Considerations Involved in Implementing Material Requirements Planning in a Government Contractor Firm

Summer 1983

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CONSIDERATIONS INVOLVED IN IMPLEMENTING
MATERIAL REQUIREMENTS PLANNING IN A
GOVERNMENT CONTRACTOR FIRM

BY
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B.S., Drexel University, 1977

RESEARCH REPORT
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ABSTRACT

The government often imposes requirements on their contractors for the purpose of monitoring and control. Many government contractors utilize a matrix organization structure to help cope with the government's ever changing and challenging requirements. It is both the government requirements and this matrix organization which lead to the need for special information and features in a government contractor's manufacturing/material control system. This report specifically addresses those features which would be desirable in a government contractor's MRP system. These features involve the operation of the master schedule, the bill of material, the MRP software, the inventory files, purchasing, and shop floor control.

No single government requirement is in direct conflict with the intent of an MRP system. However, the interpretation of these requirements vary within the government agencies and between government contractors. The contractor, the appropriate government agency, and the software vendor, if applicable, need to work together to implement a system which satisfies both internal management needs and government requirements. This
report contains features and considerations which should be evaluated when a government contractor is implementing an MRP system.
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I. INTRODUCTION

Purpose of Paper

The dominant theme in production/operations management in the 1970's was material requirements planning (MRP). The major promulgator of this concept was the American Production and Inventory Control Society's (APICS) "MRP Crusade." Today, MRP techniques have been adopted by over one thousand companies and are being taught and researched in most major universities in this country. (Benson 1982)

With all the attention MRP has received in the past decade, one would think that all applications of MRP have been explored and documented. This is not the case. This report will explore an application of MRP which is being practiced with limited success, yet has been largely ignored by the American Production and Inventory Control Society. Specifically, this application involves those firms involved with government contracts.

This report will point out and expand upon considerations which should be addressed when implementing MRP in a government contractor organization. The purpose of this research is to:

1. List the software features and other concerns government contractors should be aware of when implementing MRP.
2. Determine if government contractors are presently using MRP.
3. Determine whether currently available software packages contain features helpful to government contractors.
The need for such research has been reinforced by the comments received after a request for information sources was sent to both management consultants and aerospace-defense firms:

The need for such work is measured by the lack of information published. (Plossl 1982)

... very little has been written about MRP in the government contracting type of business. This is ironic because that is where MRP had some of its foundations. (Everdell 1982)

I appreciate that the topic you have chosen has begun to get the recognition it deserves. It is a difficult one to summarize, because of the almost nonexistence of literature dealing with it. (Anderson 1982)

**Definitions**

Before delving into the special considerations involved in implementing MRP in a government contractor company which is matrix-organized, it is necessary to define the terms involved:

1. **MRP**

2. **Government contractor**

3. **Matrix organization**

**MRP**

MRP can stand for either materials requirements planning or manufacturing resource planning. In this report both terms will be addressed. Initially, MRP stood for material requirements planning and is defined in the fourth edition of the *APICS Dictionary* (Wallace 1982).
A system which uses bills of materials, inventory and open order data, and master production schedule information to calculate requirements for materials. It makes recommendations to release replenishment orders for materials. Further, since it is time-phased, it makes recommendations to reschedule orders when due dates and need dates are not in phase. Originally seen as merely a better way to order inventory, today it is thought of as primarily a scheduling technique, i.e., a method for establishing and maintaining valid due dates on orders.

The more encompassing definition of MRP is often called MRP II or manufacturing resource planning. Manufacturing resource planning is a direct outgrowth of material requirements planning. MRP II involves getting feedback from the production and purchasing operations to monitor performance against the MRP plan. Most importantly, MRP II integrates operational and financial systems of a firm to provide a method of effectively planning and controlling all resources. Ideally, it has a simulation capability to answer "what if" questions and can predict the impact of variations with regard to sales, production, inventories, schedules, and cash flows.

In this report, MRP will refer to the more extensive definition where it is not just a system to launch orders, but involves shop control and ties into the financial systems of a firm.

Government Contractors

Government contractors consist primarily of the aerospace-defense sector of the U.S. economy, as opposed to the commercial products sector. There are over 40,000 firms which fill the needs
of aerospace-defense (Clarke 1970). Even though the government makes purchases for products which are not directly related to aerospace or defense, the majority of high dollar purchases do fall into this category, and the thrust of this report will be directed to the aerospace-defense contractor. There is, however, only one distinguishing characteristic of a government contractor, and that is the federal government must be one of their customers. Most government contractors also have other customers including the governments of other nations and the commercial sector. In this report, the reference to a government contractor generally means that at least twenty percent of their sales are to the United States government.

Matrix Organization

The matrix form of organization is an organizational structure which developed in response to the specific needs of government contractors. Since its development in the 50's, the matrix concept has been applied to various applications. As John Mee (1964) stated in his article on matrix organization,

> It is when work performed is for a specific project contracts that a matrix organization can be used effectively. If the market for the product is a single customer such as the U.S. Air Force or an industrial firm with a prime government contract, the production emphasis changes to the completion of action for a specific work project instead of a flow of work on production programs for product volume.

Therefore, many government contractors use the matrix concept in their formal organizational structures.
As shown in Figure 1, in a matrix organization, a project-oriented organizational structure is superimposed upon the traditional functional organization. Although a traditional functional manager is maintained, personnel are temporarily assigned directly to a specific project. The amount of authority the project manager has to reward or discipline personnel varies from one firm to another. However, the project manager plans, organizes, and controls the tasks and activities of the project, has influence over acquiring the required resources, and has the ultimate responsibility of the results of the assigned contract. "And if we were pressed to pick one word which characterizes the potential of the mature matrix, it would have to be flexibility" (Davis 1977). The project manager utilizes this flexibility to assure that the project objectives are met.

What Makes Government Contractors Unique?

Government contractors, like other business organizations, are designed to meet the demands of their customers. Therefore, it is the unique characteristic of the customer that gives rise to problems not normally encountered when setting up a management system in the commercial sector. Emerson Clarke (1970) lists the characteristics of the government which reflect and shape the contractor organization. These include the fact that its demands fluctuate widely, its requirements are often urgent and must be met under a compressed time schedule, and it exerts close
The functional organization has a solid line reporting structure, and the project-oriented organization has a dotted line reporting structure.
observation and control. The two major factors contributing to the special information needs of these firms are the requirements the government imposes for purposes of monitoring and control, and the untraditional organizational structure which evolved to cope with the customer's ever changing and challenging requirements.

The government requirements imposed upon the firm vary with each contract. For a cost-plus contract, where the government pays all reasonable costs incurred plus a fixed or incentive fee, these requirements would tend to be much more extensive than for a fixed price contract. The higher the total expenditure for a contract, the more restrictive the requirements will tend to be. When progress payments are involved, again the requirements become more restrictive. Also, contract requirements vary due to the political environment or the visibility of the project. National security considerations have an involvement in contractor requirements. In addition, different requirements must be met for a full production program, as opposed to pilot production or research and development. Therefore, any particular government contracting firm may not need to be concerned with some of the issues brought out in this report. However, since many of these firms are involved in more than one contract, and all of these contracts have varied requirements, most issues discussed will affect a firm to some degree.
The actual requirements a contractor must fulfill are specified in the formal contract agreement. These generally take the form of adherence to specific military standards, Department of Defense directives, or other formal documents, periodic reporting requirements, and the necessity of passing a one-time, periodic or continuous audit. This report will concentrate only on those requirements which will affect the operation of an MRP system. Specifically referenced in this report are MIL-STD 1528 (Production Management), Cost/Schedule and Control Systems Criteria Joint Implementation Guide, and associated DOD requirements, MIL-STD 881 (Work Breakdown Structures for Defense Material Items), Army Regulation 70-67 (Production Readiness Review), and DOD-STD 100C (Engineering Drawings and Associated Lists).

An additional factor which may differentiate a government contractor from his commercial counterpart is the organizational structure. Any information system must be designed to support the way the business is organized to accomplish work. In a matrix-organized structure, information must flow along both functional and project lines. For the organization to be effective, each project organization must have some degree of flexibility in the manner it accomplishes work. Therefore, a useful information system, which normally breeds consistency, must afford flexibility. In a commercial organization, the type of information collected and the procedures to accomplish work are normally independent of the final customer. In an aerospace-defense firm, it is possible
to be building the same product, but have different information-collecting requirements and different procedures to accomplish work due to budget or time constraints. In this environment, a formal system must be flexible enough to meet all needs or be used only for selective programs.

Method of Research

As detailed in Appendix A, the research method for this report included sending out a survey to government contractors. Thirteen government contractors were sent the survey in Appendix B, and nine responded. In addition to the survey, letters were sent to nine management consultant firms, eight software houses, and four government contractors. The next two chapters of this report discuss the issues brought out by those who responded to the letters and survey.
II. EFFECTS OF GOVERNMENT CONTRACTOR REQUIREMENTS ON CLASSICAL MRP

Figure 2 is a flowchart of a traditional MRP system. Oliver Wight (1982) explains the mechanics of this system in simplistic terms:

The closed loop MRP system takes a master schedule ("What are we going to make?"), "explodes" this through the bill of material ("What does it take to make it?"), and compares this with the inventory on hand and on order ("What do we have?") to determine material requirements ("What do we have to get?").

A more detailed explanation of this flowchart is as follows. A production plan outlines what the firm's products and objectives are. To meet the firm's objectives, the manufacturing of products is scheduled. The master schedule states each end item product, the quantity needed, and the date that quantity is to complete the manufacturing cycle. A bill of material structure contains both the component parts needed to manufacture the end item and the time it takes to make or procure each component part. Thus, using the master schedule and the bill of material, the MRP system calculates the firm's gross requirements for what is needed and when. The MRP system then compares these gross requirements to what is already in inventory or on order to satisfy these requirements. Those requirements which cannot be satisfied with current inventory or planned orders are net requirements.
The MRP system plans purchase orders for buy items and shop orders for make items to satisfy all net requirements.

In a closed loop MRP system, such as Figure 2, the action plans are compared with the work center's or vendor's available capacity. If capacity requirements are not realistic, the master schedule must be changed and new action plans developed. When the plans are acceptable, they are released to the shop or purchasing and their progress is tracked against the plan. As orders are completed, they become part of inventory. Actual progress is tracked against planned performance so corrective action can be taken and adjustments made.

In Figure 3, the complications of a government organized MRP are introduced. In government contractor MRP, in lieu of an integrated production plan, requirements for the master schedule are a combination of individual project schedules. Inventory is not for the entire organization, rather there are small pools of inventory for each project. The bill of materials must conform to government configuration control requirements, and be able to handle and track the multitude of project changes that will occur during the project life. The MRP process itself must be able to determine the make and buy requirements for the firm as a whole, and at the same time be able to keep these requirements segregated by project. In the shop, it is desirable to combine like products in order to achieve efficiencies, but the status and financial
Figure 2. A Classical MRP System
Figure 3. A Government Contractor MRP System
reporting of these jobs must be done by project. The remainder of this chapter will address these issues in detail.

The Master Schedule

The master schedule essentially drives an MRP system. Basically, it is a statement of what will be produced and when it will be completed. The master schedule can be thought of as the production goal of the firm and the goal of the MRP system. The MRP system generates plans to meet the goals stated in the master schedule. Feedback through the system gives visibility to whether these goals will be met. According to Oliver Wight (1982), the functions included in the master schedule process are making the schedule, updating the schedule because of "top down" (customer) or "bottom up" (capacity, vendor delivery) changes, order entry, customer delivery promises, and relieving the master schedule by issuing work and purchase orders.

The master schedule must be realistic, feasible, and aligned with the priorities of the firm. Joseph Orlicky (1975) points out that "given properly implemented and properly used systems for planning and execution, the master production schedule is virtually the sole determinant of what will happen in the areas of capacity, production, and customer delivery service." To keep the master schedule realistic, it must be aligned to changing priorities and the occurrence of unforeseen situations. The need for flexibility is stated by Orlicky:
In the modern view, a master production schedule should represent a feasible goal, subject to continuous review and adjustment. The master production schedule must no longer be considered a sacrosanct document—on the contrary, it should be treated as a flexible, living plan, adaptive to actual developments. Even in the presence of an MRP system, inventory, priority, and capacity planning will be invalidated in the face of an inflexible master production schedule. (Orlicky 1975)

Areas of concern regarding the master schedule and government contractors involve the fact that multiple program schedules must be integrated to form one master schedule and that any one program schedule may be relatively inflexible due to government requirements. Traditional MRP assumes that the firm has complete control over their schedule and can make decisions that may adversely affect one customer for the good of the firm. This is fine as long as that one customer is not a government contract imposing strict schedule controls.

Integrating Program Schedules

A government contractor with a matrix organization has various project managers who are measured primarily on the performance of their program. Normally, within this environment, many of the schedule priorities are worked out informally between the project manager and the functional organizations. Davis's book on matrix organizations (1977) points out that the project manager relies upon his knowledge, competence, relationships, force of personality, and skills in group management to assure the functional personnel will do what is most beneficial for his project. With in an MRP system, need dates establish priorities for the firm.
These need dates are entered into the master schedule file. Therefore, the priority of each project as related to all others must be formalized prior to input into the system. This formalization of priorities within the master scheduler's responsibility is sometimes seen as a threat to the project manager (Kelleher 1982). To minimize the threat in this type of environment, it is essential that the project and functional managers have a great deal of confidence in the competence of the master scheduler and his method for obtaining information. This person will establish the priorities for the business, so this position must be closely aligned with top management.

Constraints on Schedule Flexibility

An additional area of concern in the master scheduling of a government contractor is the built-in inflexibilities of the schedule of some of these contracts. In the Management of Engineering Projects, Victor Hajek (1977) points out the importance of the contract schedule:

A proposed contract schedule usually accompanies RFP's on major procurements and eventually is incorporated as a contract document. The purpose of the contract schedule is to identify precisely what is to be procured, how many, and when, and sets forth all the terms and conditions of the procurement contract. The contract schedule represents the most important legal document of a procurement and generally takes precedence over all other documents such as the specification.

The contract schedule can be a fairly broad statement which still leaves room for management decisions and flexibilities concerning specific schedule requirements. In general, this schedule
represents the latest date requirements must be met, but allows the scheduling of completions prior to these dates and leaves the scheduling of specific tasks to management discretion. However, if the contractor is obligated to meet cost/schedule control system criteria (C/SCSC), much more stringent constraints are imposed. The Cost/Schedule Control System Criteria Joint Implementation Guide (U.S. Department of the Air Force et al. 1980) requires a scheduling system to "contain a summary or master schedule and related subordinate schedules which provide a logical sequence and show interdependencies from the summary to the detailed work package levels." These types of requirements have been opposed by the defense industry and the oppositions are documented in the final report presented by the defense industry 15-man ad hoc committee for the application of C/SCSC to production (U.S. Department of Defense 1978). Specific objections brought out by this committee include the fact that the performance baseline does not allow reflection to the latest schedule resulting from internal shop loading changes, and that the required "schedule contents must be modified to reflect use of such items as master shop load and supporting schedules under which hardware is built." In this same document the following change to the wording of the joint implementation guide was proposed:

If a contractor has a dynamic and well disciplined production system (Material Requirements Planning (MRP) is one example) which is capable of reacting effectively and efficiently to the daily manufacturing environment
changes, the contractor is permitted to let the system automatically drive the scheduling or rescheduling (time phasing) of both open and unopen work packages and other discrete task measuring methods as long as these changes have no effect on the end item shipping date.

This wording was not incorporated in the joint implementation guide. Not only does the C/SCSC requirement disallow changes to the master schedule, but under certain circumstances changes to the detail plans are not allowed. This is contrary to an MRP system in which the detail plans are continually being updated and altered as a result of the MRP process itself.

How can an MRP system, which is based on planning and replanning to reflect current needs, operate under such constraints? Fortunately, for their own purposes, a government organization has developed a requirements planning system which can deal with this. A requirements planning system for the space shuttle operations schedule was designed to allow the freezing of all plans associated with one program, while the system schedules all other programs based on need date (Steinberg et al. 1980). This system is based on the concept of MRP and has additional features to handle situations where schedules and detail plans cannot be changed. In this system, the master schedule file has a priority override and schedule hold field in addition to the flight number (unique master schedule item designator), launch data (end need date), and flight type code (end item part number). The priority override is used when the need arises to circumvent the normal prioritizing scheme of the earliest launch date first. The
schedule hold capability tells the system it must maintain the existing plans and not generate a new set of plans and requirements for a given flight. This is similar to the capability of firm-planned order used in MRP systems; however, a schedule hold is for all the plans generated from a master schedule entry, whereas a firm-planned order is for one particular plan. Although an MRP system will operate most effectively if the master schedule can be dynamic to meet the business needs, and the detailed schedules can be planned by the operation of MRP, this method demonstrates the capability of using the master schedule file to keep certain plans constant if customer requirements deem this necessary. If this method is used in one or a few of the many entries in the master schedule, the benefits of an MRP system will not be totally compromised.

The Scope of the Master Schedule and the Work Breakdown Structure

Depending on the objective of the MRP system, the master schedule could reflect only hardware requirements (material requirements planning) or all contractual obligations (manufacturing resource planning). In most government contracts, in addition to the hardware, there are requirements for such things as training, data, support equipment, and operational site activation. If desired, an MRP system can support these requirements. MRP techniques have also been used to schedule design, drafting, and test activities in addition to fabrication and assembly. An MRP system
can be designed to schedule and control the resources necessary to provide all contractual requirements. In this case, the master schedule entries could be synonymous with a particular level of the project work breakdown structure provided by the customer. The project work breakdown structure will be further explored in regard to the bill of materials. However, it should be pointed out that the master schedule entries need not be limited to hardware or even tangible items.

**Bill of Material**

Simply stated, a bill of material (BOM) is a "listing of all the subassemblies, parts and raw materials that go into a parent assembly showing the quantity of each required to make an assembly" (Wallace, *APICS Dictionary* 1982). Figure 4 shows a typical BOM for an electronic assembly. In an MRP system, the BOM lists the parts needed to fabricate or assemble a part. The structuring or relationship of all the BOMs in a product partially describes how the product is put together. Bill of material is the basis for configuration control which shows that a particular product at a particular time was manufactured with a particular set of materials. An extension of configuration control is configuration management which identifies characteristics of an item, controls and keeps track of changes. A configuration management system is compulsory for all major government contractors. DOD instruction 5010.21 describes configuration management as:
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Figure 4. Example Bill of Material Format for an Electronic System and Cabinet #1
A discipline applying technical and administrative direction and surveillance to (1) identify and document the functional and physical characteristics of a configuration item, (2) control changes to those characteristics, (3) record and report change processing and implementation status.

In his article on configuration control for MRP, Quigley (1980) states that "an effective MRP system requires an accurate BOM. To have an accurate BOM you must have a well designed and managed configuration control system." Government configuration control requirements put the contractor in a supportive position for establishing the government contractor's bill of material on an MRP system. Moreover, since a successful configuration management program depends upon the rapid recording and reporting of configuration status, most government contractors have already automated their bills of material. The government will assist in determining if the BOM is accurate through audits such as the Production Readiness Review (DOD Instr. 5000.38 1979) which specifically asks if "a complete and accurate bill of material has been prepared" and "a system configuration audit has been accomplished and discrepancies resolved." In government contracts, change is inevitable and usually frequent. Numerous procedures and directives have been published for managing this change. Charles Andrews (1975) states "there is surprisingly little in the literature concerning engineering change. Except for the overly-documented procedures for government work and aerospace industry ..." Even though government publications have
documented procedures for engineering change, today's standard MRP systems have not incorporated these procedures.

Serial Number and Historical Configuration Control

One of the primary reasons a configuration management system is imposed is so the government can easily obtain the correct spare parts for a particular product. This product is normally identified by a specific serial number. Therefore, a complete MRP system would need to provide historical information of the product configuration based on a specific serial number. Very few software packages today contain serial number traceability. If there is a provision for configuration control within an MRP system, it is based on date effectivity. This is often not sufficient for government contractors. The same product may be being built within the same time frame for different customers; one customer may require an engineering change, while the other customers will not approve that change on their programs. In a statement of requirements written to a major MRP software firm, among the suggested features needed to support government requirements is the request for configuration control by both revision letter of the drawings and associated lists and serial number of the product (Arnold 1982).

In addition to being able to maintain configuration control by serial number, this information must be historical so previous configurations are not lost. In his article called "Engineering Changes to the Product Structure-Opportunity for MRP Users," Charles Andrews stated that in today's MRP system, the most common
change encountered in product structure is to add a new part and delete the old one. In his entire article there is no reference to storing previous product configurations and to being able to recall these by either serial numbers or revision or even date effectivity. These features must be designed into a government contractor's manufacturing and material control system.

One or Two Bills of Material

Many of the government contractors who have put in a BOM subsystem for MRP have had to establish two bills of material. Due to timing considerations, the MRP and engineering design bill of materials are kept in separate systems. The first cause of requiring two BOMs is a temporary situation when the program is in the development stage and change is occurring continuously. Often the contractor must begin purchasing material before the product is completely designed. If the MRP base uses the engineering design BOM, then each time a revision is made, appropriate change action must be taken. This change action is governed by the configuration management requirements and will cost from $50.00 to $300.00 in administrative costs. It is more cost-effective to release to manufacturing only an advance BOM for long lead time items. When the design is complete, the true BOM can replace the advanced order list. A system which has been designed to deal with this situation is explained in a case study of MRP.

As Engineering completes the design work for individual component items, and buildable drawing numbers are assigned to these items, an exchange is made in the product
structure file to replace the temporary part numbers with the actual part number from the engineering drawings. Consequently, as time passes, the imaginary bill of material becomes a mixture of temporary and actual part numbers, culminating in the final bill of material. (Berry et al. 1979)

Some government contractors feel it is necessary to permanently maintain two separate BOM files. This is due to the timing of revision control which is part of the configuration management system. At any given time, there are engineering change notices which are initiated or approved by the government but not yet incorporated into manufacturing. Some government contractors have resorted to maintaining two sets of bills of material so that both the latest approved design and a bill usable for ordering parts and assembling the product are contained within the system. The engineering BOM reflects the latest design and meets requirements such as DOD-STD 100C (1978). The manufacturing BOM contains the information necessary to order the correct parts and build the product. Guidelines are established concerning which BOM is used for each function such as costing, inspection, and delivery to the customer. The engineering BOM often serves as the initial baseline for the manufacturing BOM. The manufacturing organization then supplements and revises the engineering bill to meet manufacturing requirements for ordering material and assembling the part.

In response to a letter requesting information on how MRP functions with government contractors, a government contractor employee summarizes his company's solution to BOM meeting both government and MRP requirements:
The government owns the bill. Modifications must be cost justified to the government, not to our management. Redrawing is an expensive proposition. Yet to have a truly representative manufacturing bill, we have developed in-house bills at our own expense. We now maintain two (2) bills of material and the inter-relationships of the two. Formal changes are made to the engineering (gov't) bill and translated into the manufacturing (in-house) bill so that the change is actually made. --In our proposal for an MRP system, we have requirements for the vendor software to manage two bills of material. (Anderson 1982)

Bill of Material or Requirements and the Work Breakdown Structure

As mentioned in the master schedule section, an MRP system can be used to plan and control all contractual requirements, not just hardware. In this case, the bill of material is called a bill of requirements because it defines the relationship of all activities and resources used for the project, not just material. Figure 5 shows what a typical bill of requirements for an electronics system might look like. At least the first three levels of the bill of requirements are defined by the government in the form of a project work breakdown structure (WBS). An MRP system used to control the total program must conform to the WBS in any contract where Mil-Std-881A is applied. Mil-Std-881A (1975) is a requirement of most government contracts, and states that "the contract WBS shall serve as the framework for the contractor's management control system which will provide auditable or otherwise traceable summarizations of internal data generated by his performance measurement procedures." In most government contracts, manufacturing and delivery of the equipment is only one requirement
<table>
<thead>
<tr>
<th>Component ID #</th>
<th>Nomenclature</th>
<th>Qty UM</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>11111</td>
<td>Electronic Sys. H/W</td>
<td>1 ea</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>111-2</td>
<td>Training</td>
<td>4 wk</td>
<td>Marketing</td>
</tr>
<tr>
<td>111-3</td>
<td>Support Equipment</td>
<td>1 set</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>111-4</td>
<td>Data</td>
<td>1 set</td>
<td>Engineering</td>
</tr>
<tr>
<td>111-5</td>
<td>Site Activation</td>
<td>2 site</td>
<td>Marketing</td>
</tr>
<tr>
<td>111-6</td>
<td>Spares</td>
<td>1 set</td>
<td>Manufacturing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component ID #</th>
<th>Nomenclature</th>
<th>Qty UM</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>111-4-1</td>
<td>Technical Publication</td>
<td>1 set</td>
<td>Marketing</td>
</tr>
<tr>
<td>111-4-2</td>
<td>Engineering Data</td>
<td>2 set</td>
<td>Engineering</td>
</tr>
<tr>
<td>111-4-3</td>
<td>Management Data</td>
<td>1 set</td>
<td>Marketing</td>
</tr>
<tr>
<td>111-4-4</td>
<td>Support Data</td>
<td>1 set</td>
<td>Engineering</td>
</tr>
</tbody>
</table>

Figure 5. Example Bill of Requirements for an Electronic System and Data
of the contract, and often not the most time-consuming or costly area.

Even if the MRP system is limited only to manufacturing products, the system must be integrated with the hardware portion of the WBS because of the above Mil-Std-881A requirement. The reporting of performance to the government is based on the WBS. If the MRP system is recording performance data in manufacturing, then the MRP system must collate and report that data in conformance with customer requirements. If the bills of material support the WBS, then no conflict exists since MRP systems are generally designed to gather and report data based on product structure. For example, an integrated MRP system should be able to report the schedule and cost performance of a given subassembly by time-phasing and rolling up the costs of components into the next higher subassembly. Often the WBS is expressed in generic terms and does not relate to the product structure. For example, the government may wish to collect the performance data of manufacturing all cables, all formed metal parts, and all printed circuit boards. A subassembly consists of all these items, and a standard MRP system can only define performance in terms of the product structure. To provide summary reporting of classes of generic items, the system must be able to identify what class each part number belongs to. This can be done with part number coding, disciplined use of nomenclature, or a separate coding field associated with the part number. If a government contractor cannot guarantee that
the WBS and the product structure will be compatible, a method of coding each part must be designed into the system to support customer performance reporting requirements.

Part Substitutions in the Bill of Material

Another BOM feature which can be useful to government contractors is the capability of using part substitutions when the design part is unobtainable, and having the system record and track this substitution. Of eight government contractors who are presently implementing MRP systems, seven of the respondents to the survey in Appendix B responded that they use part substitutions within their MRP system; the eighth respondent uses part substitutions outside the formal BOM file. Part substitutions of a permanent nature (whenever part P is called for, buy part S until specified otherwise) is useful when a vendor's part number changes and there is no change to form, fit, or function. Deleting part P and adding part S on the government "owned" BOM would require formal change procedures which can be expensive. The capability of keeping both parts on the BOM will not require official change processing of the government owned BOM since form, fit, or function are not affected. For spare procurement, the original component part on the historical BOM (part P) for a serial numbered product would be directly traced to that part on the current BOM (part P) and the part number to purchase (part S) is readily apparent. Part substitutions of a temporary nature (use part T whenever part P is called for until 2000 part T's are used) is useful when more
timely delivery can be obtained for a part which is equal to or better than the part originally called for. In an atmosphere where requirements are often urgent and must be met under a compressed time schedule, this feature provides the means to make timely business decisions without compromising government requirements. The popularity of BOM part substitution capability attests to the fact that the benefits outweigh the costs of this feature in a government contractor environment.

**Inventory**

In a government contract, the inventory purchased and stored for use on the program may be owned by the government or the contractor. If progress payments are applicable, the inventory is considered "owned" by the government. Progress payments are economically beneficial to the contractor. The contractor will maintain detailed inventory records by program to receive these payments. Among the advantages in holding government contracts, Emerson Clarke in his 1970 book states, "The government will provide financial assistance to contractors in the form of progress payments up to the amount of 80% of the incurred costs." Progress payments give the government a vested interest in the inventory for their project, thus controls are imposed to protect the government's interest. The exerting of strict controls over a certain class of inventory complicates the implementation and maintenance of the contractor's MRP system. First of all, the amount of
information which must be maintained is more than what is normally required in a traditional MRP system. Secondly, the system must be able to manage discrete pools of inventory for each contract, as well as inventory for the total company.

A survey sent to nine government contractors who are involved with MRP indicated that inventory is closely monitored in a government project. This survey is presented in Appendix B and the method of selecting companies to receive the survey is explained in Appendix A. In response to the questions concerning inventory, seven of the nine respondents stated that the government always or sometimes "owns" the inventory to be applied to a contract. These same seven respondents stated that they are required to keep inventory for particular government contracts completely separate from all other inventory. Often this separation is actually a physical separation; i.e., separate stockrooms. This can be expensive to the contractor in terms of both real estate and personnel. However, if the contractor can prove it has a good inventory information system in place which can logically associate material belonging to a particular project, the government will probably not require the inventory to be physically separated. Therefore, the inventory records in a government contractor MRP system must have the capability of being "pegged" to an associated project.

A commercial firm's inventory file is two-dimensional, but for government contractors a third dimension is needed, as shown
THREE-DIMENSIONAL FILE

Total All Projects

Project A B C

Time Periods (1-7)

A B C A B C A B C A B C A B C A B C

TWO-DIMENSIONAL FILE

Gross Requirements

10 10

5 10 5

Scheduled Receipts

10 10

5 10 5

On Hand

72 70 55 12

50 20 70

Planned Order

20

10 20

-5 5 0

Transferred In/Out

5 0

Figure 6. Two-Dimensional vs. Three-Dimensional MRP Inventory
in Figure 6. For the inventory files used in MRP, gross requirements, scheduled receipts, on-hand balance, and planned releases must be maintained, both by time period and by project. For control over project inventories, information is often maintained for actual purchase receipts, actual issues to the shop, and actual scrap and shrinkage quantities. The capability of controlling inventory quantities for both the total and each separate project was expressed as one of the priorities in a letter from a government contractor's interest group to a software house which is in the process of developing MRP software for government contractors. The author of the letter (Arnold 1982) requested the following feature:

Stores control by WBS element

on-hand usage controlled by relationship to WBS (simultaneous capability for control of one quantity of an item for general usage and another quantity of the same item specific to the contract.)

Although each program may have its own discrete pool of inventory, interrelationships between these inventory pools will exist. It is unrealistic to assume that the material will never be transferred from one pool of inventory to another. As Oliver Wight (1974) states, "The point is a simple one: inventory is a limited resource that must be used for the best overall interests of the company." When it is in the best overall interests of the company, government contractors will borrow material from one program to be used within another program. In most government contracts, this is allowed as long as it is properly documented
and does not adversely affect the program schedule. Therefore, in addition to the fields of information already mentioned as necessary for inventory control, both planned and actual transferred-in and transferred-out information should be kept by both project and time period. The classic MRP inventory equation (Orlicky 1975) of 
\[ A + B + D - C = X \]
would be modified to 
\[ A + B + D + E - C - F = X, \]
where
- \( A \) = quantity on hand
- \( B \) = quantity on order
- \( C \) = quantity required
- \( D \) = quantity planned for future order release
- \( E \) = quantity planned to be transferred in from other programs
- \( F \) = quantity planned to be transferred out to other programs
- \( X \) = quantity available

Maintenance of the quantities shown in Figure 6 by both time period, project, and total will be sufficient to support MRP and also conform to government controls.

It has previously been stated that a government contractor's inventory file consists of discrete pools of inventory which interrelate. These interrelationships are often not consistent. Program A's inventory pool may be under strict controls in which none of its material may be transferred out until the project is complete. Another inventory pool may consist of general usage parts which are freely available to be applied to all programs. To provide for these inconsistencies in "borrowing" policies, a code could be used to represent the degree of borrowing permitted for a particular program's inventory. This inventory borrowing code is necessary so that MRP can make plans which represent the business
decisions actually made in the firm.

**Material Requirements Planning**

The MRP process uses the information from all the other files to determine both the firm's requirements and the resources available to support those requirements. "Introduction to MRP" by MITROL (1979) describes the material requirements planning function:

This function is concerned with the overall logistics of the flow of material into and through the plant in order to satisfy demand schedules for finished products. The MRP coordinates all of the information on the state and activities of the purchasing, production control, and inventory control areas, in order to determine the what, how much, and when of all material flow in each of these areas.

The MRP program itself translates schedules for end items into make or buy plans for each component part.

The MRP process begins when the bill of material for each master scheduled end item is exploded down to its lowest level. The BOM product structure, along with the specific quantities in each BOM item and the lead time for each component, are used to calculate what quantity of a specific part is needed and when it is needed. These gross requirements are compared to what is on hand (inventory) and what is on order (shop and purchase orders) to determine if and when additional orders should be placed. These requirements are summarized for each part number, and in doing this the sources of these requirements (next higher assembly or master schedule item) are obscured.
Pegging Capability

Government material control requirements often insist that material is traceable to the requirements source. This is particularly true if inventory is "owned" by the government. The pegging of requirements provides the capability to trace requirements for a part to its original source in a BOM or master schedule. In the APICS Dictionary, Wallace (1982) defines pegging and pegged requirements:

Pegging can be thought of as "live" where-used information. Pegged Requirement - A requirement at a component level that shows the next level parent item and the source of the demand that actually created the requirement.

In the survey of government contractors shown in Appendix B, five of the respondents claimed they had an operational MRP process. Four respondents use full-level pegging to trace contract requirements; the fifth respondent lumps common parts together. When requirements are pegged, the source of the component gross requirement or next higher level parent which has a planned order is stored (or pointed to) in the component record. Joseph Orlicky (1975) explains how this is accomplished and the difference between single-level and full-level pegging.

With the single-level peg a succession of peg inquiries is required to trace item demand to an end item lot (or lots) called for by the master production schedule. In order to link item demand to that schedule by means of a single inquiry, the so-called full-peg capability would be required. Under the full-peg approach, each individual requirement for a component item is identified with a specific product (or end item) lot, or customer order, listed in the master production schedule.
Full-level pegging is desirable and often necessary for government contractors so that each order can be traced to and often charged to a specific contract. At least one MRP software vendor sells two versions of an MRP package due to this feature. One version has single-level pegging and the other version has full-level pegging. The latter is called an "aerospace" version and was specifically designed to meet the needs of government contractors (Rath & Strong 1982).

Contract Separation

As stated previously, the MRP process calculates gross requirements and compares the quantities and timing to what is on hand and on order to determine what orders should be placed. In a government contractor organization, should the requirements, inventory, and orders for a part be analyzed on a contract basis or for the entire firm? If MRP is run separately for each contract, then the efficiencies offered by combining like orders will be lost. If MRP looks at the firm as a single entity, the MRP process may formulate plans based on using government owned inventory on a commercial contract. One MRP software package, which is currently being developed specifically to capture the government contractor market, offers a choice of two possible policies: MRP will cross contracts for common items, or MRP will not cross contracts for common items (Conserve 1982). In actual practice, government contractors use a combination of both these policies.

Where possible, a firm would first use the inventory
belonging to a specific contract to satisfy the requirements of that contract. However, to meet schedule constraints or to use up surplus stock, it would be quite feasible to transfer material from another contract to this government contract. A government contractor MRP should determine the actions necessary for each project without losing sight of the firm as a single entity and the resources the firm has to offer. Along this line, purchase and shop order actions should be combined to gain economies of scale, while logically kept separate within the system for cost and contract traceability. This latter requirement has been accomplished in several MRP systems being used today. The former requirement, taking into account inventory transfers, is not a feature offered in the MRP processing logic of any MRP system being commercially offered, or in any of the MRP survey respondents' systems. Although theoretically possible, this feature would require processing logic much more complicated than the classical MRP system. In order to achieve this, a set of priorities would have to be defined and entered into the system. These priorities would tell the system what inventory pools to look at if a contract's requirements cannot be met with its own inventory.

A compromise between complicating the MRP system to automatically perform inventory transfers and ignoring the fact that transfers exist is a possible approach to this issue. One such compromise would be to inform production personnel of the need for inventory transfers but not allow the system to automatically
perform these transfers. With this approach, it is not necessary to enter priorities into the system. First, the classical MRP process would be performed, looking at the entire firm as a single entity. Inventory is applied to requirements on a need date basis. Then for each part which is common across contracts, the pegged requirements are compared against the on-hand and on-order inventory for that contract. When the inventory belonging to that contract is not sufficient to meet the needs of that contract and MRP has not planned an order to cover those needs, a message would be sent to production notifying them that an inventory transfer is needed. Thus, MRP is assuming that all necessary transfers will be made. However, production is being warned of this assumption. If an assumed transfer cannot be made because of government restrictions, production will be able to take the necessary action and force an order in lieu of the inventory transfer.

Additional compromising solutions which support inventory transfers and contract separation are feasible. However, any attempt to deal with these two issues will add complications to the classical MRP process. In the words of Joseph Orlicky (1975), "With material requirements planning, 'eggs' are deliberately 'scrambled', as it were. Full pegging attempts to keep the eggs from getting scrambled in the pan--an awkward and often impossible task." Tom Hill (1982), a respondent to the survey in Appendix B, also addresses this issue of MRP and contract
The Gov't wants complete visibility down to the part level cost on a program. This is not a problem if the program has no parts in common with any other program (military or otherwise). However, if there is commonality, MRP (even pegged requirements) has a problem with cost collection and allocation if parts from different programs are run (or purchased) together. The ability to collect requirements from various programs and explode, order, control these requirements together is the strength of MRP. The mingling is unacceptable to the Gov't, at least as a matter of policy.

The Execution Subsystems--Purchasing and Shop Floor Control

The execution subsystem is where work is actually performed and monitored to ensure that work is being completed to the plan and schedule laid out by MRP. Hall and Vollmann (1978) describe the execution subsystems as "mostly detailed planning and control of purchasing and the shop floor to ensure that front-end planning is actually accomplished. As one authority put it, 'Execution in the shop is where the rubber meets the road'." Shop floor control and purchasing subsystems must provide timely feedback so that priorities can be maintained and corrective action be taken when needed.

The classical MRP system will bundle requirements so that any given shop order or purchase order may consist of requirements for several contracts. Although a company may elect to keep orders separate by contract and develop software to do this, most will choose to combine orders to gain the economies of lot sizing.
In the Appendix B survey, six of the eight respondents have systems which will combine orders at the common parts level. When this combining or bundling is practiced, there often must be a logical unbundling to meet government requirements. Restrictions imposed by C/SCSC, progress payments, strict configuration management, or consumption audits require that the line item quantities on a purchase order or shop order be directly traceable to the contract which generated it. The 15-man committee's report concerning the application of C/SCSC to production demonstrates how a shop release or purchase order is often combined as far as the vendor or foreman is concerned, yet logically kept separate within the system so quantities are directly traceable to a contract.

A typical shop release might look as follows:

<table>
<thead>
<tr>
<th>SHOP RELEASE #</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>RELEASE QUANTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>123</td>
<td>55555</td>
<td>Plate, front</td>
<td>100</td>
</tr>
</tbody>
</table>

Contract data known internally to the system includes the following:

<table>
<thead>
<tr>
<th>CONTRACT</th>
<th>QUANTITY</th>
<th>PRORATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Contract</td>
<td>50</td>
<td>50%</td>
</tr>
<tr>
<td>B-Contract</td>
<td>10</td>
<td>10%</td>
</tr>
<tr>
<td>C-Contract</td>
<td>10</td>
<td>10%</td>
</tr>
<tr>
<td>D-Contract</td>
<td>30</td>
<td>30%</td>
</tr>
</tbody>
</table>

The same type of bundling, unbundling, and prorating would be required for purchase orders.

Most government contractors contacted are using this type of system which prorates costs to the applicable contracts.
However, as one respondent (Anderson 1982) put it, "The overhead incurred by maintaining exact audit trails and lot proration by contract is enormous." He expands upon this statement with an example such as the following:

Suppose the above lot is split 80/20 due to a material shortage:

<table>
<thead>
<tr>
<th>Contract</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50%</td>
<td>10%</td>
<td>10%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>10%</td>
<td>10%</td>
<td>30%</td>
</tr>
</tbody>
</table>

Assume the lot for (20) twenty will be finished first. Material is expedited for (30) thirty more because contract A is hot.

<table>
<thead>
<tr>
<th>Contract</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50%</td>
<td>10%</td>
<td>10%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>10%</td>
<td>10%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>10%</td>
<td>10%</td>
<td>30%</td>
</tr>
</tbody>
</table>

Now, contract A has an issue of both the split lot for 20 and the one for 30. Transfer control (audit trails) must be maintained for these parts.

<table>
<thead>
<tr>
<th>Contract</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>---</td>
<td>20%</td>
<td>20%</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

Anderson sums up what this example is trying to demonstrate:

As you can see, there are lots of new and extra transactions. So even though the full-level pegging provided the base data, using it is what causes the overhead.

In addition to the capability of providing an audit trail, the execution subsystem for government contractors must have another capability which is not required in a classical MRP system. The ability to report status and provide output reports by
program is a necessity for government contractors. This capability is possible when full-pegging is carried through to the shop order or purchase order number and into the respective subsystem. Each program manager is interested in seeing the status of only his program as compared with his particular program plan. The functional manager is interested in all jobs in the shop or all outstanding purchase orders; thus he uses the standard type of reports which would be provided in a classical MRP system.

To provide the special reports which are particular to only one program, two features are necessary in the system. First, there must be full-pegging that not only ties each requirement to the contract which originated it, but goes one step further and tags specific quantities in each order (both planned and actual) to the contracts which generated the requirements. The second requirement is a report generator capable of extracting only the information which is tied to a specific contract code. This feature of an MRP system is not only feasible, but is presently available in a few standard software packages currently on the market.

Two major points have been brought out in regard to the execution subsystems providing program control with information sufficient to meet government requirements. First, a necessary prerequisite is that the MRP system has full-pegging capability. Secondly, even with full-pegging, the software necessary to
maintain shop orders and purchase orders logically segregated by project, substantially increases the computer resources needed and the complexity of the system.
III. PROJECT MANAGEMENT, GOVERNMENT REQUIREMENTS, AND COST/BENEFIT CONSIDERATIONS

This chapter discusses three general considerations for government contractors using MRP. These considerations cannot be classified as affecting any one particular module in MRP. The first concern involves the use of project managers and the concept of matrix management. A formal project organization overlapping a functional organization adds an additional layer of complexity upon implementing and operating an MRP system. The second general concern involves having the government as the customer. The MRP concept must be "sold" to the government who must audit and approve the contractor's planning and control system, and the system must satisfy the auditor's interpretation of military specifications and requirements. The third concern involves the costs and benefits of implementing MRP in the controlled and financially unique environment of a government contractor. The controls required by the government may inflate the cost of implementing an acceptable system. The standard benefits associated with MRP may be less rewarding when financial incentives such as progress payments are involved. Project management, government requirements, and cost/benefit considerations affect the design, implementation, and operation of the total MRP system.
Many government contractors use the matrix form of organizational structure that was shown in Figure 1. A project-oriented organizational structure is superimposed upon the traditional organization. This matrix structure complicates both the implementation and operation of an MRP system. Project managers must be educated in MRP concepts, and their resistance to change must be overcome. Implementing a formal MRP system may require breaking down informal personal ties which program managers previously utilized to gain resource advantages for their programs. Program managers must be convinced that the implementation of an MRP system can benefit them in achieving the objectives of their program. The power of the program manager would be greatly diminished if the MRP system did not allow the program manager to retain flexibility in acquiring resources and controlling activities. In addition, the information obtained from the system must be extracted in a format useful to the program manager. Each of these factors will have an influence on either the cost of training, implementation, software, or possibly hardware for the MRP system.

Education of Project Management

Education of personnel is the problem most often cited in implementing an MRP system (Anderson et al. 1981). Without an understanding of the new system, resistance to it must be expected.
Once a company has decided to go ahead with an MRP program, then the critical mass - virtually everybody in the company - must be educated. They need to understand that MRP will result in more of the right material being available at the right time. They need to understand what MRP is, how to use it, and especially the new set of values. (Wight 1982)

In a matrix-organized firm, the project-oriented personnel need to be educated as well as the traditional functional personnel.

David L. Baer (1982) discusses three portions of educational requirements needed for management. These are conceptional education, applied systems education, and on-going education. Since program managers serve essentially the same function as the general manager within their program, they should be educated as extensively as the general manager. Conceptional education can be obtained through video courses, seminars, or professionally run live classes either in-plant or outside. Applied systems education can be obtained from an outside consultant, a vendor of a software package, or internal systems experts. If the former methods are used for applied systems education, an in-house expert should be accessible who can relate to concerns specific to the firm and its personalities. Ongoing education can be obtained through newsletters, seminars, or in-house presentation.

No matter what method of education is used to educate project management it should do the following:

1. Provide an understanding of the concepts of MRP.

2. Point out how managers can control the output of the system through control of the input.
Provide a means to answer questions and dissolve fears concerning the new system and its specific use on "my" program.

Be undertaken prior to, during, and after implementation. Oliver Wight points out that while education typically accounts for only 20% of the cost of implementing an MRP system, it is the key element to success. "The rest of the investment in MRP will be wasted if the education job is not properly done" (Wight 1982)

A typical educational program for program management should, as a minimum, consist of a 2 to 3 day outside seminar or an MRP concepts video course, and 1 to 2 hour presentations given by in-house personnel on a monthly basis during implementation and less frequently thereafter.

Breakdown of Informal Project Ties

Project managers have the responsibility for carrying out the customer's objectives. They have the same responsibility as the general executive for their particular project; however, they do not have the same undivided authority as the general manager. Stanley Davis (1977) points out that since most of the project team members actually report to a functional manager, the program manager has very little of the required authority needed to meet their responsibilities.

Thus, they (project managers) are left with the unique job of influencing with limited formal authority. They must use their knowledge, competence, relationships, force of personality, and skills in group management to get people to do what is still necessary for project or business success. (Davis 1977)
Much of the strength of the project manager is through his informal personal ties throughout the organization. Through force of personality, the project manager can expedite activities or obtain resources for his project, possibly to the detriment of another project. Management of this type results in informal methods of establishing priorities, whereas an MRP system is based upon a single, formal plan. The two concepts are obviously in conflict. To rectify this conflict, the program manager must learn to utilize his influence to modify the unified MRP plan, rather than expediting actual activity. The effective program manager in a successful MRP environment must realign his ties from the people executing the work to the people providing inputs to the plan and the system. Conceptual education will help program managers understand and prepare for this realignment of influence necessary for the MRP system to reflect the needs of the business.

Retaining Flexibility by Project

The purposes for establishing a matrix organization are to closely monitor a project and allow flexibility in managing a project. So that project flexibility is not destroyed, two considerations must be taken into account when implementing an MRP system. First, the system should be designed so that management decisions which change all information pertaining to a particular program can be quickly and easily updated in the database. Secondly, if there are differences in the quantity or quality of
information needed for each project, this should be taken into account in the design of the system. The program manager must retain the capability of executing decisions that will facilitate meeting the program's objectives.

MRP should facilitate update by program so that program directives can be easily incorporated into the database. For example, a project with quality problems might issue a program directive to add an inspection operation to the routing of all assemblies in the program, or a part substitution notice will require using part X whenever part A is called for on a particular program. In these cases, it would be useful to have a feature in the MRP system which would use one input to update all assemblies exclusively used on a particular program. Shared assemblies would need to be screened to determine if reidentification is necessary. The system could identify shared assemblies and allow one to enter whether or not reidentification is desired. Based on the answer, the system would update the appropriate records.

The typical government contractor has various programs which require information of different quantity and quality levels. If the MRP system is designed to support the most extensive government requirements for information, then programs requiring less information will bear the cost of maintaining this unnecessary information. On the other hand, if the system does not support the most restrictive requirements, an additional system will be needed when these requirements are imposed. The program manager, working
with the contractual requirements, should have the flexibility to
determine what information is needed in support of a program.
Maintaining information costs money. If there is a difference in
the quantity and quality of information required on each program,
the MRP system should be designed to accommodate various informa-
tion requirements.

An MRP system with optional fields and features will allow
the program manager to dictate the information system requirements
for their program, while permitting all programs to work within
the same system. An example of such an optional feature would be
that all transactions for program X are stored on an historical
tape while transactions for other programs are not saved. If one
program requires more security than others, an example would be to
require a password to access the bills of material associated with
program A. While such features could be very useful, they would
definitely complicate system processing. Benefits of such a
feature would need to be weighed against the costs of processing
or the cost of maintaining unnecessary information.

Reporting by Project

The matrix organization necessitates information being
processed in two formats. Output showing the plan and status of
each project is the primary concern of the project managers. The
functional managers utilize output portraying all projects across
their function. Where possible, input and operation of the system
should be segregated by project so associated costs can be charged
directly to the appropriate project. With full-level pegging, this dual reporting is not difficult. As Davis (1977) states, the technique of dual processing is not likely to be an important difficulty:

Setting up formal systems for dual information processing is probably the easiest part of establishing a matrix organization. The difficulties, if they exist, are likely to appear in training individuals to prepare the information and apply the conclusion drawn from the systems. This problem obviously is not unique to matrix organizations.

Although dual information processing is not difficult to accomplish, it will increase operational costs. In his 1982 letter, Kelleher admits this feature does expand both the software and data storage requirements.

The Government Is the Customer

As stated previously, the only criteria for being considered a government contractor is having the government as a customer. Emerson Clarke (1970) points out that the government exerts close observation and control over its contractors. The government's method for doing this is to require contractors to meet both general system descriptions and detail information requirements. The government audits the contractor's systems and method of doing business to determine if he meets the specific requirements imposed by the contract. Therefore, a major system such as MRP must be sold to the government representatives auditing the contract. This section deals with government agencies'
attitude toward MRP, specific requirements imposed by the government, and possible difficulties with using MRP and meeting those requirements.

Selling MRP to the Government

Mil-Std-1528 (USAF 1972), Army Regulation 70-67, and Department of Defense Instruction 5000.38 are a few of the government documents which pertain to conducting a systems audit called a Production Readiness Review (PRR) on government contractors. The purpose of a PRR is defined by DODI 5000.38 (1979).

The objective of a PRR is to verify that the production design, planning, and associated preparations for a system have progressed to the point where a production commitment can be made without incurring unacceptable risks of breaking thresholds of schedule, performance, cost, or other established criteria.

In addition to a production readiness review, contractors accountable to cost/schedule control system criteria (C/SCSC) are subject to a demonstration review of their management control system.

Most government contractors will have contract requirements in which their management system must be audited and approved by a government agency. The government representatives' education and attitude toward MRP should be considered before presenting the system for audit. The contractor's government representatives should be informed about plans for an MRP system, and if education is needed, the contractor should help provide it. All respondents to the Appendix B survey stated that the government was aware of their MRP system or their plans to implement such a system. Both
the survey and personal contacts indicated that there is a large range of knowledge and appreciation of MRP techniques among government representatives. Knowledge of MRP ranged from no familiarity with MRP to extremely knowledgeable. Attitudes range from skeptical to encouraging. There was no indication of any government representative who was extremely negative concerning MRP.

The following excerpts are typical remarks from the survey respondents:

We kept our cognizant Government Agency (USAF-AFPRO) aware of our plans and made presentations on how MRP will operate. There is some skepticism, but not significant opposition. There are some areas however in which they have expressed concern. One example is the use of components from one program to satisfy the needs of another. This is being negotiated. (Kelleher 1982)

They are encouraging our efforts - the local government is not aware of the techniques - but are aware of the benefits. (Eldridge 1982)

Several other comments have indicated that the government agencies are moderately encouraging and enthusiastic, but are not educated in the techniques of MRP. It is partially due to this lack of education that some government requirements seem to be contrary to the requirements of MRP. Also, requirements cannot be changed as quickly as attitudes, and government auditors state that it is only recently that MRP has been getting attention at Defense Contracting Audit Agency (DCAA). A contractor can help educate government auditors in MRP techniques. Government requirements can be interpreted broadly enough in order to not preclude MRP as
the firm's official management system. An auditor who under-
stands and appreciates MRP would tend to recognize the need for
this interpretation. The write-up on C/SCSC in the following
section will clarify why an interpretation of the requirements
and an understanding of MRP is needed to assure these requirements
are not mutually exclusive.

Cost/Schedule Control System Criteria (C/SCSC)

The cost/schedule control system criteria (C/SCSC) is a
management technique applied to selected government contracts.
The Department of Defense has determined that this technique
affords the contractor the ability for effective program manage-
ment, and also provides the government with timely and meaningful
output for program progress evaluation. Hammond, in his 1978
research report on C/SCSC summarizes some of the philosophy and
wording of the criteria:

DOD Directive 5000.1 states that, to the maximum extent
feasible, contractor management control systems will be
the source of management information for both contractor
and DOD management of major acquisition contracts and
that the DOD will require contractors to make changes
in their internal control systems only to the extent
necessary to comply with standard DOD requirements.

Contractors are free to organize in the best manner
suited to their individual environments and management
philosophies and may elect the internal methods and
procedures of their choice. However, these methods and
procedures must result in a system which provides the
data and capabilities specified in the criteria in
order to be considered acceptable to the Department
of Defense.

The above requirements state that if the MRP system is the source
of management information, the same system must be the source of data used to satisfy C/SCSC requirements. The system must also provide the output in the format required by C/SCSC.

The output and information required by C/SCSC are the cost and schedule variance and the backup data used to determine why the variance occurred. The components necessary to achieve this include a budget, a schedule, actual costs, and actual timing. The elements scheduled must be broken down enough so that when actual performance differs from the schedule, a budgeted cost of work performed can be calculated. The output of the system is shown below.

As long as the MRP system can store a plan and capture actual cost and schedule information for a defined activity, the MRP system can provide the required C/SCSC output. A desirable feature would include monitoring and alerting appropriate individuals when actual costs or schedule falls beyond a predefined threshold. This feature would help in identification of problems and variance analysis.
Unlike the output requirements which can be satisfied through additional software, the requirement that the management system be the basis for C/SCSC creates a problem if MRP is the management system. With MRP, the firm's time-phased plan is automatically modified when lead time, designs, or other factors are modified. MRP generates a dynamic schedule which reflects the changing business needs. In C/SCSC the performance measurement baseline is the time-phased plan the contractor is expected to follow. Changes to the performance measurement baseline must be justified, and under certain circumstances, change is not permitted to the baseline. This is an area where broad interpretation of the criteria is desirable. If the reporting requirements of the contractor are at a high enough level, these requirements can be entered into the master schedule. Thus, the master schedule can remain static while detailed MRP plans are free to shift. The defense industry 15-man ad hoc committee for the application of C/SCSC to production also recognized the need for high level reporting. In their 1978 report, they stated that due to lack of education concerning production management systems, the government team members dictated lower levels of reporting than were needed to control production.

When C/SCSC must be met, a contractor implementing an MRP system should inform the government team of the planned system, and make sure the system will satisfy the requirements of the C/SCSC as interpreted by the government team.
At first glance, it may seem that government contractors are more ideally suited for MRP than other manufacturers. This is the impression that Reinfeld (1982) must have had when he stated in his book on production and inventory control:

... the companies that are most apt to use MRP successfully are those that are willing to pay heavy overtime and duplicate tooling costs in order to maintain schedules. Who are these companies? The first ones that come to mind are the military ... The military is obvious because the military always work on critical deadlines.

Mr. Reinfeld is referring to the benefit of shortening delivery lead time. There is no question that this is one of the benefits of MRP, and government contractors often find it necessary to meet very tight schedules. However, studies such as Material Requirements Planning: A Study of Implementation and Practice by Anderson, Schroeder, Tupy, and White (1981) point out that delivery lead time and delivery promises met are probably not going to be the most substantial benefit achieved from an MRP system. Improving inventory turnover rates, reducing the percent of orders requiring splits, and reducing the number of expediters are the other major benefits of MRP. Although improvement in delivery time is suited for the objectives of most government contractors, the other benefits of MRP are not as meaningful to government contractors as they would be to commercial manufacturers. This is particularly true
for the benefits of achieving higher inventory turns and decreasing inventory investment.

Higher Inventory Turns

In the MRP study mentioned above, more companies reported improvements in inventory turns than any other benefit. Average inventory turnover can be calculated by dividing the average inventory level into the average cost of sales. For example, if average inventory is two million dollars, and cost of sales was fourteen million dollars, the inventory "turns" or cycles seven times per year. Manufacturers strive for higher average inventory turns because it means less money tied up in inventory and smaller carrying costs. Unlike other manufacturers, government contractors often get progress payments and the inventory is "owned" by the government, not the contractor. If the contractor is paid his material costs as soon as material is received (or 80% of cost), there is little incentive to increase inventory turns. The government's money is tied up in inventory, not the contractor's. When inventory turnover is not an important objective for a firm, then an MRP system which controls inventory will not necessarily benefit the firm.

More Benefits

Other benefits of MRP include reducing the number of orders split and reducing the number of expediters. The nature of the firm will determine how much of an impact these results will have
on the company. Reducing the number of orders which must be
split due to material or resource shortages will save on set up
and administrative costs. Of course, if the firm is building in
lot sizes of one for reasons of control or a unique product, re-
ducing split orders is meaningless. The degree of improvement is
dependent upon how much the splitting of shop orders is currently
costing the firm.

Reducing the number of expediters is the least often re-
ported benefit of MRP. In the Anderson survey, thirty-nine percent
of the respondents reported no reduction or an increase in the num-
er of expediters since MRP was implemented. Reducing the number of
expediters would benefit a government contractor firm, as long as
the costs saved in expediting are not offset by larger costs in
the systems area. In fact, if dollars for people applied directly
to a program are replaced by dollars for a system charged to
overhead, the net result would be detrimental to the firm. When
weighing the costs and benefits of MRP, a government contractor
firm will need to take into account the affects on their applied
base and overhead rates.

In the Anderson study, data was also collected on subjective
benefits of MRP. The study shows that the greatest reported bene-
fit is better control of inventory, followed closely by better
production scheduling. If the government "owns" the contractor's
inventory, and the government requirements give little flexibility
to the production schedule, then a firm might have a hard time
justifying an investment in MRP. Each government contractor must look at the characteristics of his firm to determine whether the expected benefits of MRP outweigh the expected costs.

Costs of MRP

Oliver Wight (1982), in his book on MRP II, breaks down the costs involved in MRP, and projects the one-time and recurring costs involved in implementing MRP in a typical company. Wight classifies costs as technical (hardware, software, and systems work), data integrity (improving and maintaining files), and people costs (education and professional guidance). The technical costs for a government contractor's MRP system would be higher than a typical firm due to the complexity of the systems. Features such as full-level pegging, contract segregation, dual reporting requirements and options for flexibility will increase the cost of both the software and systems work. These same features also increase the data storage requirements and could result in a higher investment in hardware. Data integrity costs would probably be lower for a government contractor, since the government probably already required the contractor to maintain good files and information. The costs of professional guidance would not vary from that of a typical firm, but a government contractor's cost of education would be higher. In addition to the functional personnel, the project-oriented organization, and possibly even the customer, would require education. According
to Oliver Wight's breakdown of costs, the costs which will be higher for government contractors represents sixty-eight percent of the total one-time costs and ninety-three percent of the recurring costs. Wight states that a typical manufacturing firm would incur a one-time cost of $745,000 and yearly recurring costs of $145,000. If being a government contractor increases only the technical and educational costs by ten percent, then one-time costs would be expected to be over $50,000 higher than the typical firm and recurring costs would be $13,500 higher per year.
IV. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The previous chapter discussed in detail the issues that may arise when government contractors implement MRP systems. This chapter will list the specific software features, organizational issues, and customer-related concerns for government contractors implementing MRP. The present use of MRP by government contractors and the availability of vendor software for government contractors will be summarized in this chapter. Lastly, a discussion of future trends for MRP and government contractors will be presented.

Features and Concerns to be Considered When Implementing MRP

This section lists issues government contractors should consider when implementing MRP. The degree to which any particular firm should be concerned with these features is dependent upon the restrictions imposed by specific government contracts.

Software features in the master schedule subsystem which could be beneficial to a government contractor include the following:

1. A master schedule priority override code to circumvent need date as the priority scheme.

2. Schedule hold feature to freeze all existing plans associated with a given program.

The following features concern configuration management and bills of material. In each case, the government contractor should
decide upon the desirability of the feature in an MRP system to be used in their firm.

1. A configuration management system which satisfies government requirements, including such things as
   a. Part number serialization.
   b. End item serialization.
   c. Serial number and date traceability and effectivity.
   d. Historical record keeping on as built product configuration.
   e. Revision control of engineering drawings and associated lists.

2. A preliminary advance order bill of material which can be reconciled to the actual bills of material as they are released from engineering.

3. An order-dependent bill of material permitting several variations of an assembly's BOM dependent upon what program is using that assembly.

4. Ability to simultaneously maintain two bills of material: one reflecting the latest engineering design and the other reflecting the latest released manufacturing design.

5. Capability of reconciling multiple bills of material by comparing and identifying differences.

6. Capability of maintaining unincorporated engineering changes.

7. Ability to utilize, track, and record temporary part substitutions and deviations from product structure.

8. Ability to specify permanent part substitutions without losing traceability to the original part on the bill of material.

The five features listed below should be considered for incorporation into the software where the MRP calculations are actually performed.
1. Full-level pegging to identify all requirements and orders to a specific contract.

2. Firm-planned orders to freeze the plans for a given order.

3. MRP capability which, for common items, will optionally cross or not cross contracts.

4. MRP which performs or recommends transfer of inventory between programs based on entered priorities and inventory borrowing codes.

5. MRP which identifies transfer opportunities but does not actually transfer parts between programs.

The inventory subsystem should include features which control inventory both by project and for the entire firm. These features include

1. Stores control by contract--multiple stockrooms.

2. Historical storage of inventory transactions.

3. Ability to physically combine but logically segregate inventory by contract.

4. Ability to maintain both project and total inventory balances so they are readily accessible in a costed format.

5. Capability of transferring ownership of material between projects--including appropriate financial transfer.

6. A code for each project's inventory indicating the degree of borrowing allowed.

The features which would be desirable in support of the purchasing and shop floor control subsystems include the following:

1. The capability of combining purchase orders and shop orders to achieve economies of scale, while logically keeping records and ownership separate by project.

2. The capability of prorating common costs (such as scrap or freight charges) when orders are combined.

3. The ability to track orders and control by project.
4. Audit trails for both shop orders and purchase orders from identification of requirements through completion.

General features which should be considered for incorporation into a government contractor's MRP system include the following:

1. Terminology of data fields consistent with government terminology in such requirements and MIL-STD-881A or C/SCSC.

2. Capability of identifying classes of generic items for reporting purposes (cables, PWB, hardware, etc.).

3. Capability of reporting planned vs. actual for the costs and schedule of a particular program.

4. Output reporting by program as well as by functional organization.

5. Ability to allow update of all records for a given program without multiple input of update commands.

6. Identification of all data shared across contracts, and an interactive method of entering into the system whether to update this information when all data for a program changes.

7. Optional fields and features which allow the quantity and/or quality of information maintained in the system to differ for each contract.

8. Support in identifying the percentage of the cost of data base maintenance to be charged to a specific contract.

9. Provide breakdown and visibility of cost accounts, compare plan to actual for costs and schedule at the cost account level, provide the required C/SCSC reports (if C/SCSC is applicable).

In addition to software features, other questions which should be addressed by government contractors are as follows:

1. Who will be auditing the system and what is their attitude toward MRP?
2. How will the customer be informed of and involved in the system implementation?

3. Is it necessary to educate the customer on MRP techniques?

4. Does past experience show that the contractual requirements concerning the production system will be minimal or that the customer will allow a broad translation of these requirements?

5. Is the work breakdown structure (WBS) consistent with the bill of material and the way the product is being manufactured?

6. Can government restrictions on lower level schedules be avoided or kept to a minimum?

7. Is project management educated and supportive of the system?

8. Is the master scheduler in a position to get timely inputs from each project and reflect the priorities of the firm?

9. What affect will the system have on the firm's applied base and overhead rate?

10. What are the expected benefits and are these benefits significant to the firm? Is the project cost justifiable--do the expected benefits substantially outweigh the anticipated costs?

Each contractor is unique and each will find that certain of these concerns are applicable to him and others are not. No contractor needs to be concerned with all of the above features since some of them are mutually exclusive. Even those features which would be desirable for a given contractor do not have to be included when MRP first becomes operational. Most MRP installations are evolutionary in that features are added and capabilities expand continuously after initial implementation.
When asked about government contractors and MRP, George Plossl, a leading consultant in production management, responded:

Few aerospace and defense companies have "state-of-the-art" MRP based systems. They are convinced they are completely different than other types of manufacturing firms and would not benefit from work such companies have done. (Plossl 1982)

There are, however, several government contractors who are using MRP and many others who are considering it. Government contractor's use of MRP can probably be best characterized by a bell shaped curve. On one extreme are those contractors who have been operating MRP for several years, and in the middle are contractors who are considering implementing an MRP system.

The contractors who responded to the survey in Appendix B were all at the midpoint of the bell shaped curve or further along in implementing MRP. This was due to the inherent prejudice of the method used to identify candidates. Of the nine survey respondents, three have MRP systems they consider operational. One of these companies has been utilizing MRP for seven years and the other two have completed implementation in 1982. Four survey respondents are in the process of implementing a system, and two others are considering MRP implementation and are currently investigating the availability of vendor software. Of the seven companies utilizing or implementing MRP, six had purchased vendor software. The one company that developed its own software
is the same company that has been operational for seven years.

Each survey respondent reported different roadblocks and problems with MRP operation and implementation. All of the issues that were specifically related to being a government contractor were discussed in sections II and III of this report. Most interestingly, about fifty percent of the problems cited were typical of any firm implementing MRP. In other words, less than half of the problems were due to the fact that the firm had to deal with the government as the customer. However, all of the vendor software packages utilized either contained, or were modified to contain, special features designed to meet the specific needs of government contractors.

**Vendor Software for Government Contractors**

Several vendor software packages have been identified which contain specific features particularly useful for government contractors. These packages were identified through word of mouth and none of the packages are marketed as being specifically applicable to government contracts. Three of the packages which are currently available are PIOS (production and inventory optimization system) put out by Rath & Strong Systems Products, Inc., PMS (production management system) put out by Boeing Computer Services, and MAS-II put out by Martin Marietta Data Systems. All of these have both commercial and aerospace-defense users. The systems contain features such as engineering change control, substitute
parts, multiple stockrooms or inventory ownership, inventory trans-
action history, and full-level pegging. Each package has addition-
al features useful for government contractors, but at this time,
none of the packages has all the features required to support a
strict government requirement such as C/SCSC.

Another software package which is currently under develop-
ment is called AMAPS/G by Conserve. This is a funded development
system being introduced specifically for government contractors.
AMAPS/G is actually a modification of a proven MRP software
package (AMAPS) which addresses government products. A group of
government contractors has formed a user group and they are work-
ing with Conserve in developing this product. This user group in-
tends to also work with the government, and they realize that it
may be necessary to ask the government to modify some of their re-
quirements, such as MIL-STD-881A. This will not be the first time
a user group has requested or received a change in government re-
quirements in order to manage their operation more efficiently.
Certain requirements of the Federal Drug Administration have been
modified at the request of a user group for the process industry,
thus a precedent has already been set. The current status of
AMAPS/G is that the system objectives and required features have
been identified. Conserve and the users met on November 15, 1982.
The users are presently determining priorities. The product will
be released incrementally and it is expected to be about a year
before it is fully developed and released.
MRP and Government Contractors

This report has shown what makes government contractors different than other firms, what features are needed to make MRP work in a government contracting organization, how costs and benefits of system implementation are affected, where government contractors currently are in their attempt to implement MRP, and current and future software packages which contain some of the desirable features. Is it beneficial for a government contractor to implement and operate an MRP system? That depends upon the specific characteristics of the firm. An important consideration in deciding whether or not MRP should be implemented is what alternatives are available.

A delphi study designed to predict the future of manufacturing systems showed that the popularity of MRP will continue to grow at a very rapid rate, and by 1989 two-thirds of all manufacturing companies will have MRP systems (Benson 1982).

Presently it is difficult, but not impossible, to successfully operate an MRP system and satisfy government contract requirements. To alleviate these difficulties in the future, the participation of the contractors, the software vendors, and the government will be required. Government contractors must stop concentrating on their differences and start looking at why they are different and what can be done to compensate for this difference—either procedurally or with software. This report could give contractors a baseline to start this self-examination of themselves.
Software houses must develop systems which contain needed features for government contractors. This report outlines what these features are. The government agencies must educate themselves regarding manufacturing systems and MRP techniques and modify those requirements which are contrary to how MRP wants to operate. After all, the goal of government requirements and MRP systems is the same—to be able to plan and control a program. It is time for government requirements to reflect, or at least not oppose, the state-of-the-art method for controlling manufacturing.

There is already evidence that the contractor, software vendor, and government are working together to develop a workable system. This trend can be expected to continue and in the not-too-distant future MRP will be commonplace in a government contractor facility.
Information contained in this report was obtained from books, articles, management consultant firms, software houses, government contractors, and government representatives.

Books and articles related either to MRP, matrix organization, project management, or government contracts and contractors. No published information was found specifically referencing MRP in a government contractor organization.

Management consultant firms interested in MRP were identified through books and articles. Nine consulting firms were sent letters which requested further information, comments on the subject, and names of government contractors involved with MRP. Five firms responded with comments on the subject and names of government contractors. These five firms are included in the list of references.

Software houses which seemed to have contract or product traceability were identified through articles and other sources. Eight software houses were sent letters requesting additional information if they either had users who were government contractors or had software which contained full product traceability. Of the six respondents, three claimed their product does or will
support government contracts. The write-ups on these systems are included in the list of references.

Thirteen government contractors, identified through other sources, were sent the survey in Appendix B. Nine government contractors returned the survey and several included lengthy write-ups. Those write-ups referenced in this report are included in the list of references. No attempt was made to tabulate the results of this survey since the lengthy answers that were received did not fit into any categorization scheme.

Four representatives of the government (Defense Contracting Audit Agency and C/SCSC Team) were identified through other sources and sent letters requesting further information. Two responded with lengthy telephone calls, but no written information was received.
APPENDIX B
SURVEY

A. MRP

1. Does your company have an MRP system operation?
   yes  presently being  considering  no
   implemented  it

2. When did (or will) the system become operational?
   Date:

3. Are you using standard software or your own design?
   If standard please specify.

4. What was (are) the key problems or roadblocks to
   implementation?

B. Customer

1. What % of your total business has the government as your
   customer? Is your MRP system used in this part of
   your business?

2. Is MRP your principal method for planning and controlling
   government contracts?

3. Is the government aware of your MRP system?

4. What is the government's attitude toward your system?
   Are they educated in MRP techniques?

5. Does the government have access to your data base for
   auditing or informational purposes?

6. Is any of the cost of implementing or operating MRP
   applied directly to government projects?

C. Organization

1. Do you have project managers for your government
   contracts?
2. What has project management's attitude been toward MRP?

D. MRP Subsystems

For each of the following MRP subsystems please indicate if you have them operational. Please answer all yes/no questions and if any of the open-ended questions apply, please answer on the back of this sheet.

MASTER SCHEDULE  Operational?
1. Is the Master Schedule used for MRP the official schedule for the organization?
2. How are priority issues between various projects worked out?

BILL OF MATERIAL  Operational?
1. Does the government configuration requirements conflict with or support the bill of material requirements for MRP?
2. How are part substitutions handled--within the system or outside.

INVENTORY FILES  Operational?
1. Is inventory owned by you or the government?
2. Do contracts ever require inventory to be kept separate by project? Physically or logically separated?
3. Do all projects using MRP have the same stipulations as far as lending material across projects? What are these policies?
4. Are you subject to consumption audits?

THE MRP PROCESS
1. Does your MRP software keep various projects separated? How?

SHOP FLOOR CONTROL
1. Are projects kept separately on the shop floor or combined across projects?
2. Is a method of allocation used to charge costs to the correct project? Are labor or scrap charges prorated and on what basis?

OTHER CONSIDERATIONS - If applicable, please comment.
1. Education of program or project management.
2. Retaining flexibility by project.
3. Statusing and output reports by project.
4. C/SCSC reporting and MRP.
5. Gaining approval of the system from government customer.
6. Engineering change proposals and changing requirements in mid stream.

CONCLUSION - Please comment.

- Would you recommend using MRP to a government contractor?
- Would job shop or production type of operation be a better application? Why?
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