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Intelligent Manufacturing Systems

Manufacturing Scheduling Systems

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Scheduling Methodology

Scheduling Definition

For our purposes, we will consider a ***Scheduler*** be an integration of three systems which by working in harmony will achieve the company manufacturing goals. These systems are a Priority Scheduler (or Political Evaluation), a Due Date Scheduler (Traditional Scheduler) and an Efficiency Scheduler (Machine Capability). Each of these scheduling systems attempts to balance a part of the company goals.

Due Date Scheduling

This is what most of us think of when scheduling is mentioned. We believe that the scheduling system should help us match the date on which the customer wants their order delivered. In a well run company, with adequate capacity, and, even loading of the order queue, this type of scheduling can be satisfactory. You can use average setup times, ignore sequence dependent setup factors and most environmental factors. In this type of a system one could simply invoke the dispatching rules to test whether a machine was capable of a job, then juggle the sequence until all jobs could be delivered on or before the due date. Due date scheduling often interferes with efficiency scheduling in dramatic fashion if you must cope with ***Sequence Dependent Setups***.

Priority (Political) Scheduling

Priority Scheduling is usually invoked as a response to what appears to be a difficult problem. The typical reasons that a high priority is assigned to a job are as follows:

- The last order was delivered - but the parts were defective in some manner, and you must now reproduce the order correctly.
- The last order was delivered late.
- A quality problem has been discovered, and some orders must be remanufactured.
- Machine down time has forced you to sacrifice some orders since you can't keep everybody happy anyway.
- The customer has planned badly and would like you to accommodate their internal problems.
- It is new client, and you wish to prove your responsiveness.

Although some of these problems are avoidable some of the time, they are not avoidable all of the time - hence accommodations must be possible.

In ASAP-RTS, you can use a number of different scheduling methods to recognize these circumstances. Scheduling Conditions such as Start No Later Than or Finish No Later Than (SNLT, FNLT) or even Must Start on Must Finish on (MSO, MFO) can be invoked. While these conditions remove any flexibility, they do preserve the client relationship.

Efficiency Scheduling

A plant is running most efficiently when every machine is balanced to achieve maximum output, and minimum scrap. If you only make one product on a machine, and you can sell all you produce, none of the scheduling methods help much, other than for juggling the time line to minimize lateness. However, if you must make a multitude of products on a machine, and these products require setup time, and the setup time depends on the previous machine state, then you have a good case for building an optimizer that considers machine capacities and capabilities.

An efficiency scheduler will evaluate Sequence Dependent Setups, and attempt to give you the most efficient job stream that minimizes manufacturing time fore the run. Achieving the shortest possible total run time will not guarantee you on time delivery in the near term. However, optimizing for the shortest run time is a good long-term strategy.

Coordination Scheduling & Holonic Resource Management Systems

In recent years the term Coordination Scheduling has come into use. Unlike Optimization, you don't process the schedule to achieve the result, rather you give the people who use the schedule the ability to change the schedule and indicate the reasoning behind the scheduling change. Or you might also express the idea as follows:

Fig 1. ASAP-RTS Work Flow

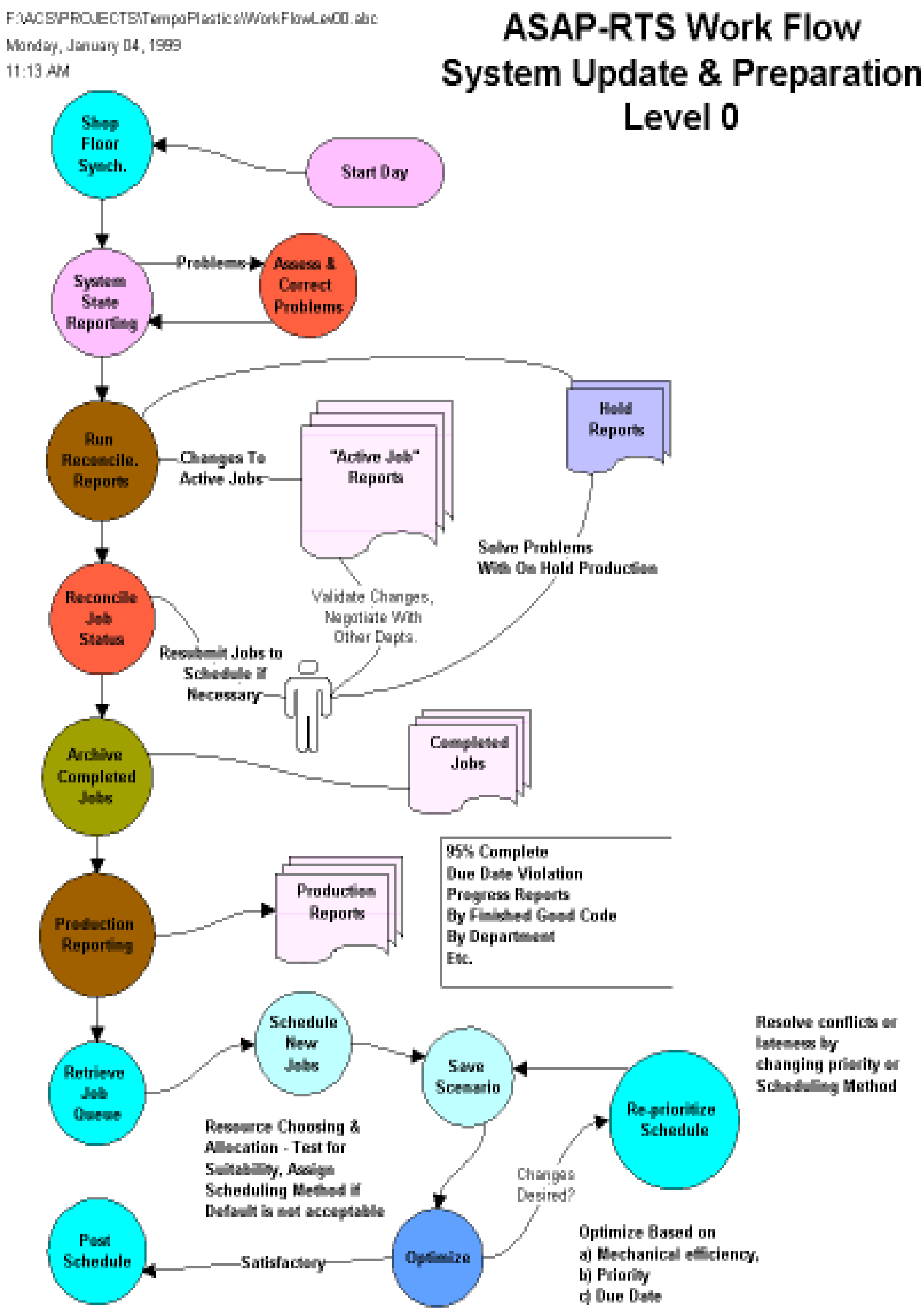
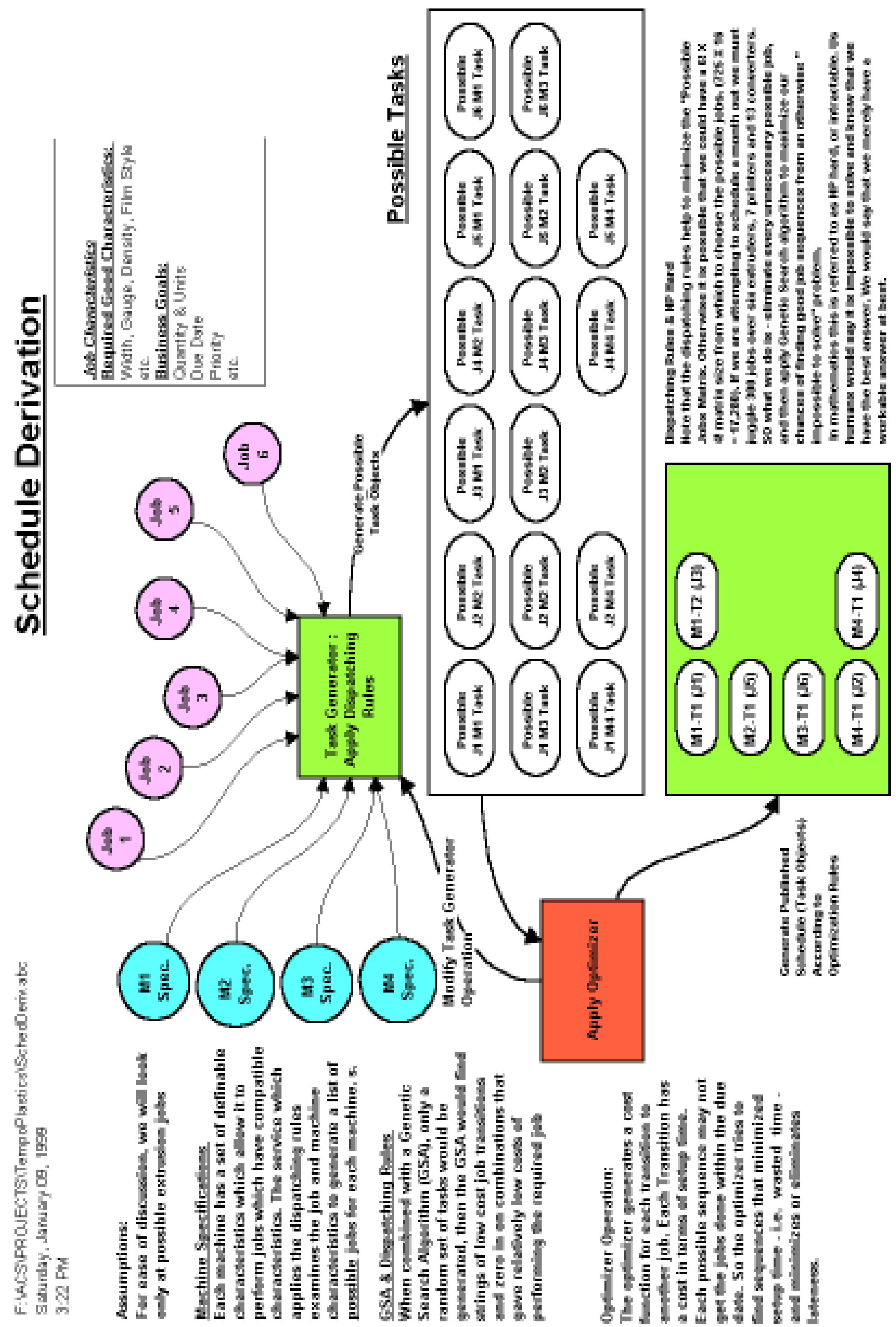


Fig. 2. Schedule Derivaton - Genetic Algorithm or Network Method



A coordination scheduler allows certain behavior from the people who use the schedule, and indicates to the network of people and systems what was done to modify the manufacturing schedule and for what reason the change was made.

The nearest analog to a coordination scheduler is probably a neural network, which has been designed to encourage or enforce synchronous group behavior. It is the precursor to the Holonic Manufacturing System, which is explained next.

A coordination scheduler requires that the data collection and the scheduling system interact in prescribed manner so that conflicts and changes can be reviewed and resolved by any user of the network that wishes to do so.

Holonic Resource Management Systems

Of course, **Holonic Schedulers and Resource Management Systems** (HRMS) are designed to work in a coordinating manner. If a scheduling system is flexible, intelligent, cooperative and self-organizing it is said to be a Holonic System. This definition requires that each major subsystem can work independently as well as cooperate in a tightly bound network. It also presupposes a message passing network communication system, and a formal protocol by which to pass requests (messages) and information throughout the network. A HRMS will meet all of the above standards and requirements.

Holonic systems are most useful where the manufacturing processes can be viewed as a network of cells, and may be least useful in a purely linear process.

A Holonic Scheduler or HRMS requires that the data collection and the scheduling system interact in prescribed manner so that conflicts and changes can be reviewed and resolved by all users of the network. While this may appear to be identical to the statement made about Coordination Schedulers, bear in mind that a Human or a Machine is viewed as a Holon (independent unit) in the HMS philosophy. Therefore, you could have a human altering the schedule, or conceivably a computer-based Holon could be altering or requesting an alteration to the schedule if its computations determine that such an alteration is favorable. Many techniques and tactics are used to design these systems however, they still require human designers with a sufficient knowledge of the particlar industry to create the scheduling and interaction algorithms, and the computers require sufficient computational power to make the required decisions in a timely fashion.

Publish Subscribe

Systems that use Publics/Subscribe systems are ideal for use as a basis Holonic Systems, or Coordination Schedulers. Their Architecture allows you to design the system modules so that they are stand alone, and communicate exclusively through a series of protocols and message passing mechanisms. These mechanisms can be be implemted though electronic message passing, RF or Network Packets for high speed applications, and through data store systems (Databases) for passing business data such as manufacturing schedules.

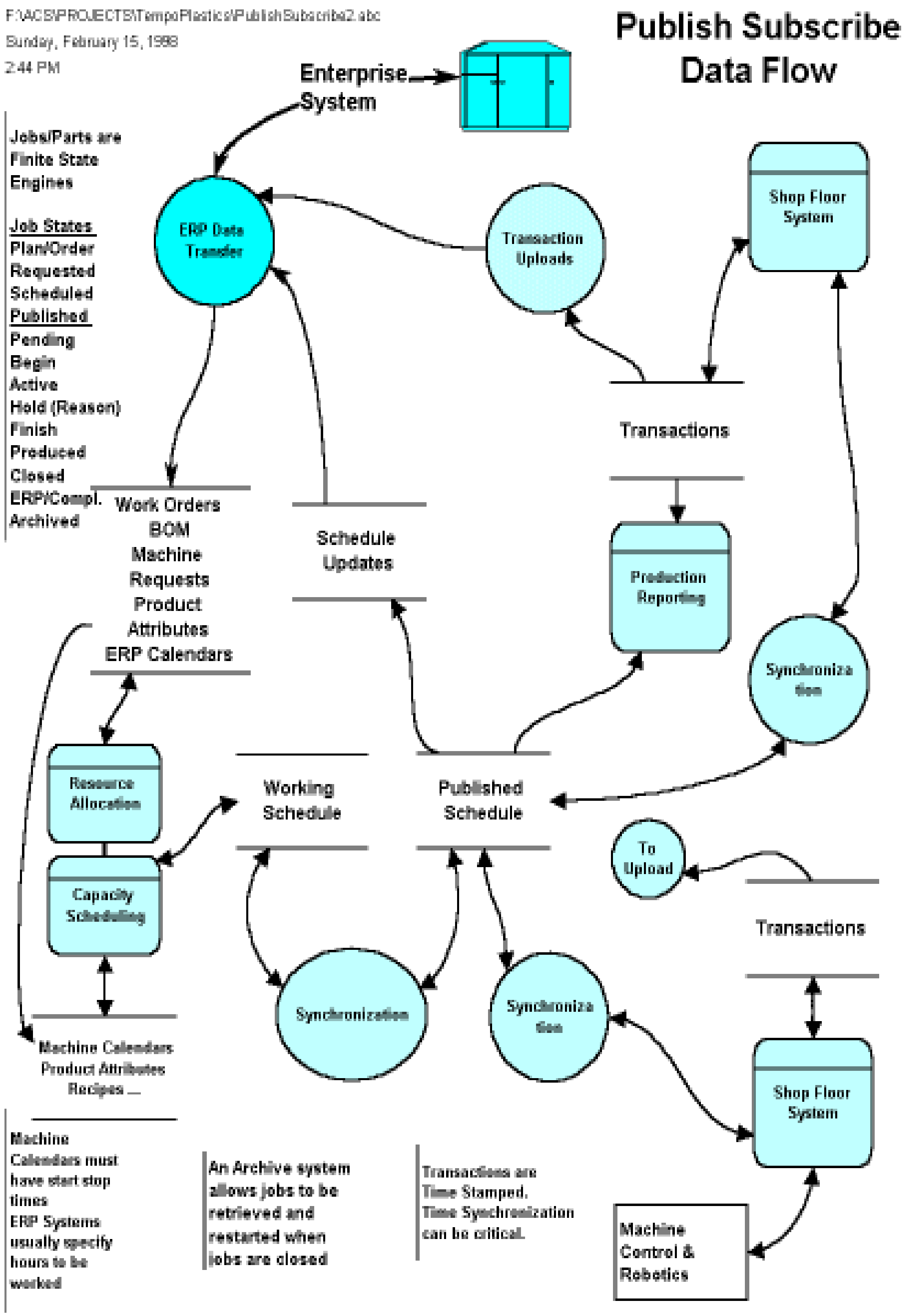
Why Use an Optimizer?

The use of an Optimzer seems redundant to many people who design and plan Holonic Systems. After all if the Holons (or Agents) ehibit intelligent behaviour, and are self organizing does that not take care of the issue? From my point of view, the answer is a resounding “maybe”.

First of all, **there is nothing wrong with having a good plan**. A manufacturing schedule that balances the three issues of Politics, Due Dates and Efficiency (machine capabilities and capacities) is just a **good plan**. What happens when the scheduler finishes the plan is what happens with any good plan - it gets “improved” by the people who **execute** the plan.

A Holonic System is supposed to be modelled after Human Behavior, so my ultimate justification for my model is rooted in normal

Fig. 3. Publish Subscribe Data Flow - MES to Business System and Data Collection



human behavior. As managers, we expect our Human Subordinates to follow the company plan, and to take independent action where necessary. So it should be with a Holarchy - at least in my mind. Someone has to make decisions, and someone has to carry them out - that is the idea of a hierarchy.

Holonic Architecture

At the present state of our design capabilities I think it is all we can hope for to design special purpose Holons (Or Agents if you will.) that can be organized into systems composed of other independent Holonic Agents. The idea of the totally reconfiguring factory may yet be a little way off. I for one have difficulty understanding how machinery that was designed to make Particle Board can be reconfigured to make Plastic Bags, or even Plywood. So I accept that our designs with current technology may be limited to designing "Pluggable Agents" that represent the factory machinery. These Agents will integrate into a Manufacturing Execution System that is capable of creating a hierarchy of Control Objects and hence organizing a manufacturing plant.

The HMS group has been doing considerable work with protcols and communications methods so that machines may talk to each other easily. So the idea of a common communications architecture is already firmly entrenched in HMS philosophy. All that is missing is the communications architecture that integrates the Factory to the goals of the Business Organization. While the Architecture of machine communication is necessarily Electronic Messaging - because of the speed requirements, the Architecture of the information interchange is of necessity rooted in database architecture because of the volume of the information that must be maintained. The smallest part of the business system deals in the "Here and Now", while the MES system, of necessity, **only** deals in the "Here and Now". The Business System stores all of the History, and all of the Future (long term) plans as well as the current plan.

Even in a Holonic System, the role of Scheduling and Optimization is to provide a feasible, short term manufacturing plan to the factory floor.

Since factories typically have many duplicate machines, we will have our lives made easier if we design a "Backbone" into which we can plug our Software Holons. These Holons will then allow us to schedule and eventually control (Coopt?) the plant machinery since we have given these Agents intimate knowledge of the machine capacities and capabilities. I say we ***will*** be capable of controlling the machines, because we do not yet have plant machinery with enough intelligence to accept a goal as an instruction. Production Machines still require far too much detail in their instructions to be called "Holonic". However, we have an opportunity to begin designing the objects that will act as agents in MES and Scheduling systems, and as the communication protocols become more sophisticated, and the machinery becomes more sophisticated, we will begin to see the Software Objects as "Drivers" - almost as we see a printer driver today.

In the future, when a new machine is delivered, it will come with its own, internal intelligence, and a "Software Driver" that will allow the MES and the business system to understand the new production machinery.

Additional Information

For more information on the Topic of HRMS and Holonic Manufacturing Systems, read the paper on our WEB site. The page is at http://www.acsi.bc.ca/education.html . The paper can be obtained from: http://www.acsi.bc.ca/pdf/hmspaper.pdf .You will need to use the Adobe Acrobat PDF viewer to read the document. There are instructions on the page for obtaining the paper.

There is also a paper on Manufacturing Execution Systems explaining the standard used by MESA to judge MES systems. The paper can be down loaded from our WEB page at: http://www.acsi.bc.ca/pdf/hmspaper.pdf .

Appendices

Acknowledgment

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.

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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, co-operative 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 organise themselves into systems and behave like humans in an organisation. (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 organisation/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 organising manufacturing accounting and planning systems.

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

Optimisation - You minimise time or use of material when you optimise 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.