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Strategy for implementing CAD/CAM systems /

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STRATEGY FOR IMPLEMENTING CAD/CAM SYSTEMS

BY

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ABSTRACT

The purpose of this thesis is to develop a methodology for successful implementation of CAD/CAM systems. Based on a strong belief that the success or failure of a CAD/CAM system depends largely on a well conceived strategy, the thesis hypothesizes, investigates, analyzes, develops and tests this strategy by concentration on the following areas:

1. Systems design, specifications and evaluation.
2. Systems justification based on cost/benefit analysis.
3. Human factors both physical and psychological.
4. Systems staffing including recruitment and training.
5. Systems implementation and follow-up.
6. Systems growth and evolution.

Each of the above areas is explored in detail to find out what role it plays in making a CAD/CAM system meet its desired goals and objectives.

Finally, the methodology developed is applied to an actual plant implementation of a CAD/CAM system by AT&T, Reading and achievements measured in terms of the objectives set for the system as a result of application of this strategy.

In order to further substantiate the hypothesis, a

case study is presented demonstrating unsuccessful CAD/CAM implementation due to the lack of proper strategy resulting in costly consequences.

Chapter 1 INTRODUCTION

Computer Aided Design, or simply referred to as CAD, in its broadest definition refers to the use of computers to create, analyze, detail and document a design. Computer Aided Manufacturing or CAM can be defined as the use of computers to support the production processes that will transform materials into the part or product designed. The term CAD/CAM similarly applies to the use of computers to integrate the exchange of data between various CAD and CAM functions.

Implementation of CAD/CAM technologies and tools can be extremely complex and can affect every aspect of the operation of a manufacturing enterprise. Changes to operational procedures in both design and production are usually required. The deployment of personnel is affected as their job skills and work responsibilities change. The means by which information and material flow through the manufacturing enterprises are altered as well. Thus, an organization's structure, its means of communications, and the relationship between previously established areas of responsibility must all be re-evaluated. These effects can be highly disruptive if they are not anticipated and planned for. Managers responsible for implementation of CAD/CAM systems should therefore have clear cut objectives and goals. They should understand the CAD/CAM technologies and their applications, as well as their far reaching effects and how to accomplish the set objectives.

The thesis, therefore covers a detailed study in an attempt to find a philosophy with reference to implementation of such complex systems.

Based on research, actual application to plant implementation and case study, the thesis recommends a logical and step by step process to be followed in order for the CAD/CAM system to meet its desired goals and objectives.

Chapter 2 PROBLEM DEFINITION

Although CAD/CAM is described as being the latest technological tool for increase of productivity, there are however, following two popularly held concepts about this system, which can be questioned:

1. The concept of a turnkey purchase that the vendor supplies the user with an integrated working system which the user only turns on to reap its benefits.
2. The view that implementation of a CAD/CAM system yields instantaneous increase in productivity and reduction of costs.

This thesis poses that this cannot be that simple. A rise in productivity cannot be easily effected by mere purchase and installation of some sophisticated hardware and software. CAD/CAM without the formulation of a well conceived strategy is bound to result in costly consequences, in terms of lost time, ill spent money and inappropriate choice of equipment.

In order to be able to take full advantage of this sophisticated technology and have the system meet its desired goals and objectives, it is imperative that the company has a planned approach. The thesis therefore develops this sound strategy based on consideration of technological, financial, physical, psychological and other issues.

Chapter 3 BACKGROUND

The inspiration for this research project is a result of my taking the graduate course IE 449 - Advanced Computer Aided Manufacturing with Dr. E. W. Zimmers, Jr., as its instructor. This has been one of the most enjoyable courses I have taken at Lehigh, as Dr. Zimmers with the richness of his background and depth in the field of CAD/CAM made this course very interesting. As a basis for the course content Dr. Zimmers used material from his book "CAD/CAM - Computer Aided Design and Manufacturing"[1] which he co-authored with Dr. M. P. Groover. Chapter 21 in this book "CAD/CAM Implementation" is an excellent overview on the guidelines and criteria for implementing a CAD/CAM system. These guidelines have been of great help during the implementation of CAD/CAM system at AT&T Technology Systems at Reading, where I am employed as a Factory Planning Engineer.

My association with the CAD/CAM project at AT&T, Reading has reaffirmed my belief that selection and implementation of a CAD/CAM system can be extremely complex, and therefore proper and detailed planning is a must for this system to be successful. As Charles S.

[1] Mikell P. Groover and Emory W. Zimmers, Jr., "CAD/CAM - Computer-Aided Design and Manufacturing" Prentice-Hall, Inc., 1984, Chapter 21, pp. 461-469

Knox[2] has put it rightly:

"The essence of successful implementation of a CAD/CAM system is to be able to identify as many alligators as possible in the swamps surrounding implementation of an integrated CAD/CAM system. CAD/CAM is expensive. It will also create comparable savings and productivity increases. To make CAD/CAM work will require trust, cooperation, intellectual honesty and courage. The hardware, the software, the ability to educate, the communication links, and probably even the money is available. A sound plan combining recognition of specific needs and a sequence to implement them is really all that's missing. CAD/CAM can be friendly revolution or another horrible nightmare for industry."

The above is very much applicable to the development of strategy in this thesis.

[2] Charles S. Knox, "CAD/CAM Systems, Planning and Implementation", Marcel Dekker, Inc., 1983, Preface p. vi.

Chapter 4 Literature Search

In recent years, CAD/CAM has increasingly become the topic of technical publications, magazine articles, and seminar presentations. Most of these articles and presentations deal with the technological developments in this field which are so wide and rapid that it is difficult to keep pace with them. There are however a few books and articles dealing with the methodology for implementation of CAD/CAM systems.

According to Charles S. Knox[1] thirty years ago accounting and manufacturing systems were in the same state of fractioned parts engineering systems are now. CAD/CAM will integrate the engineering process into the rest of the manufacturing company to create a powerful, synergistic, economical and flexible integrated system. CAD/CAM could be an expensive experiment if not planned and implemented carefully.

Paul Quantz[2] also emphasizes that CAD/CAM has changed in status from a few handy technical tools to a key element in strategic business planning for the factory

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[1] Charles S. Knox - "CAD/CAM Systems Planning and Implementation", Marcel Dekker, Inc., 1984, p. 302

[2] Paul Quantz - "Planning CAD/CAM for the Factory of the Future", Auerbach Publishers, Inc., 1984, Section 2.1.1

of the future. The planning process should produce a 10-year vision of the future factory's operation, and a 5-year CAD/CAM implementation plan. Gaining the full benefits from CAD/CAM requires breaking with tradition; restructuring organizations and work processes; changing staff skills; launching communications and education programs; and changing capital priorities. These requirements make CAD/CAM a very complex program to get under way quickly. A CAD/CAM program requires integration across organizations to a degree not encountered in less pervasive technologies. Also, it often forces an unprecedented clarity of purpose in an organization's strategic course. Launching a CAD/CAM program is complex and difficult, but CAD/CAM successful implementation can lower costs, increase effective capacity and product quality, and enhance flexibility and responsiveness to market changes. These rewards combined with better competitive position in the future will prepare organizations to launch a well planned and aggressive CAD/CAM programs.

Most of the experts in this field agree that it is the initial goal setting and planning which plays a major role in making the CAD/CAM system successful. Dr.

V. J. Thomson[3] suggests that if done properly, establishing goals and determing required and desired CAD/CAM system features represents approximately 75 percent of the total acquisition effort. The actual evaluation, checking each potential system's characteristics against the pre-determined evaluation critera, should then be relatively straightforward. In addition, these initial efforts will ensure that expectations for the system ultimately acquired are realistic and that implementation and long term planning efforts are directed toward fulfillment of the stated goals.

Dr. M. P. Groover and Dr. E. W. Zimmers, Jr.[4] in one of their recently published books recommend the following general procedure and guidelines as being appropriate for implementing the system:

a. Develop the criteria for selecting a turnkey CAD/CAM system. The criteria should be defined with the specific needs of the user company in mind.

b. Study and visit other companies using CAD/CAM

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[3] Dr. V. J. Thomson - "Preparing for and Performing a CAD/CAM Systems Evaluation", Auerbach Publishers, Inc., 1984, Section 4.1.2, p. 2.

[4] M. P. Groover and E. W. Zimmers, Jr., "CAD/CAM Computer-Aided Design and Manufacturing", Prentice Hall, Inc., 1984 pp. 461-472.

systems with similar needs. Assess their effectiveness in similar applications.

c. Study the CAD/CAM vendors. Invite them in to make presentation on their company and product lines.

d. Reduce the list of vendors down to the three or four most attractive candidates.

e. Determine a benefit/cost ratio (a system value per cost for the specific needs of the user company) for each system under consideration.

f. Invite the vendor with the highest ratio to run a benchmark.

g. If the benchmark test is successful, the vendor is officially selected. If not successful, the second choice based on benefit/cost ratio is selected for benchmark testing - and potential contract award.

It is further recommended by the authors that a CAD/CAM evaluation team should be set up whose job should be not only to develop the selection criteria, but also to evaluate the alternative systems. A representative checklist of considerations and criteria for selecting a CAD/CAM system is also presented.

Knox[5] recommends following checkpoints that can be

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[5]Charles S. Knox - "CAD/CAM Systems Planning and Implementation - p. 32-35.

used by a company to see if they can qualify and be successful in the implementation of a CAD/CAM system.

1. Recognition of productivity problems
2. Involved management
3. 50% parts internally designed.
4. Adequate engineering documents
5. Piece part drawings
6. Integrated system desire
7. Numerically controlled tool requirements
8. Design analysis
9. Willingness to analyze present methods

The above introspective approach is very useful in setting the goals and objectives for a CAD/CAM system implementation.

Charles M. Foundyller[6] also advocates following guidelines for implementation of CAD/CAM systems:

a. Define CAD/CAM's place within the organization
b. Define the systems objectives
c. Staffing and training
d. Programming
e. Environment
f. Payback accounting

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[6] Charles M. Foundyller - "Evaluating Today's Turnkey CAD/CAM Systems", Daratech Associates, 1981.

g. Acceptance test planning

h. Operations planning

i. Control access, time, data and maintenance

j. Account for usage

k. Look ahead

The above supports the basic premises of this thesis in as far as that there has to be a logical step-by-step approach for CAD/CAM implementation.

On the issue of productivity increase as a result of CAD/CAM implementation, research is being conducted by Michael Packer and Zella Kahn[7] both of MIT, which will carefully examine how a number of firms are implementing CAD/CAM. This study hopes to gauge both tangible benefits of CAD systems such as shorter project and design flexibility and such intangibles as creativity and design uniqueness. In order to provide credibility to the productivity ratios, the study will collect data from a large number of manual and CAD designs and use statistical methods to compare them. This technique, the authors say, will allow them to objectively evaluate how each facet of design complexity contributes to the actual time needed to complete a design job. In addition, they will be able

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[7]Michael Packer and Zella Kahn - "A Multi Firm Study of the Benefits of Computer-Aided Design Systems", NCGA '83 Graphics Art at Work Conference Proceedings, June 26-30, 1983.

to objectively calculate the effect of CAD systems on both design and overall project time.

Some of the preliminary data of this study has indicated that the CAD assisted designers do not seem to perform much better than manual designers in some of the intangible aspects of effectiveness. Also, that the CAD groups seem to have poorer teamwork than manual design teams. This may lead, say the authors, to a problem in transferring knowledge from experienced designers to younger engineers working on the CAD system.

The above supports some of the concepts as a part of the strategy developed in this thesis.

One other study[8] has drawn interesting conclusions. It shows that 40% of all drafters can become "good", 40% can become "expert" and only 10% "marginal" in the use of computer graphics. The study also shows, however, the time it takes to become an "expert" is approximately six months.

The conclusions drawn are that if we pressure new terminal operators excessively, we are liable to hurt them by insisting on "productive" work prematurely. A carefully planned program of training and implementation is therefore important.

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[8] "Turnkey CAD/CAM Computer Graphics Systems: A Survey and Buyers Guide for Manufacturers", Daratech Associates, Inc., 1981.

Knox[9] summarizes his philosophy underlying the implementation of CAD/CAM systems. He states that the "front end" of project planning is a far less expensive place to make an error. Typically near the end of preliminary design 4% of the total program costs have been spent; however 70% of the decisions that affect the ultimate product have already been made. Thus the introduction of new and efficient methods into the problem-solving process has the opportunity to increase the leverage of the 4% cost expenditure, and to reduce the risk in the 70% of management decisions accumulated to that point. Thus a productivity concept is to "do it right the first time".

The above supports the basic premises of this thesis that a well planned strategy is a must right at the outset for successful implementation of a CAD/CAM system.

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[9] Charles S. Knox, "CAD/CAM Systems Planning and Implementation", p. 287.

Chapter 5 STRATEGY DEVELOPMENT

Based on literature available and research, the general strategy for implementation of CAD/CAM system can be developed by concentration on the following potential areas:

5.1 Systems design, specifications and evaluation

5.2 Systems justification based on cost/benefit analysis

5.3 Human factors both physical and psychological

5.4 Systems staffing including recruitment and training

5.5 Systems implementation and follow-up

5.6 Systems growth and evolution

Each of the above areas is explored in detail in an endeavor to establish its role in the formulation of an overall strategy. As a result the following is proposed:

5.1 SYSTEMS DESIGN, SPECIFICATIONS AND EVALUATION

The CAD/CAM systems design, specifications and evaluation lays the foundation for a system which could be expected to last for decades. If there are significant flaws or omissions in the design, great inconvenience and expense could be caused long after the system is in operation.

The process of systems design, specifications and evaluation should involve:

- Determination of organization needs.
- Identification of services that are available to satisfy those needs.
- Knowledge of CAD/CAM responsibilities to help formulate CAD/CAM goals.
- List of system requirements for meeting these goals.

Keeping the above in view, the basic steps proposed are:

1. Forming the Evaluation Team

   The first step is to form an evaluation team. The departments' recommended for representation in the evaluation team are:

   - Design Engineering
   - Manufacturing Planning
   - Manufacturing Engineering
   - Engineering Standards and Drafting
   - Business Data Processing
   - Marketing

2. Performing a Needs Analysis

   The evaluation team may develop a list of the organization's CAD/CAM requirements. For this it will be necessary to conduct a complete survey by sending a standard questionnaire to all departments which will be most influenced by CAD/CAM. The survey results should highlight those areas in which CAD/CAM can improve performance, establish the focus for subsequent analysis. The areas could be:

- Drawings
- Design analysis
- Engineering changes
- Manpower
- Classification
- Manufacturing
- N.C. Machine Tools
- Service manuals

Current manual and semi-automated drawing/design and manufacturing methods should be considered, and future needs in these areas should be projected.

3. Assessing Technology Capabilities

Concurrent with the needs analysis, inquiries into the marketplace are necessary to learn the present CAD/CAM capabilities and those that are likely to develop in the next few years. Numerous resources may be used to determine what technology is available in the CAD/CAM marketplace and how it is being used. In the initial investigation stages, literature such as vendor information, technical periodicals, etc. will highlight CAD/CAM capabilities and potential uses.

4. Site Visits

Informative literature gives little insight into the quality of interaction or the rate at which work can be done with a particular CAD/CAM system. Visiting companies that have installed systems will provide more information about how automated methods can solve problems, and reveal those areas that CAD/CAM systems cannot yet help. It is also advisable to solicit criticism from users about the system features and particularly about the support received from the vendors. Obtaining realistic expectations of what CAD/CAM can do for specific engineering and production problems is essential to a successful evaluation process.

5. Trade Shows, Tutorials and Conferences

These offer additional opportunities to observe CAD/CAM systems in use and more important - a chance to obtain user feedback on system use. Usually these forums allow contact with more systems, vendors and users of systems than site visits could reasonably provide.

6. Consultants

Many firms do not have the in-house expertise necessary to evaluate CAD/CAM needs or CAD/CAM systems. In some cases a company that has the expertise may desire an independent opinion in order to confirm the validity of a CAD/CAM justification to upper management. A consultant can substantially reduce the time involved in gathering marketplace information, accessing available technology and forming realistic expectations of CAD/CAM benefits.

7. Defining CAD/CAM Goals

Management should state the goals for the CAD/CAM acquisition based on the results of the needs analysis and marketplace research. The importance of defining and documenting the reasons for installation and operation of a CAD/CAM system cannot be overstated. The manner in which CAD/CAM capabilities will be acquired and implemented must also be determined. The major choice is between building a highly customized system, usually dealing with multiple vendors and drawing heavily on in-house resources, or buying a complete system, which requires minimal customization, from a single turnkey vendor. Most companies need some customization of CAD/CAM system to meet specific design and manufacturing requirements. When evaluating CAD/CAM systems and vendors, therefore, a company should consider which system can be customized most easily to meet its particular needs.

8. Cost/Benefit Analysis

With well defined goals and an understanding of the technology and its capabilities, a cost/ benefit analysis can be performed to quantify and formalize the justifications for a CAD/CAM acquisition. At this point, management may firmly decide whether the needs for and objectives of a CAD/CAM system warrant a purchase. If the decision is affirmative, it should be backed by management's strong commitment to support the CAD/CAM project.

9. Listing Essential & Desirable CAD/CAM Features

The preparation of the CAD/CAM system technical specifications is a very important step in the process of acquisition of this system as this can be used for several purposes:

- To solicit proposal from vendors and then to assess the compliance of contending vendors.

- To guide the development of adequate system benchmarks.
- To serve as part of the purchase agreement for the selected equipment.
- To guide system installation and acceptance and subsequently evaluate system performance.
- To justify system enhancements following the initial system implementation efforts.

10. Request for Proposal (RFP)

A typical RFP should include the following sections.

a. Terms, Conditions and Special Considerations.

b. Benchmark Considerations - then alert the vendor to the requestor's desire to conduct simulated production exercises subsequent to review of the vendor's proposal.

c. Intended System use giving current methods of operation and the anticipated method of CAD/CAM System operation.

d. System Software Requirements - this is generally packaged with the vendor's computer according to the selected hardware configuration. However this should address the operating system, basic functional interactive graphics, data manipulation, utility and special applications software. Users should ask whether applications can be interfaced with basic graphics software. Desired CAD/CAM system interfaces should be specified.

e. System Hardware Requirements - the RFP document should require the vendor to provide a comprehensive system hardware proposal that describes the DPV graphics workstations, direct access and magnetic tape storage capacities, quick-look printer/plotter and precision plotting capabilities input, documents digitizing, communications to external system, the optional or future implementation of hardware devices.

f. System Support and Maintenance Requirements - System software and hardware capabilities are productive only when maintained at the required levels of responsiveness, availability and reliability. The RFP should specify that the vendor provide support and maintenance for all system components - (i.e. hardware, software and interfaces) for the life of the contract. In addition, preventive maintenance considerations should be included.

g. User Training - User training is essential to the success of CAD/CAM implementation. User instruction must be customized to accommodate a range of skill levels and functions: training will involve system overview and demonstrations for user management, in-depth system operations for the technical support staff, system programming for development personnel, and general operations and application package training for user personnel. The RFP should request training at the vendor site before installation.

h. System Warranty and Acceptance - The technical specifications should detail factory acceptance testing and hardware and software warranty periods.

11. Final Evaluation and Selection

Before the benchmarks are performed, a table of evaluation criteria can be developed and given to the reviewers of the CAD/CAM system. The criteria for evaluation could be:

a. General system capabilities

b. How each system is addressed to the Company's particular needs.

c. Benchmark performance

d. State of the technology used.

One method is to use a weighted scale for each criteria. Each reviewer scores each vendor individually and the results are then averaged. Totals are arrived at by multiplying each score by the appropriate weight and totalling the weighted values.

Concluding Comments

While the results will, of course, be different for each company because of differing requirements and evaluation criteria, the process described as above is a general methodology for any organization preparing to evaluate CAD/CAM systems, which may be modified depending upon the uniqueness of the organization.

5.2 SYSTEMS JUSTIFICATION - COST/BENEFIT ANALYSIS

The decision to invest in a CAD/CAM system for future economic gain is quite difficult and requires careful analysis. What makes this decision particularly hard is the degree of uncertainty surrounding the assumptions and forecasts about the CAD/CAM system's performance, its effects on the organization, and about likely future external conditions (for example, workload) on which such an analysis will have to be made.

In most corporations, the acquisition of a CAD/CAM system is a major capital investment and, as such is governed by the corporation's capital investment policies. These policies vary from company to company, but the underlying principles remain the same. A necessary first step in an analysis and justification is a thorough investigation of the problems and the alternatives. For example, it is always possible to do nothing and continue operation in the same way. In fact, the forecast result of this alternative can form the basis of comparison for the investigated alternatives.

Economic Analysis of CAD/CAM Investment

Some of the vendors of CAD/CAM systems claim productivity gains from CAD/CAM operations of the order of 10, 20 or even 40 to 1. Such projections however lack substance. These should be probed which could reveal omission of sizable service contract costs, training, programming, and administration costs in the overstated savings. The claims could therefore be unreliable and open to various conflicting interpretations. A safe and recommended approach is to collect data from different system user groups with similar applications. It requires extensive follow-up discussions with their respective CAD/CAM personnel and is therefore time consuming but the approach is worth its effort. It is possible this way to get realistic savings and pay-back figures and to be able to identify those systems that could provide relevant applications, perform reliably and earn a high return on invested capital.

Based on the needs analysis, it is assumed that the potential CAD/CAM applications have been clearly identified by the task force as discussed in Section I. Using data from the user group these applications can now be evaluated both operationally as well as financially with overall tangible savings in each of these areas.

For economic analysis the most commonly used techniques that can be employed are:

- Pay-Back period method
- Return on investment method
- Net present value method
- Internal rate of return method

However the financial analysis based on tangible savings in most of the cases does not turn out to be very attractive as the payback period may be more than what the company desires, or what the company policy dictates. In such cases it is safe to present the facts as they are to the upper management emphasizing conservatism and built-in compensation for variables and unknowns.

While exercising extreme caution as part of justification process, two important factors in any CAD/CAM proposal which could be addressed are the intangibles (or hidden benefits) and the long range strategic impacts of CAD/CAM.

1. Intangibles - Experience suggests that there is a strong case for quantifying some of the intangibles which are:
   - Interactive graphics can produce more ideas and better designs with fewer design changes.
   - A high degree of standardization possible by reduction of parts.
   - Enhancement of creativity by using less skilled people for higher order design activities.
2. Strategic Impact - From a strategic point of view the advantages of CAD/CAM system that could be emphasized are:

- CAD/CAM is the primary building block for developing systems and methodologies to strenghten an organizations position in the market place.
- CAD/CAM enables the design and production of higher quality products at lower cost and with fewer errors.
- CAD/CAM enables faster turnaround of higher quality proposals.
- CAD/CAM generates a higher level of customer confidence.
- CAD/CAM helps integrate engineering and manufacturing.

Concluding Comments

It is recommended that extreme caution be taken while justifying CAD/CAM system, requiring large investments by the company. Vendor claims can be misleading and should not form the basis for such a justification. Virtually all these vendors endorse their CAD/CAM system operations in glowing terms and can raise very high expectations of the system. If these claims are used in the justification process without proper examination and probing, they could lead to disappointments and catastrophe.

Justification of the system should be based on realistic expectations of the system and should be a painstaking exercise requiring thorough investigation and using reliable and impartial systems user references as a guide. This will serve as being a safeguard against any negative surprises/disappointments for the management during the process of CAD/CAM system implementation.

5.3 HUMAN FACTORS BOTH PHYSICAL AND PSYCHOLOGICAL

CAD/CAM systems generally are selected on the basis of technical capabilities. If users are to achieve significant increases in production however, the systems technical features should be balanced with consideration of human factors. Human factors engineering emphasizes that computing systems should be developed as tools that help users perform their jobs and that such an approach to systems design results in user-friendly systems that consequently are productive computing tools. User expectations and levels of experience vary widely, however it is unrealistic to expect that a CAD/CAM system will be friendly in all respects to all users. Therefore the aim should be to ensure that the most users are satisfied.

User Friendly System

The primary goal of the system should be to have user-computer interaction which is most productive. The effective user-computer dialogue maximizes the extent to which the computer automatically establishes the format, thus allowing the user to concentrate on the information content.

Dialogue consistency is a major aspect of user friendliness and is characterized by:

- Standardized procedures
- Dialogue that ensures that all users apply the same meaning to words.
- Relatively brief messages and abbreviations, particularly if the same dialogues will be used repeatedly by the same individuals.

Vendors should be able to demonstrate consistency in dialogue format and style, including similar display formats and command structures for the variety of tasks the CAD/CAM system will be used to perform. The same format should be used each time the same information is displayed. The system should be evaluated to ensure that the same basic interaction process governs all tasks performed by the system. Dialogue clarity, precision and simplicity are essential for a user friendly interface.

CAD/CAM systems exist to support human tasks and their design should be such as to anticipate human mistakes and correct them quickly and easily. Ergonomic error-handling facilities detect human errors and system failures with minimal, if any, time and data loss.

A user with no interactive computing experience does not know what is required to operate a CAD/CAM system. More important preferences and needs change as users gain system experience. For example, experience changes an operator's perception of ease of use. A system that an inexperienced user can easily learn to use may prove cumbersome to an experienced user, while a system that seems more difficult initially may have highly flexible interactive techniques that will allow experienced users to operate it more productively. Therefore vendors should be asked to demonstrate how experienced users would, for example, bypass prompts, stack commands back to back and use abbreviations rather than entire command words.

Also the ease with which users can transmit data is an important factor in the selection of a CAD/CAM system. Technical issues involving data formats, communications protocols magnetic tape formatting characteristics and the procedures required to pass data between systems can be complicated and can result in difficult user-computer interaction. Vendors should be asked to explain the communications standards they support like (IGES), etc. to evaluate how easily data can be transmitted.

The work-station is another critical component for interaction and therefore the environmental and ergonomic aspects of work-station design are very important aspects in developing and selecting CAD/CAM systems.

In conclusion designing user friendly systems interfaces is as important as the technical capabilities of any CAD/CAM system and the human factors requirements should not be ignored in its implementation.

Working Conditions

Working conditions as a whole should be improved with CAD/CAM installations. Usually an office remodelling is recommended for creating a pleasant productive environment. It is for management to instill a fueling of positive attitude towards new CAD/CAM technology. The creative aspect of the job should be emphasized which can be both satisfying and rewarding. With CAD/CAM results, gratification can come more quickly and easily and the emotional response to this amongst draftsmen and engineers can be outstanding.

However, a very intense emotional frustration can develop when things don't go right. When there is a bug in the software or the hardware is down, people get very depressed and downright hostile. The morale problems will be based on how well the system works, and hence the importance of a reliable and up-to-date system cannot be re-emphasized.

Implementing CAD/CAM - Organization's Restructuring

Planning the introduction of CAD/CAM is a delicate and demanding task that requires an understanding of the problems that are likely to come up. With CAD/CAM "letting it finds its place" is a dangerous approach that frequently limits the benefits realized and, in some cases, leads to the complete rejection of a system.

A central decision that should be made early on is how to fit CAD/CAM into the existing organization structure. The success of the new system depends on voluntary cooperation between the various engineering and manufacturing departments involved. These departments (typically engineering, drafting, manufacturing and quality control) have independent objectives, manpower, and budgets and may not at first be inclined to support all the changes in procedure proposed by a CAD/CAM manager. Further, each department will have a different perception of CAD/CAM benefits and what they stand to gain, or lose, with each proposed change. This makes the management job extremely delicate and a high level of understanding and sensitivity will be needed to anticipate and deal with the various concerns that emerge. At first it is best to make every effort to educate and accommodate the various departments rather than try to impose changes on them. Later on, when the benefits of CAD/CAM are more widely appreciated, a stronger coordinating authority may emerge with the clout to ensure that every departments' budget, manpower, and policies are coordinated with an overall plan to integrate CAD/CAM into all segments of the corporation's operations. But initially it is best to rely on the goodwill and understanding of all concerned.

As one manager I spoke to put it, "Go easy, be ready to educate the doubters, have patience, anticipate problems, and don't try to do too much at once."

Although capital shortage and top management complacency are often cited as the major obstacles to implementing CAD/CAM, inertia and middle management reluctance to change often prove to be the real obstacles to modernizing work systems. Additionally a technical staff that lacks systems engineering and data processing skills seriously inhibits CAD/CAM implementation - in the production, design, and tool design organizations.

The middle level functional managers (e.g. chief engineers, manufacturing managers) usually have limited knowledge of computers and their applications and are often the most reluctant to support CAD/CAM because they are directly responsible for the company resources (i.e. budgets, facilities, people) and productivity that will be impacted.

Established practices usually inhibit imaginative pursuit of new CAD/CAM application opportunities. Leadership initiative is required to prove the value of CAD/CAM applications.

Concluding Comments

CAD/CAM is the first on-line system that can be made inoperable by the user. If the complete understanding of the principles and the interactive human machine inter-relationship are not known, the system can fail or at least, generate disappointing results. The user should feel the system to be friendly, not threatening. Thus ease in the integration of people with the system is recommended. If we are not careful, we will fail to fully utilize one of the major benefits of CAD/CAM.

5.4 SYSTEM STAFFING INCLUDING RECRUITMENT AND TRAINING

The introduction of a CAD/CAM system needs some assistance from CAD/CAM professionals. This may come from outside consultants and vendors, by using existing expertise in the organization, by hiring CAD/CAM specialists and/or training existing employees. The level of expert involvement will depend on the scope and complexity of the service and the nature of operational needs.

The organization's existing level of expertise may be evaluated before defining CAD/CAM personnel requirements. What kinds of backgrounds are suitable for the job requirements? What type of career path can the individual be offered? What is the best balance of new hires versus internal promotions to support the company's newly defined needs? These questions should be asked in context with the requirements for the CAD/CAM system.

Key CAD/CAM Personnel Positions

In the CAD/CAM Dept. there are typical personnel positions including:

1. Internal CAD/CAM Consultant

   The internal CAD/CAM consultant is a key employee whose responsibilities encompass all of a company's CAD/CAM activities. This individual should know both the employer's industry and CAD/CAM technology in order to determine how it could best fit into the organization. A good balance of both industrial and academic achievement is required. The organization should not overlook its own employees, although internal candidates must possess strong management skills and a comprehensive working knowledge of the entire organization's goals and methods of operation.

2. CAD/CAM Systems Manager

   The system manager should have a comprehensive understanding of systems operations. In addition, the manager should have a strong software background and know-how to make the system solve a wide range of problems. The responsibilities of a system manager vary depending on the organization's level of CAD/CAM involvement. If a system evaluation and feasibility study is yet to be undertaken, the system manager usually directs the studies. If a new system is in order, the system manager handles installation and integration into daily operations and trains operating personnel. This individual would carry all the responsibilities for system operations, including staff management and operations, maintenance, and programming direction.

3. <u>CAD/CAM Applications Engineer</u>

   The applications engineer should have extensive application knowledge and understand the technology available to solve these applications. Programming skills are less critical here than applications understanding. The applications engineer should be able to communicate system capabilities to the balance of the organization in order to maximize system use.

4. <u>CAD/CAM System Programmer</u>

   Although the system programmer does not need significant applications knowledge, this individual should understand the system's software and hardware capabilities. Typically, the programmer might have a software background and know operating systems, systems utilities software, and data communications.

5. CAD/CAM System Operator

The system operator, who has a general purpose function, can be found in a myriad of sources. Individuals for this position often are found within the organization. The system operator position can provide an advancement opportunity for an aggressive individual to pursue new and different career aspirations.

6. The CAD/CAM User

The design/drafting user should possess the skills necessary to understand the systems applications and needs only a casual knowledge of how the system operates, more so in an interactive than in a batch environment. The engineering user is the actual problem solver, and the manufacturing user typically prepares programs to implement manufacturing process control software. Both the engineering and the manufacturing user should have sound knowledge of the system, its capabilities, and the means by which problem solutions and implementation are performed.

Recruiting and Compensation Plans

Recruiting employees from other companies which can be very expensive and time consuming, is often inevitable in high-tech fields in which needed skills are in short supply. An organization should define and set priorities for key positions before actual recruitment begins.

Experienced computer people with specialized skills command significant salaries. Developing compensation plans for all ranges of skilled CAD/CAM personnel is a major task for an organization. For example, there is not a vast pool of individuals with CAD experience. There is also a shortage of individuals with the skills required to operate numerical control and other automated manufacturing systems. Those that have such experience are therefore a valuable commodity.

Training and Development

The training offered by turnkey vendors varies widely, both in quality and quantity. Some offer courses at the buyer's site only and use the newly purchased equipment in the course. Other vendors hold a regularly scheduled series of coordinated courses on their own premises in well-equipped classrooms and laboratories. The better courses are structured affairs given by full-time professional instructors. Timing the training sessions can be important. The best time to undergo training is immediately before the system is installed. This is because newly learned skills are quickly forgotten if not put into practice.

Some representative courses can be as follows:

- Basic Operator's Course - An entry level course designed to teach basic skills, e.g. turning the system on and off; operating the work station components; command structure; graphics creation and editing commands, use of on-line storage; use of magnetic tape; elementary dimensioning; text insertion; function menu design.
- Advanced Operator's Course - designed to teach operators advanced commands and techniques, e.g. data structures, data extraction for bill-of-material and other reports; generating NC manufacturing tapes; 3-D operating parts properties extraction; building models for finite element analysis.
- Applications Course - an engineer's or

operator's course designed to teach how to use specialized analysis, report generating, or other design or manufacturing applications software package.

- Applications Programming Course - a programmer's or advanced operator's course designed to teach how to design, code, debug, and install special purpose programs in a graphics design language, e.g. language structure, statement format, vocabulary; operating systems interface; entering a program; editing a program; compiling a program; installing and executing a program; de-bugging a program; saving a program on a tape.
- Management Course - designed to teach the elements that go into pre-installation planning and system management, e.g. work station layout, lighting, and access scheduling; personnel selection; personnel training; hiring; wage scales; labor/management relations; career paths in CAD/CAM; establishing a high productivity environment.

Concluding Comments

In most companies the CAD/CAM systems are implemented by an in-house project team. It is important that the members of the project team are technically competent as the system can be very complex and too involved. If the persons with requisite background and expertise are not available within the organization, then they have to be hired from outside. A planned program of recruitment, training and employee development is recommended for the success of the CAD/CAM system.

5.5 SYSTEMS IMPLEMENTATION AND FOLLOW-UP

The final stages of preparing for implementing a new CAD/CAM system have frequently been regarded as the least "glamorous" aspect of a project. This has often led to a rush to implement the system using as few resources as possible without systematic planning which is so essential for implementation. Planning and policy setting ease the transition from manual design and drafting methods to CAD/CAM, minimizing frustration and encouraging success. Major considerations for CAD/CAM implementation recommended are:

Facilities Planning Considerations

During discussions with the selected CAD/CAM vendors, the project team should inquire about environmental requirements for implementation. Most vendors offer comprehensive support to help customers plan for and install equipment which involves:

- Determining the equipment configuration and proposal locations.
- Determining the available space, air-conditioning and power at the proposed installation site.
- Determining existing environmental conditions (i.e. altitude, air quality, lighting, temperature, humidity).
- Determining equipment support requirements (e.g. HVAC, power, space, cabling).
- Determining personnel and operational requirements (e.g. lighting, storage space, work flow).
- Preparing a scaled diagram of the installation layout.
- Modifying the site for compatibility with equipment, personnel, operational and safety requirements.
- Drawing out detailed installation schedule.

Vendors can assist and support facilities planning by providing a site survey, making recommendations. They also provide a detailed site preparation manual with all pertinent installation information, including power requirements, heat dissipation, etc. for all major facilities comprising:

1. Central processor
2. Printers, plotters and other peripherals
3. Work-stations

This data is necessary for planning system installation.

<u>Setting Implementation Policies and Procedures</u>

Three major procedural areas for consideration prior to actual operation of a CAD/CAM system in a production environment are:

1. <u>Establishing an Organizational Structure</u>

   A critical element of successful CAD/CAM systems implementation is the establishment of a responsive organizational structure. Such a structure would typically include a CAD/CAM planning committee, operations personnel, and system support personnel.

   Once the CAD/CAM system is installed, a planning committee should be formed to review and develop policies, procedures, and methods for applying the system's capabilities. Through the establishment of a planning committee, the short term effects of CAD/CAM are greatly enhanced, and as new CAD/CAM technology applications surface, the role of CAD/CAM in supporting the company's long-term objectives will be optimized.

Factors which may be taken into consideration to determine operations and support staff requirements include identifying the individuals who will provide the everyday operations and support to the user community and those who will perform scheduling, training and software development activities. The size of the system (i.e. the number of workstations and their dispersal) and the number of shifts needed also affect operations and support staff requirements.

2. System Usage Scheduling

Companies that have allowed system usage on an as-needed basis have suffered decreases in both user performance and system effectiveness. Scheduling system usage, however, ensures that individuals are assigned on a daily basis to programs or projects that provide the greatest benefit to the company. When scheduling initial CAD/CAM operations, one project or product should be identified as the starting point for CAD/CAM usage and data base generation. As scheduled release dates are defined for new drawing documentation, key personnel are also identified and scheduled for system usage to ensure that product definition and system usage are compatible with drawing documentation release dates. This process of scheduling key personnel and jobs on the system maximizes resource use and provides maximum benefit to the company.

3. <u>Reporting Techniques</u>

Once users are on the system generating engineering documentation, the company may provide an avenue for user feedback on system performance. One technique involves keeping a log sheet at each terminal to identify the user, the program, the task, the time spent, and any software or hardware error codes. This data can be used for generating post implementation audit trails. A remarks column should also be provided, so that users can describe any problems encountered. In this manner, users generate perpetual feedback on system performance, identifying terminal activity and the various hardware and software problems that occur.

4. Data Base Generation

A CAD/CAM system data base can be established in many ways. Careful planning is necessary to ensure that the data base will be accurate and complete. In addition, consideration may be given to the time and personnel required to construct the data base. Rarely should all previously defined documentation be input to the initial CAD/CAM data base - the loss of productive staffing is too significant and not all existing data is needed to effectively use the CAD/CAM system. If the company product is based on electrical or electronic components, the product definition data base can be generated through the use of large digitizers attached to CAD workstations. These digitizers provide an easy means of inputting two-dimensional symbols and diagrams commonly used in electronic component design. For companies with electromechanical or mechanical products that require three dimensional modelling, the only feasible approach is to reconstruct product definitions on the CAD/CAM system. The reason for reconstructing mechanical components is that drawings produced by conventional drafting methods cannot be digitized accurately.

Post Implementation Evaluation

As part of the overall information management strategy, provision may be made for evaluating, on a continuing basis, the performance of the CAD/CAM system. The post-implementation evaluation brings the systems development process cyclically back to the starting point: the management objectives which the system was designed to satisfy. Using similar terms of reference to those specified for the feasibility studies, the actual costs, benefits and operational performance should be examined and compared to the original objectives and the expected effectiveness which was promised by the feasibility studies. At first the evaluation will involve comparing costs of the new system with those for the old system but further evaluation should be carried-out on a routine basis to see that the benefits are being maintained or that inefficiencies have been corrected. Post-implementation evaluation should be carried-out with the same thoroughness and comprehensiveness as the initial feasibility studies and should involve the views and experiences of all those affected by the system.

This evaluation will serve as a springboard for further developments, identifying new opportunities that could be achieved as a by-product of the existing system and ensuring that future CAD/CAM developments can draw on the past to avoid some of the pitfalls.

At least an annual audit of the overall CAD/CAM system should be considered as part of every organization's procedures with more regular appraisals for particularly important aspects. The reactions of staff and managers should also be consistently monitored through normal management channels.

Concluding Comments

It is proposed that facilities planning and coordination for system installation be done to help ensure that the maximum benefit is derived from CAD/CAM investment. Well planned CAD/CAM system facilities can be showcase for innovative management techniques and technology use and can provide a comfortable and enjoyable place for employees to work with new tools.

Making the transition from CAD/CAM systems planning to operation requires a sound organizational structure with the establishment of a planning committee and operations and systems support personnel for successful system implementation. Through the planning committee not only a plan for implementing the system be created and managed with systematic care but a constant eye can be kept on the long term objectives that are to be met. Finally, management's commitment to controlling and developing the benefits of CAD/CAM system should not end when the system goes live but should become as much a part of the natural management process as the preparation of annual accounts and the monitoring of corporate performance.

5.6 SYSTEMS GROWTH AND EVOLUTION

A company acquiring a CAD/CAM system is bound to require additional or enhanced system capabilities in the future. It is therefore recommended that while planning the initial implementation, the system and vendor's potential growth criteria should be evaluated. For the successful evolution of a CAD/CAM system it is necessary to be able to timely add the resources needed to maximize long term effectiveness.

The growth of a CAD/CAM system can be caused due to several factors:

- Increased system use for existing applications.

- Additions of new applications.
- Integration of CAD/CAM systems with one another or with other business systems.
- Upgrading of existing processors or replacement by processors with greater capabilities.
- Systems updating with technology improvements.

Measuring Existing Systems Capacity

Many techniques can be employed to measure the capacity of the current CAD/CAM system. To simplify the capacity measurement process, a CAD/CAM installation can be viewed as a system of individual resources. Capacity can be measured as a point at which the use of an individual resource or capability becomes saturated and diminishes the performance of the entire system below acceptable performance levels. Current system capacity is measured to determine whether or not the combined capacities of the available resources provide satisfactory service for the current work load. This is accomplished through continual monitoring of system performance to measure such variables as transaction rate and response time. Simple mathematical techniques such as linear projections and analytic or queueing theories can be used for capacity planning.

Project System Growth

To accurately project system growth, the computer resources required for CAD/CAM use can be monitored for usage trends. The resources to be monitored include CPU requirements, directly accessible disk storage input/output, and terminal input/output. Future CPU requirements can be estimated by converting the current and projected user workload into a measure of CPU usage. For example, if 10 operators use 50 percent of the system and the organization plans to increase system usage to 75 percent, five additional users can be added to the system. Factors to be considered are:

a. Transaction Rate - A CAD/CAM system is transaction driven. The transaction rate is a measure of the volume of work that can be done by the computer over a period of time. The transaction rate is typically affected by the level of experience of the users, the complexity of the work performed on the system, and the number of active users.

b. Response Time Objective - The response time objective which depends on both the CPU power and the transaction rate, should be carefully considered because it affects system capacity

- more than any other factor. The response time objective determines two important parameters: how fast the system responds (and therefore how productive the system can be) and how much an organization is willing to pay for that level of service.

Although the exact response time needed varies with the organization, studies have shown that user productivity begins to diminish after waiting more than half a second for a response. An important qualification of the response time objective is that it meets the users expectations.

c. CPU Processor Model - The relative power of the processor determines the CPU portion of the response time (i.e. the more power, the greater the potential for faster response time). Thus, a CPU has an inherent minimum response time because of its internal cycle time, maximum available real memory and channel capabilities.

d. Operating System Memory - Many operating systems incorporate the use of virtual memory which can reduce the need for real memory. This makes the system available for more applications.

e. Directly Accessible Disk Storage Capacity - Most systems require the user to initially access the permanent drawing file to retrieve a design to be worked on; however the working drawing is retained on temporary disk space until the user requests a permanent copy. When two or more users try to read information from different places on the disk, causing the disk arm's reading of the information and response time to be slowed by the disk arm's need to move to various places on the disk. Such capabilities can also reduce the response time.

f. Applications Software Support - Software advances typically trail hardware advances. CAD/CAM users should investigate the internal systems used by the vendors to develop CAD/CAM software. The ability to expand the application capabilities of the system depends on an organized and effective vendor approach to software development. A vendor's ability to quickly develop and implement new and improved application programs allows CAD/CAM system users to perform more tasks and to increase system utilization.

In addition a record of vendor enhancements to the software may be useful for the potential CAD/CAM users. Most systems have user groups that meet periodically. User group meetings are usually a good place to obtain enhancement information. This information can be used to project the rate of future developments and to serve as a yardstick against vendor claims.

g. Systems Integration - The ability to integrate a CAD/CAM system with existing and developing components of computer integrated manufacturing (CIM) significantly enhances the system's growth potential. To support this integration vendors must either develop systems that can support existing CAD/CAM capabilities as well as such upstream functions such as computer-aided process planning (CAPP) or manufacturing planning and control systems, or they must provide the capability to interface their CAD/CAM system with other automated systems. When evaluating vendor ability to support future systems integration users should be aware that substantial systems development will be required; therefore vendors that have demonstrated ability for achieving systems integration clearly have an advantage.

Concluding Comments

CAD/CAM implementation plan should focus on the strategic, business and organizational issues of system implementation. Anticipating and planning for system growth should be an integral part of the implementation plan.

The volatile nature of the CAD/CAM industry requires that the organization continue to monitor its system to determine effectiveness and to plan for the system growth and evolution. Capacity measurement and planning is one method of anticipating system growth; such planning should continue throughout the life of the system to provide maximum system effectiveness and therefore user satisfaction.

Chapter 6 Plant Application Of Proposed Methodology

AT&T Technology Systems, Reading, Pa.

1.0.0 Introduction

The engineering forecast for the AT&T Technology Systems, Inc., Facility Design Organization at Reading, Pennsylvania, forecasted a compound increase of 15% in engineering and design drafting workload. To support this development and meet other commitments, AT&T Reading was required to either hire new personnel or purchase a CAD/CAM system as an alternative.

One course of action was to continue with the present manual design and drafting methods, with the intent of vast improvements. However, a major problem with this method was that it seemed difficult to effectively manage, control and utilize the enormous amount of data generated by these department activities. The manual methods hindered the ease of sharing design information, especially current information, with the various departments. Too many times we were reinventing the wheel when establishing designs.

To improve the engineering design and drafting productivity, and provide a means to collect and maintain the enormous amount of common data generated and used by departments of the Facility Design Organization, the purchase of a computer-aided design/computer-aided manufacturing (CAD/CAM) system was recommended. The system was intended to be used by the following departments in the Facilities Design Organization who have, in general, engineering functions that could be serviced by a single CAD system:

<u>Department 730</u> - Factory Planning Engineering

Proposed CAD/CAM Usage - Develop equipment installation standards and equipment layouts.

<u>Department 760</u> - Plant and Facility Design Engineering

Proposed CAD/CAM Usage - Design, layout, and modification of the factory structure, electrical, and piping facilities.

<u>Department 770</u> - Machine and Tool Design Engineering

Proposed CAD/CAM Usage - Design machine and tools, including assemblies, sub-assemblies and details, required for manufacture of the product.

<u>Department 780</u> - Test Set Design Engineering

Proposed CAD/CAM Usage - Mechanical and electrical design and modification of test equipment required for manufacture of the product.

Recommendation to purchase a CAD/CAM system was based on the fact that it will provide the Facility Design Organization with a valuable and versatile tool to improve productivity within the Organization. The CAD/CAM initial and primary goal will be to increase design and drafting productivity by performing facility layout drafting at decreased cost/sheet and with shorter turn-around time. It will be able to achieve this because of the similarities among the department's many facility drawings and frequent use of standard symbols. The CAD/CAM system will enable these departments to maintain a common set of descriptions in a common data base, stored in a computer and available to all designated users. The CAD/CAM system will also support both management and engineering activities in the design process to effectively manage the data required for these activities.

This system would be an in-house system because of the availability of existing professionals, at our location, who already have the expertise in this field. Also, we already have the draftspeople who are already trained and versed with our standard methods. These people will only have to be trained on the use of the CAD/CAM system.

In addition, a CAD/CAM system would not only improve our productivity, but it will improve the quality and accuracy of the design and provide better resource utilization along with shorter lead times.

2.0.0 Analysis of a CAD/CAM System's Manpower Savings Potential and Economic Justification

Estimating a CAD/CAM system's manpower savings potential required estimating its productivity improvement, and the systems availability in order to determine the labor savings forecast.

Analyzing productivity improvement was based on assessing work-station productivity. This required reviewing the system, engineering activities involved, user field experience, and vendor's claim. In this study, we used a forecasted 2:1 improvement for the first year, 4:1 the second, 5:1 the third, and 6:1 for the fifth and sixth years. The forecasted increase in productivity was based on an anticipated increasing demand for drawing updates and effects of increasing and more complete data base. Also, for the third through sixth years, improved operator and management skills were expected to increase productivity.

Based on above productivity improvement forecasts financial analysis was done using a detailed Differential Expense and Savings Analysis which gave a pay-off period of three (3) years and a rate of return of 18.5% on investment. The project was approved by management based on this analysis.

3.0.0 CAD/CAM Specifications

This specification defined system requirements in six major areas:

3.1.0 Central Processing Unit

3.2.0 Workstations

3.3.0 Software

3.4.0 Output Peripherals

3.5.0 Training

3.6.0 Maintenance

The system was required to have start-up capabilities of three workstations with growth capability to 16 workstations. It was intended that this specification define hardware and software requirements to be met through the use of one or more stand-alone systems or one or more centralized systems as determined by economic considerations.

All data base information was to be available in IGES (Initial Graphics Exchange Standard) format for transfer to other systems which are IGES compatible.

3.1.0 Central Processing Unit

A. The CPU shall be a 32 bit unit which shall provide no visible delay in screen changes for 2D and 3D drafting. This requirement shall be met for the maximum number of workstations specified.

B. Network Capability

C. Sufficient memory to simultaneously operate all graphic software packages defined in this specification.

D. Configured to support multiple design stations, communications, and peripherals defined in this specification.

3.2.0 <u>Workstations</u>

A. Console

1. Human engineered for operator convenience.
2. Work surface for menu-tablet and drawings.

B. Input and Output Devices

1. Menu-tablet, push button, and display
2. Text entry terminal
3. Hard-copy printer/plotter for Raster copy. Electrostatic.

C. CRT Display

1. Color
2. Raster-scan, 60 Hz. interlaced or 30 Hz. full refresh.
3. Minimum of 1024 x 1024 Resolution.
4. Minimum screen size 19".
5. Alpha-numeric text.
6. Multiple Screen Display System
7. Multiple Line Weights
8. Multiple Line Colors
9. Display of motion
10. Views - standard orthographic projection, isometric, perspective.

c. Drill

d. Punch

4. Sectioning

5. Tool path generation (2-5) asix

6. Wiring ladders diagrams

7. Assembly drawings

D. Electronic Design

1. Schematic Generation

a. Symbol library

b. Design rule checking

c. Component library

d. Wire list

2. Printed Circuit Boards (PCB)

a. Symbol library

b. Design Rule checking

c. Component library

d. Silk-screen

e. Solder mask

f. Assembly drawing

g. Automatic placement

h. Automatic routing

i. Board Testing

j. Circular performance board generation

k. Position lands at any specified angle

3.3.0 Software

A. General

1. Common data base for all workstations.
2. 2-dimension design
3. 3-dimension design
4. Dynamic Rotation
5. Interference checking
6. Automatic hidden-line removal
7. Solids modeling
8. Multiple simultaneous views
9. Pan and zoom
10. Automatic dimensioning
11. Automatic conversion - inch/metric
12. Bill of Material generation

B. Plant Design

1. Structures
2. Floor layouts (walls, door, furniture, etc.)
3. Power wiring
4. Piping

C. Machine and Tool Design

1. Flat pattern generation
2. Finite element modeling
3. Numerical control with postprocessors for:
   a. Mill
   b. Lathe

3.4.0 I/O Peripherals

A. 300 MB disk drive

B. Magnetic Tape

C. High speed paper tape reader/punch

D. Pen plotter, 4 pens, minimum drawing size 50" x 80"

3.5.0 Training

A. Operator training for eight persons divided between plant design, machine design and electrical (schematic) design.

B. Two persons trained in the CPU operating system.

C. Software user programming for one.

D. Software applications programming for one.

3.6.0 Maintenance

A. Yearly hardware service contract.

B. Yearly software service contract.

C. Hardware maintenance training for one person.

4.0.0 Benchmark Tests

Benchmark Tests to be performed by the vendor for AT&T Technology Systems, Inc., Reading Works, Facility Design Organization, were:

4.1.0 Architectural

A. General floor layout using Qty. (6) pieces of equipment. Information on Qty. (4) of the items will be provided prior to the benchmark. Use scale 1/4" = 1'-0".

B. Create a power layout for the floor layout above. All equipment to be connected to 220 VAC bus duct. Use scale 1/4" = 1'-0".

C. Create an exhaust duct layout in 3-dimension. Exhaust main ducts are 7" diameter round PVC with sub-mains 3" diameter round PVC. Entries into the main duct by the sub-mains are at 30 degrees. Use scale 1/4" = 1'0".

D. Surface and shade the drawing to provide a pictorial view of the duct work.

4.2.0 Mechanical-1

A. Perform certain modifications on the chassis you will already have in a file. After the modifications are completed, do a flat pattern layout of the chassis.

B. Mount the chassis slides as specified at the time of the benchmark.

C. Provide an assembly drawing of the panel in 3-D with hidden lines removed.

4.3.0 Mechanical-2

A. Using a linkage drawing on a computer assembly machine, rotate the linkage and perform some trig calculations.

4.4.0 <u>Mechanical-3</u>

A. Check ease of detailing from an assembly.

4.5.0 <u>Mechanical-4</u>

A. Do a solids model of a connector insulator.

4.6.0 <u>Mechanical-5</u>

A. Generate a tape for a 3-axis NC problem.

4.7.0 <u>Electrical/Printed Circuit Board (PCB)-1</u>

A. Generate a schematic from a rough sketch. You will receive most of the schematic prior to the benchmark to allow the shapes (except those we wish to see generated during the benchmark) to be stored in your library.

B. Generate a PCB of the above schematic as follows:

1. Provide an assembly drawing from the PCB on a 25 ("B") size diag.

2. Generate a stocklist on a 45 sheet. The format for this stocklist will be provided prior to the benchmark.

3. Provide 800 bpi tape output for the Gerber plotter for:

   - slide one and two of the PCB
   - solder mask
   - silkscreen

4. Provide a papertape in EIA format with drill

information.

4.8.0 Electrical/Printed Circuit Board (PCB)-2

A. Generate a PCB per our sketch with a 2 inch round hole in the center and a specified number of contacts evenly spaced around the periphery of the hole. This will demonstrate the ability to place lands around the radius of a circle.

B. Provide a raster plot of the board.

4.9.0 Miscellaneous

A. Plot a 135 drawing ("F" size) in background.

B. Load, display and plot the Autotrol tape. If capability doesn't exist to use the Autotrol tape we will provide a 135 drawing to be loaded prior to the benchmark so it can be plotted in the background.

C. Demonstrate the use of the user language to define a family of shape (i.e. hex head screws or hex nuts).

D. Digitize a drawing.

E. Generate a complementary tape of the Autotrol tape to be run on the Autotrol system.

F. Four terminals shall be used at the same time as follows:

terminal #1 - solids modeling

terminal #2 - PC auto routing

terminal #3 - solids modeling

terminal #4 - kinematics problem

The four terminals shall be connected to a common VAX 11-780.

F. There will be no timed tests except solids modeling.

G. We will want color pictures of the screen when solids modeling.

H. Benchmark shall be run using puck and tablet.

I. Provide a raster plot of solids model.

J. Vendor may be asked to perform any of the functions defined in our specifications.

5.0.0 <u>Installation Preparation</u>

After management support and funding was approved to proceed with the purchase of a CAD/CAM system for the Facility Design Organization, the project leader selected a competent project team to install this system. For this installation, the project leader was a senior design engineer who was intimately familiar with and responsible for the design work to be developed by this system. He was responsible for coordination of all phases of the computer installation and start-up. In addition, his responsibility was to define the function and responsibility of each member on the project team. This team consisted of members from each of the four departments the system was intended to serve. It also included other professionals, as required, who could contribute to an efficient installation, such as software programmer, computer and communications engineer.

Another task of the project team was to develop an installation schedule detailing the sequential steps required for an efficient installation with little or no interruptions.

6.0.0 Building Design Work

After floor space was allocated the next step was to start building design work. At this state site preparation plans were obtained from the vendor in order to determine power requirements, heat dissipation, and other pertinent installation information. This information was used to perform an electrical requirement study for sizing power panel and electrical source. Also, a heat load study was done to determine the sizing of the air conditioning unit.

The following drawings and details were involved in the building design work:

- Equipment Layout

  This drawing was required to determine the size of area needed to be developed for the CAD/CAM

Computer Room and Workstation Room. It was also used in developing the Architect drawing.

- Architect Drawings

  Details -- walls, door schemes, color decor, etc.

  Suspended ceiling plan - coordinated with light fixture layout, and air-conditioning supply and return ceiling penetrations. Raised floor with No-wax linoleum for Computer Room.

  Wall insulations around Computer Room.

  Fire protection -- alarming, detection, and halon system.

- Air-Conditioning Drawings

  Equipment heat load study required.

  People, lighting, and other heat production items considered.

  Air-Conditioning Unit sizing and location required.

  Duct work arrangement -- supply and return.

  Automatic humidity control

- Electrical Drawings

  Equipment electrical requirement study required.

  Dedicated and protected power supply with line conditioning equipment.

  Isolated grounding system with perimeter grounding for raised floor.

Ceiling lighting plan-standard office lighting for computer room.

Subdued and track lighting for workstation room.

Power distribution for computers and workstations.

Computer cabling routing system -- cable limitations.

Wall receptacles in computer and workstation rooms.

Telephone and modem arrangements.

Security arrangements, combination door locks for computer and workstation rooms.

7.0.0 Building Construction Work

To begin building construction work, the area where the CAD/CAM system was to be installed was cleared. This required relocating office equipment to another location. The work was scheduled and completed at least three days before the construction start date.

Preparation for construction work also required, in order to minimize dust into surrounding areas, a dust partition, floor to ceiling, constructed around the perimeter of the CAD/CAM rooms. Also, to provide for minimal interruptions to existing operations around the new construction area, certain types of work, such as tapping into existing light circuitry was done off-hours.

8.0.0 CAD/CAM Staffing and Training

A design engineer who was familiar with the daily operation and functional specifications of the design process was made in charge of administrating the everyday operations and support to the user community. This engineer was concerned with improving the output process and help the operators perform better. Also, since most installations were to be modified or expanded at one time or another, the engineer ascertained the long-range compatibility of the system with the plant objectives.

Initially, two staff members were assigned to assist the design engineer. They administered scheduling and training activities. These staff members were trained through practice during the acceptance of the CAD/CAM system and once they became proficient helped develop and provide in-house training for the users of the system.

The staff members were also required to place purchase requisitions for furniture, storage cabinets, and supplies. They also determined and ordered the data and telephone services required to support the CAD/CAM operation.

9.0.0 System Installation

The CAD/CAM system being installed was a turnkey package. Therefore, the vendor was responsible for the computer, peripherals and workstation installation. They instructed our millwrights and electrician in the installation and cabling of this sytem.

The software was also completely developed by the vendor. It contained the operating system program, development aids, service routines, drive routines for interfacing equipment, and other software features requested. It was entirely their responsibility for the programming task, and they were liable if the program did not perform to specifications.

Vendor-supplied test programs were used to check out proper functioning of all components of the computer system. When all software and hardware was checked out properly, the system was ready for activation. The start-up of the system was done step by step. There were sufficient safety precautions taken so that the system can be shut down immediately if sudden difficulties were encountered. Alternate courses of action were also provided in case of service difficulty.

In this installation, it was to our advantage to have a reputable vendor who will support their hardware and software and will make sure that the installation operated properly. Thus, we saved valuable time by not concerning ourselves with the painful debugging procedures.

10.0.0 Implementation Plan

The implementation plan required specifying those steps needed to make a smooth transition from the Facility Design Organization's manual drafting and design method to the CAD/CAM system. This required planning and policy setting as follows in order to minimize frustration and encourage success.

10.1.0 Phased Implementation

The plan for implementing the CAD/CAM system required setting a policy designed to establish a path for applications to be phased into the system. One advantage of using phased implementation was that it could be carried out with the normal work staff. By working in small steps, one or two applications could be converted, while continuing difficult and urgent assignments manually. This procedure enabled the operators to gain experience and confidence in using the system proficiently.

To implement this plan involved identifying each transition phase based on the amount of work of each department, similarities between the department's work types, and the staff's ability to perform the work. Then provisions were made for a gradual transition for each application to be added to the system, one at a time, seeing that it worked properly, and then moving on to the next application.

The first step involved phasing in all drafting applications before design work. The reasoning behind this was that drafting productivity can be measured more easily than design work. The next step was to determine which types of drafting work could most advantageously be put into the system and in what order. In this case, the Factory Planning and Plant Design departments have in common similar applications. Therefore, it was to our advantage to schedule these applications first. Each application to be performed was viewed as a project with a start and completion date. A schedule was developed depicting the work priorities for these applications.

10.2.0 Personnel

A senior design engineer was appointed as the data base administrator for the CAD/CAM system. He was responsible for protecting the data base against intentional or unintentional damage. Although the users were responsible for the accuracy and completeness of the data they entered, the administrator was responsible for maintaining the integrity of that data once it had been entered. He was also required to maintain backup copies of the entire data base in case of loss of data.

There were three drafters assigned and solely dedicated to the CAD/CAM system for the purpose of phasing in the drafting applications. These drafters were obtained through the job bidding process and were in-house trained during and after the acceptance testing of the system. Two drafters were mechanical and the other electrical. Depending upon the phasing-in process meeting the schedule, additional drafters were recruited which required working in second shift, there being only three workstations available.

A trainer was appointed to establish and monitor standards and procedures for each of the various application disciplines. This was to ensure that all of the users applied agreed-upon standards and procedures.

A drafting coordinator, who assigned manual drafting, was involved initially in assigning the phasing-in applications to the CAD/CAM drafters. As the system and requirements grew the scheduling job has now been computerized.

10.3.0 Identifying and Scheduling Users for the System

The drafters were designated users of the system as they would spend the greatest amount of ti e on the system. On the other hand, the designers were designated as casual and quasi-casual users, as their work required other activity away from the system. Initially, the quasi-casual user was scheduled for system use until the system was expanded.

Eventually, engineering assignments were phased into the system. At that time, the engineers were designated as casual users and were scheduled accordingly for use of the system.

10.4.0 <u>Development of Computerized Drafting Scheduling</u>

Early in 1984 it was recognized that the number of active jobs in the plant and factory mechanical drafting workload had increased to the level of being virtually unmanageable using manual scheduling methods. This condition triggered investigation into the availability of software that could handle our prime requirement of "time frame scheduling" along with other requirements regarding priorities, insertion of unscheduled rush jobs, estimate changes, capacity changes, output formats, etc.

The investigation included a thorough examination of the Teleplan, Ramis, Facman and Prompts software packages from the known available packages. Some consideration was also given to the development of a new software system to meet our needs. The Prompts (Project Management Planning and Tracking System) software package was identified as having all of the features originally sought for our scheduling needs.

The development stage required the formation and organization of key data taken from existing manual information. The data was established and assembled for logical entry into the data base.

Prompts software being very flexible and general it was necessary to determine sequential operations and field capacities to allow for proper time frame scheduling and output formatting.

Additional development was essential to define software parameters enabling the accommodation of a broad scope of work input.

Many sub-groups of resources were generated to handle priority workload in a timely fashion. This eliminated the overloading of work scheduled at one time to a particular engineer as well as giving projected drafting schedule dates. To further expand on the system's capabilities, a long range workload forecasting operation was developed in conjunction with existing workload schedules. This provided an all-inclusive planning control system.

By August 1984, the initial task of loading the drafting workload, 500 individual drafting tasks, into the computer was completed. This phase was followed by two months of evaluating the capabilities and various output formats available with this scheduling program. By October 1984 we had an operating computer scheduling system that met all of the original objectives.

With this system we have a very controlled operation with documentation of work and the ease of inputting new data, which is scheduled automatically by the computer after it is fully evaluated against all other tasks to be performed. In addition the system allows the user to override start dates for work that must be completed by a given time.

At present there are computer outputs that are very useful to anyone concerned about workload details (i.e. management, plant/factory engineers, N/C design organization and plant construction). The system can also aid management with short and long term manpower requirements, permit identification of drafting work associated with any particular engineer or project, and reduce manually prepared paperwork. In addition to these intangible benefits, which are by far the most significant benefits, we were also able to demonstrate tangible annual savings based on reduced manual scheduling time.

Originally this system was developed in Section 0760 to handle a specific drafting workload, but on a broader look the software can be implemented for a variety of similar tasks. At present it is being expanded to accomodate all machine and tools present and future scheduling needs. It also can be applied to any organization's workload that requires time frame scheduling.

11.0.0 Concluding Comments

The above is an illustration of a successful implementation of a CAD/CAM system at AT&T Reading by application of the methodology developed in this thesis. As demonstrated, a logical step-by-step process was followed. As the plan progressed, problems were encountered, but these problems were recognized and solved immediately before serious damage and expenses were incurred. There are, however, some lessons learned from this implementation which are as follows.

The start-up of the CAD/CAM system could be the most frustrating part of the total project. The morale of all personnel involved is put to a crucial test at this time. Therefore, it is important that management be well briefed in advance so they will be sympathetic to minor difficulties that may be encountered, realizing that a reasonable amount of time is necessary to achieve a smooth operation. Unless a substantial majority of both management and operating personnel are sold on the system, it will be in serious trouble from the start. It is necessary that everybody feel comfortable with the CAD/CAM system and that no fear exists that people will lose their jobs.

The human factors, which are so important throughout all of the systems work, are also put to their maximum test. No amount of planning or briefing can eliminate completely the anxiety, pressure, overwork, and confusion that is so often present at such a time. Advocates of the manual system may feel jealousy or resentment toward those working with the CAD/CAM system. Also, some diehards inevitably will tend to gloat over real or imagined inadequacies in the CAD/CAM system.

Therefore, it is important that management provide full support and supervisors exercise the utmost tact during this period of stress. Fortunately, respect for individual feelings, recognition of work well done, and good communications and training were practiced throughout this project in order for morale to survive these periods of stress and provide for a smooth transition.

The system has since been functioning satisfactorily.

Chapter 7

Case Study
The Firestone Tire & Rubber Co.[1]

In January 1977, Firestone purchased and installed four station Auto-trol CAD System. The initial objective of CAD use was to perform facility layout drafting at decreased cost per sheet and with shorter turnaround time. They established one major policy for CAD use; the transfer of manual operations to the CAD system would be final and conclusive. Since 1977, the CAD group has grown from a five member staff producing facility layouts to a 45-member staff performing numerous design and drafting functions. Engineering and analysis applications are also being phased in.

The policies, standards and procedures established for the Firestone CAD group evolved through trial and error. As inexperienced CAD users, Firestone discovered many blind alleys and pitfalls before recognizing the need to develop, document, and enforce policies for system use. A complete set of policies was not established formally until the CAD system had been operating for three years. Many frustrating hours and substantial amounts of money were spent in reaching the present performance level.

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[1] R. C. Pallito "Policies for System Implementation and Use: The Firestone Tire and Rubber Co. Case Study in CAD/CAM: Management Strategies, Auerback Publishers, Inc., 1984, Sec. 3.2.3.

Although Firestone's initial goal for the CAD system was to increase productivity in facility layout drafting, specific policies to attain that goal had not been prepared. Instead, the entire facility layout work load was transferred immediately from manual to CAD methods of drafting. This was a mistake. Time should have been allotted for training, building the data base, and formulating procedures and policies.

In addition, Firestone attempted to justify the CAD investment too soon. Therefore, the CAD group tried to achieve improved productivity while it was still learning to use the system. Financial expectations were not fulfilled, proving that it was unrealistic to expect that early efforts would produce any payback.

The transition from manual drafting to CAD was slow. The experience of converting facility layout drafting to CAD proved that it takes time for the staff to become proficient at using the system for a new discipline. Piping, applications and electrical drafting followed the facility layout work. This advanced CAD operation meant that CAD organizational planning and procedures for growth were required. Job descriptions were also defined for each CAD staff position.

Standards and procedures were not developed by Firestone before actual work was begun. This resulted in wasted hours and frustrating weeks spent undoing or re-doing drawings. It was finally recognized that CAD required a totally new method of drawing documentation.

Several preparatory steps can reduce or eliminate transition problems. The first is to establish and outline procedures and required standards at the start of the CAD investigation. Second, time and money should be allocated to provide a sound foundation for the CAD group. And finally, all interested parties and departments should participate in defining standards and procedures, thus providing a concensus and majority support during the transition. The Firestone CAD group did have full management support, but without policies, the first few years of system operation were difficult.

Preparations have now been made and provisions established to help achieve future objectives. All work that can be produced on CAD has been carefully analyzed. In addition, outlines have been written for each new field to determine personnel, time, and system capability requirements. Firestone has concluded that all engineering disciplines can be enhanced by using CAD. The company plans to expand computer use in the areas of finite element analysis and simulation. The long-range goal is to have workstatios available for all engineers to use as needed. Firestone also plans to provide the latest software tools to all the technical staff.

Firestone learned it the hard way but it did learn finally that a well conceived strategy is required to ensure that CAD/CAM system implementation and operation is accomplished as planned.

Chapter 8

Summary

In the beginning of this thesis it was posited that CAD/CAM implementation is not a simple task. Simple implies that an instantaneous improvement in productivity is a guaranteed result of the implementation of a CAD/CAM system. This thesis has attempted to deal with this problem and has presented support for the hypothesis that a well conceived strategy must be established in order for the system to meet its desired goals and objectives.

A general strategy has been developed and recommended by concentration of the following key factors.

1. Systems design, specifications and evaluation.
2. Systems justification based on cost/benefit analysis.
3. Human factors both physical and psychological.
4. Systems staffing including recruitment and training.
5. Systems implementation and follow-up.
6. Systems growth and evolution.

A systematic step-by-step approach has been presented. Potential problem areas and other precautions have been identified.

Having developed the methodology, part two of this thesis discussed the actual application of this strategy to a plant implementation of a CAD/CAM system at AT&T, Reading, Pa. The strategy helped to establish clear cut policies and set of objectives for the CAD/CAM system. It also enabled the project team to evaluate and select, through benchmark tests and other criteria, an appropriate CAD/CAM system amongst various systems offered. Installation of the system and phased implementation was accomplished as planned. The system has since been functioning satisfactorily.

Finally, one case study of The Firestone Tire and Rubber Co. was discussed which exhibited lack of a proper strategy. The policies, standards and procedures in this case evolved through trial and error. This resulted in wasted and frustrating weeks spent undoing or re-doing things, with devastating and costly consequences.

The research, actual plant implementation, and the case study bear testimony to the fact that there has to be a well planned strategy, in order for the system to be successful.

Chapter 9 Conclusion

It can be concluded that the strategy developed in this thesis provides a sound basis for evaluating, selecting and implementing CAD/CAM systems. The methodology has been developed by exploring certain potential areas and the strategy recommended broadly consists of:

1. Determining organization needs.
2. Establishing CAD/CAM systems requirements for meeting these needs.
3. Setting criteria for systems evaluation and selection.
4. Justification based on realistic expectations of the system.
5. Taking human factors both physical and psychological into consideration.
6. Planning for recruitment, training and employee development.
7. Planning for facilities installation and setting implementation policies and procedures.
8. Auditing system after implementation.
9. Anticipating and planning for systems growth and evolution.

This comprehensive step-by-step approach developed in this thesis is recommended as a general strategy for implementation of a CAD/CAM system. It is further recommended that this general strategy be tailored to the uniqueness of the organization to which it is applied through consideration of the potential areas encompassing this strategy.

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