AN OUTLINE FOR A MANUFACTURING PLANNING AND CONTROL SYSTEM FOR A REPAIR/OVERHAUL/REBUILDING ENVIRONMENT

THESIS

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This study outlines a structure for a manufacturing planning and control (MPC) system for a repair/overhaul/rebuilding environment. Included is an examination of the organizational components that must be incorporated into the system and the planning functions for which the system can be used. The study compares and contrasts the differences between an MPC system for a maintenance organization and a manufacturing organization and concludes that the MPC system for a maintenance organization must account for the greater degree of variability that occurs within the process. The proposed system is composed of an information system which collects data from throughout an organization and a planning support and decision testing system which makes use of computer simulation models to test management decisions prior to their actual implementation. The basic outline is applied to the C-141 maintenance operation at Warner-Robins Air Logistics Center at Robins AFB, GA. A description of the organization and the C-141 maintenance process is provided. A specific system for Warner-Robins is proposed and a simulation model is developed. The use of such a system is illustrated by using the simulation model to address specific questions and concerns of the senior leadership at Warner-Robins.

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THESIS

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Peter H. Miyares, B.S.

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Peter H. Miyares

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Abstract

This study outlines a structure for a manufacturing planning and control (MPC) system for a repair/overhaul/rebuilding environment. Included is an examination of the organizational components that must be incorporated into the system and the planning functions for which the system can be used. The study compares and contrasts the differences between an MPC system for a maintenance organization and a manufacturing organization and concludes that the MPC system for a maintenance organization must account for the greater degree of variability that occurs within the process. The proposed system is composed of an information system which collects data from throughout an organization and a planning support and decision testing system which makes use of computer simulation models to test management decisions prior to their actual implementation. The basic outline is applied to the C-141 maintenance operation at Warner-Robins Air Logistics Center at Robins AFB, GA. A description of the organization and the C-141 maintenance process is provided. A specific system for Warner-Robins is proposed and a simulation model is developed. The use of such a system is illustrated by using the simulation model to address specific questions and concerns of the senior leadership at Warner-Robins.

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I. Introduction

A manufacturing planning and control (MPC) system is a management tool that integrates every aspect of producing a product, "from [the] acquisition of raw materials to [the] delivery of the completed product" (Vollman, Berry, and Whybark, 1988:1). It provides various management levels with information with which they can plan and monitor the entire production process and make informed decisions when the process is forced to adapt to higher demands, tighter constraints, bottlenecks, broken machinery, or other similar influences. The system also provides information useful in designing, testing, and improving processes. This information includes system capacity, activity scheduling, and resource requirements data.

Background

Traditionally, MPC systems have been used in the production or manufacture of products. More recently, the need has been identified to develop similar systems for the repair, overhaul, or rebuilding of existing products (Chrissi, 1991). One particular operation in need of such an MPC system is the C-141 Management Directorate at Warner-Robins Air Logistics Center at Robins AFB, GA (Chrissis, 1991). The center's need stems from upper-level management's concerns over lack of control over current operations and the difficulties involved in expanding operations given that lack of control (Scoskie, 1991). One of the reasons management lacks this control is because they do not have access to information that is vital to completely understand the details of their operation and the effects of imposing changes to it.

Efforts are currently underway to develop an MPC system for Warner-Robins. The organization which oversees Warner-Robins and the other Air Force logistic centers, Air Force Logistics Command (AFLC), is developing the Defense Maintenance Management Information System (DMMIS) in order to improve the planning and control functions for maintenance throughout the Air Force.

The C-141 Maintenance Process

The USAF/Lockheed C-141 is one of the largest cargo planes in the United States Air Force inventory. The Warner-Robins Air Logistics Center is responsible for conducting programmed depot maintenance (PDM) on the entire fleet of C-141s. PDM is a maintenance process that includes the inspection, overhaul, repair, and, if necessary, replacement of most of an aircraft's systems. PDM must be conducted regularly on all aircraft, and must be scheduled and completed so as not to interfere with the mission capabilities of the C-141's users, the major one being Military Airlift Command (MAC) (Davis, 1991).

In addition, because of the age of the C-141s, the logistics center must now repair cracks and fatiguing joints in the wings of almost every aircraft replace a major structural support in many aircraft, and repaint most of the fleet -- all within the next two to four years. Incorporating these additional requirements into the current operation at Warner-Robins and ensuring sufficient levels of resources to meet these requirements are two issues of great concern to the leadership within the C-141 Management Directorate (Davis, 1991).

Research Objective

The purpose of this investigation is to design a general manufacturing planning and control system for a repair/overhaul/ rebuilding environment, apply it to the C-141 maintenance process at Warner-Robins Air Logistics Center, and use this system to address certain questions and concerns at Warner-Robins.

In accomplishing the overall objective, this investigation defines and describes all the necessary components of an operation that must be incorporated into an effective MPC system and how they interact with each other. This investigation also compares and contrasts the components for a manufacturing operation with those of a repair/ overhaul/rebuilding operation. The result is an outline of a general MPC system for a repair/overhaul/rebuilding operation and an outline of the key steps an organization should follow to successfully implement an MPC system. This study includes the application of the general MPC system to the situation at Warner-Robins where some parts of the system may already exist or be in the planning stages, while others may require development. This study also uses portions of the MPC to analyze certain key areas of the operation at Warner-Robins in greater detail to address management concerns regarding system capacity and how that capacity might be improved.

Approach to the Problem

Developing the general MPC system and the steps to implementing it required the research of general MPC systems for both manufacturing and repair/overhaul/rebuilding environments. This included the study of each component of an operation and how they interact, the interfaces required to link the components, and the key steps an organization should go through in implementing its own MPC system. In addition, this study examined MPC systems that are currently in place in both environments to determine how other organizations have adapted general systems to their operations and successfully implemented them.

The application portion of this investigation required the detailed study of the operation at Warner-Robins. The research focused on how to adapt the general MPC system to the operation's components and incorporate portions of an MPC system that may already be in place or in the planning stages. The proven successes of other companies provided the basis for suggested alternatives for those elements of an MPC that currently do not exist.

The analysis portion identified certain areas of concern within the Warner-Robins process and analyzed them in greater detail. Most of these concerns pertained to system capacity, whether it was sufficient to meet maintenance objectives and how it might be improved. Analyzing proposed solutions to these problems and testing these solutions for their effectiveness required the development of measures of effectiveness, the use of computer simulation models, and hypothesis testing.

Overview

Chapter II reviews the literature pertinent to this research proposal. The review examines the role an MPC system plays in an organization and develops a basic outline for the system's structure, implementation, and use. This chapter also highlights the key differences between manufacturing operations and repair/overhaul/ rebuilding operations that must be considered. In addition, Chapter II provides examples of MPC systems that have been successfully implemented.

Chapter III provides a more detailed description of the operation at Warner-Robins Air Logistics Center. It outlines the basic maintenance process, the logistic center's organizational structure, and the management philosophy within the C-141 Management Directorate. Included is a basic description of DMMIS. Chapter III also describes the specific areas of concern to the management at Warner-Robins and examines the results of previously conducted analyses.

Chapter IV outlines the methodologies that were used to develop the MPC system and address the areas of major concern. Contained within the MPC is a computer simulation model of the C-141 maintenance process at Warner-Robins. Chapter IV contains a basic description of this model and how it was embellished to suit the needs of this analysis and the final MPC system.

Chapter V provides an outline for the basic structure of an MPC system for a repair/overhaul/rebuilding operation and a more formal system outline specific to Warner-Robins ALC. Results of the analysis are provided.

Chapter VI reviews the basic structure of the proposed MPC system and outlines the basic steps an organization must undertake to develop and implement such a system. Specific recommendations are provided for the development of the system at Warner-Robins and for addressing the concerns of upper level management there. The chapter also includes a list of areas for future research.

II. Literature Review

This chapter reviews literature pertinent to this research proposal. Specifically, the discussion covers the role an MPC system plays in an organization, the basic components of an operation that must be incorporated into an MPC system, the interfaces (systems that transmit information) required to link the components, and the key steps that should be taken to implement an MPC system. This section also outlines the basic structure of an MPC system and what it should provide to the user. In addition, this review describes how some companies have implemented and are currently using MPC systems in their production processes.

The Role of MPC Systems

The strength of an MPC system is its ability to assist managers at all levels in making decisions. Even when a process is operating at steady state (in full, normal operation), production managers are constantly planning and making decisions. These decisions can vary from operating, controlling, and updating a production process, to designing new sub-processes and selecting new equipment to enhance the operation (Biswas, Oliff, and Sen, 1988:236-237).

In making these decisions, management must continually gather information from every aspect of the operation and compare this data to established standards and goals. If these standards are not being met, data must be analyzed so as to identify the reasons why. Once the problem is located, management must choose the appropriate corrective measure and implement it (Biswas, Oliff, and Sen, 1988:237).

These actions require managers to be familiar with their operation, have data available to identify problems, and have the appropriate analytical tools to make and test their decisions (Biswas, Oliff, and Sen, 1988:237-238). Given the first, an MPC system is a means to provide the remaining two.

Key Organizational Components

Thomas Vollman, professor and chairman of the department of Operations Management at Boston University's School of Management, states that there are five basic components of a manufacturing operation that must be incorporated into an MPC system (Vollman, Berry, and Whybark, 1988:4). They are: material planning and control; financial control; engineering activities; quality assurance; and sales/marketing coordination. Each has its own key role to play in the planning and operating of a manufacturing process and its own, often conflicting, objectives. In addition, these components must interact with each other. Decisions made by upper-level managers and by managers and operators within each component are influenced by and have a direct or indirect effect on the others. Figure 1 illustrates this interaction.

Material Planning and Control. The primary purpose of this component is to plan and schedule system operations and capacity and to monitor the inventory status of an organization. An organization's inventory includes not only supply of materials, but also the actual number and status of the objects within the production process (work-in-process inventory). The types of decisions that would be made using

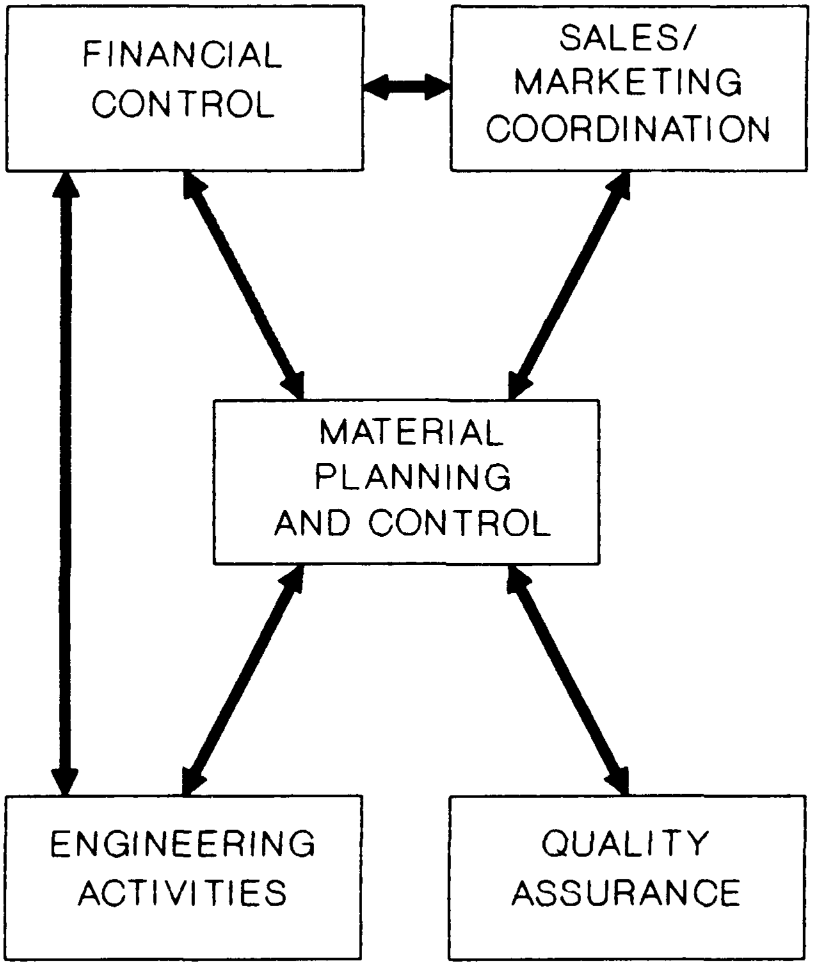

FIG 1: KEY ORGANIZATIONAL COMPONENTS AND THEIR INTERACTION

(Adapted from Vollman, Berry, and Whybark, 1988:4) this information pertain to the master production schedule, material requirements planning, purchasing, and shop-floor control. Material planning and control is the most critical of all the components since it interacts with each of the others (Vollman, Berry, and Whybark, 1988:4). The main objective of this component's managers is meeting the production schedule (Bedworth and Bailey, 1987:2).

Financial Control. Managers within this component monitor and report information that influences budgeting and cost accounting decisions. This component interacts primarily with material planning and control and engineering activities (Vollman, Berry, and Whybark, 1988:4). These managers seek to minimize the amount of capital tied up in facilities, personnel, and inventory (Bedworth and Bailey, 1987:2).

Engineering Activities. An organization's engineers are responsible for planning and developing the actual plant layout, the systems, materials, machinery to be used, and the number and types of people to hire. They also conduct product engineering (Vollman, Berry, and Whybark, 1988:4). The manufacturing engineering tasks are important not only in the development of new plants, but also in the constant upgrading of a current operation (Rucker, 1990:31-32). The engineers' objectives are to determine appropriate work requirements and how best to accomplish them from a facilities and equipment standpoint. This component interacts with both material planning and control and financial control (Vollman, Berry, and Whybark, 1988:4).

Quality Assurance. Quality assurance personnel monitor and control quality within the system as they oversee the areas of process control and system maintenance. Their objective is to minimize the number of flaws in an operation's final product. This component interacts with the material planning and control component (Vollman, Berry, and Whybark, 1988:4).

Sales/Marketing Coordination. Sales and marketing planning are conducted within this component. These planning functions incorporate market research, sales planning and forecasting, order entry, and physical distribution. This component interacts with material planning and control (Vollman, Berry and Whybark, 1988:4). The objectives of sales and marketing managers are to maximize shipments and minimize delivery delays (Bedworth and Bailey, 1987:2).

Component Interactions and Interfaces

The primary tool used to link components that interact with each other is information. Each component provides and requires information from at least one other component. With this information, managers within one component make decisions that may directly affect operations within other components. For example, data from material planning and control, especially in the area of requirements planning and purchasing, impacts budgeting and accounting decisions within the financial control component. In turn, financial data is required to make requirements planning and purchasing decisions (Vollman, Berry, and Whybark, 1988:4).

The engineering activities component directly influences the shop-floor and thus indirectly affects all other aspects of material planning and control. Any engineering changes would also have budgeting and accounting implications and may be limited by budget constraints. High production costs, scheduling delays, and shop-floor control problems may initiate engineering activities in an attempt to identify and solve the problem (Vollman, Berry, and Whybark, 1988:4). Without the proper information, problem identification and solution development cannot be accurately accomplished (Biswas, Oliff, and Sen, 1988:237-238).

Quality assurance requires constant information on product quality from material planning and control so that when problems arise, their cause can be identified and proper action can be taken to solve them. This action may include maintenance on a faulty machine or the implementation of a new process or procedure to prevent the problem's recurrence (Vollman, Berry, and Whybark, 1988:4).

Sales/marketing coordination requires production data from material planning and control to develop sales plans and handle distribution. Sales forecasting, market research, and customer ordering data influence the master production schedule, material requirements, and shop-floor management within the material planning and control component (Vollman, Berry, and Whybark, 1988:4).

For these components to operate efficiently and interact effectively, managers within each component need to be aware of their information needs, the information needs of others, and how their decisions affect other components of the operation. This requires a communication/feedback and information sharing network to be in place (Vollman, Berry, and Whybark, 1988:15).

Due to the volume and complexity of the data being shared and the speed with which it must be collected and distributed, the network should be computerized. The databases within this network must be accurate; otherwise incorrect decisions could be made. Proper management of the databases is crucial (Vollman, Berry, and Whybark, 1988:13).

MPC System Use and Development

Planning. An effective MPC system can be useful throughout the planning and decision-making process. This process consists of two major areas, strategic and tactical. Strategic planning examines the overall process over the long term. Tactical planning examines short term issues (Sadeh and others, 1989:22).

The planning process is accomplished in three phases: direction, detail, and execution. The first two phases can be viewed as strategic, the last tactical. Figure 2 illustrates the relationship between these planning phases.

Establishing the direction of a manufacturing operation is the responsibility of top management. The resulting production plan should be consistent with all strategic objectives, budgets, and production demands. It should concentrate on the production aspects of an operation and should incorporate all five organizational components. Because certain requirements and demands for facilities, capacity, resources, and finished product will be estimated, the production plan must be flexible enough to incorporate any changes that are necessary once production begins (Vollman, Berry, and Whybark, 1988:14-15).

With this plan, a master production schedule is developed and detailed capacity planning begins (Vollman, Berry, and Whybark, 1988:15-16). Given a defined list of tasks to be accomplished and materials required (bill of material--BOM), a master production schedule attempts to use the plant's capacity effectively to achieve the strategic objectives of the firm as reflected in the production plan, and to provide a basis for making customer delivery promises. Since these two objectives can often conflict, it also resolves trade-offs between

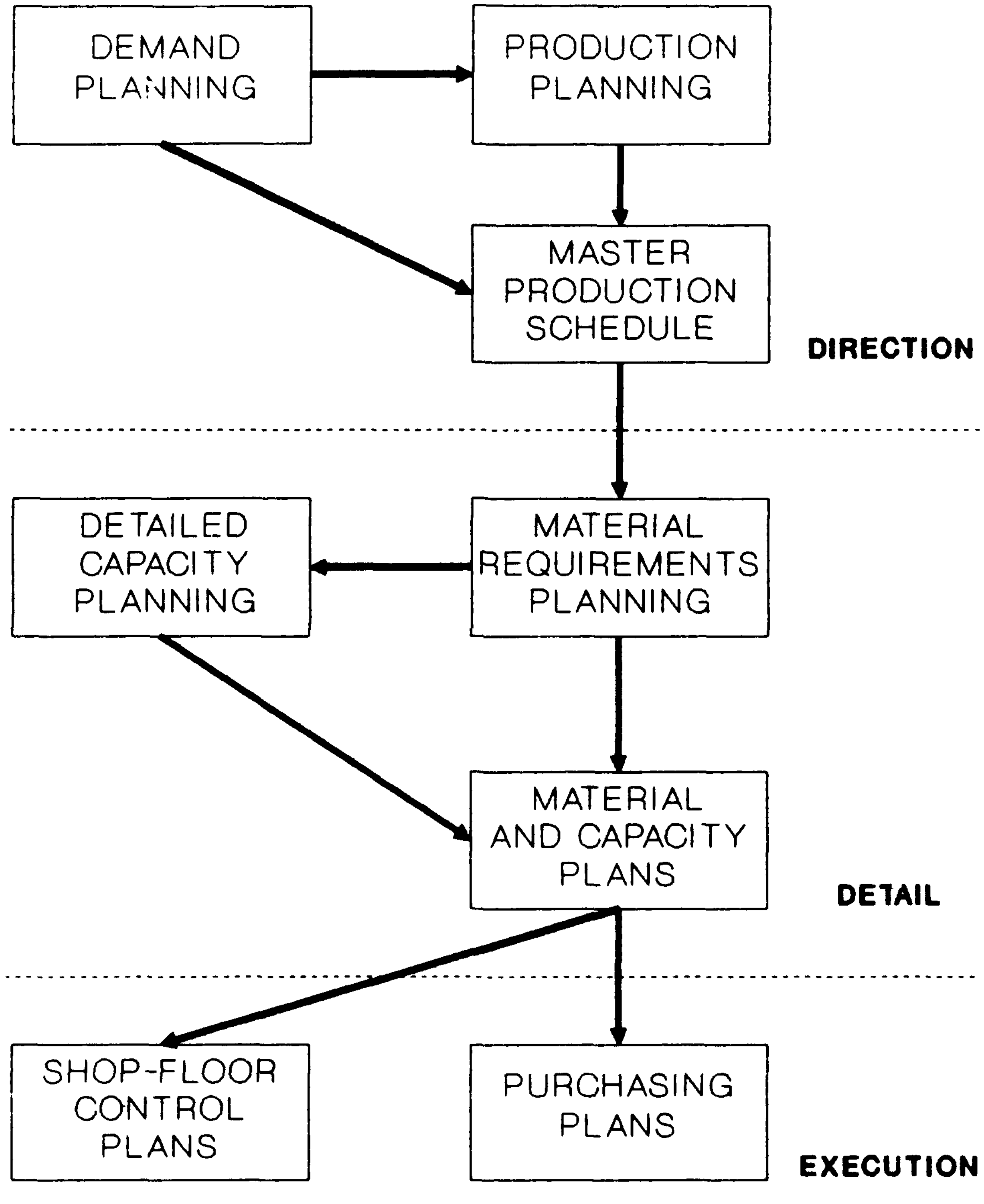

FIG 2: STRATEGIC and TACTICAL PLANNING PHASES

(Adapted from Vollman, Berry, and Whybark, 1988:16, 27) manufacturing and marketing. The master production schedule is built around end product delivery requirements (Vollman, Berry, and Whybark, 1988:296). It does not, however, consider how these requirements will be met, nor does it take into account any dynamic changes within the system that might affect how they are met (Bedworth and Bailey, 1987:5).

The purpose of detailed planning is to develop the methodology with which an organization's facilities and resources will be used to meet the master production schedule. From the master production schedule, material requirements plans are developed to ensure the necessary resources are available when needed. This is followed by detailed capacity planning which attempts to ensure that there is sufficient capacity available to meet the production plan. Accomplished by mid-level management, capacity planning uses planned material requirements to identify areas of surplus capacity, which is not always cost effective, but sometimes desirable, and areas of insufficient capacity, which must be scheduled around or improved. Conflicts and discrepancies are resolved and material and capacity plans result (Vollman, Berry, and Whybark, 1988:16, 115-116).

In the execution phase, the material and capacity plans are refined and a detailed schedule is developed. This generates purchase requirements and shop-floor order releases and the system begins operation (Vollman, Berry, and Whybark, 1988:16). In addition, this tactical planning phase involves daily decision making and determining how the goals outlined in the strategic plans are to be met. These planning and control decisions require data gathering, analysis, solution development, and decision implementation (Biswas, Oliff, and Sen, 1988:237).

Within the execution phase, managers must work together and communicate often to discuss production delays and plan solutions. Each must be aware that others may have conflicting control priorities (e.g., meeting production schedule vs controlling costs) and each must be aware of upper and lower management priorities that may also conflict (e.g., rush orders for special customers). Priorities must be arranged and the manufacturing process must be closely monitored and controlled in order to operate effectively and efficiently (Bertrand, Wortmann, and Wijngaard, 1990:301-302, 307).

Information Requirements and Systems. Both strategic and tactical planning require information to ensure appropriate decisions are made. Strategic planning requires information on costs, market demands, and engineering capabilities. Tactical planning requires information pertaining to the particular issue at hand and how a decision on that issue could influence all five components (Biswas, Oliff, and Sen, 1988:238). Personnel from each component gather information for strategic planning, often from outside sources. This information should be stored in a system from which it can be accessed by planners as needed. Tactical planning requires information on how the process is operating, so a system must be developed to collect this information, as well as to store and to distribute it. The type of information needed for tactical planning must be anticipated to ensure its availability when required. Since this information can come from any of the five components, the components' interfaces must be planned and developed together (Haupt, 1989:1062).

An MPC system requires a system for collecting, storing, and reporting this information. At the very least, this system should collect and contain the following data items (Bedworth and Bailey, 1987:21, 29):

1. The types, quantities, operating status, and limitations or capabilities of manpower and equipment resources.

2. The status of each job including the operations that correspond to that item and the completion status of items within the process.

3. The types and amounts of each material resource, the number allocated to active work orders, the number of parts on order, and the expected delivery date.

4. The schedule status of each resource including the operations scheduled, the expected processing time and completion time of each operation, the total scheduled processing time, and the present sequence of operations.

5. The status of materials moving through the system, both those actively moving and the urgent requirements for moves.

6. Recent system performance information including percentage of resources used, average time in system for jobs, present value of existing inventory, average ratio of operation run time over standard run times for operations, percentage of items scrapped at inspection, number of inspection variations authorized, and average time to complete a material move; and any resources, jobs, parts, etc. that performed out of acceptable limits for all these.

7. Cost information on manpower, equipment, and material resources by item, by operation, and by final product.

8. Budget and funds availability information.

9. Quality information including types and frequency of errors and location within the process where they occur.

10. Forecast demand information for final product including quantity and date required.

The system should provide managers with a wide range of information reports. They include reports for requirements planning, inventory control, operations scheduling, materials handling, resource utilization, quality control, assembly, shop-floor control, and finance. This information is used by managers to accomplish the various planning functions. (Bedworth and Bailey, 1987:25). The system also requires formal feedback systems from each planning function to the one directly preceding it (Bedworth and Bailey, 1987:55, 173).

Figure 3 illustrates the information flow and planning system relationships within an MPC system. The time horizons indicate the future time period for which the system is planning.

Planning Support and Decision Testing Systems. A critical function of an MPC system is to provide managers with an ability to analyze their operation in support of the planning process and to test decisions before they are implemented. This ability to predict the possible outcome of a decision allows managers to develop more realistic plans and to study the effects of their decisions on many aspects of the system. This helps to ensure that these decisions will provide the desired results.

Three techniques commonly used to provide this capability are math programming, material requirements planning (MRP), and computer simulation modeling. Math programming is a technique which seeks to optimize an objective function given a series of constraint equations. MRP is a sequential planning technique which provides a production and ordering schedule based on production demand, material needs, and lead times to order, receive, and prepare these materials (Bedworth and Bailey, 1987:164-169). Simulation models are actual computer programs that reflect the operation being analyzed (Pritsker, 1986:1).

One of the strengths of simulation models is their ability to account for variability within a system and thus provide a more accurate reflection of reality (Haupt, 1989:1062). These other techniques assume that no variability occurs within a process. While this assumption may be valid for a manufacturing operation, it is not valid for a

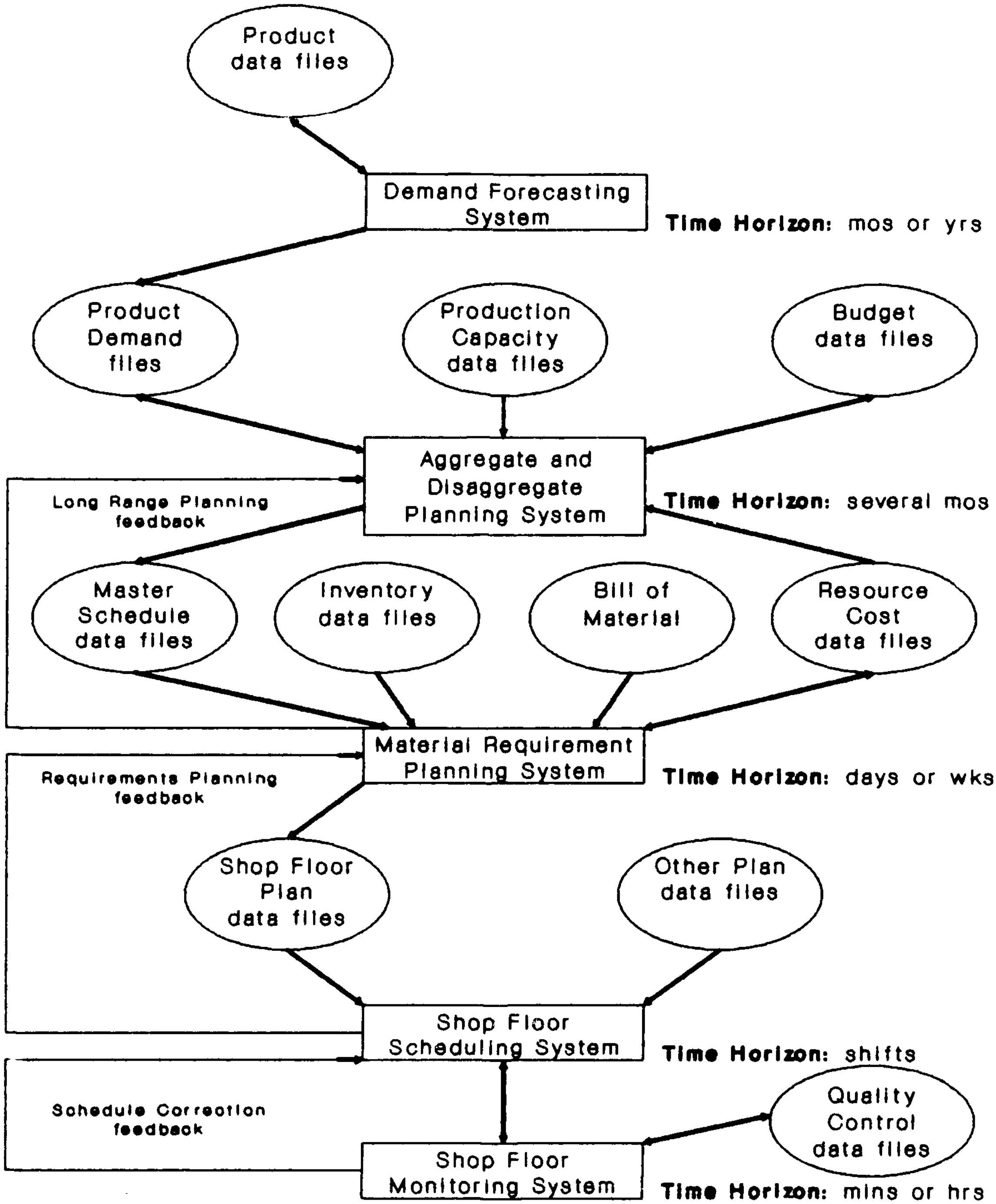

FIG 3: MPC SYSTEM INFORMATION FLOW

(Adapted from Bedworth and Bailey, 1987:56) repair/overhaul/rebuilding operation and can lead to poor planning decisions. This issue is addressed in greater detail in the following section.

Simulation modeling can be a time consuming and computationally intensive procedure. However, when used in production planning over a large number of time periods, math programming and MRP tend to be even more time consuming and computationally intensive. Obtaining results using these other techniques can often take many hours or days of computer time (Sadeh and others, 1989:27).

Simulation models also have other advantages. These models can incorporate the interactive and synergistic effects of many variables within a process (Haupt, 1989:1062). They can incorporate discrete decisions into a continuous process (Sadeh and others, 1989:22) and be updated as the operation changes (Rucker, 1990:32). They can be used to determine critical elements within a system, evaluate solutions to problems within a system, and predict how a system will operate (Pritsker, 1986:1). Having these capabilities greatly enhances both the strategic and tactical planning processes.

Like the other techniques, simulation models also allow for sensitivity analysis -- that is, the analysis of the effects of changing certain variables or parameters within the model (Sadeh and others, 1989:29). To accomplish sensitivity analysis using MRP requires a regeneration of the entire set of results -- a very time consuming process (Miller, 1991).

While the technique of computer simulation may be limited by some of the assumptions that must be made to model a production process, particularly in areas that cannot be quantified or have not been accurately defined (Browne and Davis, 1984:344-345), it is still a more than adequate technique for modeling most production processes. This is due to the fact that these assumptions usually involve a level of detail that does not affect the results of most analysis projects (Haupt, 1989:1062).

For strategic planning, simulation models can be used to develop systems requirements, define capacity, and identify bottlenecks before a system is even implemented. This saves a great deal of time and money that would have to be spent in adjusting the system once it was in operation (Rucker, 1990:31-32). For tactical planning, decisions can be tested for their effect on a system without disrupting normal operations (Browne and Davis, 1984:42-45). Some organizations have found that one large encompassing simulation model is adequate for their needs (Production Control Systems, 1990:39-41), while others have found that many models are needed to address particular planning issues or examining specific areas of their operation (Rucker, 1990:30-32).

For tactical planning, a simulation model requires current information that includes how long an activity takes, what resources a task might use, and how often certain processes are or are not required. Using the most current information ensures that the model reflects the actual operation (Haupt, 1989:1062). In order to incorporate this current information into the model, the simulation requires an interface with the data collection system (Hehnen and others, 1984:45).

Variations for an MPC System in a Repair/Overhaul/Rebuilding Environment

Planners and managers within manufacturing operations and within repair/overhaul/rebuilding operations share many of the same concerns and information needs. These include status of work-in-process, resource and product inventory levels, budget and cost information, engineering requirements, and product quality. Each can make use of historical data to plan workload, manage supply, and reduce capacity overload and idleness (Bertrand, Wortmann, and Wijngaard, 1990:297-299). Figure 4 illustrates the basic flow of an item through the repair process.

The key difference comes in the area of sales and marketing. No sales or marketing function is accomplished in a repair/overhaul/ rebuilding environment. For unlike a manufacturing operation, whose demand is based on market conditions, a repair/overhaul/rebuilding operation's demand is based on maintenance requirements, both scheduled and unplanned. This adds a great deal of variability to the process in terms of production rates, processing times, and demand upon the system, and must be managed within a scheduling and demand management component.

A large portion of the demand on a repair/overhaul/rebuilding operation is generated by preventive maintenance requirements. While preventive maintenance occurs on a regular schedule, until an initial inspection of the repair item is conducted, the type and amount of work and materials required to complete the job is unknown (Bertrand, Wortmann, and Wijngaard, 1990:291). While managers take this into account, planning for the worst case can lead to a great deal of idle capacity and using the average of historical data will require schedule adjustments for items that exceed these figures.

Many factors contribute to variability within the system and each must be closely monitored and controlled. The repair of an item often calls for the removal of many parts. Usually, these parts need to be

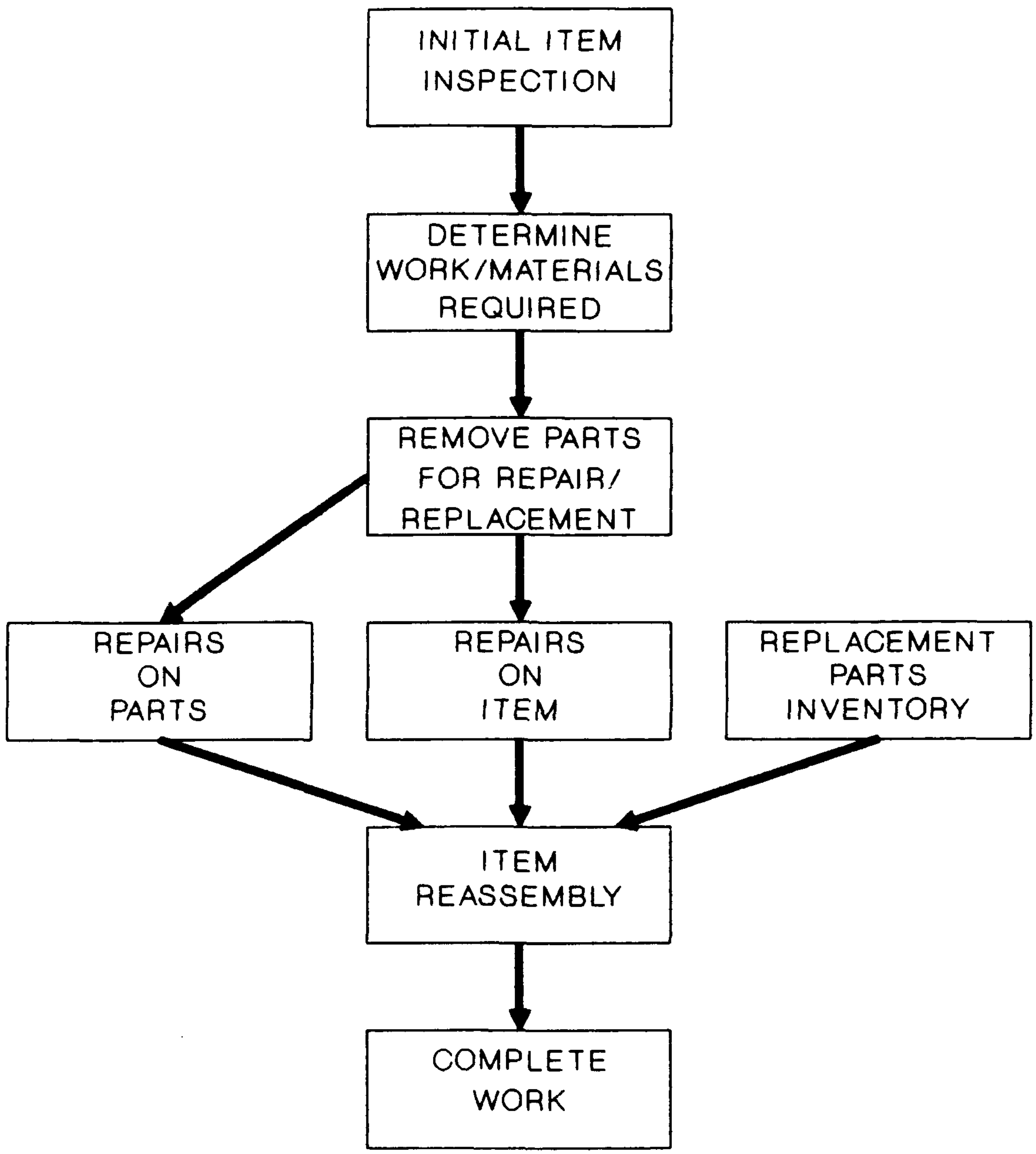

FIG 4: FLOW OF ITEM THROUGH BASIC REPAIR PROCESS

repaired or replaced before being reinstalled. While the time between removal and reinstallation varies from part to part, the part must be ready for installation at the required time or a delay in the system occurs. The delay not only affects that particular item, but may also affect the schedules of other items within the operation (Bertrand, Wortmann, and Wijngaard, 1990:291, 298). Inventory managers and those in charge of the repair process must try to prevent this from happening.

In addition, the item from which these parts were removed may also need repairs. This workload varies from item to item. Shop-floor managers must ensure that these items are ready to receive the removed parts for reinstallation at the required time (Bertrand, Wortmann, and Wijngaard, 1990:298).

Unscheduled maintenance due to item failure can also add a great deal of disruption to the operation schedule and overall resource requirements (Bertrand, Wortmann, and Wijngaard, 1990:291). Delays can also be caused by facility breakdown, personnel absences, and rush orders, but these occur in a manufacturing operation as well (Bertrand, Wortmann, and Wijngaard, 1990:294). All this variability must be accounted for within the planning process and simulation modeling is an appropriate mean for accomplishing it.

In both operating environments, an MPC system should provide managers with the proper information so they can make decisions that will prevent or best accommodate these delays and unscheduled maintenance requirements. This information includes: processing time; inventory; resource utilization and availability; costs and funds available; and status of work-in-process for the repair item and its parts. Possible decisions include: the use of overtime; reallocation of manpower and resources; reprioritizing work orders; contracting work out; increasing supply levels; and expanding capacity (Bertrand, Wortmann, and Wijngaard, 1990:291-301). Each of these decisions could be tested within the framework of an MPC to ensure the desired results are achieved prior to implementation. In determining whether a decision should be implemented, managers must decide which of many conflicting objectives they wish to achieve. For example, reprioritizing workload to meet due dates conflicts with an objective of minimizing costs because it can require additional set-up costs and other change-over costs.

Development and Implementation

In developing an MPC system, the system developers must ensure that all activities of planning, scheduling, and inventory management are identified and delegated to managers within one of the five components of the organization. The people responsible for making the necessary decisions must clearly understand their roles, the objectives they seek when making decisions, the information available to them, and the accepted procedure for making decisions. The information provided to the decision makers must be accurate and timely. A system must be in place that can identify when nonroutine situations occur that require immediate and unusual decisions. Developers must also work to ensure that personnel within all organizational components are satisfied with the system (Bedworth and Bailey, 1987:3).

One approach to developing an MPC system includes the following steps (Bedworth and Bailey, 1987:6):

1. Determine the objectives of the system.
2. Define the system and set definable boundaries.

3. Determine the significant components that make up the system.
4. Perform a detailed study of each component in light of the overall system.
5. Combine the analyzed components into the system.
6. Test the system according to some performance criterion.
7. Improve the system by repeating steps 2-6 as needed.

Vollman also outlines certain keys to successful development and implementation of an MPC system (Vollman, Berry, and Whybark, 1988:23). One such key is setting implementation goals for the organization and continually evaluating the system to see if the goals are being met. Another is ensuring that any organizational changes are consistent with the system, whether they are changes in an organization's attitudes and goals or in an organization's actual structure. However, the most important is selecting the right people to be involved in the planning and development of a system.

Because human expertise in system planning and control is a company's most crucial resource (Biswas, Oliff, and Sen, 1988:235), an organization must take its best people from all areas that will use the system and form project teams. Vollman emphasizes that being assigned to a project team and developing the MPC system should not be treated as an additional duty for the newest or least qualified person in the company, nor should it be delegated to systems planners and designers who don't have daily exposure to the affected areas. Rather, this assignment should be the full time job of the most experience personnel within each component.

The project teams, assigned to the appropriate management levels, should determine information requirements for each component and the effect each component's actions have on the others. Once the project teams complete these tasks, systems designers and planners should develop information systems to collect, store, and distribute the data, and the planning support and decision testing system that will be used to make planning and operational decisions.

Once the MPC system is developed, everyone involved in the production process must be educated on how the system works. They must also be convinced of the system's importance to the operation. Otherwise, they may not use it properly and the information gathered and distributed may be inaccurate. This could lead to incorrect management decisions in the future (Vollman, Berry, and Whybark, 1988:23). Implementation must also be gradual. Too much, too fast can cause chaos in an operation. Data collection processes and systems must be compatible with the interests of the shop-floor personnel or the data may not be collected accurately, if at all. Output reports should be similar to those currently being used within the operation in order to reduce confusion and disruption (Bedworth and Bailey, 1987:9, 11).

System implementation must be monitored and the results audited to ensure accuracy. Measurements of MPC system performance should be relevant, meaningful, and not just easy to measure (Hehnen, 1984:45). Depending on an organization's objectives, these measurements could include the amount of inventory reduction, production delay reduction, or production level increase.

Some Success Stories

Three companies that have successfully implemented MPC systems are the Weyerhaeuser Company, a lumber producer in Raymond, Washington; USBI, a subsidiary of United Technologies that remanufactures the solid rocket boosters used in NASA's space shuttle program; and GE aircraft Engines, a subsidiary of General Electric.

The Weyerhaeuser Company. The Weyerhaeuser MPC system is built around two separate but integrated software packages that link all the components of the organization. The first package is a merchandising decision system (MDS). This system analyzes tree stems (trunks with their branches removed) as they are brought into the mill and computes the optimal point at which to cut them so as to maximize the profit potential of each stem. Profit potential is based on market, sales, and other economic data. The optimal cutting point information is passed to saw operators and automated machinery and the stems are cut appropriately.

The second package is a simulation model of the company's entire process that Weyerhaeuser calls COMPASS. Managers use COMPASS to analyze their operations and to test management decisions before implementing them. One way they use COMPASS is to explore alternative merchandising strategies. When management selects a particular strategy to examine, COMPASS gathers historical stem data from the MDS and calculates how that wood would have sold if it were cut and marketed according to this new strategy. They also use COMPASS to explore potential changes in the economy, lumber prices, operating costs, and processing rates. "What if" scenarios can be programmed into the simulation model to help managers make appropriate decisions for future sales based on market predictions. COMPASS also assists managers in determining on which areas of the operation and which types of decisions to concentrate. While this learning process takes some time, managers, after repeated use of the system, can identify the decisions that have little or no effect on the overall process.

Once management makes a decision to change the production process, COMPASS communicates these changes to the MDS through an interface system. The MDS can then calculate optimal cutting points based on the company's new marketing strategy.

While the MPC system was developed by an outside consultant, a discovery was made that supports Vollman's claim that user involvement is key to successful implementation. The consultants began their work without much input from Weyerhaeuser personnel, but they soon realized that the employees and managers had to be shown and convinced that such a system would collect the right information and would be beneficial to the company.

One positive result of the process was the enhancement of communication between employees and management. Managers became more aware of the details of daily operations, while workers could see how their jobs influenced the company's success.

The system's overall success can be measured in Weyerhaeuser's increased profits and business growth and expansion. Top management at Weyerhaeuser attributes much of this success to their MPC system (Hehnen and others, 1984:44-52).

USBI. USBI uses an MPC system that the company calls its Integrated Production Control System (IPCS).

The operation at USBI, like that at Warner-Robins, is a refurbishing operation. USBI operates in a unique business environment which has many parallels with the operation at Warner-Robins. The space shuttle solid rocket boosters are designed to be reusable. Of the tens of thousands of parts that make up a solid rocket booster, some are reusable while others are not. USBI manufactures several of these parts itself. In addition, no two shuttle missions are alike so the requirements placed on the solid rocket booster change from flight to flight. NASA is USBI's only customer, so NASA's needs dictate demand, production requirements, and the production schedule. Often times, USBI is not given a great amount of lead time to make all the necessary adjustments to the boosters to meet a particular mission's requirements.

To meet their unique needs, USBI, with the help of the Unisys Corporation, developed IPCS. This system is used throughout the booster refurbishing process and handles all stock tracking, material requirements, and scheduling. In addition, it generates most of the required documentation and even conducts quality control.

When the rocket boosters are recovered from the ocean, they are returned to USBI where technicians identify the parts which can be reused and which need replacing and enter the information into IPCS. The system tracks USBI supply inventory to ensure the necessary parts and tools are available and generates orders for those that are not. It also monitors the progress of all work being done to the booster. IPCS then assists human inspectors in ensuring that the particular solid rocket booster being inspected has been assembled properly and meets the requirements of its particular mission based on NASA specifications programmed into the system.

One of IPCS's key strengths is its documentation features. Because of the critical and highly technical nature of its business, USBI must document almost every phase of the booster refurbishing process. Since all the pertinent information is stored within IPCS, most required reports can be generated quickly and accurately. This allows employees to spend more time concentrating on their actual jobs and less time doing paperwork. The system also generates reports used by upper-level management to monitor its operation and allows mid-level management to pass pertinent data between the company's operational components quickly and accurately (Production Control Software, 1990:39-41).

GE Aircraft Engines. GE Aircraft Engines (GEAE) has made great use of computer simulation. They use it not only as a management tool in operating their plants, but also as a management tool in designing them. Though the work was initially contracted out, GEAE recognized the need for an in-house capability since they use simulation models in designing and analyzing every level of their operation, from single-process machines to integrated factories.

In designing their operations, simulation models have helped answer questions about system capacity and the type and quantity of tooling. It allows GEAE to adjust flow rates and queue sizes and incorporate many different job types into their operation. The simulation models can be embellished to include many areas of concern to management. Sensitivity analysis and "what if" analysis can be conducted all before a plant is ever built. This saves a great deal of time and money that would have been spent debugging an operation once it was built and running.

These same types of concerns can be addressed once the production process is operating. Simulation provides managers with more information, faster, which leads to better decisions and the removal of a great deal of guess work (Rucker, 1990:30-32).

Conclusion

Managers need information to make proper decisions and need to know how those decisions affect their production process. A manufacturing planning and control (MPC) system should provide both by linking the five key components of an operation and providing the appropriate data to managers at every level of a company. The system should provide 1) a means for collecting, storing, and distributing data and 2) one, or a collection of, simulation model(s) for use in supporting planning functions and testing management decisions prior to their implementation.

Successful development, implementation, and operation of an MPC requires a great deal of planning and the involvement of the best people from each key component of an operation. They should determine what information each component needs to have from the others to operate as expected and how each component influences the others. In addition, upper-level management should determine what information it requires.

System designers should take the teams' conclusions and develop an information collecting, storing, and reporting system, and a computer simulation modeling capability that can be used to test management decisions. Any simulation models should be integrated with the information system.

A company's work force must be educated on the system operation and importance to ensure the system operates properly, the information it provides is accurate, and the decisions based on it are sound.

III. The Operation at Warner-Robins Air Logistics Center

The C-141 Management Directorate at Warner-Robins Air Logistic Center is responsible for conducting programmed depot maintenance (PDM) on the entire fleet of C-141s. Maintenance is conducted year round, except for the 10 Federal holidays per year and an occasional down day. Two full 10-hour shifts work Monday through Thursday and a smaller 10-hour shift works Friday through Monday. In a typical year, 50 to 60 aircraft receive PDM and are painted.

Recently, the demand on the C-141 maintenance system has increased. The major user of the C-141, Military Airlift Command (MAC) is considering a directive that will call for the repainting of all of their aircraft that have not been recently repainted. In addition, most of the C-141s are over 20 years old. Because of their age, and in order to extend their lifetime, the logistics center is introducing two major repair programs: the speedline program; and the center wing-box replacement program (Davis, 1991).

Speedline

The speedline program calls for the repair of cracks in the aircraft wings and the possible replacement of the wing's beam caps which are wing joint support structures. The process is called "speedline" because the logistics center would like to accomplish the process on each aircraft as quickly as possible. The center has two years to complete the process on 183 aircraft, so planners and engineers have arranged and organized maintenance schedules and facilities in an attempt to process each aircraft through speedline in as little time as possible so as to meet this requirement. Aircraft that have not received the speedline process within the next two years will be grounded. In order to receive the speedline process, an aircraft must arrive at Warner-Robins by 30 September 1993.

Some of the aircraft going through speedline are also to receive PDM and/or be repainted (Davis, 1991). When the speedline program is completed at the end of FY93, the normal PDM process will resume at Warner-Robins (Colter, 1991a).

The Process Flow. Figure 5 illustrates the flow through the speedline process. After an aircraft bound for speedline arrives at Warner-Robins, it receives an initial inspection and initial preparation. In addition, if the aircraft is going to be painted following speedline, it must first be depainted. The aircraft then receives additional preparatory work for speedline which varies depending on whether the aircraft is going to be painted and/or receive PDM.

Once prepared, the aircraft is towed to one of several hangar positions where the actual speedline process is conducted. If no hangar positions are available, an aircraft must wait until one is available (Davis, 1991).

The speedline process itself is conducted on eight separate sections of the wings: the right and left, upper and lower portions of the forward and aft sections. The first phase of the process is a nondestructive inspection (NDI) of all the rivet holes on a wing. All holes that do not pass this inspection must be redrilled and then reinspected. Prior to the reinspection, the wing undergoes two possible

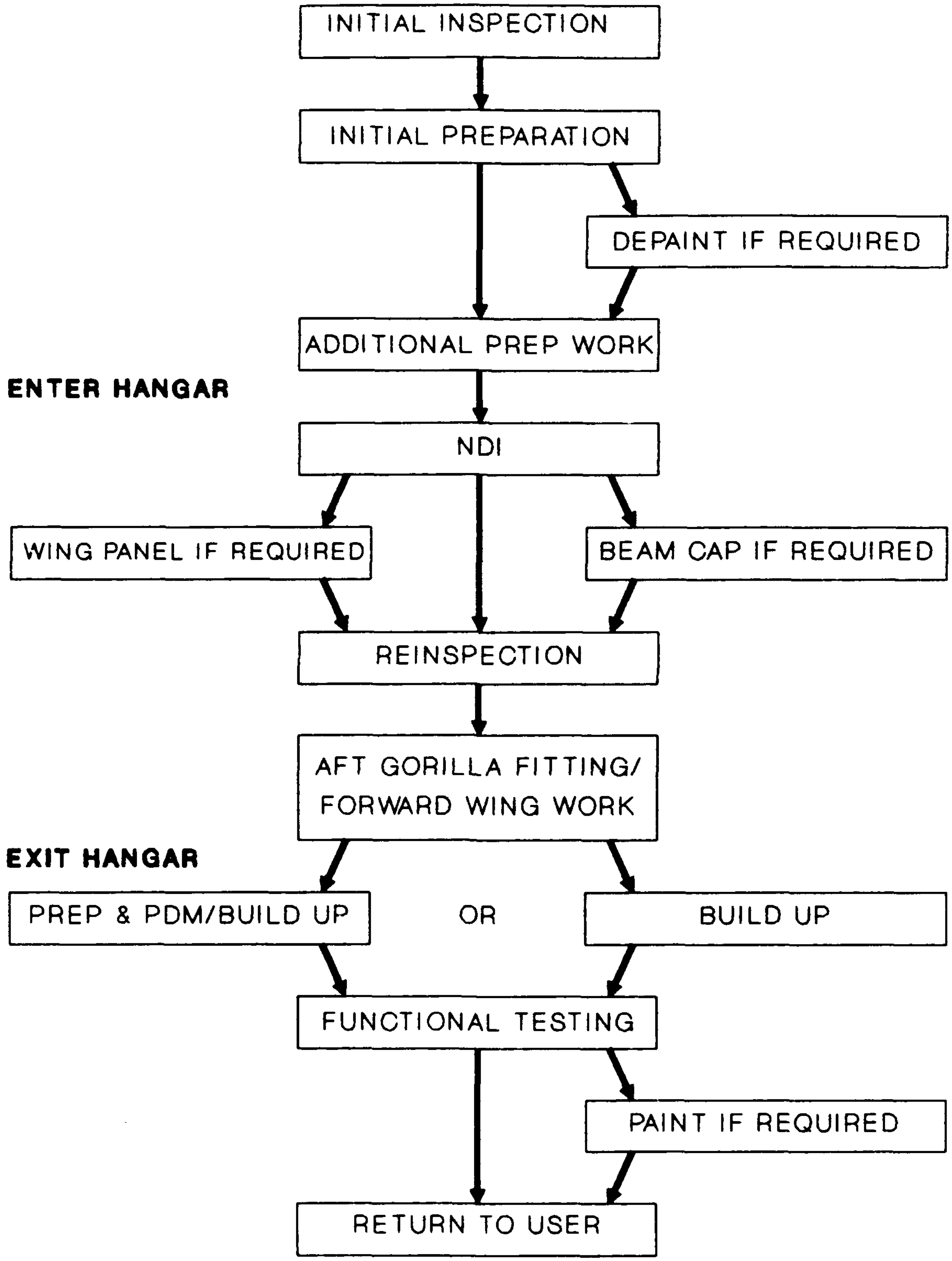

FIG 5: FLOW THROUGH SPEEDLINE

repairs. The first is the repair and replacement of cracked wing panels, required on about 90% of the lower forward sections. The second is the replacement of beam caps which is required on about 12% of the lower aft sections (Colter and Lister, 1991).

Following these repairs and the reinspection of the rivet holes, every aft section receives a gorilla fitting (a reinforcement for the wing joints) while additional wing work is conducted on the forward sections. Once this work is complete, the aircraft is prepared for and processed through PDM if required, and then built up (reinstallation of any systems or equipment removed during any part of the operation) and functionally tested to ensure it is ready to be returned to service (Davis, 1991). Those planes requiring paint are then painted (Colter and Lister, 1991).

Center Wing-Box Replacement

The center wing-box replacement program calls for the replacement of the C-141's center wing-box, a structural support which attaches the wings of the aircraft to the fuselage and acts as part of the spine of the fuselage (Davis, 1991). Originally, the program called for 124 aircraft to receive new center wing-boxes over the next four years (Colter, 1991a). The program at Warner-Robins has since been scaled back so that as few as 17 aircraft may receive new center wing-boxes. The remaining 107 wing-boxes will be replaced at Warner-Robins or by a civilian contractor. All center wing-box aircraft processed at Warner-Robins will be repainted and most will receive PDM. (Colter, 1991b).

The Process Flow. Figure 6 illustrates the center wing-box replacement process flow. Aircraft arriving at Warner-Robins to receive

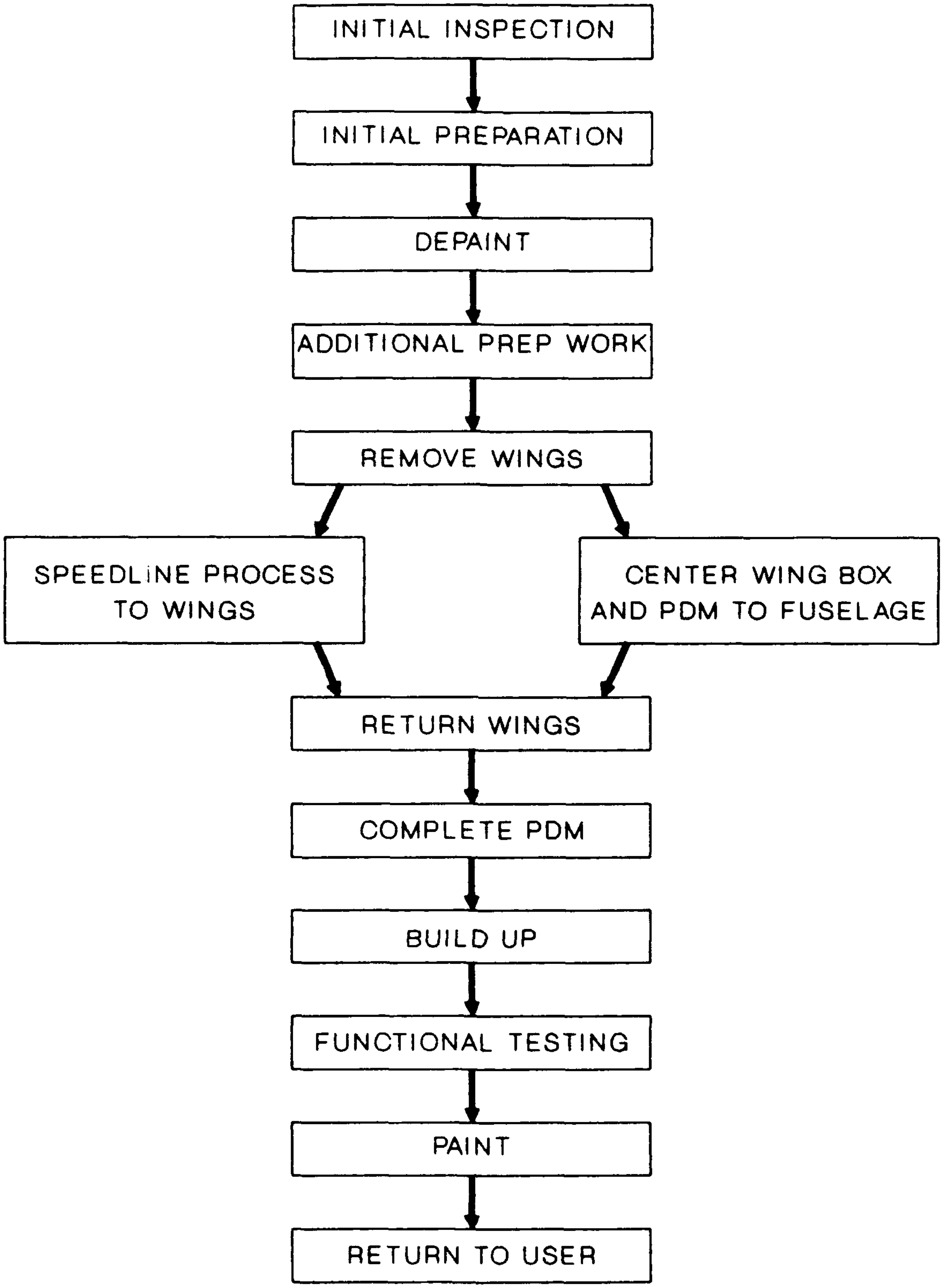

FIG 6: FLOW THROUGH CENTER WING BOX

a new center wing-box will also receive an initial inspection, initial preparation, and be depainted. After additional preparatory work, the wings are removed from the aircraft. The fuselage receives a new center wing-box while the wings receive the same repairs conducted in the speedline process. However, the speedline process associated with the center wing-box replacement program is independent of the other speedline process and is accomplished with its own facilities, personnel, and most of its own equipment. The majority of PDM is also accomplished while the center wing-box is being replaced. This PDM work is also conducted by different personnel and equipment than the PDM conducted following the speedline process. Once all repairs are complete, the wings are reinstalled onto the aircraft and the remainder of PDM is conducted. The aircraft is then built up, tested, and painted (Davis, 1991).

Resource Sharing Within and Between Processes

It is important to note that the speedline and center wing-box replacement processes share very few resources. The aircraft are depainted and painted in the same facilities and by the same personnel. The depaint facilities are also used to wash and prepare an aircraft for painting. The processes share a few pieces of equipment and the initial inspection, initial preparation, and functional testing activities are all conducted by the same personnel regardless of which other repair processes an aircraft undergoes.

Resources are also shared with processes outside of center wing-box and speedline. The building up of the aircraft is conducted by the personnel that accomplished the preparatory work or by the PDM crew in the case of a speedline aircraft that received PDM as well (Colter and Lister, 1991). If during functional testing a problem is detected, personnel from the process that conducted that repair are called upon to fix it (Davis, 1991).

The Organizational Components

Figure 7 illustrates the organizational structure of the logistics center and the dotted lines indicate the interaction between functional areas. This diagram is merely illustrative in nature and is not the official organizational diagram of the center.

The Production Division of the C-141 Management Directorate oversees the entire maintenance process. One of the integral subcomponents of their operation is the Control Support Center (CSC). The CSC is responsible for ensuring that the mechanics in every area of each maintenance operation have all the tools, equipment, and materials to accomplish their jobs. The CSC interacts with the mechanics, the production schedulers within the division, and the logistic center supply depot to ensure everything is available when needed. If supply problems arise, they can seek support from the logistic center's Industrial Products Directorate, which manufactures and repairs parts and tools for all the maintenance operations at the logistic center (C-141, F-15, C-130), or they can manufacture and repair their own parts and tools (Colter, 1991a).

The Production Division also oversees the quality assurance component. Quality assurance personnel work with functional testing personnel to identify, record, and report areas of poor quality. In addition, they evaluate and inspect the work being accomplished

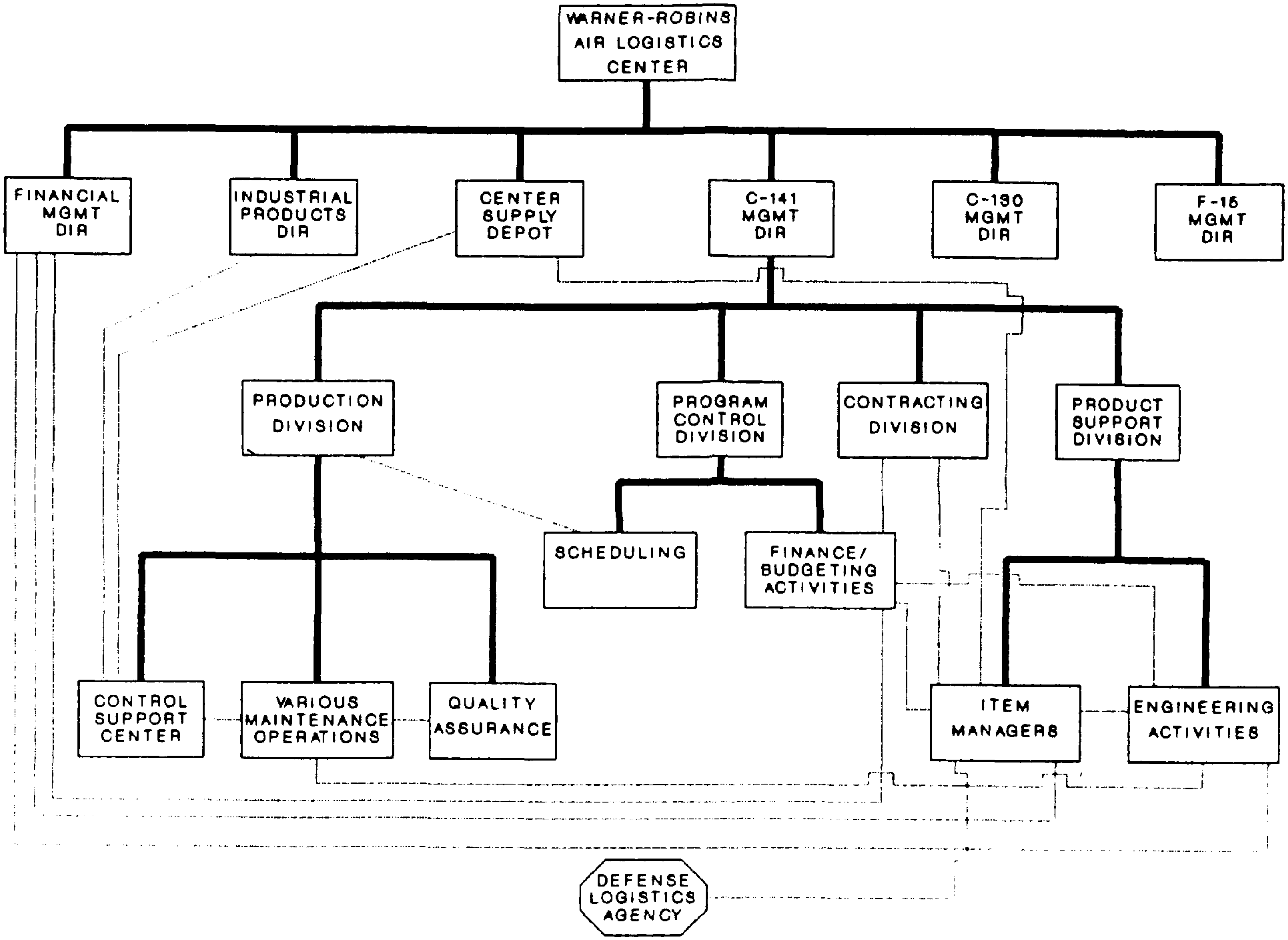

FIG 7: INTERACTION OF ORGANIZATIONAL COMPONENTS

throughout the operation to help ensure that quality standards are being met in order to prevent the need for rework once an aircraft reaches functional testing (Hammock and Lancaster, 1991).

The financial control activities are conducted both within the C-141 Management Directorate and outside of it. Financial issues that pertain specifically to C-141 maintenance are handled by the Program Control Division. General issues that affect all the maintenance organizations at Warner-Robins are handled by the Financial Management Directorate (Baggarley, 1991b).

The majority of equipment and supply orders are handled by the item managers (IMs) within the Product Support Division. The IMs interact with the supply depot and the engineers to ensure that all required parts and equipment are available when needed. They also interact with both finance organizations to ensure that proper funding is available to order parts and equipment as necessary. Most parts and equipment needs are planned and budgeted for annually. The IMs work with the Defense Logistics Agency (a central contracting and supply agency for all of DoD) when ordering non-aircraft-specific parts, and with the Contracting Division of the C-141 Management Directorate when ordering parts that can only be used on C-141s (Baggarley, 1991b). The parts and equipment are stored at the central supply depot used by all the maintenance organizations at Warner-Robins (Baggarley, 1991a).

The Product Support Division also oversees the engineering activities which include not only establishing and designing facility requirements, but also determining what repairs need to be accomplished on an aircraft and what parts and equipment are required. For example, the engineers were responsible for initially identifying the need to replace the center wing-boxes and conduct the speedline repairs. The engineers also determine what PDM is to consist of and what is required to accomplish it (Baggarley, 1991a).

Being a repair/overhaul/rebuilding operation, demand on the system is not generated from sales and marketing, but rather from maintenance requirements. The requirements are determined by the engineers and are controlled by the maintenance schedulers who also work in the Program Control Division. The schedulers maintain a data file on each aircraft which contains information on what repair operations need to be accomplished and when. Working with the Production Division, they determine when an aircraft should be brought in for a specific repair process (speedline, center wing-box replacement, PDM, paint) based on the planned inventory and capacity of each process. This schedule is coordinated with the aircraft user to ensure they and their subordinate units can surrender the aircraft and still meet their mission requirements. If the user cannot afford to surrender the particular aircraft identified by the schedulers, every effort is made to supply a substitute aircraft requiring the same exact repairs so as not to disrupt the Production Division's schedule (Mallory, 1991).

A series of interviews with managers within each area revealed that, while communication links were well established, managers are not aware of all the information available to them from each of the other components, nor are they aware of the informational needs of those within other components that they could meet. In addition, they do not have a complete understanding of the effects their decisions have on other components, nor do they always understand the actions of others and why certain plans are enacted by others that disrupt their operation. If managers knew a particular course of action might be disruptive, they might not implement it. If a plan had to be implemented, managers within areas whose operations are disrupted might be more sympathetic and accommodating of these changes if they understood why the changes had to be implemented.

Lower level managers within some components also seemed to lack a complete understanding of the management philosophy of the senior leadership. Many reports and briefings prepared by these people were inconsistent with this philosophy and provided little useful information to senior leadership. Adding to this problem were information systems that generated reports that were also inconsistent with upper level management philosophy.

Management Philosophy

Senior management within the C-141 Management Directorate is in the process of implementing a management philosophy based on the Theory of Constraints (ToC). The basic premise of ToC is that every manufacturing operation has a goal (Goldratt, 1986). The C-141 Management Directorate goal is to process as many aircraft as possible while not disrupting the users' missions.

Once the goal is determined, ToC calls for the identification of the portions of the process that are hampering efforts to achieve that goal -- the constraints. Once the constraints are identified, items processed through the operation should be scheduled so that there is never a large backlog of items waiting to be processed through the constraint and that the constraint is always operating at peak capacity (Goldratt, 1986). This ensures that, in this instance, aircraft are not waiting to be repaired when they could be flown and that the maximum number of aircraft are being repaired (maximum throughput) in the shortest period of time. The next step is to evaluate the constraint and determine if its capacity or rate of operation can be increased. As these improvements are identified and implemented, the processing schedule should be adjusted accordingly (Goldratt, 1986).

The inconsistencies at Warner-Robins noted in the previous section occur because most systems and many managers are operating under a philosophy that seeks to maximize resource utilization rates. This is not efficient and conflicts with ToC because emphasis is often placed on work that does not increase throughput and only builds work-in-process inventory. This is both costly and wasteful.

Initial Analysis Efforts

While in the process of implementing the speedline and center wing-box replacement processes, the leadership within the Production Division solicited the assistance of the Operational Sciences Department of the Air Force Institute of Technology (AFIT) to help determine the resources and personnel necessary to conduct the speedline and center wing-box replacement processes and to help determine the constraints in the entire operation. Supervised by three faculty members, four students analyzed the operation and built a computer simulation model of the C-141 maintenance process at Warner-Robins (Harvey, Miyares, McElveen, and Puhek, 1991).

While specific resource levels were not determined, system constraints were identified and later confirmed by the C-141 Management Directorate. The constraints were the hangar space in which speedline is conducted, the facilities used to paint and depaint the aircraft, and the facilities in which the fuselage work is conducted on center wing-box aircraft (Harvey, Miyares, McElveen, and Puhek, 1991).

Management's biggest concern was over the speedline hangar space given the short period of time in which the program needs to be completed. Even with the addition of hangar positions, the simulation results indicated that an original requirement of 169 aircraft (now 183) could not be met. This meant that a number of aircraft would either have to be grounded or the speedline process would have to be accomplished on some aircraft by civilian contractors, greatly increasing the cost of the program.

Recent Management Decisions at Warner-Robins ALC

In reaction to the results of the initial analysis and because of outside factors, upper level management within the Management Directorate ordered the following changes to their operation.

1. The number of center wing-box aircraft that were to be repaired simultaneously has been reduced from six to one.

2. The objective for the speedline process has changed from 169 to 183 aircraft. Some aircraft originally bound for the center wing-box process, will now go through the speedline process. Some aircraft will receive the speedline at other locations.

3. The center wing-box facilities and resources, as well as some from the PDM process, will be transferred to the speedline process. Eventually, the total number of speedline hangar positions will rise from six to nineteen.

4. Beginning on 1 Apr 92, an additional inspection will be required of speedline aircraft once they have entered the hangar.

5. Some speedline aircraft will receive portions of PDM while still in the speedline hangar. The work will be done in specific hangar positions designated as speedline/PDM positions.

In addition, a few minor activities have been added or rearranged (Colter and Scoskie, 1992).

These changes generated many questions and concerns.

1. Given the increase in resources allocated to the speedline process, is the new objective of 183 achievable?

2. If not, how soon after 30 September 1992, could the last aircraft arrive at Warner-Robins to receive work?

3. What reduction to the in-hangar time would be required to ensure the objective is met?

4. What would be the effect of reducing the processing time through the depaint process by adding additional resources? By reducing the effect of this constraint would overall throughput be improved?

5. What would be the effect of lowering the number of resources allocated to the speedline process?

6. What is the minimum number of aircraft that need to be located at Warner-Robins to keep the hangars operating at peak capacity?

Current System Development Efforts

DMMIS. Currently, Air Force Logistics Command (AFLC), which oversees the work at all five Air Logistics Centers (ALCs), is developing an MPC system called the Defense Maintenance Management Information System (DMMIS) with the assistance of Grumman Data Systems. When completed, DMMIS will be an enormous information and planning system incorporating nearly all of the key elements and organizational components required of an MPC system outlined in Chapter II. The system will store and provide information for and assist in conducting most planning functions and provide information sharing between all five ALCs. The only major function omitted is budgeting, although DMMIS is being designed to provide information that will be useful in the budget development process (Gunst, 1991).

From the time an aircraft arrives, DMMIS will track it and all its removed components through the maintenance process. As work requirements are determined during the initial inspection and evaluation, work orders will be generated and material requirements identified. A maintenance schedule for the aircraft and its sub-components will be generated and an inventory check will take place to ensure the required resources will be available when needed. If any resources will not be available, DMMIS will generate an order requirement. Throughout the process, costs, resource utilization, and quality information will also be tracked (Cowan, 1991).

The system is currently being tested within a few divisions at the Ogden Air Logistics Center at Hill AFB, Utah. Implementation at Warner-Robins is not scheduled to begin until 1996 (Cowan, 1991).

Most of the information stored within DMMIS will be entered through computer keyboard entry or by downloading from data tapes. Shop-floor information will be entered using optical scanning devices which can be used to track inventory, activity duration, and resource utilization (Gunst, 1991).

The shop-floor scheduling system will use a PERT (Program Evaluation and Review Technique) system called the Program Network Schedule System (Cowan, 1991). PERT is a scheduling and tracking methodology which uses networks to plan activities given a defined set of precedence relationships (Hillier and Lieberman, 1990:389-390). All other planning systems and decision testing systems will use material requirements planning (MRP).

MRP in a repair environment. MRP provides planners with resource requirements and ordering schedules given the following information.

1. The desired completion date.
2. The materials required (BOM).
3. The repair activities required.
4. The lead time required in material ordering and preparation.
5. Activity durations.
6. Current resource inventory.

Within a repair environment, the first three pieces of information are determined during the initial inspection of the repair item. The last three should be known from past experience and/or engineering estimates (Cowan, 1991) (Demmy, 1990:9-10).

When a completion date is determined, the MRP algorithm works backward through the series of required repair activities to determine what resources are required at which point in time in order to complete the repairs by the desired date. The algorithm also checks material requirements against inventory levels and if the necessary materials will not be available by their required time, the system provides information on when and how many of each item to reorder based on the number and time required and the lead time required to order, receive, and prepare these materials (Bedworth and Bailey, 1987: 164-169). If the lead time required is too great to meet the required time, the necessary parts must be salvaged from other repair items, repaired locally instead of being replaced (Demmy, 1990:10), or the completion date must be extended (Cowan, 1991).

Problems may arise from the fact that MRP assumes infinite capacity at each work center within the process. By simultaneously scheduling many repair items, the system may propose a work schedule on a work center that is beyond its capacity. When this happens, additional adjustments to the schedule are required (Miller, 1991).

Like all MPC systems, implementing an MRP system requires a complete management commitment and user involvement in its development (Finnern, 1988:14, 20). Implementation must be given a priority second only to accomplishing daily mission requirements (Faulkner 1989:97).

Every level of management and worker must be held accountable for their responsibility within the process of system development, implementation, and use (Faulkner 1989:23). The users must be educated about the system and be convinced that this system, and doing their jobs differently, will be beneficial to them and to the organization (Finnern, 1988;36, 47) (Faulkner, 1989;24). In fact, initial results at Ogden show that more education has led to less resistance (Finnern, 1988;70). Developing a system that is easy to use also helps build acceptance (Moore, 1991).

Even with education and acceptance, production can be expected to decrease initially as workers learn to use the system and incorporate it into their routine. Managers must be aware of this and not become overly concerned or penalize workers for this initial decrease in productivity (Finnern, 1988;16).

The implementation schedule must be well planned. If a system is implemented too quickly, it may overwhelm the users. If it is implemented too slowly, the users may lose interest. In either case, the user may resort to their old work practices if they feel it is the best and/or only way to accomplish their jobs and meet their requirements (Finnern, 1988;49). Depending on the scope of the operation, complete implementation should take between two to six years (Faulkner, 1989:33).

Data accuracy is also critical. An MRP system requires that the bill of material be 95-99% accurate. Inventory records must be 90-95% accurate which requires an initial wall-to-wall inventory check and periodic updates (Finnern, 1988:54, 57). A wall-to-wall inventory is a detailed investigation and accounting of inventory levels of all items and material resources throughout an operations facilities.

Once implemented, the system, its operation, and the information it collects and distributes must be constantly monitored to ensure information accuracy, plan feasibility, and proper system use (Demmy, 1990:10).

DMMIS Strengths. The greatest benefit that DMMIS will provide is its information system. Data which is either currently not available or scattered throughout the organization will now be collected, centrally stored, and readily available to every management level. This information includes engineering requirements, financial information, quality information, scheduling requirements, inventory levels, activity durations, and resource utilization (Gunst, 1991). DMMIS's other main strength is its shop-floor scheduler which should also meet an ALC's short term scheduling needs.

DMMIS Weaknesses. The DMMIS system, and its implementation plan does have some critical flaws which must be addressed.

MRP. MRP was developed for use in a manufacturing environment where bills of material, lead times, and activity durations are well defined and relatively constant. MRP assumes this information to be accurate and available. In a repair/overhaul/rebuilding environment, resource requirements are not known until after the item receives its initial inspection and activity durations and lead times can vary greatly (Miller, 1991). To compensate, the system must assume longer than average lead times and managers must maintain a large safety stock of materials to ensure the resources are available when needed. Because MRP assumes these lead times are constant, a buffer of extra aircraft must be maintained at Warner-Robins to maintain process flow when any activity is completed ahead of the schedule. Thus, DMMIS will propose a plan for which the number of aircraft at Warner-Robins at the same time (work-in-process inventory) will be greater than necessary, which may impede the users ability to meet its mission. Because resource requirements are also assumed to be constant, DMMIS will propose a resource requirements plan which calls for a higher resource inventory, which will increase costs for materials and storage (Cowan, 1991).

If any schedule or resource adjustments are required, the entire set of results must be recomputed, which takes over 50 hours of computer processing time. In order to reduce this time, certain planning functions will have to be removed from the system (Cowan, 1991). Often times, the need for these adjustments are found too late for the system to provide any response. Managers must then make independent adjustments which typically further delays repair completion (Kanet, 1988:59).

Data Accuracy. MRP requires a bill of material accuracy of 95-99% and an inventory accuracy of 90-95%. Air Force standards require each to be 90% accurate and a recent GAO study of ALCs revealed that they were as low as 40% accurate (GAO, 1988:3, 23). In addition, no wall-to-wall inventory is planned for any ALC (Gunst, 1991).

Education. Studies of the Ogden test implementation showed that education was the key to successful implementation. There, a strong and comprehensive education plan was developed and over 80% of the personnel received some sort of training, many prior to system implementation (Faulkner, 1989:25). This will not take place for implementation at the other ALCs. The Ogden training was developed independently and provided prior to Grumman Data Systems' involvement with the program. Grumman is now responsible for providing system training, but this training will be less comprehensive, will not be provided until implementation begins at an ALC, and will not be offered to as many people (Finnern, 1988:41-42).

Management. The Ogden study indicated that while local management was behind DMMIS, some program managers at AFLC headquarters were skeptical and not totally committed to the system's success. In addition, past failures at attempts to implement large management systems for AFLC have left a stigma throughout the command which adds to further doubts about DMMIS's potential for success (Faulkner, 1989:64, 62).

DMMIS Implementation. DMMIS is still undergoing tests at Ogden ALC. A final decision to fully implement DMMIS throughout AFLC will be based on these test results (Cowan, 1991). If implementation is to go forward, the system's weaknesses will have to be addressed to ensure successful implementation and effective use of the system. Despite these weaknesses, the data bases within DMMIS, if accurate, and the system that collects the data will be of great benefit to all the ALCs and to AFLC.

Systems at Warner-Robins

Systems currently under development at Warner-Robins may assist managers in overcoming some of the weakness found in DMMIS.

Timeline. *Timeline* is a resource scheduling software package currently being used to schedule the maintenance activities and resource requirements within the Production Division. This system can also track and store activity duration data and resource utilization data. This data will soon be collected by shop-floor personnel using scanning devices similar to those planned for DMMIS (Colter and Scoskie, 1992). This system will assist in the transition to the DMMIS system because data collection procedures will be well defined and already part of the shop-floor procedures. It will provide training in the use of similar tools, data analysis, and problem identification. It will provide managers with insight as to where implementation and user problems could occur when DMMIS is implemented. This system can also be used to illustrate the importance of data accuracy and the benefits such a system could provide the user. Therefore, the lack of proper education may be overcome within at least some of the organizational components.

Control Support Center (CSC). Procedures being implemented by the CSC to ensure the required parts are available at the proper time will help overcome possible shortfalls in materials caused by variability within the operation.

Planning Support and Decision Testing System. The simulation model developed by the AFIT students and enhanced as part of this analysis does take into account variability in lead times, activity durations, and resource requirements and utilization. It could be used to provide more reasonable schedules and resource requirement plans. The model results can also be regenerated in a matter of minutes, if necessary. In addition, the Management Directorate is developing its computer simulation and analysis capabilities so this model can be expanded, other models developed, and managers provided with better information to assist them in making decisions.

Conclusion

The Warner-Robins Air Logistics Center has one main objective: to meet its maintenance requirements. All management levels of each organizational component should work together to meet that objective. Concerns have emerged that these objectives may not be met. To address these concerns and take the appropriate action, managers at Warner-Robins need the appropriate information and a means with which to develop and test their decisions. Systems are being developed to assist these managers and, while some contain flaws, they can still be used to address these concerns and suggest appropriate action. This study now turns to focus on using these systems to provide recommended courses of action that should assist the logistics center in meeting its objectives.

IV. Methodology

As stated in Chapter I, the purpose of this investigation is to design a general manufacturing planning and control system for a repair/overhaul/rebuilding environment, apply it to the C-141 maintenance process at the Warner-Robins Air Logistics Center, and use this system to address certain questions and concerns at Warner-Robins. This chapter describes the methodologies used in developing the MPC system and addressing the questions and concerns expressed by the leadership at the logistics center.

The Information System

An outline for the information network was developed based on the research results found in Chapters II and III. The information system's cornerstone is DMMIS. Specific suggestions are offered on how to implement the system. Certain problems within the organization that require management attention prior to implementation are also identified.

The Planning Support and Decision Testing System

The research results in Chapter II indicate that an appropriate tool for use in planning and decision testing is the technique of computer simulation modeling. An organization may find that its needs are met with one simulation model, while others may require a series of models to adequately analyze their operations. This investigation takes the existing model developed by the AFIT students and updates it, adding embellishments as required.

The Existing Simulation Model

The simulation model is written in SLAM II, a FORTRAN-based simulation language, and also makes use of a small FORTRAN program as well. The model simulates the operation and flow defined in Chapter III over the four fiscal year planning horizon. Its level of detail focuses on major repair activities as defined by the Production Division.

Some of the repair activities can be completed in parallel, while others must be completed in series. Most are order-dependent and cannot begin until one or a group of parallel activities are completed. Because actual activity time distributions were not available, the duration of each activity is based on a triangular distribution whose peak is the planned duration time in work days provided by the Production Division. The simulation model assumes that most of these activities can be completed up to 20% ahead of schedule or 30% behind schedule. This assumption is based on information provided by the Production Division (Davis, 1991). For programming simplicity, some minor activities which must be accomplished in series are treated as one large activity. For example, two half-day activities are treated as one full-day activity.

The model processes each aircraft that is scheduled to enter the system over the next four fiscal years (FY92-FY93) based on the type of repair required. This information is stored in an input data file and is accessed by the simulation model using the short FORTRAN program. The input file contains two data elements for each aircraft, the planned work day of arrival and the type of work required. The day of arrival ranges from 1 to 1416 based on the assumption that maintenance will occur 354 days a year over the four years of the program. The type of work required is classified by the following categories (Colter, 1992):

1. Speedline only (81 aircraft)
2. Speedline/paint (33 aircraft)
3. Speedline/PDM/paint (46 aircraft)
4. Center wing-box/PDM/paint (62 aircraft)
5. PDM only (46 aircraft)
6. Speedline/PDM (23 aircraft)

The model does not allow speedline aircraft to enter the system after 30 September 1993, but work on all the aircraft already in the system by that date will continue. PDM aircraft do not arrive to the system until 1 October 1993, while center wing-box aircraft enter the system throughout the four years of planned operations.

Embedded in the model is an assumption that one work day is no different from another. It assumes any loss of work-time due to worker nonavailability is embedded in the triangular distribution of the activity durations -- that is, worker nonavailability is not explicitly programmed into the model, but is part of the reason the expected duration is sometimes exceeded by up to 30%. Also embedded is an assumption that most equipment and resources are always available to conduct work, or delays due to waiting for them are embedded in the duration distributions.

The only exceptions to this last assumption are the hangars for the depainting and painting of an aircraft, the speedline process, and the center wing-box replacement process; the facilities to conduct PDM and functional testing; and equipment to no-load, water pick, and conduct nondestructive inspections (NDI) on the aircraft. These resources are explicitly modeled within the simulation. An aircraft requiring them must wait until that resource is available before proceeding with processing.

Hangars and facilities. As mentioned in Chapter III, maintenance hangars and painting facilities are the most critical resources. The C-141 maintenance operation has access to one depaint hangar and one paint hangar. The depaint facility is also used to wash and prepare an aircraft prior to painting.

In the original model, the speedline process had six hangar positions, but because of spatial constraints, two hangar positions had to be filled and emptied at the same time -- that is, aircraft could not enter unless both positions were free, had to enter in pairs, and could not leave unless both were ready, at which time both departed together. On 1 October 1992, two additional speedline hangar positions were to be available. These two were not to be spatially constrained.

The recent management changes to the operation outlined in Chapter III required the that model be updated. The new model also begins with six speedline hangar positions, but none are spatially constrained. On 15 January 1992, three additional positions are added in which speedline as well as portions of PDM are conducted. Only aircraft requiring PDM work are allowed to enter these positions. On 1 April 1992, two of these new positions revert back to being speedline-only positions. On 1 November 1992, four addition speedline/PDM positions are added; on 1 January 1993, another two; on 1 April 1993, another four. Imbedded in these additions is the assumption that, based on the assurance from management within the production division, all necessary material, personnel and equipment resources are available to conduct the particular maintenance operations at each position as it is added.

The original model had the center wing-box replacement process using two hangar positions in which wings could be removed or attached and the facilities to repair four pairs of wings and six fuselages simultaneously. On 1 October 1993, the process would receive additional hangar space to process two additional pairs of wings and two additional fuselages. The new model allows for only one of each type of facility for the entire four years of the program.

The PDM process can accommodate six aircraft at the same time and functional testing can process four.

No-load equipment. The no-load equipment is used to secure the aircraft in both the speedline and center wing-box processes. Only one set of equipment is available and it is used on a first-come, first-served basis.

Water picking equipment. The water picking equipment is used to clean speedline aircraft that also require PDM. Only one water pick is available and it is used on a first-come, first-served basis.

NDI equipment. NDI equipment is used to inspect rivet holes in the speedline, center wing-box replacement, and PDM processes. The number of NDI equipment sets available varies depending on which shift it is needed (ten sets/day shift, six sets/swing shift, four sets/weekend shift) based on the number of NDI-trained personnel available on each shift. Because the simulation model does not take shift differences into account, an average figure of seven sets of NDI equipment is used. (The average of 6.7 sets is rounded up because more work is generally accomplished during the day shift.) Priority for this equipment is given to speedline aircraft first, then center wing-box aircraft, and finally PDM aircraft.

With the recent management changes, additional personnel and equipment will be made available so that no aircraft will have to wait for NDI equipment. Analysis results indicates that this change will not affect the system.

Within the speedline process, NDI equipment remains with an aircraft until all inspections, repair work, and reinspections are completed on the rivet holes of each of the eight wing sections. The only exception is when a wing requires new wing panels and/or beam caps. If these repairs, which occur prior to reinspection, are required, the NDI equipment is used to reinspect the unaffected areas and is then released for use on other aircraft until these conditional repairs are complete. The aircraft is then allocated the first available set of NDI equipment to complete the reinspection process of the affected areas.

Controlling work-in-process inventory. The model can also restrict the number of aircraft in the entire system as well as the number of aircraft processed through each operation at the same time. This is used to model the Management Directorate's policy of not removing too many aircraft from their user organization at once, to control the flow in each process and ensure that a constraint is never left idle, and to reduce the amount of time an aircraft waits to enter any phase of the maintenance process.

Additional changes to the original model. For the purpose of this study, the original model required changes and embellishments in addition to those mentioned in the previous sections. A number of changes were required because the validation and verification process, the process by which a model is examined to ensure it is accurate and producing reasonable results, identified discrepancies in activity durations and the order in which certain activities were accomplished. Also, within the speedline process, functions were added to monitor the time an aircraft spends in a speedline hangar and the number of speedline hangar positions being used. The first was used to conduct statistical tests, the second to ensure that this constraint is always operating to capacity. Additional changes were made to account for activities which the Production Division added and/or rearranged.

Updating the Model in the Future

It is important to note that the validation and verification and updating processes should continue once the MPC system is in place. These processes illustrate how the information system interfaces with the simulation models. As changes are made to the operation and/or activity duration data is collected, the simulation model should be updated in order to accurately reflect the current operation. Other data provided by the information system, such as resource utilization and work-in-process inventory, can be used to verify that the model is adequately reflecting the operation. In addition, this model may need to be expanded or other models developed to allow the examination of particular areas of concern in greater detail or to address concerns that are beyond the scope of this model.

Analysis Procedures

To illustrate how a simulation model within an MPC system can be used and to respond to the needs of the C-141 Management Directorate, this analysis addressed the questions and concerns outlined in Chapter III.

Model changes. In order to conduct the analysis, certain changes had to be made to the model and to the aircraft input data. The first change was to increase the number of aircraft allowed to enter the system and each process at the same time to ensure the constraints were always operating at full capacity. The second change was to ignore the current aircraft arrival schedule from the input data file and allow the model to determine when it could accept the next aircraft and assume that that aircraft was immediately available. This ensured that the schedule was not a constraining factor on the system. The third change was to add 100 speedline aircraft to the input file. The number of aircraft from each work-type category was based on the proportion of each type within the original 183. For example, 81 of the first 183 aircraft (44.3%) were aircraft requiring speedline only. So 44 of the next 100 were also speedline-only aircraft. This would allow the model to exceed the 183 objective whenever possible which was required to develop confidence intervals used in analyzing results. These additional aircraft were sorted in no particular order of entry into the system.

Statistical analysis and hypothesis testing. For each separate analysis outlined in the next section, the simulation was run 30 times and the results of each iteration was collected. The mean and variance of each set of results were computed. With 30 observations, an assumption could be made that these results were normally distributed about the mean because the error within the distribution was normally distributed (Mendenhall, Wackerly, and Scheaffer, 1990:317). The analysis of system throughput (total number of aircraft to exit the speedline process) and of arrival times was conducted using 95%

confidence intervals based on a Student's t-distribution. Normal distribution hypothesis testing was used when comparing the means and variances of different distributions of throughput.

Normal distribution hypothesis testing is a technique which can be used to determine whether the means and variances of two distributions are equal or not with the assumption that the error within the distribution is normally distributed about 0. The equality of variances is tested by computing the ratio of the greater of the two sample variances over the lesser of the two. If this ratio exceeds a predetermined value, the two are deemed to be not equal. Given equal variances the same technique can be used to determine whether the means of two distributions are equal. This is accomplished by computing the absolute value of the difference of the two sample means and dividing it by the pooled sample variances of the two distributions. This too is compared to a predetermined value. If this value is exceeded, a conclusion is made that the means are different (Mendenhall, Wackerly, and Scheaffer, 1990:374, 454, 457). Both of these tests were conducted at a 95% confidence level.

Addressing Specific Questions and Concerns

This section describes the approach used in addressing each specific question and concern outlined in Chapter III. Each question is restated, an objective provided, a measure of effectiveness (MOE) defined, and the analysis procedures described.

QUESTION: Goal achievability. Given the increase in resources to the speedline process, is the objective of 183 aircraft achievable?

Objective. The purpose of this analysis was to determine if the resources allotted was sufficient to achieve the objective of 183 aircraft through the speedline process.

MOE. This analysis used throughput as its measure of effectiveness.

Analysis procedures. Based on the throughput observation of 30 simulation runs, a 95% confidence interval was developed. The location of 183 relative to this interval determined the goals achievability. (This throughput distribution was also used in many of the following analysis procedures when testing for the effect of system changes on throughput. It will be referred to as the initial results.)

QUESTION: Last aircraft arrival date. If the goal was not achievable, how soon after 30 September 1993 would the 183rd speedline aircraft arrive at Warner-Robins?

Objective. The purpose of this analysis was to determine the date on which the 183rd speedline aircraft arrives at Warner-Robins, given that the goal is not achievable in the time allowed.

MOE. The analysis used work days as its measure of effectiveness.

Analysis procedures. The model was altered to allow aircraft to enter the system after 30 September 1993. The model recorded the work day that the 183rd aircraft entered the system. The results were compiled from 30 simulation runs and a 95% confidence interval was determined. The upper limit of this interval was then converted from work day to calendar date as a worst case answer to the question.

QUESTION: In-hangar time reduction. If the objective of 183 aircraft is not achievable, what reduction to the in-hangar time would be required to the ensure the objective could be met?

Objective. The purpose of this analysis was to determine how much the in-hangar time of the speedline process needs to be reduced in order to meet the 183 aircraft requirement.

MOE. This analysis used throughput as its measure of effectiveness.

Analysis procedures. This analysis required the substitution of all in-hangar activities with one in-hangar activity based on the distribution of time aircraft spend in a hangar accomplishing speedline related activities. This in-hangar time distribution was developed based on simulation results. The development of this distribution, illustrated in Figure 8, required a number of steps. Observations of 30 simulation runs were made of the in-hangar time of speedline aircraft with the new inspection and in-hangar PDM work removed from the model. The inspection and the PDM work were removed because not all aircraft would receive it. The distribution was found to be bimodal (observations clustered about one of two peaks). These peaks were based on whether an aircraft required at least one beam cap replacement. Since 12% of the wings require new beam caps, laws of probability show that 22.56% of the aircraft would require at least one. (Prob{aircraft requires new beam cap} = 1 - Prob{aircraft does not require new beam caps} = 1 - Prob{neither wing requires a new beam cap} = 1 - (.88)(.88) = .2256)

These peaks were neither normal nor triangular in shape, but an attempt was made to approximate this distribution analytically as a

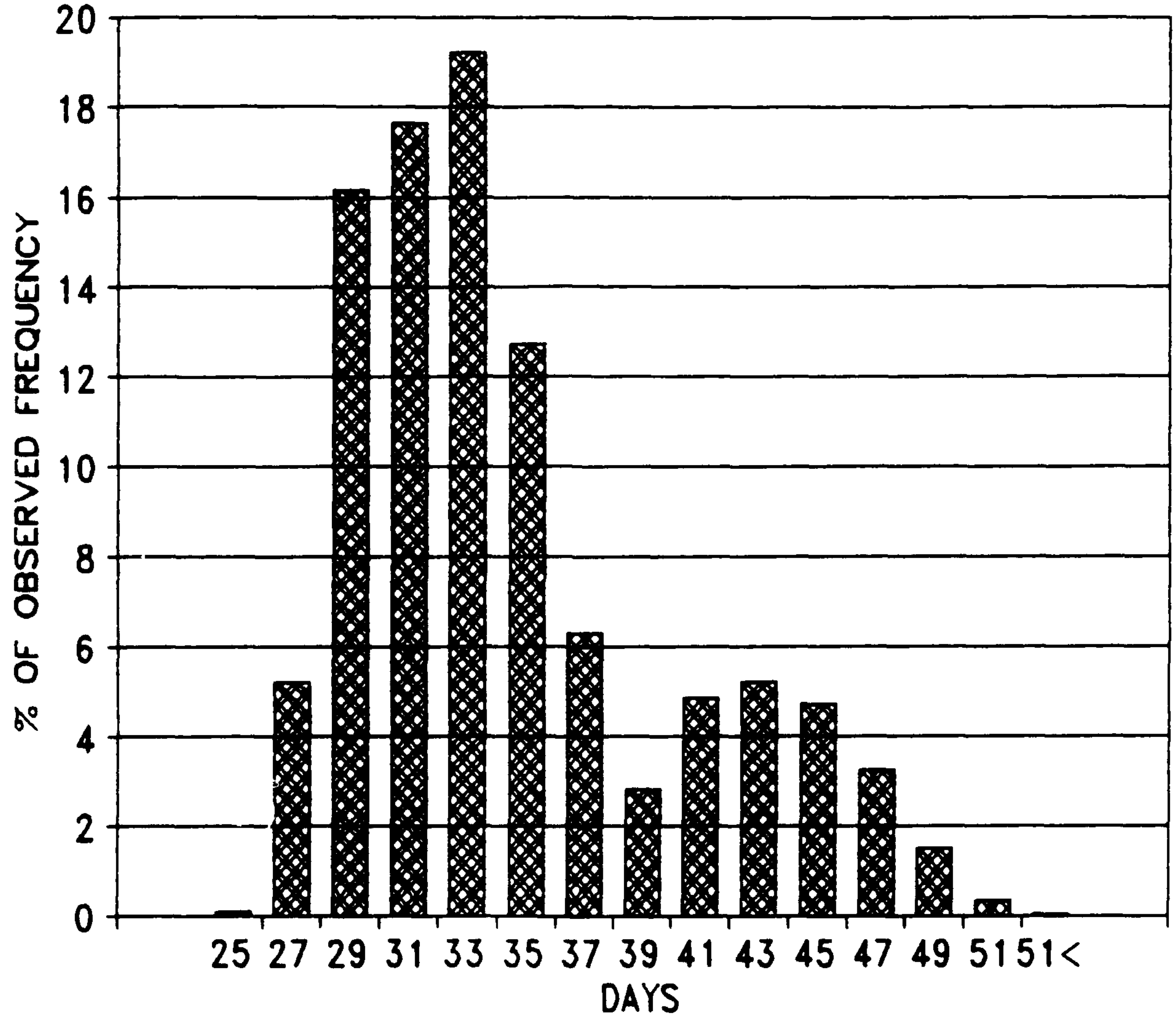

FIG 8: IN-HANGAR TIME DISTRIBUTION

combination of two normal distributions and two triangular distributions. Neither provided acceptable results. The normal distributions allowed for in-hangar times in the tails of the distribution that were a great deal longer and shorter than observed. The triangular distribution initially did not allow for the tight enough clustering. An adjustment was made to tighten the clusters, but this distribution did not allow for enough tail observations and had little variation about the peaks.

As a result, an empirical distribution was developed based on 30 simulation runs. The distribution was divided into 2-day increments and the percent of total aircraft over all 30 runs to fall within each increment was determined. Within each increment, a uniform distribution was used.

The current in-hangar activities in the simulation were replaced by one activity with this distribution and the new inspection was returned to the model as a separate activity within the hangar. Based on the throughput observations of 30 simulation runs and the assumption that these results are normally distributed, statistical analysis and hypothesis testing was used to ensure that the throughput distribution obtained with and without the detailed in-hangar activities are not significantly different.

Once the equivalent distribution was determined and substituted into the model, its mean was reduced until a solution was found that satisfied the requirement of 183 aircraft. This requirement was considered satisfied when the 95% lower confidence limit of the throughput distribution exceeded 183. In doing this, an assumption was made that, even with a reduction in the mean of this distribution, its variance would remain constant.

QUESTION: Reduction of depaint processing time. What would be the effect of reducing the processing time through the depaint process?

Objective. The purpose of this analysis was to determine if, by reducing the processing time through the depaint process, the overall throughput through the speedline process would increase.

MOE. This analysis used throughput as its measure of effectiveness.

Analysis procedures. The depaint processing time in the model was reduced by 50%, from a triangular distribution with a mode of 4 days and lower and upper tails of 3 and 5 days, respectively, to a distribution with a mode of 2 and tails of 1.5 and 2.5 days. A throughput distribution was found based on 30 simulation runs and this distribution was compared to the initial results to determine if throughput increased. The determination was made using normal hypothesis testing, first ensuring the variances were equal and then testing to see if the means of the distributions were different.

QUESTION: Reduction of resources. What would be the effect of transferring fewer resources to the speedline process?

Objective. The purpose of this analysis was to determine if too many resources were allocated to the speedline process.

MOE. This analysis used throughput as its measure of effectiveness.

Analysis procedures. The number of speedline/PDM hangar positions was reduce by increments of one, starting with the positions last added, until normal hypothesis testing identified a difference in the mean of the throughput distribution based on 30 runs when compared to the initial results. Tests were first conducted to confirm, with a 95% confidence level, the assumption that the variances of the distributions were not different. This process was repeated for speedline-only positions.

QUESTION: System capacity. What is the minimum number of aircraft that need to be located at Warner-Robins to keep the hangars operating at peak capacity?

Objective. The purpose of this analysis was to determine what policy the Management Directorate should invoke pertaining to the total number aircraft that can be located at Warner-Robins at the same time.

MOE. This analysis used throughput as its measure of effectiveness.

Analysis procedures. In obtaining the initial results, a restriction on the total number of aircraft within the system was not imposed. For this analysis, the number of aircraft allowed in the system was first held to 40, then reduced by one, incrementally, until normal hypothesis testing idertified a difference in the mean of the throughput distribution based on 30 runs when compared to the initial results. As before, tests were conducted to confirm that the variances of the distributions were not different prior to testing the means. All tests used a 95% confidence level.

Additional Analysis

Each of the previous analyses address one particular question or policy issue. In anticipation of management's desire to examine the results of applying more than one policy simultaneously, the additional analyses were conducted.

QUESTION: System capacity and resource reduction. Given the results of examining the levels of system capacity and resource reduction that do not affect the system, could both policies be implemented and still not affect the system?

Objective. The purpose of this analysis was to determine if the Management Directorate could invoke a policy of limiting the number of aircraft in the system to the level determined by previous analysis while reducing the number of hangar positions allocated to the speedline process by the number determined by previous analysis.

MOE. The analysis used throughput as its measure of effectiveness.

Analysis procedures. The simulation model was altered to limit the number of aircraft in the system and reduce the number of speedline hangar positions to levels that previous analysis indicated had no affect individually on system throughput. 30 observations of throughput were made and the mean and variance of this distribution were compared with those of the initial results using normal hypothesis testing to determine, with a 95% confidence level, if applying both changes to the system affect throughput.

QUESTION: Adjusted last aircraft arrival date. If both of these policies could be implemented, how would that affect the arrival date of the 183rd aircraft?

Objective. The purpose of this analysis was to determine the date on which the 183rd aircraft would arrive to Warner-Robins if the number of aircraft allowed in the system is limited and the number of speedline positions reduced to the levels indicated by previous results.

MOE. The analysis used work days as its measure of effectiveness.

Analysis procedures. The model was altered to limit the number of aircraft allowed in the system, reduce the number of speedline hangar positions, and allow aircraft to enter the system after 30 September 1993. The model recorded the work day that the 183rd aircraft entered the system. The results were compiled from 30 simulation runs and a 95% confidence interval was determined. The upper limit of this interval was then converted from work day to calendar date as a worst case answer to the question.

QUESTION: In-hangar time reduction, system capacity, and resource reduction. While time did not permit the examination of every possible combination of in-hangar time reduction, system capacity limitations, and resource reductions, an analysis was conducted to determine what system capacity limits could be imposed and speedline hangar position reductions made if the previously determined in-hangar time reduction could be achieved, while still ensuring the maintenance objectives could still be met.

Objective. The purpose of this analysis was to determine what combination of system capacity limitations and resource reductions could be imposed once an in-hangar time reduction sufficient to meet the maintenance requirement of 183 aircraft was realized.

MOE. The analysis used throughput as its measure of effectiveness.

Analysis procedures. This analysis used the simulation model developed for the previous in-hangar time reduction analysis. The in-hangar time was reduced to the level that previous analysis determined was sufficient for meeting the maintenance objective. Two separate approaches were then taken. The first was to determine the capacity limitation that could be imposed while still achieving the objective of 183 aircraft. This was accomplished by setting the limit to 40 and decreasing it incrementally until the 95% lower confidence limit of the throughput distribution no longer exceeded 183. Once this limit was determined, the number of hangar positions was reduced, starting with the last added, until the lower 95% confidence limit once again no longer exceeded 183. The second approach was similar, only the number of hangar positions was reduced first and then the system capacity level.

Time would not allow the examination of every possible combination of capacity limits and hangar position reductions, even at only one level of in-hangar time reduction. The results in Chapter V indicate that this would not be necessary.

Conclusion

The outline of the MPC system for C-141 Management Directorate at the Warner-Robins ALC is based on the research results found in Chapters II and III. Specific questions and concerns expressed by managers within the directorate are analyzed using a computer simulation model, distribution analysis, and normal hypothesis testing. The following chapter contains the MPC system outline and the analysis results.

V. RESULTS

This chapter provides an outline for the basic structure of an MPC system for a repair/overhaul/rebuilding operation based on the research results found in Chapter II. This system outline is then applied to the C-141 maintenance operation at Warner-Robins ALC, for which a more formal system design is developed. Existing components of this system are then used to address specific management questions and concerns.

General System

An MPC system for any organization should be designed to gather, store, and report information from all five major components of an organization: material planning and control; financial control; engineering activities; quality assurance; and sales and marketing. It should be designed and developed with user involvement and should provide information that is consistent with and supports management objectives and philosophies.

The system should consist of two subsystems, an information system and planning support and decision testing system, which support strategic and tactical planning and control functions and allow managers to study the effects of alternative courses of action prior to their implementation. These two systems should be integrated to ensure the planning support and decision testing system accurately reflects the current operation. The system should also have formal communication and feedback procedures established between the planning functions, management levels, and organizational components.

In the repair/overhaul/rebuilding environment, an organization will not, in most cases, have a sales and marketing component, but rather a scheduling and demand management component. This component develops maintenance schedules by coordinating "customer" requirements with the repair system's capacity. This environment also contains a higher degree of variability which the MPC system must account for and accommodate. The variability occurs in the repair requirements of each item entering the system, the resources required to complete a task, the duration of specific maintenance activities, and the schedule as unexpected repair items enter the system for unscheduled maintenance. The information system may provide data that can be used to identify many areas of variability and the degree to which it occurs, particularly in material requirements, resource utilization, and activity durations. To account for this variability a planning support and decision testing system which makes use of computer simulation models is recommended.

Warner-Robins' MPC System

The MPC system for Warner-Robins ALC should be comprised of DMMIS and a series of computer simulation models. DMMIS will adequately meet most of the logistics center's information requirements, omitting only budget information, and link all the organization components. Computer simulation models, some of which exist and can be enhanced, as well as others which may need to be developed in the future, provide a planning and decision testing capability which accounts for the inherent variability in the operations at Warner-Robins. By monitoring the data within the information system, managers may be able to identify some of the areas where variability is occurring and determine its severity. As information on resource utilization, activity duration, work requirements, costs, and schedules is collected by existing systems and later by DMMIS, the simulation models can be updated to more accurately reflect the current operating conditions at the logistics center.

<u>The MPC system's interaction with organization components</u>. All five major organizational components would provide information to and collect information from this system. Personnel from material planning and control would collect data on activity duration, resource utilization, material requirements, and inventory. They would receive information on aircraft arrival, maintenance requirements as determined by the engineers, quality, budgets (which must be added to DMMIS), and funds availability. They would use the shop-floor scheduling system within DMMIS to plan and control their daily operations. They could use simulation models to determine if the overall maintenance schedule is being met, if resource and material levels are sufficient to meet their needs, and if work-in-process inventory levels anywhere within the system are projected to be unsatisfactorily high in the near future. Financial managers would use the information system to monitor costs and could use simulation models in developing future budgets. Engineers would use the data bases to determine maintenance requirements on aircraft prior to their arrival and could use simulation models to determine long term resource requirements, shop-floor layouts, and the effects of mandating new requirements on the current operation. Quality assurance personnel would use the information system to monitor the quality of work being accomplished and could use simulation models to determine the effects of conducting additional inspections at various

points throughout the operation on system throughput. Demand management personnel would use the information system and simulation models to develop schedules that meet the maintenance requirements of each aircraft, ensure the overall production objectives are met, and provide the least disruption to the mission requirements of the aircraft's users.

The MPC system's use in strategic and tactical planning. In conducting strategic and tactical planning, the degree to which each subsystem is used varies. In the direction phase, simulation models would be used to develop and test demand plans, production plans, and master production schedules. These models would not require a great deal of system detail, but would focus on overall requirements and basic system capacity and would not always require a great deal of detailed information on the operation. As more detailed material and capacity plans are developed, the amount of information required increases. This information would be incorporated into the simulation models used in developing and refining these plans. Aircraft schedules and material reordering schedules would also be developed using simulation results. In the execution phase, managers would make a great use of the information system and the shop-floor scheduling system to make day-to-day decisions. Simulation models would play only a minor role in these activities.

The MPC system and the Theory of Constraints. The use of simulation models will be of great assistance to an organization using the Theory of Constraints. Like ToC, a simulation model's focus is on throughput and the factors which determine and restrict it. Simulation models have already been used to identify the constraints at Warner-

Robins. These models can be embellished to develop schedules that reduce work-in-process inventory within the system while still ensuring the constraints are operating at peak capacity. While some of the reports generated by the information system may need to be altered, both the information system and the simulation models could be used to identify how and where improvements to the system could be made in order to increase throughput. These improvements could also be tested to ensure the desired results would be realized prior to their implementation. Because simulation models account for system variability, they are of greater use and provide a more accurate assessment of an operation then systems that assume no variability exists in the operation.

Analysis Results

The simulation model described in Chapter IV is used to address the questions and concerns outlined in Chapter III. The simulation currently contains estimates for activity duration times and their variability based on the planning figures developed by the Production Division. Some resource requirements are also based on planned estimates. Others are known and well defined. As mentioned above, as DMMIS and other systems are used to gather more accurate information, the model should be updated.

Goal achievability. Under the process configuration based on the recent management changes, the results indicate the Warner-Robins should not expect to meet its objective of 183 speedline aircraft. The throughput distribution over 30 runs has a mean of 176.8 aircraft with a standard deviation of 1.97. A 95% confidence interval for this distribution ranges from 173.0 to 180.8, short of the 183 objective, as illustrated in Figure 9a.

Last aircraft arrival date. Based on an average of 30 runs, the 183rd aircraft enters the system on workday 724.1, 16.1 work days beyond the desired 708. The standard deviation of the distribution is 8.30 work days. A 95% confidence interval, illustrated in Figure 9b, ranges from workday 655.3 to 741.1. Using the upper limit as a worst case, the last aircraft should enter the system on workday 742, which would be 4 November 1993, 35 days beyond the 30 September deadline.

In-hanger time reduction. Table 1 contains the results of reducing the in-hangar time by the given number of days starting on 1 April 1992. A 95% lower confidence limit is computed to identify the reduction required to be 95% confident of making and exceeding the 183 aircraft objective. The results indicate a reduction of 3.4 days in-hangar time, beginning on 1 April 1992, would provide the desired outcome.

TABLE 1

RESULTS OF IN-HANGAR TIME REDUCTION ANALYSIS

Days Reduced	Distribution Mean	Standard Deviation	Lower Confidence Limit
3.0	185.4	2.86	180.5
3.2	185.6	2.30	181.9
3.3	186.1	2.31	182.2
3.4	186.6	2.07	183.1
3.5	186.9	1.89	183.7
3.8	188.5	2.71	183.9
4.0	188.8	1.90	185.5

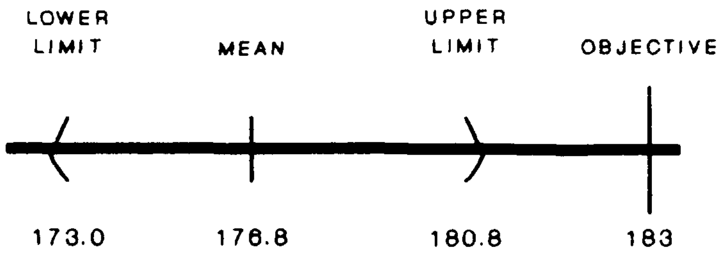

FIG 9a: THROUGHPUT DISTRIBUTION (# OF AIRCRAFT)

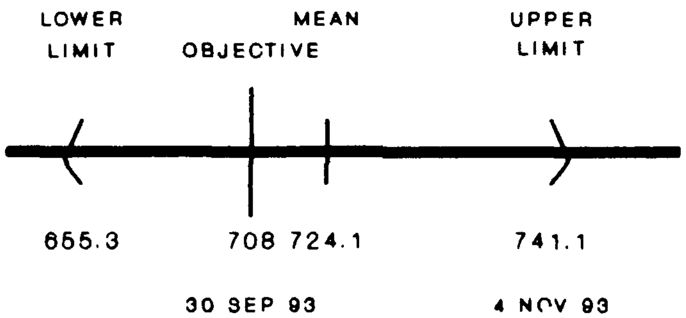

FIG 9b: LAST ARRIVAL DATE DISTRIBUTION (IN WORK DAYS)

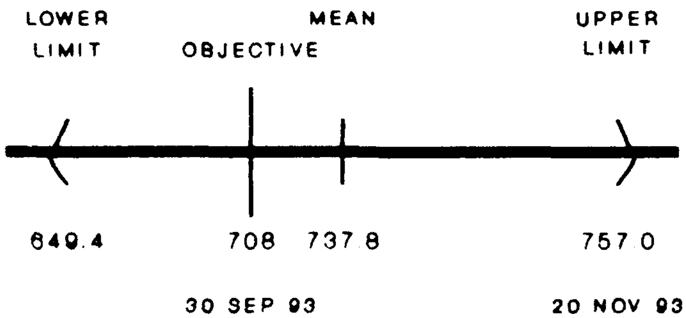

FIG 9c: ADJUSTED LAST ARRIVAL DATE DISTRIBUTION (IN WORK DAYS)

Reduction of depaint processing time and resources. Table 2 contains the results of decreasing the processing time in the depaint activity and the results of reducing the number of each type of hangar position. The variance test statistic column contains a F-test statistic value used to test whether the variances of two distributions are the same. This is a prerequisite for testing for differences in means. A value of 1.86 or greater leads to a conclusion, with 95% confidence, that the variances are different. None failed this test. The mean test statistic column contains a t-test statistic used to test if the means of the two distributions are different. A value of 2.002 or greater leads to a conclusion, with 95% confidence, that the means were different and the adjustment made to the system would affect throughput.

TABLE 2

RESULTS OF REDUCING DEPAINT PROCESSING TIME AND HANGAR POSITIONS

Adjustment	Distribution Mean	Standard Deviation	Variance Test Statistic F-crit=1.86	Mean Test Statistic t-crit=2.002
Initial	176.8	1.97	n/a	n/a
Depaint	177.0	2.27	1.33	0.34
-3 SL/PDM	177.0	1.75	1.26	0.58
-4 SL/PDM	176.0	2.32	1.39	2.12
-1 SL only	172.9	2.62	1.78	9.37

Depaint. From table 2, the results indicate that reducing the duration of the depaint process would not affect throughput.

Hangar reductions. The results indicate that up to three speedline/PDM hangar positions could be lost without affecting throughput. However, no speedline-only hangar positions could be spared.

System capacity. The initial model did not restrict the number of aircraft on the ground at Warner-Robins and all previous analysis results reflect this. The initial model runs indicated that, while an average of about 35 aircraft were in the system at the same time, the total number rose to 45 at times. Table 3 contains the results of placing various limits to the number of aircraft in the system simultaneously. The results indicate that a ceiling of 38 could be placed on the system without affecting throughput.

TABLE 3

RESULTS OF RESTRICTING THE TOTAL NUMBER OF AIRCRAFT IN THE SYSTEM

Limit	Distribution Mean	Standard Deviation	Variance Test Statistic F-crit=1.86	Mean Test Statistic t-crit=2.002
Initial	176.8	1.97	n/a	n/a
40 aircraft	176.7	2.10	1.14	0.36
38 aircraft	176.5	1.66	1.41	0.90
37 aircraft	176.1	1.60	1.51	2.04
35 aircraft	175.2	1.74	1.28	4.72

System capacity and resource reduction. Based on the previous results, the number of aircraft within the system was limited to 38 and the number of speedline/PDM hangar positions was reduced by three. The resulting throughput distribution has a mean of 176.6 and a standard deviation of 1.96. When comparing these to those of the initial results (mean: 176.8; standard deviation: 1.97), the variance test statistic is 1.01. Since this is less than 1.86, a test of means can be conducted and indicates with a test of 0.564 (less than 2.002) that the means are not different and both policies can be implemented simultaneously without affecting the system's throughput.

Adjusted last arrival date. With both of these policies implemented, the 183rd aircraft arrives, on the average, on workday 737.8. With a standard deviation of 9.41 days, a 95% confidence interval ranges from 649.9 to 757.0. Using the upper limit as a worst case estimate, the last aircraft arrives on workday 758, which would be 20 November 1993. Figure 9c illustrates this confidence interval, and when compared to Figure 9b, highlights the fact that imposing these policies would delay the arrival of the 183rd aircraft by 16 calendar days over not imposing either policy.

In-hangar time distribution, system capacity, and resource reduction. Table 4 contains the results placing various limits on system capacity and reducing the number of speedline/PDM hangar positions given a 3.4 day reduction to the in-hangar time. 95% lower confidence limits are computed to identify which combinations still allow the objective of 183 aircraft to be met. The results indicate that the number of aircraft could be limited to 39 and the number of speedline/PDM hangar positions reduced by one or the limit could be 40 aircraft and the number of positions could be reduced by two.

In addition to the combinations generated by the procedures outlined in Chapter IV, one other combination is examined. Noting the results in Table 4, a policy of imposing a limit of 38 is rejected as a possible course of action. But this is due to the value of the standard deviation. Imposing a limit of 39 aircraft results in the same distribution mean and is accepted as a course of action because the distribution has a smaller standard deviation. Because of this, the additional combination of a 38 aircraft limit and a hangar position reduction of one is examined, but rejected.

TABLE 4

RESULTS OF EXAMINING COMBINATIONS OF SYSTEM CAPACITY AND RESOURCE REDUCTION WHEN A 3.4-DAY REDUCTION IN IN-HANGAR TIME IS REALIZED

Aircraft Limit	Hangar Position Reduction	Distribution Mean	Standard Deviation	Lower Confidence Limit
40	0	186.8	1.93	183.6
39	0	186.3	1.66	183.5
38	0	186.3	2.10	182.7
38	-1	186.0	2.08	182.5
39	-1	187.3	2.18	183.6
39	-2	185.7	2.17	182.0
n/a	-1	186.6	1.74	183.6
n/a	-2	187.3	2.09	183.5
n/a	-3	185.3	1.97	182.0
40	-2	186.6	1.75	183.7
39	-2	185.7	2.17	182.0

Conclusion

An MPC system for a repair/overhaul/rebuilding environment must account for differences in organizational structures and components and for higher system variability. By combining the information system and the shop-floor planning system of DMMIS with a series computer simulation models, Warner-Robins's needs should be met.

In addressing the questions and concerns of higher management at the logistics center, results indicate that their objectives currently can not be met, but could be if a reduction of 3.4 in-hangar days per aircraft could be realized by 1 April 1992. Decreasing depaint processing time would have no effect on throughput levels for the current system, nor would reducing the number of speedline/PDM hangars by three and/or instituting a 38 aircraft ceiling on the number of aircraft in the system at the same time. If a reduction of 3.4 in-hangar days per aircraft is realized, one of the two following policies could be implemented while still meeting the objective 183 aircraft through the speedline process:

1. Limit the number aircraft in the system at the same time to 39 and reduce the number of speedline/PDM hangar positions by one.

2. Limit the number aircraft in the system at the same time to 40 and reduce the number of speedline/PDM hangar positions by two.

VI. CONCLUSIONS AND RECOMMENDATIONS

This chapter reviews the basic structure of an MPC system for a repair/overhaul/rebuilding environment and the process an organization should go through to develop and implement such a system. Recommendations for the specific system at Warner-Robins ALC are provided. The chapter highlights critical issues that must be addressed to ensure successful system development, implementation, and use. The chapter also provides recommended courses of action that management could take in order to meet specific maintenance objectives. The chapter concludes with a list of areas and ideas for future research.

MPC System Structure

Manufacturing planning and control systems are designed to assist managers to plan, monitor, and operate their production processes. The systems provide information with which managers can conduct both long and short term planning for all or portions of their operation.

An MPC system for a repair/overhaul/rebuilding environment must incorporate the organization's five major components: material planning and control; financial control; scheduling demand and management; engineering activities; and quality assurance. The components must be linked by communication and information, using both to overcome conflicting objectives, such as maximizing production while minimizing costs.

An MPC system must have an information system and a planning support and decision testing system. The information system should be designed to collect, store, and report data on resource requirements, utilization, and availability; activity requirements, duration, and status; scheduling, inventory status; costs and budgets; and quality control. The planning support and decision testing system should account for variability throughout the process including scheduling, resource utilization, and activity requirements and duration. The two systems should be interfaced to allow for the exchange of information. This interface need not be automated.

The MPC system should have a formalized feedback network between the 5 organizational components, the various planning functions, and the different management levels.

Development and Implementation

An organization must assemble teams of its best people from each component. They must have or be given a complete understanding of the overall operation and their role in developing an MPC system for it. They must also understand management's objectives and philosophies.

The system's objectives must be determined and its boundaries set and well defined. The teams must determine which components are to be included and how each component will use and be affected by the system. The system should be designed to be easy to use and each component must be satisfied with the resulting system and convinced of its importance.

Once the system is developed, it must be tested against performance measures to ensure it is meeting its objectives. The system should be constantly monitored to be sure that it adequately reflects the current operation and contains accurate data. Efforts should be made to constantly improve the system as well.

Managers must ensure that any changes to their approach or philosophies are consistent with the system. Otherwise, the system may not provide the information and support they require. They must ensure that their personnel are adequately trained and educated on the system. This ensures greater acceptance of the system and ensure its proper use. This is important because misuse leads to inaccurate information, resulting in poor management decisions.

The implementation schedule should be well planned. Chaos could result if implementation is accomplished too quickly and interest lost if accomplished too slowly.

The Warner-Robins System

It is recommended that the Warner-Robins MPC system consist of the information system within the Defense Maintenance Management Information System (DMMIS), which will incorporate all the critical organizational components, and a series of computer simulation models. DMMIS will provide for all the center's information and most feedback needs, as well as a good shop-floor scheduling system. Simulation models will meet their planning support and decision testing needs as they can account for most of the variability within the operation. The two can be linked by a manual process of monitoring the information provided by DMMIS and reprogramming the simulation models as necessary.

While DMMIS is being developed and tested at other sites, working groups can be formed to lay the ground work for its implementation and address some specific issues. One critical issue is information exchange and feedback between components. While most communication networks at Warner-Robins are well defined and established, managers within each of the components are not entirely aware of the information available from other components, nor are they aware of all the information needs of others that they could meet. In addition, they do not completely understand the effect of their decisions on other components and do not always understand the actions of others. Communication is the key to overcoming this issue.

Another issue that must be addressed is personnel's understanding of senior leadership philosophy. Many lower level managers and workers don't have a complete understanding of the Theory of Constraints (ToC) and are developing reports and briefings that are inconsistent with this philosophy and provide little useful information to senior leadership. Information systems currently add to this dilemma because many of the reports they generate are also inconsistent with ToC.

The proposed system supports the management philosophy of ToC because it can be used to identify constraints, develop schedules that reduce work-in-process inventory while ensuring constraints are operating at peak capacity, and with adjustments to some information reports, can be used to improve the throughput levels of the operation.

Meeting Maintenance Objectives

Under currently planned operating conditions, the logistics center will not meet the objective of 183 speedline aircraft. Senior leadership has four possible courses of action. The first is to seek to reduce the average in-hangar maintenance time by at least 3.4 days beginning on 1 April 1992. Some reductions may be realized as workers become more proficient through practice. The rest could be realized through increasing manpower and/or material resources. If this course of action is selected, a system ceiling of 39 aircraft could be imposed and the number of speedline/PDM hangar positions reduced by one or a ceiling of 40 aircraft could be imposed and a reduction of two positions could be realized.

The second is to seek an extension to the program beyond 30 September 1993. A 35-day extension should be adequate.

The third possible course of action would be to contract the work to a civilian company. While this would be costly, at most only ten aircraft would be affected based on the lower confidence limit of 173.0 from the initial results.

The final alternative would be to fly the remaining aircraft to Warner-Robins before 30 September. Since on 1 October these aircraft would be grounded, where they are housed should be irrelevant provided their is sufficient space available at Warner-Robins. And since they arrived to the center prior to the deadline, the work could be conducted under the current program and would be completed less than two months after the original desired completion date. This last course of action could only be pursued if the users could spare these aircraft for the additional time.

If either of the last two alternatives are chosen, a ceiling of 38 aircraft can be imposed and the number of hangar positions reduced by three. If these policies are implemented, and seeking a deadline extension is the desired course of action, a 51-day extension beyond the 30 September 1993 deadline for aircraft arrival would be required for the 183rd aircraft to enter the system. This is 16 days longer than if neither policy were implemented.

Further Research Efforts

This study concentrated on the material planning and control component's use of an MPC system. Future research could analyze, in greater detail, how other components interact with the system. At Warner-Robins, specifically, research efforts could concentrate on how the financial components, the item managers, and various supply organizations will interact with each other and with DMMIS. Further analysis could be done on how specific planning functions would interface with the MPC system in developing plans that are more realistic, more complete, and more efficient than the MRP-based systems being planned as part of DMMIS. The current simulation model could be used to analyze other effects of implementing more than one of the suggested courses of action outlined in Chapters IV and V. The model could also be enhanced to include more resource utilization information and a more detailed network of some the maintenance of activities, particularly PDM which is now modeled by only a few activity statements. This model could also be used to develop and test a better maintenance schedule and a more efficient distribution of resources. Other models could be developed to collect and analyze budgeting and cost information. System designers could explore the possibility of developing an automated interface between DMMIS and the simulation models.

Conclusion

MPC systems can be a useful management tool in providing information to the decision maker and can be used to address and solve many critical issues. But the system itself will not solve problems.

Managers must still be responsible to take the information provided by the system, and an adequate assessment of what the information is telling them, and develop and implement the appropriate course of action (Mozenson, 1991:20-29).

While having accurate information is important to any organization, the key to developing an MPC system for a repair/overhaul/rebuilding environment is to account for variability within the operation. Computer simulation models not only do this, but do this faster and provide better sensitivity analysis than the MRP-based system being developed as part of DMMIS. With some minor adjustment, complete management support and commitment, and the proper education, DMMIS can fulfill the information needs of Warner-Robins, but its MRP-based planning functions must be replaced with computer simulation models.

Appendix A: SLAM II Simulation Model

```
GEN,C141 GROUP,C141 PROJECT,8/11/1991,30,N,N,Y/Y,Y,Y/1,72;
LIMITS,40,25,500;
EQUIVALENCE/ATRIB(1),MT/ATRIB(2),TAIL_NU/ATRIB(12),TIME/ATRIB(13),WINGT;
EQUIVALENCE/ATRIB(14),CIGART/ATRIB(15),SYST/ATRIB(8),NDIFLAG;
NETWORK;
      RESOURCE/1,IN_SYS(400),1;
      RESOURCE/2,EQUIP(4),15,16;           ALL INIT PREP & SL/NoPDM BLDUP
      RESOURCE/4,DE_PT(1),8,11,13,7;
      RESOURCE/5,PAINT,14,12,10;
      RESOURCE/6,SPDLIN(20),18;            LIMIT NUMBER OF A/C IN SYSTEM;
      RESOURCE/7,SNGL_HNG(6),20;           SINGLE BAY HANGARS;
      RESOURCE/8,PDM_HNG(0),21;            HANGAR WHERE A/C GET SL+PDM;
      RESOURCE/12,WTR_PICK(1),22;          WATER PICK IF A/C NEEDS PDM;
      RESOURCE/9,NO_LOAD(1),28;            NO LOAD EQUIP FOR SL AND WS;
      RESOURCE/10,NDI(7),24,25,27,26,23;   NDI EQUIP FOR SL, PDM, AND WS;
      RESOURCE/11,DMPREP(1),31;            Assuming can only prep 1 ac
      RESOURCE/3,M_DEM(1),32,33;           Mate De-Mate Facility
      RESOURCE/13,Pre_WS(1),34;            Prep Wing Shop
      RESOURCE/14,WING(1),35;              Wing Shop
      RESOURCE/15,POST_WS(1),36;           Post Wing Shop
      RESOURCE/16,CIGAR(1),37;             Cigar Shop
      RESOURCE/17,CWB_SLOT(2),38;          One CWB line open
      RESOURCE/18,CWB_ONGRND(2),39;        CWB a/c on ground at a time
      RESOURCE/19,PDM_SLOT(6),29;          PDM POSITIONS
      RESOURCE/20,PDM_ONGRND(8),30;        PDM A/C ON GROUND AT A TIME
      RESOURCE/21,FUNCTEST(4),17;          FUNCTIONAL TEST
      RESOURCE/22,COUNT(50),4,3,2;         TRACKS TOTAL A/C ON GROUND

      CREATE,,104,,1;
      ALTER,PDM_HNG/+3;               SL + PDM HANGARS ON 15 JAN 92
      TERM;

      CREATE,,265,,1;
      ALTER,SNGL_HNG/+2;              TWO MORE SINGLE HANGARS ON 1 APR 92
      ALTER,PDM_HNG/-2
      TERM;

      CREATE,,384,,1;                 1 NOV 92
      ALTER,PDM_HNG/+4;
      TERM;

      CREATE,,443,,1;                 1 JAN 93
      ALTER,PDM_HNG/+2;
      TERM;

      CREATE,,515,,1;                 16 DAYS PRIOR TO NEW HANGARS
      ALTER,SPDLIN/+5;                   COMING ON LINE
```

```
      TERM;

      CREATE,,531,,1;                  1 APR 93
      ALTER,PDM_HNG/+4;
      TERM;

      CREATE,,709,,1;
      ALTER,SPDLIN/-25;
      TERM;
;
;*****************************************************
;GENERATION OF 5 TYPES OF PLANES WITH A USER FUNCTION
;*****************************************************
;
BGIN  CREATE,,0,1;
      ACTIVITY,USERF(1);
G1    GOON,2;
      ACTIVITY,,ATRIB(3).GT.0,BGIN;
      ACTIVITY,,ATRIB(3).GT.0,SYST;
      ACTIVITY,,ATRIB(3).EQ.0,STRM;
STRM  TERM;
;
;GENERATION OF DROP-IN PLANES
;
SYST  AWAIT(1),IN_SYS,,1;
      ACTIVITY,,,TAIL;
;
;INITIAL PREPERATION NETWORK
;********************************************
;
TAIL  ASSIGN,II=II+1,ATRIB(2)=II,ATRIB(1)=TNOW,1;
      ACTIVITY;
;
;SEND A/C TO APPROPRIATE PORTION OF NETWORK WHERE THEY ARE HELD UNTIL
;THE NETWORK CAN ACCOMODATE THEM
;
      GOON,1;
      ACTIVITY,,ATRIB(3).EQ.4,SLOT;                    CWB TO GET GRND SLOT
      ACTIVITY/1,UNFRM(709,1269),ATRIB(3).EQ.5,PDMG;PDM-ONLY TO GET SLOT
      ACTIVITY,,ATRIB(3).NE.4.AND.ATRIB(3).NE.5,SPLN;SL TO GET GRND SLOT

SLOT  AWAIT(39),CWB_ONGRND,,1;       CONTROL NUMBER OF CWB A/C IN SYSTEM
      AWAIT(2),COUNT,,1;
      ASSIGN,ATRIB(1)=TNOW,1;
      ACTIVITY,TRIAG(.32,.4,.52),,PREP;       INITIAL OPCK

PDMG  AWAIT(30),PDM_ONGRND,,1;       CONTROL NUMBER OF PDM A/C IN SYSTEM
      AWAIT(3),COUNT,,1;
      ASSIGN,ATRIB(1)=TNOW,1;
      ACTIVITY/2,TRIAG(.32,.4,.52),.5,PDM;     PDM NO PAINT INITIAL OPCK
      ACTIVITY/3,TRIAG(.32,.4,.52),.5,ADP;     PDM PAINT INITIAL OPCK
ADP   ASSIGN,ATRIB(10)=1,1;
```

```
      ACTIVITY,,,DEPAT;

SPLN  AWAIT(18),SPDLIN/1,,1;         CONTROL NUMBER OF SL A/C IN SYSTEM
      AWAIT(4),COUNT,,1;
      ASSIGN,ATRIB(1)=TNOW,2;
      ACTIVITY,TRIAG(.32,.4,.52),,PREP;       INITIAL OPCK
      ACTIVITY,,,ALLIN;

ALLIN TERM,500;                        USED WHEN DETERMINING WHEN A
;                                         CERTAIN NUMBER OF SL A/C
;                                         ENTER THE SYSTEM

PREP  AWAIT(16),EQUIP/1,,1;            GET PREP RESOURCE
      GOON,1;
      ACTIVITY,,ATRIB(3).EQ.4,CWIP;
      ACTIVITY,,,SLIP;
;
;****************************************************
;               DEPAINT NETWORK
;****************************************************
;
DEPAT AWAIT(7),DE_PT,,1;
      ACTIVITY/11,TRIAG(3,4,5);        DEPAINT;
FDEPT FREE,DE_PT,1;
      ACTIVITY,,ATRIB(3).NE.4.AND.ATRIB(3).NE.5,SLPRP;
      ACTIVITY,,ATRIB(3).EQ.4,DMPR;
      ACTIVITY,,ATRIB(3).EQ.5,PDM;
;
;************************************************************;
;++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
; BEGINNING OF SPEEDLINE BLACK BOX;
;++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++;
;************************************************************;


; INITIAL PREP FOR SPEEDLINE TO INCLUDE PREP FOR PAINT IF REQUIRE;
;================================================================;


 SLIP  GOON,1;
       ACTIVITY,,ATRIB(3).EQ.2.OR.ATRIB(3).EQ.3,IP23;
       ACTIVITY,,ATRIB(3).EQ.1.OR.ATRIB(3).EQ.6,IP16;

 IP23  GOON,2;                              PREP FOR SL/PDM & SL/PDM/PNT
       ACTIVITY,TRIAG(.16,.2,.26),,B23A;       FOD INSPECTION;
       ACTIVITY,TRIAG(.16,.2,.26),,B23A;       RM 780 EQUIPMENT;

 B23A  BATCH,30/2,2,,LAST,NONE;

       ACTIVITY,TRIAG(.08,.1,.13),,B23B;       REMOVE ANTENNAS;
       ACTIVITY,TRIAG(4.24,5.3,6.84),,B23B;    CRIT PATH:FROM DEFUEL TO;
;                                              REMOVING FLIGHT CONTROLS;
 B23B  BATCH,30/2,2,,LAST,NONE;
```

```
 FE23  FREE,EQUIP/1,1;

       ACTIVITY,TRIAG(.16,.2,.39),,DEPAT;      TOW TO DEPAINT;


 IP16  GOON,2;                               PREP FOR SL & SL/PDM;
       ACTIVITY,TRIAG(.16,.2,.26),,B16A;       FOD INSPECTION;
       ACTIVITY,TRIAG(.16,.2,.26),,B16A;       REMOVE 780 EQUIPMENT;

 B16A  BATCH,30/2,2,,LAST,NONE;
 FE16  FREE,EQUIP/1,1;

       ACTIVITY,TRIAG(.96,1.2,1.56),,SLPRP; FROM DEFUEL TO TOW FOR;
;                                                FOR STRIPPING;


; PREP FOR SPEEDLINE;
;==================;

 SLPRP GOON,1;
       ACTIVITY,,ATRIB(3).EQ.1,SP1;
       ACTIVITY,,ATRIB(3).EQ.2,SP2;
       ACTIVITY,,ATRIB(3).EQ.3,SP3;
       ACTIVITY,,ATRIB(3).EQ.6,SP6;

 SP1   GOON,5;                              PREP FOR SL ONLY;
       ACTIVITY,TRIAG(3.2,4,5.2),,B1C;        OPS CHK TO RM PYLONS;
       ACTIVITY,TRIAG(1.6,2,2.6),,B1C;        DEPAINT REPAIR AREAS;
       ACTIVITY,TRIAG(1.28,1.6,2.08),,B1C;    RM LEAD EDGE AND AIR DUCS;
       ACTIVITY,TRIAG(1.28,1.6,2.08),,B1C;    STRIP T/E FOR TCTO 773;
       ACTIVITY,TRIAG(1.28,1.6,2.08),,B1C;    OPEN FUEL TANKS & DEPUDDLE;

 B1C   BATCH,30/2,5,,LAST,NONE;

       ACTIVITY,,,HNGR;                     GO TO RECEIVE HANGER ASGNMNT;


 CP2   GOON,3;                             PREP FOR SL/PNT;
       ACTIVITY,TRIAG(1.76,2.2,2.86),,B2C;  INST NOSE WGHT TO RM LD EDGE
       ACTIVITY,TRIAG(1.28,1.6,2.08),,B2C;  STRIP T/E FOR TCTO 773;
       ACTIVITY,TRIAG(1.28,1.6,2.08),,B2C;  OPEN FUEL TANKS AND DEPUDDLE

 B2C   BATCH,30/2,3,,LAST,NONE;

       ACTIVITY,,,HNGR;                     GO TO RECEIVE HANGER ASGNMNT;


 SP3   GOON,3;                              PREP FOR SL/PDM/PNT;
       ACTIVITY,TRIAG(2.4,3,3.9),,B3C;        INST NOSE WGHT TO RM PYLONS
       ACTIVITY,TRIAG(1.68,2.1,2.73),,B3C;    RM LEAD EDGE AND AIR DUCS;
       ACTIVITY,TRIAG(1.28,1.6,2.08),,B3C;    STRIP T/E FOR TCTO 773;
```

```
B3C   BATCH,30/2,3,,LAST,NONE;

      ACTIVITY,,,WP;                           SENT FOR WATER PICKING;


SP6   GOON,4;                                  PREP FOR SL/PDM;
      ACTIVITY,TRIAG(5.28,6.6,8.28),,B6C;        OPS CHK TO RM PYLONS;
      ACTIVITY,TRIAG(1.6,2,2.6),,B6C;            DEPAINT REPAIR AREAS;
      ACTIVITY,TRIAG(1.68,2.1,2.73),,B6C;        RM LEAD EDGE & AIR DUCS;
      ACTIVITY,TRIAG(1.28,1.6,2.08),,B6C;        STRIP T/E FOR TCTO 773;

B6C   BATCH,30/2,4,,LAST,NONE;

      ACTIVITY,,,WP;                           SENT FOR WATER PICKING;


; WATER PICKING FOLLOWED BY FUEL TANK PREP FOR PLANES GOING THROUGH PDM;

WP    AWAIT(22),WTR_PICK/1,,1;
      ACTIVITY,TRIAG(3.2,4,5.2);                 WATER PICKING A/C;
      FREE,WTR_PICK,1;

      ACTIVITY,TRIAG(1.28,1.6,2.08),,HNGR;       OPEN FUEL TANKS & DEPUDDLE
;                                                 THEN GO TO RECEIVE HANGAR
;                                                 ASSIGNMENT;


; RECEIVE HANGAR ASSIGNMENTS
;==========================;

HNGR  GOON,1;                                    HANGAR SELECTION;

      ACTIVITY,,ATRIB(3).EQ.3.OR.ATRIB(3).EQ.6,PHNG;
      ACTIVITY,,,SHNG;


PHNG  GOON,1;
      ACTIVITY,,NNQ(21).GE.3.AND.TNOW.LE.300,SHNG;
      ACTIVITY,,NNQ(21).GE.4,SHNG;
      ACTIVITY,,,PHAW;
PHAW  AWAIT(21),PDM_HNG/1,,1;                    WAITING FOR SL + PDM HANGAR
      ASSIGN,ATRIB(9)=1,1;                       HANGAR TYPE FLAG - 1=SL+PDM
      ACTIVITY/9,,,TOW;                          SL + PDM HANGAR

SHNG  AWAIT(20),SNGL_HNG/1,,1;                   WAITING FOR SL-ONLY HANGAR
      ASSIGN,ATRIB(9)=0,1;                       HANGAR TYPE FLAG - 0=SL
      ACTIVITY/8,,,TOW;                          SL HANGAR

TOW   GOON,1
TIH   ASSIGN,ATRIB(6)=TNOW,1;                  FOR TIME-IN-HANGAR STATISTICS
      ACTIVITY,TRIAG(.32,.4,.52);              TOW A/C TO HANGAR AND HANGAR;
      GOON,1;
```

```
      ACTIVITY,TRIAG(.32,.4,.52);           JACK A/C;

 NLD  AWAIT(28),NO_LOAD/1,,1;
      GOON,1;
      ACTIVITY,,ATRIB(3).EQ.4,WSHP;         BACK TO CENTER WING AREA;
      ACTIVITY,TRIAG(.8,1,1.3);             NO-LOAD AND SHORE A/C;
      FREE,NO_LOAD;

      ACTIVITY,TRIAG(.8,1.0,1.3);            STRIP WING TANKS;

;CHORDWISE/SPANWISE INSPECTION
;=============================

; INSPECTION CONDUCTED ON FIRST FEW A/C THEN HALTED UNTIL 1 APRIL 92
;   ASSUMES SUFFICIENT NDI WILL BE AVAILABLE

      GOON,1;
      ACTIVITY,,TNOW.LT.177.AND.ATRIB(2).GT.9,NFLG
      ACTIVITY,TRIAG(8,10,13),TNOW.GE.177.OR.ATRIB(2).LE.9;,NFLG;

; BEGIN PHASE I OF TCTO 773;
;==========================;

 NFLG ASSIGN,NDIFLAG=1,1;                  INITIALIZE NDI FLAG;
 NDI  AWAIT(27),NDI/1,,8;                   GET NDI EQUIPMENT;

      ACTIVITY,TRIAG(1.6,2,2.6),,WPNL;     RIGHT FORWARD LOWER;
      ACTIVITY,TRIAG(1.6,2,2.6),,WPNL;     LEFT FORWARD LOWER;
      ACTIVITY,TRIAG(2,2.5,3.25),,FUX;     RIGHT FORWARD UPPER;
      ACTIVITY,TRIAG(2,2.5,3.25),,FUX;     LEFT FORWARD UPPER;
      ACTIVITY,TRIAG(2.4,3,3.9),,BCAP;     RIGHT AFT LOWER;
      ACTIVITY,TRIAG(2.4,3,3.9),,BCAP,     LEFT AFT LOWER;
      ACTIVITY,TRIAG(2.4,3,3.9),,AUX;      RIGHT AFT UPPER;
      ACTIVITY,TRIAG(2.4,3,3.9),,AUX;      LEFT AFT UPPER;

; BEGIN PHASE II;
;===============;

; CONDITIONAL REPAIRS;

 WPNL GOON,1;                               R&R *6 WING PANEL;
      ACTIVITY/21,,.1,FLX;                       WP NOT NEED REPAIR;
      ACTIVITY/22,,,RPWG;                        WP NEEDS REPAIR;
 RPWG   GOON,2;                                 CONDUCT REPAIRS;
        ACTIVITY,,,FRB;                           FLAG -- DON'T HOLD NDI
        ACTIVITY,TRIAG(5.6,7,9.1);                 DO REPAIR WORK;
        ASSIGN,NDIFLAG=0,1;                        GET OWN NDI IF NEEDED
      GOON,1;                                     IS NDI NEEDED?;
      ACTIVITY,,0,WWRK;                                 NOT NEEDED;
```

```
       ACTIVITY,,1;                                           IS NEEDED;
 WPNDI AWAIT(25),NDI/1,,1;                               WAITING FOR NDI;
       ACTIVITY,TRIAG(1.12,1.54,2);                     NDI WORK;
       FREE,NDI;
       ACTIVITY,,,WWRK;                              SEND ON TO COMPLETE WNG
WORK;

 BCAP  GOON,1;                                     REPAIR 405 BEAM CAPS;
       ACTIVITY/23,,.88,ALX;                           BM CAP NOT NEED REPAIR;
       ACTIVITY/24,,,PRPBC;                            BM CAP NEEDS REPAIR;
 PRPBC   GOON,2;                                     PREP FOR BEAM CAP REPAIR;
         ACTIVITY,,,FRB;                               FLAG -- DON'T HOLD NDI;
         ACTIVITY,TRIAG(.8,1,1.3),,RPBC;               DO PREP WORK;
 RPBC    GOON,2;                                       DO REPAIRS;
         ACTIVITY,TRIAG(11.2,14,18.2),,BCB;              REPAIR LOWER INBOUND;
         ACTIVITY,TRIAG(11.2,14,18.2),,BCB;              REPAIR LOWER OUTBOUND;
 BCB     BATCH,20/2,2,,LAST,NONE,1;                      REPAIRS COMPLETE;
       ASSIGN,NDIFLAG=0;                               GOT OWN NDI IF NEEDED;
       GOON,1;                                         IS NDI NEEDED?;
         ACTIVITY,,0,LGF;                                NOT NEEDED;
         ACTIVITY,,1;                                    IS NEEDED;
 BCNDI   AWAIT(24),NDI/1,,1;                              WAITING FOR NDI;
       ACTIVITY,TRIAG(1.12,1.54,2);                    NDI WORK;
       FREE,NDI;
       ACTIVITY,,,LGF;                              SEND TO GORILLA FITTING WORK

; CHECK TO SEE IF NDI IS NEEDED IMMEDIATELY FOLLOWING PHASE I FOR THOSE;
;   ENTITIES NOT REQUIRING WING PANEL OR BEAM CAP WORK.  THOSE ENTITIES;
;   DO THEIR OWN CHECKS ABOVE. -- CURRENTLY SET THAT ALL WILL NEED IT!;

 FLX   GOON,1;                                    IS NDI NEEDED FOR FWD LOWER?
       ACTIVITY,,0,WWRK;                            NOT NEEDED;
       ACTIVITY,TRIAG(1,1.6,2),1,FNDI;              WAITING FOR NDI OUT OF PHS I

 FUX   GOON,1;                                    IS NDI NEEDED FOR FWD UPPER?
       ACTIVITY,,,WWRK;                             NOT NEEDED;
       ACTIVITY,TRIAG(.5,1.1,1.5),1,FNDI;           WAITING FOR NDI OUT OF PHS I

 ALX   GOON,1;                                    IS NDI NEEDED FOR AFT LOWER?
       ACTIVITY,,0,LGF;                             NOT NEEDED;
       ACTIVITY,,1,ALNDI;                           IS NEEDED, MINIMAL WAIT;

 AUX   GOON,1;                                    IS NDI NEEDED FOR AFT UPPER?;
       ACTIVITY,,,UGF;                               NOT NEEDED;
       ACTIVITY,,1,AUNDI;                            IS NEEDED, MINIMAL WAIT;

; USING NDI IN PHASE II WHEN REQUIRED;

 FNDI  GOON,1;                                    FORWARD UPPER AND LOWER NDI;
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```
       ACTIVITY,TRIAG(1.12,1.54,2),,WWRK;

 ALNDI GOON,1;                              AFT LOWER NDI;
       ACTIVITY,TRIAG(1.12,1.54,2),,LGF;

 AUNDI GOON,1;                              AFT UPPER NDI;
       ACTIVITY,TRIAG(1.12,1.54,2),,UGF;


;REQUIRED REPAIRS;

 WWRK  GOON,2;
       ACTIVITY,TRIAG(8,10,13),,B773;       FORWARD WING WORK;
       ACTIVITY,,NDIFLAG.EQ.1,FRB;          FLAG -- DONE WITH NDI EQUIP;

 LGF   GOON,2;
       ACTIVITY,TRIAG(12,15,19.5),,B773;    LOWER GORILLA FITTING;
       ACTIVITY,,NDIFLAG.EQ.1,FRB;          FLAG -- DONE WITH NDI EQUIP;

 UGF   GOON,2;
       ACTIVITY,TRIAG(16,20,26),,B773;      UPPER GORILLA FITTING;
       ACTIVITY,,,FRB;                        FLAG -- DONE WITH NDI EQUIP;

 FRB   BATCH,20/2,8,,LAST,NONE,1;           EVERYONE DONE WITH NDI;
       FREE,NDI;                              EXCEPT POST WING PANEL AND
       TERM;                                    BEAM CAP, THEY MAY GET
;                                               THEIR OWN.

 B773  BATCH,20/2,8,,LAST,NONE,1;             TCTO 773 COMPLETE;


 PLUS  GOON,1;                                            IN-HANGAR PDM
       ACTIVITY,TRIAG(24,30,39),ATRIB(9).EQ.1,SLFN;        FOR A/C THAT
       ACTIVITY,,ATRIB(9).NE.1,SLFN;                       REQUIRE IT

; FINAL ACTIVITIES PRIOR TO LEAVING HANGAR;

 SLFN  GOON,1;

;   SL - PRESSURE CHECK, REPAIR LEAKS, BUILD UP TANKS, DEJACK, DEDOCK;

       ACTIVITY,TRIAG(3.92,4.9,6.37),ATRIB(3).EQ.1,FRHNG;

;   SL/PNT - BUILD UP TANKS, DEJACK, DEDOCK;

       ACTIVITY,TRIAG(.48,.6,.78),ATRIB(3).EQ.2,FRHNG;

;   SL/PDM/PNT AND SL/PDM - INSTALL TEMP TANKS, DEJACK, DEDOCK;

       ACTIVITY,TRIAG(.72,.9,1.17),ATRIB(3).EQ.3,FRHNG;
       ACTIVITY,TRIAG(.72,.9,1.17),ATRIB(3).EQ.6,FRHNG;
```

```
; FREE HANGARS;
;=============;

 FRHNG GOON,1;                                    SORT BY HANGAR TYPE;
       ACTIVITY,,ATRIB(9).EQ.1,FPHG;
       ACTIVITY,,,FSNG;

 FPHG  FREE,PDM_HNG;                              FREE SL + PDM HANGAR;
       ACTIVITY,,,RTE;

 FSNG  FREE,SNGL_HNG;                             FREE SINGLE HANGAR;
       ACTIVITY,,,RTE;


 RTE   FREE,SPDLIN;                               SEND TO APPROPRIATE FOLLOW-ON
;                                                     PROCEDURES;

       GOON,2;                                    COLLECTS TIME IN HNGR;
       ACTIVITY,,,ALLO;
       ACTIVITY,,ATRIB(3).NE.0,TSLH;
       ACTIVITY,,ATRIB(3).EQ.0,PASS;

 ALLO  TERM,500;                                  TERM PROGRAM WHEN CERTAIN
;                                                 NUMBER OF A/C OUT OF HANGARS

 TSLH  COLCT(1),INT(6),TIME IN SL HANGAR,13/25/2,1;
       ACTIVITY;
 PASS  GOON,1;
       ACTIVITY,,ATRIB(3).EQ.1.OR.ATRIB(3).EQ.2,SLBLD;  TO SL BUILD UP;

       ACTIVITY/86,,ATRIB(3).EQ.3.OR.ATRIB(3).EQ.6,PDM;     TYPE 3 AND 6
;                                                                TO PDM;


;  BUILD UP FOR SPEEDLINE AND SPEEDLINE/PAINT - PDM FOLKS WILL DO
;  OTHERS;
;=========================================================================
;

 SLBLD AWAIT(15),EQUIP/1,1;
       GOON,1;
       ACTIVITY,,ATRIB(3).EQ.1,BLD1;
       ACTIVITY,,ATRIB(3).EQ.2,BLD2;

 BLD1  GOON,3;                                         SL ONLY BUILD UP;
       ACTIVITY,TRIAG(.16,.2,.39),,B1D;                  INSTALL AIR DUCS;
       ACTIVITY,TRIAG(.48,.6,.78),,B1D;                  INSTALL LEAD EGDE;
       ACTIVITY,TRIAG(.4,.5,.65);                        PAINT REPAIR AREAS;
       GOON,2;
       ACTIVITY,TRIAG(.16,.2,.26),,B1D;                  BUILD UP T/E;
       ACTIVITY,TRIAG(2.16,2.7,3.51),,B1D;               INSTALL ENGINES;
```

```
B1D   BATCH,20/2,4,,LAST,NONE;
FBU1  FREE,EQUIP/1,1;

      ACTIVITY/87,,,FTEST;                    TYPE 1 TO FUNCTIONAL TEST


BLD2  GOON,7;                                  SL/PNT BUILD UP
      ACTIVITY,TRIAG(.16,.2,.26),,B2D;           BUILD UP T/E;
      ACTIVITY,TRIAG(.16,.2,.26),,B2D;           INSTALL PYLONS;
      ACTIVITY,TRIAG(.48,.6,.78),,B2D;           INSTALL LEAD EDGE;
      ACTIVITY,TRIAG(3.2,4,5.2),,B2D;            INSTALL FLT CONTROLS;
      ACTIVITY,TRIAG(.08,.1,.13),,B2D;           INSTALL ANTENNAS;
      ACTIVITY,TRIAG(.16,.2,.26),,B2D;           INSTALL MLG/NLG DOORS;

B2D   BATCH,20/2,6,,LAST,NONE;
FBU2  FREE,EQUIP/1,1;

      ACTIVITY/88,,,FTEST;                    TYPE 2 TO FUNCTIONAL TEST

;*********************************************************************;
;SECTION INTERACTS WITH CENTER WING BOX CODE TO SEND ENTITY BACK TO
;
;APPROPRIATE POINT ONCE IT RECEIVES NO LOAD EQUIPMENT
;
;*********************************************************************;

WSHP GOON,1;
     ACTIVITY,,ATRIB(11).EQ.1,DMN1;
     ACTIVITY,,ATRIB(11).EQ.2,WSN2;

;*********************************************************************
;
;+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
;
; END OF SPEEDLINE BLACK BOX
;
;+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
;
;*********************************************************************
;


;PDM NETWORK
;===========
;
PDM   AWAIT(29),PDM_SLOT/1;
      ACTIVITY/4,0;                A/C THRU PDM-ALL TYPES (OUTPUT LABEL)
      GOON,1;
      ACTIVITY,TRIAG(6.4,8,10.4),,PNDI;                     PRE-NDI WORK;
PNDI  AWAIT(23),NDI,1,,1;
      ACTIVITY,TRIAG(8.96,11.2,14.56);                      NDI WORK;
```

```
      FREE,NDI,1;
      GOON,1;
      ACTIVITY,TRIAG(32.8,41,53.3),ATRIB(9).NE.1,PBU;      POST NDI WORK;
      ACTIVITY,TRIAG(8.8,11,14.3),ATRIB(9).EQ.1,PBU;
 PBU  GOON,1;
      ACTIVITY,TRIAG(8,10,13);                              BUILD UP;

      FREE,PDM_SLOT,1;

      GOON,1;
      ACTIVITY,,ATRIB(3).EQ.5,FPOG;
      ACTIVITY,,,FTEST;

FPOG  FREE,PDM_ONGRND,1;


;FUNCTIONAL TEST
;===============

FTEST GOON,1;                                   PREP FOR FUNTIONAL TEST;

      ACTIVITY,TRIAG(4.16,5.2,6.76),ATRIB(3).EQ.1.OR.ATRIB(3).EQ.2,FTEQ;
      ACT,TRIAG(12.32,15.4,20.02),ATRIB(3).EQ.3.OR.ATRIB(3).GT.4,FTEQ;
      ACTIVITY,TRIAG(6.4,8,10.4),ATRIB(3).EQ.4,FTEQ;

FTEQ  AWAIT(17),FUNCTEST,,1;
      ACTIVITY,TRIAG(4,5,6.5),ATRIB(3).EQ.1.OR.ATRIB(3).EQ.2,BAD;
      ACTIVITY,TRIAG(5.2,6.5,8.45),ATRIB(3).EQ.3.OR.ATRIB(3).GT.4,BAD;
      ACTIVITY,TRIAG(5.6,7,9.1),ATRIB(3).EQ.4,BAD;

BAD   GOON,1;                                 REWORK REQUIRED AT FUNCT TEST;
      ACTIVITY,TRIAG(2.4,3,3.9),.2,FFT;
      ACTIVITY,,.8,FFT;

FFT   FREE,FUNCTEST,1;
      ACTIVITY,,ATRIB(3).EQ.1.OR.ATRIB(3).EQ.6,OUT;   NO PNT-LVNG SYSTEM
      ACTIVITY,,ATRIB(3).EQ.5.AND.ATRIB(10).NE.1,OUT; PDM NO PNT-LVE SYS
      ACTIVITY,,,PPNT;                                GO TO PREP FOR PNT


; PAINT NETWORK
;==============

PPNT  GOON,1;                                         PREP FOR PAINT;
      ACTIVITY,TRIAG(1.76,2.2,2.86);

WASH  AWAIT(8),DE_PT/1,1;                             WASH IN DEPNT HANGAR
      ACTIVITY,TRIAG(.8,1,1.3);
      FREE,DE_PT;

PAINT AWAIT(10),PAINT;
      ACTIVITY/12,TRIAG(3.2,4,5.2),,;                 PAINT;
```

```
FPANT FREE,PAINT,1;

OUT   GOON,1;
      ACTIVITY,TRIAG(.32,.4,.52);
SYS   FREE,IN_SYS,1;
      FREE,COUNT,1;

;+++++++++ COLECT TIME IN SYSTEM & THRUPUT NODES ++++++++++++

TIS   CCLCT(2),INT(1),TIME IN SYSTEM,,1;
      GOON,1;
      ACTIVITY,,ATRIB(3).EQ.4,CBOX;
      ACTIVITY,,ATRIB(3).EQ.5,CPDO;
      ACTIVITY,,ATRIB(3).EQ.1,CSPL;
      ACTIVITY,,ATRIB(3).EQ.2,CPTS;
      ACTIVITY,,ATRIB(3).EQ.3,CPDM;
      ACTIVITY,,ATRIB(3).EQ.6,SLPD;
CSPL  COLCT(3),INT(1),TIS SL ONLY,,1;
      ACTIVITY,,,ZAAE;
CPDO  COLCT(7),INT(1),TIS PDM ONLY,,1;
      ACTIVITY,,,ZAAE;

; ***********   Network Terminate *************

ZAAE  TERMINATE,305; Terminates after 305 thru network

CPTSL COLCT(4),INT(1),TIS SL PNT,,1;
      ACTIVITY,,,ZAAE;
CPDM  COLCT(5),INT(1),TIS SL PDM PNT,,1;
      ACTIVITY,,,ZAAE;
CBOX  COLCT(6),INT(1),TIS CW BOX,,1;
      TERMINATE,90;   Terminates after 90 CBOX;
SLPDM COLCT(8),INT(1),TIS SL PDM,,1;
      ACTIVITY,,,ZAAE;
;
;
;*******************************************
;F-15, C-130 PAINT/DEPAINT COMPETITION (left inactive for this analysis)
;*******************************************
;
;DE130 CREATE,10,6,,,1;
;      ACTIVITY;
;D130  AWAIT(11),DE_PT,,1;
;      ACTIVITY,4;
;      FREE,DE_PT,1;
;      ACTIVITY;
;      TERMINATE;
;
;DE15  CREATE,,99999,,,1;
;      ACTIVITY;
;D15   AWAIT(13),DE_PT,,1;
;      ACTIVITY,4;
```

```
;       FREE,DE_PT,1;
;       ACTIVITY;
;       TERMINATE;
;
;P130   CREATE,10,6,,,1;
;       ACTIVITY;
;PT130  AWAIT(12),PAINT,,1;
;       ACTIVITY,4;
;       FREE,PAINT,1;
;       ACTIVITY;
;       TERMINATE;
;
;P15    CREATE,,99999,,,1;
;       ACTIVITY;
;PT15   AWAIT(14),PAINT,,1;
;       ACTIVITY,4;
;       FREE,PAINT,1;
;       ACTIVITY;
;       TERMINATE;
;
;*************************************;
;+++++++++++++++++++++++++++++++++++++;
;  BEGIN CENTER WING BOX SECTION      ;
;+++++++++++++++++++++++++++++++++++++;
;*************************************;
;*************************************;
;    INITIAL PREP FOR CENTER WING BOX  ;
;*************************************;
;
 CWIP   GOON,2;                                    PREP FOR CENTER WING BOX;
        ACTIVITY,TRIAG(.16,.2,.26),,B4A;             FOD INSPECTION;
        ACTIVITY,TRIAG(.16,.2,.26),,B4A;             RM 780 EQUIPMENT;

 B4A    BATCH,20/2,2,,LAST,NONE;

        ACTIVITY,TRIAG(.08,.1,.13),,B4B;             REMOVE ANTENNAS;
        ACTIVITY,TRIAG(4.24,5.3,6.84),,B4B;          CRIT PATH:FROM DEFUEL TO;
;                                                    REMOVING FLIGHT CONTROLS;
 B4B    BATCH,20/2,2,,LAST,NONE;
 FCW    FREE,EQUIP/1,1;

        ACTIVITY,TRIAG(.16,.2,.39),,DEPAT;           TOW TO DEPAINT;
;
;******************************
;    PREP FOR DEMATE            *
;******************************
;

DMPR  AWAIT(38),CWB_SLOT,,1;
      ASSIGN,TIME=TNOW,SYST=TNOW,1;
DMTP  AWAIT(31),DMPREP,,1;
      ACTIVITY,TRIAG(.8,1,1.3);                    Remove Sealant WS77 Joint
```

```
      GOON,1;
      ACTIVITY,TRIAG(.4,.5,.75);    Install Pet Rock
      GOON,4;
      ACTIVITY,,,DMENG;
      ACTIVITY,,,DM2;
      ACTIVITY,,,DM3;
      ACTIVITY,,,DM4;
;
DMENG GOON,1;
      ACTIVITY,TRIAG(.8,1,1.3);               Remove Engine
      GOON,1;
      ACTIVITY,TRIAG(3.2,4,5.2);    Remove Electrical Wiring
      GOON,1;
      ACTIVITY,TRIAG(.8,1,1.3),,DMJN;         Remove Pylons
;
DM2   GOON,2;
      ACTIVITY,TRIAG(3.2,4,5.2),,DMJN;        Strip Aft Fairing Area
      ACTIVITY,TRIAG(2.4,3,3.9);    Disconnect Hydraulic System
      GOON,1;
      ACTIVITY,TRIAG(2.4,3,3.9),,DMJN;  Remove SPR Lines Control Cables
;
DM3   GOON,1;
      ACTIVITY,TRIAG(3.2,4,5.2);    Strip Forward Fairings
      GOON,1;
      ACTIVITY,TRIAG(1.6,2,2.6),,DMJN;  Remove Air Distribution
;
DM4   GOON,1;
      ACTIVITY,TRIAG(.32,.4,.52);   Remove Leading Edges
      GOON,1;
      ACTIVITY,TRIAG(.32,.4,.52),,DMJN;        Remove Hot Air Ducts
;
DMJN  BATCH,10/2,5,,,,1;
      FREE,DMPREP,1;
      ACTIVITY,,,DMATE;
;
;********************************
;       WING REMOVAL     *
;********************************
;
DMATE ASSIGN,TIME=TNOW,1;
DeMT  AWAIT(32),M_DEM,,1;
      ACTIVITY,TRIAG(.32,.4,.52);   Jack & Level Fuselage
      GOON,1;
      ACTIVITY,TRIAG(.32,.4,.52);   Locate Wing MEC
      ASSIGN,ATRIB(11)=1,1;
      ACTIVITY,,,NLD;
;
DMN1  GOON,1;
      ACTIVITY,TRIAG(.32,.4,.52);   No Load Wings
      FREE,NO_LOAD,2;
      ACTIVITY,TRIAG(1.6,2,2.6),,DMB2;     Remove WS77 Fasteners
      ACTIVITY,TRIAG(2.24,2.8,3.64),,DMB2;       Remove Shear Bolts F&A
```

```
;
DMB2  BATCH,10/2,2,,,,1;
      ACTIVITY,TRIAG(.8,1,1.3);             Remove Tension Bolts
      GOON,1;
      ACTIVITY,TRIAG(.4,.5,.65);  Move & Lower Wing
      FREE,M_DEM,1;
      GOON,2;
      ACTIVITY,,,WING;
      ACTIVITY,TRIAG(1.6,2,2.6),,CIGR;      Prep Fuselage
;
;*******************************
;      WING SHOP       *
;*******************************
;
;   Pre Wing Shop
;
WING  ASSIGN,WINGT=TNOW,1;
      ACTIVITY;
WSPRe AWAIT(34),Pre_WS,,1;
      ACTIVITY,TRIAG(3.2,4,5.2);  Wing Root DePaint
      ASSIGN,ATRIB(11)=2,1;
      ACTIVITY,,,NLD;
;
WSN2  GOON,1;
      ACTIVITY,TRIAG(.8,1,1.3);             No Load Wings
      FREE,NO_LOAD,2;
      ACTIVITY;
      FREE,Pre_WS,1;
      ACTIVITY,,,WSaC;
;
;    Actual Wing Work
;
WSaC  AWAIT(35),WING,,2;
      ACTIVITY,,,WNDI;
      ACTIVITY,,,W526;
;
WNDI  AWAIT(26),NDI,,1;
      ACTIVITY,TRIAG(9.6,12,15.6);      NDI Wing Root
      FREE,NDI,1;
      ACTIVITY,TRIAG(3,5,8),.20,WJOI;  Repair NDI Discrepancies
      ACTIVITY,,,WJOI;                (20 chance for rpair)
;
W526  GOON,1;
      ACTIVITY,TRIAG(1.6,2,2.6);  Strip Wing Tanks
      GOON,3;
      ACTIVITY,TRIAG(24,30,39),,WJOI;      TCTO 773
      ACTIVITY,TRIAG(6.4,8,10.4),,WJOI;      C/W Wiring Work
;
;   *** ROUTINE TO EMULATE NDI UTILIZATION *****
;
      ACTIVITY;
NDIA  AWAIT(26),NDI,,1;
```

```
      ACTIVITY,TRIAG(1.6,2,2.6);
      FREE,NDI,1;
      ACTIVITY,TRIAG(4,5,6);
NDIB  AWAIT(26),NDI,,1;
      ACTIVITY,TRIAG(1.6,2,2.6);
      FREE,NDI,1;
      ACTIVITY,TRIAG(4,5,6);
NDIC  AWAIT(26),NDI,,1;
      ACTIVITY,TRIAG(1.6,2,2.6);
      FREE,NDI,1;
      ACTIVITY,TRIAG(4,5,6);
NDID  AWAIT,NDI,,1;
      ACTIVITY,TRIAG(1.6,2,2.6);
      FREE,NDI,,1;
      ACTIVITY,,,WJOI;
;
;    Post Wing Shop
;
WJOI  BATCH,10/2,4,,,,1;
WSPst AWAIT(36),POST_WS,,1;
      ACTIVITY,TRIAG(2,3,5);        Pressure Check
      GOON,1;
      ACTIVITY,TRIAG(.8,1,1.3);           Paint Wing Root
      GOON,1;
      ACTIVITY,TRIAG(1.6,2,2.6),.20,WSP1; Repair Leaks A/R (20% prob)
      ACTIVITY,,,WSP2;
WSP1  GOON,1
      ACTIVITY,TRIAG(.8,1,1.3);           Pressure Check A/R
;
WSP2  GOON,1;
      ACTIVITY,TRIAG(3.5,4,5);                Build Up Wing Tanks
      FREE,POST_WS,1;
      ACTIVITY;
      FREE,WING,1;
      ACTIVITY,,,JOIN;
;
;********************************
;      CIGAR SHOP      *
;********************************
;
CIGR  ASSIGN,CIGART=TNOW,1;
CIGAR AWAIT(37),CIGAR,,1;
      ACTIVITY,,,CWRE;


;
; ***************  CW Box Removal  ***************
;
CWRE  ASSIGN,TIME=TNOW,1;
      ACTIVITY,TRIAG(.24,.3,.39);  Install Spider Fixture
      GOON,1;
      ACTIVITY,TRIAG(.32,.4,.52);  Jack & Level Fuselage
      GOON,1;
```

```
      ACTIVITY,TRIAG(.32,.4,.52);  Verify CW Box Coordinates
      GOON,1;
      ACTIVITY,TRIAG(.16,.2,1.6);  Locate Fus Stands
      GOON,1;
      ACTIVITY,,,CWD1;
;
CWD1  GOON,2;
      ACTIVITY,TRIAG(.8,1,1.3),,CWB1;          Fwd Fus Skin Fasteners
      ACTIVITY,TRIAG(.8,1,1.3),,CWB2;          Aft Fus Skin Fasteners
;
CWB1  GOON,1;
      ACTIVITY,TRIAG(1.6,2,2.6),,CWBT;         FS734 Frame Fasteners
;
CWB2  GOON,1;
      ACTIVITY,TRIAG(1.6,2,2.6),,CWBT;         FS958 Frame Fasteners
;
CWBT  BATCH,12/2,2,,,,2;
      ACTIVITY,TRIAG(1.2,1.5,1.95);    Remove WL255 Longerons
      GOON,1;
      ACTIVITY,TRIAG(1.6,2,2.6),,CWDA;         Drag Angle Fasteners
;
CWDA  GOON,2;
      ACTIVITY,TRIAG(1.6,2,2.6),,CWBF;         FS958 Frame Fasteners
      ACTIVITY,TRIAG(1.6,2,2.6),,CWBF;         FS734 Frame Fasteners
;
CWBF  BATCH,24/2,2,,,,1;
      ACTIVITY,TRIAG(1.6,2,2.6);   Continue Stripping
      GOON,1;
      ACTIVITY,TRIAG(.16,.2,.26);  Remove CW Box
      GOON,1;
      ACTIVITY,,,CWR1;
;
;  *************** Prep for Reinstal ***************
;
CWR1  ASSIGN,TIME=TNOW,4;
      ACTIVITY,,,CWNDI;
      ACTIVITY,,,CWR2;
      ACTIVITY,,,CW95;
      ACTIVITY,,,CWPT;
;
CWNDI AWAIT(26),NDI,,1;
      ACTIVITY,TRIAG(1.2,1.5,2);   NDI Open Fastener Holes
      FREE,NDI,1;
      ACTIVITY;
CWD2  AWAIT(26),NDI,,1;
      ACTIVITY,TRIAG(1.2,1.5,2);
      FREE,NDI,1;
      ACTIVITY,,,CWB3;
;
CWR2  GOON,2;
      ACTIVITY,TRIAG(1.2,1.5,1.95),,CWB5;     Rmv FS734 Brace Fittings
      ACTIVITY,TRIAG(.96,1.2,1.56),,CWB5;     Rmv FS734 Straps
```

```
;
CWB3  GOON,2;
      ACTIVITY,TRIAG(11.2,14,18.2),,CWB4;    Install Fwd Fus Skin
      ACTIVITY,TRIAG(11.2,14,18.2),,CWB4;    Install Aft Fus Skin
;
CWB4  BATCH,10/2,2,,,,1;
      ACTIVITY,,,CWB6;
;
CWB5  BATCH,19/2,2,,,,2;
      ACTIVITY,TRIAG(8,10,13),,CWB7;        Rew/Insp FS734 Brace & Frame
      ACTIVITY;
      AWAIT(26),NDI,,1;
      ACTIVITY,TRIAG(1.6,2,2.6);   Inspect FS734 Frame
      FREE,NDI,1;
      ACTIVITY,TRIAG(5.6,7,9.1),.16,CWBB;  Replace/Repair FS734 Frame
      ACTIVITY,,,CWBB;                         16% Probability
;
CWB7  GOON,1;
      ACTIVITY,TRIAG(2.4,3,3.9),,CWBB;      Install Brace Fittings

CWBB  BATCH,11/2,2,,,,1;
      ACTIVITY,,,CWB6;
;
CW95  GOON,1;
      ACTIVITY,TRIAG(1.6,2,2.6),,CWB6;      FS 958 Work
;
CWPT  GOON,1;
      ACTIVITY,TRIAG(.8,1,1.3);             Depaint Underwing Fus
      GOON,1;
      ACTIVITY,TRIAG(.8,1,1.3);             Refinish Underwing Fus
;
CWB6  BATCH,10/2,4,,,,1;
      ACTIVITY,,,CWRP;
;
; ***************  CW Box Replacement  ***************
;
CWRP  ASSIGN,TIME=TNOW,1;
      ACTIVITY,TRIAG(0.8,1,1.3);   Locate & Verify CW Box
      GOON,1;
      ACTIVITY,TRIAG(4,5,6.5);              Inst Aft BL 0 Long
      GOON,2;
      ACTIVITY,TRIAG(2.4,3,3.9),,CWP1;      Inst Fwd Skin Doubler
      ACTIVITY,TRIAG(3.2,4,5.2),,CWP1;      Inst AFT BL 38.5 Fast
;
CWP1  BATCH,12/2,2,,,,2;
      ACTIVITY,TRIAG(4.8,6,7.8),,CWP2;      Upper FS 734 Frame Fast
      ACTIVITY,TRIAG(6.4,8,10.4),,CWP2;     Upper FS958 Frame
;
CWP2  BATCH,13/2,2,,,,2;
      ACTIVITY,TRIAG(4,5,6.5),,CWP3;        Inst FS958 Strap Fast
      ACTIVITY,TRIAG(4.8,6,7.8),,CWP3;      Splice FS 958 Frame
;
```

```
CWP3  BATCH,14/2,2,,,,2;
      ACTIVITY,TRIAG(3.2,4,5.2),,CWP4;       Inst Fwd BL 38.5 Fast
      ACTIVITY,TRIAG(2.4,3,3.9),,CWP4;       Inst FS734 Brace Ftg
;
CWP4  BATCH,15/2,2,,,,6;
      ACTIVITY,TRIAG(3.2,4,5.2),,CWP5;       Inst CTR Drag Angl Fast
      ACTIVITY,TRIAG(4,5,6.5),,CWP5;         Inst Fwd Drag Angles
      ACTIVITY,TRIAG(1.6,2,2.6),,CWP5;       Machine FS734 Frame St
      ACTIVITY,TRIAG(2.4,3,3.9),,CWP5;       Inst Fwd BL 0 Fast
      ACTIVITY,TRIAG(3.2,4,5.2),,CWP5;       Inst AFT Drag Angles
      ACTIVITY TRIAG(3.2,4,5.2),,CWP5;       Instal AFT BL 0 Fasteners
;
CWP5  BATCH,16/2,6,,,,1;
      ACTIVITY,TRIAG(1.6,2,2.6);   Inst FS 958 Brace Ftgs
      GOON,1;
      ACTIVITY,TRIAG(1.6,2,2.6);   Machine FS 958 Frame St
      GOON,1;
      ACTIVITY,TRIAG(3.2,4,5.2);   Inst WL 255 Longerons
      GOON,1;
      ACTIVITY,TRIAG(1.6,2,2.6);   Inst Fus/Drag Angle Fas
      GOON,1;
      ACTIVITY,TRIAG(0.8,1,1.3);   Pressure Check Fuselage
      GOON,1;
      ACTIVITY,TRIAG(1.6,2,2.6);   Repair Leaks A/R
      GOON,1;
      ACTIVITY,TRIAG(0.8,1,1.3);   Pressure Check Fuselage
      GOON,1;
      ACTIVITY,TRIAG(8,10,13),,FRCG;  TEN ADDITIONAL DAYS NOTED WITHIN
;                                     SYSTEM BUT SOURCE UNKNOWN;
;
FRCG  FREE,CIGAR,1;
      ACTIVITY,,,JOIN;
;
;********************************
;    Mate Facility  *
;********************************
;
JOIN  BATCH,50/2,2,,,,1;
      ACTIVITY;
      ASSIGN,TIME=TNOW,1;
      ACTIVITY,,,MATE;
;
MATE  AWAIT(33),M_DEM,,1;
      ACTIVITY,TRIAG(.22,.25,.325);          Jack & Level Fuselage
      GOON,1;
      ACTIVITY,TRIAG(2.4,3,3.9);             Locate Wing to CW Box
      GOON,1;
      ACTIVITY,TRIAG(.22,.25,.325);          Install Tension Bolts
      GOON,1;
      ACTIVITY,TRIAG(2.4,3,3.9);             Measure/Make Shims FS734 & 9
      GOON,1;
      ACTIVITY,TRIAG(.8,1,1.3);   Pilot Shears +Sep,Deburr,Seal
```

```
      GOON,1;
      ACTIVITY,TRIAG(.12,.125,.1625);  Move Wing To Center WB
      GOON,3;
      ACTIVITY,TRIAG(.18,.2,.25),,MTBC;      Install Tension Bolts
      ACTIVITY,TRIAG(.8,1,1.3),,MTBC;        Install Fwd Shear Bolts
      ACTIVITY,TRIAG(.8,1,1.3),,MTBC;        Install Aft Shear Bolts
;
MTBC  BATCH,10/2,3,,,,1;
      ACTIVITY,TRIAG(6.4,8,10.4);            Install Lwr WS77.7 Splice
      GOON,1;
      ACTIVITY,TRIAG(.8,1,1.3);              Install BL 67 Tube Braces
      GOON,1;
      ACTIVITY,TRIAG(3.2,4,5.3);             Install Upr WS77.7 Splice
      FREE,M_DEM,1;
      FREE,CWB_SLOT,1;
      FREE,CWB_ONGRND;
      ACTIVITY/99;                           THRU CWB;
      GOON,1;
      ACTIVITY,TRIAG(16,20,30),,FTEST;       BUILD-UP A/C AND SEND TO
FUNC TEST;
;
;*****************************************************************
;                                ***
;      End of CW Box Module      ***
;                                ***
;*****************************************************************
      END;
INITIALIZE,,1417,Y;

;MONITOR STATEMENTS USED FOR SCHEDULE AND SYSTEM MONITORING;
; CURRENTLY TURNED OFF
;
;MONTR,TRACE(SPLN,SHNG,DHNG,FSNG,FDBL,RTE),0,1000,ATRIB(2),ATRIB(3),
;NNQ(18),NNRSC(6),NNQ(20),NNRSC(7),NNQ(21),NNRSC(8);
;MONTR,TRACE(SYSSL,SYSCW),0,709,ATRIB(3);
FIN;
```

Appendix B: FORTRAN Program Used for Data Input/Output

```
      PROGRAM MAIN
      DIMENSION NSET(900000)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET(5000)
      EQUIVALENCE(NSET(1),QSET(1))
      NNSET=900000
      NCRDR=5
      NPRNT=6
      NTAPE=7
      I=0
      OPEN(UNIT=1,FILE='ARRIVENEW.DAT',STATUS='OLD')
      OPEN(UNIT=2,FILE='COUNT.OUT',STATUS='NEW')
      OPEN(UNIT=3,FILE='HANGDAT.OUT',STATUS='NEW')
      OPEN(UNIT=4,FILE='TIME.OUT',STATUS='NEW')
      OPEN(UNIT=10,FILE='DD.OUT',STATUS='NEW')
      CALL SLAM
      CLOSE(1)
      STOP
      END
C
C THE FOLLOWING IS THE USERF(I) SUBROUTINE
C
      FUNCTION USERF(I)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
C
C READ ORDER ATTIBUTES, ADJUST START DATE TO DELAY TIME
C
      READ(1,FMT='(2F5.1)',END=10) TIME, ATRIB(3)
      NEWTIME=TIME/TIME
      USERF = NEWTIME-TNOW
      RETURN
C
C END-OF-FILE:  SET DUE DATE TO ZERO TO END CREATIONS
C
10    ATRIB(3)=0.
      USERF=0.
      RETURN
      END
C
C THE FOLLOWING IS A SUBROUTINE THAT REWINDS THE INPUT FILE TO
C ALLOW FOR MULTIPLE RUNS
C
      SUBROUTINE INTLC
      REWIND(1)
      RETURN
      END
```

```
C
C THE FOLLOWING IS A SUBROUTINE THAT COLLECTS THROUGHPUT DATA AND
C PUTS IT IN A SEPARATE OUTPUT FILE
C
      SUBROUTINE OTPUT
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
C
      OTH=RRAVG(22)-RRAVG(6)
      TOT=RRAVA(7)+RRAVA(8)
      WRITE(2,*) CCNUM(1),CCNUM(6),RRAVG(22),RRMAX(22),OTH
      WRITE(3,*) FFAWT(20),FFAWT(21),RRAVA(7),RRAVA(8),TOT
      WRITE(4,*) TNOW
      WRITE(10,*) CCNUM(1),FFAVG(20),FFAVG(21),RRAVA(7),RRAVA(8)
      RETURN
      END
```

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Vita

Captain Peter H. Miyares was born on 19 February 1964 in Buffalo, New York. He graduated from Orford High School in Orford, New Hampshire in 1982 and attended the University of New Hampshire, graduating summa cum laude with a Bachelor of Science degree in Mathematics in 1986. He was a distinguished graduate from Air Force ROTC and received a regular commission upon entering active duty. His first tour of duty was at Randolph AFB, Texas, where he served as chief of market analysis for the USAF Recruiting Service. His accomplishments include the annual development of goal allocation models for over 20 separate recruiting programs and the development of a recruiter allocation model used in three nationwide command reorganizations and which saved the Air Force over $10 million in O&M funds. He served there until August of 1990 when he entered the School of Engineering, Air Force Institute of Technology (AFIT). He graduated from AFIT on 20 March 1992 with a Masters of Science degree in Operations Research and followed on to an assignment as the chief of weapons system assessment for Headquarters Air Combat Command at Langley AFB, Virginia.

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This study outlines a structure for a manufacturing planning and control (MPC) system for a repair/overhaul/rebuilding environment. Included is an examination of the organizational components that must be incorporated into the system and the planning functions for which the system can be used. The study compares and contrasts the differences between an MPC system for a maintenance organization and a manufacturing organization and concludes that the MPC system for a maintenance organization must account for the greater degree of variability that occurs within the process. The proposed system is composed of an information system which collects data from throughout an organization and a planning support and decision testing system which makes use of computer simulation models to test management decisions prior to their actual implementation. The basic outline is applied to the C-141 maintenance operation at Warner-Robins Air Logistics Center at Robins AFB, GA. A description of the organization and the C-141 maintenance process is provided. A specific system for Warner-Robins is proposed and a simulation model is developed. The use of such a system is illustrated by using the simulation model to address specific questions and concerns of the senior leadership at Warner-Robins.

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