

White Paper
CMII 850C

**How MRP Improved
BOM Practices in Aerospace**



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Page 1	A	B	C	
Page 2	A	B		
Page 3	A	B	C	
Page 4	A	B		
Page 5	A	B	C	
Page 6	A	B		
Page 7	A	B	C	
Page 8	A	B	C	
Page 9		B	C	

Purpose of This White Paper

Aerospace firms had spent over 40 years evolving their development and manufacturing processes before MRP came along. This white paper describes key areas in which MRP has resulted in a major overhaul of pre-MRP practices.

OUTLINE

- **A Little MRP/ERP History and Timeframes**
- **A Little Aerospace History and Timeframes**
- **Managing Options, Changes and Traceability**
- **MRP Basics and How Bills of Material are Used**
- **How MRP Uses Item ID Numbers and Meta Data**
- **MRP/ERP Rules and Lessons Learned**
- **Tabulated Drawings for Defining Configurations**
- **The Manufacturing Control Process**
- **Summary**

A Little MRP/ERP History with Timeframes

Material Requirements Planning (MRP) was one of the earliest automated scheduling and material control systems and ran on bills of material. It was one of the earliest forms of Supply Chain Management. The timeline for this evolving "resource planning system" began in the 1960s:

The 1960s — early computers, reorder point systems and early MRP;

The 1970s — Material Requirements Planning (MRP);

The 1980s — Manufacturing Resource Planning (MRP II);

The 1990s — Enterprise Resource Planning (ERP).

IBM developed one of the earliest MRP systems called *COPICS (Communications Oriented Production Information and Control System)*. Its eight volumes of documentation, released in 1972, was the source for many of the engineering change terminologies used in the CMII model.

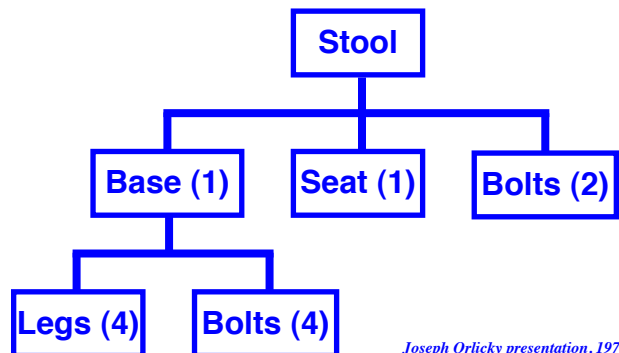
The first MRP crusade was launched by the American Production and Inventory Control Society (APICS) in 1972.

Joseph Orlicky published *Material Requirements Planning* in 1975. It was the first and most comprehensive book on the subject. In his book, he discusses indentured bills of material, lead times and lot sizes along with the concepts of dependent and independent demand. He also introduced the concept of net change.

Indented BOM

Stool
 Base (1)
 Legs (4)
 Bolts (4)
 Seat (1)
 Bolts (2)

Graphical BOM



Joseph Orlicky presentation, 1974

Dave Garwood published *Bills of Material* soon thereafter which went into greater depth on how bills of material can, and should, be used.

A Little Aerospace History and Timeframes

Early Commercial Aircraft History and Timeframes

1903 — the Wright brothers first successful flight.

1925 — the Kelly Airmail Act provided an opportunity to carry mail.

1929 — Charles Lindbergh piloted the first airmail service flight to South America for Pan Am World Airways.

1931 — American Airlines and United Airlines were formed.

1938 — the Civil Aeronautics Authority was developed to regulate the many air transport companies flying the new DC-3s created to carry both mail and passengers and wide enough to seat 21 people.

1947 — developed 4-engine aircraft such as the Lockheed Constellation.

1959 — Jet service was introduced.

Early Military Aircraft History and Timeframes

1918 — The typical combat aircraft was a fabric-covered externally braced biplane with fixed landing gear and open cockpits. Few aero engines developed as much as 200 horsepower and top speeds of 120 miles/per/hour were exceptional.

1939 — Combat aircraft of the major powers were all metal monoplanes with retractable landing gear. Powered by engines that developed 1,000 or more horsepower, and supercharged to permit flight above 30,000 feet, fighters were capable of exceeding 350 mph and some bombers flew faster than 250 mph.

KEY POINT: Aerospace companies had been developing, producing and maintaining commercial and military aircraft for 40 years before computerized scheduling tools such as MRP came along.

Managing Options, Changes and Traceability

Many manufacturers build to customer order wherein final assembly of the product includes customer-selected options. The same basic product can be produced for many customers without any two being alike — yet the process can be as efficient as if they were all alike.

With any product, there is an ongoing flow of engineering changes. Some serve to introduce new options. Some serve to improve existing features. Some serve to replace components that are no longer available.

End-item traceability deals with knowing the specific content of an end-item. This includes customer-selected options and changes. In cases where development and/or production are funded by the government, it could include knowing the actual cost of each component.

Aerospace and defense-oriented companies developed techniques for tracing options, changes and costs to specific end-items long before MRP came along. Some did it by linking each component at each indenture level directly to the end-item tail number or serial number.

The developers and users of MRP were confronted with the same challenges. However, they found ways to do it that were more reliable and efficient. They did it by taking advantage of the capabilities provided by indentured bills of material and the rules of dependent demand.

Although aerospace companies were slow to adopt MRP and the associated methodologies, MRP's popularity grew very fast in other industries throughout the 1970s. The first aerospace firms began trying to implement MRP in the early 1980s.

Rath and Strong's PIOS (Production Information and Optimization System) was the first MRP system designed for the aerospace environment. End-item serial numbers were used to assign change effectivities and provide traceability of actual component costs to specific contracts.

KEY POINT: Aerospace firms and MRP providers had different ideas on how to control effectivities and achieve traceability.

MRP Basics and How Bills of Material Are Used

A production plan defines the number of end-items to be produced in each time period. There is a separate production plan for each like-family of end-items and each like-family has its own model number.

An MRP system runs on planning bills and order bills. In a build-to-order environment, there is a planning bill for each unsold end-item which contains all of the customer options along with percentages that represent the expected rate of usage. Once sold, the planning bill for the specific end-item is replaced with an order bill which represents the specific configuration that was ordered.

The following stool, Model 123-0, is used as an example. It may be ordered with a red or a blue seat. Based on past history, 60% of the customers will order red and 40% will order blue. A stool with a red seat is part number 123-1. A stool with a blue seat is part number 123-2.

Planning Bills for 123-0 Stool

123-0 Stool (123-1 and 123-2)

234 Base	(1) @ 100%
345 Legs	(4) @ 100%
456 Bolts	(4) @ 100%
567-1 Seat, Red	(1) @ 60%
567-2 Seat, Blue	(1) @ 40%
678 Bolts	(2) @ 100%

Order Bill for 123-2 Stool

123-2 Stool

234 Base	(1)
345 Legs	(4)
456 Bolts	(4)
567-2 Seat, Blue	(1)
678 Bolts	(2)

For the stools to be produced in each period, MRP simply reads the bills of material and, using the principles of dependent demand, automatically nets the required number of bases, seats, legs and bolts against on-hand and on-order assets and advises of the needed reorder quantities and/or reschedules.

For changes, assume that the (2) 678 bolts are to be replaced with (2) 789 bolts. Both sets of bolts are displayed in the planning bill with an effectivity. MRP uses the effectivity to select the correct bolts when the planning bill is replaced with an order bill.

How MRP Uses Item ID Numbers and Meta Data

In an MRP environment, each physical item has an ID number, a name, a description and possibly a lot number and also a serial number.

In an MRP environment, the ID number is used to control interchangeability. MRP systems trust part numbers. The system trusts that any two items with the same ID number are fully interchangeable. The system trusts that the rules of interchangeability are being followed when changes are made. An MRP system does not recognize revision levels.

With MRP, all information about a physical item is linked to its ID number. More specifically, all information about a physical item is entered into its item master (or metadata) which shares the same ID number. Such information may include:

- *its name*
- *its description*
- *its procurement (make or buy) code*
- *its source and/or CAGE code*
- *its type code*
- *its scheduler*
- *its lead time*
- *its lot size*
- *its cost or cost code*
- *its hazardous material code*
- *its packaging and/or handling requirements*
- *its shelf life*
- *its supporting documentation (if not maintained in a baseline)*
- *its inventory control and/or reorder policy*
- *its work unit code*
- *its security code*
- *its active/inactive status; and so on*

With MRP, bills of material define the parent-to-child relationships between physical items. Part numbers define the specific configuration of each item. It is possible to perform a where-used transaction for any part number and identify all of its applications. It is also possible to review the change history for any item by its ID number and identify all superseded and superseding configurations.

MRP/ERP Rules and Lessons Learned

Bills of material need to be properly structured. The best structure is that which best emulates how material is to flow through the supply chain. The responsibility for structuring bills of material should belong to those who manage the supply chain.

Development and production should share the same bills of material. Products being developed should be managed by a cross-functional team which includes a representative from Supply Chain Management.

The physical item hierarchy for an end-item product provides the ideal framework for its baseline. The hierarchy should extend from the application requirements at the top (level 0), to the components, software items and raw materials at the lowest levels. The end-item should reside at indenture level 1. Each item at each level should be linked to its own unique set of documented requirements.

Customer selected options should reside below the end-item at indenture level 2 so they can automatically be part of final assembly.

Most changes take place at the lower indenture levels. One option for achieving end-item traceability is to roll the part numbers of parent level items up to the end-item part number. Rolling part numbers for this sole purpose is not recommended.

A better solution is to group changes that affect the same documentation and which can share the same effectivity. In this case, lower-level changes are grouped with higher-level changes wherein the rules of interchangeability will require the higher-level part numbers to change.

The idea of rolling part numbers up to the level where interchangeability is restored is, in itself, insufficient. As a minimum, part numbers must be rolled up to include the item immediately below the end-item (which will cause the end-item bill of material to be revised).

In addition to the above, the biggest problem with MRP systems is data integrity. The problem is compounded because so many data sets are used in-series. Data integrity must be given top priority.

Tabulated Drawings for Defining Configurations

Each customer (such as an airline) wants their own version of the same basic model (such as a Boeing 767 or an Airbus 340). One approach used by engineering to define the basic configuration and selected options for each airline was to tabulate each applicable drawing with the name of the airline. Such tabulations typically go down to the Lowest Replaceable Unit (LRU) and may involve hundreds of drawings. Such tabulations were discontinued as it was discovered that bills of material can serve the same purpose and at a much lower cost.

The Manufacturing Control Process

Manufacturing, in turn, must ensure that the correct assemblies and components are used to build the end item. One approach is to put the aircraft tail or serial number on each assembly and each replaceable unit. The same approach was often used to control the cut-in point for changes. Tail or end-item serial numbers were assigned to each superseded and superseding item accordingly.

The sequence in which each customer's plane is to be built is often referred to as the "firing order." A common practice is to build assemblies and subassemblies in the same sequence — which supports just-in-time objectives and helps guide the correct parts into the correct end-items. A change to the firing order results in a reschedule of all assemblies and components. This can be a major task when all assemblies and components are tagged with the end-item serial number.

Ability to accommodate such a re-sequencing of the end-items is built into the MRP/ERP logic — which includes provisions for capacity planning and priority control within each assembly station or work center.

Summary

After 40 years of evolution prior to MRP, development and manufacturing practices in the aerospace industry were well entrenched. They were highly advanced in many ways but, compared to today's standards, rather archaic in other ways. The innovations brought forth by MRP have resulted in significant improvements in aerospace practices.