Modelling Complex Organizational Coordination Processes: A Case Study of Engineering Change Processing

by

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ABSTRACT

The linkage between information technology and organizational structure has been identified by many researchers. However, investigation of this link has possibly been limited by the generality of frameworks and techniques that have been applied. The object-oriented modeling (OOM) approach presented here attempts to refine earlier work by integrating and applying concepts borrowed from object-oriented programming and process flow representations.

This technique is demonstrated through the analysis of engineering change coordination processes in a development and manufacturing environment. Potential benefits of using the technique are described, including:

1. Identification of potential failures in existing processes,

2. Definition of specific interactions which can be monitored and measured to assess effectiveness of coordination mechanisms, and

3. Requirements definition for information technologies which can support organizational information processing.

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1. Introduction

As the capabilities of information technology (IT) increase and organizations begin to recognize the significant impacts technology will have [Porter and Millar, 1985:152.], researchers are becoming more interested in the linkage between technology and organizations. Modeling the impact of technology on organizational structure would lead to improved understanding and potentially, consistent and well-structured implementations. [Ellis, 1979;3]. However, such modeling techniques are not sufficiently sophisticated at this time.

Previous work has shown that alternative organizational forms [Galbraith, 1967; Malone] trade off costs of coordination and vulnerability, or weaknesses. Although the linkage between information technology and organizational structure has been identified, an analytical tool for modeling organizations and studying the impact of technology has not been fully developed.

However, work examining the link between IT and organizational structure has led to the development of an information processing view of organizations [Galbraith, 1974, 1977; Tushman and Nadler, 1978]. In this view, organizations are composed of sets of subunits; groups, departments, or individuals. Organizational structure is the pattern and content of the information flows between groups, and the way they process this information.

Interestingly, this view of organizations seems particularly useful for investigating the potential impact of IT. Tushman and Nadler (1978) hypothesized that different organizations face different levels of uncertainty and that an organization's effectiveness would depend on the fit between its information processing capacity and its environment. They discuss ways to improve this fit and noted that, "the information processing model holds promise as a tool for the problem of designing organizations" [Tushman and Nadler, 1978:300].

One of the limitations of these theories is that the studies only discuss these concepts generally; as one manager in manufacturing planning and controls explained:

> *[Our company] is acknowledged as a leader in managing engineering change to large, complex systems...but even those of us who are deeply involved can't tell you exactly what it is that we do right. In fact, we know that there are lots of things we don't do well, but we can't figure out how to do things any better...*

Crowston et. al. (1986) developed a new perspective to investigate this link using a technique that analyzes information processing in organizations in a more detailed way than most previous work. Using concepts of object-oriented programming from artificial intelligence, it characterizes the information processing that occurs in organizations in terms of the kinds of messages people exchange and the ways they process those messages. The models that can be developed using these object-oriented concepts have more of the precision and flavor of cognitive science theories than most previous models based on the information processing view of organizations.

Using these techniques, a model of the complex, formal and informal intra-organizational coordination processes for managing engineering change is developed. This model can be used to assess the strengths and weaknesses of current organizational information processing. Then, actions can be proposed for choosing organizational forms and establishing coordination mechanisms that can smooth the change process, improve turnaround times for resolving problems, and improve the quality of engineering solutions. In particular, these detailed models of communication and interaction are especially useful for analyzing directly the changes that information technology may provide for organizational information processing.

Chapter Two provides briefly describes the structure of those functions involved in engineering change processing for the firm studied in this case. Chapter Three presents a high-level description of the information flows that coordinate engineering change management[1]. Chapter Four integrates flow representations and modeling techniques from earlier work [Crowston, Malone, and Lin, 1986; Ellis, 1979; Clement, 1987] to represent the coordination processes in with greater granularity. Chapter Five describes how the object-oriented modeling technique illustrated in the previous chapter differs from traditional flowcharts and modeling techniques such as Information Control Nets [Ellis, 1979]. Finally, conclusions and recommendations for future work are presented.

1 Open-ended interviews with functional (2) and project (3) managers, and engineering change administrators (4) and engineers (2) in development and manufacturing were used to generate this representation. Although the processes identified are not wholly inclusive, they represent a consensus of primary information flows.

2. Company Background

The company studied is a large, manufacturing firm organized along functional lines. The control structure is highly centralized and hierarchical. This case focuses on the coordination processes for managing engineering changes (EC) in the following functions:

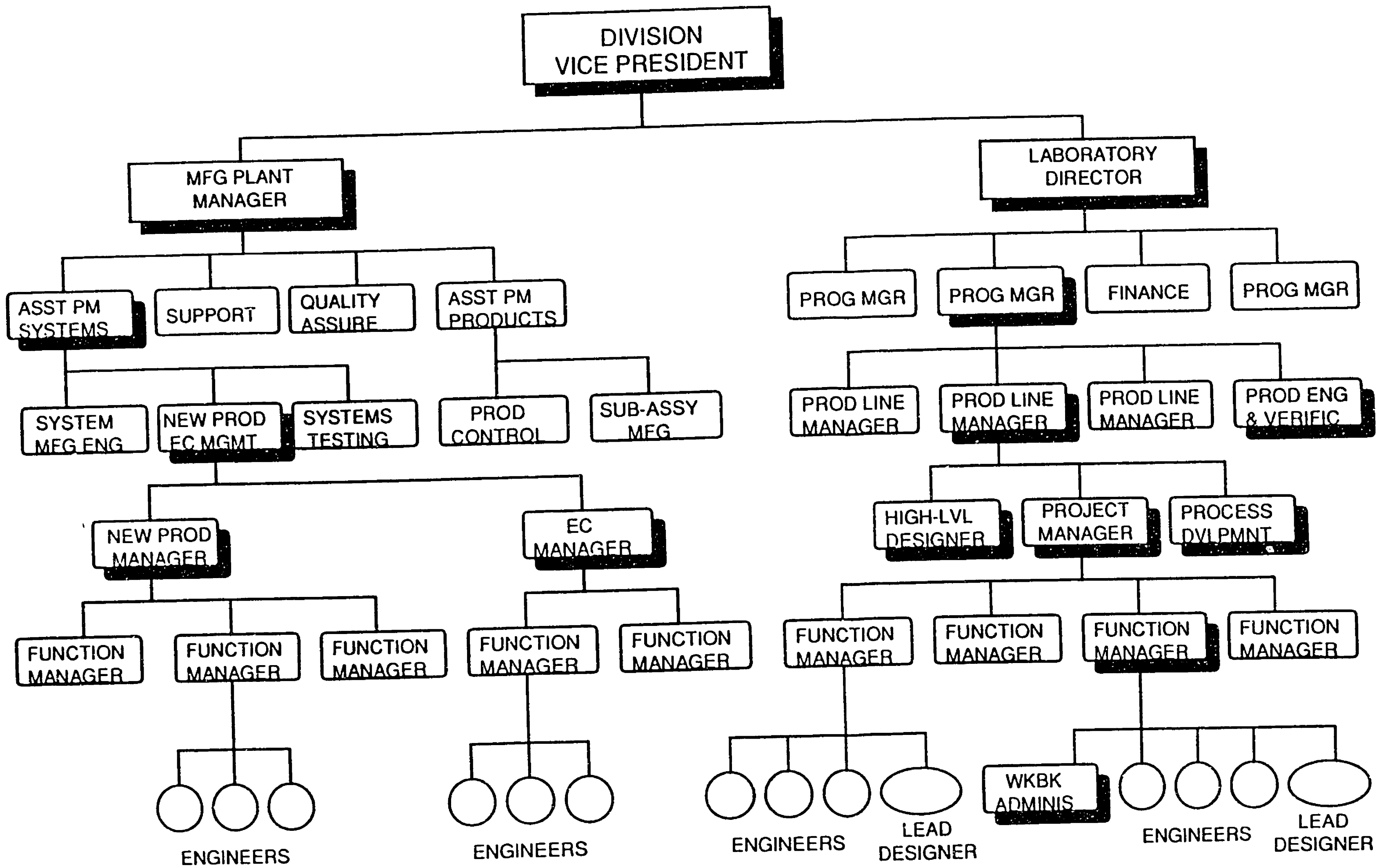
- o Engineering (development);
- o Manufacturing;
- o Product Engineering

Each division of the firm might have an engineering function, a manufacturing function, field service, and supporting functions. Figure 2.1 shows how a typical division might be organized.

2.1 Engineering (Development)

The engineering organization for this firm is primarily directed towards product development. Within the engineering function are Program Managers who are responsible for a number of product lines which have similar functionality. A number of Product Managers, who have responsibility for similar products, report to each Program Manager. Project Managers, who are responsible for the development of a single product, report to the Product Managers and typically manage a number of Functional Managers, who direct teams of engineers designing product assemblies

FIGURE 2.1
MANUFACTURING AND ENGINEERING ORGANIZATIONS



The organizational structure of the development group closely reflects the structure of the products designed. Managers at higher levels in the organization think of products in terms of product lines, and individual projects. Functional managers are more concerned with the engineering details of functional units of individual products, and resolve contention between engineering designs for those units. At higher levels in the organization, product level decisions are made regarding areas such as production scheduling and component vendor selection. Here, liaisons manage interactions between development and outside organizations.

A Project Office (Process Development in Figure 2.1) for each product organization coordinates the development function with outside organizations such as manufacturing, or vendors. The project office schedules production deadlines, negotiates changes in scheduling, components, technologies, and manufacturing processes.

A high-level designer provides staff-level assistance to project and functional managers. He is an experienced engineer and a member of the original team assembled to develop a product that meets objectives established by a business plan. As he refines the high-level design, engineers and functional managers are recruited to develop the detailed assemblies required to release the product as scheduled by the project office.

Finally, within one of the engineering teams is a workbook administrator who reports to a functional manager. The workbook administrator is responsible for maintaining a centralized, paper copy of the functional description and design for the product. Changes to the workbook represent fundamental changes to the machine and are evaluated by the high-level designer and functional managers before they are accepted.

2.2 Manufacturing

Manufacturing operations are functionally organized as illustrated in Figure 2.1. The plant manager reports directly to a division vice-president. Functions reporting to him include production support, plant quality assurance, and systems and sub-products manufacturing.

The groups that actually manufacture products are managed by assistant plant managers. One group focuses on the production of sub-assemblies while the other focuses on system assembly and testing. Each of these organizations includes a number of manufacturing engineers who design and implement the manufacturing processes required for actual production.

The engineering change manager for new products is the liaison between manufacturing and development during the development of new products. Although there may not be much formal interaction during the early stages of design, the EC manager establishes early contact with development engineers and attempts to determine when the product will be released to manufacturing for prototype production and general release. In addition, the liaison works with the project office in development to determine new capital tooling requirements and specialized manufacturing requirements before designs are released to manufacturing. The project office in development also works with the EC Manager in manufacturing to develop appropriate test and release plans, and scheduling of changes.

2.3 Product Engineering

The size and structure of product engineering groups largely depend upon the age of the particular products they support. Within each program (or product line) exists a product engineering organization for supporting each product. Soon after new products are released, these groups tend to be comprised of a large number of engineers from the original development group. As products age, the number of engineers in the product engineering team decreases and those familiar with the product tend to become dispersed throughout the corporation.

The product engineering manager acts as a liaison between product support engineers and all other organizations. When product problems are identified by manufacturing or field engineering, the product engineering manager becomes responsible for determining that an engineering problem exists, and for managing the engineering change process. Based on the severity of the problem, the product engineering manager may need to call back a number of the engineers who worked on the product development team, even if they might currently be working on other projects. These engineers would then be recalled to resolve the problem before returning to their current assignments.

2.4 Centralized Electronic Database Systems

A number of centralized database systems are used to track problems with products during testing, manufacturing, or customer operation. These systems are typically updated by system support administrators and provide information to field locations, development managers, manufacturing managers, and project staff as needed. Appendices 1-5 describe these systems in detail.

With the exception of the Development Production Release System (DPRS), these systems are used to broadcast information about problems and changes to groups of individuals who need the information. In some instances, the information may be targeted to specific groups (more accurately, information access is limited to certain individuals). Information flows to these programs usually consist of completed electronic forms with a problem description, background information, and diagnostics.

3. An Overview of Engineering Change Processing

In some ways, product development and manufacturing in the company studied is similar to designing and constructing an office building. After creating a business plan that addresses market requirements for the project, a core team of designers begins identifying basic features of the design for meeting business specifications, e.g. the number of floors; the appropriate architecture; or, the proportion of retail to office space. As the design begins taking form, the team of architects, artists, and decorators would grow to manage greater levels of detail as development progresses.

Scheduled commitments from electricians, plumbers, subcontractors, and suppliers are tentative in the early phases of the design cycle and become firmer in the later stages. For these reasons, changes early in the design cycle can generally be easily accommodated. However, any changes that could affect scheduling in the later stages have more far-reaching consequences. The same holds true for products being developed in the company studied.

Eventually, the core team will grow to an unmanageable size, leading to the formation of teams organized according to functional responsibility. One team might handle project scheduling and administrative functions including qualifying suppliers and obtaining necessary building permits. Other teams might be assigned responsibility for design of the superstructure, support services, or interior spaces. When one group proposes changes to existing plans, such as relocation of an elevator shaft, other teams must be notified.

For the purposes of this study, the definition of an engineering change will be limited to the primary effects of a change driver. For example, when an elevator shaft is relocated, floor layouts change. To compensate, interior designers would redesign say, the layout of a bathroom. Subsequently, plumbing and electrical services to the room may require changes. For my purposes, the redesign of the bathroom will be considered the primary impact of the shaft relocation. One could view subsequent changes in support services as a primary impact of the changes in the bathroom layout if they resulted from acceptance of changes in bathroom layout. In this thesis, an engineering change is defined to include the processes set into motion by requests for modifying existing designs, and is limited to revision of the particular designs directly related to the initial request.

For the products that were studied, changes that are introduced during engineering development (a period which will also be called *initial release*) are distinguished from those following general availability (or *post-release*). In general, the processes for managing EC is less formal early in the design cycle and more formal toward the end. Early in the design process, engineers have not yet created the full implementation of their functional assemblies. When groups change existing drawings, other areas will be able to change their approach without changing their existing designs. However, later changes in one area might have an impact on a number of other assemblies.

Engineering changes during product development usually require significantly less coordination than EC's that occur after the product is released to manufacturing. During development, most of the changes only require coordination of engineers. After the product has been released to production, outside organizations become involved and changes require coordination of field service, engineering and manufacturing engineers.

3.1. Sources of Change and Types of Coordination

During initial release, design modifications may be requested by many different people. For example, a quality assurance liaison for the development might question the reliability of a particular component and require substitution of another qualified component. Or, the project office may learn that a component vendor is having sourcing problems that may impair his ability to deliver key components on schedule. The criticality of the component in the final product, availability of qualified substitute components, and the cost of alternatives can affect the amount of coordination necessary for finding a solution to the problem. If another qualified source for the component is readily available and commits to delivery, little coordination is necessary; if the component is not readily available and alternatives would require significant redesign of a number of assemblies, resolution of the problem would be much more complicated.

Although a significant amount of testing and evaluation of the initial design will be performed by design engineers prior to building a prototype, errors are inevitably found. According to one development manager, a large percentage of these post-release problems occur because of:

- The use of design tools that cannot be expected to model and test the system designed with absolute accuracy;
- The transition to newer technologies that become available after assemblies have been designed, and which have been substituted to provide cost or performance advantages;
- Operating variations of vendor components or reliability problems that are severe enough to require modification;
- Use of the product outside of the recommended range of operation;
- Miscommunication or lack of coordination between design teams earlier in the design process.

These problems are usually detected when the prototype is built and tested, during testing by customers who receive early shipments of the product, and after general availability. By the time the products are generally available, problems that might impact the normal operation of the products are rare. Engineering changes are usually found during maintenance cycles or as a result of problems due to unanticipated operating conditions.

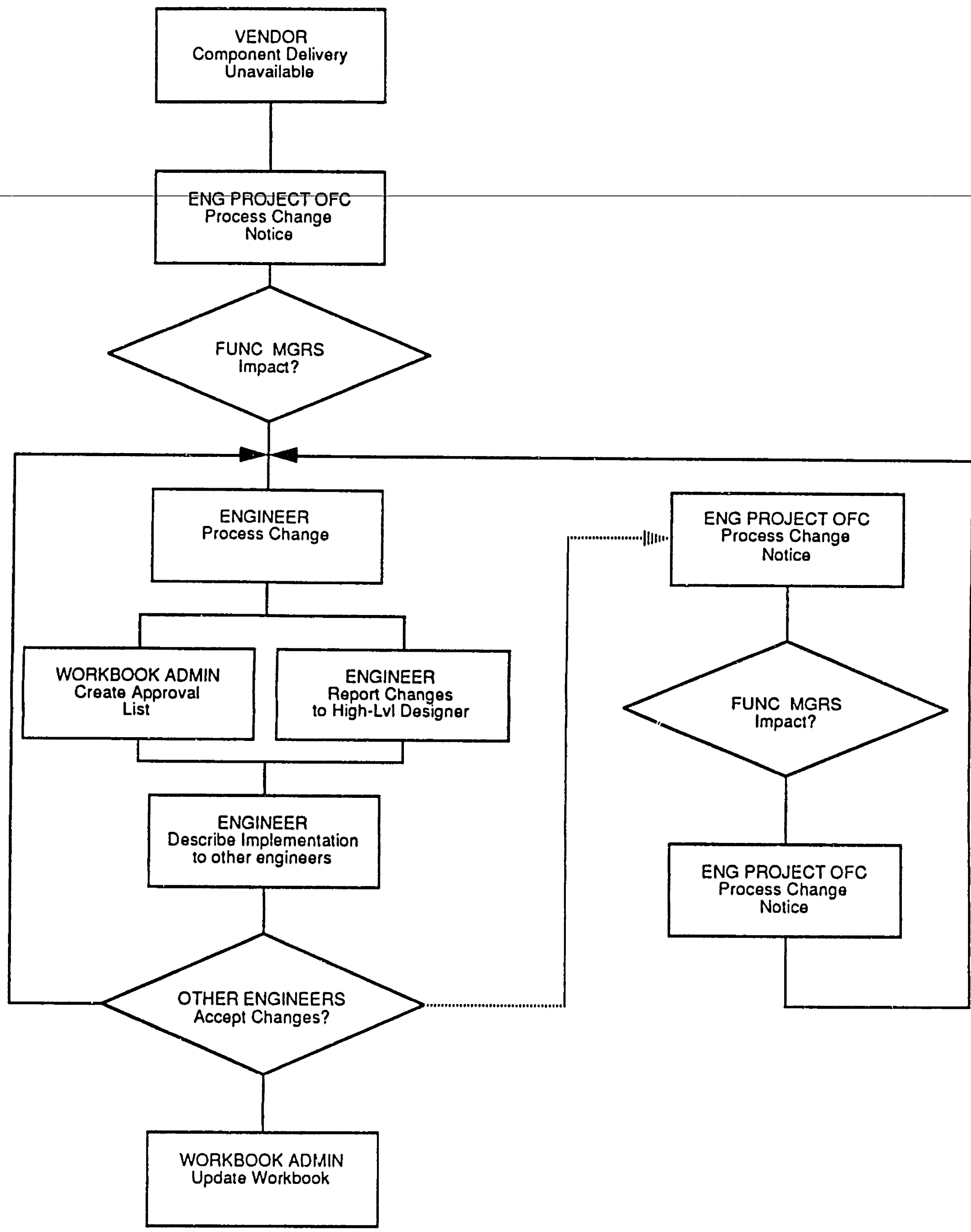
3.2. Initial Release Processing

The project development managers and engineers interviewed described the general engineering change process shown in Figure 3.1. Here, change processes respond to a vendor's inability to deliver components on schedule. The project office would report the situation to project and functional managers. They in turn would assess the impact of the event and can (1) ignore the situation if it has no impact on their areas, (2) ask the project office to arrange alternative sources, or (3) request that engineers redesign assemblies to use available components.

Given the task of implementing changes, engineers would identify and gather resources and information needed to make modifications. After an engineer has made changes to existing designs which have been documented in a central design workbook, other engineers and managers who will be affected must approve the change. Those involved in the approval process include the workbook administrator[2] and the

[2] The workbook administrator does not have the detailed knowledge of every drawing and function that will be affected, but can identify the functional areas. The engineer would then propose his change to the lead designer of that area, who would be able to identify the engineers and drawings that would be affected for his area.

FIGURE 3.1
COORDINATING EC DURING INITIAL RELEASE



high-level designer, who identify those managers and engineers that will be affected by proposed modifications.

Then, the engineer proposing the change will describe his new design to those groups. If those who are required to approve the change do not do so, the engineer might design an alternative solution that answers individual concerns. However, he could choose instead to have managers evaluate the problem and resolve contention. Sometimes, functional managers will reassign tasks and the engineering change process will begin again.

On rare occasions when functional managers cannot come to agreement, the project manager will be asked to resolve the situation. When required approvals for modifications are obtained, the workbook is revised.

3.3. Post Release Processing

After a product is released for production, resolution of problems requires coordination among engineers in field service, development, and manufacturing. Moreover, the tracking systems and information flows for ensuring that a change is processed properly is somewhat more rigid than those used for administering workbook updates during initial release. After a product is released from development to manufacturing, necessary design changes typically become more difficult to coordinate. Consider, for example, the following scenario:

> Years after a product becomes available, a product fails under uncommon operating conditions. Field engineers are unable to solve the problem, with serious consequences for the customer. Product support engineers are unable to locate the source of the trouble and engineers from the original team must be located and brought back. Eventually a proposal for addressing the problem can be presented and an engineering change committee then recommends that the improvement be installed on all existing products.

Depending on the events which are set into motion, field engineers may need to be trained to modify existing equipment; manufacturing receives new part numbers on revised drawings, new components may be ordered, and publications will be updated. Once the changes have been completed, systems that track installed products will be updated to reflect the change. In the course of making changes, manufacturing may find still another obstacle, leading to further changes requiring interaction between manufacturing and development engineers.

3.3.1. Information Flows in Engineering Development

After a product has been released to production, most new problems are found by field engineers at customer installations. Field engineers report the nature of the problem, actions taken, and may request engineering action (REA) if the problem cannot be fully corrected. REA's are forwarded to a product engineering manager responsible for supporting the product and tracked by a site REA administrator who acknowledges the time-stamp and priority of the request. Figure 3.2 illustrates the process flows which manage EC after initial release.

The product engineering (PE) manager then evaluates the REA and determines if an engineering problem actually exists. He may act on the request or refuse by explaining why an engineering change is not necessary. If the PE manager rejects the request, field engineers can appeal to the supervising product manager.

The PE manager may otherwise take the following actions in response to the REA:

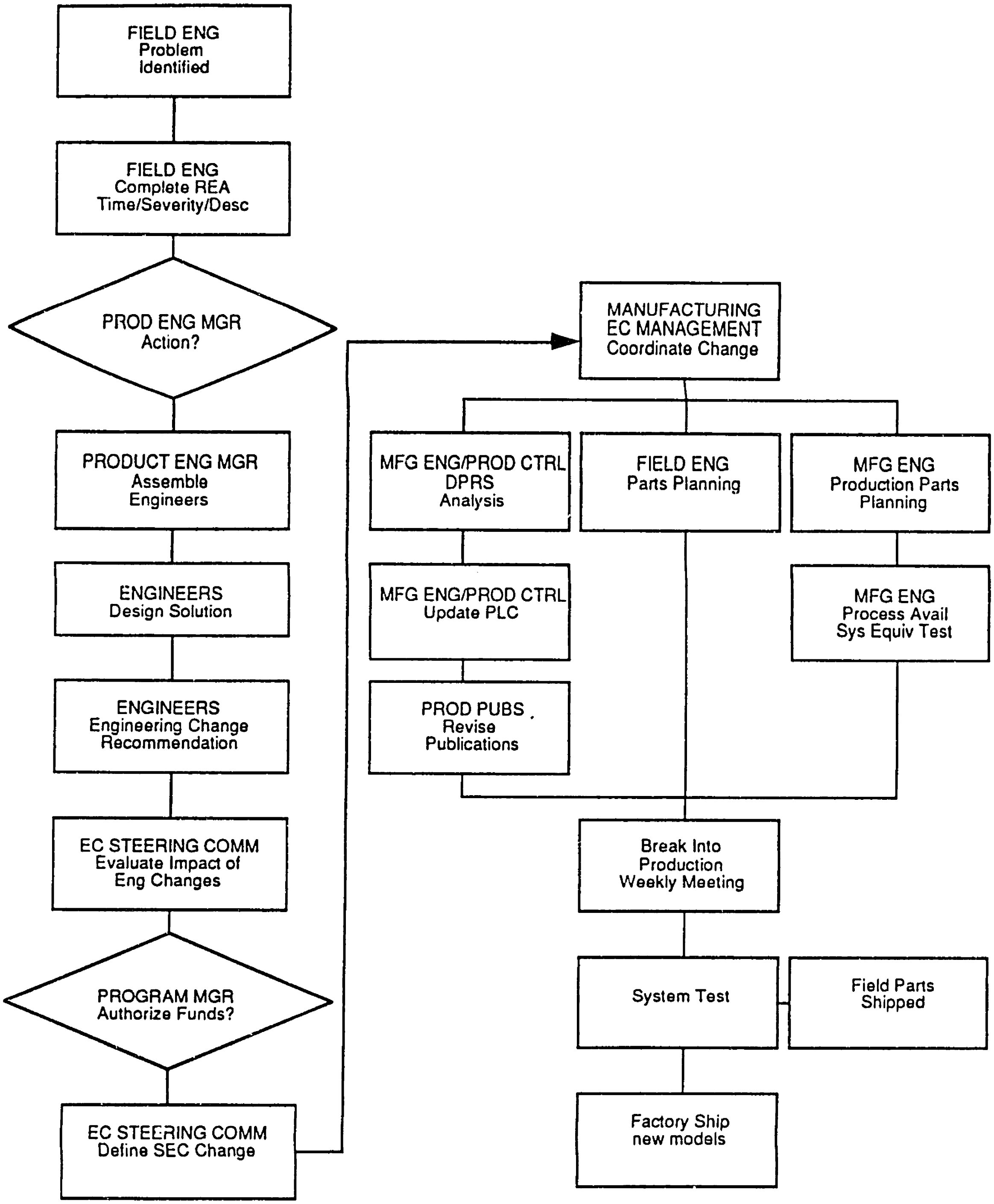
1. Assign product support engineers under his supervision to review the REA and develop recommendations for a solution.

2. Involve some of the original product design engineers in work toward a solution by recruiting them from various other projects on which they might currently be working.

As products age, their original designers ability to recall design details diminishes and PE managers may be less inclined to seek their assistance in solving a problem. However, when a product fails in operation, all available resources may be focused on the situation as quickly as possible. In developing a solution, the team of engineers are managed as a single group by a single manager. The engineers would identify a solution and report its recommendation to an engineering change committee.

Engineering change committees are comprised of managers representing development, manufacturing, field engineering, product engineering, and production control who evaluate the

FIGURE 3.2
COORDINATING EC AFTER GENERAL AVAILABILITY



EC's recommended by product engineering. After product engineers have identified solutions to a given problem, the managers of each organization would evaluate the costs to their organizations of implementing the recommended changes. The committee then agrees to a change action which may include one or more of the following:

1. **Change as Needed** - This recommendation is the most common; generally specifies that new assemblies or components are installed based on need by field engineers. The production process is not changed.

   Publications are revised; Field engineering locations are notified of the change and trained to make modifications; After product modifications are completed, PLC (Product Level Codes) are updated to show that a specific product was modified.

2. **Manufacturing Change** - Installed products are not modified unless the change is required, but all new products being manufactured would contain the update.

   Design drawings are revised and sent to manufacturing through DPRS (Development Production Release System) which identifies changes and creates new bills of material for ordering purposes; Changes in scheduling may be managed with vendors for new components; engineering documentation is updated; and PLC's for new products being shipped reflect the update.

3. **Limited Factory/Field Change** - Replacement assemblies or parts will be installed for a specified group of customers; specific models of products or products sold to targeted groups of customers will be manufactured with the engineering update.

Design drawings are revised and sent to manufacturing through DPRS. Changes are specified for specific models of the product. Negotiations with vendors and manufacturing may be required to obtain components and commitments for delivery.

Alternatively, modifications will be made to a limited number of installations; training for field engineers would be required. PLC those machines would be updated.

4. **Factory/Field Change** - All new products being manufactured will contain the engineering update. All installed products will be updated during routine maintenance cycles or earlier.

   Design drawings are revised and provided to manufacturing through DPRS. Production processes will be modified to accommodate the change. Publications are revised. Field engineers are trained to install the changes and coordination of the return and modification of old parts may be required. PLC for new products and modified installations will be updated.

3.3.2. Information Flows in Manufacturing

The engineering change recommendation is reported to EC management in manufacturing, accompanied by marked-up drawings reflecting changes through DPRS. Manufacturing engineers analyze the changes and begin developing the processes that will be required to update new products being manufactured. Product publications and the PLC for the new release of products will be updated to reflect the changes.

At the same time, manufacturing engineers will develop plans for testing the modified assemblies as they are manufactured, and for performing a systems equivalent test. The systems equivalent test places the modified components in a fully operational system and performs testing under controlled operating conditions.

Parts planning for bills of materials that will be required to implement the change on currently installed products will also occur. This information is necessary for evaluating the best time and method for implementing a single or multiple changes.

Representatives of these groups meet weekly to discuss when and how the various pending changes will be implemented. In some cases, a fairly isolated, minor change such as a substitution of a more reliable component will be delayed until the inventory of existing components is exhausted. In other cases, the criticality of the change will require that it be implemented immediately. After a change in the manufacturing process is implemented, system testing is performed and the new version of the products will be shipped.

4. An Object-Oriented Model of Organizational Processes

The high level view of engineering change coordination processes and information flows described in the previous chapter was developed through interviews with managers and engineers at all levels of development and manufacturing. The essence of EC processing is captured by the description, and might seem both straightforward and well-defined at first glance. However, modeling process flows in a traditional manner fails to provide the insight for identifying problems that might exist with established practices. Ironically, the general description might even argue that little else can be done to improve existing practices.

In this chapter, I will first improve the granularity of process description in Chapter Three and then combine concepts of object-oriented programming with other modeling techniques [Ellis, 1979; Clement, 1987] to create a useful model of engineering change processing. The object-oriented model (OOM) can then be used to answer questions that traditional approaches could not.

The sections that follow decompose the information flows of Figure 3.1 and 3.2 into message types that are passed between the various members of the organization (whom we will refer to as agents). The actions performed by each agent are represented as oval-shaped processes under their respective column headings. Messages exchanged between agents are identified in italics on precedence arrows signifying prerequisite information necessary for initiation of tasks. Filled circles (dots) represent parallel information flows. Circled dots are used when a number of tasks generate identical information flows that initiate the same task; the presence of any of the information flows can trigger the task. Diamonds in each column denote decisions made by respective agents. Finally, the separations in position headings signifies organizational hierarchy.

Double-bordered processes are used to signify the beginning of a secondary change process, i.e. when Other Functional Managers receive a change notice from the high-level designer (bottom of Figure 4.1A), the processes that are initiated analogous to those resulting from the initial change notice (top of Figure 4.1A). Also, when Other Engineers are asked to process changes, the processes that follow are the same as when the first Engineer processes a change in Figure 4.1A.

A double-line is used to couple the figures and has no other significant meaning. A broken line is used to show which processes are identical, and is only used to improve readability.

4.1 Initial Release Processing

4.1.1 Agents, Actions, and Messages

Figure 4.1 shows how the OOM technique would represent the high-level information flows of Figure 3.1. For the purpose of this illustration, the EC process is modeled starting from the time an engineering manager is aware of an exogenous change requiring processing. The initial processing of external sources of change could be modeled similarly. Furthermore, Figure 4.1 is simplified; it only shows one functional manager receiving a change notice. In actuality, any of the functional managers might receive the same change notice, but each would evaluate the message appropriately for their respective functions.

The contents of a change notice would include a description of the change, the date it becomes effective, and possibly some recommendations. After evaluating the impact of a change, functional managers either distribute the notice to the lead designers for their respective groups or take no action. Lead designers in turn evaluate the impact of the change and could request comments about the impact of the change from group members.

Late in the design cycle, changes in component availability are likely to require design modifications. The lead designer of functions which are affected could then ask engineers in his group make necessary revisions. When the

FIGURE 4.1A
INITIAL RELEASE ENGINEERING CHANGE PROCESS

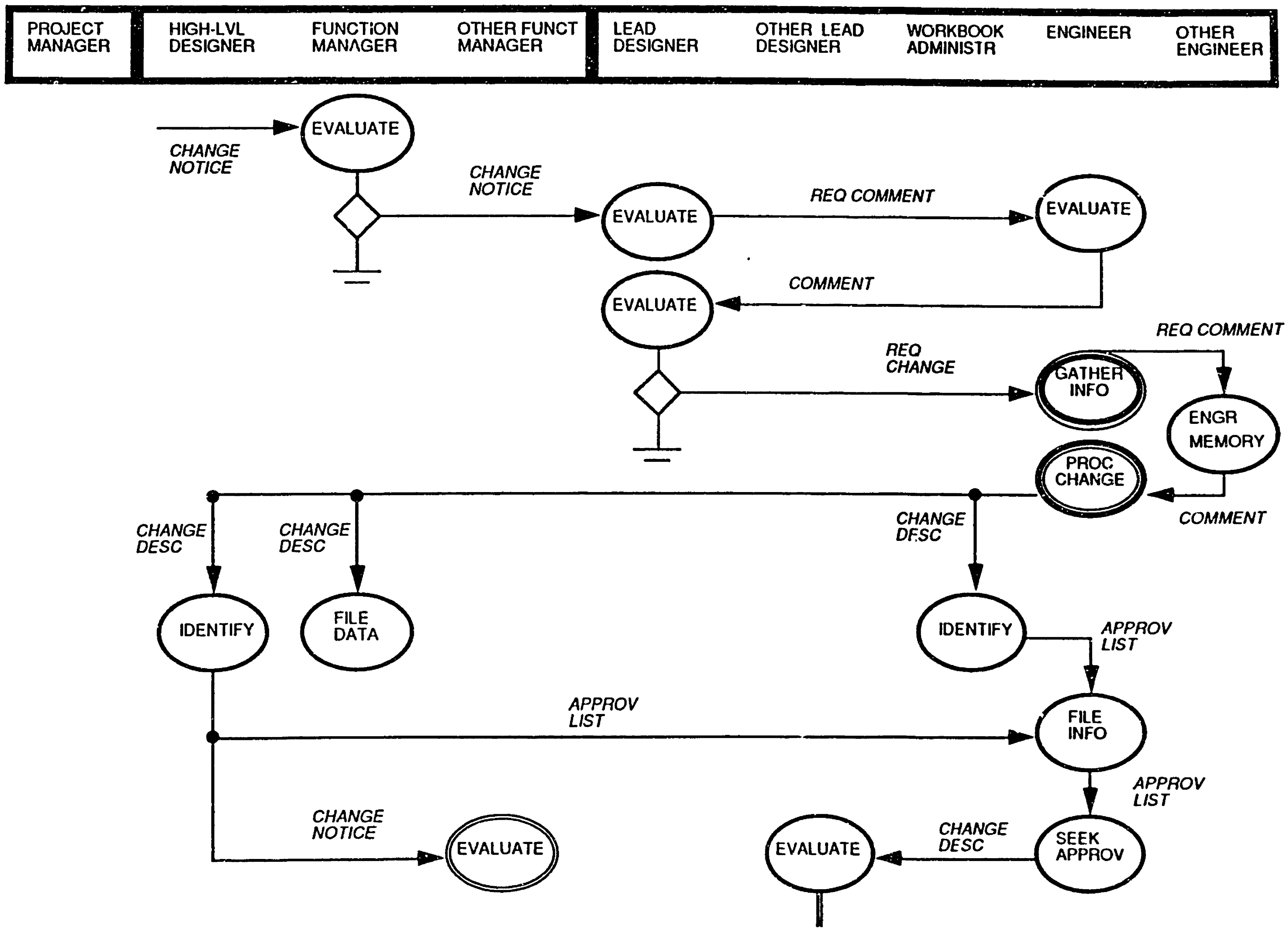
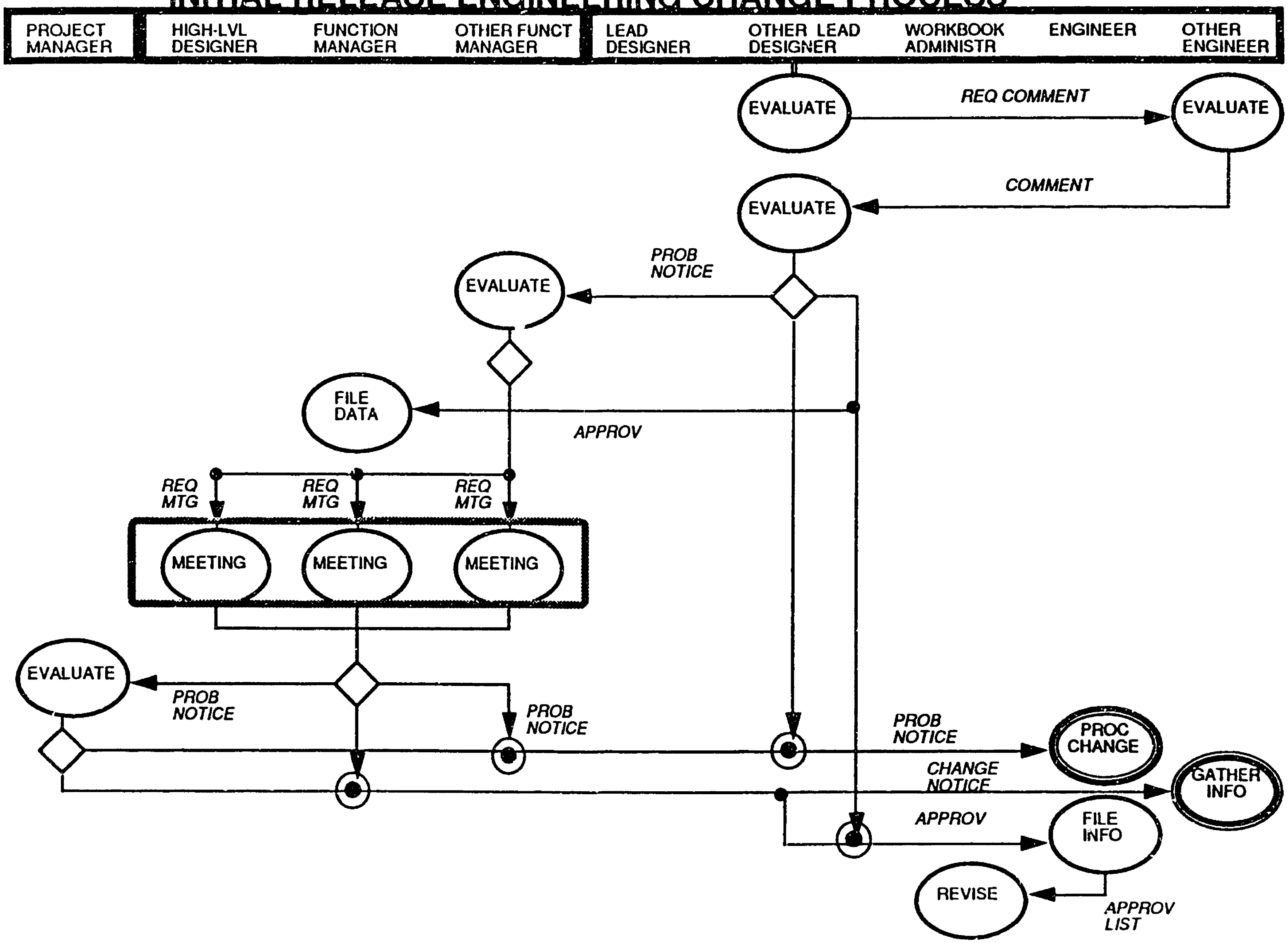


FIGURE 4.1B
INITIAL RELEASE ENGINEERING CHANGE PROCESS



modifications are completed, other members of the project will have to be notified and will be required to approve proposed revisions. The procedure for receiving approval begins when an engineer responsible for implementing changes describes his proposal to the project's high-level designer and workbook administrator.

Both the high-level designer and workbook administrator would provide a list of engineers and managers who must accept the proposal before modifications to existing drawings can be recorded in the project workbook. After evaluating the impact of proposed modifications, the high-level designer would also communicate the impact of those changes to functional managers whose teams might be affected by the revisions. These other functional managers then circulate a secondary change notice among lead designers and engineers in their groups. This is represented by the double-bordered process at the bottom of Figure 4.1.

Using the sign-off list provided by the high-level designer and workbook administrator, the engineer proposing design changes would typically be asked to provide details of his changes to lead designers of other functions. The lead designers of each function would either meet with the members of their groups, or ask for comments regarding the effects of the proposal.

Based on feedback from engineers in the group, the lead designer could either notify his functional manager and the requesting engineer that there is no problem, or could report on anticipated problems. If no problems are presented by anyone required to approve the request, the requesting engineer can send a description of his implementation and the authorizations to the workbook administrator who catalogues the changes and revises copies of the workbook.

If problems with the proposal arise, the requesting engineer may have to begin the entire process again. However, if the engineer does not anticipate that he can devise an alternative solution that will be acceptable, he can forward a description of the problem and his proposed solution to his functional manager.

In the latter case, the functional manager's evaluation would lead to one of the following actions: (1) ask the engineer for a redesign; (2) meet with the other functional manager(s) who rejected the proposal. One situation which might create contention between groups could be that scheduling constraints for the revised design preclude additional rework. The functional managers may be able to distribute the work load so that the original problem can be solved through modifications to subassemblies in more than one area.

The meeting could lead to any of the following outcomes:

1. Functional manager(s) who originally resisted the proposal might now allow the modification

and request secondary changes from engineers in their areas,

2. The requesting engineer's manager may ask him to make further revisions,

3. a combination of (1) and (2) or,

4. Functional managers may be unable to resolve the situation and may send a problem notice to the project manager.

When problems escalate to the project manager, the high-level designer, project manager, and functional managers meet to resolve contention. After evaluating the impact of the original change on development schedules or engineering designs, the project manager would assign engineering changes to each functional area. Functional managers would relay these secondary changes to their lead designers and the process begins again.

4.1.2 Message Types and Content

Although seven distinct message classifications were used in Figure 4.1, some contain similar types of information. For example, a change notice could look like a change description out of context. The seven classifications used in Figure 4.1 are grouped into five semi-structured message classifications below:

1. **Change Notice/Request Change/Change Description** Problems/changes tracked by PTS which includes a brief description of the problem, the functional manager or individual assigned to correct a problem, the time and date the problem was found, deadline for solution, and current status.

Change Descriptions include a brief description of the solution, the individual responsible for addressing the problem, the time and date the notice originated, a deadline for evaluating and approving the revisions, and the current status.

2. **Request Comment**
Description of a change and a request that comments be returned to the sender before a deadline.

3. **Problem Notice**
Statement evaluating the effects of proposed changes or revisions on portions of the design for which a particular agent has responsibility.

4. **Approval/Approval List**
List of individuals who must approve or have approved of proposed modifications which will be recorded in the workbook.

5. **Request for Meeting**
Brief description of the items to be discussed, the date and time of the meeting, and those involved.

Based on the information received from other agents, individuals might perform one of four different actions. These actions are particular to the individual performing the action and the inputs that initiate them.

1. **Evaluate**: Requires assessing the impact of proposed changes on the features of the overall design <u>for which the individual is responsible</u>. May include effects of changes on scheduling, engineering design, and other downstream effects.

2. **Process Change/Revise**: Relevant to engineers who are asked to alter their designs to accommodate changes. Could also include actions taken by members of the project office who might reschedule resource commitments or identify alternative suppliers.

   Only the Workbook Administrator would record design changes that document the functional implementation of the product.

3. **Meeting**: Attend Meeting to discuss information identified by information flows.

4. **Identify**: Identify individuals who must approve proposed changes.

5. **File Data/File Info/Gather Info**: Store information from other agents for future use.

4.2 Post Release Processing

4.2.1 Agents, Actions, and Messages

The process flow illustrated in Figure 4.2 uses an OOM technique to model the coordination processes represented in Figure 3.2. In the example illustrated, a field engineer finds a problem at a customer location. After performing diagnostic routines and compiling information about the problem, the field engineer completes a Request for Engineering Action (REA), noting the time and date of the problem, the severity, and a description of the problem.

The REA is processed and forwarded to the Product Engineering Manager (PEM) responsible for supporting the product. The PEM will evaluate the REA and determine whether the problem warrants an engineering change. If the severity is low and the PEM feels that an engineering change is not required, he would notify the field engineering office that the REA will not be processed further. The field engineer then has the opportunity to agree, or disagree by escalating the problem to the attention of the appropriate Program Manager. If the Program Manager rejects the REA, no further engineering action will be taken.

FIGURE 4.2A
GENERAL AVAILABILITY ENGINEERING CHANGE PROCESS

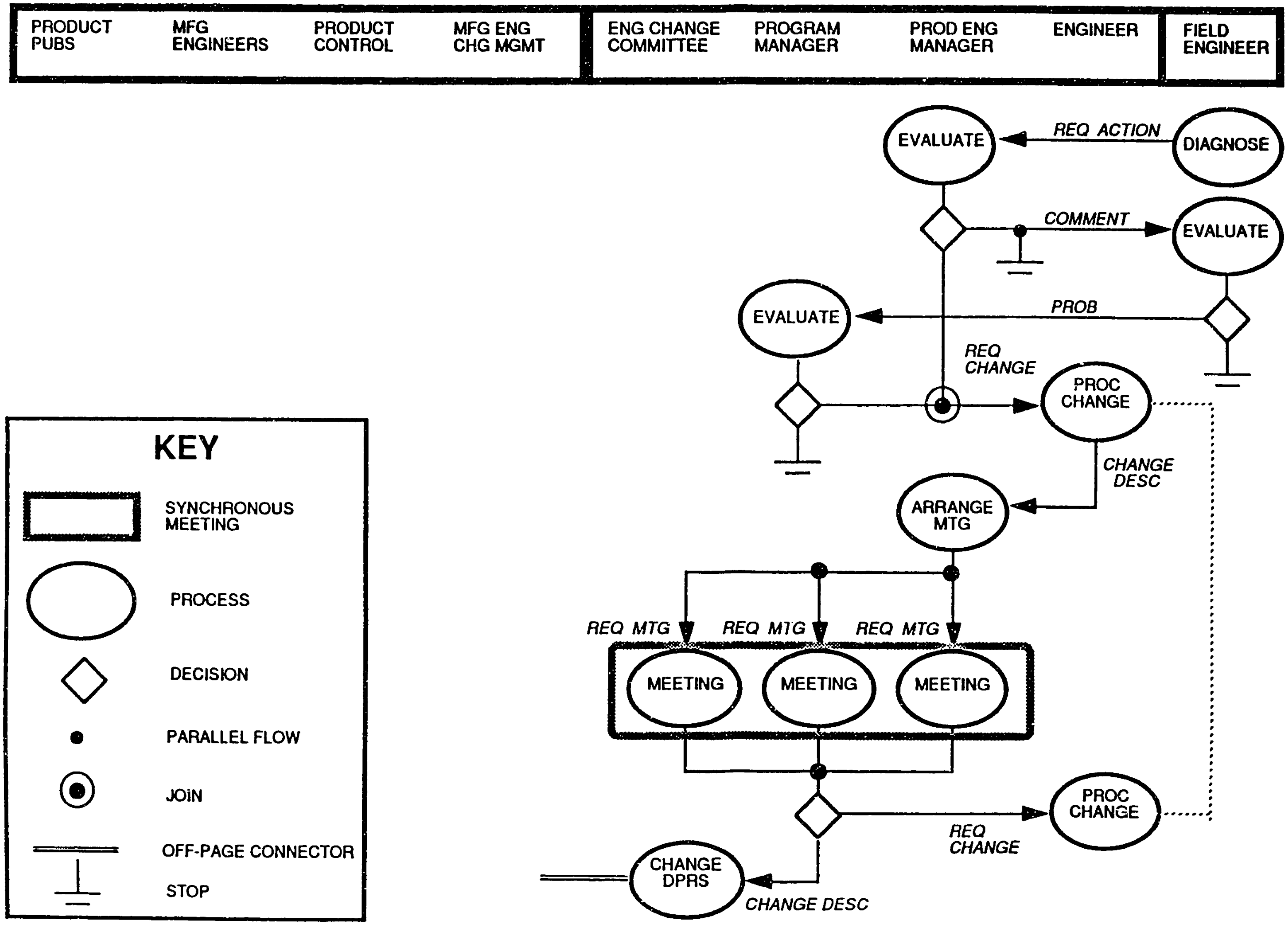
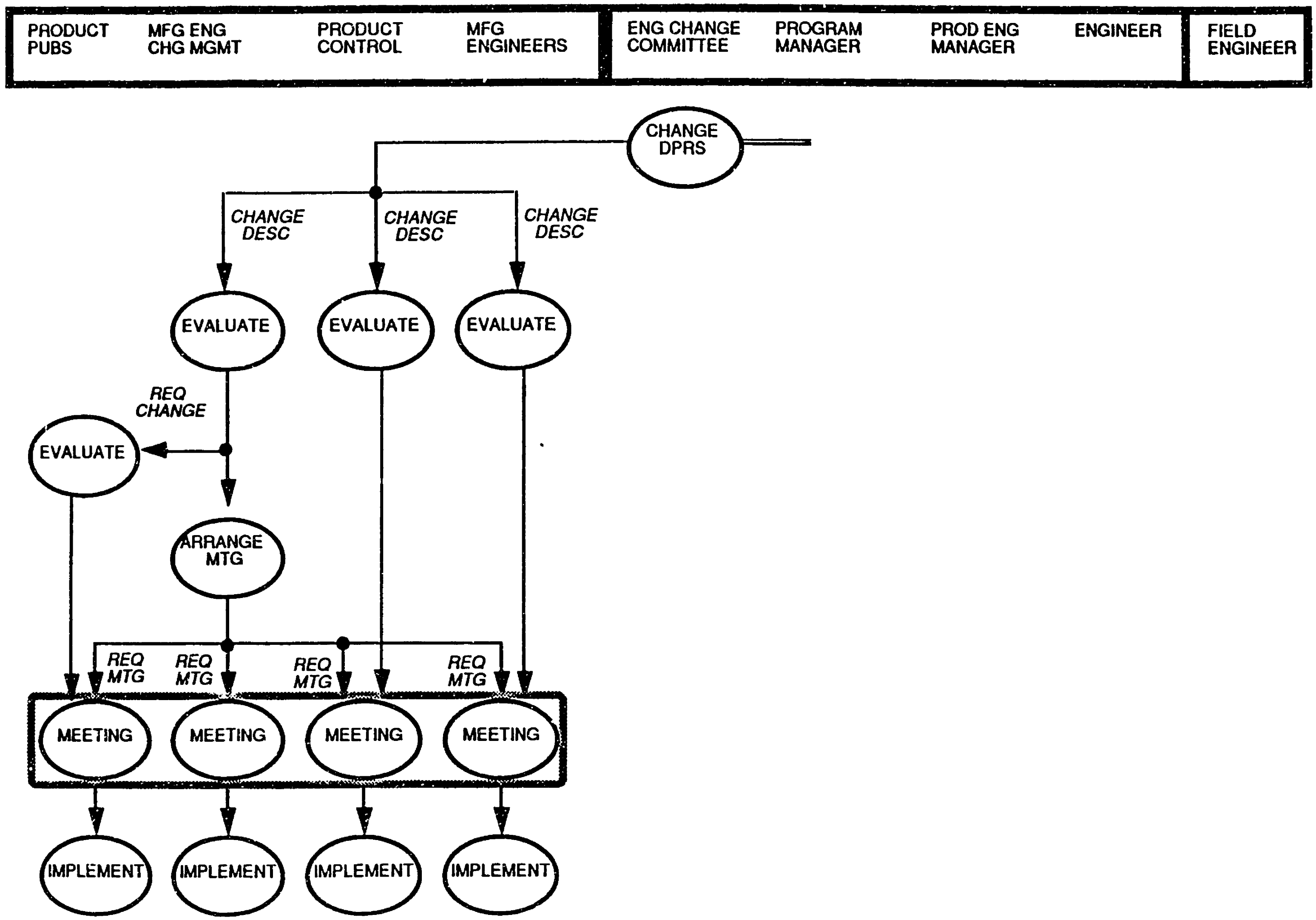


FIGURE 4.2B
GENERAL AVAILABILITY ENGINEERING CHANGE PROCESS



However, if the PEM accepts the REA, or if the Program Manager accepts the appeal by the Field Engineer, an engineering team will be assembled by the PEM to address the problem. An expedient, not necessarily minimal cost, solution to the problem would be developed and documented by the engineers and presented to a meeting of the engineering change committee. The Engineering Change Committee might reject the proposal if reliability, testability, or functionality are questioned, resulting in further engineering development before another presentation to the committee. However, even if the committee approves the design, the program manager must authorize the resources to implement the change in manufacturing.

With the program manager's approval, a description of the change would be forwarded to engineering, together with revised drawings and bills of materials tracked by DPRS. This description would be simultaneously communicated to the Production Control, Manufacturing Engineering, and Field Engineering organizations. Production control would be responsible for ensuring that the required parts were ordered or in stock; manufacturing engineering would set up new processes for producing the revised assemblies; field engineering would prepare for product upgrades at customer installations; and engineering change management would ensure that proper testing procedures including a systems equivalent test be available. In addition, manufacturing engineering would ensure that the PLC database could be updated to reflect the revisions installed in new products and product publications would identify the product documentation and literature that would be revised.

After all of the functions have been notified that an engineering change is being prepared and have identified the procedures and facilities that will require modification for the implementation of the engineering change, representatives will meet to agree upon a time that for actual implementation. At this meeting, any problems identified in any area will be addressed and time will be allocated to resolve the situation so that a full implementation can be coordinated.

4.2.2 Message Types and Content

The primary message types and actions performed are identified below:

1. **Request Engineering Action**: Identifies the problem, and contains a brief description, diagnostic data, the field engineer's name, time, and severity of the situation. The REA is automatically tracked by the product support organization, which operates 24 hours a day.

2. **Description**: Contains a brief description of the solution, the time the notice originated, and the current status of the problem.

   Tracking deadlines for evaluating and approving the revisions and the current status of the engineering change are not required. The first feasible solution is generally considered the "best".

3. **Request Change**: References or contains a copy of the REA. Immediate attention is commanded so deadlines and responsibility are not tracked.

4. **Problem Notice**: Problem notice identifies the person identifying the problem, a description of the problem, action taken, a reference to an REA or other message, date, and severity.

5. **Request for Meeting**: Brief description of the items to be discussed, the date and time of the meeting, and those who will be involved.

The actions taken by each agent in either the manufacturing, development, or field engineering organizations are specific to the role of those agents in their respective organizations. Although each of the agents identified in Figure 4.5 perform specific actions based on the messages they receive in the context of implementing an engineering change, they would perform other actions based on messages they receive in another context.

For example, manufacturing engineers would implement production processes for producing assemblies described by DPRS during the initial release of a product. However, that action would likely be initiated by a message from a manufacturing manager that a new product will be produced. When a description of an engineering change is received, manufacturing engineers will evaluate the impact of the change and determine how the change can be processed, and how long it will take to actually set up the processes.

A summary of the actions and the agents that perform them are listed below:

1. **Evaluate:** Identify the impact of information flows that are provided in the context of an individual's position in the organization.

2. **Implement:** Initiate changes required to effect proposed revisions. Could involve actual order entry, implementing new manufacturing processes, etc. depending on an individual's responsibilities.

3. **Change DPRS:** Modify the drawings contained in DPRS and create system engineering change notice for actual manufacturing changes.

4. **Meeting/Arrange Meeting**

5. Benefits of the Object-Oriented Modeling Approach

Organization theorists [Cyert and March, 1963; Galbraith and Kazanjian, 1978] have viewed the structure of organizations as a means of organizing resources to accomplish goals and objectives. Alternative organizational forms are not equally effective for implementing a given strategy; choosing a particular structure represents decisions concerning how the resources of an organization will be applied. The Information Processing (IP) view of organizations views structures in terms of their ability to provide information to members of the organization for the control and coordination of activities, effective performance measurement, and planning.

Using concepts borrowed from object-oriented programming, the IP view can be further refined. The resulting models of organizations can then be used to evaluate the effectiveness of organizational information processing and more closely analyze the linkage between organizational structure and information technology. The following sections will describe how the OOM technique:

1. Finds potential limitations in existing coordination mechanisms used by organizations studied and helps evaluate proposals for correcting deficiencies,

2. Identifies the key measures and actions that must be monitored to evaluate and improve the processes for managing information flows in organizations,

3. Highlights the key features and capabilities of new information technologies that make them most useful to particular organizations.

5.1 Identifying Limitations in Coordination Mechanisms

One measure of effectiveness for the organization studied is the turnaround time required to complete an engineering change. From the standpoint of providing planning and control for engineering development, the functional structure of development seems highly appropriate. However, until the information flows are decomposed (as in Figures 4.1-4.2), problems leading to reasons for lengthy turnaround times and related downstream impacts are difficult to identify.

5.1.1 Identifying the Components of Turnaround Time

Unlike previous views of organizations, an OOM view of organizational IP can be both descriptive and prescriptive. In this particular study, the coordination processes for managing ECs in development and manufacturing are described in terms of information exchange between various actors. In this section, I will show how the OOM technique could be used to identify the factors contributing to a significant problem identified by managers in development and manufacturing: unpredictably long turnaround times. The technique will then be used to make suggestions for addressing the problem.

Turnaround time represents the delay between the time a problem or change is identified, and the time that problem is resolved. Lengthy turnaround times can be costly for a number of reasons: the longer it takes to redesign an assembly which cannot be used, the greater the likelihood that other related assemblies will be designed that will also require modification. In manufacturing, long turnaround times translate into scrap/rework, or loss of production.

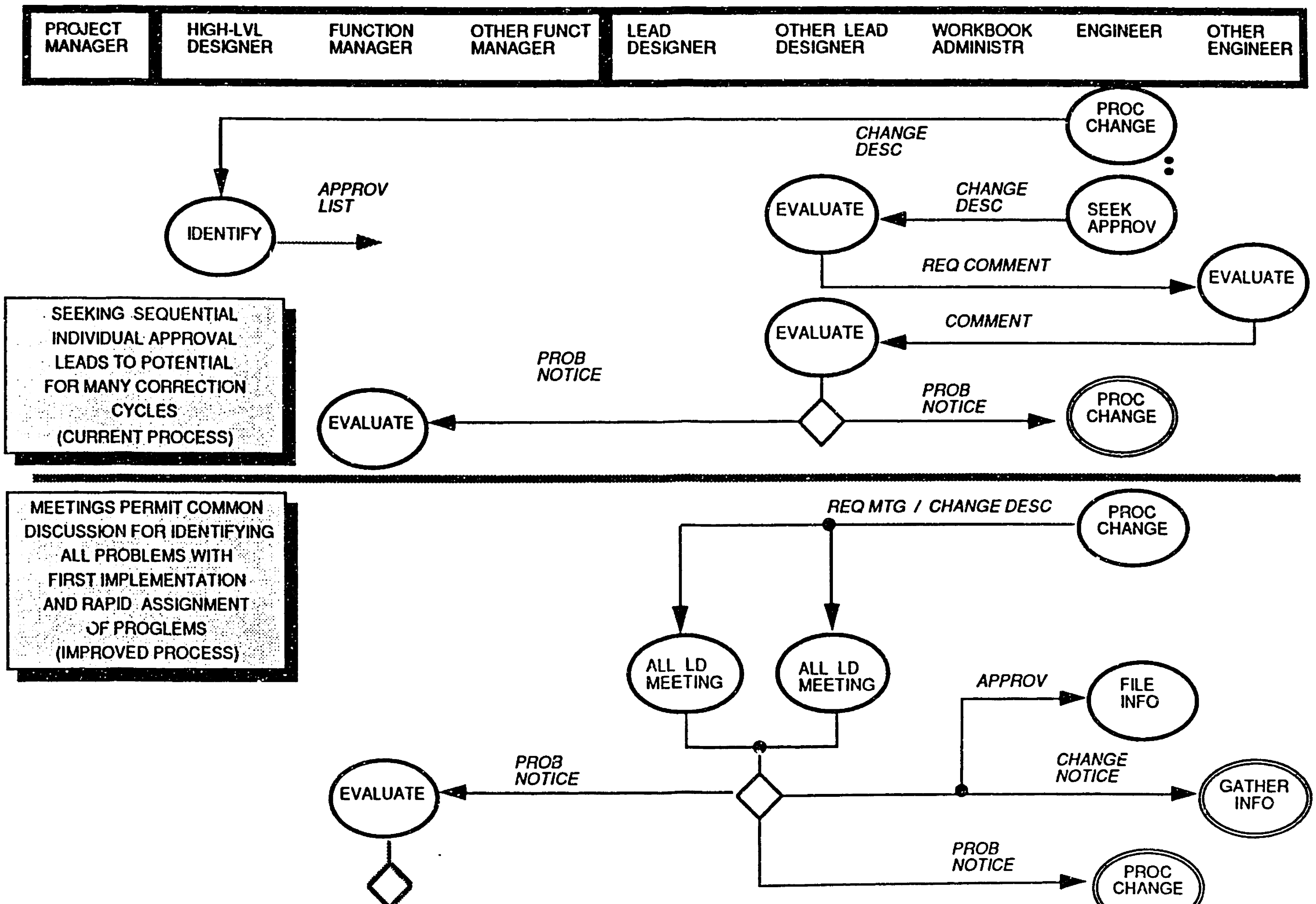
A small portion of the initial release EC process is provided in Figure 5.1 highlighting the particular processes that contribute to unpredictable turnaround delays. When an engineer implements changes that affect other functions, he should notify other engineers whose designs will be affected and obtain their approvals for the new implementation. Because the engineer is responsible for communicating information about his implementation to each of the individuals separately, long delays could be caused by any of the following circumstances:

1. Obtaining the approval of each lead designer might involve his interaction with other engineers before authorization is obtained. In some cases, messages requesting comments from an engineer might be lost, resulting in further delays,

2. Other unrelated activities performed by the engineer could suspend the sequential process of gaining approvals,

3. Any of the engineers might find fault with the proposal, requiring further incremental changes and initiation of the approval process.

FIGURE 5.1
DECREASING TURNAROUND TIME



Rather than sequentially seeking approvals from each of the other lead designers, a meeting of all functions involved could lead to a common agreement about approval or subsequent responsibility for changes. This process would change an asynchronous, sequential process to a synchronous, parallel approval process.

5.1.2 Minimizing Costs of Downstream Effects

Downstream effects are the secondary problems caused by an initial change. For example, a 200 watt power supply could be substituted for a 150 watt power supply of the same size without changing the dimensions of the product frame, but engineers may later find that a larger cooling fan is needed.

When the engineers specify the larger power supply, they could perform a thermal analysis immediately and request mechanical changes in the frame dimensions or revise the cooling requirements for the machine. Sometimes, secondary changes will be obvious. Other times, the downstream effects will not be noticed until system testing or product failure. One engineer described a basic rule-of-thumb used to estimate the cost of engineering changes:

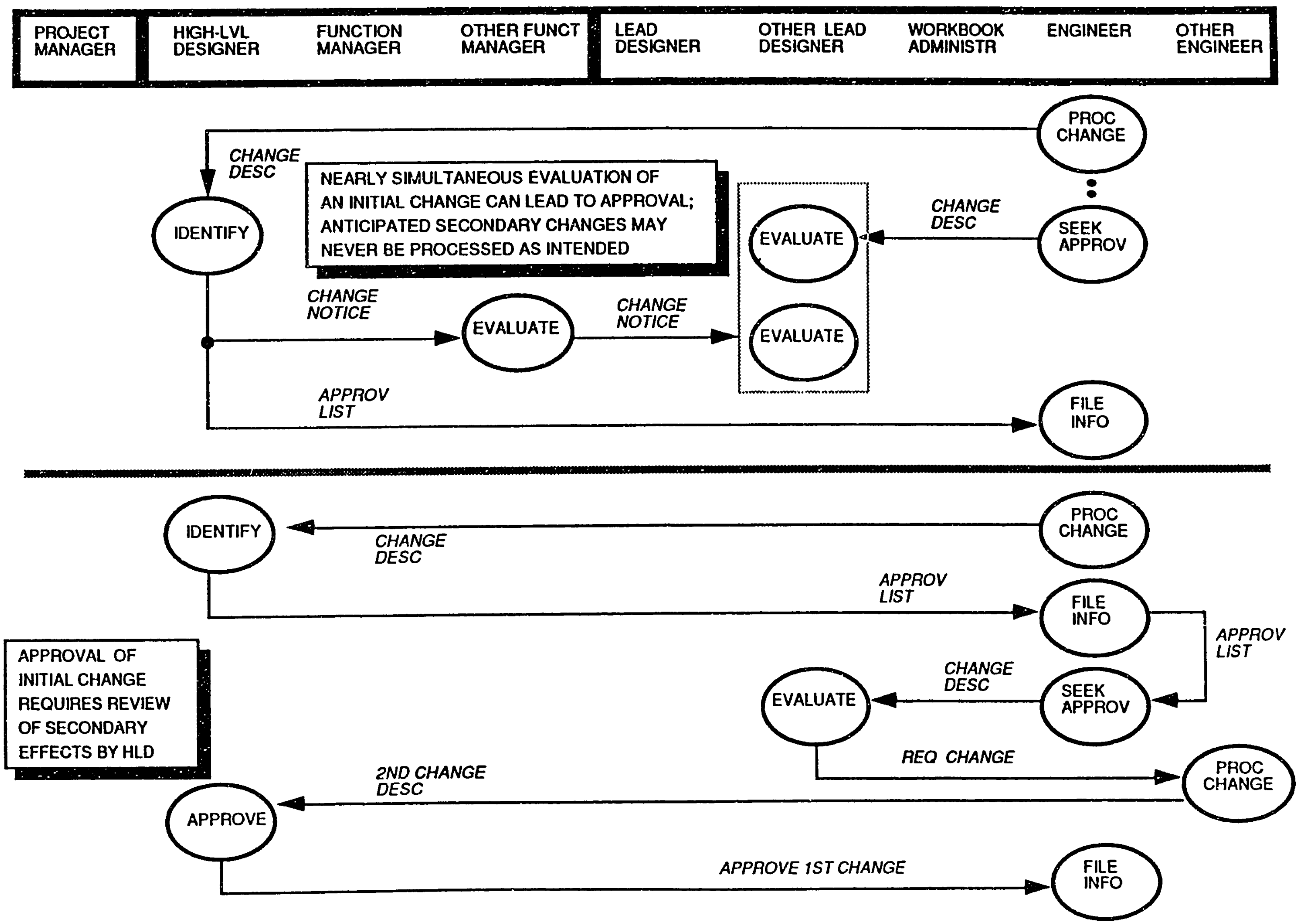
Where/When the Problem is found	**Cost to fix**
Engineer's Desk	*$ 0.10*
Parts ordered	*1.00*
Components assembled	*10.00*
Prototype test	*100.00*
Manufacturing	*1,000.00*
Field Installation	*1,000,000.00*

The messages exchanged in Figure 5.2 will show how an OOM approach can be used to improve the quality of a final implementation by minimizing unforeseen secondary changes. For the purpose of this discussion, consider the case of automobile design. Suppose that mechanical engineers are told that they will be able to use a stronger fastener to attach the car body to its chassis. However, cost benefits accrue only if fewer fasteners are used. As a result, the chassis designer might reduce the number of fastening points from eight to four, and would change the location of the chassis holes to non-standard positions.

The engineer (chassis designer) notifies the workbook administrator and high-level designer that he has made a significant change to accepted fastening practices. After receiving a sign-off list from the workbook administrator and high-level designer, gaining approval from body design engineers would be likely. The high-level designer would notify the manager of the body design team that changes had occurred. According to the managers interviewed, this change notice seems to greatly reduce the probability that the initial change will be overlooked when the body designers specify fastening points in their design.

At the time the chassis designer makes his change, the car body designers may not be ready to implement the complementary change. And because the change seems to be one that can easily be accommodated when they get to that

FIGURE 5.2
IMPROVING DESIGN VERIFICATION



stage of design, the change would be approved. It is not difficult to imagine that weeks later, when the design team actually specifies the locations for fastening the body to the chassis, the locations chosen are for the standard, eight-hole design traditionally used for that chassis. The problem may then go undetected until workers attempt to assemble the first unit.

One possible improvement can be identified by studying the information and messages exchanged between those involved in tracking the changes. For example, the high-level designer could <u>require</u> that the manager of the car body design team return a description of the design that accommodates the relocated fastening points, rather than simply sending out a notification of design changes. This policy would require that the high-level designer track the downstream effects of change. However, as a mechanism for double-checking that the downstream effects of a given change are managed properly, it could be more effective than simply duplicating change notices.

5.2 Identifying Key Information Measures and Actions

Tushman and Nadler (1978) suggested that an information processing view of organizations would be useful for designing structures that are useful for helping a firm accomplish its goals. The OOM approach to modeling information processing provides a detailed technique for identifying the components of organizational processes that can be effectively supported by alternative organizational forms. A computer simulation of an organization, based on a model such as that developed above could be used by a designer to quickly and easily experiment with new organizational forms, and predict the effects of different kinds of IT. A general design tool such as this could also be used to examine the properties of organizations that are not yet feasible, and thus explore the potential of future technologies.

Using the flowcharting technique of Figures 4.1 and 4.2, a summary of the information exchanged and actions taken by each agent of the organization can be compiled. The time required to perform a particular action or communicate information might be modeled using assumptions about the costs of communication using alternative organizational forms [Malone, 1985][3]. After identifying all of the inputs, outputs, and actions for the agents in the organization, a simulation program can then be developed. Using the program, the effects of any stimulus or problem can be evaluated according to the actions which result and time required for other agents to respond.

Moreover, as new information technologies are introduced, assumptions about the coordination or vulnerability costs of various organization forms may be

[3] Malone compares a number of organizational forms in terms of their ability to achieve the organization's goals, coordinate the tasks among agents in the organization, and the ability to adapt to changing situations.

altered. Based on assumptions about how tasks are assigned to engineers or other agents in the organization, models for simulating alternative organizational forms might provide insights that lead to the design of more effective organization structures.

Even if a full simulation of organizational information processing is not desired, the OOM technique is useful for identifying the components of organizational processes which should be measured to improve organizational effectiveness. One staff manager in manufacturing EC administration framed the problem this way:

> *One of the biggest problems facing us today is that we cannot figure out where all the indirect costs associated with EC are coming from. Even with very sophisticated cost-accounting systems, we cannot accurately track, and therefore have difficulty reducing, our EC costs.*

Viewed in this way, the OOM technique could be considered a cost-accounting system for coordination and information processing. The OOM technique is especially useful for iteratively refining a model of organizational coordination processes and evaluating the effects of potential changes such as implementation of new information technologies or organizational restructuring.

5.3 Highlighting Key Features of New Technologies

By identifying potential weaknesses in the information processing capabilities of organizations, the OOM technique helps suggest and evaluate opportunities for addressing those weaknesses. Among the various alternatives are new or modified information technologies.

Malone et.al. (1985) showed that the capabilities of an system for information sharing in organizations have powerful implications for coordinating group work. The Information Lens helps people filter, sort, and prioritize messages that are already addressed to them, and it also helps them find useful messages they would not otherwise have received. Given a set of semi-structured messages, rules for automatically processing the messages can be created. Together these capabilities would provide a more sophisticated level of communication support than currently exists for managing engineering change.

Chapter Four showed that a limited number of semi-structured message types account for the majority of information exchanged by engineers in development and manufacturing. A system that could intelligently route messages to individuals and take a proactive role in motivating responses could greatly improve the time-intensive, and error-prone process of passing paper memos to groups of individuals.

While the Information Lens would provide individuals with notification regarding messages that they might have otherwise missed, it does not have the ability to automatically require actions. For example, coordination of engineering change should require that all engineers view a notice regarding a change before allowing the message to be sent to the workbook administrator. However, the information lens does provide message templates that would be helpful to authors of messages [Malone, Cohen, Brobst, Grant, & Turbak; 1986:8]. For example, a memo requesting some kind of action might include in a prominent place, the deadline by which the action needs to be taken[4].

Other approaches for structuring information sharing in electronic communities include use of associate links between textual items to represent relationships such as references to earlier (or later) documents on similar topics, replies to previous messages or examples of general concepts (e.g., Engelbart, 1968; Trigg, 1983) This type of system might be useful for improving the ability of product engineering functions to identify closely related field problems that have been corrected using a number of different solutions for the same underlying problem. Rather than processing a large number of alternative engineering changes, a single approach to a number of problems may be more quickly identified.

Depending on the communication problem identified, a real-time information sharing system such as teleconferencing might be useful, or an asynchronous form

[4] Malone et.al. also discuss the potential problems with this type of system including, excessive filtering, imperfect finding, excessive processing loads, and privacy concerns. However, they make suggestions for addressing these problems as well.

such as computer conferencing. These tools could be useful for improving the ties between product engineering, manufacturing and field engineering with such benefits as: (1) improved access to the latest diagnostic information regarding field problems, (2) greater satisfaction from field engineers that action is being taken to address a given problem, faster turnaround on new problems, and (3) greater access of inexperienced individuals to the knowledge possessed by those with greater experience.

5.4 Differences Between OOM and Other Modeling Techniques

The OOM technique presented earlier synthesizes earlier work by Clement (1987) and Ellis and Nutt (1979) for developing process models of organizational information processing. Ellis and Nutt's Information Control Net (ICN) approach modeled the data flow, precedence constraints, and actions performed in office tasks. They also proposed minimizations of particular patterns of tasks for streamlining office functions.

Though OOM borrows much of its notation from ICNs, the two are significantly different in many ways. Perhaps the most obvious difference is the use of columns for identifying the agents who perform each process. This feature provides three advantages by:

1. Summarizing quickly and easily the processes performed by each agent. As a result, evaluation of the accuracy of the model can be simplified by the identifying and possibly interviewing individuals about those particular roles.

2. Identifying to a greater degree, the linkage between organizational structure and coordination processes; the resulting model can be visually scanned to quickly assess the amount of vertical or lateral flow of information as well as the locus of decision-making.

3. Capturing context sensitivity. In the relatively unstructured process of managing EC, the impact of decisions varies according to the agent making the decision, e.g. when a PE Manager rejects an REA, it can be appealed; when the program manager rejects the REA, it is rejected.

This third point seems particularly interesting because it captures some of the unstructured characteristics of particular processes in a structured model; the use of columns lends an organizational context to the processes that does not exist in other modeling approaches. To model the EC process using ICN, one would have to represent the EVALUATE process differently for each agent, i.e. PROGRAM-MANAGER-EVALUATE, FUNCTIONAL-MGR-EVALUATE, etc. The resulting model would certainly be more difficult to use.

Another major difference between OOM and ICN is that ICN permits the transformations of series of processes into minimal forms mathematically [Ellis, 1979]. This is possible because the processes are modeled discretely. In contrast, the OOM transformations suggested in this thesis (Figures 5.1-5.2) can only be recommended based on a careful evaluation of the processes and contexts involved. These transformations are much more similar to the types of tradeoffs that Malone describes for choosing alternative organizational forms. For example, a higher degree of centralized control over decision-making processes would be identified by prerequisite information flows that span many columns (corresponding to managerial levels) in an OOM model. Decisions regarding the choice of alternative organizational forms or coordination processes can be quickly modeled and evaluated using OOM, though the resulting transformations might never be "ideal".

6.0 Conclusions

The linkage between information technology and organizational structure has been identified by many researchers. However, investigation of the link has possibly been limited by the generality of frameworks and techniques that have been applied. The object-oriented modeling approach presented here attempts to further refine such earlier work by integrating and applying concepts borrowed from object-oriented processing and process flow representations.

Unlike traditional process flowcharts, OOM consciously focuses on the interactions between people in organizations, rather than simply what they do. By identifying precedence relationships, prerequisite information needs, and the information processing performed by people in organizations, OOM provides a more precise view of complex, coordination processes. In addition, the OOM representation permits:

1. Identification of potential failures in existing processes,

2. Definition of specific interactions which can be monitored and measured to assess the effectiveness of particular coordination mechanisms,

3. Creation of proposals for defining requirements of automated information technologies that can support organizational information processing needs without disrupting existing communication patterns.

Together, these benefits can help managers better understand how to reduce communication delays, track intermessage interval delays, and implement systems for providing online intervention (e.g. messaging systems that actively demand a response from the receiver).

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Appendix 1

Problem Tracking System (PTS)

PTS is a database system that supports project development managers by tracking field and manufacturing problems for by product. Managers are provided access to information regarding product problems based on their association with a program and their responsibility for the design of product functions.

In addition to tracking the date a problem is identified and the severity of the situation, the system identifies an individual who is responsible for solving the problem. In many instances, that individual is not the engineer who is working on the problem, but a product engineering manager or functional manager. Although PTS is actually used during both initial- and post-release periods, the system has traditionally provided little value during the initial-release stage. Managers commented that "engineers traditionally have an aversion to documenting problems". Others noted that engineers do not distinguish between "problems" and design objectives during development. As a result, engineering designs that do not fully meet operational specifications are not usually regarded as problems until the engineer realizes that he cannot meet a deadline.

Appendix 2

Development Production Release System (DPRS)

DPRS is a sophisticated system for storing engineering drawings and maintaining related bills of material. DPRS provides check-in and check-out features that prevent multiple and conflicting updates to a single engineering drawing by two or more engineers. The system also automatically generates bills of materials from information in the drawings, and updates the bills as changes are made. Finally, the system automatically identifies subassemblies that require modification due to changes in another drawing.

Figure A.3 shows how revisions to an engineering drawing would be identified. New part numbers are generated and arrows highlight the modifications from the previous drawing. Figure A.4 documents the information that would be tracked to implement a change in DPRS. For example, the dates the change were implemented and released to production, the status of the change, references to other drawings, engineering responsibility for the change, the product(s) affected, and a description of the change are maintained.

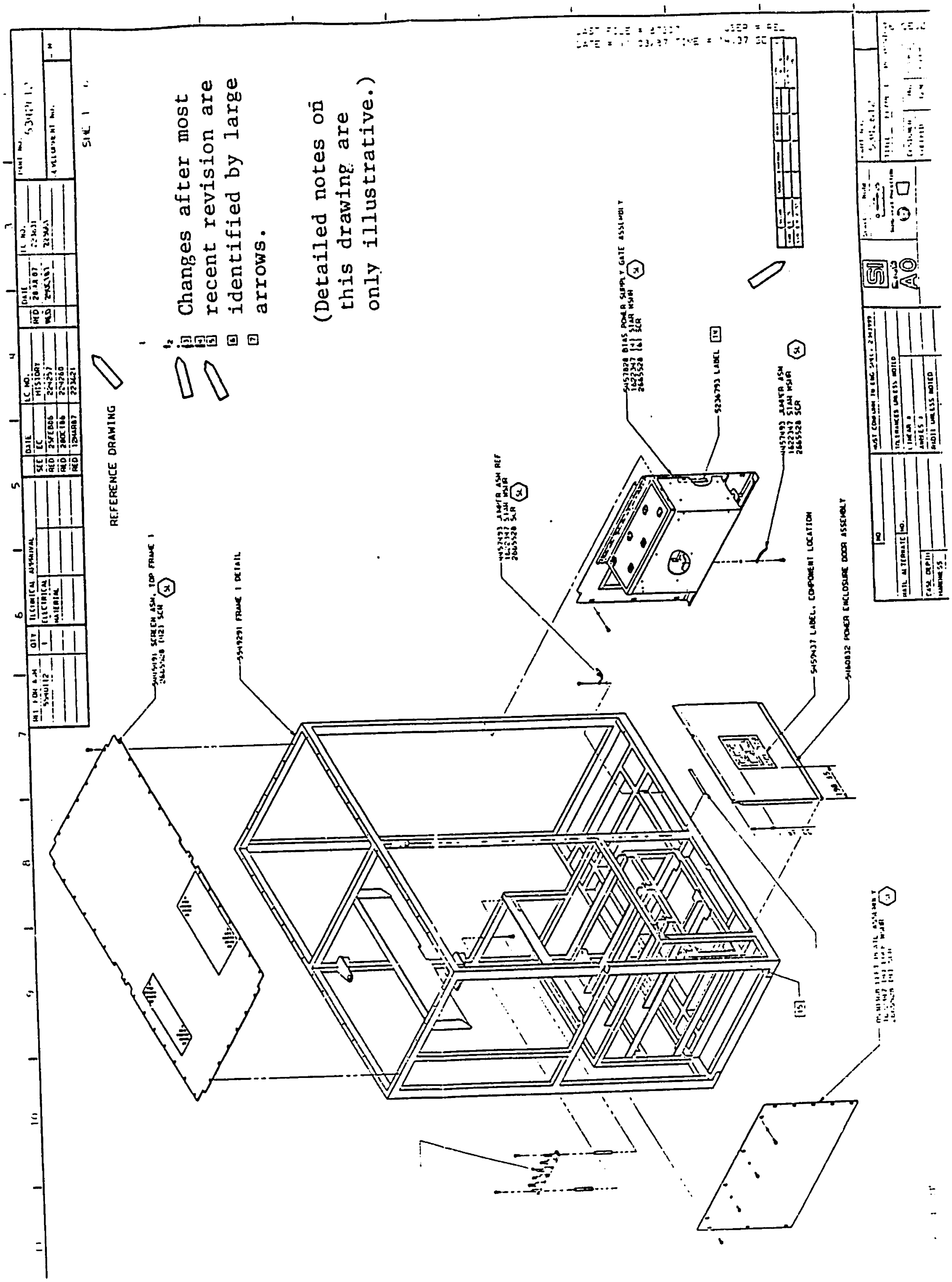

Figure A2.1
DPRS Drawing Revisions

```
-ADDA -ART                                        PGE 0001
   ORG- P30    AT 59K07MMW TIME-880331 11.41
   CHNG 100000227799
   ESTAB  RELSE  CHG                CHG    ORIG     MACH
   DATE   DATE   STAT XREF CHG NBR STAT   GROUP    AFF
   871211 880201 E                         9624116
                                                    2000004116
```

PROSE TEXT

/01 DEHZZZKZZ

REVISE ROUTING FOR 280E MACHINE

PROVIDE FIELD-USE LABELS FOR MES CONVERSIONS
SEE REWORK REFERENCE DWG 6012971 SHEET 1&4
FOR REVISIONS

RELEASE LABELS PN 14F3589 AND 14F3597
TO BE PICKED UP ON A FIELD BM AT A LATER DATE

Figure A2.2
DPRS Change Documentation

Appendix 3

Request for Engineering Action (REA)

When a Field Engineer submits a Request for Engineering Action, a description of the problem including machine type and other diagnostic information available is recorded in a centralized national database which is available to all field locations. Field Engineers typically review RETAIN daily. This sensitizes them to the types of problems that they may encounter and allows them to provide supplementary diagnostic information by evaluating machine conditions at similar installations.

REA's are originated in an on-line database using electronic forms. Figures A.4 - A.6 illustrate the forms that are used to originate, track, and respond to field problems. However, although the forms provide fields for field engineers to indicate the severity of a particular problem, the system treats each request passively. Human administrators at each product support center are responsible for ensuring that REA's are acted upon in a timely manner consistent with the field engineers assessments.

```
      ***** REALM GENERATED REQUEST FOR ENGINEERING ACTION *****      | REA NO: 0253433
      ---------> REVISED AFTER INVESTIGATION APPROVAL <---------      |  PAGE:  1 OF 1
MACHINE/MODEL: TEST
ORIGINATING LOC:        LAB OF CONTROL: 962     LAB OF DESIGN: 962      ATTACHMENTS: 00
SYSTEM: 0370            SERIAL NO:              FRAME NUMBER: 2         CSA:
PART NO: 000004223456   EC LEVEL: 10000223630A  INSTALLED ON MACH: Y    PRIORITY: E
REA TYPE:                                       SAFETY REV REQD: Y      MFI: N
ROUTE DEST: 546         ROUTE CODE:
EC REASON CODE: AF      EC REASON CODE: DD

ORIGINATOR: MANNY ASHONG          EXTENSION: 31070                   DATE: 17SEP87
DEPARTMENT: 546                   BUILDING:  4141

                              ORIGINATION REVIEWS
     NAME          ORGANIZATION    DATE            NAME        ORGANIZATION    DATE
1. **OVERRIDDEN**     D546        28SEP87     4.
2.                                            5.
3.

ORIGINATION APPROVAL: SEE TEXT MANNY      ORGANIZATION: S.M.E        DATE: 28SEP87

INVESTIGATOR: MANNY ASHONG        EXTENSION: 31070                   DATE: 28SEP87
DEPARTMENT:   546                 BUILDING:  4141

ACCEPT: N          PU EC NUMBER:
DISPOSITION CODES -- STOCK IN PROCESS:            FURTHER ASSEMBLIES:

                              INVESTIGATION REVIEWS
     NAME          ORGANIZATION    DATE            NAME        ORGANIZATION    DATE
1.                                            4.
2.                                            5.
3.

INVESTIGATION APPROVAL:                   ORGANIZATION:              DATE:

 |MFI AFFECTED:
H|THIS IS A TEST.
J|
R|
R|PRIORITY CHANGED FROM I TO X PER MANNY          PAM
 |---------------------------------------------------------------------------
 |PUMEC:          PUSEC:          TARGET TO B84:
 |*** TEXT BELOW ADDED ON 28SEP87 ***
Z|TEST FOR REALM/GTS BRIDGE 9/28/87 PAM/MANNY
```

Figure A3.1
Request for Engineering Change Report

ORIGINATE REA MENU

```
REALM (level) ------------------ ORIGINATE REA ---------------------- (time)

REA Number:                     Machine/Model:
------------------------------------------------------------------------------
Origin loc:                     Lab of control:              Lab of design:
System:                         Serial number:               Frame number:
CSA(Y/N):                       Part number:                 EC level:
Installed(Y/N):                 Priority(E/X/I):             MFI(Y/N):
Type(LMPUDOBS|SW):              Safety rev reqd(Y/N):        Security(I/C):
Route dest:                     Route code:                  Attachments:
A-Code:                         B-Code:
[Func/Non-func(F/N):            Qty/Time limit req:                          ]
[Corr act reqd(Y/N):            Person responsible:                          ]
Originator:                        Dept:       Building:           Ext:
------------------------------------------------------------------------------
Enter text type and text below:  (H=Reason  J=Justification  R=Remarks)



  PF1=Save            PF2=Add/Edit Text           PF4=Dup            PF12=Exit
```

INVESTIGATE AN REA MENU

```
REALM (level) --------------- INVESTIGATE AN REA -------------------- (time)

REA Number:                     Machine/Model:
------------------------------------------------------------------------------
Origin loc:                     Lab of control:              Lab of design:
System:                         Serial number:               Frame number:
CSA(Y/N):                       Part number:                 EC level:
Installed(Y/N):                 Priority(E/X/I):             MFI(Y/N):
Type(LMPUDOBS|SW):              Safety rev reqd(Y/N):        Security(I/C):
Route dest:                     Route code:                  Attachments:
A-Code:                         B-Code:
[Func/Non-func(F/N):            Qty/Time limit req:                          ]
[Corr act reqd(Y/N):            Person responsible:                          ]
Originator:                        Dept:       Building:           Ext:
------------------------------------------------------------------------------
Investigator:                      Dept:       Building:           Ext:

[Accept(Y/P/N):                 PU EC Number:                                ]
[Disposition Codes -- Stock in Process:            Further Assemblies:       ]
[Accept(Y/P/Q/N):               Qty/Time limit acc:                          ]
[                               PU EC Number:                                ]

Enter text type and text below:  (R=Remarks  Z=Investigator report)

  PF1=Save            PF2=Add/Edit Text           PF4=Dup            PF12=Exit
```

Figure A3.2
REA Origination and Investigation Forms

UPDATE FIXED FIELDS MENU

```
REALM (level) --------------- UPDATE FIXED FIELDS -------------------- (time)

REA Number:                  Machine/Model:
------------------------------------------------------------------------------
Origin loc:                  Lab of control:               Lab of design:
System:                      Serial number:                Frame number:
CSA(Y/N):                    Part number:                  EC level:
Installed(Y/N):              Priority(E/X/I):              MFI(Y/N):
Type(LMPUDOBS|SW):           Safety rev reqd(Y/N):         Security(I/C):
Route dest:                  Route code:                   Attachments:
A-Code:                      B-Code:
[Func/Non-func(F/N):         Qty/Time limit req:                             ]
[Corr act reqd(Y/N):         Person responsible:                             ]
Originator:                     Dept:        Building:            Ext:
------------------------------------------------------------------------------




PF1=Save                     PF2=Add/Edit Text                     PF12=Exit
```

```
REALM (level) --------------- UPDATE FIXED FIELDS -------------------- (time)

REA Number:                  Machine/Model:
------------------------------------------------------------------------------
Origin loc:                  Lab of control:               Lab of design:
System:                      Serial number:                Frame number:
CSA(Y/N):                    Part number:                  EC level:
Installed(Y/N):              Priority(E/X/I):              MFI(Y/N):
Type(LMPUDOBS|SW):           Safety rev reqd(Y/N):         Security(I/C):
Route dest:                  Route code:                   Attachments:
A-Code:                      B-Code:
[Func/Non-func(F/N):         Qty/Time limit req:                             ]
[Corr act reqd(Y/N):         Person responsible:                             ]
Originator:                     Dept:        Building:            Ext:
------------------------------------------------------------------------------
Investigator:                   Dept:        Building:            Ext:

[Accept(Y/P/N):              PU EC Number:                                   ]
[Disposition Codes -- Stock  in Process:            Further Assemblies:      ]
[Accept(Y/P/Q/N):            Qty/Time limit acc:                             ]
[                            PU EC Number:                                   ]



PF1=Save                     PF2=Add/Edit Text                     PF12=Exit
```

Figure A3.3
REA Update Forms

APPROVE/REVIEW REA MENU

```
REALM (level) --------------- APPROVE/REVIEW REA -------------------- (time)


       Enter REA Number:
          Machine/Model:

             REA status: *
             Route dest: ****      Route code: *      (optional)

                User id:              (only if overriding
          Override code:               logon user id)

         [     Signature:             (only if removing other       ]
         [ Organization:               user approval/review)        ]

        Indicate the desired function by hitting the PF key:
             PF1  --------------- Origination Review
             PF2  --------------- Originating Manager Approval
             PF3  --------------- Investigation Review
             PF4  --------------- Investigating Manager Approval
             PF5  --------------- Display Status, Route dest, Route code
             PF6  --------------- Remove Approval/Review
             PF12 --------------- Exit
```

Figure A3.4
REA Approval/Review Form

Appendix 4

Machine Level Code (PLC) and RETAIN

The PLC is a centralized database which tracks all field-serviceable products by serial number and identifies which modifications have actually been made to each particular product. By maintaining a current listing of all installed products and the enhancements that have been performed for each individual product, the firm is able to quickly determine if problems have resulted because an upgrade was not installed.

RETAIN is a centralized, national database that provides upgrade information to field engineers and locations which have responsibility for supporting the associated products. Problems are tracked by machine and model number and date of notice. By cross-checking the PLC against RETAIN, field engineers can determine if an upgrade to a machine may solve a particular problem.

Appendix 5

Managing Changes Found During Prototype System Testing

Before a new product is released for general availability, it will be thoroughly tested by design engineers, early installations of the product at different locations in the corporation, and test installations of the product at special customer locations. Problems found before general availability can be corrected by design engineers, usually without having a serious impact on manufacturing or other organizations.

In many cases, the machine prototype will be assembled and will be required to operate under stringent conditions. Any problems that are identified during this shake-out period by the testing and verification organization would be tracked using PTS (Problem Tracking System). The problem is traced back to a functional assembly and responsibility for identifying a solution would be assigned to the functional manager who was managing the design of that assembly. After the functional manager has been notified, an engineer may be assigned to work on a solution. Alternatively, the functional manager can pass the problem to another area or the project manager if he believes that the problem can be more appropriately resolved elsewhere, perhaps due to impending commitments.

If a problem notice reaches a functional manager and his team of engineers addresses the problem, workbook changes will be processed using the same sign-off procedures required during initial release. However, when this happens, new drawings must be quickly forwarded to manufacturing and problems may arise with OEMs and vendors who may be unable to accommodate changes.

Because the products have not been released for general availability, changes generally have a limited impact on manufacturing. Manufacturing processes for assembling the product will be tailored to accommodate changes identified before general availability. However, it is possible that a change is significant enough to require a high degree of coordination between the project office and other organizations to resolve scheduling conflicts, or to authorize additional expenditures.