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AUTOMATING THE ENGINEERING-MANUFACTURING INTERFACE
PHILOSOPHY, METHODOLOGY, EXPERIENCE

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ABSTRACT

This paper is comprised of three major elements: one, a view of the essence of CADCAM, that aspect of this acronym that makes it a major milestone in the improvement of industrial productivity; two, a specific philosophy for the implementation of CADCAM within an existing major industrial complex; and three, recent and future developments within Sikorsky Aircraft which demonstrate that philosophy and begin to reveal the full spectrum of CADCAM and the associated opportunities.

1.0 Introduction

Many categories of activity exist in a manufacturing industry for which numerous types of information are required. CADCAM has the potential to affect all of the information in such an organization, but for the purpose of this discussion only that information which defines the product and permits its manufacture, delivery and support will be examined. Two categories of information will be defined: engineering information which describes the product, and the tools and process of its manufacture; and derivative information such as procurement, factory loading, and inventory requirements.

Both engineering information and derivative information consist of three distinct subtypes: textual, geometric, and logical information. The easiest of these for the computer to assimilate is textual information. The easiest was tackled first and has been substantially computerized by many companies. For example, bill of material, process planning, production control, and many other "text-based" systems are in routine use.

Powerful mechanisms now exist for the computerization of geometric and logical information and it is these areas on which Sikorsky's attention is focused. Computerization means different things to different people. To Sikorsky, it means providing, in the computer, the understanding of geometry and creative logic that is currently captured only in the mind of man. Without such understanding on the part of the computer, truly "intelligent," productive automation will be impossible.

The primary function of CADCAM is to improve an organization's profitability either by direct cost reduction, quality improvements, or responsiveness to competitive pressures. Examples abound which demonstrate that CADCAM methods can simply be substituted for existing techniques in a manufacturing organization and yield substantial benefits. The effects that have been observed to date, even by the most advanced users of CADCAM, are small by comparison to its potential.

It is clear that CADCAM has the potential to affect every aspect of industrial operation, while allowing an industry to produce products that would be unimaginable without it. However, if widespread effects are not anticipated and prepared for, an organization may find itself in a serious state of disarray, experiencing all the unnecessary costs that such a condition produces. If these ideas are valid, then the preparations necessary, organizationally, technologically, and philosophically are of no trival significance.

1.1 The Essence of CADCAM

As discussed, CADCAM is enlisted primarily in the search for increased productivity and competitiveness. The technology of CADCAM is all too often thought of as being easily implemented and at the same time expected to have rather unsophisticated results. But if CADCAM is such a truly revolutionary force, what are the elements that allow it to be? Simply stated, the essence of CADCAM is the ability of this technology to meld the very diverse disciplines of an organization into a streamlined "organism" constituted to carry on activities of operation by means of groups separate in function yet mutually dependent. The life blood of the organism is information (not data, see Appendix A) and the force that binds it together and assures coordinated and efficient operation is integration.

The essential elements, then, are the ability of CADCAM to produce not simply more data but true information, and to integrate that information throughout the organization. In the past, as manufacturing organizations grew large and complex, many different sources of information became necessary to describe a product and provide for its manufacture. Presently, many different documents must be read and interpreted to obtain all the required information. All too often, even with a virtual mountain of data, bits of information are missing or incorrectly interpreted. This jeopardy exists throughout the spectrum of product flow, from design to product delivery.

Efforts have been made to alleviate the problem by applying computer techniques to the individual sources of information. Examples are: the widespread use of interactive computer graphics to produce drawings, and the use of specialized programs to store bills of material or process instructions. Even with such extensive computer-based files, the data contained there really only became complete information after being extracted and interpreted by a human being. In addition to this lack of "in situ" understanding, the islands of data that exist remain, to a large extent, unconnected. Even when connected, because the connection is "unintelligent," the data are not truly integrated. In the final analysis, the computer must understand the information inherent in the geometry of a part or tool design, or the hierarchy and precedence of an assembly of components, or the logic on which a design or process decision is based.

In order to provide a CADCAM system based on integrated information, Sikorsky has established four required characteristics of the data for that system. The characteristics are: uniqueness, explicitness, completeness, and manageablility. They are defined below:

Unique - data must flow from a single source. Even if separate systems are employed and the data appear to be copied in separate files, the data must be derived from a single reference point. The existence of each apparent copy of the data must depend entirely on the master source.

Explicit - data must be understood by the computer without the need for human interaction (e.g. geometric elements), and without ambiguity or multiple interpretations.

Complete - data must provide not only a description of an entity, but a complete definition (including tolerances, surface finish, etc.). In addition to the physical descriptive elements, the data must contain the complete logic on which the entity's design was based (such entities can include parts, tools, processes, etc.).

Manageable - data and the carrier system must allow for syntactic regulation to provide unambiguous and clear understanding, and for relational control to provide efficiency, accuracy, and no redundancy.

The creation of a so-called "central data base" is clearly insufficent. What must be created is a central information base, comprised of data, that, on request, can be transformed into information by the computer and not by the man. What constitutes information is, of course, dependent on the needs of the user and is also a function of the tools employed by him. For instance, a facsimile of a drawing (stored on CADAM), with dimensions, notes, and format, may, for someone reading a hardcopy plot of the data, constitute information. However, for a tool designer accessing the data on CADAM, and expecting to use the geometry directly, the data may be virtually useless if the designer failed to make the geometry and dimensions consistent.

Such definitions of information (ie. the usefulness of the data) must be well understood to achieve the four qualities described above. More significantly, an organization may have to change its "rules," its ways of doing business, to implement such a scheme of computerized information storage. In many cases, more information than is conventional may have to be defined by a particular element of the organization in order for a downstream element to be able to extract information without repetitive work. The previous example of information content is a case in point. The detail designer does additional work to ensure that the CADAM "drawing" faithfully represents the geometry implied by the dimensions on it. Doing so enables the tool designer, N/C programmer, planner, and technical illustrator to use the information inherent in the geometry without having to redraw or copy -- activities which would be necessary were the data simply data and not information.

2.0 The Traditional Approach

Understanding the important aspects of CADCAM, at least what Sikorsky believes to be the important aspects, requires a philosophy so that implementation can proceed in a well coordinated and efficient manner, especially in light of CADCAM's capacity to integrate and its ability to affect every facet of the organization.

In order to describe Sikorsky's present philosophy for CADCAM implementation, the historical or traditional approach should be examined. Indeed, while drafting the present philosophy Sikorsky analyzed closely the implementation methods it was using and the problems associated. Many companies, including Sikorsky, have sound and sophisticated programs or projects to introduce or increase utilization of CADCAM in one department or another. What seem to be largely lacking are objectives which are of sufficiently broad scope coupled with coordinated work plans.

CADCAM is usually introduced and expanded within a company by individuals, or at best individual groups, who recognize some very attractive gains which can be realized unilaterally. In the traditional scenario, individual groups press for systems and system utilization that are defined solely by their own requirements and the parochial objectives of their own organization. As a result, a random pattern begins to evolve as described by Figure 1.

"TRADITIONAL" APPROACH

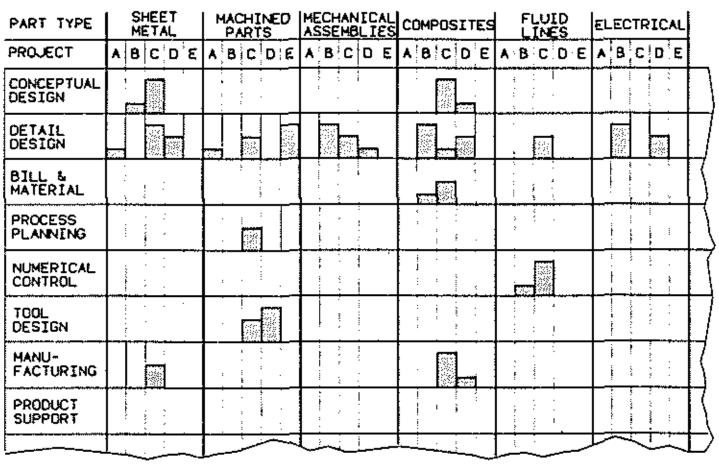

Figure 1

In the case of Sikorsky, pools of CADCAM concentration were showing up sporadically across the three-dimensional matrix of discipline (e.g. N/C, detail design, etc.), part type (e.g. sheet metal, composite) and aircraft program (e.g. S76, BLACKHAWK). If left to continue in this fashion, the CADCAM system would probably have expanded throughout most of the organization. At best, it would surely have been unsophisticated, poorly, if at all, integrated, and of relatively low productive value. At worst, it could have been a very costly investment which produced no sound information and required a complete redesign and conversion to a viable system.

The problems with the traditional approach are:

1. Poor control of data flow
2. Low productivity visibility
3. Few synergistic effects
4. No prototyping.

These are not offered in any order of importance, for the effect will depend on the organization and the stage and maturity of the CADCAM system. A short description of these problems follows.

In an organization which is even somewhat episodic about data building and CADCAM use, it is very difficult to insure that the data produced by one department will be suitable for use by another. If the other department, or group within the department, is on a different and uncoordinated course of development, it might well decide what it needs long after substantial data files have been created. Since computers are especially adept at producing data rapidly, such coordination cannot be carried on at a casual or informal level. Only if the data flow is established and understood at the outset of implementation can the proper controls be installed.

As CADCAM has grown in the last decade from an interesting concept to a major functional tool, so has it grown in its appetite for the financial resources of the host organization. As this demand has increased, so has the degree to which it is being scrutinized by those responsible for the direction of capital investments. Measuring CADCAM productivity is becoming more and more a major task. There are reasons for such introspection beyond the justification of the investment, however. Though most system developers address this task in a perfunctory manner, understanding the effects on productivity and the elements which drive this productivity is vital to proper CADCAM implementation. Companies have finite reserves of capital on which to draw and no matter how large these reserves may be they are insufficient to meet every conceivable challenge of CADCAM. If the productivity of the system is well understood, not only can the organization make the most of its evolving system, but early and maximized returns can be re-invested in the system itself to further stimulate and accelerate its growth.

In the traditional approach, because the implementation is compartmental and driven by parochial interests, the productivity increase is nearly always confined to the direct user group itself, and then probably limited further to particular projects within that group. This makes the productivity changes measured (when they can be measured) very small and a fraction of the direct user's total budget, and an even smaller fraction of the operating costs of the entire organization. This usually leads to reliance on sparse and highly scattered data or benchmarks, both of which can lead to wholly erroneous conclusions. Any concerted implementation plan must be constructed upon sound and meaningful data if it is to commit capital and human resourses where they will do the most good.

The last two problems, the lack of synergism and the dangers of no prototyping, will be deferred to the next section.

2.1 The Strategic Approach

The philosophy that Sikorsky has adopted provides for CADCAM implementation in a very <u>focused and directed</u> manner. This approach, which is called the "Strategic Approach," is intended to focus the activity of a designated group of individuals to the task of building a fully integrated CADCAM system which operates from early design to manufacturing of a <u>specific family of parts</u>. This very specific group or family of parts is called the strategic "target." Implementation which proceeds primarily along these target corridors forms the pattern described in Figure 2. Specific reasons for the selection of one target over another target are numerous. Logic for selection will be given in the section on methodology and several examples will be given in the description of the first target.

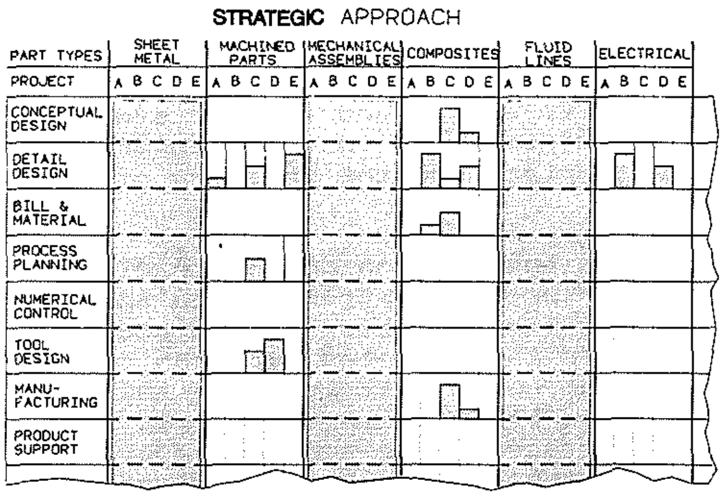

Figure 2

There are three basic reasons for singling out individual targets. The first is that the task, of implementing CADCAM across the entire engineering and design operation at once, requires resources and, especially, involves substantial risk. The second is that part family targets present a representative subset of the larger operation, so that the CADCAM system would impact a typical number of disciplines, exposing a maximum number of the problems and opportunities. And the third reason is to learn from real experience as each of these smaller systems comes into routine operation; this experience provides needed input to the direction and emphasis to be placed on the target part families that follow.

The Strategic Philosophy has four basic precepts: one, implementation will be focused on defined target areas (not necessarily to the exclusion of all other CADCAM activity); two, a dedicated team to oversee and provide technical continuity to implementation; three, a delineated "methodology" will be constituted and the methodology will produce a "Strategic Target Plan" as its working document; and four, the systems it creates will form a single operating system using data which are strictly defined by the characteristics of information discussed above.

As the "focused" implementation proceeds, CADCAM activity in other areas is not discouraged. This activity is brought under scrutiny so any extensive program or system development does not get out of control and diverge from the global objectives of the "primary" system. Such pockets of activity are very useful -- they have provided valuable information to the strategic planners and the users themselves. It has been found that when individual groups are self-motivated to action and are assisted in the early stages of CADCAM introduction in their department, they become strong supporters for the creation of the "primary" system.

Discussed in the section on the traditional approach were the four major problems attendent to that method of implementation. The first problem is the poor control of the data created. In the targeted approach the data flow is quite clear from the outset. It is given that all data for all programs will be produced in a specific manner, and that that manner must be acceptable and usable by whomever is in the chain of that part's design and fabrication. The second problem is the low visibility of increased productivity. In the targeted approach, since all the data involved (not just specific product lines or disciplines) are to be affected, measurements of impact can be made on the bottom line cost of producing that family of parts, where the effect is be the greatest and the most important.

The third problem is the lack of synergism. The compounding of CADCAM productivity and cost avoidance, has been of significant magnitude at Sikorsky, even when such synergistic effects are not caused intentionally. It should be obvious that few if any synergistic effects, which develop from the passing of electronic information from upstream user to downstream user, are possible in a randomly and sporadically evolving system. The recognition of these highly fruitful relationships is extremely important, for the magnitude of the synergised effects can be many times greater than that possible by the direct or upstream user alone. Indeed, these synergisms can drive the entire course of target selection and implementation.

In the targeted approach, synergisms are forced even where they are not anticipated. Since the information must flow throughout the system, the compounding effects quickly become apparent. It should be noted that synergistic effects can be positive or negative. Occasionally, an upstream use of the system puts a new burden on a downstream group. It usually turns out that this negative effect is tolerated because the adversely affected user is transmitting the information to a user still further downstream, who, in turn, is made significantly more productive. The analysis of such complex and multifaceted flow synergisms is simply not possible in the abstract.

The fourth problem in the traditional approach is turned to a decided advantage in the Strategic approach. This is the ability of the targets in the Strategic approach to serve as working prototypes for subsequent targets and the primary system. The value of using and experiencing CADCAM is of paramount importance. The prototype is important in a number of aspects: it serves as a test bed for equipment or systems before expansion throughout the company and prior to major capital expenditures; it provides a working model for refinement of subsequent target specifications and implementation plans; it provides valuable financial data which will be used to confirm or adjust investment return predictions and expectations; and it provides an early, yet operational, look at a fully functional CADCAM environment for other users who will be affected by upcoming implementations, thereby increasing their knowledge, enthusiasm and support.

2.2 The Methodology

The "Strategic" approach demands a well planned and managed methodology if its implementation is to be successful. The following method is presently in place and operating at Sikorsky. For each selected target group (in the case of Sikorsky, a specific part type) there are associated, three major steps:

Step 1 - Determine the targets. This is the rather obvious prerequisite for any implementation. Target selection criteria will vary undoubtedly from company to company. Targets are selected for many different reasons, the primary concern need not be the target's potential for return on investment. Indeed, Sikorsky's first target was chosen not for the potential improvement in productivity but because it was a small, manageable task that would serve well as a prototype for the succeeding targets and part types. Specific critera for the first target will be expanded upon later in this paper.

Sikorsky elected to select not a single target, however, but five separate targets to be started at three month intervals. It is believed that implementation of CADCAM has to proceed with the caution and structure of the Strategic approach, but the time scale must be compressed as much as possible to take advantage of productivity opportunities that do exist.

The selection of several initial targets is important for another reason beyond the compression of overall implementation timetables. Each target should be selected with respect to its predecessor and successor, and with regard for the overall implementation scheme. A target should be able to use the experience and knowledge gained in the excecution of the preceeding target. As has been shown above, the value of prototyping of this sort can extend to investment and productivity projections.

Step 2 - Establish goals and methods for each target. As each target is selected a series of overall goals is created. The actual creation of goals occurs prior to and during the target selection process. The goal definition is an evolutionary process, beginning perhaps with a generic idea and then proceeding by subsequent refinement to meaningful and target-specific items, such as, for example the reduction of part rework. Actual goals will be given later in the description of the first target.
In the case of the first target, after the goals had been established, a series of methods were developed that were considered necessary for the accomplishment of the goal. For each goal a number of paths to achievement exist. Many criteria have guided Sikorsy's selection of the particular methods, again, these will be examined in some depth later on. The following examples are offered to describe a method, and to distinguish it from a goal, a tool or a specific action.

The goal of reducing part rework is to be accomplished by the following five methods:

1. Assuring the process instructions are accurate and up-to-date on the shop floor.
2. Maximizing the use of numerically controlled equipment
3. Direct access to part data from a central data file without reduction to punched tape or other media.
4. Automatic computation of part drawings and fabrication instuctions directly from the geometry and an established logic set.
5. Maximizing the use of integrated three dimensional design

Step 3 - Set action items to accomplish each goal. This level of activity is certainly the longest and most detailed. Each goal was addressed separately, but there was found to be considerable overlap between methods and action items. While in the process of accomplishing one goal, another goal might be affected, and such effects may be positive or negative.

Action items are the specific tasks to be accomplished. Taken together, they form an outline and guide for complete target implementation. Each action item defines the manpower, or range of manpower, required for its execution as well as the disciplines or departments involved. Where multiple departments are involved, the responsible or key individual or department is identified. A range of manpower is used where there is some uncertainty in the actual requirement. As will be seen later, this range is used in the calculation of the potential return on investment.

Each action item defines the calendar duration of the item and milestones to mark its progress along the way. Some action items are fairly straightforward, while others are in themselves rather complex and require a subset of actions within. Milestones are either simply features of completion used to estimate progress or actual subtasks which are critical to the completion of subsequent items. A range is employed for duration, again for the purpose of creating a sensitivity for the risk or return on investment.

The action items as a group can be logically divided into two main phases: development and implementation. Frequently these categories can not be neatly separated chronologically. Such classification, however, is useful in the placing of decision points, so that the major capital expenditures (which usually lie within the implementation phase) can be avoided if post-development analysis yields a overly risky projection.

As early as possible an estimate of the required capital or external expenditures is determined for each action item. This includes real capital goods like equipment and facilities, computing hardware and software, and services such as external programming or the copying of engineering information into computer format. A range is used here, as before, for the same reasons.

The compiled action items form the Strategic Action Plan for a specific target. This plan is intended to produce four pieces of information in addition to being an outline of things to be done. First, the plan will produce an overall timetable for events. This allows the proper visibility, since extreme change is likely within a target. Because of the magnitude of the possible change such visibility is necessary so the departments known to be affected can prepare, and other departments, seemingly not affected, can determine whether they are affected and if so to what extent.

Second, the plan will provide detailed specifications for work to be contracted outside, and specifications or subplans for individual pieces of work to be accomplished internally, which are, in and of themselves, very detailed.

The plan will also provide <u>procedures</u> for the <u>operation</u> of the implemented system. These procedures will grow as the number of targets increase. Eventually they will form the master procedure for the overall fully integrated system. As the targets are being developed, the procedures comprise a clear picture of system operation. This picture will be used by succeeding target areas to sharpen their understanding and help prepare for the future.

Third, the plan will estimate a complete cost of the development and implementation of the operating system for the target. The costs will include expenditures of internal manpower, external contracted manpower, and all capital investments. All costs will be given in a range between the minimum and maximum that is likely. This range is then applied to a risk versus gain analysis which will be elaborated below. In addition, the width of the range between minimum and maximum provides a measure of the confidence level which can be applied to the estimate.

Fourth, the plan will estimate the complete cost avoidance for the target in a fully operational mode. As with the cost, all types of avoidance are considered and a range and timetable are provided. Taken together, the cost and the cost avoidance form the basis for a risk versus gain analysis. The analysis is fundamentally a plot of the cost and cost avoidance over time (usually three to five years). Both cost and cost avoidance are bands of values -- this permits the computation of a return on investment prediction with a sensitivity analysis.

This sensitivity analysis for the return on investment, together with a subjective consideration for confidence level, leads to the "risk" analysis. This data is gathered and computed prior to and during the entire development process. Under prevailing financial criteria, with the risk analysis complete, the decision to proceed or not to proceed to the implementation phase is made.

3.0 Fluid Lines - the first target

The first target for Sikorsky's new Strategic Approach and its implementation methodology was the Fluid Line family of parts. This family group includes all rigid pipes of all diameters and all materials. It includes all flexible hoses, again without limit to diameter or material of construction. The part family also includes all assemblies, details, and components.

The CADCAM spectrum of information flow starts with early conceptual design and layout of the required part routing (this includes some rough airframe details which must be considered). It continues through the automated creation of the descriptive engineering drawing of detail and assembly, with the automatic selection of appropriate components, and the automatic creation of fabrication instructions complete with N/C information for cutting and bending, and illustrations for assembly and inspection. All information will be contained within the operating CADCAM data system which will have links to the bill of material file, procurement and inventory requirements, and factory loading and scheduling. All data will remain within the electronic system and will not require reduction to paper or other physical media. Even comments or adjustments to the fluid line design which are made on the factory floor are returned via the electronic link.

The Fluid Line group was chosen for the following four reasons: one, it was a small but highly representative design and manufacturing flow. That is, it required two- and three- dimensional design, it contained both detail and assembled parts, and it already employed N/C equipment for manufacture and inspection. Two, the design, process planning, and manufacturing units were somewhat separate and major introduction of new technology could be contained. Three, fluid lines are a ubiquitous component in helicopter design and manufacture and possess similar attributes to electrical wiring, another important component and a near-future target. And four, fluid line manufacture at Sikorsky is well established, well documented, and operating efficiently. It is believed that CADCAM implementation here is still very valuable, and measurement of productivity in this environment would not be obscured by the inadvertent solution to another problem as might be the case if implementation was begun in a part family that was more prone to problems or whose operation was not as well understood.

Fluid Lines then was the initial target for this new coordinated and concerted effort. Actual work on the end-to-end system began in late 1982 and will complete its planned level of implementation by mid-1984. Targets begun shortly after and which are now underway include the Sheet Metal group, the Electrical group, the Small Assembly group, and the Composite group.

3.1 The Support Systems for CADCAM

Sikorsky currently uses systems which are, almost exclusively, mainframe based for the storage and manipulation of text, geometry, and logic. It is quite likely that computer processing will decentralize in an effort to increase flexibility and responsiveness as hardware becomes cheaper, smaller and more powerful. However, the data which carries information throughout the industrial organization will appear to the end user to be centralized even if it is not physically stored in one location. Without considerable logical centralization it will be impossible to achieve the goals described above of uniqueness, explicitness, and manageability of information.

Sikorsky has been an active developer of CADCAM systems for internal use for the past 15 years. Such developments include high function two and three dimensional design graphics, automated process planning, and paperless electrical harness design and fabrication. It has become clear, however, that without the benefit of income from sales of such systems, and with the significant increase in sophistication (and therefore development costs) of CADCAM software, that a company is unable to justify such large expenditures for internal system development in the face of rapidly emerging externally developed products.

These systems (e.g. CADAM, CATIA, etc.) are refered to as "secondary" systems, meaning ones which feed the primary overall system of product design and manufacture. Sikorsky software development will, therefore, concentrate on the task of integrating the secondary systems into the primary system function which is the design and manufacture of helicopters.

The secondary or support systems currently in-house, and the function to which they are applied are shown in Figure 3. Several standalone systems exist at the tertiary level for specialized activities such as N/C control of machining, tube bending, fabric cutting, robotics, sheet metal nesting, and inspection measurement machines. Links are, and will, be established according to specific Strategic plans to connect these systems into the centralized network of the primary system.

SYSTEM	AUTHOR	TYPE	APPLICATIONS
EO3	SIKORSKY AIRCRAFT	2-D WIREFRAME	DESIGN, ANALYSIS, LOFT, N/C
FMILL	SIKORSKY AIRCRAFT	3-D SURFACE	LOFT, TOOL DESIGN, N/C
CAIDS	SIKORSKY AIRCRAFT	3-D WIREFRAME	LOFT, DESIGN, DRAFTING, TOOL DESIGN,FEM
CADAM	CADAM INC.	2-D WIREFRAME	DESIGN, DRAFTING, TOOL DESIGN, PLANNING, N/C
CATIA	DASSAULT SYSTEMES	3-D SURFACE/SOLID KINEMATICS	LOFT, DESIGN, TOOL DESIGN, ANALYSIS, N/C
CMPP	UNITED TECHNOLOGIES	AUTOMATED PROCESS PLANNING	PROCESS PLANNING

Figure 3

3.2 Conclusion

CADCAM, it is believed, can affect an industrial organization in the most fundamental -- and profitable -- way imaginable. But the changes experienced by a company as a result of haphazard or piecemeal introduction of the technology are likely to be neither fundamental nor profitable. It is essential to approach CADCAM implementation with the clear understanding that the potential exists to substantially change the way of doing business. With such an outlook, the huge scope of CADCAM becomes obvious and the need to concentrate initially on elements of the organization is apparent.

For Sikorsky, perhaps the most significant conclusion is that complete factory-wide computerization is best managed in the form of discreet, well-focused projects, projects which are logically linked together and which build incrementally upon each other. The recognition that knowledge and foresight are limited by the very fast technological pace that CADCAM has set underscores the need for this incremental development. The prototyping which results from this approach provides valuable insight for the system planners, while creating a picture of the future for the rest of the organization.

Appendix A - Information

"Data" is defined by Funk and Wagnalls Standard dictionary as "facts or figures from which conclusions may be drawn". The word of significance here is "may". After some consideration, it can be seen that only the potential for conclusion or inference is required for entities to be considered data. Data is derived from the pluperfect form of the Latin verb dare to give. Literally then data are the media by which communication is given, regardless of language or form, regardless of whether or not anything interesting, useful, or even understandable is received. Data are simply the fundamental constituents, like matter in the physical world.

Computers are magnificently able to produce data, whether the machine or program is operating properly or not, whether it is intended or not. Chances are if the thing is plugged into the wall, it will spill out data with very little coaxing. Computers are natural data engines, but the data they produce need not be of any value to anyone, indeed, it is so easy to produce data with a computer that less and less thought is being given to excercising restraint.

The same Funk and Wagnalls defines information as "Timely or specific knowledge". Two ideas seem the characterize information, one, that understanding is given, and two, that such understanding is required. All of the preceeding is not just semantical excercise, computers are easily applied to the task of producing data, but computers do not automatically produce information, for information can be defined as "data which provides required understanding".

For example, imagine the books of a library, in their usual condition they are orderly arranged on selves and coded and cross referenced for easy retrieval. Someone desiring information can quite easily find the appropriate data. Now imagine the same library of books is reduced to individual pages and the pages are strewn randomly throughout the room. The amount of data remains unchanged; the room is still quite filled with data. The amount of information in the library, however, is really quite small; the potential information is as high as in the orderly library, but the actual usefulness of that data is very low.