THE ELECTRONIC REORGANIZATION OF INDUSTRY

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In case you haven't noticed, we are in the midst of a revolution. The way in which goods are being designed and made is changing. Put simply, computers have moved beyond replacing clerks and accountants and are busily replacing engineers and workers. This trend is just beginning---the use of computer aided design (CAD) stations and their integration with computer aided manufacturing (CAM) is just now starting to accelerate and take off. Like all the real revolutions in business, this one has not been brought to us by managers, or strategic planners, or by MBAs, or even by Global Strategic Management Departments. It comes to us from technologists.

The technically oriented people who are developing these systems have their own language and ways of talking. Most of the material you can read on the subject of robotics or CAD/CAM technology deals with problems of software design, of obtaining numerical representations of solid objects, of graphic display, of system implementation, or perhaps with the savings that can be reaped by installing these systems. But the implications of this new technology go far beyond cost savings and the improvement of productivity.

This technology promises to substantially alter the balance among basic economic forces: the cost of variety, the cost of flexibility, the speed of product modification and redesign, the sunk costs required to enter a market, and the degree to which skills are embodied in systems rather than people.

Technologists create these forces, but continue to view their purposes and potential impacts narrowly. It is responsibility of the general manager to look beyond the cost, efficiency, speed, and even workforce management issues and try to perceive the fundamentally new choices that are being created. Technical changes of this type and magnitude do more than promise savings; they will alter the structures of industries. The day may not be far off when economies of scope sharply reduce the number and attractiveness of niche positions in manufacturing industries. The time may come fairly soon when multinational corporations transfer technology via computer tape reels and ship high-variety products in the form of electronic data on the specifications for their manufacture. It is already possible to envision the possibility of a new form of distinctive corporate competence---the skill immanent in a company's software and systems architecture-—-that will create whole new forms of competition.

Faced with these changes, many firms have to either make risky choices or fade away. The strategic problems posed by these changes differ from those with which most top managements are familiar. But of course it is this kind of productive turbulence that shakes things up enough to allow a real reordering. For many firms, the risks of decline and the chances to move past competitors and take a commanding position are greater now than they have been for half a century.

THE TECHNOLOGY

The new technology[1] is emerging from the synthesis of a number of hitherto independent areas: computer graphics, numerical machine tools, job shop scheduling techniques, and industrial robotics. All are in a stage of explosive change and growth because of microprocessors. Previously, each technology was tied to costly large computers. This not only limited immediate applications, it had the more important effect of making experiment, play, and the inventive juxtaposition of new elements

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[1]See Bylinsky [1981] for an up-to-date review.

prohibitively expensive.

To the lay person, the most dramatic aspect of the new technology is computer aided design (CAD). At the simplest level, these techniques do for engineering drawing what word-processing equipment does for typing-—-errors are corrected with ease, new drawings can be made by modifying standard drawings or old ones, and libraries of standard shapes and specifications speed the Job. This technology is operating now and by quickening the making of drawings, engineers become two or three times more productive.

However, the full potential of CAD is not realized unless the system does more than assist in drawing. Newer implementations (1) access company-wide libraries of designs so that repetition and duplication are minimized, (2) provide software that helps the designer <u>evaluate</u> the design, perhaps by showing response to temperature, vibration, or stress, (3) locate manufacturing problems by finding aspects of the design that strain or exceed tool limitations, and (4) generate the computer-coded instructions which, when fed to the proper tools, will produce the part.

Two rough families of CAD installations can be identified, and their differences foreshadow the two basic directions in which this technology will evolve. One type is a general purpose video drafting machine with software to convert <u>part</u> geometry into commands to numerically controlled tools. Design evaluation capabilities of these systems is limited, although each user may add software for that purpose. Systems like this are offered by several firms. The other type is a company-crafted system that has extremely sophisticated software to support the evaluation of designs of special products (not just parts) like automobiles, chemical molecules, integrated circuits, and aircraft. In these cases, the computer deals with "models" of the item and cannot produce instructions for its manufacture.

On the computer aided manufacturing (CAM) side, the new trend is smart machines and distributed control---rather than having one big computer run a whole facility, each separate machine is now controlled by its own local microprocessor. There may also be a central "brain" that tells the local machines what to do. The biggest problems in automating most manufacturing is not the actual cutting, painting, etching, rolling, or casting process---these have been mechanized for a long time. The weak link is moving materials around, sorting, handling items, setting up machines, and positioning blanks. Industrial robots are beginning to perform these tasks, but the technology is just emerging. The critical issue is the development of reliable "visual" or "tactile" sensors that will allow the robot to deal with a jumbled environment.

Substantial potential synergy is available from combining these two technologies to form CAD/CAM. The same system that aids the designer also creates the control program that enables a machine tool, automated or semi-automated facility to produce the part. One West-Coast electronics firm is developing a system that will support circuit design on a CRT and automatically make an actual prototype of the electronic circuit. The time saving alone from this combination can justify the investment. Lead-times on the making of special purpose parts can be cut from twelve weeks to a few days.

One clear type of enterprise will emerge from CAD/CAM -- the general purpose metal cutting and working shop. With numerical tools, materials handling robots and associated equipment, and computer aided parts design capabilities, such a facility would be able to quickly and reliably respond to a wide variety of needs. The key point about such a shop is that batch processing is no longer critically important. "Random" scheduling is possible, with a constant rapid flow of totally different tasks on different machines.

FIRST-ORDER IMPACTS ON COST AND PERFORMANCE

CAD systems reduce the number of engineers and drafting personnel required to perform a function and quicken throughput. Engineering is not, in general, a variable cost of production. It is a set-up cost that attends design, design change, and the creation of product modifications. Consequently, one major impact of CAD technology is to substantially reduce the fixed, or set-up, costs associated with product design and product modification.

CAM systems have somewhat the same property. Although they can drop variable unit costs by replacing labor, their major impact will be on set-up costs and throughput. This is because very high volume manufacturing of standardized items tends already to be accomplished with special purpose automated equipment. The ability of such equipment to produce alternative designs is limited, but flexible shops, no matter how automated, cannot match the specialized line in achieving low units costs when volume is high.

The construction of a full-scale CAD/CAM system is no minor undertaking. When the system is specialized to the user, the costs mount even further and become sunk and largely unrecoverable. However, once such a system exists, it becomes a public good. That is an economist's term for something that once created becomes costlessly available for a variety of users or goods. Another way of saying the same thing is to notice that information is the core of the system and that there is almost no variable information already collected.[2]

THE IMPACT ON COMPETITION

When the fixed, or set-up, costs of producing products are reduced, and if the market values variety, then the number of different

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[2] Gold [1980] discusses the problems of capital budgeting that stem from this public-good property and the uncertainty in future applications.

product variants produced will increase.[3] Therefore, we can make the straightforward prediction that CAD/CAM technology will increase the variety of manufactured parts and assemblies.

The drop in product design and modification costs will generate variety of a different type---a larger flow of new and different products. Thus, CAD/CAM will not only increase the variety of goods produced at any given moment, it will increase the rate at which products are changed and modified. This, in turn, means either greater customization of products, or shorter life-cycles, or both.

A very fascinating issue with regard to CAD/CAM is the size of the scale economies CAD/CAM will enable. There are two opposing forces at work here. One is the obvious heavy fixed and sometimes sunk costs involved in getting a CAD/CAM facility going and the free-good aspect of its use. The other is the regularization of the interface between design and manufacturing. Williamson [1979] argues that organizations really exist in order to impose order on transactions that are too ambiguous, infrequent, and unique to be carried out easily in a market place. Once <u>computers</u> <u>begin</u> to <u>specify</u> <u>parts</u> <u>fabrication</u> <u>needs</u> in a <u>standardized</u> <u>language,</u> and once <u>automated</u> <u>facilities</u> <u>exist</u> <u>that</u> can turn <u>these</u> <u>specifications</u> into a <u>part,</u> the need to <u>have</u> them <u>within</u> the <u>same</u> <u>enterprise</u> <u>diminishes.</u>

Perhaps it is a science-fiction fantasy, but why not imagine for a moment a future in which a design engineer draws a part on a video screen and then enters the specifications into a regional clearinghouse for bid. Seconds later an acceptable bid is made by one of several local facilities and an electronic contract is formed. Two hundred units of the specified part are delivered the next week, having been made at just that facility with the right machines and job schedule to minimize their cost.

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[3] See Salop [1979].

There are problems with the above scenario, but it will be close enough to the truth to suggest that the gains from general purpose CAD/CAM systems will not, in the main, be captured by the people running the automated facilities. Those facilities will have to exist, but they will not return superior profits.

Additionally, the possible gains from the CAD side are limited by the extent to which a standard system is used. CAD systems based on standard software and commodity-like engineering skills in using that software will clearly exist and be economically important, but will not generate unusual returns.

Will the benefits of CAD/CAM fall only on the consumer? No. Those firms which develop specialized systems around unique engineering abilities and products will begin to occupy increasingly advantaged positions. And those firms which use the variety and flexibility generated by the general purpose systems as an integral part of global marketing efforts will also benefit. The losers will be general job shops without the skill or capital to adapt, and large manufacturing firms that simply see CAD/CAM as a way to save money. Both will be eclipsed by organizations that understand the forces at work.

VULNERABILITIES AND RISKS

There are three main risks facing firms that have to deal with this new technology. They are (1) failing to develop a distinctive competence, (2) not adapting to the new needs for variety and flexibility, and (3) falling prey to a K-strategist. Which risks a firm faces depends on its current position and intended future strategy.

Distinctive Competence

The CAD/CAM technology promises to open up a whole new realm within which organizations can excel. Companies in aerospace, specialized electronics, and other businesses, where complex design engineering of custom products is the norm, must not only take positions in this new technology, they must develop or maintain distinctive competencies while doing so.

Firms that buy off-the-shelf CAD systems will experience a few years of improved performance. Costs will go down and life will be easier. But soon competitors will also have reduced their design and modification costs and the gap will close. If the corporation's existence depends upon superior design, it will eventually fall behind competitors who have developed distinctive and unique CAD systems.

Adapting

Most manufacturing firms do not live or die on the basis of design -- they produce a line of products (e.g., tractors, connectors) and compete on the basis of performance, price, distribution, innovativeness, service, and other factors. CAD/CAM technology's primary impact on such firms will be an early reduction in costs, followed by a later benefit in terms of product variety and change. But the early cost benefits can lull organizations into a false sense of security so that some may not put forth the effort required to adapt to increased variety and change.

Increased product variety and shorter life-cycles have several implications. For moderately sized firms it may actually mean giving up some manufacturing capability---backwards disintegration. As the capabilities of automated shops grows, and as the pressures for change and variety increase, smaller and moderately sized firms will find it more profitable to concentrate on design and let others handle the manufacturing than to attempt to build their own CAM system.

Finally, variety and change are ultimately marketing tools and organizations must look to the substantial restructuring of service, distribution, and advertising policies if they are to reap the benefits of the new technologies. There is no sense in increasing product variety if service people cannot handle it or if distributors are expected to double their inventories. Coordinated efforts and a general rethinking of the company's competitive strategy will be required.

<u>K-S strategists</u>

In the field of population biology[4] scientists distinguish between two type of selection equilibria---and two types of strategy. The r-type strategist exists by having a rapid reproduction rate and thereby being quick to fill new niches and locate and occupy new sources of energy. Examples are ants, wild grass, and mice. K-strategists, by contrast, are deeply specialized and make much fuller use of available energy. Examples are oak trees and bears. In business, r-types are firms that can deal with many environments and make use of rapidly appearing but ephemeral niches. CAD/CAM systems are of greatest immediate aid to r-strategists: the new quickness of response and product variety make shorter product life-cycles and a wider range of markets served. But r-type strategists are vulnerable to specialists. Companies that bet heavily on CAD/CAM must be aware that they are betting on variety and quickness. If a K-competitor develops a product and production system that is totally specialized, not using general purpose machinery and processes, and thereby achieves substantially lower costs, the generalist is in trouble. The market may value variety, but not at a markedly higher price.

An excellent example of K-strategy is documented in the Boston Consulting Group's [1975] analysis of the British and Japanese motorcycle industries. Although many have concentrated on the experience curve arguments of BC G, the report emphasizes the importance of the Japanese production system. The British motorcycle makers used general purpose machine tools. Honda, by contrast, had designed its own special purpose machine tools, and designed them around its own

[4] Wilson and Bossert [1971] give a clear treatment.

special product concept. In essence, while the British could not justify the purchase of a new general purpose tool on a cash flow basis, Honda had gone ahead and created an integrated product-process system on a global scale.

One element of the K-strategy that deserves special attention is the close connection between product and process design. For firms to follow this path, they must have product design engineers who have an intimate understanding of alternative production processes and of the subtle trade-off involved in producing different designs. There are two barriers to the development of this capability. The first is cultural. In the United States there is an increasing tendency for engineers to define their jobs in terms of design-for-performance and to let others worry about producibility.

The second is managerial; few managers and fewer senior managers understand enough about the strategic manufacturing alternatives to ask their technical people for the right things.

As firms emphasize variety and rapidity of response they become increasingly vulnerable to K-strategies. When K-strategists appear, firms retreat into the specialized segement of their markets.

CONCLUSIONS

The new technologies of CAD and CAM will restructure a number of industries on a global scale. Some firms will face the need to abandon certain manufacturing activities, others will have to develop new modes of distinctive competence, and still others will need to closely examine their ability to to deliver increased variety and to cope with a shorter product life cycle. Finally, although CAD/CAM systems will breed a new type of fast-responding high-variety enterprise, they will be an increased vulnerability of these firms to highly specialized producers. One unanticipated result of the new technology may be an eroding middle ground between generalist and specialist producers.

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