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The Computerized Design Firm

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This paper is not just about the future of computerized design practice. It is about what to do today in contemplation of tomorrow-the issues of computer-centered practice and the courses of action open to us can be discerned by the careful observer.

The realities of computerized design practice are different from the issues on which design education still fixes its attention. To educators, the present paper recommends further clinical research on computerized design firms and suggests that case studies on the matter he developed and utilized as teaching material.

Research conducted by the author of this paper indicates that a new form of design firm is emerging-the computerized design firm-totally supported and augmented by the new information technology.

The present paper proceeds by introducing an abridged case study of an actual totally electronic, computerized design practice.

Then, the paper concentrates on modelling the computerized design firm as an intelligent system, indicating non-trivial changes in its structure and strategy brought about by the introduction of the new information technology into its operations-among other considerations, different strategies and diverse conceptions of management and workgroup roles are highlighted.

In particular, this paper points out that these structural and strategic changes reflect back on the technology of information with pressures to redirect present emphasis on the individual designer, working alone in an isolated workstation, to a more realistic conception of the designer as a member of an electronic workgroup.

Finally, the paper underlines that this non-trivial conception demands that new hardware and software be developed to meet the needs of the electronic workgroup-which raises issues of human-machine interface.

Further, it raises the key issues of how to represent and expose knowledge to users in intelligent information-sharing systems, designed to include not only good user interfaces for supporting problem-solving activities of individuals, but also good organizational interfaces for supporting the problem-solving activities of groups.
The paper closes by charting promising directions for further research and with a few remarks about the computerized design firm's (near) future.

Introduction

The new information technology is shaping the structure and strategy of design firms, and not only their products. Further, the new information technology-computers and communications-is affecting competition within crucial industries, among them the metal-working and the building industries, and within the professional services. Thus, it is affecting the essence of strategy formulation for design firms. Concomitantly, it is changing the entire process by which these firms create their products and services, while reshaping the product itself-the entire package of goods, services, and information which they provide to create value for their clients. A new form of design firm is emerging-the computerized design firm-totally supported and augmented by the new information technology.

To set a background to the discussion of these key issues, the introductory section of this paper summarizes non-trivial changes in the structure and strategy of design firms brought about by the incorporation of the new information technology into their operations. In particular, this section delineates diverse conceptions of management and workgroups roles, and different strategies open to a computerized design practice.

The computerized design firm is a structurally flexible, knowledge-based organization where the emphasis is placed on information creation, and work is performed by computerized experts brought together electronically in spontaneous workgroups. These workgroups' assignments, composition, and leadership are decided on a case-by-case, project-by-project basis.

In today's demanding business environment the new information technology gives design firms a competitive advantage. This is done by increasing productivity, thereby facilitating cost reduction strategies. Further, it is done by increasing the breadth of their value-creating activities, enabling diversification strategies to take place, and by otherwise supporting differentiation strategies leading to a premium price.

Certainly, and most importantly, the computerized design firm poses its own special management problems and opportunities. It presents problems and

opportunities such as creating a vision that can unify an organization of highly trained computerized experts, willing to discipline themselves while enjoying a considerable degree of interpretative freedom; motivating and rewarding them; devising a management structure that works well with task forces; and ensuring the supply, preparation, and testing of management well acquainted with the process of technological development-to name lust a few.

Solving these kinds of structural problems, along with those pertaining to strategy formulation under the impact of the new information technology, seems to be the management challenge for the rest of the century. Blaming the technology is of no use; it is management that makes the difference -and what is to be managed are intellectual assets, not just equipment.

In this context, success comes to those firms and those managers able to incorporate strategically the power of the new information technology:

1. To augment the capacity of the human mind to deal with demanding knowledge work.
2. To create information, and to process effectively large volumes of information.
3. To achieve continuous improvements through organizational learning and experimentation.

In managing the computerized design firm we cannot ignore the social implications of our technical progress. The optimum design for either a tool system or a human system is dependent on the match it must make with the other. The high degree of mutual dependence implies that a balanced evolution of both is necessary.

We are compelled to learn new roles, change attitudes, and adopt different methods because of the technological development we, ourselves, introduced. Organizational structures need to evolve concomitant with the new information technology to achieve mutual impact. Over the last forty years, the computer industry changed us; of late, we are changing it.

The work of implementing the new information technology is uncovering a distinctive set of opportunities, problems, dilemmas, and challenges-not the least, the task of creating intelligent organizations, flexible enough to adjust, adapt, and learn continuously.

To this end, those managers who introduce innovations of this technological kind into design firms should engage knowledgeably in a process of technological development, and be able to function as intelligent change agents in the concomitant organizational self-renewal process.

The Computerized Design Firm Examined: A Case Study
Current computer-aided design education is largely lacking in the study of these key issues. Again, these are not trivial changes, and we ignore them at our peril.

To further research in this context, this paper concentrates now on the computerized design firm as the natural place to bring together the task, the mind, and the machine, to analyze their synergy and to examine how this kind of technological development may be understood, enhanced and managed. Special attention is being given to:

1. The inherent synergies between people and computers-between the human system and the tool system-and how these synergies have been exploited in relation to the value activities.
2. The kind of learning that took place, and how the firm evolved as a total intelligent system with capacity for learning and for displaying other forms of adaptive behavior.

Unlike cognitive experiments in the controlled environment of a laboratory, this paper advocates that the research methods utilized to examine computerized professional design practice be of a clinical nature, given the important aspects of complexity, contingencies, and the fundamental organizational learning involved.

Needless to say, more clinical studies of this kind are needed to help to address the fundamental question of how the new information technology can best be made useful in the development and application of technological know-how.

These concepts are of particular importance. Moreover, this paper proposes to model the computerized design firm as an intelligent system, broadly defined as a dynamic organization with capacity for learning and for exploiting the synergy between three sets of elements-formal (hardware and software), human (mind, workgroups), and activities (value operations, tasks, sub-tasks). It also suggests recognition of this system as a distinct class for purposes of management.

Along these lines and under a grant from Harvard University, the author of this paper has conducted research on professional design practice and, largely as a by-product, has developed case studies of computerized design firms to support the much needed class discussion of these issues. Consequently, these case studies were utilized as teaching material in both graduate and professional development courses of instruction at Harvard.

These case studies combine systems, behavioral and decision-making approaches to the study of computerized design firms, and they are categorized

as either "Problem/Opportunity-Identifying Cases' or, more frequently, "Ground-Breaking Cases." The later category engages everyone involved in its analysis as an exploratory mission, covering new ground.

The terrain to be covered is certainly new, because the business situations the computerized design firms face are largely new, and the underlying opportunities and problems are frequently unclear.

Relevant concepts, teaching objectives, and approaches to the design and business problems or opportunities posed by the new situation, have not yet been clearly identified. Consequently, everyone involved in the analysis of these case studies must be capable of extending-not just applying-existing, tangentially-related theory and practices in order to build upon existing knowledge. Simultaneously, they must be ready to structure and organize the cases' data in new ways bearing little resemblance to existing concepts.

In order to highlight some of these issues, an abridged case study of an actual small computerized design firm follows. Shaped as an interview with the firm's founder and principal, this case study touches on issues of a technological, structural, and strategic nature. It reflects the point-of-view of the manager in charge of introducing new information technology and engaging the firm in a process of technological development.

This case is intended to convey opportunities, problems, and managerial dilemmas as perceived by the firm's management rather than to illustrate either effective or ineffective handling of an administrative situation.

Case Study: The Computerized Design Firm in Action

The computerized design firm operates quietly through the snowy winter morning. Its mezzanine, perceived as a glass cube gliding over the calm glow of the workstation's monitors below, is occupied by the electronic conference room-networked megascreen and video projector, computers and communications equipment, infrared lighting controls and electronic remote-control shutters.

There, the interviewer, sitting comfortably in a black leather reclining armchair, is located in the intended vantage point that allows one to observe the firm in action and to be observed-at once he realizes this firm is conceived as a single workspace composed of computers and communications equipment, people, and activities relating mind, space and time. A single, well- proportioned workspace; a node in a wide electronic network.

A place in which all the familiar sights of the professional practice of design are conspicuously absent. No drafting tables, no triangles, no pencils, no cardboard models, no desk lamps. . . all the workspace has ambient and task lighting with electronic preset dimming plus infra-red controls tuned to provide at all times the right kind of background to the monitors in the spine of workstations. In the center of the workspace and in full view from the conference room above, this spine of networked

workstations truly performs as an electronic round table-no partitions separate the designers from one another... or from the world.

The feeling of the place is that of a well-run operation-serene, smooth, crisp, precise, efficient and yet relaxed and informally youthful. The interviewer smiles and turns on his tape recorder knowing that the firm's founder has strong convictions with clear-cut opinions, and is about to share them.

"Our 12-person workgroup represents an example of a totally electronic, computerized design practice increasing its value as a small business through commitment to state-of-the-art information technology-from network computing linking us with clients, consultants and manufacturers, to in-house developed software for solid modelling and animation, to expert and decision support systems, to multimedia..

"We started thinking about computerization about 1980 while doing several projects for manufacturers of computer equipment. This work gave us the opportunity to see up close the advantages and limitations of the technology. It also took us over the threshold by contractual obligation, requiring of us to go ahead and begin computerizing our operations. So, we purchased the first drafting software to run on two personal computers-fit to a very small firm, like ours was at the time."

"Gradually we upgraded the hardware and acquired more applications programs. By 1984, workstation prices had dropped some tenfold, enough to arouse my interest in network configuration rather than stand-alone operations. But there is more to it than hardware and hardware cost. Early on I realized that we should be going into the computerization effort full force if we were to make it work for us properly."

"So, first, we acquired two mid-range workstations at a cost of approximately $18,000, which gave us not only networking capabilities but also multi-tasking plus a powerful operating system that communicates with the personal computers' operating system as well; the new equipment allowed us to port drawings between old and new equipment in order to preserve the investment in earlier hardware and software packages."

"And, second, as soon as we had a bunch of information technology equipment in here, I realized that we had to have a way to keep this equipment alive at all times. So I hired our first computer engineer; our firm was about seven people at the time, and for a firm that size to add a computer engineer was unheard of. But we realized very early on that we were going to have staff that was really outside the traditional roles for a design firm; so, we added first a computer engineer and, later on, an electrical engineer and computer programmer to our full time staff-that insures that the system is up and running all the time. Because we are a truly electronic firm. You pull the plug on us and that is it-we are dead."

"But, equally important, I also realized that there were certain necessary adjustments to be made to my traditional image of a design firm and how it is supposed to operate. And this behavioral change becomes very significant over the course of time. Now, I did not have this grand vision that I embarked on; I got burned and adjusted the course accordingly, but I was not afraid to stray off the old path."

"So, as we grew successfully with our design practice, I understood that rather than go and rent more workspace and hire more designers, computers would allow me to keep the talented people of the firm augmented by a powerful set of tools-we would not expand or contract the staff, just augment our existing knowledge workers. So, we gave computers to all our designers, and still call them what they are-design professionals with powerful tools."

"We always thought of our firm as being horizontally integrated; now, with computers it is absolutely horizontal-there is no need for most of the levels of the hierarchy-the designers are actually in control of all the information. Everyone has access to the databases; they are not only responsible for them but, for example, they are capable of conceptualizing the design and then of executing it in 3-D, animation, etc., and still then of conducting a very articulate networked discussion with the client, consultants or manufacturers."

"In fact, in our firm, work is being performed by computerized experts with a generalist outlook, brought together electronically in spontaneous workgroups-it really depends on how the project or problem gets defined to decide who is going to be the leader, who is going to be in charge of what value activity, and the like. And it changes not only from one project to the next but sometimes within the same project. . . It depends."

"Our firm is not a traditional, command-and-control organization mostly because of the way we are organized around the information technology. We are a series of task forces... workgroups in which the person who talks to the client is the same "project manager" that later talks to the foreman or to the consultants. As a result, we are more like the organization of a law firm-people manage their own projects; you have your own cases, you have co-workers, and you have para-legals who are almost your equals. And you have secretaries and other support staff. All muscle and no fat... A lean, adaptable workgroup."

"And the interesting thing is that we actually have the capability to produce the work of fifty people using manual techniques-among other things this means that when we get very busy we do not have to hire help, and when the business is slow we are still only twelve people."

'Yet, a problem in our firm is inter-personal communication, people talking to other people-informal contact and the like does not come easy. Our people are the firm's true assets... and they get to be so good in computer-aided design that eventually we lose some of them to larger firms with better money. In fact, my lawyers are exploring right now ways to retain them-golden handcuffs" they are called. But their leaving does not have anything to do with fear of computers, quite the contrary. Although we have had cases like that 24-year-old guy who graduated with honors from a prestigious design school and who, when shown a computer, froze. I find that shocking, and this person realized that he had just spent a fortune for an education that was, in many respects, irrelevant."

"In our firm we mean to have a progressive attitude about our business, our professional practice. Let me give you a couple of examples. We just have held conversations with a very large investment bank. In fact, we are interesting them in the notion of strategic control of their real estate division by consolidating in one system all the financial information, the design information, the facilities management information, and so on. We see our professional service to them as suppliers of information-integration technology-which is beyond what people think of traditional design firms' doing. Another example: Once I realized we had considerable in-house expertise on information technology and that this technology is very expensive, it became clear to me that the best way to finance our own technological development was to turn around and sell it."

"Since I was afraid neither of computers nor to stray off the traditional path, I became a hardware and software dealer. For us, this occupation has the added

advantage of remaining on-line with the manufacturers for first-hand information about new equipment and software.. So, in 1988, our firm elicited considerable response by offering turnkey CAD solutions to other design firms. I even have engaged in completely non-traditional professional behavior by taking a booth on the floor of a designers' convention, along with all the other vendors that sell equipment to designers.

"And, yes, I smiled and shook hands as any good old used-car salesman would do. Well, I also quickly found out that most designers are very confused about information technology, how to get it, how to use it, etc... and I soon realized that if we were going to sell this technology to designers we would have to run some kind of education program-an expensive proposition. Nowadays, we are doing more business in this area with large corporations; they tend to have engineers on their staff-and the engineers understand what we are talking about."

"Incidentally, in addition to developing our own CAD sales division and expanding into facilities management services and the like, the firm has also successfully integrated multimedia techniques into its design and presentation strategies-as you can see there are no drafting tables or cardboard models in our office. With our video equipment, 2-D and 3-D and walk-through elements can be developed into real-time, unedited computer presentations for projection via video projector here, in the conference room. For speedy presentations we prepare computer runs. Our firm uses video for recording site details. Loaded into the computer, individual frames may be worked on and used for meetings with clients and so on."

"Finally, I must say that we have become a curious commodity. We have such a spare capacity. I have created a monster for myself-this hungry machine. Now, being a group of twelve persons that produces like a firm fifty strong, we are too big to be small and too small to be big. The perception of us, as a design firm, is becoming a problem because we do not fit into any sort of traditional category. In fact, we are a new category-the totally computerized design firm. Clients that are out there shopping for big firms with, let's say, fifty people and ten offices around the country, do not look at us because they think we cannot compete-but we can, to a point, and do compete well."

"So, I have been advised by my lawyers to seek a merger, which will further capitalize on the firm's resources. But there is a price to be paid by following that path, too-loss of our identity as independent designers."

In departing, the interviewer finds himself taking mental notes of a set of questions raised by his visit to this computerized design firm, some of which will be now posed to the readers of this case. What kind of firm is this today? What set of decisions made it this way? What is your reaction to the approach and ideas of the firm's founder and principal on the matter? What do you think about the way the new information technology was decided upon, selected, introduced and implemented in this firm? How would you say this firm is to develop in terms of its organizational structure? If you were a member in a lean, adaptable workgroup at this firm, what would you think the next strategic move should be in order to preserve and augment the firm's competitive edge?

The Computerized Design Firm as an Intelligent System

This case study, representing a fairly typical computerized design firm, touches upon several important issues of technology, structure, and strategy. What

 follows is an attempt to highlight some of those issues, based on modelling the design firm as an intelligent system.

Modelled as an intelligent system, it can and does simultaneously hold both the conception of technology as science as a formal system based on procedures, logic and reasoning-and that of technology as expertise-as an informal or human system based on experience, judgement, intuition and skill. Thus, the computerized design firm is functional in exploiting the synergy of science and expertise, in ways that allow for a sequential move to a higher stage of knowledge, which is at the essence of an intelligent system.

This leads us to focus on two contrasting philosophies of system development. So far, the developers of computer systems for design firms have been drawn heavily from the ranks of computer science rather than from the design domain, and they naturally feel that if the narrowly defined computer science issues have been dealt with, the system as a whole is essentially done. At this stage, the initial developers typically withdraw from the system and move on to something else, dismissing lack of practical application due to failure of the end user.

The cognitive and domain-specific issues that concern these end users, however, are of legitimate and integral concern for the design firm system as a whole-the formal elements may or may not be adequate in terms of true complements to the other elements, that is people and value activities. For example, the design and development of procedures, and of training programs for people, are almost always ignored until the formal element is finished and transferred.

This is very different from the philosophy of system development suggested in this paper-developing a computerized design firm from its conception as a total intelligent system, broadly defined. Such a philosophy advocates that all elements, from the formal, to the human, to the value activities, should be set up in parallel to fit together, reinforce each other's strength and complement each other's weaknesses. As in the case studied, development of such a system should be directed by experts in the design domain acquainted with the formal system-and enough of the original development team should remain with the system to enable it to evolve as the design domain, itself, evolves.

The case study further indicates that a computerized design firm conceived and developed as a total intelligent system also exploits effectively the synergy between human cognitive operations, formal signal processing and value activities, by emphasizing and relating both the spatial and electronic architecture of the workspace.

As reflected in the case study, the computerized design firms that have mastered the new information technology struggle to recombine effort and

intelligence internally-even to the point to dislike dependence on outside vendors or organizations for expertise. While respecting and utilizing the capabilities of others, they want to develop their own formal elements, value activities and people. Great effort goes into recruiting, training, and retaining highly skilled computerized experts.

Most important is the fact that computerized design firms must be managed differently; their novelty and complexity coupled with the very dynamic situations for which they must be designed, do make managing them more difficult. However, a considerable amount can be learned from the management of earlier systems, such as the one represented in this case.

Radical changes in technology come along only once every generation or so; when one appears there is little expertise that managers can draw on. So, the most common mistake that design firms make is to treat their newly introduced information technology simply as physical assets. Yes, they are buying the hardware of programmable automatization-but are using it very poorly. In many cases the firm ends up performing worse than with the conventional technology.

Again, the technology itself is not to blame; it is management with its conception of the technology that makes the difference. Very soon, management discovers that programmable automatization demands a more interactive decision-making process and a tight integration among the firm's functions. It also discovers that the new information technology demands attention to non-financial long-term considerations and, in particular, to its impact on the firm's intellectual assets.

The new information technology not only creates the conditions for programmable automatization of conventional manual operations to take place. More important, it also creates information-and if this information is made available to each workstation, and if knowledge workers are trained and encouraged to use it, then the new hardware and software becomes a powerful mean for augmenting and enhancing knowledge.

This bears a direct connection to our observation that the computerized design firm is made up of multidisciplinary workgroups with powerful computation and communications tools. Such workgroups-intelligent organizations in themselves-are spontaneous and ephemeral structures, formed when projects surface and disbanded when they are concluded; in their network computing they include clients, consultants, manufacturers and other elements from outside the firm. Exploiting the information potential of these dynamic coalitions becomes a new managerial challenge-the managers should push at the margins of their expertise striving to shape dynamic learning coalitions.

In fact, as seen in the case study, most principals and managers are having difficulty reaping the advantages of the new information technology and

continue behaving "as before' its introduction and deployment. With this new technology, though, "as before" can mean disaster. If principals and managers fail to understand and prepare for the revolutionary capabilities of the technology, it will become as much a liability as an asset-and considerably more expensive.

This new technology provides added freedom, but it also makes possible more ways to succeed or to fail. Therefore, it requires new skills on the part of managers-an integrative imagination, a passion for detail-and a quantum jump in a design organization's precision and integration.

To maximize the capabilities of the firm, managers must learn to think more as computer programmers-people who break down production into a sequence of microsteps-and at the same time to perform as cross-disciplinary generalists, with a true designer's skill for creation and integration.

They must also learn to direct highly educated knowledge workers performing in a small, tightly-knit workgroup; and they must facilitate organizational learning, harmonizing the effort of computerized experts willing to discipline themselves.

Traditional managerial attitudes, manifested in hierarchical decision-making, piecemeal changes, and a "bottom-line" mentality are incompatible with the requirements and unique capabilities of the new technology. Until these attitudes change, design firms will be slow to adopt and change the new technology.

For both small start-ups and well established design firms, such attitudes cannot change at a basic level without meaning changes in capital budgeting, performance measurement procedures, and human resource management. At the next level, change means new organizational structures that can accommodate more interactive and cooperative working relationships.

At a next level still, it means that externally the firm relates to a constellation of other computerized organizations, tending to constitute a tightly integrated network, structurally flat, self-managing, and highly responsive to evolving market needs. Services or products can be elaborated efficiently, in relative small quantities, and to order.

Some principals and managers of design firms have argued that because the new information technologies are evolving so rapidly, they should hold off investing in them until the rate of technological progress slows down. Perhaps what is behind this kind of rationalization is not the fear of technological instability as much as the fear of these technologies' tendencies to destabilize the chain of command. The inter-functionality engendered by the new technology does mean more informal cooperation at the operating levels of the organization.

This kind of spontaneous team work is unnatural behavior for design firms whose structures, staffing policies, and performance measures operate according to the traditional command-and-control mentality, where relations among people are only conceived as vertical in nature, and information technology tends to be perceived as physical assets.

Moreover, to reduce the risks that come with change, design firms often seek piecemeal improvements of their operations via 'islands of automatization"-informatization is not considered. Consequently, these firms are often upgraded technologically through a series of independent projects, each justifiable in its own dollar terms until, eventually, a way is found to link those individual islands into a profitable whole-the desired returns are expected to materialize only when all these technological advances are in place. But, in fact, a design firm does not learn to exploit the full potential of advanced hardware and software unless and until it is organized to do sounless and until changes in its structure and strategy occur.

Unfortunately, most design firms regard their choice of information technology hardware and software as non-strategic investments, even though it will change the company's cost structure, improve its ability to introduce new products, and affect the way it interacts with its clients, consultants, and manufacturers, as has been exemplified in the case study.

Understanding these basic strategy issues is paramount to understanding the computerized design firm's actions. Consequently, the rest of this section will focus on issues of strategy for computerized design practice.

For industry, design is a strategic activity-it influences everything from the efficiency of manufacturing to the flexibility of sales strategies. And it is hard to underestimate the significance of the new information technology for strategic product design.

Now this technology is transforming not only the nature of design products-and the design process itself-but more fundamentally, it is transforming the nature of competition within industries crucial to national economic performance, such as the metal-working industry which produces from coffee grinders to jet-fighter engines; the building industry; and the professional services.

The new information technology is thus affecting the essence of strategy formulation for design firms in three vital ways:

1. It changes industry structure and, in so doing, alters the rules of competition.
2. It creates competitive advantage by giving firms new ways to out-perform their rivals.
3. It spawns entirely new business, often from within a firm's existing operations.

So, every design firm has no choice but to understand the structural effects and strategic implications of the new information technology, and how it can create substantial and sustainable competitive advantage for even the smallest of firms.

In fact, a design firm is profitable if the value it creates exceeds the cost of performing the value-creating activities. Therefore, to gain competitive advantage over its rivals, a firm must either perform these value-creating activities at a lower cost or perform them in a way that leads to differentiation and to a premium price for more value added.

A design firm's ability to differentiate itself reflects, in essence, the contribution of each value activity toward client satisfaction, in the particular markets in which the firm is operating. By employing a broad vertical scope, a design firm can exploit the potential benefits of performing more value activities internally, rather than using outside suppliers-as reflected in the case study. Alternatively, by selecting a narrow scope of value activities, a firm may be able to tailor its chain of value activities to a particular target segment of the market.

Therefore, the new information technology-computers and communications, from inexpensive but powerful microprocessors and integrated software, to expert and decision support systems, to networks, groupware and multimedia-gives design firms competitive advantage not only in terms of cost reduction by increasing productivity, but also in terms of allowing them to diversify the breadth of their value activities by facilitating vertical or horizontal integration.

And, equally important in terms of supporting differentiation strategies, it gives competitive advantage by allowing an ever-increasing bundling of quality information in the package delivered to the client.

There is an unmistakable trend towards expanding the information content of the design firm's products and services, as seen in the case study. This trend combines with changes in the firm's chain of value activities to underline the increasingly strategic role of the new information technology.

This technology not only affects how individual value activities are performed but, through new information flows, it greatly enhances the firm's ability to exploit linkages among activities both within and outside the firm. Now the computerized design firm can and does coordinate its actions more closely with those of its clients, consultants, and manufacturers, conforming true electronic workgroups across the firm's boundaries.

Also, the new information technology does alter the relationship between competitive scope and competitive advantage-the technology increases the design firm's ability to coordinate its value activities regionally, nationally,

and globally, unlocking the power of a broad geographical scope to create competitive advantage.

Finally, the managerial choice of emphasis on either of the technology's two capabilities-supporting automatization or informatization-leading to cost reduction, diversification or other differentiation formulations, is above all a basic question of strategy for design firms. Clearly, it derives from management's conception of the contribution of the new technology to the business.

The Computerized Design Finn's (Near) Future

As the new information technology is unfreezing the structure and the strategy of crucial industries, creating the need and the opportunity for change, design firms that anticipate, incorporate, and change this technology-becoming total intelligent systems-will have a better chance of being in control. Those that do not, will be forced to accept changes that others initiate and will find themselves at a competitive disadvantage.

But, again, this paper is not just about the future of computerized design practice. It is about what to do today in contemplation of tomorrow-the issues and the courses of action open to us can be discerned by the careful observer.

Modelling the computerized design firm as an intelligent system, this paper's focus has been upon the changes in the structure and strategy of designfirms   brought about by the introduction of the new information technology into their operations. The paper closes now by indicating some ways in which these structural and strategic changes reflect back on the technology of information.

The present paper has described how design firms become computerized following discernible patterns in the process of introducing the new information technology into their operations, and how this technology is shaping the structure and strategy of design firms, and not only their products.

Long in the making, the same developments that are reshaping the powerful computer industry, itself, are setting the patterns of design firm's technological innovation:

1. Microcomputers have become so powerful and affordable that they can perform many of the functions once reserved for minicomputers and even mainframes. This convergence leads firms to focus on special-purpose chips (graphics, voice), and on efficiency issues.
2. Firms have become adamant that computers and communications equipment manufacturers make their systems work together-the focus is shifting to network computing and related coordination and control issues.
3. Once companies have sophisticated computer networks in place they move beyond the automatization of operations like drafting or accounting to connect

people to information, to informatize designers. Automation yields to informatization and the firm's technology, structure, and strategy are transformed radically.

The informatization of designers implies shifting the conception of the computer as machine-tool to that of a knowledge-based system that augments the capacity of the mind to deal with complex issues. Truly smart machines meet smart people in the accomplishment of smarter value activities, and the firm starts realizing the importance of the new information technologies, not primarily to compute things, but primarily to coordinate value activities. Among other considerations, this leads the firm to a different conception of management roles.

Introducing technological innovation of this nature into a design firm presents a different set of challenges to management than does the work of competent traditional project administration. Those who manage this kind of technological change in design firms often serve as technical developers and implementers. But, as the competitive environment of the firm changes rapidly and the strategic effect of the new information technologies becomes more pronounced, the work of implementing those technologies is imposing a distinctive set of organizational challenges, not the least of which is the task of creating organizations flexible enough to adjust, adapt and learn continuously-the design firm, itself, is conceived as an intelligent system.

Success comes to those firms and those managers able to incorporate strategically the information creation potential of the new information technologies, and able to achieve continuous process improvements through organizational learning and experimentation. To this end, those who manage this kind of technological innovation in design firms should be able to serve as change agents in the organization's self-renewal process-as seen in this paper.

Interestingly enough, these structural and strategic changes reflect back on the technology of information with pressures to redirect present emphasis on the individual designer working alone in an isolated workstation, to a more realistic conception of the designer as a member of an electronic workgroup.

This non-trivial conception demands that new hardware and software be developed to meet the needs of the electronic workgroup-which raises issues of human-machine interface. Further, it raises the key issues of how to represent and expose knowledge to users in intelligent information-sharing systems, designed to include not only good user interfaces for supporting problem-solving activities of individuals, but also good organizational interfaces for supporting the problem-solving activities of groups.

The call is out in academic and professional circles for an emphasis on semiformal systems, which can be defined as computer systems that have the following properties:

1. They represent and automatically process certain information in formally specified ways.
2. They represent and make it easy for humans to process the same or other information in ways that are not formally specified.
3. They allow the boundary between formal processing by computers and informal processing by people to be easily changed.

Semiformal systems are most useful when enough is understood to formalize in a computer system some, but not all, of the knowledge relevant to acting in a given situation. Such systems are useful in supporting individual work. They are especially important, however, in supporting cooperative work, where there are usually some well-understood patterns in people's behavior, but where there is usually also a very large amount of other knowledge that is potentially relevant and difficult to specify.

In order to create such a flexible semiformal system, the knowledge embodied in the system must be exposed to users in a way that is both visible and changeable-users must be able to easily see and change the information and the processing rules included in the system.

For example, passive information can be represented in semistructured objects with template-based interfaces, while active rules for processing information could be represented in semiautonomous agents.

Semiautonomous agents provide a natural way of partitioning the tasks to be performed automatically by the system; when a semiautonomous agent is triggered, it applies a set of rules to a specified collection of objects, while remaining always under the control of the user.

In combination with electronic networking and workgroup computing, these and other recent developments in interface technologies, such as the notable advance in voice recognition, will have a broad impact on the operations, structure and strategy of the computerized design firm over the next few years.