a permanent shelter. This era covers most of human civilization.

Industrial revolution: Within a generation during the last century, technology expanded to very large, complex systems requiring multiple workers. Information is controlled by the system owner. Shelter moves past needs to wants, but the location is controlled by the work site. Adequate resources are available for limited saving and planning for the future.

Information explosion: Technology explodes to ubiquitous availability for anyone wanting to learn and willing to take risks. Shelter location can be at the choice of the owner. Resources are available to those who seize the available information.

In a developed society, all these exist simultaneously. Later advancements are simply added options. With each change, it is apparent that the choices are greatly augmented. Nevertheless, not everyone will access the opportunities of the new paradigm because of ties to and dependence on the previous period.

Life Cycle

Within each technological era, a defined business life cycle follows technology development. *Technology* is dominant during the birth and period of growth. *Management* brings in a period of stability and expansion by acquisition. *Legal* protection and risk avoidance portend the end. The curve can be plotted with money, recognition, or some other measure of wealth on the vertical axis, and time on the horizontal [3].

The corresponding technology cycle is proposed. (1) Any new technology begins with a dream, a *concept* or an idea. (2) As the dream becomes focused, a *plan* matures and a process forms. (3) During a *growth* phase, the system has reached critical mass; it can progress merely on its own merits. (4) As a technology reaches *maturity*, the wealth curve flattens out over the bandwidth of the life cycle. The system is stable enough to be self-sustaining until a replacement technology arrives. (5) The new technology begins to push the wealth curve downward at the *roll-off*. (6) No new applications exist for the original technology during the *satiation*. (7) Eventually the plug is pulled for the *demise*. Fig. 1 graphically illustrates the life cycle.

At the turn of this century, the productive period of technology could exceed that of one generation. With the approach of the next century, technology life expectancy is often less than five years.

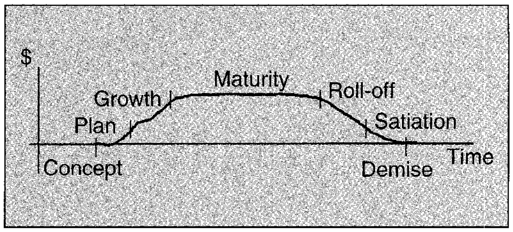


Fig. 1. Technology life cycle.

Extending the Life Cycle

Because of the transition cycles, few companies can thrive for long periods of time. Two approaches appear to be the dominant models for survival. The first cleans up the old act. The second takes a new tack.

Resurrection: This is not part of the life cycle, but rather is an admirable effort to recapture some of the strength of the dream, stretch the life of the maturity segment, and enhance the life of the organization.

The new corporation is a development to salvage a historical management hierarchy from satiation and demise. The basic premise is to reduce costs and number of people, employ technology where feasible, and focus on a core business. Companies that have effectively changed their organization have been rewarded substantially by the stock market increasing the value of shares [4].

Application technology, such as computers, is used to enhance ancillary performance. New advancements in the core business technology may not occur as they should. Nevertheless, costs will be controlled to the point of extending maturity.

The organizational structure becomes very flat. One designated hitter will have numerous people directly under his authority. The organization again takes on some of the image of entrepreneurs. Each worker is responsible for his own performance without supervision. A slip-up or political *faux pas*, and he is out.

Support services consist of a personal computer and voice mail. With the rapid developments, the type of support will change before this article is published. Technology has been elevated to reduce costs. Many specialized functions, such as design, training, and construction, are outsourced to specialists.

Network: Companies that flourish become managers of technology. The major chore becomes coordination among the three corners of the product triangle—suppliers, marketers, and transporters. The technology is developed and provided by outside sources. The managers develop a distribution system to the client for the product. It may take on a private label or a widely recognized branded moniker. The remaining pin of the triangle is responsive transportation for movement of products and information.

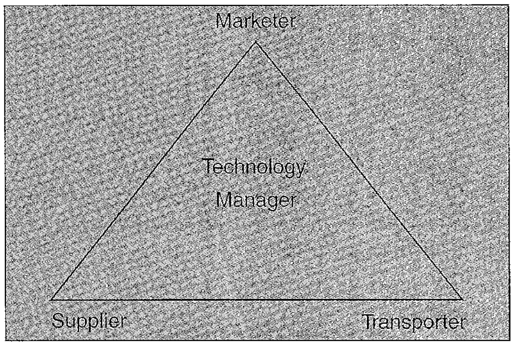


Fig. 2. Network for technologists.

Fig. 3. The client's perspective.

Under this structure, the individual risks are limited. Nevertheless, managers can draw on the financial strength of the suppliers. Different levels of risk are allocated to the independent entities.

The cost of manufacture and product development is concentrated at the most effective source. Cost of customer education and development is located nearest the client. Cost of vehicles and movement is relegated to innovators. Cost of coordination and responsibility for support is concentrated at the manager. Improved cost, service, and access of goods are provided to the client.

Within an information society, this is the optimum system [5]. The technologists in each of the corners of the triangle, the manager, and the client are independent. However, the network shown in Fig. 2 makes a winning system for all.

Although the support system appears as a triangle, the client sees only a straight line. From his perspective, all the components are collapsed into a telescope under the marketer (Fig. 3).

Many unfortunately feel they have no opportunity because there is nothing new to be developed. This concept is steeped in the traditional technology-management-legal life cycle. In reality, 90% of purchases now are for things that did not exist 20 years ago. New ways of doing old things and development of new things are growing explosively.

The major wealth in the past 20 years has come from managing, developing, and applying technology to distribution. This includes directing information, moving products, and supplying transportation.

Theory of Technology

One of the fundamental principles of science is the conservation of energy [6]. In essence the law, simply stated, is "the sum of the energy in a system must be zero." A variation can be restated as "nothing can be created or destroyed, it can only change form."

From this basis, every closed, physical system can be identified as a "zero-sum" game. In other words, if there is an increase or winner in one area, then there must be a corresponding decrease or loser in another area. This is a valid observation when the system is completely and adequately defined. Notice that one of the necessary criteria is a closed system. A closed system is completely self-contained without any outside influence. In other words, there is no substantive growth.

This is highly desirable in a control system. Damping is used to force the performance to a stable condition. Stable by definition means there is no building or growth.

A more significant observation is that many systems can be regarded as open. These have a continually changing source of energy that is derived from outside the narrowly defined arena. If a closed system is a "zero-sum" game, then an open system can be described as a "find-more" game.

For example a nomadic society attributes value to hunting and herding skills and equipment. Within the society, he who has the most arrows and can deliver them is the winner. Others lose out on the available game. This is a closed system.

Enter the agrarian society. Game has less significance while land ownership, domesticated livestock, and crops take on a new meaning. The technology advances allow the farmer to achieve a more stable, greater wealth. It is not at the expense of the hunter. The skilled hunter can flourish and maintain his limited wealth without interference from the farmer as long as they avoid the same land.

The society, then, is not a closed, but an archetype of an open system. Outside energy comes from technology development. The technology provides value to items previously without worth.

Within a defined set of conditions, physical systems are closed. However, technology, which is an outside influence, by definition creates an open system for a society. Unlike a "zero-sum" condition, many can experience growth and wealth without it being at the expense of others. This is the model to be expected if the world is adequate for human survival and development.

Theory of Economics

Economic theory during the span of the United States has been built on the work of Adam Smith in his 1776 tome *The Wealth of Nations*. He discussed that the individual pursues his own selfish interests. In the process, an invisible hand leads to achieving the best good for all. From this comes the philosophy of "what's good for (insert your own) is good for the country."

The theory was replaced by John Maynard Keynes in the 1930s. The pivotal work was explained in *The General Theory of Employment, Interest, and Money* [7]. Coming out of a depression, he advocated the satisfaction of the consumer. From this theory, once a consumer had the immediate primary needs met, he would quit accumulating. The demand for products would reach a plateau. To keep money flowing, Keynes advocated progressive taxation. The more money a person had, the more he would pay in taxes.

Paul Samuelson reflects the restrictive philosophy in his perennial text *Economics* [8]. "Economics is the study of how people and society choose to employ scarce resources. ..."

John Kenneth Galbraith had an expanded view in *The Affluent Society* [9]. In 1958, he observed "In the affluent society, no sharp distinction can be made between luxuries and necessaries." As a result, there is a constant demand for new and better things.

Sixty years of economic experience demonstrates obviously that the basic premise of Keynes is in error. Consumer demand for products is never satisfied. Therefore, the progressive taxation approach must be in error.

The consumer will gather goods until a desired *quantity* is reached. Then his focus will shift to higher *quality*. Once that phase of the cycle is begun, he desires a new quantity of the higher quality. The resulting quantity-then-quality demand creates an unending desire for new things.

The economic alchemist Paul Zane Pilzer passionately develops a theory of expanded wealth in his watershed volume *Unlimited Wealth* [1]. The early alchemists, in their attempt to make gold, laid the foundation to modern investigative science. Although a formula for gold was not found at the time, in essence they achieved their dream to create value where none existed. Alchemists developed the framework for pharmacists, chemists, metallurgists, and engineers.

Building on this definition of scientific development, Pilzer has formulated the three basic tenets of the Theory of Alchemy:

1. Technology is the major determinant of wealth because it determines the nature and supply of physical resources.

2. The advance of technology is determined mainly by our ability to process information.

3. The backlog of unimplemented technological advances (that is, the technology gap) is the true predictor of economic growth for both the individual and society.

Table 1. Manufacturing/Distribution Tradeoffs Historically

Date	Manufacture	Distribution	Era
pre-1950	4/5	1/5	Resource limited
1965	1/2	1/2	Engineer's dream
1985	1/3	2/3	Reorganize fever
1990	1/5	4/5	Flat society
1995	1/6	5/6	Technology market

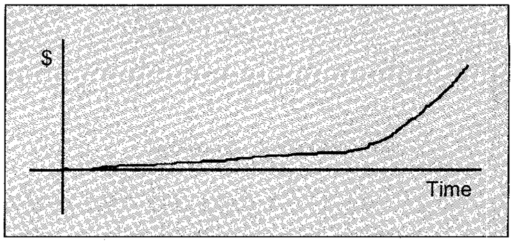


Fig. 4. Growth.

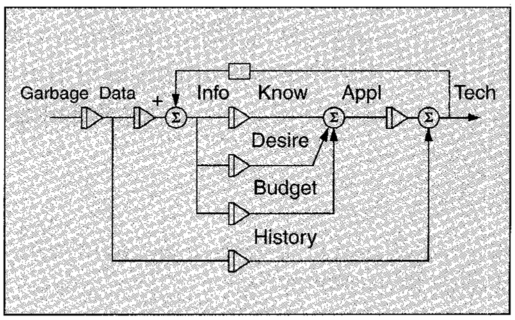


Fig. 5. Control system model.

The relationship can be stated mathematically. Wealth (W) is the product of physical resources (P) and technology (T) advances to the exponential power n [1].

$$W = P * T^n$$

The theory categorically emphasizes that wealth is not a zero-sum game. It can expand. The exponent grows because technology feeds on itself with positive feedback.

We have modified this relationship to fit closer to a second-order model $W = P * e^{Tn}$.

Traditionally technology has not advanced very rapidly. Therefore, wealth was proportional to the physical resources one could accumulate or control. This carried from the nomadic society through the agrarian society. Technology was virtually flat, as shown in Fig. 4.

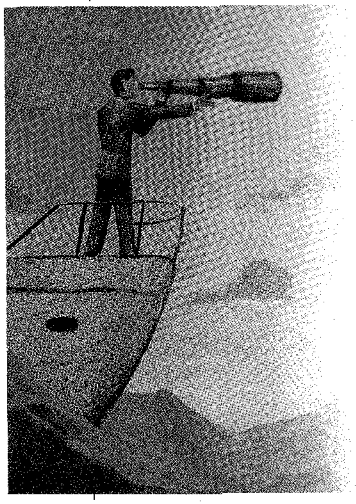
Advances in technology brought in the industrial society. Since the growth was slow, the one who controlled technology could control the physical resources and would have greater wealth.

A major paradigm shift exploded in the 1980s. The control on technology was broken. Information transfer was enhanced by the personal computer and the associated paraphernalia. With very little investment and training, anyone could have access to technology.

The present expansion in technology appears unlimited. Later, we will illustrate the boundaries on technology expansion.

The major industrial corporations prevented collapse by seemingly endless reorganizations. In reality, people were released from the corporate motherhood.

Ron Cost was a Nobel laureate in 1991 based on a 1931 paper, "Nature of Firms." He proposed that



The very principle that provided the theoretical framework for the mega-corporation now provides the impetus to the minimal-sized entity that can successfully network.

a firm would grow until transaction costs (*T*) were equal to inefficiency costs (*I*).

$$T = I$$

Transaction costs are the costs of doing business. When these are high, small businesses are kept out. Inefficiency costs are the burden added by a large company. When these are high, large companies start a slide.

With the advent of information exchange and inexpensive computer technology, the cost of transactions have tumbled to the point any entrepreneur can profitably develop a business. The very principle that provided the theoretical framework for the mega-corporation now provides the impetus to the minimal-sized entity that can successfully network.

Theory of Information

Technology is inextricably linked to information. He who has control of information controls technology. We propose a mathematical relationship between the terms.

A clarification must be made between data and information. *Data* is raw, often random noise. Data must be filtered to provide valuable *information*. The information must be further filtered to provide *knowledge*. Knowledge that is used is defined as *application*. Fig. 5 is a control system model for technology and information.

We have linked the relationship between technology and information, application, and history. Technology is proportional to the acceleration of information, the speed of application, and the changes from history.

$$Tech = \frac{d^2}{dt^2}(Info) + \frac{d}{dt}(Application) + d(history)$$

The equation is similar in form to a standard second-order relationship. This is the cognitive or *rational* line contribution. Two other lines contribute. These are the emotion or *desire* lines, and the physical or *budget* lines. The control system representation is shown in Fig. 5.

If the equation depended on a single basis, then the basis would experience an exponential decay. However, in this relationship, each of the terms on the right side are dependent on feedback from the technology.

$$Info = Filter1 * Technology$$

$$Application = Filter2 * Info$$

This self-feeding causes a positive feedback growth. Traditional theory indicates this is impossible for a physical system because an explosion would result. In fact, there is an information and technology explosion.

Positive feedback causes growth and expansion. Negative feedback causes control and stability.

Classical control theory dictates stability with no changes [10]. This is required for physical systems. However, it is not desirable for economic systems. To have growth, there must be positive feedback. It is critical that feedback from government, education, and industry be kept positive.

A filter can have multiple effects on the signal. First, the filter may impact the width of the information. This chops off extraneous noise frequencies and restricts the time response to provide usable value.

Second, the filter may impact the height of the signal. The resistance or opposition will attenuate the level and restrict the maximum value. This is a passive process. However, an active filter with gain will amplify the maximum value.

Third, the filter may influence the rate of change either as a velocity or a summation. Fig. 6 illustrates filter action.

In reality, the continued growth in technology will be curtailed. Often information is not effectively or accurately transferred. A backlog will result from applications not being developed to the full capability. Invariably history is not interpreted correctly.

In addition, government and social organization tries to regulate to protect an existing interest. As a result, the growth will be stymied.

Table 2. Engineers' Typical Time Allocation, by Experience

Years	Tech	Project
5	15%	85%
10	5%	95%
30	2%	98%

Limits on Technology

We propose a relationship for the limits on technology.

Level of technology is limited when cost of technology equals or exceeds perceived value.

Perceived value (PV) is equal to *functional* value (FV) minus the change (*d*) in *manufacture* cost per unit (MC), *business* cost of management per unit (BC), and the *distribution* cost per unit (DC) multiplied by the *number* of units (N).

$$PV = FV - d\,(MC + BC + DC) * N$$

A technology gap (TG) exists when technology can be implemented at a cost (TC) lower than the benefit, but it has not been realized.

$$TC = PV + TG$$

This relationship is the element in the feedback loop on technology.

With these constraints, what is the most effective way to raise the limits on technology costs?

Often the discerned functional value is the item that must be clarified before broader implementation. If functional value is thought to be greater, then perceived value increases and technology gap decreases. Functional value can be raised by items such as increased reliability and added features. Another consideration for increasing value is by education, whether technically or through appropriate advertising. The whole quality issue comes wrapped in the functional value.

The other option for improving perceived value is to decrease the product costs. These include total manufacturing, business, and distribution components.

Shift of Costs

The efficiency of technology has lowered costs and increased manufacturing performance to the point that the physical costs are a minor component of delivered cost of products. A good-quality 15" color television in the 1960s cost more than $300. A unit with better performance and more features now costs about one-half that amount in current dollars. It is even less expensive when corrected for inflation. Since inflation has increased by a factor greater than four, the net effect is the electronics are an order of magnitude less expensive.

More significant is where the costs are incurred. The big trade-off is design and manufacturing versus distribution to the market. The historical relationship is illustrated in Table 1. Each of the dates represent a time block of approximately five years.

The numbers are broad-based, high-volume units. Even other equipment is impacted to a similar extent. Because of the preponderance of technology, more features are often added to older items at no incremental user cost. In essence, the user is getting more and better equipment, but the cost of manufacturing has not increased.

Since costs of manufacturing and development are relatively insignificant in the later equipment, improvements in that area will provide little product cost relief. The most substantial benefits are realized in using technology to reduce distribution.

The major U.S. retailer has accomplished this by minimizing the number of layers between the manufacturer and the store [11, 12] . Immediate communications are maintained with suppliers by computer links. Improved technology in material handling minimizes stocking. In addition, all utilities and heating, ventilation, and air conditioning for every store throughout the country are controlled from one central location at the headquarters in Arkansas.

A major package express company has accomplished this with a new airline for packages. All items from the central U.S. go to Memphis, Tenn. There a tremendous sorting system reassigns the package to an exit route. The process is totally automated using programmable logic controllers. All packages are reloaded on aircraft for distribution. A package shipped to an adjacent community will still be routed to the central sorting mall and perhaps returned on the same aircraft. One major difference is the destination of the bag containing the package.

Another major international distributor is using computer networks for links directly with the end consumers. The products are ordered via a computer and modem. An advanced system is being implemented with direct, digital, two-way satellite communication that allows individual product demonstration. The requested item is shipped from a "just-in-time" warehouse to the customer via a parcel express company. With products from more than 450 of the Fortune 500 companies, as well as thousands of other smaller vendors, listed in their system, the distributor has pushed the application of advanced technology to distribution [5, 13].

The major new companies and wealth created in the last two decades have come from organizations that handle information and distribution. None of these are traditional heavy industry manufacturers.

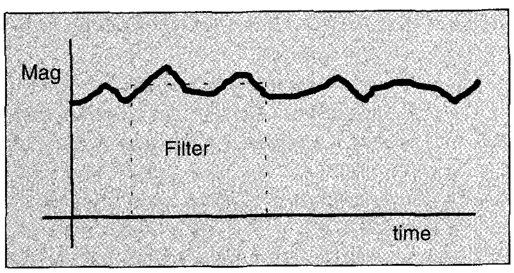
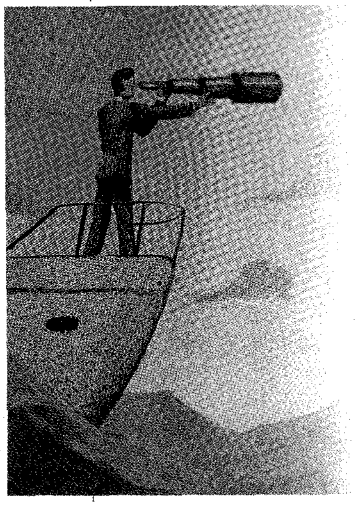


Fig. 6. Filter action.



No longer will lifetime employment with one concern be an option. Furthermore, a lifetime of doing the same thing is no longer possible.

People Placement

Change is never pleasant. Although someone may consider himself progressive, change creates a difficult situation. Changes provide two choices. Most simply try to *cope*. The alternative is to compare new *options*.

The restructuring of corporations has resulted in many job losses. These are unpleasant for the individuals. Nevertheless, there has not been a substantial change in the overall unemployment figures. What became of those released from the corporate culture?

The *skilled "blue collar"* troops moved into other jobs. Although the benefit structure may have changed somewhat, the lifestyle often was not dramatically impacted. There remains a gap and need for additional skilled workers, perhaps in a different enterprise.

Unskilled labor encounters a more difficult situation. Since they originally had little performance-based experience, they have no basis for learning a new function or job. The demand for unskilled capabilities is diminishing. The only option is often personal service-based. Unless individual motivation and moral responsibility are realized, those in this category are relegated to a greater and growing separation from the rest of society.

The *managers* are more seriously rearranged. There is no longer a need for numerous middle managers. Similar to those without a marketable skill, these often take a lifestyle change. Those that learn and transition to become independent technology managers flourish.

The *technologists*, such as engineers, saw a different environment. Often they left the company but were hired back as consultants. This outsourcing of technical requirements is a buzzword of organizationally flat corporations. Others used their skills to begin new enterprises. Typically these practitioners desire a secure environment where they can do their thing without involvement in extraneous activities. However, many find themselves without a "traditionally secure" job, but with an increased disposable income and more independence.

The release of technology and information has caused phenomenal growth in those quarters willing to evaluate the risks and take advantage of the paradigm shift. It appears that the alchemy theory of economics is at least partially validated.

Two days' articles in a national newspaper give a clue of the new paradigm. "More Homes Get More than One Phone Number" indicates the expansion of information [14]. "Energizing the 'Net" gives statistics about the growth of the number of sites on the World Wide Web of the Internet [15]. Fig. 7 illustrates the explosive growth in the early days of general application.

Another article on the same page [16] provides further data: "Software Firms Tap Growth Potential." "Cyberspace Snares Entire Town in a Net of Business Opportunity" relates how the town-wide computer network in small, rural Lusk, Wyo., has expanded global activity [17].

All these articles relate to one thing. It is not computers. Rather, it is the release and expansion of information to more people. Technology is no longer in the exclusive domain of managers.

Future for Technologists

Undoubtedly, the industrial revolution begun more than 100 ago has advanced past the roll-off phase. As a result, the major industrial corporations are experiencing a deterioration of the empire [18]. No longer will lifetime employment with one concern be an option. Furthermore, a lifetime of doing the same thing is no longer possible.

However, that is the good news. Although change is seldom pleasant, the employed will have to adjust to a different role. The change in employment resulting from technology is good for society. When technology replaces a person, it provides more money to the owner of the technology. In turn, more money is available to spend on other

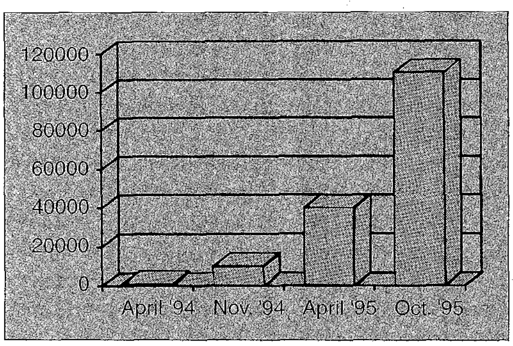


Fig. 7. Internet connections.

non-necessary items. Subsequently, new enterprises develop to support the new lifestyle.

A few years ago, it took five years from conception to development of a viable, marketable product. Now, the life cycle of the technology is less than five years. This imposes unusual pressure to remain current in the skills. But the reality is that advanced skills are less necessary than an idea of how to use or apply an inexpensive mass-produced component.

With these dynamics, the more successful entrepreneurs may have several separate businesses simultaneously. This provides a broad base to cover alternative impacts of technology changes. One may flourish while the others are in incubation.

The potential for technologists, technology managers, and entrepreneurs is phenomenal. The information transfer makes it possible for those with a dream and a drive to reach fascinating new altitudes. Each can develop his own business where he wants. The information can be transferred anywhere in the world within seconds [19].

How does anyone recognize an opportunity? Three steps provide the key.

1. First, look for a wide technology gap between available technology and that implemented by the customer.

2. Second, fill the gap with a technology ready to be implemented. Make the technology as transparent to the user as possible.

3. Third, select a technology solution that can be a building block for other things. For example, a cartridge recorder requires cartridges and programming for the medium.

The greatest asset exists where there is the widest technology gap. However, the gap must result from increasing technology not from a stagnant or decaying society.

One new criterion is imposed on the entrepreneur unlike anything in the past. Although he is independent and may be physically isolated, he is completely dependent on a network. Without others who are aware of his skill, he has no market, nor anyone to market for him.

The network becomes the order of the day in the information society. Engineers will exchange skills with practitioners of other disciplines.

Furthermore, the technologist will become a marketer. The engineer must move from a focus only on technology to a focus on people. Otherwise, there will be no market for his talent.

Although change is seldom comfortable, it provides the opportunity for personal and professional development. The future is bright. The options are exciting.

Future for Education

Education must undergo a substantial change. The requirements are unusual.

One major concern is analysis of technology. Technology is available with little investment and training. However, this does not necessarily translate into an acquisition of knowledge. Reams of data can be generated and large reports published. However, the reporter often cannot review the results and determine whether they are valid. Even in valid information, he cannot ascertain problem areas.

Without an understanding of the underlying basic principle, grievous errors can be created. In the industrial era, technical experts were available. In this era, the artificial expert is considered the final authority. Skill is still required to validate the artificial intelligence. Education must focus on the fundamental principles without total dependence on the technology.

A second major concern is relationship with people. A recent investigation revealed the time allocated to tasks for engineers at various years into their careers (see Table 2). *Tech* is used to represent time spent on calculations and tasks relative to technology. *Project* represents time spent on project management, coordination, and people interaction.

Traditional collegiate education spends most of its effort on technical theory. Although it is a requirement to obtain a position, it is not the major factor needed to perform. Furthermore, technology changes come faster than the educator can respond. At best, the educator can hope to teach a couple of basics and how to critically investigate alternatives.

A separation was not made between the other project skills and the people skills. However, discussions indicated that the senior individuals spent more than 50% of their time dealing directly with *interpersonal* relationships.

This is a shock to the technocrat. As a group, individuals tend to enter the field because *they would rather deal with things than with people.* After all, things are predictable according to a formula. People are not.

At first blush, one would expect the information age to be the haven for hiding of the technocrat. The opposite is true. To be effective in this era, everyone must operate within a network of people. That requires very substantial people skills.

Another change necessary in the educational mix is the necessity for continuing education. Because of the dynamics, recurrency training and instruction in new developments and rethinking old problems become a routine part of the work picture. Seminars, short courses, and professional society conferences become the norm and are a crucial component. These even are requirements for many professional registrations [20, 21, 22].

The effective individual has technical skills. These are applied to a distribution network. He has economic and financial skills. These are applied to his wealth. He has people skills. These are applied to his growth network. The skills in each area must be enhanced by continual training.

Future of Organizations

The effective organization in the information age has a very simplistic, distributed structure. Each segment is independently responsible for maintaining state-of-the-art performance.

1. Technology comes from entrepreneurs with a particular niche and creativity. They will constantly be changing their focus to address advances.

2. Manufacturing is provided by efficient concerns that service several vendors. Efficiency is determined by time and cost responsiveness.

3. Marketing is done by entrepreneurs with a particular niche or clientele.

4. Distribution is accomplished by technology managers who develop efficient dispersal networks for products and information.

Each of the entities must develop a support network. Without a large, traditional organization, interdependence will determine the success.

Will major companies exist? Certainly, the group that best manages an emerging technology will grow explosively [23]. However, these will not make long-term commitments to a technology or an employee.

A major paradigm shift has occurred in information, technology, and organizations. The acceleration of information and speed of application has caused technology to expand at a near-exponential rate. The limit on technology is the perceived cost.

A gap exists between technology advance and that implemented. Most opportunities exist in applying available technology to bridge the gap. The implementation should consider future spin-off and support systems as additional sources of revenue.

Because of the rapid development, the inertia of traditional large organizations tend to make them unresponsive. Hence the organization must be pared to a flat structure. The most effective system is one with a network of independent manufacturers, marketers, and transporters. Effective application of technology in each sector allows tremendous cost benefits.

Technologists typically enter the arena because of an intense interest in things and how they work. Traditional education focuses primarily on these items. To survive in the rapidly changing environment brought on by their own success, technologists must develop exceptional communications and people skills.

Education systems can complement the advances by focusing on basic systems and development of project and people skills. The other side of the training must include continuing education.

The key is simply a matter of control. The stability of a negative feedback system has been traded for the explosive growth of a positive feedback.

Acknowledgments

Many people contribute to the development of unconventional ideas. Richard Scott, M.D., motivated us to expanded investigation. Chet Sandberg, IEEE Fellow, and Kaveh Ashenayi, bounced around the technical solutions. Robert Cotton, John Kassebaum, John Propst, and Gene Fagan, IEEE Fellow, reviewed concepts and principles.

References

[1] Paul Zane Pilzer, *Unlimited Wealth, The Theory of Economic Alchemy*, Crown Publishers, New York, 1990.

[2] Newt Gingrich, *To Renew America*, Harper Collins Publishers, New York, 1995.

[3] Philip Kotler, *Marketing Management*, 3rd ed., Prentice-Hall, Englewood Cliffs, NJ, 1976.

[4] "Riding High: The Productivity Bonanza," *Business Week*, October 9, 1995.

[5] Bill Quain, *Reclaiming The American Dream*, 2nd ed., Wales Publishing, New Wales, PA, 1994.

[6] Gordon J. Van Wylen, *Thermodynamics*, John Wiley, New York, 1964.

[7] John Maynard Keynes, *The General Theory of Employment, Interest, and Money*, HBJ Publishers, San Diego, 1964.

[8] Paul A. Samuelson and William D. Nordhaus, *Economics*, 12th ed., McGraw Hill, New York, 1985.

[9] John Kenneth Gailbraith, *The Affluent Society*, 4th ed., New American Library, New York, 1958.

[10] James Rowland, *Linear Control Systems*, John Wiley, New York, 1986.

[11] Vance H. Teimble, *Sam Walton: The Inside Story of America's Richest Man*, Penguin Books, New York, 1990.

[12] *The Wall Street Journal*, "Wal-Mart Set to Eliminate Reps, Brokers," Dec. 2, 1991.

[13] John Naisbitt, *Megatrends*, 1982.

[14] David J. Lynch, "More Homes Get More Than One Phone Number," *USA TODAY*, Oct. 30, 1995, p. B1.

[15] "Energizing the 'Net," *USA TODAY*, Oct. 30, 1995, p. B1.

[16] James Kim, "Software Firms Tap Growth Potential," *USA TODAY*, Oct. 30, 1995, p. B1.

[17] Paul Hoversten, "Cyberspace Snares Entire Town in a Net of Business Opportunity," *USA TODAY*, Nov. 1, 1995, p. A10.

[18] Bob Vandewater, "Greater Utility Competition Expected," *The Daily Oklahoman*, Oct. 18, 1995, p. 15.

[19] Frank J. Denniston and Peter K. Runge, "The Glass Necklace," *IEEE Spectrum*, vol. 32, no. 10, October 1995, p. 24.

[20] M. Dayne Aldridge and Paul M. Swamidass, "Where We're Headed: IAS Membership Survey Results," *IEEE Industry Applications*, IEEE, Piscataway, N.J., vol. 1, no. 5, September/October 1995.

[21] Linda Geppert, "Educating the Renaissance Engineer," *IEEE Spectrum*, vol. 32, no. 9, September 1995, p. 39.

[22] Dennis Kelly, "Adults Say Lifelong Learning Critical to Job Success," *USA TODAY*, Sept. 13, 1995, p. D7.

[23] Dave Dooling, "Big, Bold, and Expensive," *IEEE Spectrum*, vol. 32, no. 10, October 1995.