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Manufacturing Execution Systems

Their Place in the Enterprise System

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Introduction

It's difficult to imagine what you would do without a computer and manufacturing software system in place in your company. The need to track vast quantities of information to satisfy customer service requirements can be overwhelming at times. Recently many companies have turned to Enterprise Resource Planning systems in an effort to bring all the development and implementation effort under one roof. However, all of the required functionality does not exist in one package, and companies usually end up with a mixture of ERP (or MRP II legacy systems) and new mini applications to extend the ERP. Companies like SAP (SAP R3), Baan (Triton) and QAD (MFGPro) have partnered with many smaller companies to round out their offerings through bolt-on software.

Many manufacturers have a significant investment in MRP or MRP II software and find themselves commissioning new "bolt-on" software, or adding PC networks and creating Windows based software for Manufacturing Execution System (MES) functionality including product tracking, bar coding Quality Assurance systems and ISO 9000 requirements. Usually, the planning and materials requirements systems are installed and running well, however, the operations side of the system is weak or nonexistent. In our opinion this is often due to the "accounting related emphasis" of most MRP installations. The folks on the shop floor are left to their own devices – as always.

Recently MES systems and components have started to appear. These systems have begun to give plant managers a taste of what they could have to improve their manufacturing facilities, and improve the value of the data in the MRP II legacy system. Understanding how MES and ERP or MRP II can function together to give you the data you need is essential to understanding the opportunity for successful implementation of an integrated system.

An understanding of the data flow possibilities between the enterprise system and the factory floor can aid the understanding and implementation process greatly. The Manufacturing Execution Systems Association (MESA International) has published a series of papers that you can obtain from their site. These papers include a number of models including the following Data Flow model which we have adapted from their Paper Number 1.

MES System Architecture

The MES system fits into the overall architecture as an interface between all of the major planing and financial systems used in your enterprise. It provides the framework or "glue" for holding together all of the systems in an all-encompassing information web.

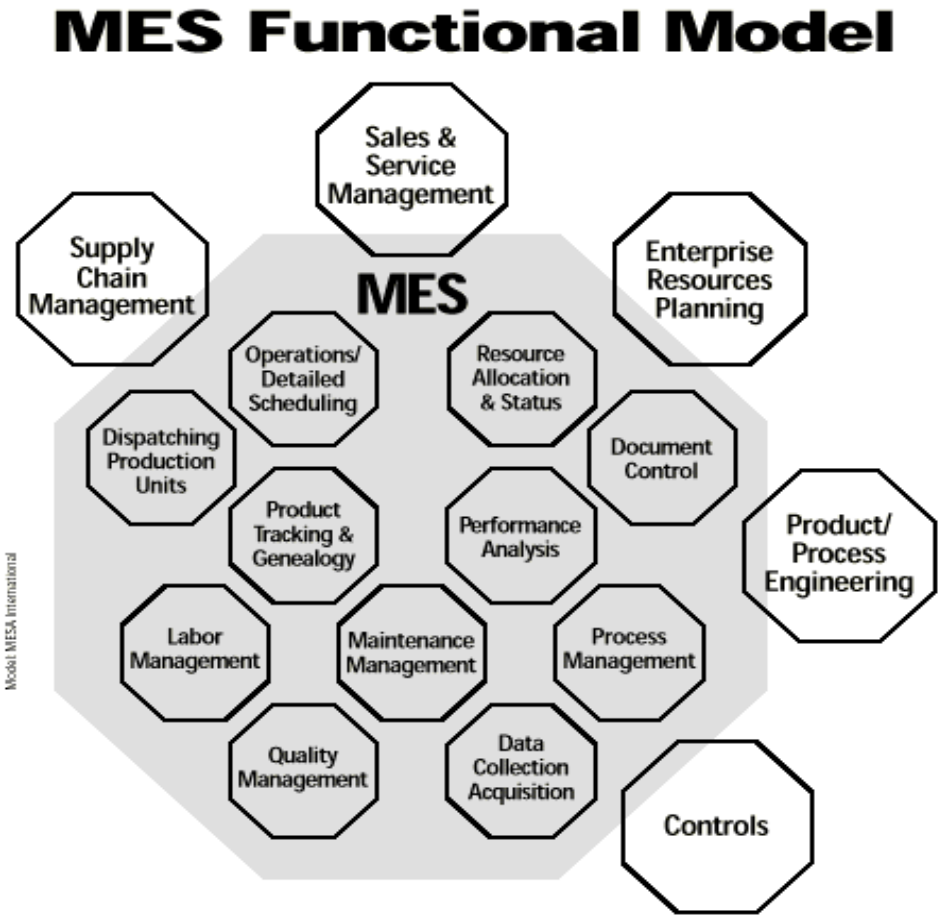
MES and Manufacturing Systems Information Architecture. See figure 1.

Enterprise Resource Planning

ERP consists of those systems that supply financial reporting, order management, production and materials planning, and related functions.

Supply Chain Management

SCM includes functions such as forecasting, distribution and logistics, transportation



The MES Functional Model – and General System Architecture – Figure 1.

management, electronic commerce and advanced planning systems.

Sales and Service Management

SSM comprises software for sales force automation, product configurators, service quoting, product returns, complaint tracking and so forth.

Product and Process Engineering

PPE includes computer aided design and computer aided manufacturing (CAD/CAM), process modelling (which uses the data from MES), and product data management (Specifications, drawings etc.)

Controls Systems

CS systems are usually hybrid hardware and software systems such as distributed control systems (DCS), programmable logic controllers (PLC), distributed numerical control (DNC or NC), supervisory control and data acquisition systems (SCAD such as Wonderware).

Manufacturing Execution Systems

These systems consist of plant-wide information systems providing information on which to effectively execute operations to meet business goals.

From MES to Other Systems

MES feeds information to all other major systems.

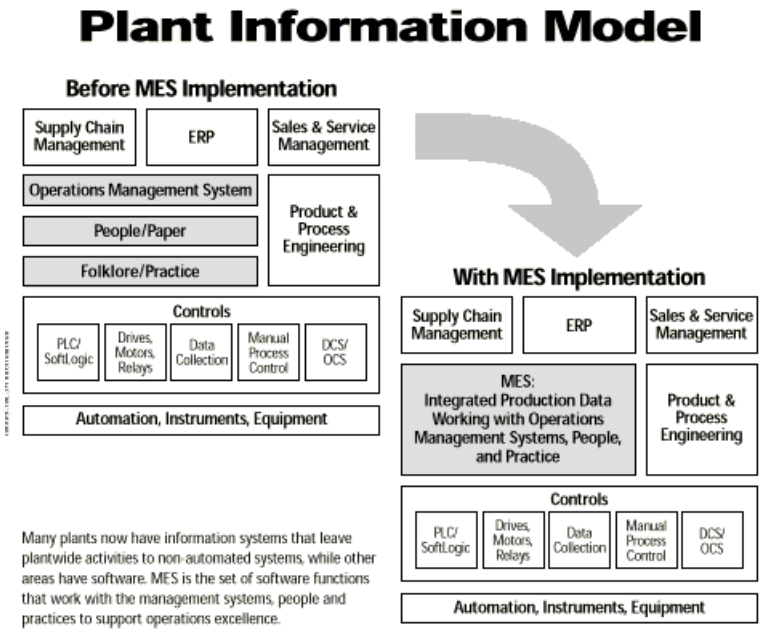
- ERP receives actual production tallies such as cycle times, throughput, materials usage, labour and general production performance figures.
- Location of goods (WIP) is fed to other systems.
- Sales and Service Management links to MES since their success in quoting depends on what is happening in the plant at any given moment.
- Supply Chain Management applications must link to MES for actual order status, production capabilities and shift-to-shift constraints.
- Product and Process Engineering uses the MES production data to fine tune the process model and improve yields.
- Control and SCADA systems get recipes and information downloads that reflect the optimum schedule based on production parameters and current time constraints.

From Other Systems to MES

MES takes in information from all the other enterprise systems to ensure intelligent use of the production requirements information in the plant. ERP feeds the production plan which the MES converts to capacity and constraint based scheduling requirements based on current plant operation. Sales and Service information along with Supply Chain Management figures help provide the baseline for production. Product and process engineering drive the recipes and operational parameters. Data from the manual data logging, Controls and SCADA systems is used to update the actual conditions as they change in the plant-wide system.

MES Benefits

Delivery, quality and the speed to market are the key issues for any manufacturer. Along with the need to comply with federal and state reporting requirements, as well as major initiatives such as ISO9000 – manufacturers must improve their yields and



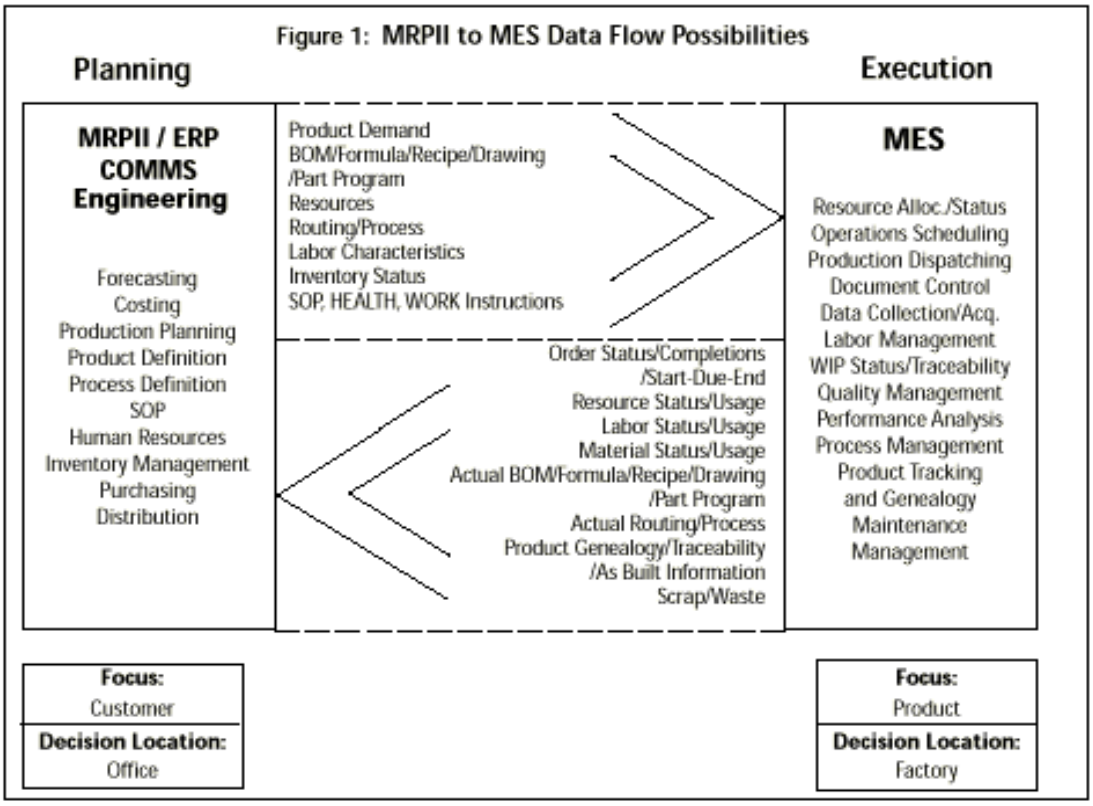
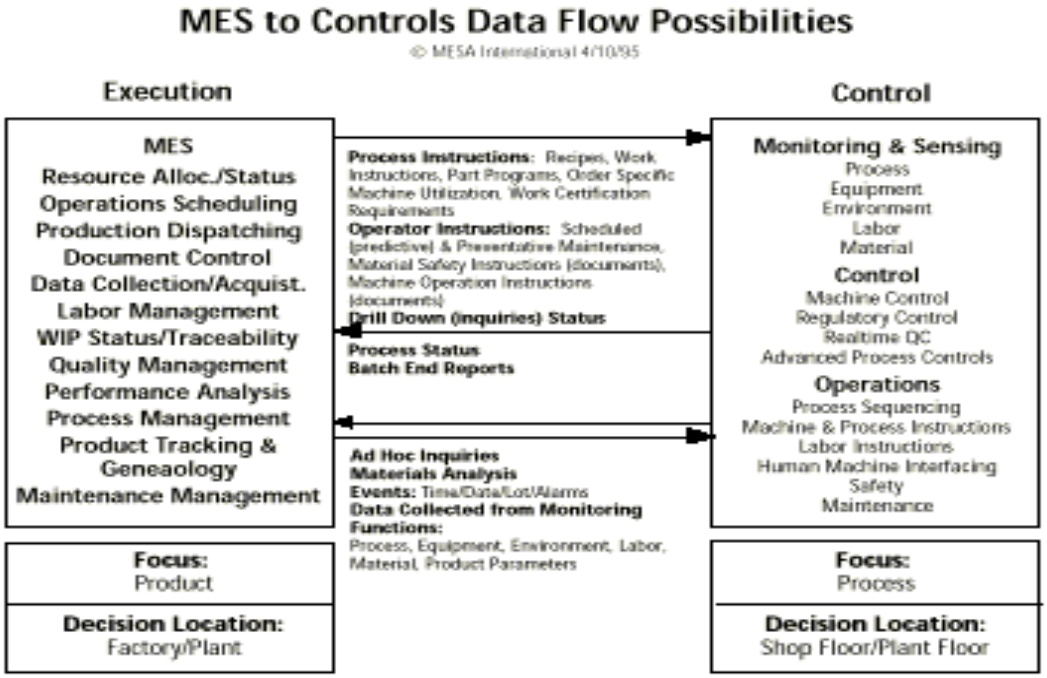


Figure 1: MRPII to MES Data Flow Possibilities
Planning
Execution
MRPII / ERP
COMMS
Engineering
Forecasting
Costing
Production Planning
Product Definition
Process Definition
SOP
Human Resources
Inventory Management
Purchasing
Distribution
Product Demand
BOM/Formula/Recipe/Drawing
/Part Program
Resources
Routing/Process
Labor Characteristics
Inventory Status
SOP, HEALTH, WORK Instructions
Order Status/Completions
/Start-Due-End
Resource Status/Usage
Labor Status/Usage
Material Status/Usage
Actual BOM/Formula/Recipe/Drawing
/Part Program
Actual Routing/Process
Product Genealogy/Traceability
/As Built Information
Scrap/Waste
MES
Resource Alloc./Status
Operations Scheduling
Production Dispatching
Document Control
Data Collection/Acq.
Labor Management
WIP Status/Traceability
Quality Management
Performance Analysis
Process Management
Product Tracking
and Genealogy
Maintenance
Management
Focus:
Customer
Decision Location:
Office
Focus:
Product
Decision Location:
Factory


MES to Controls Data Flow Possibilities
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Execution
Control
MES
Resource Alloc./Status
Operations Scheduling
Production Dispatching
Document Control
Data Collection/Acquist.
Labor Management
WIP Status/Traceability
Quality Management
Performance Analysis
Process Management
Product Tracking &
Geneaology
Maintenance Management
Process Instructions: Recipes, Work Instructions, Part Programs, Order Specific Machine Utilization, Work Certification Requirements
Operator Instructions: Scheduled (predictive) & Preventative Maintenance, Material Safety Instructions (documents), Machine Operation Instructions (documents)
Drill Down (inquiries) Status
Process Status
Batch End Reports
Ad Hoc Inquiries
Materials Analysis
Events: Time/Data/Lot/Alarms
Data Collected from Monitoring Functions:
Process, Equipment, Environment, Labor, Material, Product Parameters
Monitoring & Sensing
Process
Equipment
Environment
Labor
Material
Control
Machine Control
Regulatory Control
Realtime QC
Advanced Process Controls
Operations
Process Sequencing
Machine & Process Instructions
Labor Instructions
Human Machine Interfacing
Safety
Maintenance
Focus:
Product
Decision Location:
Factory/Plant
Focus:
Process
Decision Location:
Shop Floor/Plant Floor

reduce their costs through process improvement.

MES can assist you by providing a focal point for production information. It can help you cope with a myriad of minor product variations, which cause most paper based, human managed systems to collapse. The ability of a good MES to coordinate effort can not be understated. Manual systems simply can not keep pace with product changes, regulatory issues, ISO9000 requirements, FDA regulations and the like. Changes in process and recipe requirements frustrate most production people and cause change to be fought or frustrated. Since operations must change rapidly in the modern manufacturing environment, manufacturers must establish Agile Manufacturing Practises to cope.

Supply Chain demands require that manufacturers have an accurate view of production and order status. Products and materials must be monitored continuously to provide you with the "Just in Time" capability you need. Plant status, material status and shipping capability all play a part in this process. The ability to respond quickly and deal with problems as they occur is a key part of the information flow process in today's markets.

What can an effective MES provide?

1. Reduced manufacturing cycle time – usually an average of 45%
2. Reduced work in progress (WIP) – by an average 24%
3. Reduced paperwork between shifts – typically 60%

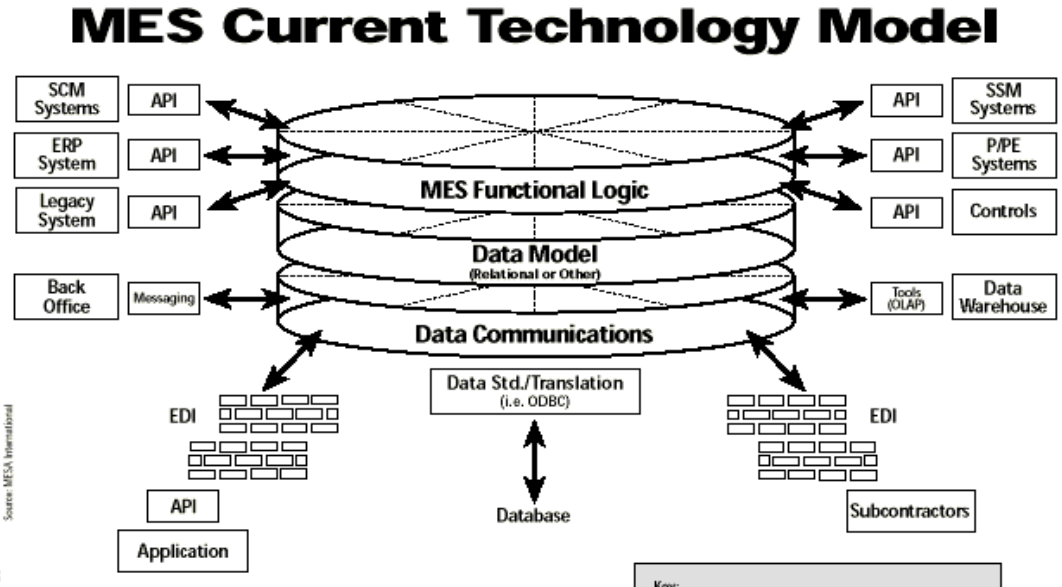

Figure 8, Current Technology Model Source: MESA International

4. Reduced lead time – an average of 27%
5. Reduced paperwork and blueprint losses by an average of 56%
6. Reduced product defects and average of 18%

See the MESA white papers for an explanation of how they validated these results.

MES focuses on how the plant is actually operating and how to improve the processes, while the ERP and MRP systems plan how things should work. MES improves the core value-adding process of a production company. Between the MES and ERP systems, and the improved access to information, both systems leverage the other to provide improved productivity, higher quality work and reduced supervisory and management overhead.

MES Architecture Comparison

MES Current Technology

Current technology is based on interfacing to and dealing with ERP/MRP systems in the same architectural style.

The Future – Today

The ASAP-RTS is built on the technology shown below. The system is modular and object oriented – in conformance with the principles of Holonic Manufacturing Systems. In our opinion, the new MES technology is very similar –—if not identical to – the architecture espoused by the Holonic Manufacturing Systems consortium – which is the architecture of our original ASAP-RTS system – circa spring 1995.

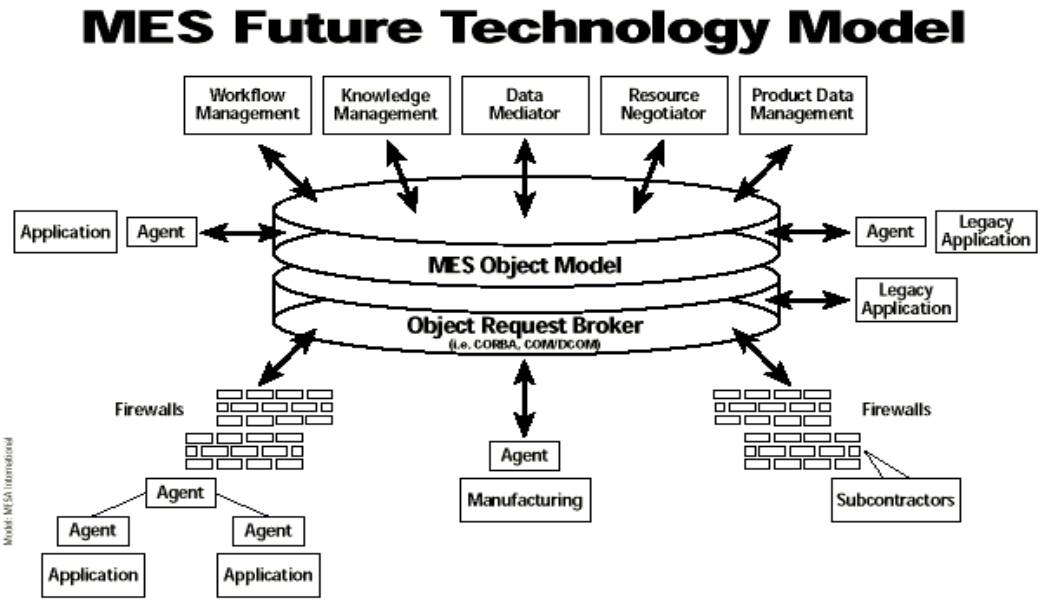

Figure 9, Future Technology Model

MES is incrementally evolving toward a consistent object model, along with the rest of the software industry. In this future information systems model, MES uses an object request broker to pass manufacturing events to workflows, agents, and external systems (SCM, ERP, Legacy, SSIM, P/PE, Controls, Data Warehouse) through data mediation. Unique plant business policy is represented as sets of rules within knowledge management which can initiate manufacturing events.

Source: NIIP-SMART Reference Architecture

Holonic System Architecture

A Holonic Manufacturing System (HMS) integrates the entire range of production activities in a manner that provides a dynamic, agile manufacturing system. An HMS is built on autonomous, intelligent, cooperative building blocks (Holons). An HMS is capable of reorganizing itself and rescheduling the resources of the system to deal dynamically with external or internal change. Because the HMS adapts quickly to change the promise is one of agile manufacturing at a low cost.

For further information see our paper on Holonic Manufacturing and MES systems.

Acknowledgments

Some of this material was taken from publications of the HMS and the IMS group and modified for the purpose of this information paper.References 7-16 are proprietary information available only to the HMS Consortium.

Appendices

Contacting PMC Consulring

Any changes are the responsibility of PMC Conulting and do not reflect on the policy or the directions of the IMS or the HMS consortium.

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Glossary of Terms

ALAP As Late As Possible. (Backward Scheduling) - Allocate the production so that the job finishes on the due date.

Algorithm - A method of solving a problem — a step-wise solution.

ASAP (Forward Scheduling) - Allocate the job in the first available time slot.

ASAP-RTS - The Amber scheduling system. (Amber Scheduling and Production – Real Time Systems)

Bottleneck - The machine that sets the production pace.

Constraint - A constraint is a restriction – as in - it must be on a certain machine, or in a certain sequence, or done by a given date.

Constraints, Theory of - See the series of books by Goldratt about how production can be improved by always finding and improving the slowest or most restricting process.

Data Highway - An Allen-Bradley term for the Ethernet system used on their PLC's.

ERP (Enterprise Resource Planning - System) - A software system used for manufacturing. Many companies who used to produce an MRP II package are now claiming that they are a wider more encompassing ERP system.

Ethernet (See Data Highway and TCP/IP) - A data communications protocol and hardware description for communicating on LANS – closely linked to TCP/IP and the Internet.

Finite Capacity Scheduling - A scheduling methodology that takes into account the rates of the machines and the time and resources actually available.

Genetic Algorithm or Genetic Search Algorithm (GA or GSA) - New programming technique used in systems that learn.

Heuristic - A rule of thumb – or assumption about how an algorithm should proceed to solve a problem.

HMS (Holonic Manufacturing Systems) - A Holon is an intelligent, independent, autonomous, cooperative unit – for example a human. Holonic systems exhibit these characteristics.

Holon see above.

Holarchy - A hierarchy of Holons. The Holonic philosophy states that machines should be able to organize themselves into systems and behave like humans in an organization. (There are scientists who believe that this is not necessarily a good thing.)

IMS - The Intelligent Manufacturing Systems Association of which the HMS is a member organizations/project.

Infinite Capacity Scheduling - Most MRP systems do not take into account the actual capacity, but will simply accept new orders, and tell you what you have to order to build these new orders.

Makespan - The total time that a set of

orders takes to processed on a (set of) machine(s).

MES (Manufacturing Execution System) - See the MESA WEB page at for a series of White Papers that describe the ideal MES system. They have an 11 point rating system.

MESA or MESA International (Manufacturing Execution Systems Association) See above

MRP and MRP II (Material Requirements Planning) - Originally developed in the late 1960's and 70's as a way of organizing manufacturing accounting and planning systems.

Objective Function - This is a mathematical function that defines the goal or objective of the scheduling system.

Optimization - You minimize time or use of material when you optimize a schedule.

Penalty Function - Certain actions are acceptable but still undesirable when you schedule or build a product. A penalty function attempts to persuade the algorithm - by assigning a bad score to an action - not to do things in certain ways - unless the alternative is even worse.

PLC Programmable Logic Controller - A low level machine controller. Programmed by ladder diagrams.

Process Industry - Any industry that uses measurement as opposed to discrete units when assembling goods. E.g. Board Plants, Food Processing etc. As opposed to building carburettors – for example – where you can count the parts precisely.

Resource - A machine or worker used in building a good.

Resource Calendar - The availability list for machines and workers.

SCADA (Supervisory Control and Data Acquisition) The supervisor system in a network of data acquisition systems.

Search Space – A mathematical expression for degree of the equation(s) used to solve the schedule.

Tardiness - A term for lateness or earliness of the individual item in the schedule.

TCP/IP Transmission Control Protocol / Internet Protocol - The communication protocol for the Internet and some LANS.