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THESIS

IMPLEMENTING MANUFACTURING RESOURCES PLANNING FOR MARINE CORPS LOGISTICS BASE, ALBANY, GEORGIA

by

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June 1989

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In today's age of scarce DOD resources, the Depot Maintenance Activities (DMA) in all services are searching for ways to cut costs. One way to accomplish this is to procure a more efficeint automated production control system (APCS). Inventories, turn-around time, and labor costs all have the potential to be reduced with proper management supported by an appropriate and effective system.

This theses deals with the procurement and implementation of an APCS at the DMA located at the Marine Corps Logistics Base in Albany, Georgia. The current system in use at Albany is related, a system in the process of being implemented at the Naval Ordnance Station in Louisville, Kentucky, is discussed in terms of system attributes and implementation concerns, and a system alternative in the Army (cont'd)

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19. ABSTRACT (cont'd)

DMA's Maintenance Shop Floor System is offered.

Conclusions and recommendations include an EOQ vs. MRP inventory ordering discussion, repair part replacement factor forecasting and fill probability calculations, and general system implementation recommendations.

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Implementing Manufacturing Resources Planning for Marine Corps Logistics Base, Albany, Georgia

by

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ABSTRACT

In today's age of scarce DOD resources, the Depot Maintenance Activities (DMA) in all services are searching for ways to cut costs. One way for a DMA to accomplish this is to procure a more efficient automated production control system (APCS). Inventories, turn-around time, and labor costs all have the potential to be reduced with proper management supported by an appropriate and effective system.

This thesis deals with the procurement and implementation of an APCS at the DMA located at the Marine Corps Logistics Base in Albany, GA. The current system in use at Albany is related, a system in the process of being implemented at the Naval Ordnance Station in Louisville, KY, is discussed in terms of system attributes and implementation concerns, and a system alternative in the Army DMA's Maintenance Shop Floor system is offered.

Conclusions and recommendations include an EOQ vs. MRP inventory ordering discussion, repair part replacement factor forecasting and fill probability calculations, and general implementation recommendations.

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I. INTRODUCTION

A. BACKGROUND

In today's age of scarce Department of Defense (DOD) resources, Depot Maintenance Activities in all services are searching for ways to cut production costs. While the overhaul of systems already saves the services considerable amounts of money, by refurbishing equipment and reducing the need for new procurement, the upgrading to more efficient production control systems has the potential to save even more. Inventories, turn-around time, and labor costs all have the potential to be reduced with proper management supported by an appropriate and effective system.

B. OBJECTIVES

The objective of this thesis is to identify those considerations which the Depot Maintenance Activity (DMA) at Marine Corps Logistics Base (MCLB), Albany, Georgia should be aware of as they plan to implement a Manufacturing Resources Planning (MRP II) production control system. (See Appendix A for information on MRP II.) These considerations include system alternatives, implementation concerns, and system attributes.

C. RESEARCH QUESTIONS

Primary research questions include:

1. What type of production control systems are used by other DOD activities?
2. What implementation and system concerns should the DMA at MCLB be aware of in regards to a new production control system?

Secondary Research questions include:

1. What inventory ordering model, MRP I, MRP II or Economic Order Quantity (EOQ), should be utilized by the DMA for specific items?

2. How should item replacement factors be determined and updated?

D. SCOPE AND LIMITATIONS OF THE THESIS

The scope of this thesis is an identification of the current structure in place at the DMA and the identification of the production control systems used at Naval Ordnance Station, Louisville (NOSL), Kentucky and at all United States Army Depot Maintenance Facilities. These investigations form the basis for the recommendations of this thesis.

The choice of limiting research to only include NOSL and the Army's system was made for several reasons. First, while many DOD facilities have implemented Material Requirements Planning (MRP I) in their inventory ordering system, NOSL is the only DOD facility found to have procured and implemented Manufacturing Resources Planning (MRP II) on a activity-wide basis. In addition, a Naval Ordnance Station, as opposed to a Naval Air Rework Facility, performs maintenance on equipment more closely associated with the equipment worked on at the DMA at MCLB. The investigation of the Army's system was conducted because of the significant similarities between the equipment and the depot maintenance requirements in both the Army and the Marines. The final reason for limiting this research was the availability of funding to visit those additional facilities which could have also been included in this study.

This thesis assumes a basic knowledge of DOD Depot Maintenance Activities and the unique environment that they operate in. It further assumes a working knowledge of production systems, both automated and manually controlled.

E. RESEARCH METHODOLOGY

Research was conducted by first doing a literature review of automated production control systems. This was followed by visits to both the DMA at MCLB and at NOSL. *Discussions with personnel and observations of current systems at these* facilities provided the preponderance of research materials.

F. ORGANIZATION OF STUDY

The Thesis is organized as follows:

Chapter	Title/Description
I.	INTRODUCTION.
II.	DMA AT MCLB OVERVIEWS. This chapter gives an overview of the organization and systems currently in use at the DMA at MCLB.
III.	OTHER DOD DMA OVERVIEW. This chapter offers an overview of the production control systems in place at NOSL and at Army depot maintenance activities.
IV.	SUMMARY, CONCLUSION, AND RECOMMENDATIONS. This chapter summarizes the previous chapters, offers a system alternative, general recommendations concerning implementation, system features, and concludes the thesis.
APPENDIX A	MRP II. This appendix contains a general overview of MRP II production control system.
APPENDIX B	LIST OF ABBREVIATIONS.

II. REPAIR DIVISION/DEPOT MAINTENANCE ACTIVITY OVERVIEW

A. MISSION

The DMA is tasked by the Commandant of the Marine Corps with the following missions [Ref. 1:p. 1]:

1. Repair, rebuild, and modify all types of Marine Corps ground combat, combat support, and combat service support equipment.
2. Provide technical on-the-job training to Marines assigned to the DNA.
3. Provide preparation for shipment and care-in-storage support to the Remote Storage Activity.
4. Provide calibration support to various Marine Corps customers.
5. Provide technical assistance to the Fleet Marine Force and Marine Reserve units.
6. Develop Automatic Test Equipment to support Marine Corps units.
7. Conduct special projects as directed.

B. HISTORY

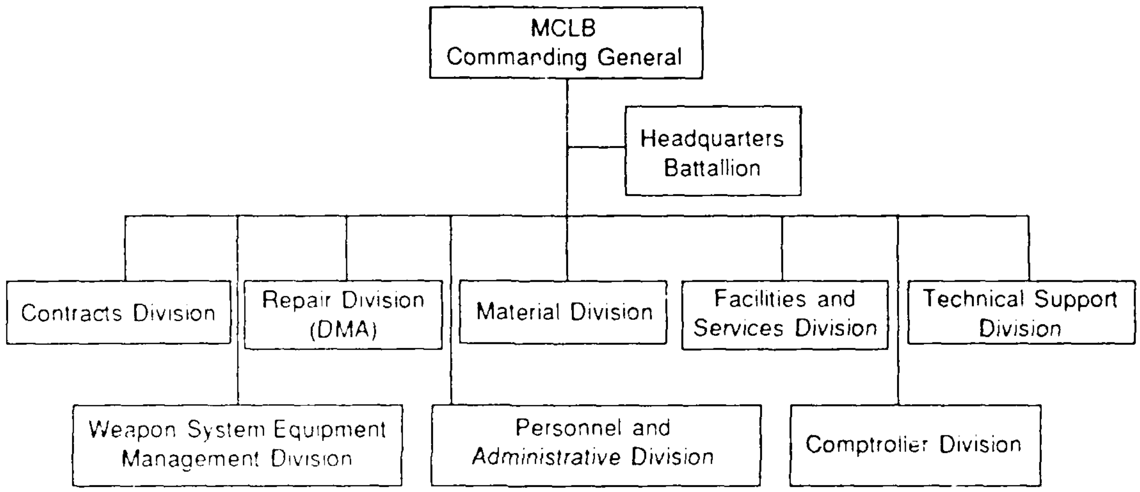
The Repair Division was originally established in February, 1954 as Repair Branch, Marine Corps Supply Center, Albany. On 1 October 1954, actual production began with a work force of approximately 400 Marines and civilians employed in Repair Branch. By October of 1955, the Branch had significantly increased its workload and expanded its work force to over 1000 personnel. On 1 July 1956, the Repair Branch was redesignated as Repair Division, and as such became a major unit of the Supply Center. During April of 1976, the Supply Center's name was changed to Marine Corps Logistics Support Base, Atlantic, and in November 1978 it was further redesignated to Marine Corps Logistics Base (MCLB) by Marine Corps Bulletin 5420. [Ref. 1:p. 1]

The current organization of MCLB is contained in Figure 2-1. All divisions support and help to sustain the needs of the Marine Corps world-wide. While all divisions interact with one another, the most significant relationship in regards to the Repair Division is that with Materials Division. It is Materials division which provides supply support and end items to the Repair Division so that it may accomplish its depot maintenance mission.

1. Source of Work/Workload

The Repair Division's source of work for fiscal year 1988 was as follows [Ref. 1:p. 2]:

Source of Work	Workload
FMF Equipment Rebuild	56%
Special Projects	20%
Care-in-Storage/Prep for Shipment	17%
FMF Overflow/Customer Support	4%
Other DOD Support	2%
Technical Assistance	1%



MARINE CORPS LOGISTICS BASE
(MCLB) ORGANIZATION
Fig. 2 - 1

The magnitude of the work load can best be summarized by the following figures from fiscal year 1987 [Ref. 1:p. 8]:

Description	Total
Cost of Production	$48,784,000
Man-hours of Direct Labor	940,000
Major Line Items Worked	700
Individual Items Worked	21,000

2. PHYSICAL PLANT

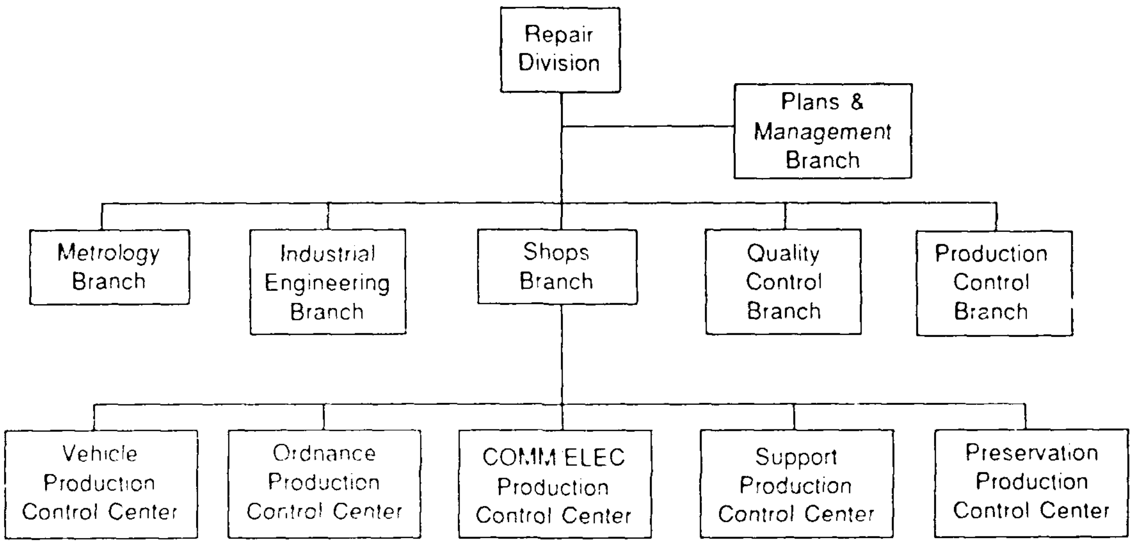
The DMA building provides some 523,000 square feet of covered floor space. Of this total, 315,000 square feet is given over to shop space for production. There is an additional 165,000 square feet of work space located in several permanent and semi-permanent structures in the general area. Outside, there is an area of about 1,400,000 square feet paved with concrete which provides storage, staging, and limited work area.

In the main building, the central craneway is serviced by one 75-ton and two 30-ton overhead cranes. Additional shops are located adjacent to the central craneway. Shop equipment ranges from common hand tools to heavy industrial equipment and is currently valued at about $24,000,000.

[Ref. 1:p. 3]

3. REPAIR DIVISION/DMA ORGANIZATION

The Repair Division is currently organized into six distinct branches [Ref. 2:pp. 6-12]. (See Figure 2-2) The Plans and Management Branch is an administrative branch which provides the DMA with a variety of services. Its Programs and Projects



REPAIR DIVISION ORGANIZATION
(DEPOT MAINTENANCE ACTIVITY)
[Ref. 1]
Figure 2 - 2

Section coordinates military matters, conducts tours and briefings, and provides for division security. The Systems and Procedures Section conducts program planning, productive performance and manpower utilization analysis, and management studies. Budget formulation, cost analysis, funds control, and job order administration are performed by the Financial Management Section. The remaining section, Management Services, takes care of all personnel administration, training, table of organization matters, and maintains the technical library.

The Industrial Engineering Branch provides traditional industrial engineering functions to the DMA. The Engineering Section solves production problems, formulates technical and modification instructions, provides tool, jig, and fixture designs, and produces all industrial graphic arts, reproduction, and drafting. In the Methods and Standards Section, shop layouts, equipment routings, and engineering performance standards are established, methods improvement and time and motion studies are conducted, and process and production plans are formulated. A Special Projects Section is tasked with the design and fabrication of special systems as required.

The third branch is the Quality Control Branch. The Quality Inspection Section of this branch is responsible for the inspection units which are co-located with the ordnance, vehicle, electronics, and support shops. They also conduct pre-repair, in-process, and final inspections. In the Quality Evaluation Section, defective and "out of control" processes are analyzed and evaluated, acceptable quality levels are established, control charts are developed and maintained, and customer complaints are investigated.

The Metrology Branch controls the Electronic, Radiac, and Mechanical Calibration and Repair Sections, furnishes calibration support to Fleet Marine Force customers, and develops calibration procedures and instructions. In addition, this branch coordinates and controls the Marine Corps infantry weapons gauge exchange program.

The core of the production effort of the Repair Division is conducted by Shops Branch. It is within its "Production Control Centers" that the actual production work is performed. These industrial facilities overhaul, repair, rebuild, modify, fabricate, preserve, and test the equipment processed by the DMA. A secondary function of this branch is to provide Marines with on-the-job and technical skill enhancement training. [Ref. 1:pp. 6-8]

The Shops Branch is separated into five Production Control Centers (PCC). The Vehicle PCC performs depot level maintenance on all motor transport equipment, as well as selected engineer equipment items such as bulldozers and forklifts. Its facilities include an engine shop, a power train shop, an overhaul shop, a hydraulics and accessories shop, and an engineer equipment shop. The depot maintenance support of ordnance items is performed in the Ordnance PCC. Three separate work sections accomplish this task; the small arms shop, the fire control and optics shop, and the tracked ordnance/artillery shop. The Communications/Electronics PCC repairs and rebuilds communications and electronic equipment in its three shops. These shops are the radar shop, the communications equipment shop, and the electrical equipment shop. The Support PCC provides a variety of support functions to all of the other centers. Within this center there is a welding section, a machining section, a sheet metal section, and a body section. Finally, the Preservation PCC provides all cleaning, painting, battery maintenance, preparation for shipment, and care-in-storage preservation.

The Production Control Branch operates as the heart and mind of the overall production effort. This branch plans, schedules, controls, and evaluates all work done in the Repair Division. These functions are controlled by three sections. The first is the Workload Plans and Scheduling Section. It is here that the Master Work Schedule is produced, man-hours and costs are estimated, material requirements are determined, and shop loading data is computed. The Control Section monitors the progress of productive work, furnishes miscellaneous shop support, and initiates parts requisitions. The Materials Handling Unit, which controls all material handling equipment throughout the facility, is also the responsibility of the Control Section. The final section in this branch is the Material Support Section. This section processes, coordinates, and follows up on all material requirements, receives, stores, and issues all materials, and operates the DMA tool room.

C. CURRENT PRODUCTION MODEL OVERVIEW

The current production system in use at the DMA is formally called the Depot Maintenance Management System (DMMS). This system was developed using Yourdon structured analysis technique [Ref. 3:p. 1-2]. This technique defines the flow of information into, within, and out of a system through the use of data flow diagrams, process descriptions, and a supporting dictionary. In this portion of the thesis, selected processes will be identified as they are now practiced. [Ref. 3:pp. 2-16 to 2-71]

The DMA production system is supported by an automated data collection system connected to a mini-computer which records historical information. Daily transactions, including attendance and labor distribution, material control, cost control, and manpower performance are collected from input made at one of several remote input devices.

1. Funding

The DMA is a Department of the Navy Industrially Funded (NIF) activity. The NIF finances industrial and commercial type activities that produce and furnish goods or render services to other activities on a reimbursable basis. The fund's basic concept begins with the NIF receiving its initial funding, or CORPUS, from Congress. The DMA then bids for and receives orders for work from Marine Corps and some other DOD customers. Work commences, drawing moneys from the fund until customers are billed on a monthly basis and payment is received. The DMA then reimburses the NIF which would theoretically bring the CORPUS back to its original level. [Ref. 4:Mod. H]

2. Planning

On an annual basis, the Production Control Branch (PC) receives the Master Work Program (MWP) from Headquarters, Marine Corps (HQMC). The MWP consists of the depot overhaul requirements for the current fiscal year as well as the next three years. Significant changes to the MWP are also received by PC throughout the year from HQMC.

From the MWP, the Master Work Schedule (MWS) is generated. At this time, MWS Cost Data Sheets are initially created and a Job Order Folder is created for each line item. After researching historical material and labor costs, PC then develops a rough Job Order Work Plan. Initial Supply Support Planning is done at this time.

3. Scheduling

Initial scheduling of the induction of items to be overhauled is performed by taking into account of several factors. An inquiry is forwarded to Material Division (MATDIV) concerning the availability of equipment to be overhauled to the DMA. Once a reply has been received by PC, a prioritized induction schedule is developed.

The next step is to match manpower and shop capacities with this prioritized schedule. This is done by discussing the above information with the Shops Branch supervisors to get an agreement on the best product mix for induction.

4. Induction

Once PC receives a notification of funds available from the comptroller, MATDIV is informed that the DMA is ready to repair a particular item of equipment. For items that are not held by MATDIV, items arrive as shipped to the DMA but not inducted until scheduled.

Job Order Packets are then produced and forwarded to each applicable shop from information contained in the Job Order Folders previously discussed. These packets include Process Sequence Number cards, Modification Sheets, and a Master Components List. The item is then inducted for overhaul by the DMA.

5. Routing/Tracking

A manual Routing Card File is used to route assets and components through the DMA from induction to final inspection and shipment. Routing tags are physically placed on items by PC personnel. The personnel draw on historical job knowledge to indicate where and in what sequence an item is to be routed. Components are routed individually, with a group of identical components requiring similar processing, or with a group of dissimilar components requiring similar processing. The components also have routing tags whose routes have been determined by the PC personnel. Once processes are completed on items or components, the PC personnel will move them to the parent work center, which is the work center which has cognizance over the item, or to a holding area.

6. Inventory Control

The DMA's inventory control process determines material requirements, orders and tracks the status of requisitions, maintains material storage areas, issues material, maintains inventory records, and provides for financial interface with the industrial fund. The material requisitioning process begins with a Shop Planner receiving the Job Order Packet from PC. The planner uses the Material Issue History File, working knowledge, and the technical library to determine gross requirements. He then checks the On-Line Material Area and the Receipt Control File to determine what material is on-hand and on-order in order to determine the net requirements.

Material is obtained from one of two sources. The first is Supply System Stocks which are parts held in inventory by the federal government. Open Purchase, the second source, is all material obtained directly from vendors, within the federal contracting system, by the DMA.

Once the net requirements are determined, the Shop Planner prepares a Parts Requirements List (PRL) and sends it to Supply Operations (SO). SO verifies the information provided by the Shop Planner and determines if the material is available through the federal Supply System or through Open Purchase. For Supply System items, SO prepares a Material Requisition and forwards it to the appropriate federal

Item Manager. A locator card, containing the National Stock Number (NSN) and quantity is forwarded to the Material Planner to use in tracking material due.

It may be determined that certain materials must be coded for Open Purchase. This generally comes about because of unavailability in the federal supply system or because an available item cannot meet the DMA required delivery date. This determination is initially made by the Shop Planner and then verified by SO. SO then prepares an Open Purchase Request and forwards it to MATDIV. At MATDIV, the designated contracting officer places an order and forwards documentation to SO. The PRL is then annotated and returned to the Shop Planner.

The Shop Planner receives an estimated time of arrival for all parts ordered, through the Supply System or Open Purchase, by calling SO and requesting this information. Periodically and on request, SO prepares follow-up inquiries on all material ordered. Once parts are received by the DMA, the Shop Planner forwards a DD-1348 to SO where a picking ticket is prepared and forwarded to the storage area for issue.

Repair parts stored in the storage area at the DMA warehouse is stored in specific location by NSN. All parts are associated with a particular Job Order Number (JON). Although these parts are associated with a specific JON, their costs are not charged to the job associated with the JON until they are actually drawn and used.

7. BOM/Mini-BOM

The DMA separates planned material requirements into BOM and Mini-BOM material. BOM material consists of those parts or materials managed by Weapons

Systems/Equipment Support Management (WS/ESM) Division. Mini-BOM materials are those managed by the Defense Logistics Agency (DLA).

On an annual basis, the Shop Planner references several sources to prepare a BOM spreadsheet containing planned requirements of material from WS/ESM. This spreadsheet is forwarded to SO for validation and planned requirements for BOM materials are forwarded to WS/ESM.

Mini-BOM assets are also reviewed on an annual basis. These requirements are prioritized and forwarded to MATDIV who may hold these items. A financial limitation is placed on the amount of Mini-BOM material that MATDIV can hold in inventory.

D. MCLB AND MRP II

1. History

The desire to increase productivity and decrease operating costs, and thereby becoming more competitive, has led the DMA to investigate more efficient production control systems. This led to the assignment of an Automated Production Control System Project Manager and the development of the original Project Management Plan in the spring of 1988. The original Request For Proposals (RFP) was released in July of 1988 with bids being closed in December of 1988. [Ref. 5:p. 6] As of 15 June 1989, technical proposals have been received and reviewed with operational cabilities demonstrations scheduled for the following several weeks. Contract award is anticipated within 4 months.

2. Objectives of Desired System

The objectives of the desired system are to provide the DMA with a wide range of production control tools. These include [Ref 5:p. 8]:

1. Structuring of Bills of Materials
2. Definition of individual cost centers
3. Routing and tracking information
4. Capacity planning
5. Production planning
6. Material Requirements Planning
7. Master Production Scheduling
8. Shop floor control
9. Labor distribution
10. Time and attendance
11. Inventory management

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

A. NAVAL ORDNANCE STATION, LOUISVILLE, KENTUCKY (NOSL)

NOSL is in the process of completing the implementation of an MRP II system that it acquired approximately four years ago. The general attributes of NOSL's system, developed during the implementation phase, system and implementation issues, and the personal comments of key implementation personnel can greatly assist MCLB.

1. General Information

The mission of NOSL is very similar to that of MCLB. Its primary mission is to overhaul, repair and manufacture shipboard weapons systems for the fleet of the U.S. Navy. It is also tasked with providing technical, logistics, and engineering support to its customers. It differs from MCLB in that it acts as contractor, providing actual research and development as well as manufacture of weapons systems. [Ref. 6:p. 3]

NOSL was originally commissioned in 1941 as a government-owned, contractor-operated facility. Westinghouse Electric managed the plant until 1946 when it became government-operated as well as owned. The work force dwindled to only 100 workers prior to the Korean conflict. In August of 1950, the station was reactivated and quickly grew to again become a major overhaul facility. Today, NOSL employs nearly 2400 personnel. [Ref. 6:p. 2]

NOSL is located on approximately 150 acres and includes more than 122 permanent and semi-permanent structures. The nine main production buildings contain more than 1.4 million square feet of production floor space. NOSL has a broad range of industrial equipment which is used to accomplish its mission. There is a large inventory of conventional manufacturing equipment ranging from hand drills to furnaces. In addition, some 50 numerically controlled machines assist in the production effort. [Ref. 6:p. 5]

2. MRP II at NOSL

a. General Information

MRP II is the primary productivity initiative ongoing at NOSL. The principle characteristics which made MRP attractive to NOSL were: its product orientation; its ability to look to the future; and its priority planning system. [Ref. 7]

The idea to procure an MRP II system was conceived originally in July 1983. Administrative and budget constraints precluded the issuance of a Request For Proposal (RFP) until July of the following year. Bids were received until October 1984 when the bidding process was closed. After a year of technical evaluations, the contract was finally awarded in October 1985. [Ref. 7]

During the contract award phase of MRP II at NOSL, several cost/benefit analysis studies were conducted. The results are interesting in that they predict significant advantages in the implementation of such a system. The results of these studies are contained in Tables 3-1 through 3-3. [Ref. 7]

b. System Attributes

The MRP II system, referred to as the Production Management System (PMS), which was procured and is now in place at NOSL, is one whose main attribute is that it integrates all of the departments at NOSL into a single system. Once NOSL is fully cut-over to the new system, all departments will speak the same language and

ONE TIME SAVINGS

[Ref. 7]

• USE DOWN INVENTORY	$ 15.2 M
• STATION "GOLD PILE"	$ 3.2 M
• NCR PHASE OUT	$ .74M

TABLE 3-1

ESTIMATED ANNUAL BENEFITS

[Ref. 7]

• INVENTORY CARRYING COSTS	$ 800,000
• PURCHASE COST DEDUCTIONS	$ 850,000
• PRODUCTIVITY	$4,450,000
TOTAL	$6,100,000

TABLE 3-2

ESTIMATED COSTS

[Ref. 7]

ONE TIME COSTS

• COMPUTER HARDWARE	$ 1,200,000
• PMS SOFTWARE AQUISITION	$ 70,000
• PMS ENHANCEMENTS INTERFACE	$ 225,000
• TRAINING	$ 400,000
• DATA CONVERSIONS(ELECTRONIC)	$ 200,000
• DATA CONVERSIONS(MANUAL)	$ 320,000
• IMPLEMENTATION MANAGEMENT	$ 200,000
TOTAL	$ 2,615,000

RECURRING COSTS

• COMPUTER MAINTENANCE	$ 90,000
• SOFTWARE MAINTENANCE	$ 60,000
• INTEREIM COMMUNICATIONS(FY87 & FY88)	$ 132,000
• TRAINING	$ 100,000
TOTAL	$ 382,000

TABLE 3-3

access the same database. Sub-optimization will be reduced, if not eliminated, as managers at all levels will be able to work towards a common objective and remain aware of each other's problems. Some of the general traits of the PMS are [Ref. 8]:

1. It functions in "real time" to provide up-to-the-minute data on contract and project requirements, material status, labor charges, estimated completion times, production status, and tracking information.

2. It allows all personnel to communicate with the system, using terminals in their own work areas.

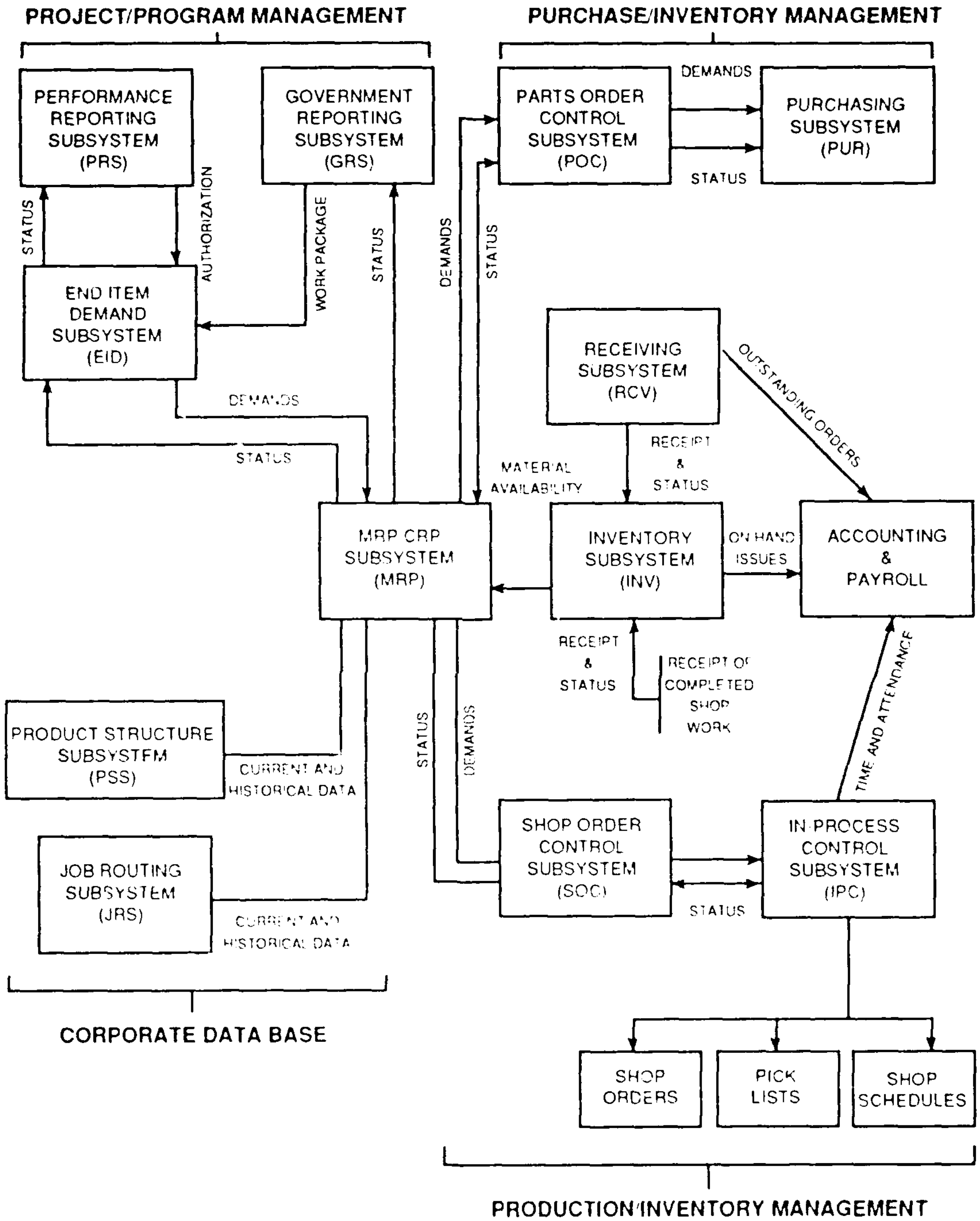
3. It allows for more accurate cost data collection, using actual material and labor figures from the shop floor.

4. It provides accurate information to compare progress with the Master Production Schedule (MPS).

5. It provides the capability to immediately identify the impact of directed changes to the MPS on the overall production effort.

The PMS is made up of many sub-systems which contribute to its overall success (See Figure 3-1) [Ref. 8]. Each of them will be discussed in general terms below.

The End Item Demand (EID) Subsystem maintains the MPS and master delivery schedules to the customers and provides the basis for scheduling all downstream events required to satisfy those demands. This subsystem provides the ability to forecast capacity requirements and assess the impact on the current production schedule if changes are required to the MPS. In addition, the EID maintains historical shipping and receiving information which is used to demonstrate proof of contract performance. Reporting capabilities include: Schedule Dates, Part Number Inquiries, Delivery Schedules, and Shipment Records.



NOSL MRP II Diagram
[Ref. 7]
Figure 3-1

The Product Structure Subsystem (PSS) is where the BOMs for each major item and component overhauled are built. Information from engineering provides the structure of the BOM which includes associated data such as drawings, document data, and assembly notes. The subsystem allows for product structure information to be copied from one like system to another. In addition, the PSS identifies quality control requirements for both purchased and assembled parts. The subsystem produces a variety of reports including: Single level and indented BOMs, Where-used Reports, and Part Master Inquiries (QC/Customer/Approval Reviews).

In the Job Routing and Standards Subsystem (JRS), information specifying through which shops an assembly must flow is maintained. The JRS has the ability to produce reports containing the total routing plan for any assembly part number. The standards portion of this subsystem is established to relate standard labor hours for setup and run time for each assembly. This data is then used as the basis for performance reporting.

The Material Requirements Planning Subsystem (MRP) is the primary order planning module of the PMS. MRP is run on a weekly basis or as demanded. Each time it is run, the subsystem considers all unsatisfied demands, compares this data to the on-hand inventory and to current orders, and attempts to satisfy all demands that exist. If a sufficient supply of an item does not exist, an order is planned so that it will arrive in time and in sufficient quantities to meet the master schedule. Shop load listings, capacity requirements, production plans, and forecasts are all generated in the MRP module as well.

All purchase requisitions are controlled by the Parts Ordering Control (POC) Subsystem. This subsystem tracks all procurement items from the generation of requirements by MRP until they are received at NOSL. Each purchase requisition is assigned an ID number and an expected delivery date. The POC contains three purchase requisition release modes: 1) automatic, based on MRP-calculated data; 2) forced release, which is the manual release of planned requisitions, to avoid critical shortages; and 3) unplanned order release. In addition, the POC has the ability to consolidate demands for certain items which experience high demands in multiple cost centers. A myriad of reports are generated by the system including: Planned and Open Purchase Reviews, Purchase Status Reports, and Buyer Follow-up Reports.

The Purchasing (PUR) Subsystem consolidates and maintains procurement cycle information for both production and non-production goods and services. The subsystem can create, track, and maintain purchase orders within the Defense Material Priority System span of control. The single report generated by the PUR identifies all outstanding requirements and their related purchase orders.

The procurement cycle is completed in the Receiving (RCV) Subsystem. This subsystem provides for the control of materials from the receiving dock, through the inspection process, and into stock. The RCV tracks all full and partial deliveries and maintains inspection and certification records. Documents generated include: Receiving Backlog Reports and Material ID Tags.

All transactions pertaining to inventory issues and receipts are processed by the Inventory Control (INV) Subsystem. Financial and contract ownership of all inventory is accounted for as well. The subsystem contains detailed audit trails of all transactions affecting on-hand quantities, locations, and contract ownership. All usage of material is recorded and forwarded to accounting for final processing and includes an inventory cost based on actual dollar values paid by the contract and assigned by the INV. In addition, the INV contains all multiple stores and bin locations information. Physical inventory updates are conducted to compare actual to system counts and discrepancies are instantly reported by INV. Reports generated include: Obsolescence and Shrinkage Variance Reports, Inventory Balances (sorted by contract), and Total Inventory Value Report.

The Shop Order Control (SOC) Subsystem is responsible for all shop-related events, from the conversion of planned orders into open orders through the receipt of completed orders in stores. The SOC has the ability to consolidate multiple contracts into single shop orders while still maintaining discrete identities of each for the purposes of posting inventory and labor costs. The generated shop orders serve as the instructions to the manufacturing shop to assemble a part and also serve as the as-built configuration record. Shop orders are released by the SOC in one of four ways: 1) automatic release, based on date-to-order maturation; 2) forced release, which is the manual release of planned orders to avoid critical shortages; 3) rework and/or repair orders; and 4) manual release, to manually release unplanned orders fill any requirements identified in circumstances not planned for such as a response to an urgent fleet request. The subsystem has the ability to split shop orders so that portions of an order can be moved ahead or rerouted.

The In-Process Control (IPC) Subsystem captures all statistical data corresponding to each routing sequence of every shop order. This data includes all actual labor hours of production and rework and the sequential tracking of shop orders. Employee information, which includes clock in/out, job log-on, job complete, and discrepancy data is collected by the IPC. The subsystem provides management with the capability to query the system to ensure that all assigned employees have logged on to a job order. Reports generated include: Attendance Reports, Labor Reports, and Shop Order and Sequencing Status Reports.

Finally, the Performance Reporting System (PRS) is used to establish, control, and monitor performance reporting data which is critical to specific contracts. Real time cost and performance data is the result. The PRS allows for the creation of Task Control Numbers (TCN) for any accumulation of cost performance data at any level of the production effort. Exception Reports are generated reporting any performance variances above or below limits established for labor efficiency and standard hours. Other reports generated by the PRS are: TCN Table Reports, Exploded Statements of Work Reports and Estimate-at-Completion Reports.

3. Implementation Issues

Several issues were of major concern during the MRP II implementation process at NOSL. These issues had a significant impact at NOSL and it is appropriate to mention them to make MCLB aware of their existence.

a. Inventory Issues

Two issues pertaining to inventory were addressed during the implementation of MRP II at NOSL. The first was that station inventory values would initially increase significantly, leading some to believe that the system was failing. The other inventory issue was the development of ordering rules for each part. Both issues will be discussed below. [Ref. 7]

Station inventory values have initially increased during the implementation phase of MRP II. This increase can be attributed to two main factors. First, many cost centers held stockpiles of inventory of significant value, called "goldpiles" at NOSL, that were not included in official station inventory values. A major goal to be accomplished in conjunction with the implementation of the new production system was the collection of and accounting for the inventory held in these goldpiles. When these goldpiles were included in the official inventories, the value of the inventory rose.

The second reason for the rise in the value of inventory is that items are now being manufactured to support specific overhauls instead of to fill stores. As there is now less manufacturing of items, materials and supplies previously scheduled to be included in work-in-process are now in stores instead. The value of the raw materials and supplies inventory will initially rise until they are moved to work-in-process.

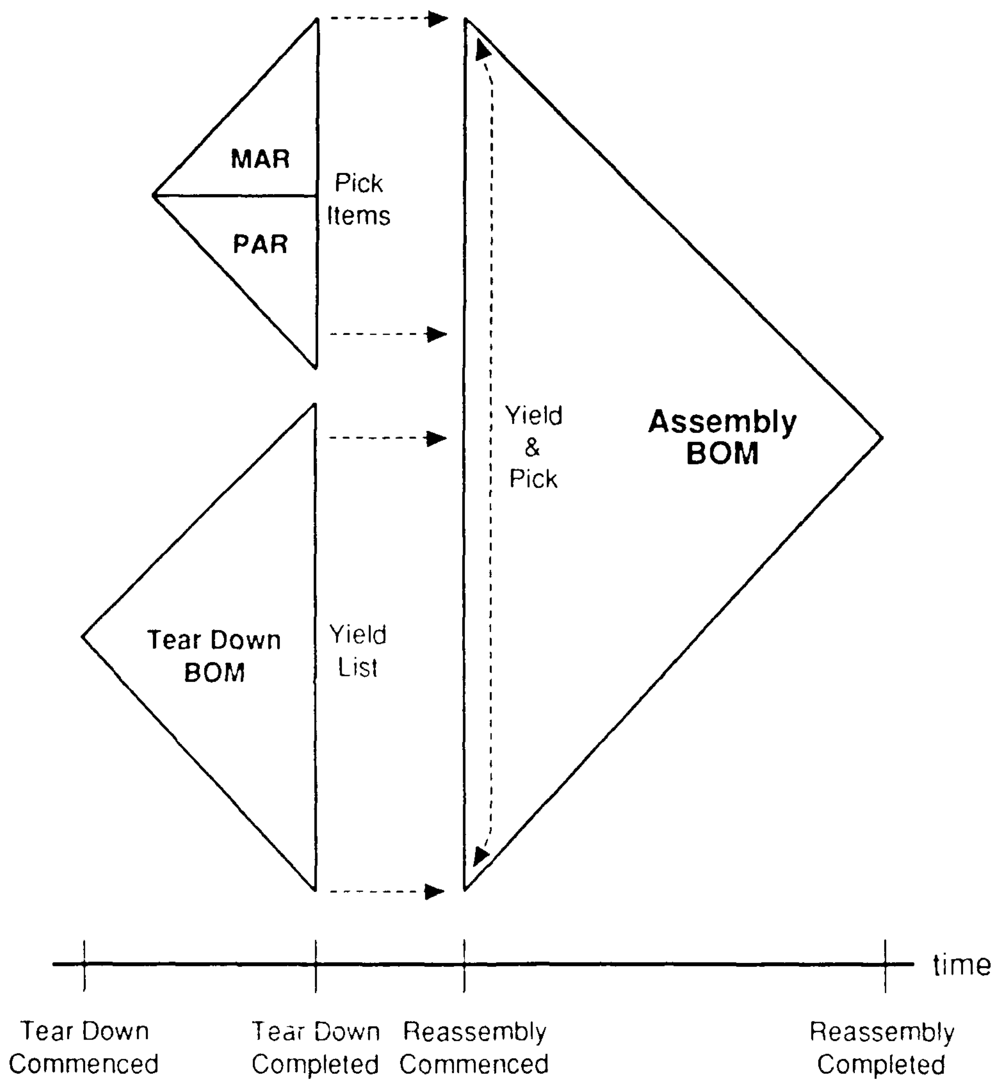
Though the initial value of station inventory has risen, the end result of implementing MRP II will be a lower overall inventory value. Explicit in the implemented system is the design that future investments in inventory will only reflect those materials and supplies necessary to support workload requirements. No inventory will be ordered if it is available on station. Because of this, the inventory gained from the elimination of the station goldpiles will either be used up over time or rolled back if obsolete. Similarly, materials and supplies in stores will decline because of less work-in-process. As these reductions occur, the value of the ordnance station's inventory will decrease.

The second inventory issue was that of the development of ordering rules for each specific item of material or supply. Each item must be addressed in approximately 20 different terms, from lead time information to minimum order quantity if applicable. If desired, these ordering rules allow for the effective use of Economic Order Quantity ordering by entering appropriate parameters. Further discussion of this issue can be found in Chapter 4 of this thesis. [Ref. 8]

b. BOM Structure

The structure of BOMs in a rebuild and overhaul environment is significantly different from that in a new manufacturing concern. In new manufacturing, the production process begins with raw materials and supplies. The final product is assembled from these. In an overhaul and rebuild environment, the production process begins with an end item which must be torn down into its components and parts. Each component and part must be evaluated to see if it can be reused. Those that cannot be reused must be reworked or replaced in the reassembly process. The BOM structure at NOSL reflects these fundamental differences in process. There are effectively four separate BOMs in the NOSL MRP II system. They are the Tear-down BOM (T-BOM), the Assembly BOM (A-BOM), the Purchase Assembly Request (PAR), and the Manufacturing Assembly Request (MAR) [Ref. 9]. Figure 3-2 illustrates the relationships between these BOMs.

The T-BOM is generated for use during the tear-down process. It identifies all components and parts which are disassembled at each stage of tear-down.



NOSL BOM Structure
Figure 3-2

During tear-down, parts and components are inspected, and at the end of the tear-down process all reusable parts and components are identified in a "yield" list. For those parts and components which are not reusable, a "pick" list is generated. This list contains those parts and components which must be purchased or manufactured for each step of final assembly.

During the tear-down process, or prior to it if necessary, all items with an expected replacement factor are programmed for manufacturing or purchase by the MAR or PAR, respectively. Though not BOMs in name, in practice they are structured as such. Items are only manufactured or purchased during this process if they have a positive probability that they will not be reusable. Their expected demand levels are ordered if sufficient quantities are not already available in stores. Ordered items which are later found to be not needed in the reassembly process are placed in stores for future use. All items in the PAR and MAR are programmed to be received or manufactured as specified to support the reassembly.

The A-BOM is the BOM which supports the final reassembly process. It is this BOM which most closely resembles the BOM in a new manufacturing concern. It contains all items and components necessary for reassembly and a map for doing it. The final product of the A-BOM is the overhauled or rebuilt item.

c. Partial Cutover Issues

The implementation of the MRP II system at NOSL was begun with a pilot program and continued with successive programs being placed on-line. There are several problems associated with this approach. First, coordination between those programs which had been cut-over and those not yet cut-over were difficult. It is difficult to have those shops, which are not cut-over, work in synchronization with those that are.

Second, the support shops, such as the machine shop, experienced difficulties in meeting the priorities set by the new system for the support required for those shops which were cut-over. Capacity problems have developed because of the competition between those shops cut-over and those not cut-over. A major contributor to this problem was the expediting still being conducted by those shops not cut-over to MRP II.

Both of these cut-over issues have resulted in the inability of NOSL to identify an increase in throughput as a direct result of the implementation of the new system. It is felt by NOSL that once total implementation has been accomplished, these problems will diminish.

d. Routing Issue

Routing information, in terms of physical location, is entered into the system by production control personnel located on the shop floor. Once a process is completed in a particular shop, the production control personnel must input the completion into the system. The system then identifies the location of the item as the next shop in the system routing sequence. Some problems have arisen from the fact that while the system identifies the item as being in the new location, it has not physically arrived. The station tram runs through all production buildings twice daily for the transportation of items which meet its size limitations. Larger items must be moved by special Material Handling Equipment (MHE) and truck. The delays experienced by these transportation systems has caused some system and management confusion.

e. *Training Issues*

As with any new system or change in an organization, resistance is present at NOSL. This resistance takes many forms, from the feeling that the old system works just fine to the fear that jobs will be eliminated. Another fear is that the system will become a "Big Brother" used to monitor, catch, and punish those who "necessarily" bend the rules to accomplish the mission. Finally, there was a fear and distrust of the automated system, with terminals located throughout the production facilities. The management at NOSL felt that many of these concerns could have been averted with a more aggressive training program reaching to the lower levels of the production work force. [Ref. 9]

B. ARMY DEPOT MAINTENANCE SHOP FLOOR SYSTEM (MSFS)

1. General Information

The MSFS was developed by Headquarters, Depot Systems Command (HQDESCOM) for use throughout the Army's depot maintenance facilities. [Ref. 10] This system is comprised of 11 modules which can be used either in conjunction with each other or independently. Another option in configuration is that the MSFS can be used at different levels in the production process: at the MPS level, the individual item level, and/or the component level.

While no implementation data is available, as this system has been in place for some time, it is felt by HQDESCOM that this system could be easily adapted and implemented by other services. [Ref. 10] This system is mentioned in this thesis as an alternative to an expensive MRP II-type system.

2. Modules

As previously mentioned, the MSFS is made up of a series of modules which may be implemented as a complete system or independent of one another. A brief description of each module is found below. [Ref. 10]

a. End Item Tracking Module

This module allows for the capability to load into the system a pre-defined routing for selected items. Critical checkpoints, from induction to job completion, are identified in the process and estimated cycle days can be compared to actual process days. All shop floor input is by a remote cathode ray tube device or by scanning a bar code.

b. Component Tracking Module

This module provides the ability to track components and parts removed from end items, along their processing routes, until all production processes are completed and the end item is reassembled. The system relates these components back to the applicable end item to identify potential tardiness which would affect projected end item completion. Once initially established for an item, the tracking module may be modified to reflect any changes in the routing sequence for the item. As items move from work station to work station, bar-code scanning is utilized to enter tracking information.

c. Work Station Requirements Module

This module identifies, establishes, and maintains records of necessary repair parts and kits required at the work station level to assemble a unit of production. These records are used to project material requirements based on the MPS. This module is intended to be used in conjunction with the inventory, kitting, and requisition modules discussed below.

d. Requisition Module

This module generates requests for issue from the shop floor via computer terminals located in the work stations. It eliminates the manually prepared, hard copy requisitions. The module eliminates time lags associated with paper flow and allows for the real time identification of requirements on the shop floor and in inventory control.

e. Material Request Suspense Module

This module automates the process of tracking and maintaining correct statuses on all open requests for material issue generated by the shop floor. It includes delivery and requisition status dates.

f. Inventory Module

This module is the heart of the MSFS and interfaces with the component tracking, requisition, material request suspense, kitting, and work station requirements modules. The inventory module provides the capability to establish and maintain on-hand balance reports for all parts, supplies, and components at each level of production.

g. *Kitting Module*

This module establishes and maintains records about items which can be prepacked and stored as kits. These kits are then issued and used on specific maintenance jobs.

h. *Test Equipment Tracking Module*

This module, which functions as a control mechanism over test equipment used in the production process, identifies the location of test equipment items, in storage or in use. It tracks both individual items and those which are issued in sets. Reference files in the module identify the test equipment which is needed in processing specific end items and define the particular items which make up a test set.

i. *BOM Module*

This module was specifically designed to manage large special fabrication projects. It can, however, be configured to perform typical BOM functions for any item. The BOM structure is limited to nine levels of production. Inquiries may be made to the module to provide completion status and on-hand availability of end items, assemblies, or components.

j. *Bench Stock Module*

This module provides the ability to establish, monitor, and replenish low-cost, fast-moving supplies held at the work station level. When the quantity of a particular bench stock item reaches a predetermined reorder point, a requisition for a 15-day supply of the item is automatically placed by the system.

IV. SUMMARY, CONCLUSION, AND RECOMMENDATIONS.

A. SUMMARY

The DMA at MCLB has decided to purchase an MRP II automated production control system. This system will offer the DMA the potential to replace the mostly manual system described in Chapter 2 with a system which is more effective and efficient. A valuable source of information can be found in the system and the system implementation process developed at NOSL. Described in Chapter 3, the MRP II system at NOSL contains virtually all of the components that the DMA has identified as necessary in their proposed system. Also in Chapter 3 is a discussion of the Army's MSFS. This system may offer a viable and cost effective alternative for the DMA to investigate.

The following three sections of this chapter contain the specific recommendations in regards to a system alternative, general implementation, and specific system features.

B. A SYSTEM ALTERNATIVE

The complex production effort conducted by the DMA at MCLB is at once archaic and efficient in its manual mode of operation. It is archaic in that many of the functions performed manually, such as routings, BOM structure, inventory ordering, and tracking, could be automated and managed more effectively. It is, however, efficient in its production. Batches are small and individual items are moved forward in the production process as soon as they are completed, batch identity notwithstanding. Inventory is ordered on a material requirements planning basis, only as needed and after end items are inducted into the depot maintenance cycle.

The most quickly identified production problem at the DMA is its lack of an adequate routing and tracking information system. This sentiment was expressed in turn by the heads of the Production Control and Shops Branches [Ref. 11]. More importantly, the lack of an effective routing and tracking information system was the greatest concern of the individual shop floor managers. They expressed concern and frustration over the feeling that, on some days, over 90% of their time was spent attempting to locate and expedite components and materials that their respective shops needed to accomplish their portion of the production effort.

At NOSL, system software costs of $295,000 were 11% of the total system cost, which included hardware and vendor assistance [Ref. 7]. Since the hardware requirements at the DMA should be significantly lower as it is a considerably smaller facility, this percentage could well reach much higher levels. While the DMA is in need of an updated ADP system, where hardware costs will be realized irregardless of the system acquired, software costs could be significantly reduced with the adoption of all or part of the Army's Maintenance Shop Floor System.

As discussed in Chapter 3, the MSFS is a modular system whose modules may be used independently of one another. It contains both end item and component tracking modules which identify the production route and tracks items through the production process from induction to completion. In addition, both modules allow for the modification of routing information to reflect any unique processes required for any particular end item or component. This already developed system is adaptable to the DMA at Albany and available from the Army's Depot Systems Command located at Letterkenny Army Depot, Chambersburg, Pennsylvania.

The first recommendation of this thesis is that the system alternative of the Army's MSFS be investigated by the DMA. This course of action is recommended for several reasons. First, there is the potential for significant cost savings by adopting and adapting this system. Next, the DMA could ease the shock of the transition to automation by implementing those modules of the MSFS which provide the most immediate and visible results to the shop floor. By answering the expressed needs of the shop supervisors and the shop floor in a first step towards automation, further automation will be more easily accepted. The final reason for this recommendation is that the MSFS appears to be a much more simple system than the proposed MRP II system. Just as a person must learn to walk before he can run, so too must a complex production system, operating in a basically manual configuration, enter into the world of automated production control slowly to realize success.

C. WORKING WITH THE MRP SOLUTION

If the decision is made to go forward with the implementation of an MRP II-type automated production control system, there are several recommendations that this thesis offers.

1. NOSL Liaison.

As discussed in Chapter 3, the Naval Ordnance Station in Louisville, Kentucky (NOSL) has procured, and is in the process of completing the implementation of, an MRP II automated production control system. This formidable task has been ongoing for the past four years. The staff at NOSL has considerable amounts of knowledge and experience with regards to every aspect of the implementation concerns which are attached to placing this type of system into operation at a DOD depot maintenance facility. The management at NOSL, committed to making their new system work, have also expressed a willingness to assist other DOD facilities make the same transition by sharing their information on a variety of topics relating to an MRP II system.

In light of this information, this thesis recommends that liaison be made with NOSL to discuss the implementation of an MRP II system. Some particular issues which should be addressed are:

a. Modifications to off-the-shelf MRP II software;

b. Hardware requirements;

c. Management/worker change and training issues;

d. Capacity management/inventory management/ordering rules;

e. BOM structure.

This list is by no means all-inclusive, but offers those topics which the DMA would gain the most benefit from discussing.

2. Managing Change

Managing a change to any organization is difficult. Managing a change of the magnitude of that which is proposed at the DMA will be difficult as well. The move from a manual system to the automated world of MRP II will consume great amounts of resources and time. If this transition is successful, the DMA will realize gains in efficiency and competitiveness. If it is not successful, and the production process continues even informally in its manual mode of operation, the DMA will have wasted scarce resources and valuable time in its efforts.

The sources of resistance to change offered by personnel at Albany closely parallel traditional sources offered by management textbooks [Ref 12]. These sources are outlined as follows:

a. Uncertainty about system effects on the workforce

Employees at the DMA, from management to shop supervisors to floor workers, are unsure of the effect the new system will have on the security of their positions; security in the sense of both employment and power and control.

b. Uncertainty about the need for change

Many at the DMA feel that the system in place is in no need of change. They feel that the production process is run as efficiently and effectively as possible under the current system. Plans to change the current system have resulted feelings of inadequacy in performance among the workforce.

c. Uncertainty about the new system's advantages.

Rumors and partial information about the attributes of a proposed system cause discomfort in all levels of the organization. New tasks, more difficult than the old way, and the perception that a new system will offer no advantages over the old make the workforce wary of a change in system.

d. Fear of automation

This source of resistance is tied closely with the first source. There is a perceived cost to the employee with an automated system. This cost is one of loss of power and control in the lower levels of management. The automated system is seen as a sort of "Big Brother" which will be used by upper-level management to identify what they feel is substandard performance or lack of adherence to the rules.

Given these sources of resistance to change were expressed by personnel at the DMA, there are several effective ways for management to overcome these obstacles and therefore help to ensure the successful implementation of the new system. Specifically, these are:

a. Management commitment

This is the most crucial component of overcoming resistance to change in an organization. Any perception that management is not completely behind a new system will create doubts about the system in the minds of the workforce. To ask the workforce to implement a system that they, and their managers, perceive to be of dubious value will result in an unsuccessful implementation process. Managers at all levels must be committed to the new system to achieve success. [Ref. 13]

Included in the management commitment concept is the assignment of a full-time Project Leader. To demonstrate that the new system is truly a "company system," this Project Leader should be a person who is from within the organization, has the power, prestige, and respect to influence personnel at all levels, and can commit to the implementation of the new system on a full-time basis. [Ref. 13:p. 368]

b. Training

Complete and informative training will help to overcome the uncertainty which creates resistance to change in an organization. Training should be conducted addressing system attributes and advantages, the reasons why change to a new system is necessary, and the effects that a new system will have on the workforce in terms of employment, responsibilities, and rights. To be most effective, this training should be conducted in a "trickle-down" manner; that is, each level in the organization should conduct the training for that level which is directly below it in the chain of command. A shop floor employee would be more likely pay closer attention and give greater heed to instruction from his shop supervisor than to the head of production control.

c. Employee involvement

Since management, as the initiators of the change to the new system, do not have all of the information, skill, knowledge, and time to implement the system without the participation of the workforce, employees are necessarily involved in its implementation. Employees who feel that they are involved in the planning for and implementation of a new system will be more likely to be committed to its success.

d. Visit from NOSL personnel

All levels of the production team at NOSL have gained considerable knowledge and experience during the past four years while implementing an MRP II system. This valuable source of information should be used to the fullest extent possible by the DMA to ease their implementation process. To this end, and in addition to the liaison visit to NOSL that was previously proposed, it is further proposed that arrangements be made for personnel from NOSL to visit the DMA prior to and during the implementation process of the new production control system.

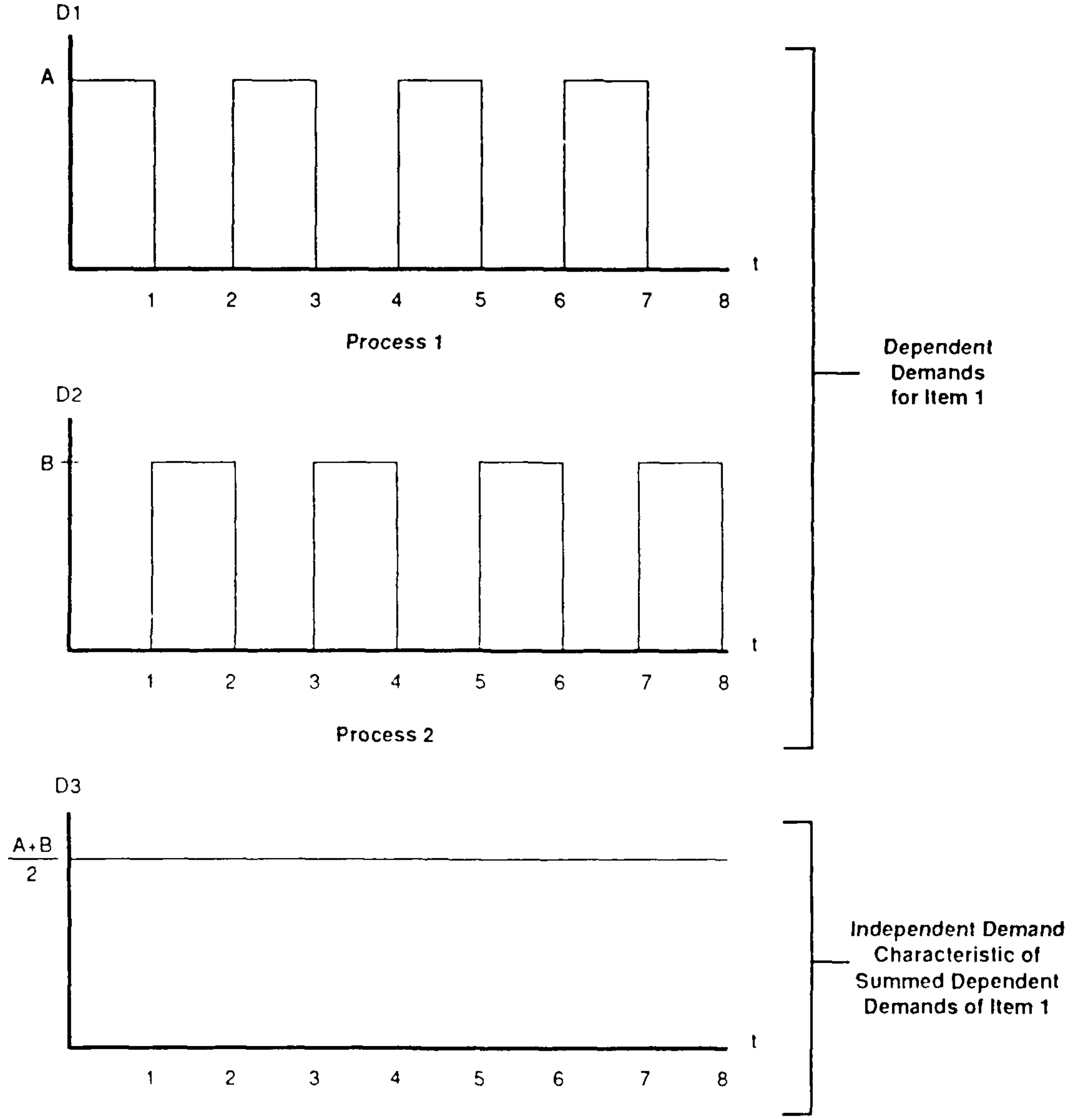
The DMA should invite, and fund if possible, personnel in all levels of the production process at NOSL to make liaison visits. With upper management meeting upper management, inventory personnel meeting their counterparts, shop supervisors meeting with shop supervisors, and shop floor workers meeting their peers, correct and accurate information about the MRP II system can be exchanged. The personnel at NOSL, committed to making their system work and sold on its attributes, by sharing their knowledge and experience firsthand with the personnel at the DMA will do much to eliminate the misinformational and uncertainty sources of resistance to change.

D. MRP II SYSTEM CONSIDERATIONS

1. Material Requirements Planning (MRP) vs. Economic Order Quantity (EOQ) Inventory Ordering

A fundamental tenet of MRP II is that dependent demand items should not be forecasted separately, nor should they be ordered by the EOQ method. Instead, they should be explicitly derived from a BOM explosion and end item demand. Using the MRP inventory ordering technique, the inventory of dependent demand items, when not needed, is theoretically driven to zero and the risk of shortages built into EOQ inventory forecasts is eliminated. (See Appendix A).

There are times, however, when an item experiences a series of dependent demands at various levels and stages in a production process. These dependent demands, when summed together, exhibit characteristics of independent demand items [Ref. 14]. As seen in Figure 4-1, The demand for an item (D_i), which is dependent in process 1 and 2, exhibits independent demand characteristics when all demands for the item are summed. It may be cost effective to order these items using EOQ inventory ordering logic.



Independent Demand Characteristic
of Summed Dependent Demands
Figure 4-1

Ignoring EOQ in favor of MRP inventory ordering for all items will generate unnecessary costs which may be eliminated by EOQ calculations. These unnecessary costs may be realized in several ways. First, the costs of processing individual orders of a particular dependent demand item that exhibits the characteristics of low cost and high usage through several levels of production may be excessive if the item is ordered using MRP logic. Second, maintaining accurate on-hand counts and usage data required by an MRP system may be inordinately costly in terms of employee time. MRP system size and attributes are the final components of increased costs associated with MRP inventory logic when EOQ can be effectively utilized. An MRP inventory system designed to track all items regardless of item cost and usage will be larger and more costly than necessary.

It is proposed that the incorporation of EOQ be accomplished in one of two ways. The first suggestion is that the Bench Stock Module of the Army's MSFS be incorporated into the ADP system at the DMA to manage EOQ-designated items. This system can be modified to reflect the EOQ parameters developed by the DMA and generate orders to be sent to suppliers.

The second process which may be used to implement a de facto EOQ ordering system for inventory, while still tracking all items within the MRP system, is to ensure that the parameters contained in the ordering rules associated with the inventory ordering subsystem in MRP II be configured to have the capability to reflect EOQ ordering. The parameters contained in the ordering rules may be identified in an EOQ context, with minimum lot sizes, reorder points, and order interval denoted in such a fashion as to mimic EOQ calculations. This second method would only offer the DMA the cost savings associated with reduced ordering costs associated with EOQ.

2. BOM Structure

The BOM structure within the MRP II system should be altered to reflect the needs of a repair/rebuild environment. In Chapter 3, the BOM structure in the system implemented at NOSL was discussed in terms of its unique configuration. The features of the recommended BOM structure are outlined as follows [Ref. 9]:

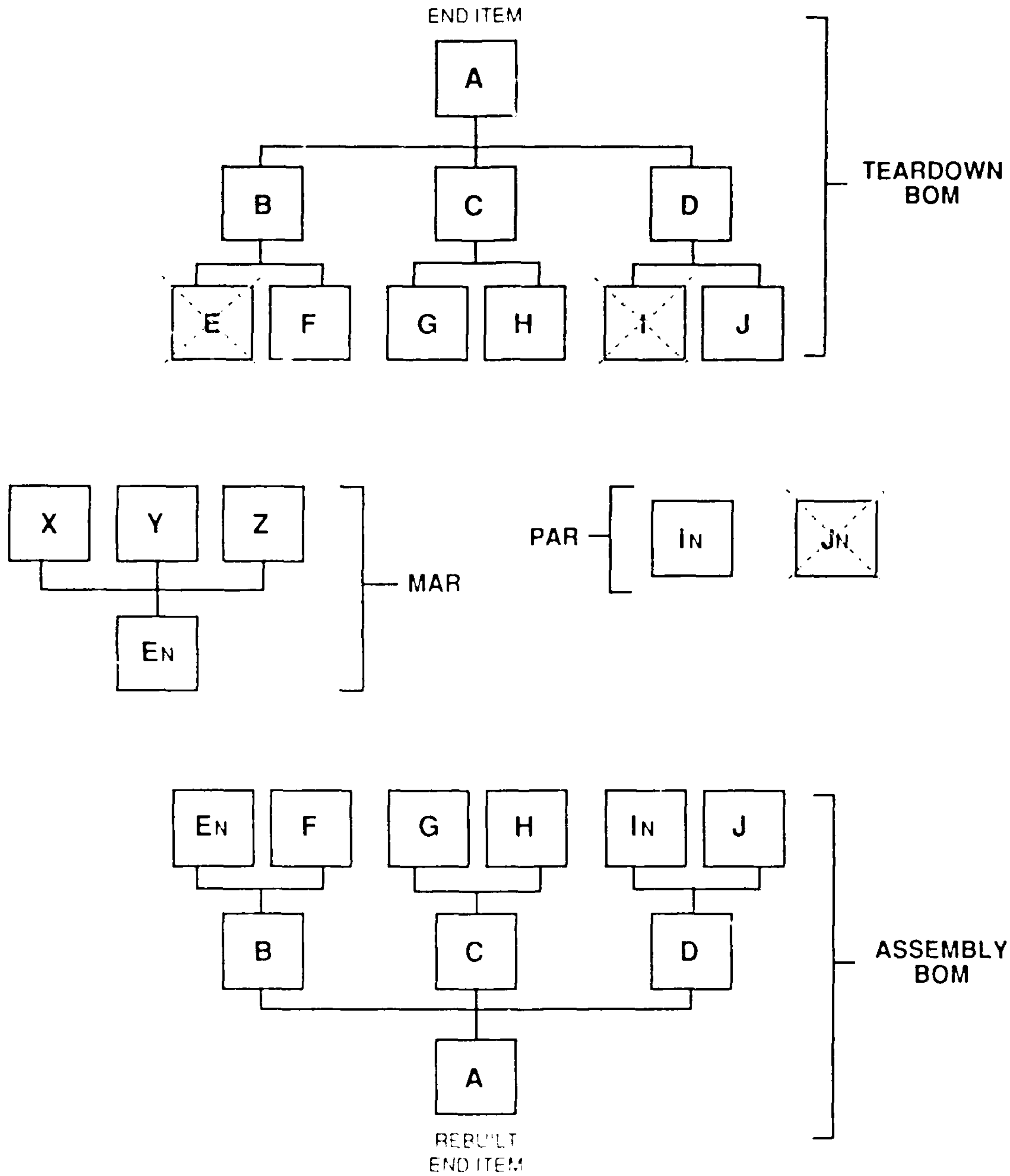
a. Teardown BOM

The Teardown BOM is the mirror image of the traditional manufacturing BOM (See Fig. 4-2). This BOM identifies the subcomponents which are to be yielded at every stage of the teardown and inspection process. The final yield, consisting only of those items which may be reused in the rebuild process, will be compared against rebuild part requirements to generate a pick list of items to be taken from the PAR and MAR discussed below.

In Figure 4-2, end item A is torn down to yield components B, C, and D. These components, when torn down, yield subcomponents E through J. Subcomponents E and I were found to be in need of replacement, therefore the final yield identified in the teardown BOM consists of only items F, G, H, and J.

b. PAR and MAR

The Purchase Assembly Request (PAR) and the Manufacturing Assembly Request (MAR), as previously mentioned in Chapter 3, are structured as BOMs for a particular end item. Those items which have associated positive possibilities of replacement and are not available in stores are assigned to the PAR



Suggested DMA
BOM Structure
Figure 4-2

if purchased from or supplied by an outside agency and to the MAR if manufactured by the DMA.

Items are assigned to the MAR and PAR in one of two ways. First, items are placed in the PAR or MAR as they are inspected and identified to be in need of replacement. This first method is used for items whose lead-time is short enough to first inspect the old item and then purchase or manufacture the item to meet a need date. The second way for an item to be placed in the PAR or MAR is much more pre-emptive, in that the item is placed on the PAR or MAR prior to the inspection of the old item. The second method is used for those items whose lead-times are too long to meet required need dates if assignment to the PAR or MAR is postponed until inspection of the old item could take place.

These pseudo-BOMs run concurrently with both the Teardown and Assembly BOMs so that items in the PAR and/or MAR are received and/or completed as they are needed in the rebuild process. Once the final yield is established by the teardown BOM, a pick list is generated and items are "picked" as needed from the end results of the PAR and MAR. These pick items, when added to the final yield of the teardown BOM, constitute the starting point of the Assembly BOM.

In Figure 4-2, subcomponent E is identified in the MAR as a possible replacement item and subcomponents I and J make up the PAR. Subcomponent J was placed in the PAR because it met the requirements of the second method described above. As subcomponent J was found to be fit for reuse and is part of the yield, the pick list in our example consisted of only items E and I.

c. *Assembly BOM*

The Assembly Bom is that BOM which most closely resembles the traditional new manufacturing BOM. It is from this BOM that the rebuild process is conducted. In Figure 4-2, the yield items identified in the Teardown BOM and the necessary pick items constitute the lowest level subcomponents which are needed to rebuild end item A. The Assembly BOM is the blueprint for the rebuild process.

By structuring the BOM using this four part configuration, positive control of all materials and components is assured at every step of the rebuild process.

3. *Replacement Factor Forecasting*

In a rebuild environment, many parts of an end item are found to be reusable and are used in the reassembly process. Other items have associated with them a probability that they will be found to have defects which render them not usable in the rebuild process. This probability has been called the replacement factor (RF). Items with an associated RF, in an MRP environment, are programmed to be manufactured or purchased to be available at that stage in the production process where they are needed. It is crucial to the goals of the MRP system that these RFs are calculated correctly and updated on a continuous basis. If an item or component has an RF and/or stockage level inappropriately assigned, the costs of purchasing or manufacturing the item will be lost if the item is not used in the rebuild process or a shortage will occur if an item is needed and not available.

Several factors can cause the initial RF assigned tc an item to change or be eliminated completely. First, suppliers of an item may change over time. The new supplier of an item or component may offer a product which is significantly superior or inferior in quality. A change in the process or standards associated with an item or component may be the second reason that RFs could change. Third, modifications directed and made to an item prior to the induction process could significantly alter the RF. Last, a change in the workforce on the production line could affect the RF. A new worker may interpret the generally vague standards set for the serviceability of a particular item or component in a significantly different way from the previously assigned worker.

Replacement factors can be assigned and updated by using a fairly simple two-step process. The original RF may be assigned by using a historical average from existing production records. This original RF should be reviewed and updated on a quarterly or semi-annual basis. The recommended procedure for accomplishing this review is a simple exponential smoothing calculation to forecast the RF. The applicable formula is as follows:

$$\hat{RF}_p = \alpha RF_{p-1} + (1 - \alpha)\hat{RF}_{p-1}$$

Where is the exponential smoothing factor ($0<\alpha<1$), RF_{p-1} is the actual replacement rate in the previous update period, and $\hat{RF}_{p-1}$ is the forecasted RF from the previous update period. The exponential smoothing forecasting technique allows for the carrying over of historical data in a single term, $\hat{RF}_{p-1}$ which identifies the forecasted RF for the previous period. The value of α should be determined by performing trial runs of the exponential smoothing model with different values until the best fit with historical data is found. The exponential smoothing model is valid as long as no significant changes, such as a change in vendor, are introduced into the system.

Once RFs are determined, specific inventory ordering decisions must be made with regards to how much inventory to order and carry. Before the rebuilding is done, the number of units needed is not known fo certain. The maximum number is known from the number of end items (n) to be inducted and the number of units of the repair part (m) in question in each end item. The probability of needing x units of the repair part is obtained from the binomial distribution as follows: [Ref. 15]

$$p(x)=\{\frac{nm!}{x!(nm-x)!}(RF)^{x}(1-RF)^{nm-x}\}$$

The fill probability of a replacement item is defined as the probability that an item will be available, given a certain stockage level (x), if needed in the rebuild process. For example, suppose an item is used at 20 different points in a particular end item. Suppose that even though the item has a RF which is < 1 associated with it, at each point the item is found to be in need of replacement. If the plan is to have 20 units of an item in inventory all demands will be satisfied. But, if the plan is to have 15 units in inventory, then the rebuild process is short by 5 units and will have to stop until these additional units are obtained. The fill probability, given an inventory of k units of the repair part and an induction schedule of n end items, will then be: [Ref. 15]

$$FP = \sum_{x=0}^{k} \{\frac{nm!}{x!(nm-x)!} RF^{x} (1-RF)^{(nm-x)}\}$$

This ability to determine associated fill probabilities with each possible stockage level leads to the question of what is the acceptable fill probability for each replacement item. Factors that should be taken into account include the shortage costs of the item, such as work stoppage costs, which identifies the cost of the impact on the production process of not being able to fill a requirement, the holding costs of the replacement item if it is not used in the rebuild process, and lead times associated with acquiring additional items to meet demands. A model to accomplish the determination of acceptable fill probabilities is presented in Reference 15. The stockage level necessary to maintain the optimal fill probability may then be determined.

E. CONCLUSION

The automated production control system proposed at the DMA has the potential to be effective if developed and implemented properly in the proper configuration. Management commitment to whatever system is decided upon is the single, most important factor necessary to ensure success. The Army's MSFS is worthy of further investigation if the final decision on which type of system to procure has not been finalized. If the decision has been made to procure an MRP II-type system, liaison with NOSL and the proper management of change will help to get the proper MRP system in place and functioning. In addition, the specific system recommendations of inventory ordering, BOM structure, and replacement factor and stockage level calculations will, if implemented, will make an off-the-shelf MRP II system more compatible with the depot maintenance repair and rebuild environment.

APPENDIX A

MANUFACTURING RESOURCES PLANNING (MRP II)

MRP II results in management finally having the numbers to run the business. One set of numbers, and everybody using the same set of number.
Oliver Wight
[Ref 13:p. 58.]

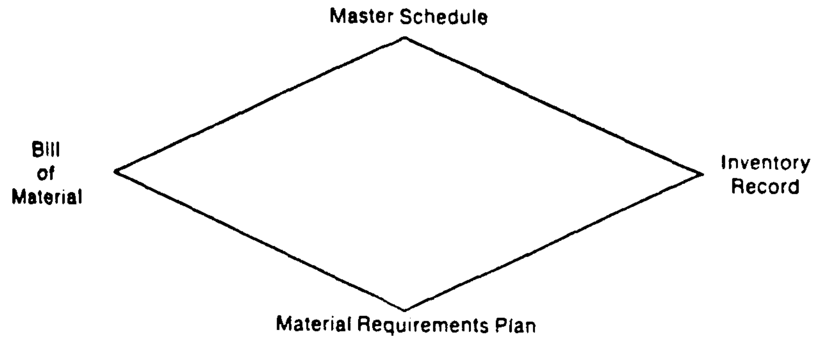
While this thesis does not deal directly with the inner workings of an MRP II system, it is important to summarize the fundamentals of MRP II.

A. GENERAL INFORMATION

MRP II systems simulate material, scheduling, and capacity requirements for management. This simulation is accomplished far enough in advance of actual production so as to allow management to adjust to potential problems and conflicts before they develop.

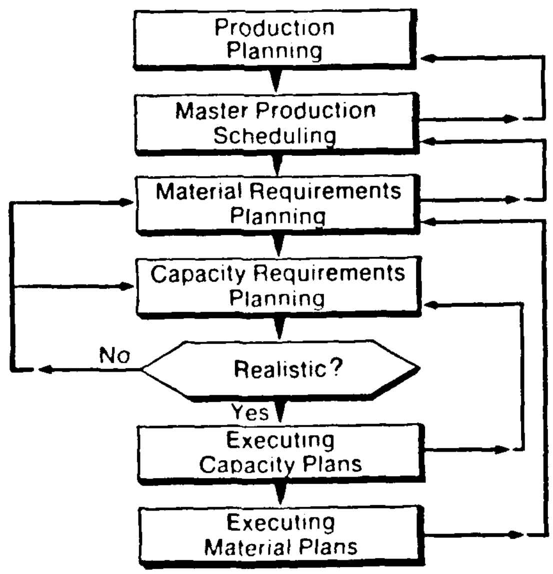
The history of MRP II began in the mid-1960s with Material Requirements Planing (MRP) and the advent of the computer [Ref. 16: p11]. MRP was basically a dependent demand material ordering system which attempted to provide for the precise order release to match the receipt of materials with the actual need for materials on the production floor. This was accomplished by determining valid Master Production Schedules (MPS), Bills of Material (BOM), and Inventory Records (IR) and molding them into an effective Material Requirements Plan (see Figure A-1).

While MRP was found to be an effective material ordering system, its fatal flaw was that the materials system did not take into account capacity restraints found



MRP Logic
(Ref. 14)

Figure A-1



Closed Loop MRP
(Ref. 14)

Figure A-2

in the production process. By the mid-1970s, the second step in the evolution of MRP II, Closed Loop MRP, was developed to identify capacity limitations as an additional variable in the material requirements plan (See Figure A-2).

B. MRP II

1. General

MRP II is defined by the American Production and Inventory Control Society as follows [Ref 17:p. 531]:

> A method for the effective planning of all resources of a manufacturing company. Ideally, it addresses operational planning in units, financial planning in dollars, and has a simulation capability to answer "what if" questions. It is made up of a variety of functions, each linked together: business planning, production planning, master production planning, capacity requirements planning, and the execution support systems for capacity and material. Output from these systems would be integrated with financial reports such as the business plan, purchase commitment report, shipping budget, inventory projections in dollars, etc. Manufacturing Resources Planning is a direct outgrowth and extension of closed-loop MRP.

MRP II can be best utilized in production concerns which have long processing times and complex multi-stage production sequences. There are several desirable characteristics that a production system should have to make it more suitable for MRP II [Ref. 17:p. 533]:

1. An acceptable computer system.

2. Accurate computerized bill of material and inventory status files for all end items and materials.

3. A production system that manufactures discrete products made up of raw materials, parts, subassemblies, and assemblies that are processed through several production steps.

4. Production processes requiring long processing times.

5. Relatively short and reliable lead times for materials purchased from suppliers.

6. The master schedule frozen for a period of time sufficient to procure materials without excessive expediting and confusion.

7. Top managenent support and commitment.

In addition to the desirable characteristics in the production concem, certain key performance measures must be met or exceeded for an MRP II system to work [Ref 13]. These key measures are:

1. Inventory at 95% accuracy.

2. Bills of Materials at 98-99% accuracy.

3. Routings at 95% accuracy.

4. MPS at 95% accuracy by item.

5. Shipping dollars at 100% shipped within the month.

6. Delivery performance at 95% delivery against the original promise date each week.

7. Output by work centers at +/- 5% each month.

8. Shop delivery to schedule at 95% each week.

9. Vendor delivery to schedule at 95% each week.

10. Engineering delivery to schedule at 95% each week.

11. Forecast accuracy at 90% within 60 days in advance.

2. MRP II System

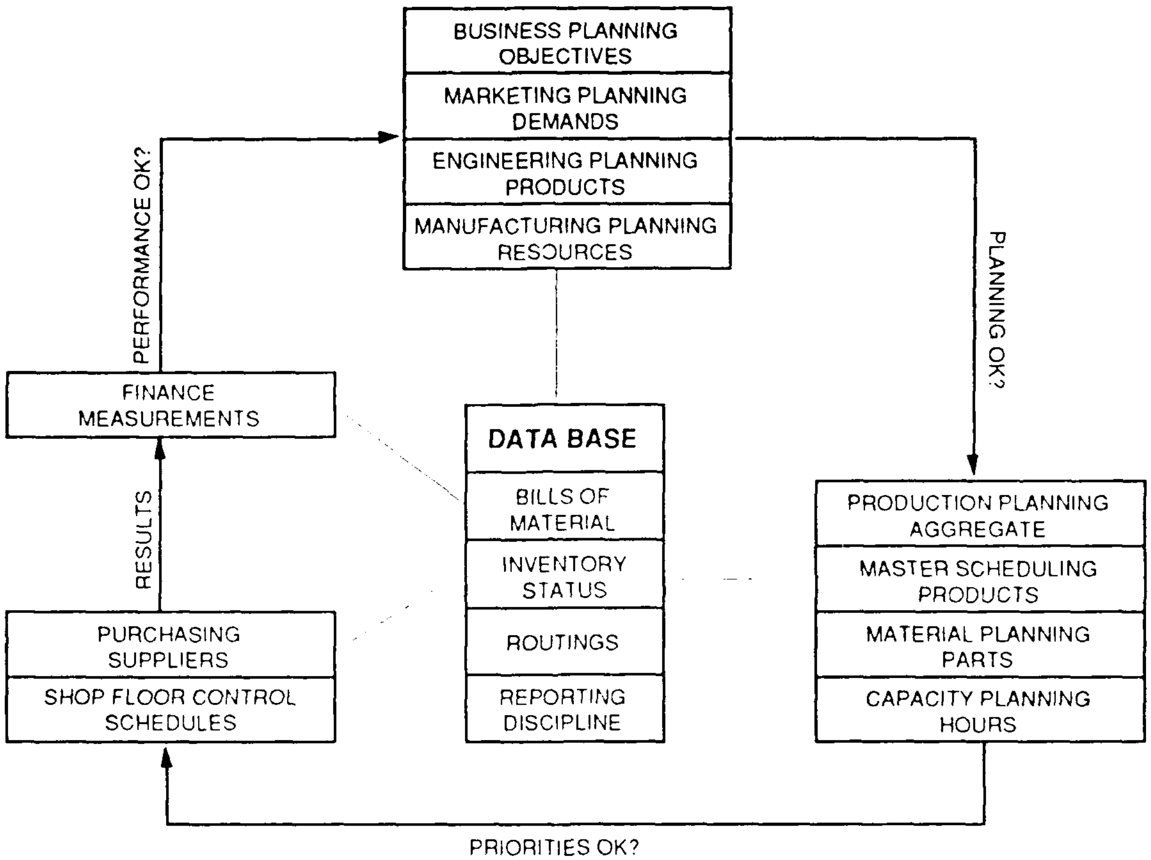
a. System Overview

As previously mentioned, the MRP II system attempts to have all facets of a manufacturing concem speaking the same language and working from the same system. To this end, a closed loop is formed which links all of the individual planning processes together via a common data base in the MRP II system. Refer to Figure A-3 during the following discussion. [Refs. 7 and 13]

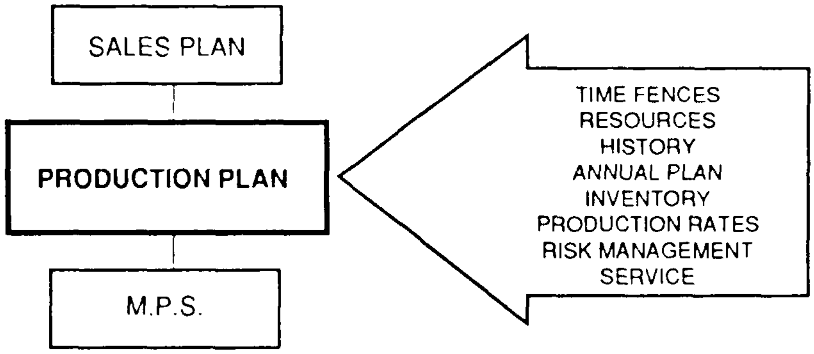
General business planning sets the overall objectives for the manufacturing concern. The overall objectives include both marketing and manufacturing goals. These marketing objectives in turn drive the marketing strategy employed. The demand projected by marketing drives both the engineering plans, for new or modified products, and the manufacturing plan as to anticipated product completion requirements.

From the business, marketing, engineering, and overall manufacturing plans, the overall production plan is generated (see Figure A-4). Considered in the aggregate production plan is the annual business plan, demand history, production rates, time fences, and resource requirements. The end result of production planning is the generation of the master production schedule (MPS). The MPS is the anticipated build schedule for the manufacturing plant. This schedule has yet to be executed and may change, emphasises the production aspect and its differences from selling and shipping, and implies the need for configurations, quantities, and requirement dates.

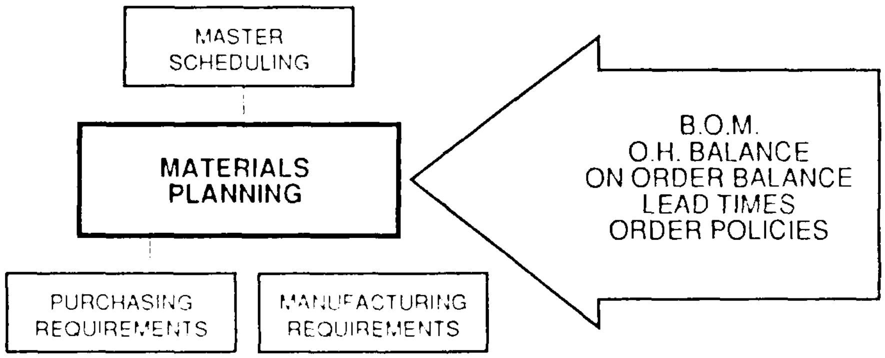
The next step in the closed loop MRP II process is the materials requirements planning (see Figure A-5). Accessing the common data base, materials planning is conducted by considering the BOM structure for each individual product and the inventory issues that manufacturing faces. These inventory issues include on-hand and on-order balances, lead times, and ordering policies. The materials plan then generates a set of purchasing and manufacturing requirements that are necessary



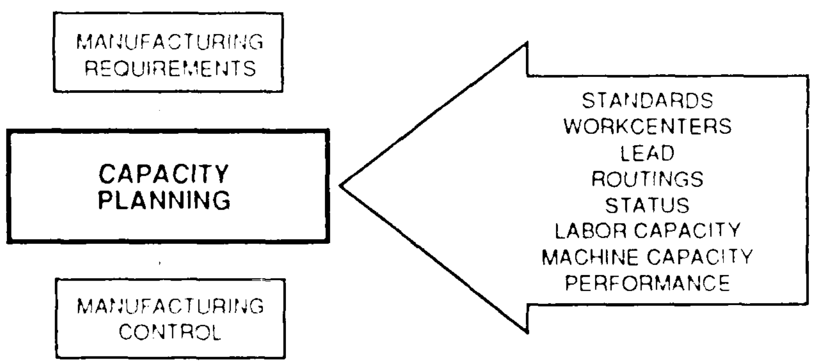
Closed Loop MRP II
[Ref. 7]
Figure A-3



PRODUCTION PLANNING
[Ref. 7]
Figure A-4



MATERIALS PLANNING
[Ref. 7]
Figure A-4



CAPACITY PLANNING
[Ref. 7]
Figure A-5

to complete the production process. All items necessary to produce a given product, whether acquired through the purchasing process or themselves manufactured, are ordered to effect receipt as close to their actual need date in the production process.

Once the manufacturing requirements are established in the MPS, capacity planning is conducted by the MRP II system (see Figure A-6). In order to determine capacity requirements and limitations, manufacturing standards and routings, workcenter capacities which including machine and labor limitations, historical performance, and,finally, the overall manufacturing plan are all considered. Capacity planning then determines the required capacity in each workcenter for each period.

Once the MPS, and its associated materials and capacity plans are finalized, the MRP II system determines the shop floor control required to accomplish the manufacturing plan. Schedules are generated for each work center on the shop floor.

Financial measurements can be equated to manufacturing operations reports generated by the MRP II system. The following financial reports can be a by-product of the operating reports as follows [Ref. 13:p. 251]:

Operations	Finance
Production Plans	Business Plan Master Schedules, Shipping budget, transfers to inventory
Mat'l Rqmts Plan	Current inventories, projected consumption and future inventory balances
Capacity Rqmts Plan	Labor rqmts by grade, capital investments plans
Input/Output Reports	Standard hours of output by workcenter (in units and $)
Dispatch Lists	WIP, labor reporting, efficiency reports
Vendor Schedules	Commitments by vendor

2. References

The following references contain further information about MRP and MRP II:

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APPENDIX B

ACRONYMS

BOM	Bill Of Materials
DLA	Defense Logistics Agency
DMA	Depot Maintenance Activity
DMMS	Depot Maintenance Management System
DOD	Department Of Defense
EID	End Item Demand
EOQ	Economic Order Quantity
FMF	Fleet Marine Force
HQDESCOM	Headquarters, Depot Systems Command
HQMC	Headquarters, Marine Corps
ID	Identification
INV	Inventory Control
IPC	In-Process Control
JON	Job Order Number
JRS	Job Routing and Standards
MATDIV	Material Division
MCLB	Marine Corps Logistics Base
MHE	Material Handling Equipment
MPS	Master Production Schedule

MRP I	Material Resources Planning
MRP II	Manufacturing Resources Planning
MSFS	Maintenance Shop Floor System
MWP	Master Work Program
MWS	Master Work Schedule
NIF	Navy Industrial Fund
NOSL	Naval Ord nance Station, Louisville, Kentucky
NSN	National Stock Number
PC	Production Control
PCC	Production Control Center
PMS	Production Management System
POC	Parts Ordering Control
PRL	Parts Requirements List
PRS	Performance Reporting System
PSS	Product Structure Subsystem
PUR	Purchasing Subsystem
QC	Quality Control
RCV	Receiving Subsystem
RFP	Request For Proposal
SO	Supply Orders
SOC	Shop Order Control Subsystem
TCN	Task Control Number
WS/ESM	Weapons Systems/Equipment Support Management

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