Engineer On a Disk

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Automation

AA:2. AUTOMATION

• As machines are used in production, we need to consider how they are applied to the tasks.

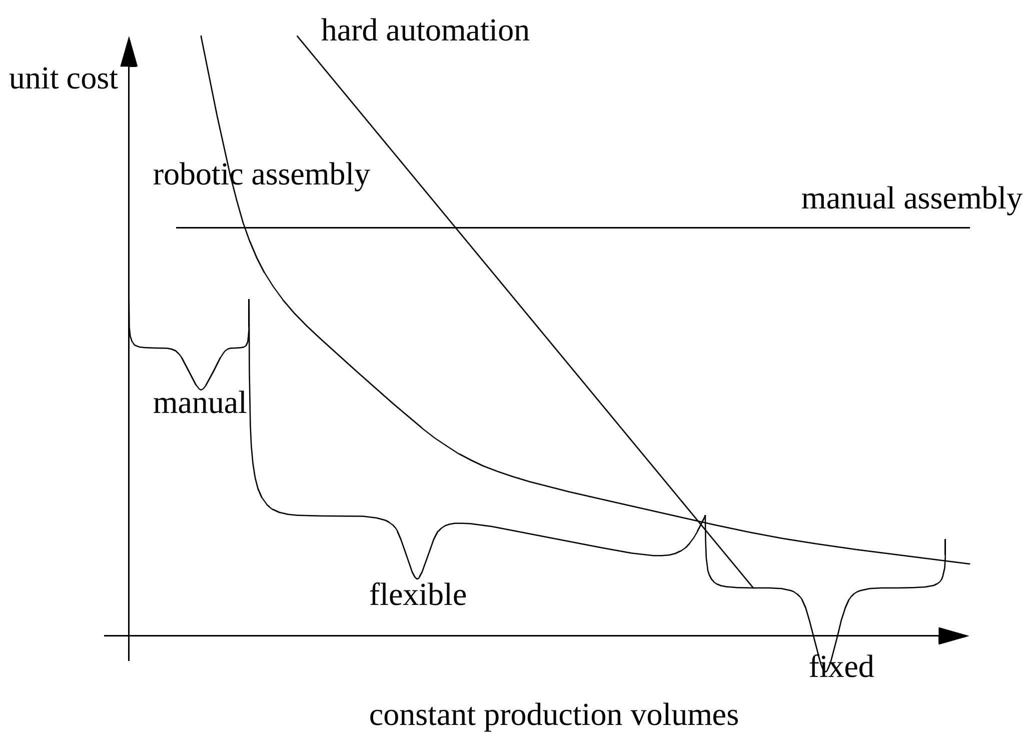
AA:2.1 INTRODUCTION

AC:2.1.1 The Questions

• What? - By adding electronics, sensors, actuators, computers and mechanisms human capabilities can be augmented to improve manufacturing.

• Why ? - In many cases there are valid reasons for assisting humans
  - tedious work -- consistency required
  - dangerous
  - tasks are beyond normal human abilities (e.g., weight, time, size, etc)
  - economics

• When?



AC:2.1.2 Why Bother with Automated Manufacturing?

• Without production, a company has nothing of real value to sell.

• A company which is poor at production is guaranteed to go out of business eventually.

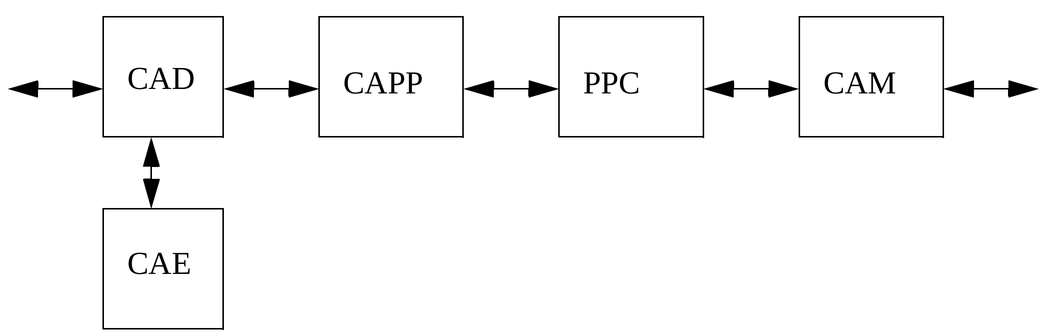
• Competition drives production, and every advantage counts.

• Automation can act as valuable weapons against competitors.

• Advantages of Automated Manufacturing,
  - improved work flow
  - reduced handling
  - simplification of production
  - reduced lead time
  - increased moral in workers (after a wise implementation)
  - more responsive to quality, and other problems
  - etc.

AC:2.2 THE BIG PICTURE

How Computers Can Be Used in an Automated Manufacturing System



• Some Acronyms

CAD - Computer Aided/Automated Design - Design geometry, dimensions, etc.

CAE - Analysis of the design done in the CAD system for stresses, flows, etc. (often described as part of CAD)

CAM - Computer Aided/Automated Manufacturing - is the use of computers to select, setup, schedule, and drive manufacturing processes.

CAPP - Computer Aided Process Planning - is used for converting a design to a set of processes for production, machine selection, tool selection, etc.

PPC - Production Planning and Control - also known as scheduling. Up to this stage each process is dealt with separately. Here they are mixed with other products, as required by customer demand, and subject to limited availability of manufacturing resources.

Factory Control - On a minute by minute basis this will split up schedules into their required parts, and deal with mixed processes on a factory wide basis. (This is very factory specific, and is often software written for particular facilities) An example system would track car color and options on an assembly line.

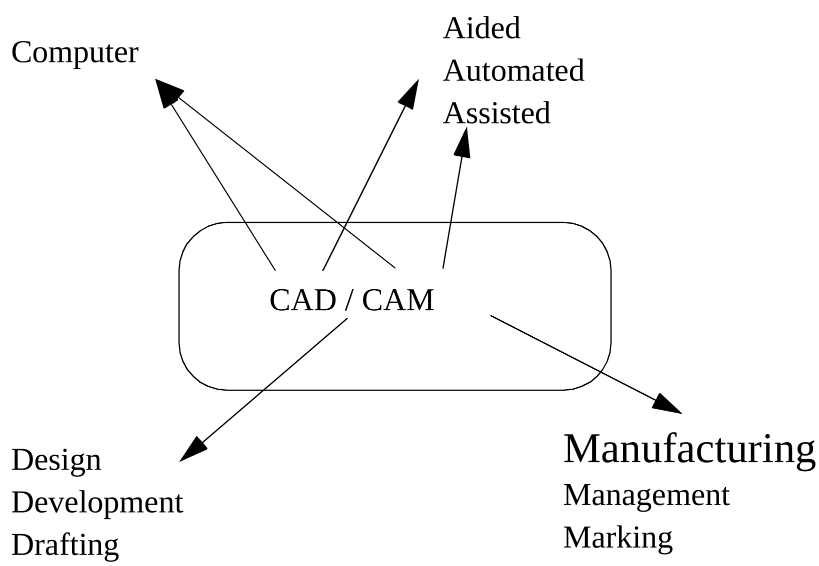
Workcell Control - At this system level computers deal with coordination of a number of machines. The most common example is a PLC that runs material handling systems, as well as interlocks with NC machines.

Machine Control - Low level process control that deals with turning motors on/off, regulating speeds, etc., to perform a single process. This is often done by the manufacturers of industrial machinery.

AC:2.2.1 Acronyms

• A Blessing and a curse

• Acronyms make it possible to convey exact technical meaning in a quick efficient way. But, they also make it possible to confuse a subject with poorly defined terms



• There are many acronyms involved with this book, such as CAPP, CIM, CAM, CAD, CAE, PPC, MRP, MRP-II, UNIX, DOS, CNC, DNC, etc.

AC:2.2.2 What is CAD/CAM?

• Using computers for design and manufacturing

• We computerize the easier tasks, which are tedious and mistake prone when done manually.

• In CAD we design product geometries, do analysis (also called CAE), and produce final documentation.

• In CAM, parts are planned for manufacturing (eg. generating NC code), and then manufactured with the aid of computers.

• CAD/CAM tends to provide solutions to existing problems. For example, analysis of a part under stress is much easier to do with FEM, than by equations, or by building prototypes.

• CAD/CAM systems are easy to mix with humans.

• This technology is proven, and has been a success for many companies.

• There is no 'ONE WAY' of describing CAD/CAM. It is a collection of technologies which can be run independently, or connected. If connected they are commonly referred to as CIM

AC:2.2.3 What is the difference between CAD, CAM AND CIM

- CAD/CAM involves the use of computers to make Design and Manufacturing more profitable.

- Parts of CIM use CAD/CAM techniques and products to try and make the factory fully connected using computers.

- The essential difference is CAD/CAM provides the tools, CIM is the philosophy which is used when organizing the computers, programs, etc. and all the information that flows between them.

- Another way to think of CIM is that it allows the structure of an organization to be entered into the computers.

- CIM focuses on connecting the various CAD/CAM modules.

AC:2.2.4 Examples of CAD/CAM Usage

- An FMS is made out of CAD/CAM components (and can be PART of a CIM system).

- The list below shows users of FMS in the U.S.A. The variety of applications illustrates that the technology may be used by any industry. The companies employing the technology show confidence in the technology. [Source -- find]

Table 1:

Company	FMS location	Product	Main supplier
Aerospace: Engines			
Avco Lycoming	Stratford, CT	Engine components	Kearney & Trecker
Pratt & Whitney	Columbus, GA	Engine components	
General Electric	WIlmington, NC Lynn, MA	Engine components	Lodge & Shipley
Aerospace			
Boeing	Auburn, WA	Aircraft components	Shin Nippon Koki

Table 1:

Company	FMS location	Product	Main supplier
FMC Corporation	Brea, CA Aiken SC	Joints and Hoses components for military vehicles and rocket launch systems	Cincinnati Milacron
General Dynamics	Fort Worth, TX	Components for F-16 aircraft	Westinghouse
Lockheed Georgia	Marietta, GA	Airframe parts	White-Consolidated
Vought	Dallas, TX	Aircraft fuselage for B-1 bomber	Cincinnati Milacron
McDonnell Douglas	Torrence, CA St.Louis, MO	Aircraft components Missile bodies	Cincinnati Milacron Giddings & Lewis
Westinghouse Electrical Systems	Lima, OH	Aircraft generator components	Westinghouse
Equipment			
Caterpillar	East Peoria, IL Decatur, IL	Tractor components	Cincinnati Milacron Giddings & Lewis
John Deere	Waterloo, IA	Tractor parts	Kearney & Trecker
Detroit Diesel	Detroit, MI	Piston engines	Lamb Technicon
Ford	New Holland, PA	Sheet metal parts for farm equipment	Trumpf
Ingersoll Rand	Roanoke, VA	Hoist equipment	White-Sunstrand
Mack-Truck	Hagerstown, MD	Transmission Housing and casting	kearney & Trecker
Machine Tool			

Table 1:

Company	FMS location	Product	Main supplier
Cincinnati Milacron	Mt. Orab, OH	Parts for plastics Processing equipment	Cincinnati Milacron
Mazak	Florence, KY	Parts for machine tools	Mazak
White-Sunstrand	Belvidere, IL	Machine tool parts	White-Consolidated
Other Industries			
Allen-Bradley	Milwaukee, WI	Motor starters	kearney & Trecker
Borg Warner	York, PA	Compressor components	Comau
Federal Mogul	Littiz, PA	Bearings	
G.E. Medical Systems	Milwakee, WI	Parts for medical equipments	Trumpf
Mercury Marine	Fond Du Lac, WI	Outboard motor crankcase and block	Kearney & Trecker
NY Air Base	Watertown, NY	Brake Systems	
OMC-Evinrude	Milwakee, WI	Outboard motor parts	Swedish Machine Group
Onan	MInneapolis, MN	Electrical switchgear for generators	Trumpf
Remington Arms	Ilion, NY	Firearm parts	
Union Special	Huntley, IL	Sewing machine bodies	kearney & Trecker
Westinghouse Electric Corp.	Pittsburgh, PA	Wire harness for electrical equipment	
Xerox	Webster, NY	Panels for copiers	

• The table below indicates the countries which are using the FMS technology. The countries with the higher numbers of FMS systems are also a sample of the major economic leaders. [Ayres et al, 1991, pg. 212, an estimate based on limited information] [source - find]

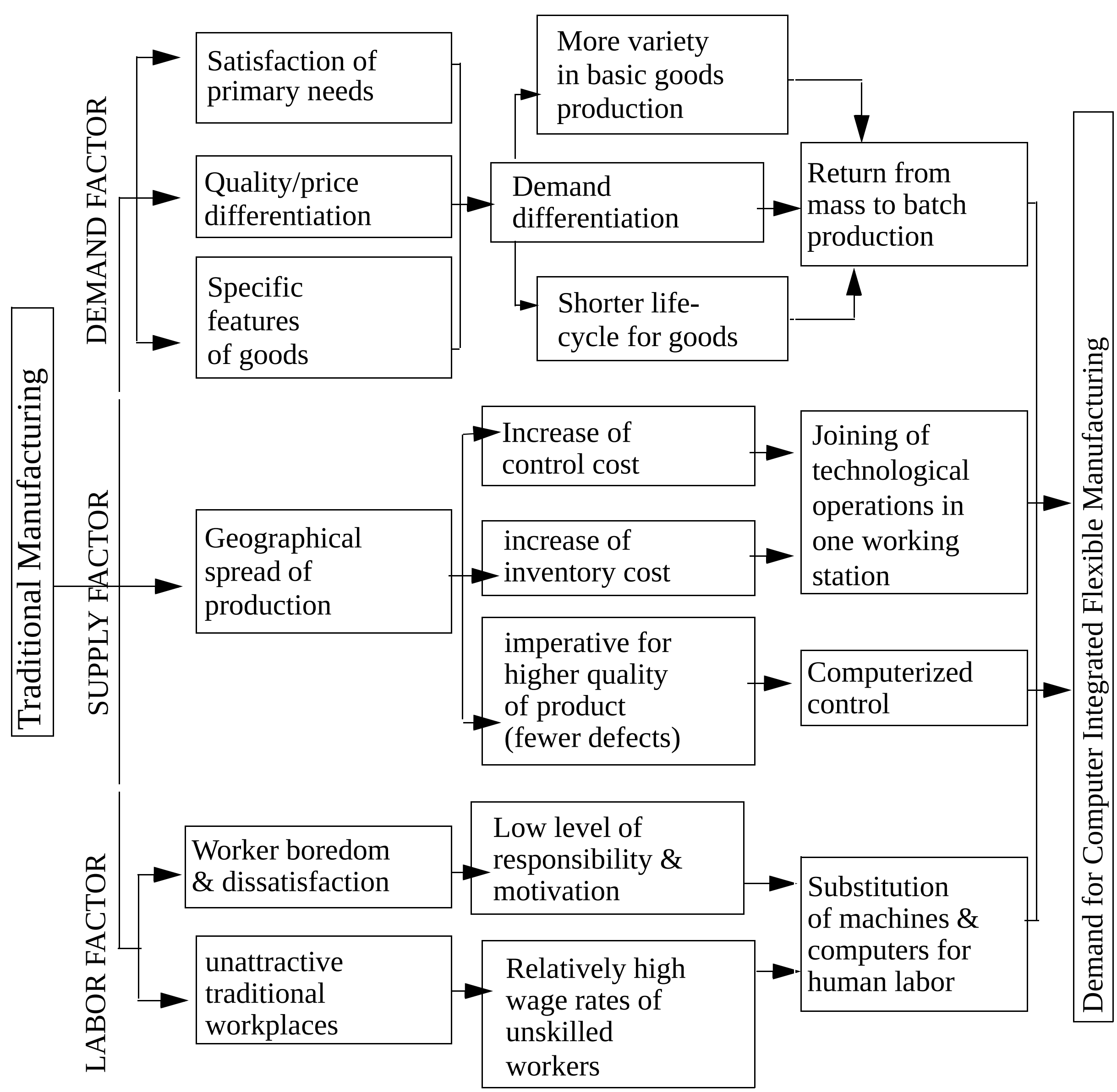
Table 2:

Country	FMS installed	percentages
Austria	6	0.7
Belgium	6	0.7
Bulgaria	15	1.7
Canada	4	0.5
CSFR	23	2.6
Finland	12	1.4
France	72	8.2
FRG	85	9.7
GDR	30	3.4
Hungary	7	0.8
India	1	0.1
Ireland	1	0.1
Israel	2	0.2
Italy	40	4.5
Japan	213	24.2
Netherlands	8	0.9
Norway	1	0.1
Poland	5	0.6
Romania	1	0.1
Singapore	1	0.1
South Korea	4	0.5
Spain	2	0.2
Sweden	37	4.2
Switzerland	6	0.7
Taiwan	5	0.6

Table 2:

Country	FMS installed	percentages
UK	97	11.0
USA	139	15.8
USSR	56	6.4
Yugoslavia	1	0.1

• Driving forces of CIM/FMS are shown in the figure below[source - find]



AC:2.2.5 Computer Integrated Manufacturing (CIM),

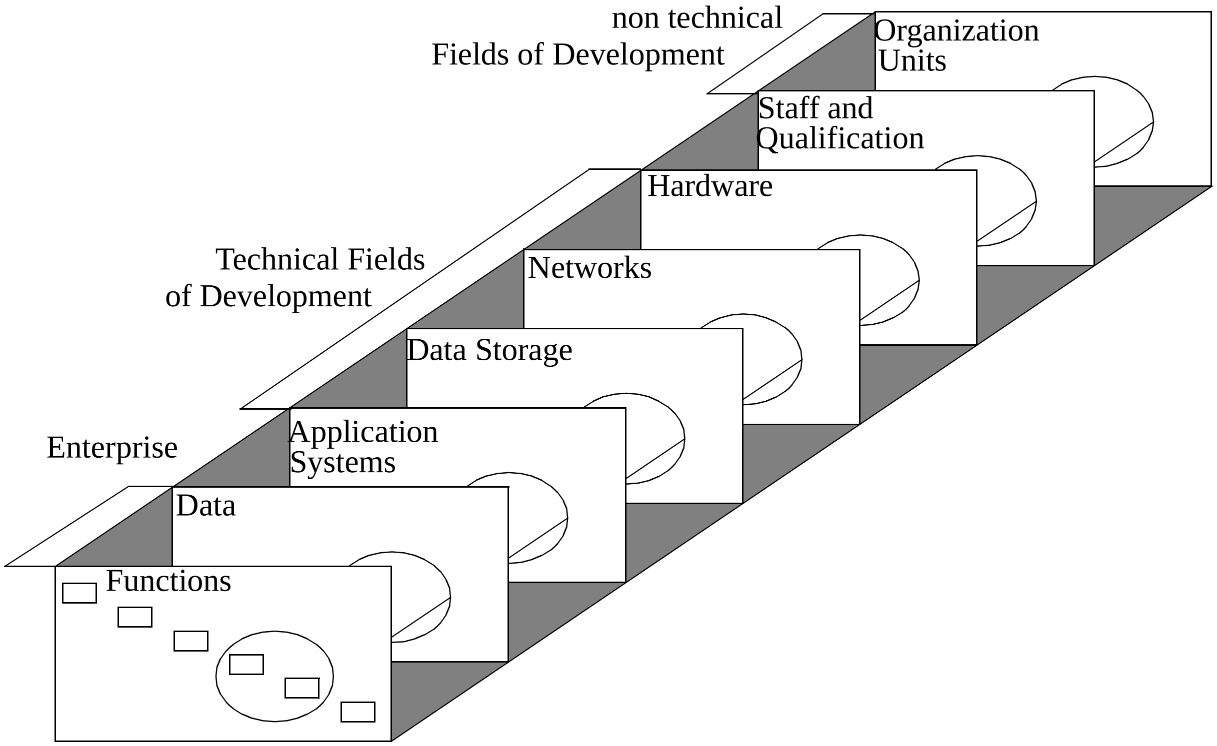
• We should aspire to meet the ideals of CIM when designing CAD/CAM technology

• CIM architectures contain,
- Computing Hardware
- Application Software
- Database Software
- Network Hardware
- Automated Machinery

• CIM benefits,
- Optimizes data flow in company
- Simplifies sharing and translation of information
- Reduces careless errors in data
- Allows checking of data against standards
- Promotes use of standards

• CIM modules,
- Customer Order Entry
- Computer Aided Design (CAD) / Computer Aided Engineering (CAE)
- Computer Aided Process Planning (CAPP)
- Materials (e.g., MRP-II)
- Production Planning and Control (Scheduling)
- Shop Floor Control (e.g., FMS)

• Reference model for enterprise related CIM [find source]



AC:2.3 PRACTICE PROBLEMS

1. CAD and CAM are,
    a) Integrated production technologies.
    b) The best approaches to manufacturing.
    c) Part of CIM.
    d) None of the above.

(ans. c)

2. FMS systems are,
    a) faster than robots.
    b) a good replacement for manual labor.
    c) both a) and b)
    d) none of the above.

(ans. d)

AE:2.4 COMPUTER AIDED MANUFACTURING (CAM)

• CAM is the use of computers for any part of manufacturing.

AE:2.4.1 Overview

• The competitive world of manufacturing is requiring that computers now be used in a production environment to make things faster and more precise.

• Some basic roles of computers in manufacturing are,
  - Prepare product designs for shop floor production
  - Schedule jobs into machines in the factory
  - Track inventory, work in process, etc.
  - Control workcells
  - Control of processes

• When these functions happen automatically, and don’t require human intervention, we tend to say they are part of a CIM system.

AE:2.4.2 Devices

• Basically any device that can be controlled or interfaced to a computer, and be used in automated manufacturing.

• These devices include,
  - robots
  - NC machines
  - PLCs
  - material handling

AO:3. FLEXIBLE MANUFACTURING SYSTEMS (FMS)

AO:3.1 OVERVIEW

AO:3.1.1 Distinguishing characteristics,

• An automatic materials handling subsystem links machines in the system and provides for automatic interchange of workpieces in each machine

• Automatic continuous cycling of individual machines

• Complete control of the manufacturing system by the host computer

• Lightly manned, or possibly unmanned

• Characteristics of application,
  - Medium product mix
  - Medium production volume
  - Allows fast changeover on products

• Various measures of flexibility,
  - Able to deal with slightly, or greatly mixed parts.
  - Variations allowed in parts mix
  - Routing flexibility to alternate machines
  - Volume flexibility
  - Design change flexibility

• Major historical developments,
  - Weaving Looms with paper tapes,
  - NC machines with paper tapes
  - Hard wired NC machines
  - Computer controlled NC machines (CNC)
  - Direct Numerical Control (DNC)

• Components of FMS Systems,
  - Robotics
  - Material Handling / Transport
  - Machines
  - Manual / Automated Assembly Cells
  - Computers
  - Controllers
  - Software

- Networks
- Interfacing
- Monitoring equipment

• Humans are not without function in an FMS cell,
- loading and unloading workparts to and from the system
- changing tools and settings
- equipment maintenance and repair

• Computers provide essential support in a workcell for,
- CNC - Computer Numerical Control
- DNC - Direct Numerical Control of all the machine tools in the FMS. Both CNC and DNC functions can be incorporated into a single FMS.
- Computer control of the materials handling system
- Monitoring - collection of production related data such as piece counts, tool changes, and machine utilization
- Supervisory control - functions related to production control, traffic control, tool control, and so on.

• FMS systems are intended to solve the following problems,
- Production of families of workparts, often based on group technology
- Random launching of workparts into system is OK, because setup time is reduced with FMS.
- Reduced manufacturing lead time - this is possible because FMS has organization, and fast setup.
- Reduced work in process
- Increased machine utilization
- Reduced direct and indirect labor
- Better management control

• The most common problems in an FMS are,
- Scheduled maintenance
- Scheduled tool changeovers
- Tooling problems (failures and adjustments)
- Electrical Failures
- Mechanical Problems (e.g., oil leaks)

• Implementation Strategies,
- find and identify a champion (someone who will push for automation)
- spend time to educate workers and engineers on FMS
- invest in the planning stages
- look at others in industry
- use employee involvement from the start
- install in stages - don’t try to implement all at once

• Things to Avoid when making a decision for FMS,
  - ignore impact on upstream and downstream operations
  - allow the FMS to become the driving force in strategy
  - believe the vendor will solve the problem
  - base decisions solely on financials
  - ignore employee input to the process
  - try to implement all at once (if possible)

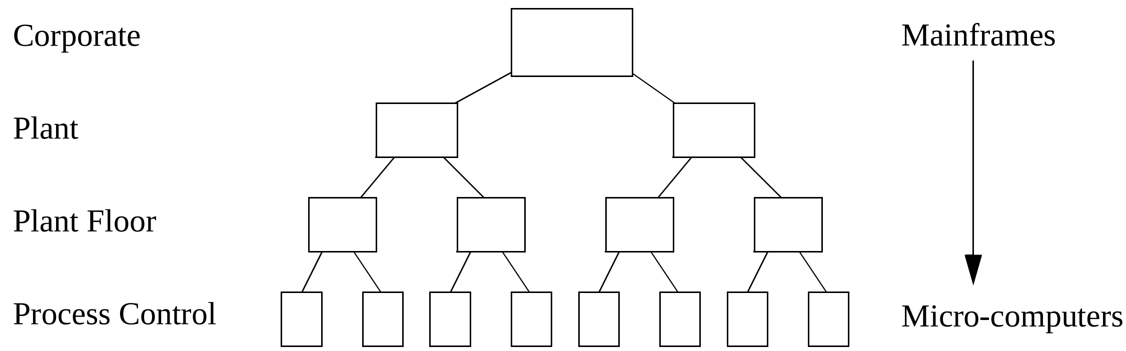
• Justification of FMS,
  - consider “BIG” picture
  - determine key problems that must be solved
  - highlight areas that will be impacted in enterprise
  - determine kind of flexibility needed
  - determine what kind of FMS to use
  - look at FMS impacts
  - consider implementation cost based on above

• Factors to consider in FMS decision,
  - volume of product
  - previous experience of company with FMS
  - product mix
  - scheduling / production mixes
  - extent of information system usage in organization (eg. MRP)
  - use of CAD/CAM at the front end.
  - availability of process planning and process data
  * Process planning is only part of CIM, and cannot stand alone.

AO:3.1.2 General Concepts

• Manufacturing requires computers for two functions,
  - Information Processing - This is characterized by programs that can operate in a batch mode.
  - Control - These programs must analyze sensory information, and control devices while observing time constraints.

• A CIM system is made up of Interfaced and Networked Computers. The general structure is hierarchical,

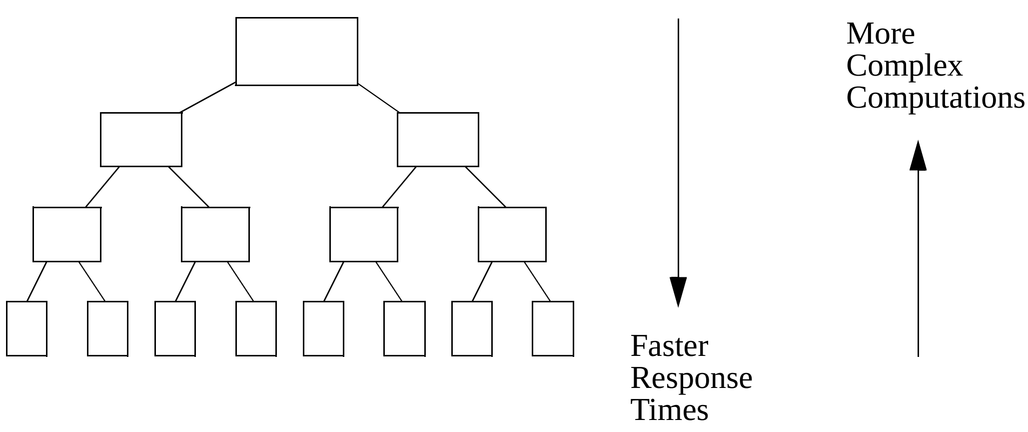


• The plant computers tend to drive the orders in the factory.

• The plant floor computers focus on departmental control. In particular,
  - synchronization of processes.
  - downloading data, programs, etc., for process control.
  - analysis of results (e.g., inspection results).

• Process control computers are local to machines to control the specifics of the individual processes. Some of their attributes are,
  - program storage and execution (e.g., NC Code),
  - sensor analysis,
  - actuator control,
  - process modeling,
  - observe time constraints (real time control).

• The diagram shows how the characteristics of the computers must change as different functions are handled.



• To perform information processing and control functions, each computer requires connections,
  - Stand alone - No connections to other computers, often requires a user interface.
  - Interfaced - Uses a single connection between two computers. This is characterized by serial interfaces such as RS-232 and RS-422.

- Networked - A single connection allows connections to more than one other computer. May also have shared files and databases.

• Types of common interfaces,
- RS-232 (and other RS standards) are usually run at speeds of 2400 to 9600 baud, but they are very dependable.

• Types of Common Networks,
- IEEE-488 connects a small number of computers (up to 32) at speeds from .5 Mbits/sec to 8 Mbits/sec. The devices must all be with a few meters of one another.
- Ethernet - connects a large number of computers (up to 1024) at speeds of up to 10 Mbits/sec., covering distances of km. These networks are LAN's, but bridges may be used to connect them to other LAN's to make aWAN.

• Types of Modern Computers,
- Mainframes - Used for a high throughput of data (from disks and programs). These are ideal for large business applications with multiple users, running many programs at once.
- Workstations (replacing Mini Computers) - have multiprocessing abilities of Mainframe, but are not suited to a limited number of users.
- Micro-processors, small computers with simple operating systems (like PC's with msdos) well suited to control. Most computerized machines use a micro-processor architecture.

3.2 COMPUTER COMMUNICATION TO SUPPORT FMS

3.2.1 Basic Computer control functions

• NC part program storage

• Distribution of the part programs to the individual machine tools
- include post processing for specific machine formats

• Production control

- decisions of part mix, rates, inputs to parts of system
- considers data like,
  - desired production rate for parts per day
  - number of raw workparts available
  - number of applicable pallets
- routes pallets to load/unload area
- gives instructions to operator about desired parts via a data entry unit (DEU)

- Traffic Control
  - Regulates materials transfer system to ensure parts are moved between desired workstations. This may be problematic, depending upon the transportation system used. Can act like a railway switch operator.

- Shuttle Control
  - moves parts between stations and main conveyor
  - coordinates actions between machines, and primary handling system

- Work handling system monitoring,
  - monitor both work parts, and pallets.

- Tool Control
  - tracks tools at each station (and reroute parts if necessary, or notifies operator to install parts)
  - tool life monitoring, and operator orders for replacement

- System performance monitoring and Reporting
  - Generate management reports

3.2.2 Data Files Required in a FMS system,

- Part program file
  - numerical control files for each part, and for each machine which may make a part

- Routing File
  - A list of machines which the parts must be routed through for completion, including alternates in some cases.

- Part Production File
  - Production parameters for each workpart
    - production rates
    - allowances for in-process inventory
    - inspections required
    - etc.
  - used for production control

- Pallet reference file
  - a record of which parts a specific pallet is fixtured for
  - each pallet is individually identified

- Station Tool File
  - a file for each workstation identifies,

- codes of cutting tools at station
- used for tool control purposes

• Tool-life file
- keeps tool-life value for each tool in the system for comparison with maximum value.

3.2.3 System reports generated by an FMS system,

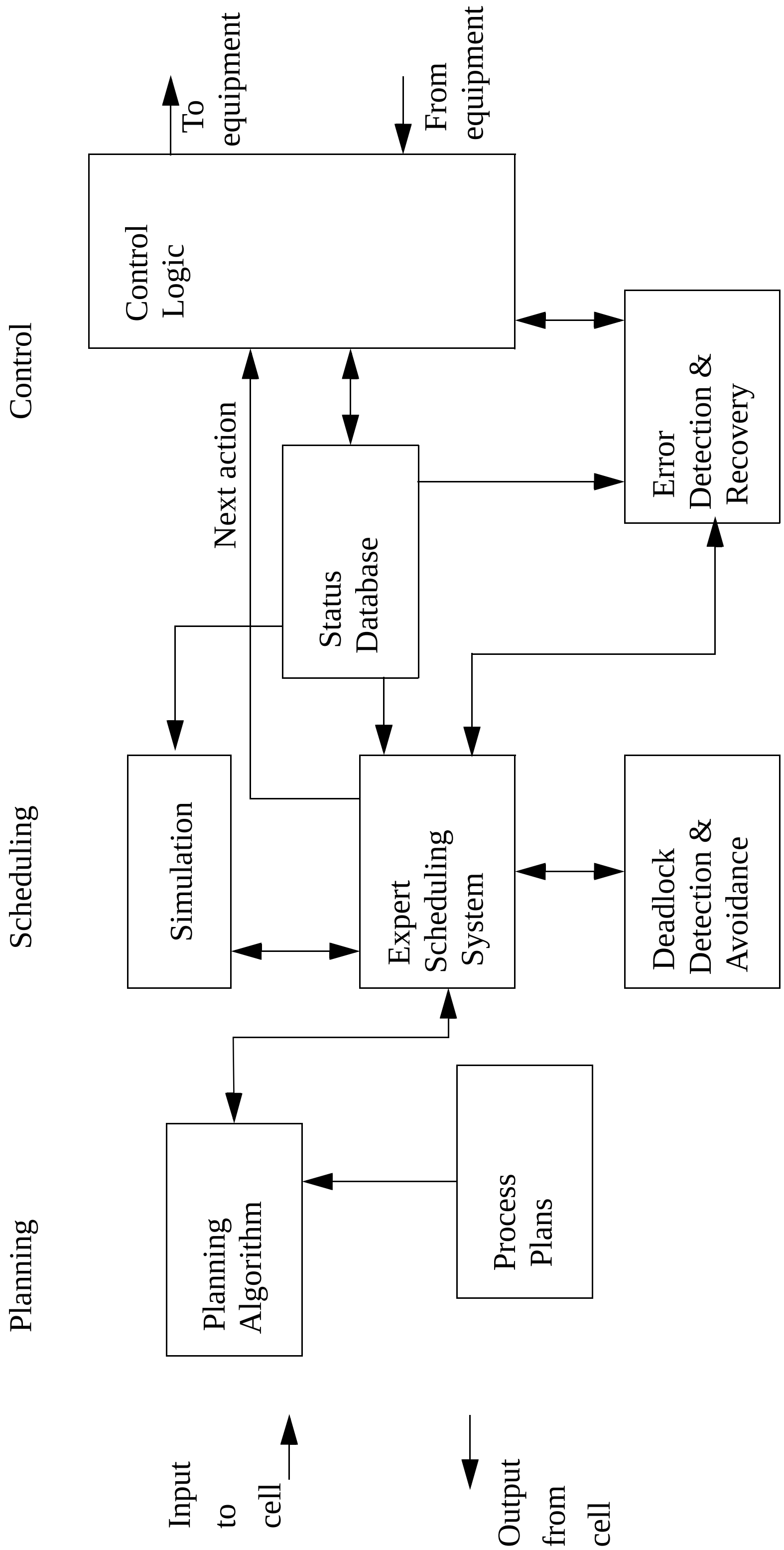
• Utilization Reports
- summarize individual, and group efficiencies for stations.

• Production Reports
- daily and weekly reports of parts produced in the FMS

• Status Reports
- a snapshot of present conditions in the FMS system for,
    - tools
    - parts
    - stations
    - pallets
    - etc

• Tool Reports
- list of tools at (or needed at) a workstation
- tool life status reports

• A Graphical Depiction of a Workstation Controller



Detail of Workstation Controller

AO:3.3 THE FUTURE OF FMS

- FMS systems which deliver directly into warehouse, and do not require labor
- The use of robots that have vision, and tactile sensing to replace human labor
- Technology will make 100% inspection feasible. Thus making faster process adjustment possible.
- Computer diagnosis will improve estimation of machine failure, and guide work crews repairing failures.
- International coordination and control of manufacturing facilities.
- Customers have completely custom orders made immediately, and to exact specifications, and at a lower cost
- Networks will tend to eliminate the barriers caused by international borders
- Standards will be developed which make installation of a new machine trivial
- Networking between manufacturers and suppliers will streamline the inventory problems
- Marketing will be reduced, as customer desires are met individually, and therefore do not need to be anticipated by research.
- Finished goods inventories will fall as individual consumer needs are met directly.
- Better management software, hardware, and fixturing techniques will push machine utilization towards 100%
- The task of Design and Process Planning will become highly automated, therefore reducing wasted time on repetitious design, and discovering careless mistakes.
- Simplification of systems overall - MRP, MPCS, etc.
- More front end simulation
- Computing power increases - more sophisticated tools

AO:3.4 PRACTICE PROBLEMS

1. What is concurrent (parallel) processing and why is it important for workcell control?

(ans. to allow equipment to do other tasks while one machine is processing)

2. What is meant by the term “Device Driver”?
(ans. a piece of hardware that allows a connections to a specific piece of hardware)

AO:3.5 AN EXAMPLE OF AN FMS CELL

AO:3.5.1 Overview

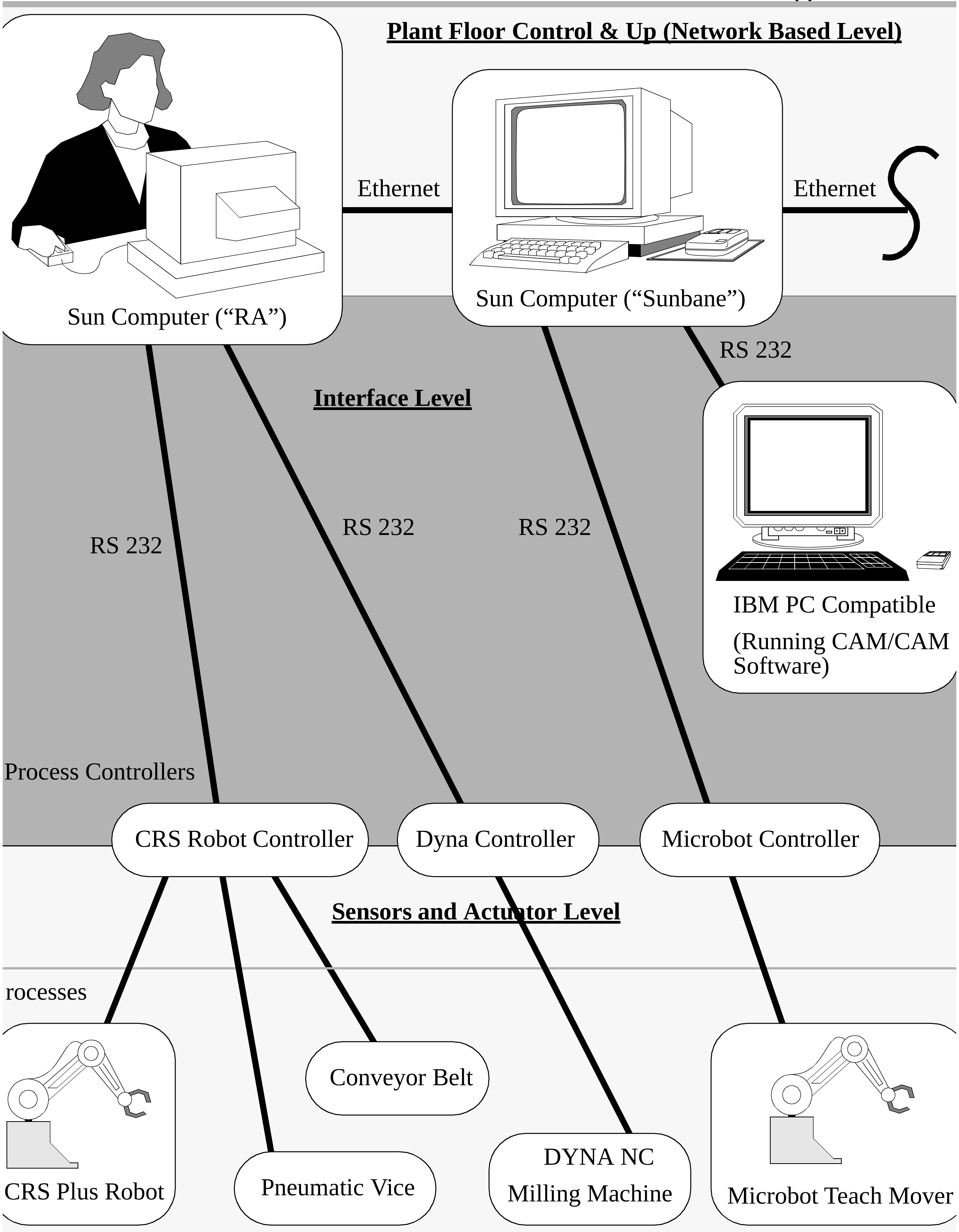
• A workcell has been constructed using one light industrial robot, and one NC milling machine. Some automated fixtures are also used.

• All of the devices in the workcell are controlled from a single Sun computer. This is an engineering workstation with UNIX. Thus, it is capable of multitasking (running more than one program at once).

• Software drivers, interfaces, and applications have been developed, to aid in teaching and demonstration.

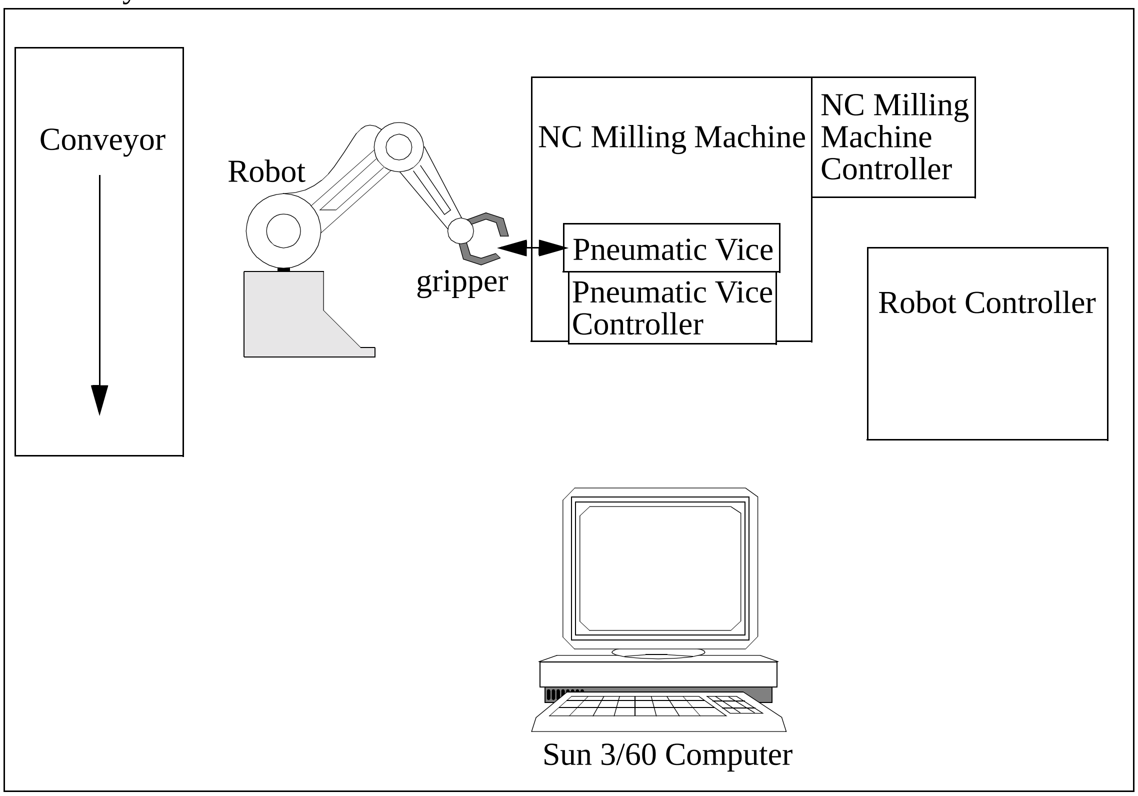
• The following pages will describe the interfacing in the workcell, as an example of the connection between process control computers and a plant floor computer. A project in development will be discussed for networking Plant Floor (and higher) computers.

FMS Cell Connection Diagram



AO:3.5.2 Workcell Specifications

• Workcell Layout



• Devices:

1 Sun Computer

2. CRS-Plus robot
   • A five axis, articulated robot arm
   • Communicates over an RS232 serial data line
   • Interprets a language called RAPL
   • Has 16 Digital I/O lines
   • Uses a pneumatically controlled gripper
   • The robot controller is 8088 based

3. DYNA-Mite Milling Machine
   • A 3-axis 2.5D milling machine
   • Uses a proprietary NC code
   • Can be run locally, or remotely (over RS232 serial communication lines)
   • Programs may be executed as they are entered, or when they are completely ordered
   • Can handle objects of dimensions 6” by 5” by 4”
   • Can machine plexiglass, wax, aluminum, steel (at low feed rates)

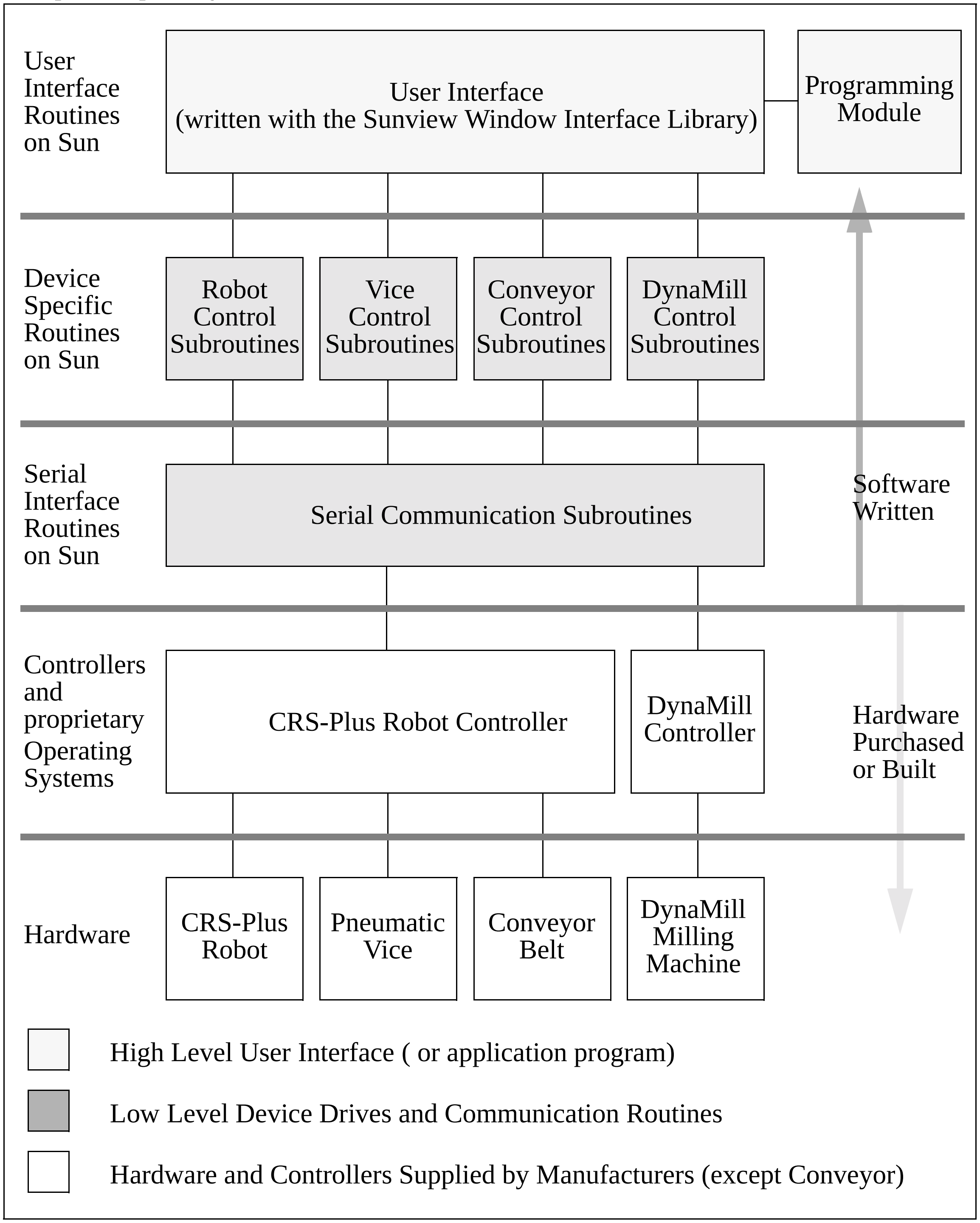
4. Pneumatic Vice

- Has a maximum opening of 4 inches
- Has a maximum travel of 1 inches
- Controlled by a pneumatic solenoid
- Pneumatic solenoid controlled from CRS-Plus robot controller

5. Conveyor
   - A former undergraduate student project
   - Activated electronically by the CRS-Plus robot controller
6. Fixtures (for making customized keytags)
   - These are highly specific to the task being performed
   - Parts Feeder - Provides a structured environment so that the robot may easily pick up the parts.
   - Robot Gripper - Designed to provide a reasonable reach into the vice (and parts feeder), and to firmly grasp the workpiece.
   - Vice Fixture - Designed to hold the workpiece at a level fixed height, and has a location for drill through of the keytag. This part does not effect the travel of the vice.

AO:3.5.3 Operation of The Cell

• Developed/Proprietary software in the workcell



2.1.4 - Example of Robot and Vice Software Driver Use

```
void demo()
{
        static double a1, a2, a3, a4, a5;

        crs_init();

        crs_speed(40.0);

        crs_open();
        crs_close();

        conv_on();

        crs_xy_r_move(-5.0, -5.0, 0.0);
        crs_xy_status(&a1, &a2, &a3, &a4, &a5);

        conv_off();

        crs_xy_a_move(a1+3.0, a2+2.0, a3);

        crs_depart(-2.0);
        crs_depart(2.0);

        crs_home();
        crs_r_move(0.0, 10.0, 0.0, 0.0, 0.0);
        crs_speed(100.0)

        vice_closed();

        crs_a_move(-90.0, 0.0,0.0,0.0,0.0);

        vice_open();
}
```

Set up Robot

Set speed to 40% of Maximum

Open the Gripper

Close the Gripper

Turn on Conveyor

Move Robot with relative Cartesian Coordinates

Return Cartesian Position of End Effector

Turn off Conveyor

Move Robot to absolute Cartesian Position

Move robot gripper 2” forward

Move robot gripper 2” backward

Move robot to home position

Move robot in relative joint coordinates

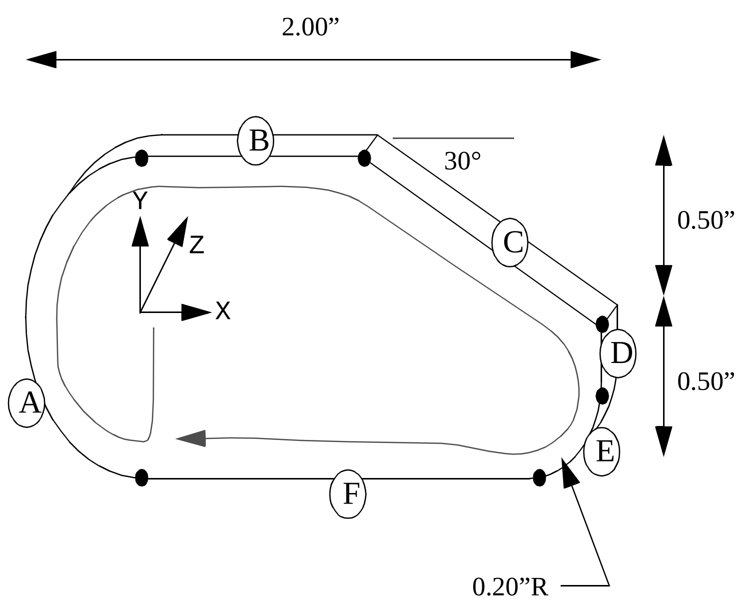
Close the Vice

Move the Robot in Absolute Joint Coordinates

Open the Vice

• NC code Example (for the Dyna Milling Machine)

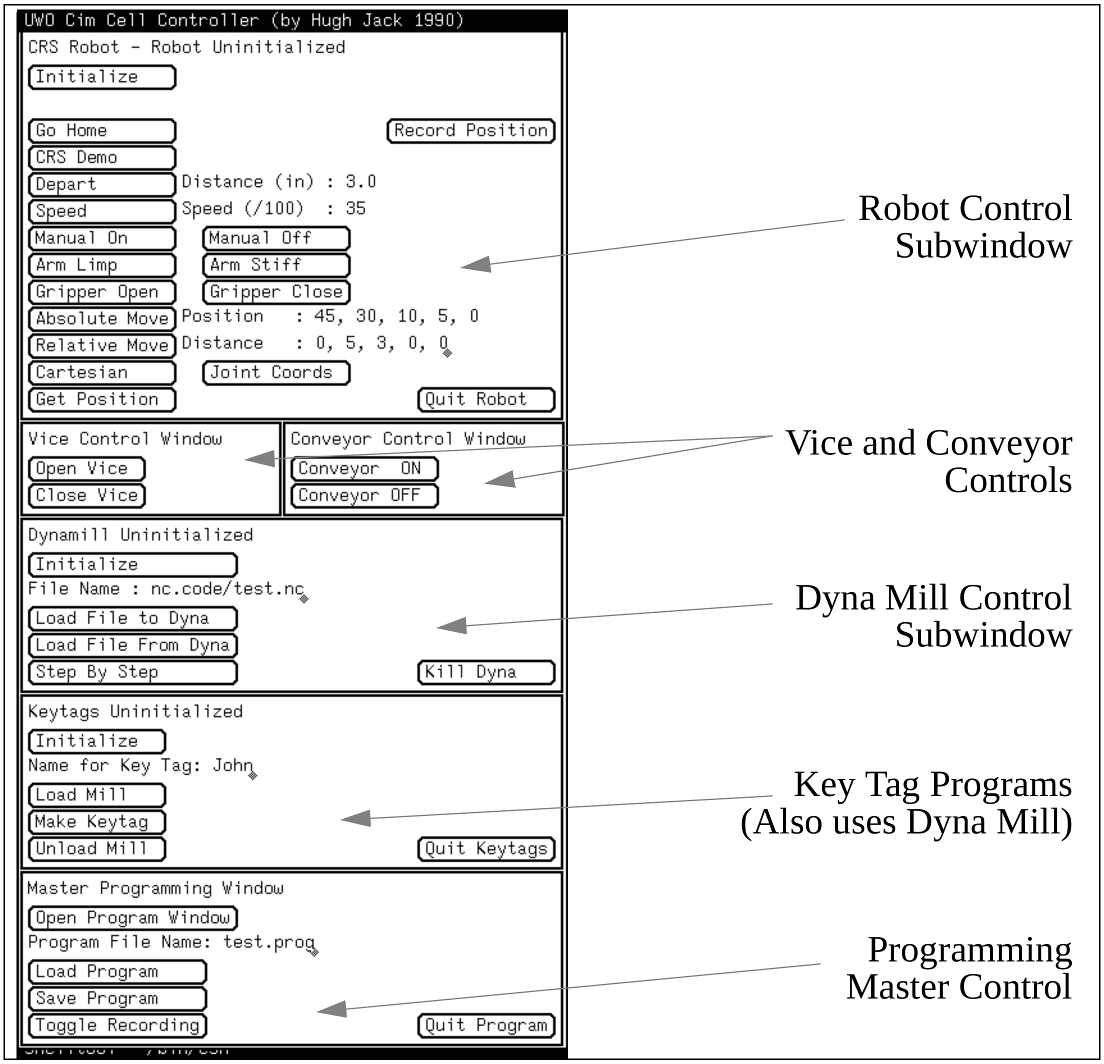
000 START INS 01		Start Program in inches
001 TD = 0.125		Set Tool Diameter
002 FR XY = 10		Set Feed Rates
003 FR Z = 4		Set Feed Rates
004 SETUP > zcxyu		Set Absolute Zero Position
005 GO Y -.625		Move to Start Position
006 GO Z -.125		Move to Start Position
007 GR a -180	A	
008 ZERO AT	B	
009 X .634	B	
010 Y .5	B	
011 GO r .125	B	
012 a 90	B	
013 GR a -30	C	
014 > REF COODS	C	
015 ZERO AT	C	
016 X 1.50	C	
017 Y 0	C	
018 GO r .125	C	
019 a 60	C	
020 GR a -60	C	
021 > REF COODS	D	
022 ZERO AT	D	
023 X 1.5	D	
024 Y -0.3	D	
025 GO r .125	D	
026 a 0	D	
027 GR a -90	E	
028 GR X -1.3	F	
029 END		End Program



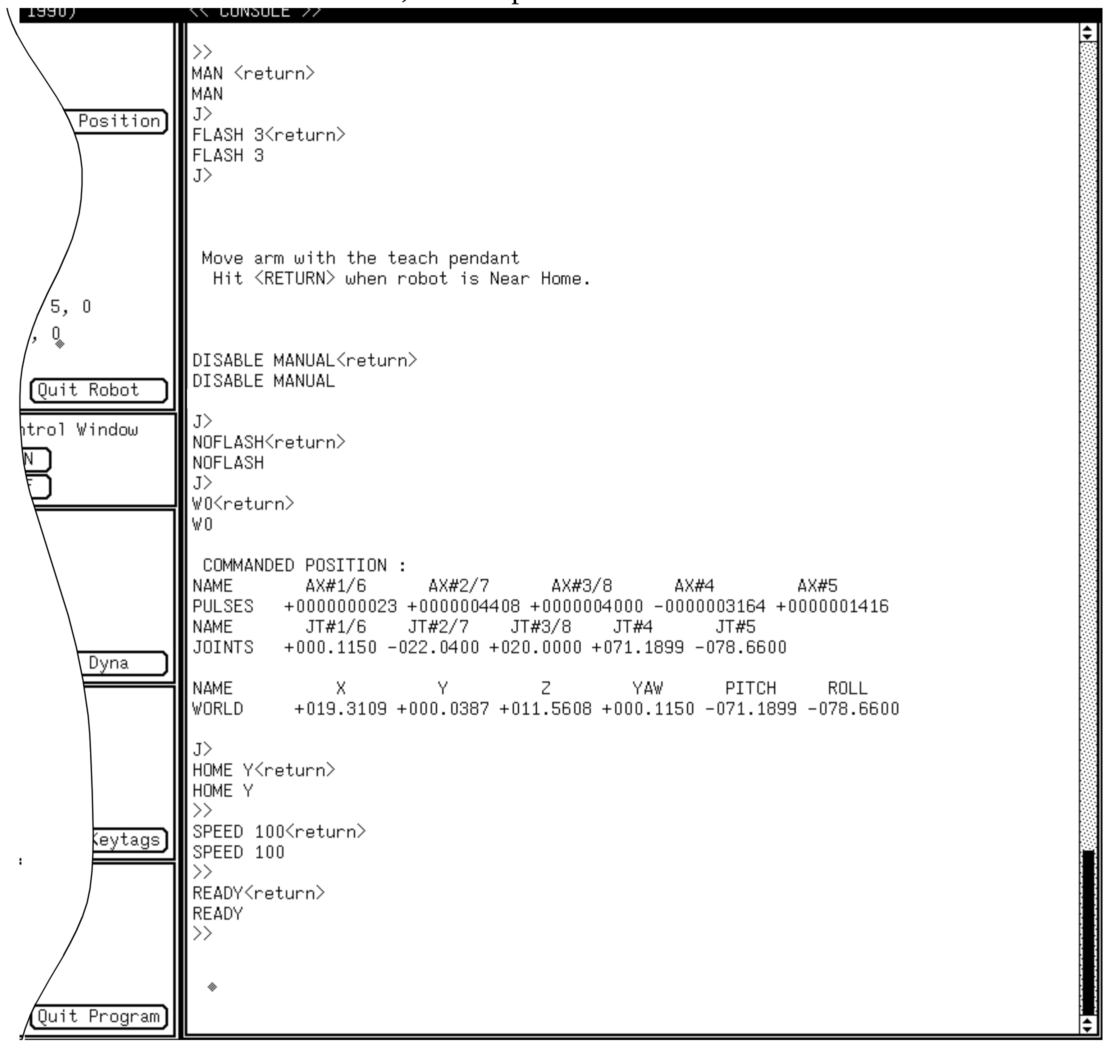
• An Example of the Dyna Mill Software Drivers

```
void demo()
{
        char ret[100];
        /* Initialize Dyna Mill and check for failure */
        if(dyna_init() == NO_ERROR){
                        /* Send NC Program to Dyna Mill */
                        dyna_load("/usr/people/cim/nc.code/test1.nc");
                        /* Download program from NC Mill */
                        dyna_download("/usr/people/cim/nc.code/test");
                        /* Send program to mill 1 step at a time */
                        dyna_step("/usr/people/cim/nc.code/test2.nc");
        }
        /* Deinitialize mill */
        dyna_kill();
}
```

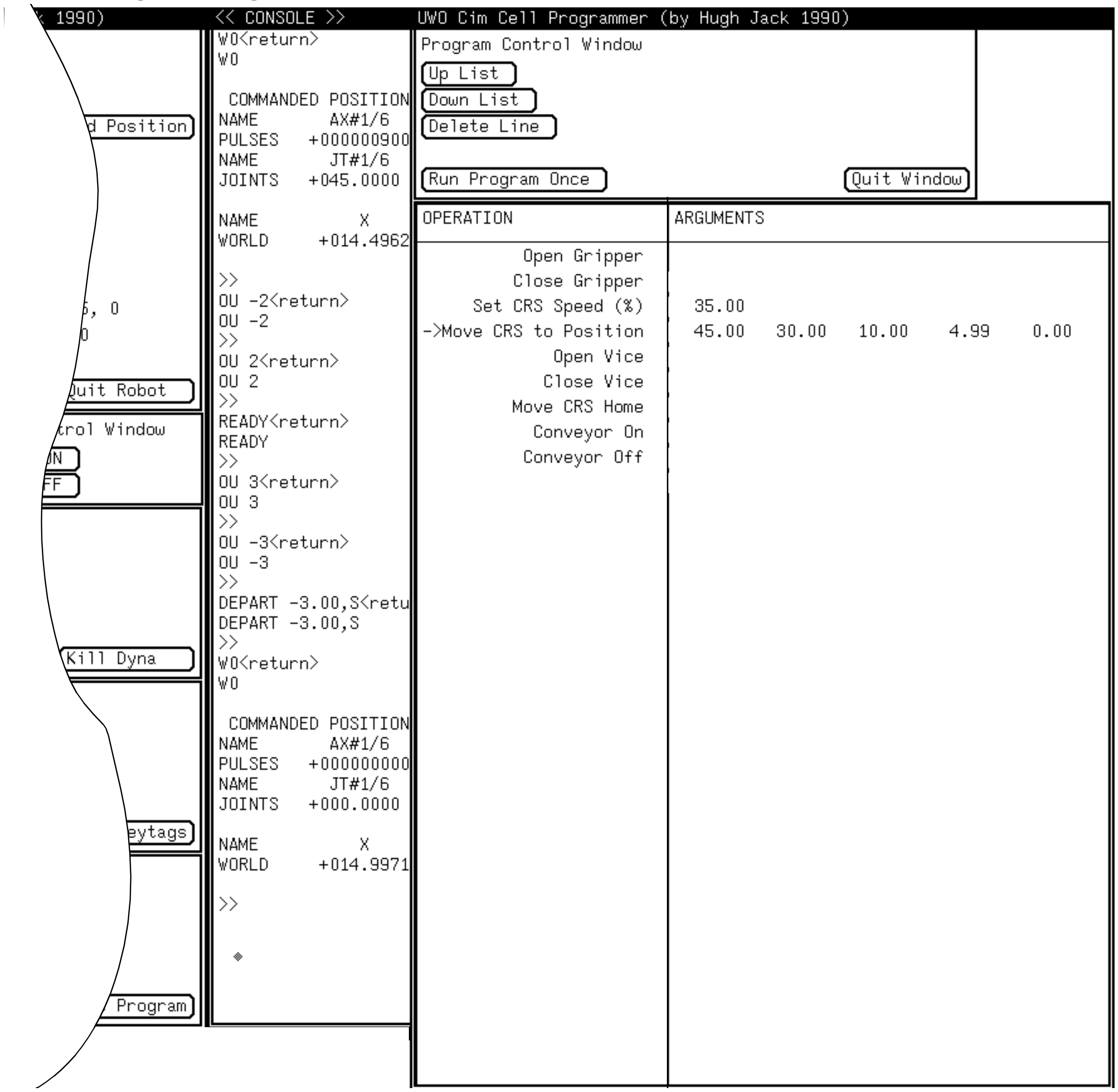
• A User interface for Workcell Control



• Actual Communication with devices, via a report window



• Workcell Programming window



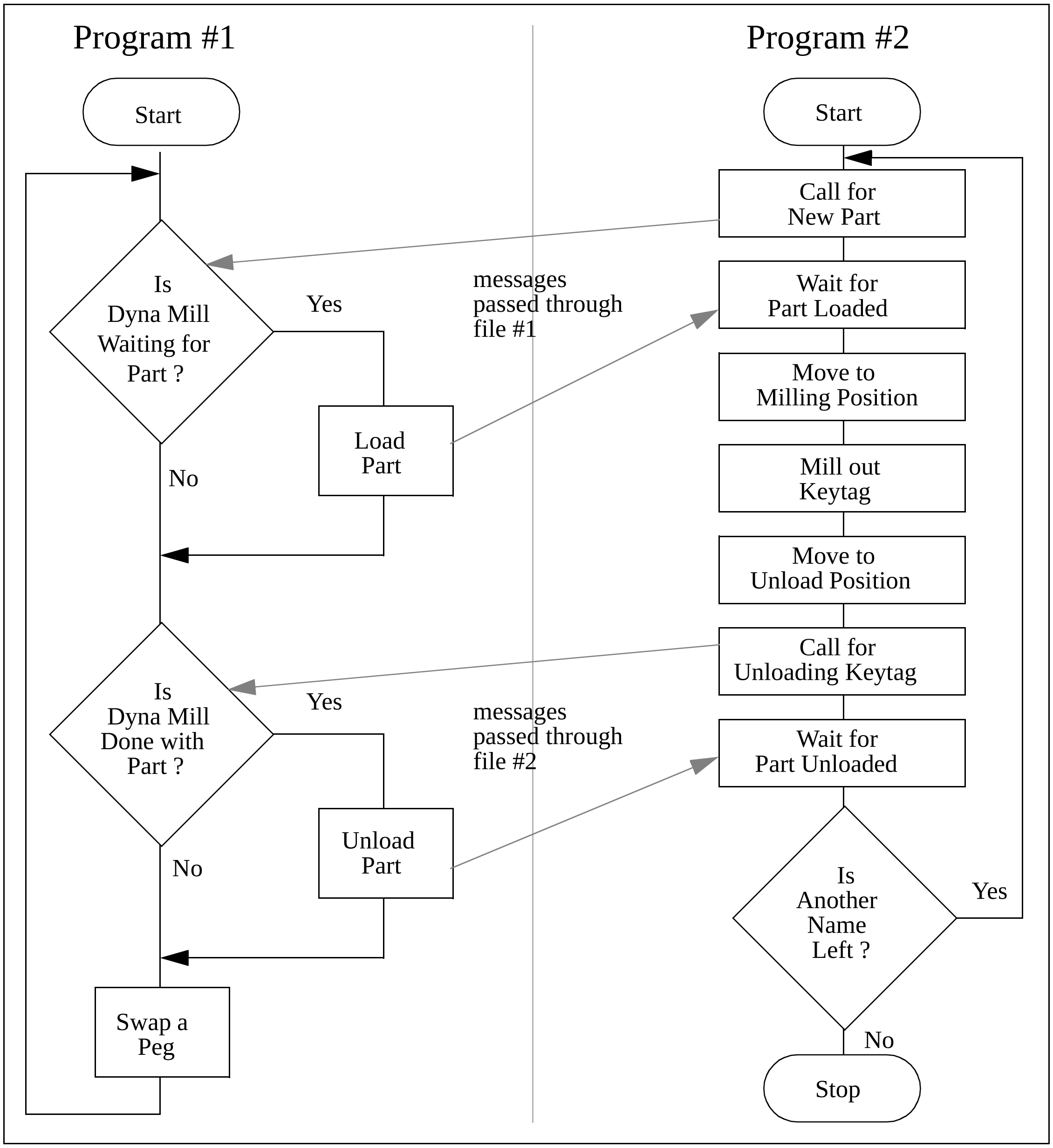
• Advantages:
  • UNIX Based system allows easy control of cell in modes which are both parallel and/or concurrent
  • A blend of high level computers with low level devices allows for a very modular system, with a variety of computing resources.
  • Synchronization of processes is very simple.
  • Allows rapid reconfiguration of the workcell.
  • This workcell will perform all of the basic CAD/CAM/CIM functions.
  • The hierarchical design of software tools has simplified the development of new applications.

• Disadvantages:
  • Many Equipment manufacturers have not considered this type of control (they prefer stand alone modes), and thus their machines lack self calibration features, and soft-

ware is made to be user interactive, and batch, but is not very friendly for software applications.
• Requires technical people to operate the equipments.

AO:3.6 THE NEED FOR CONCURRENT PROCESSING

• An individual computer is not powerful enough to control an entire factory. And, a single program would be too complex. Therefore, there is a need for many computers and programs which interact.
• The example below involves two programs. The first program will control the robot, and the second will cut key tags with the NC machine.
• While the keytags are being cut, the robot program will move pegs around in the cell. This requires that the control software be very complex, or that two programs be used.
• if two programs are used, then some communication is required for sequencing tasks in the work cell.
• Concurrent tasks in the workcell use message passing between programs,



• Strategies for Concurrent processing, involve how the processes are split apart, and how they communicate,
  - Have a number of processes which communicate directly to one another (point to point). This is synchronous and well suited to real-time control.
  - Use a buffered message passing system. This allows asynchronous communication between processes running at different speeds, which do not do real-time control.
  - Remote Procedure Calls allows one program to run other programs remotely. This is suited to well defined problems, but every program must have knowledge of the other computers in the network.

AO:3.7 PRACTICE PROBLEMS

1. What is concurrent (parallel) processing and why is it important for workcell control?
(ans. to allow equipment to do other tasks while one machine is processing)

2. What is meant by the term “Device Driver”?
(ans. a piece of hardware that allows a connections to a specific piece of hardware)

AA:4. MATERIAL HANDLING

• Basic purpose is to provide automatic transfer of workparts between automated machines, and interface with individual work stations.

AA:4.1 INTRODUCTION

• Basic layouts for material handling include,
  - lines - stations arranged along a fixed part transfer path.
  - batch - stations are grouped by function and batches of raw materials/WIP are brought in batches
  - job shop - individual parts are carried through one or more stages by one worker
  - job site - equipment is brought to the work

• These transfer systems can also be categorized by their timing approach,
  - synchronous - the entire line moves parts with a fixed period cycle. This is well suited to mass production of similar products.
  - asynchronous - parts are moved as completed or needed. Often buffers are required, but this is more tolerant of problems than synchronous systems.
  - continuous - the product flows by without stopping

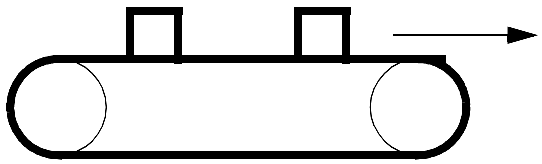
• Basic Requirements,

  • Random, independent movement of palletized workparts between workstations in the FMS
    - pallets can flow from any station to any other
    - parts are mounted in pallet fixtures
    - pallets can move independently to avoid interference
  • Temporary storage or banking of workparts
    - queues allow parts to wait for machines, thus increasing efficiency
  • Convenient access for loading and unloading workparts
    - easy to do manual load/unload.
    - automatic loading/unloading of parts at workstations
    - can load/unload from either side of system
  • Compatible with computer control
  • Provision for future expansion
    - modular extensions to system are desirable

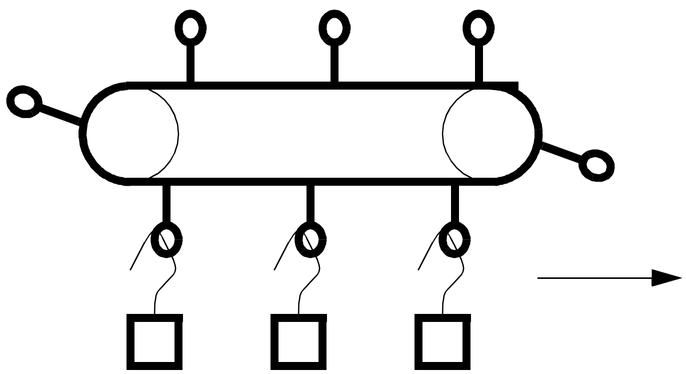
  • Adherence to all applicable industrial codes
    - safety, noise, etc.
  • Access to machine tools
    - allow unobstructed floor level access to each workstation

• Operation in shop environment
  - must be reliable when exposed to metal chips, cutting fluids, oil, dirt, etc.

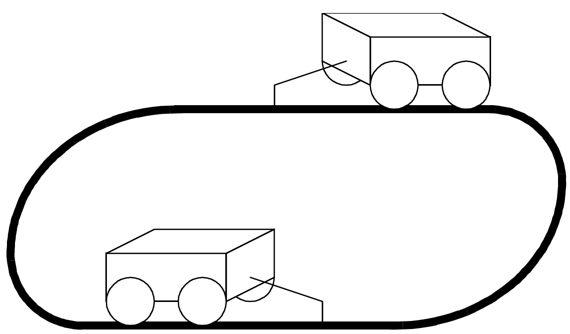
• Common type of Material handling systems
  - power roller conveyors



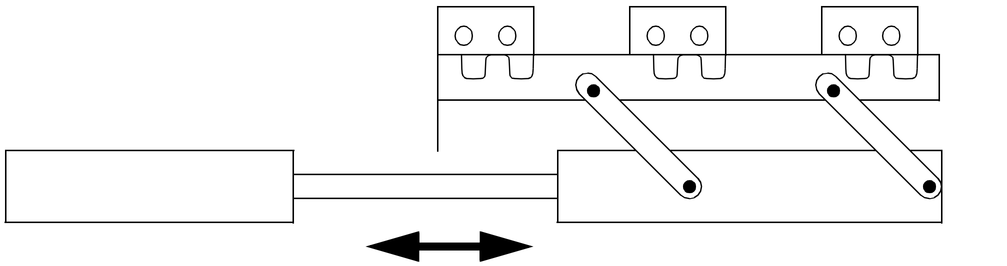
  - power and free overhead conveyors



  - shuttle conveyors
  - floor “towline” systems



  - robots (in a limited sense)
  - indexing (geneva mechanism)
  - walking beam



AA:4.2 VIBRATORY FEEDERS

• When small parts are hard to orient we can dump them in a vibratory feeder.

• The vibrations cause parts to ‘hop’ forward.

• Various cutouts, tracks, etc are added to sort parts.

AM:4.3 PRACTICE QUESTIONS

1. What are pallets used for?
(ans. to acts as holders for work that is being transported)

2. List possible methods for guiding an AGV.
(ans. guide wire, vision, painted lines, chain)

AI:5. COMPUTERS IN THE FACTORY

AI:5.1 COMPUTER HARDWARE AND SOFTWARE

• Considering CAD and CAM both start with C’s, computers are a dominant factor

AI:5.1.1 Hardware

• Hardware is much more advanced than software, and it is often less expensive.

• There are four major functions which must be addressed when dealing with the application of a computer system.

- Input
- Output
- Processing
- Storage

• An Example - If you are implementing a system on a shop floor with inexperienced typists, input devices should be simple, like a mouse, or rugged like a touch screen. If the computer is controlling a large machine, an emergency stop button is required. Disk drives may have problems if there is vibration, or static. ETC.

AI:5.1.2 Software

• Software is expected to perform many tasks with more speed, and accuracy than a person. Software will not perform a task better, Hence the term ‘Garbage in Garbage Out’

• The software has similar functions to the hardware,

- Input
- Output
- Processing
- Storage

• An example is software to be written to run on a Nintendo Game System. If this is the case, the software must use the game paddles for input, there is some memory storage (the game programs are stored in ROM chips in the cassettes), Output is visual and audio. Processing could include trajectory calculations, collision detection and scenery drawing.

• Software is clearly distinguished from hardware by the lack of commitment when it is purchased. Software undergoes updates, it may be adapted to suit new demands, etc., hardware is often fixed.

• Computer software and hardware have both decreased in cost, keep in mind that the cost of software and hardware are often both in the same cost range. (originally hardware was more expensive (1940s-1970s) then software went through an expensive phase (1970s-1990s), but the enlargement of commercial markets has brought economies of scale to both products.

• A Good Computer Rule to Remember

> "If a problem cannot be solved by a human on paper (ignoring the time factor), then it cannot be done by computer. The computer requires that a task is well defined, and understood"

AI:5.2 IDEF MODELLING OF THE CORPORATION

• IDEF is a diagraming method used to describe systems.

• developed by ICAM (Integrated Computer Aided Manufacturing)

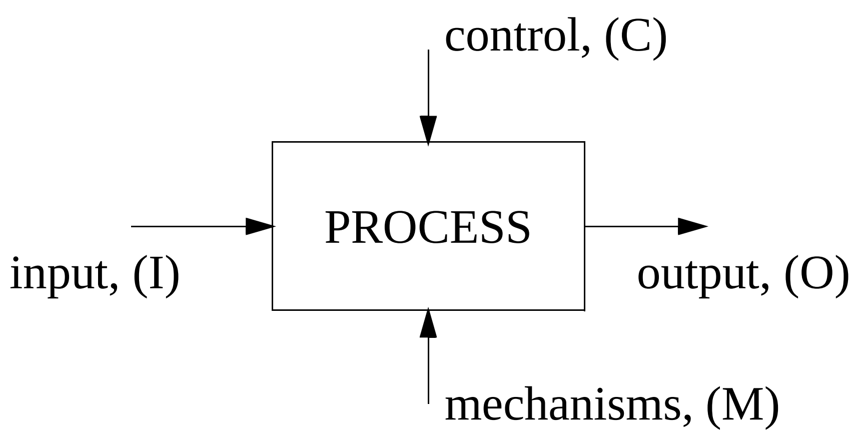
• Three (3) levels of IDEF models:
  $IDEF_0$ - model of process flows
  $IDEF_1$ - modelling of the nature of data handling
  $IDEF_2$ - modelling of the dynamic behavior of a process

• We will examine IDEF0 for modelling processes. Other models would be useful when designing complex inofmration systems.

• A process can also be represented with an $IDEF_0$ diagram.

• IDEF serves to illustrate the relationship of all processes in a system in a graphical format

•Boxes represent activities or functions.



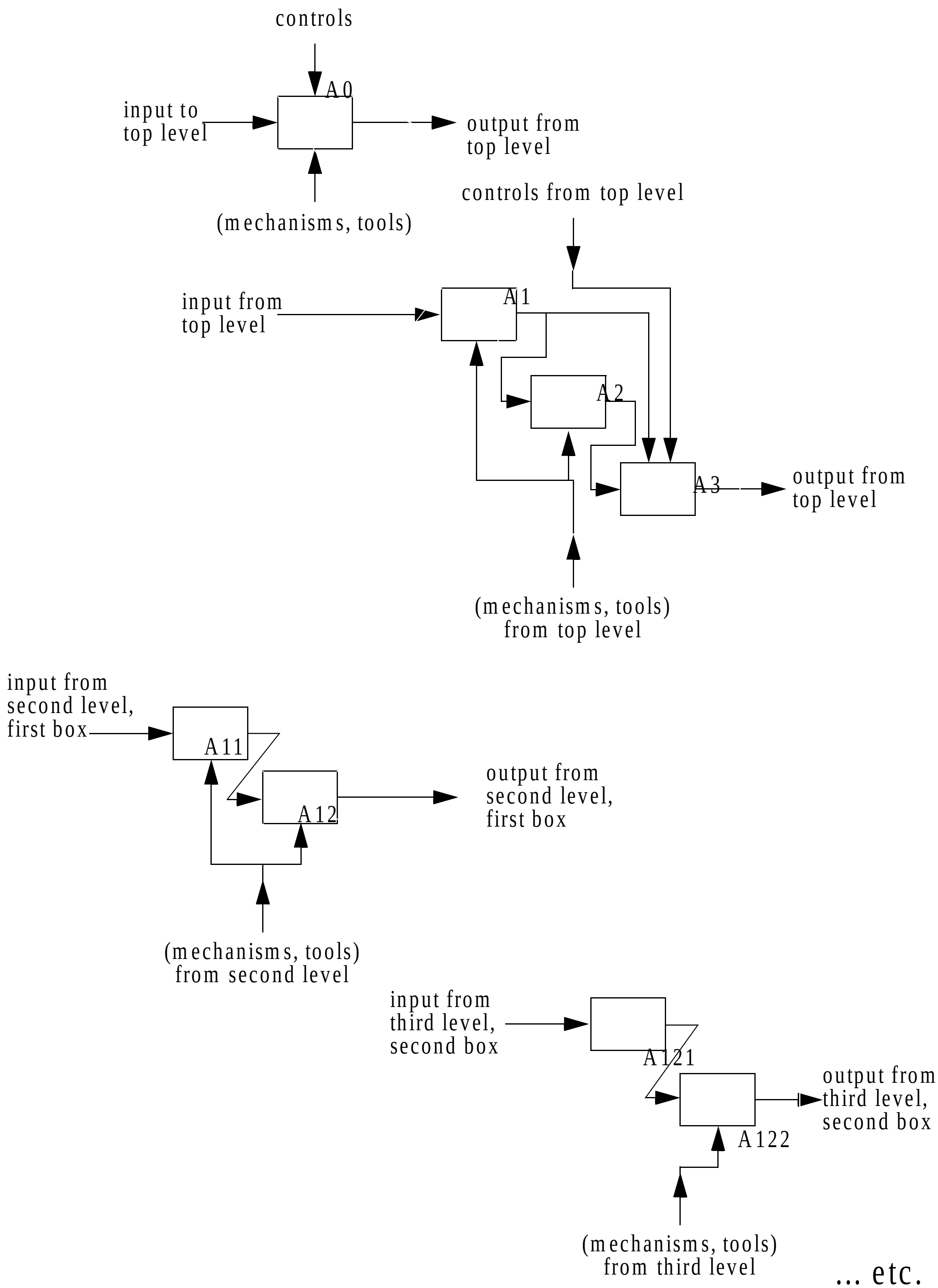
•Information or data needed to carry out the activities or products produced by the activities are represented by arrows.

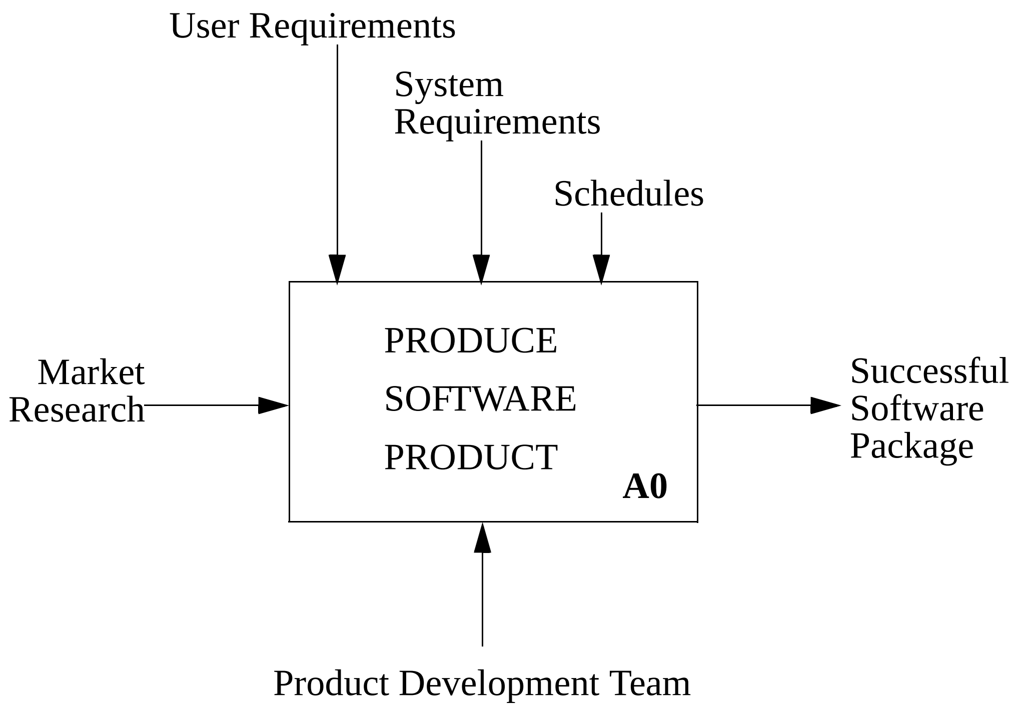
•A top down diagramming method is used.

•The model starts off with a single block that represents the entire system or process.

•The first block diagram is “expanded” to more detailed diagrams or processes.

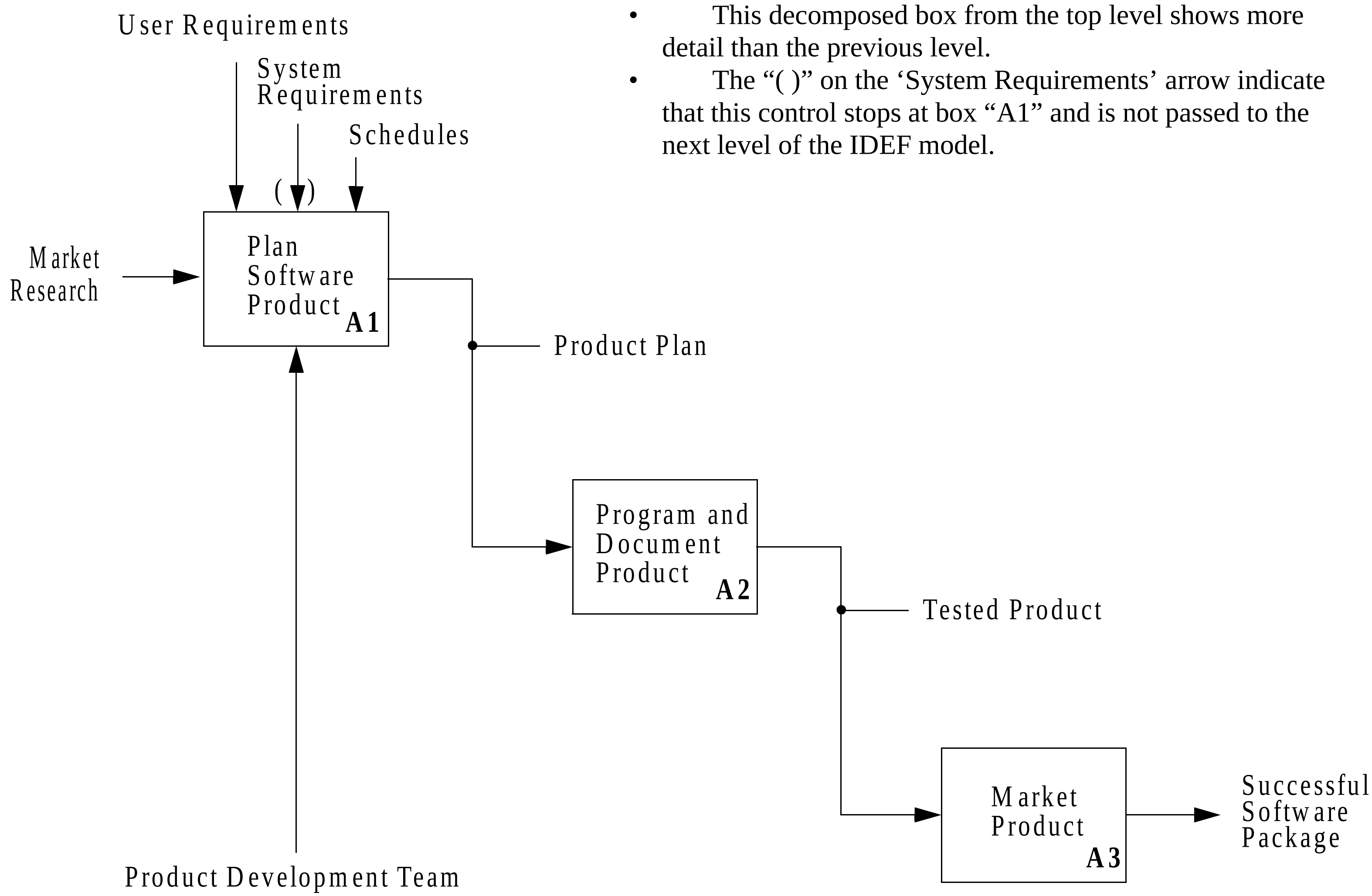
•The collection of successively more detailed diagrams is the IDEF model

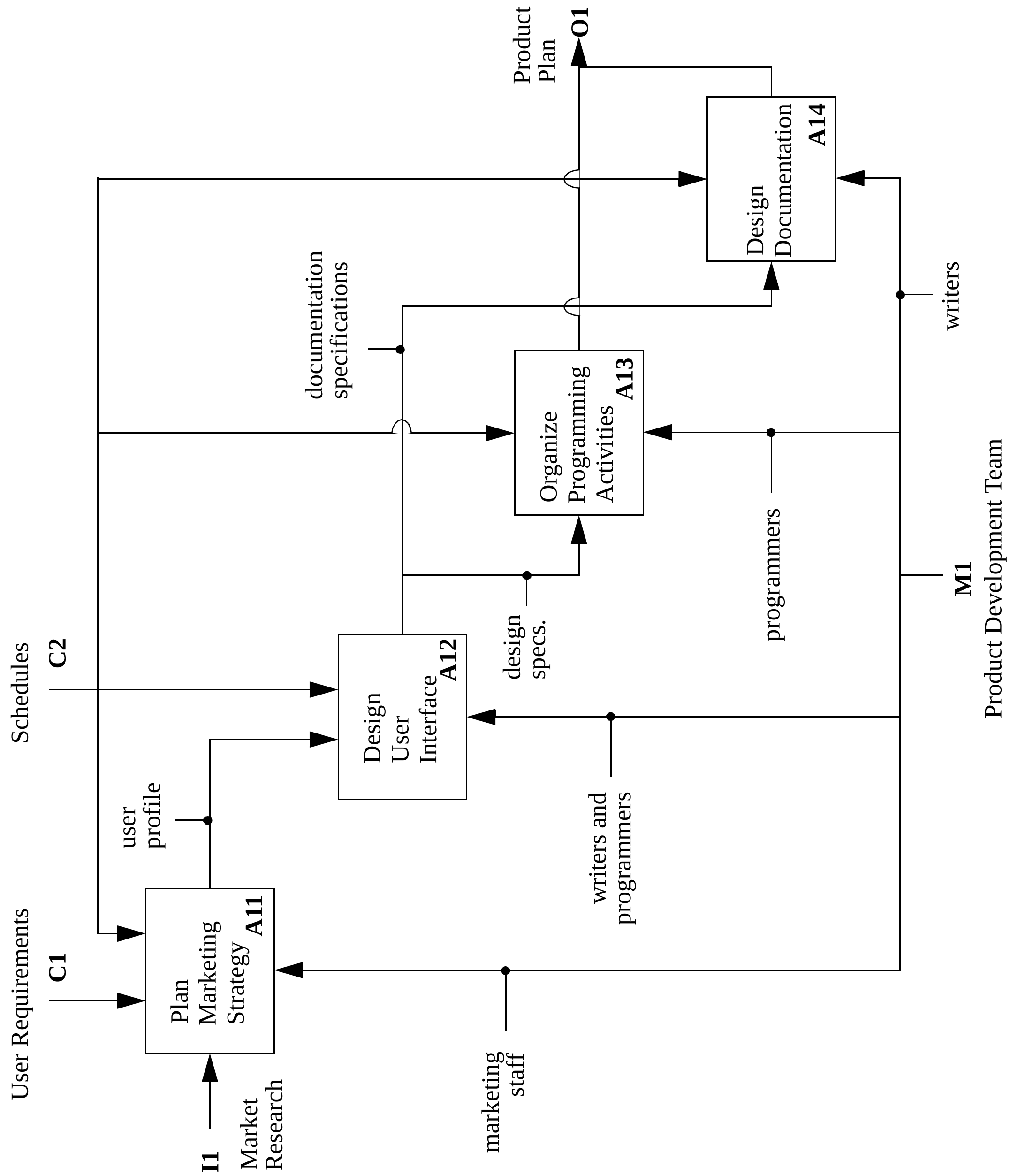

controls
A0
input to
top level
output from
top level
(mechanisms, tools)
controls from top level
input from
top level
A1
A2
A3
output from
top level
(mechanisms, tools)
from top level
input from
second level,
first box
A11
A12
output from
second level,
first box
(mechanisms, tools)
from second level
input from
third level,
second box
A121
A122
output from
third level,
second box
(mechanisms, tools)
from third level
... etc.



- This is the top level of the IDEF model.
- This box is labeled as A0 (“0” indicates the top level)
- Decomposing “A0” will produce another set of boxes and process flows.

- This decomposed box from the top level shows more detail than the previous level.
- The “( )” on the ‘System Requirements’ arrow indicate that this control stops at box “A1” and is not passed to the next level of the IDEF model.



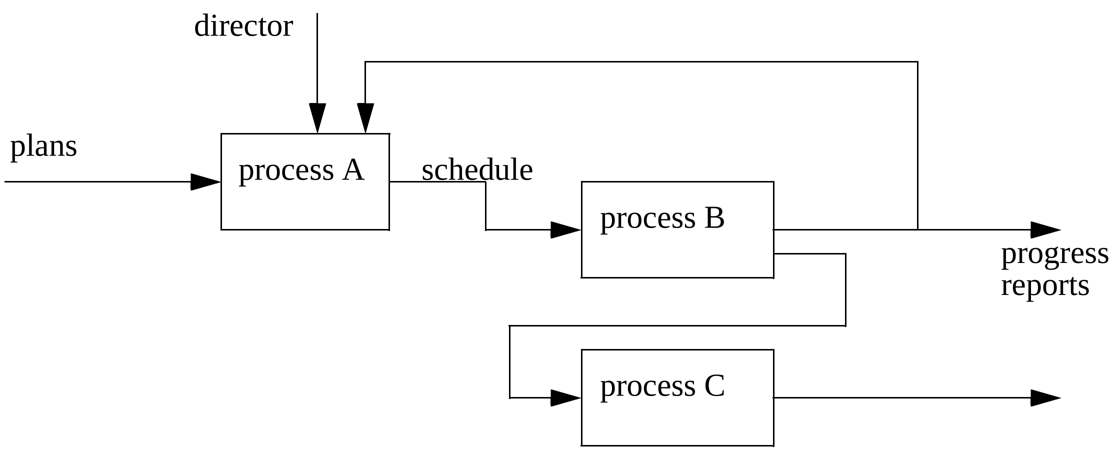


AI:5.3 PRACTICE QUESTIONS

1. In the Shop Floor Production Model (SFPM), a PLC connected to a robot, NC machine and safety systems would be considered,
    a) Section/Area Control (Level 4)
    b) Cell Control (Level 3)

c) Station Control (Level 2)
d) Equipment Control (Level 1)
(ans. c)

2. In the IDEF0 diagram below,
a) there are more than 10 problems
b) there are 6 to 10 problems
c) there are 1 t o 5 problems
d) there are no problem



(ans. b)

3.Draw an IDEF diagram to describe how you study for, and write an exam.

AA:6. INTEGRATION ISSUES

AA:6.1 CORPORATE SSTRUCTURES

• First consider the major functions within a company,
  - Production
  - Materials
  - Process Planning
  - Design
  - Customer Orders / Service
  - Marketing
  - Accounting
  - Management

• All of these functions generate and use common information which must be communicated between departments.

• Since computers handle information, we must be aware of what we get, and what we produce.

AA:6.2 CORPORATE COMMUNICATIONS

• Previous paper based systems provided support for data transfer between departments, and provided a good basis for the introduction of computers

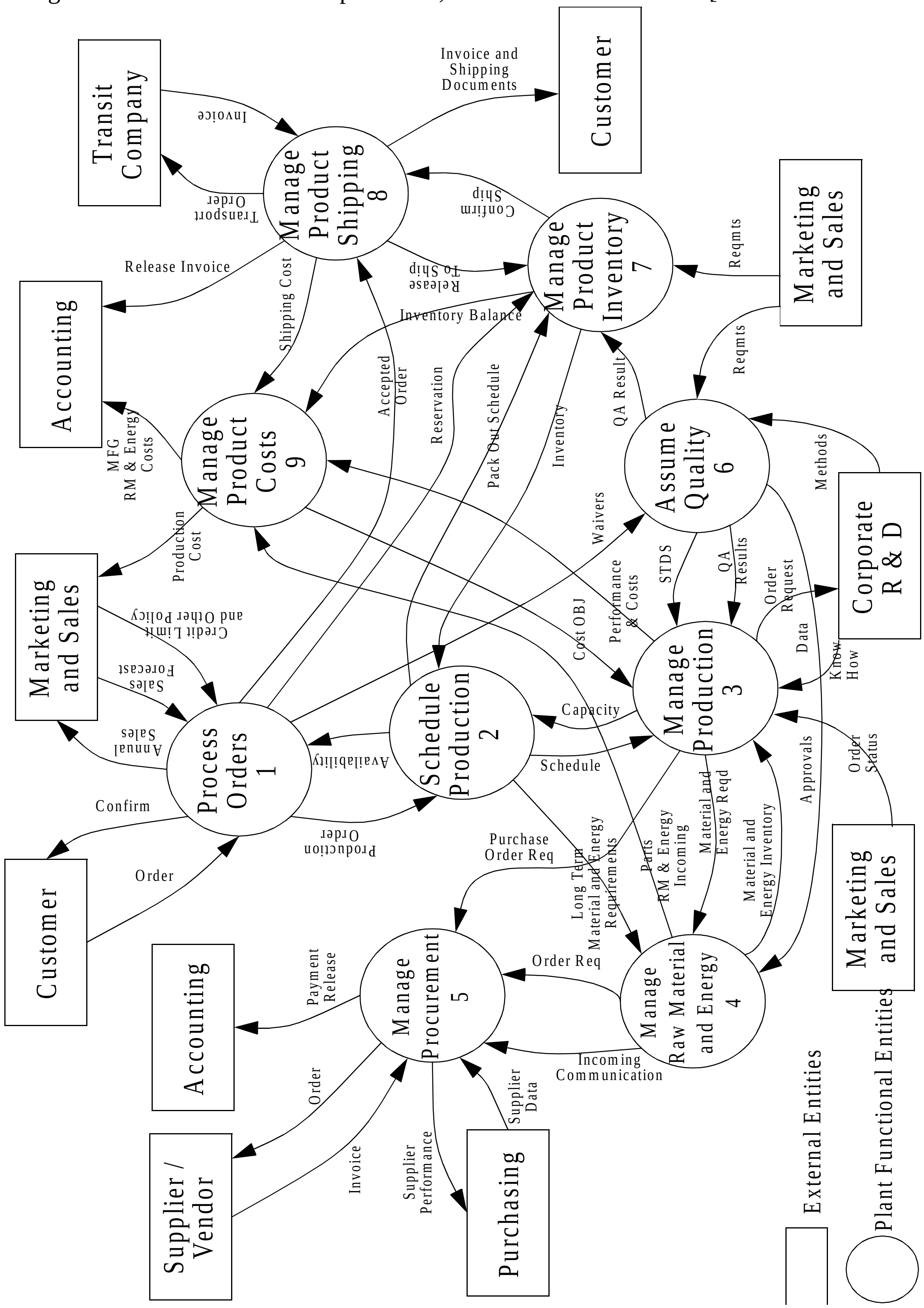
• ASIDE: Computers can make a good system better, but they will always make a bad system worse. This is because a system which is not well defined and poorly understood cannot be programmed, or optimized.

• Characteristics of paper based manufacturing systems,
  - Multiple copies of same information.
  - Revising information is hard when multiple copies exist.
  - Delays for the transfer of paper.
  - Easy to lose paper.
  - Paper is not interactive.
  - Paper requires bulky storage.

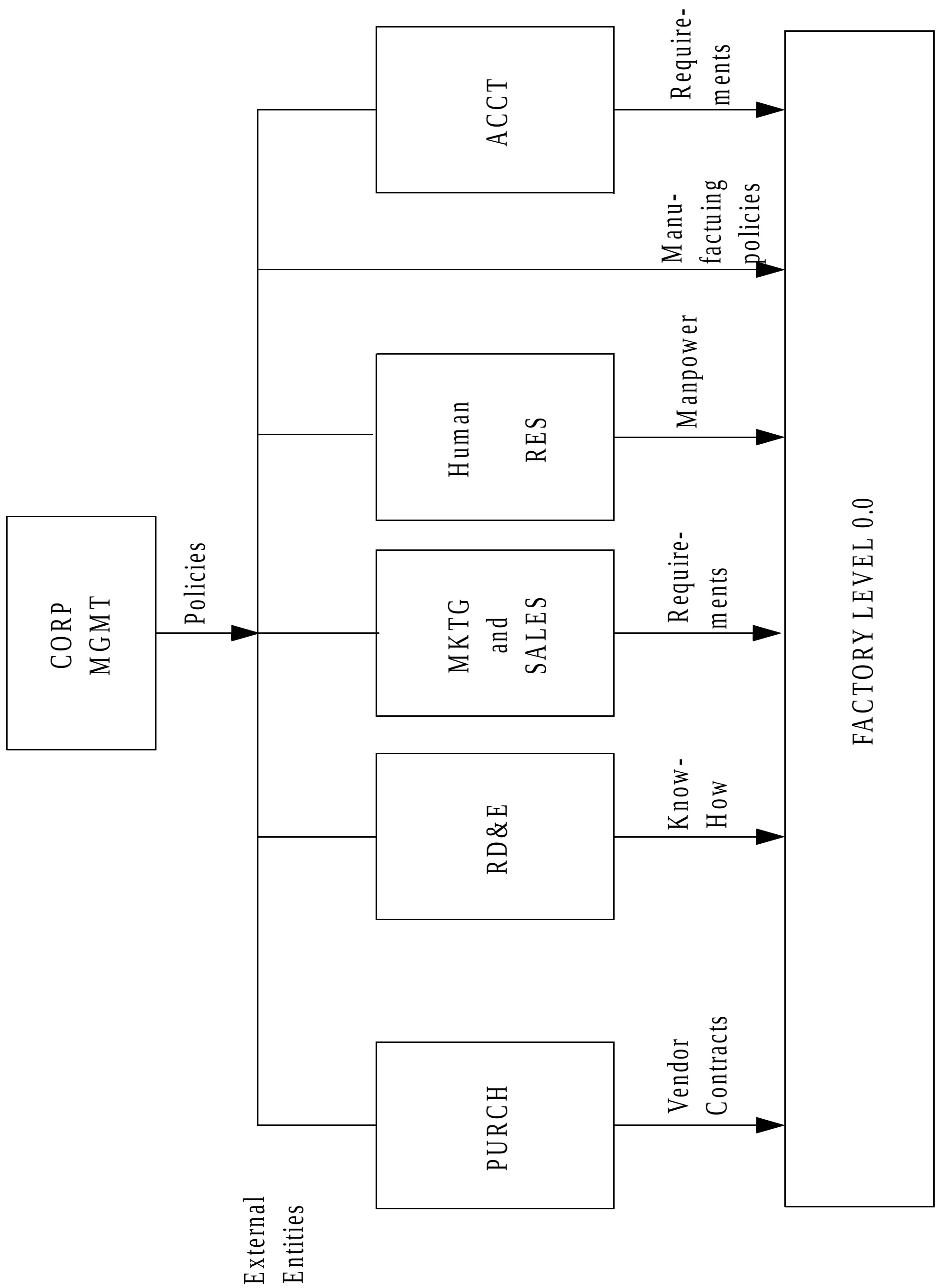
• Computers overcome and reduce the problems above, but introduce some technological challenges,
  - Creating programs to support corporate functions.
  - Software to support interdepartmental communication and data sharing.

- Hardware to support the software.

• This figure below shows various departments, and the information flow [source - ???

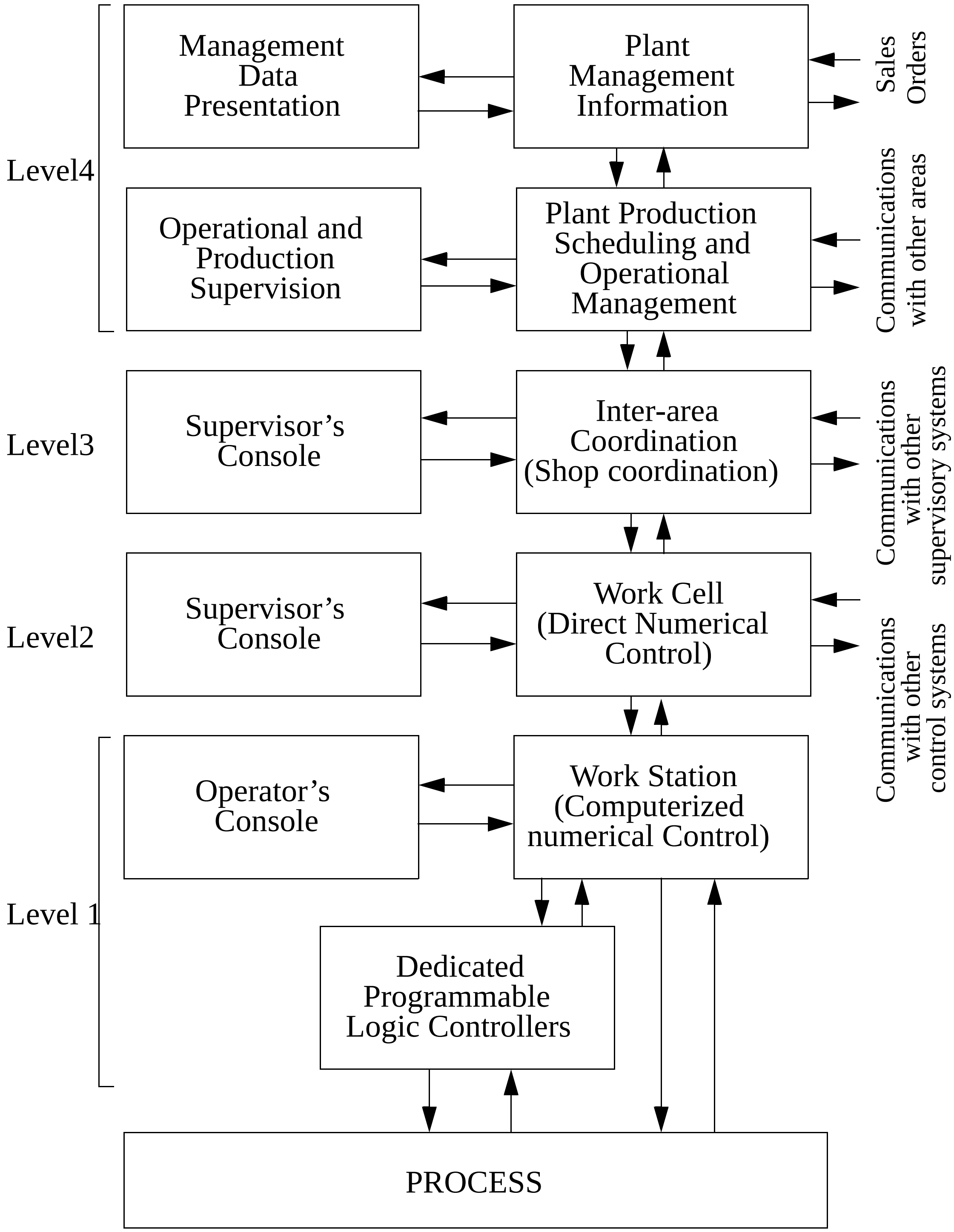


• Requirements for interfacing corporate management and staff functional entities to the factory



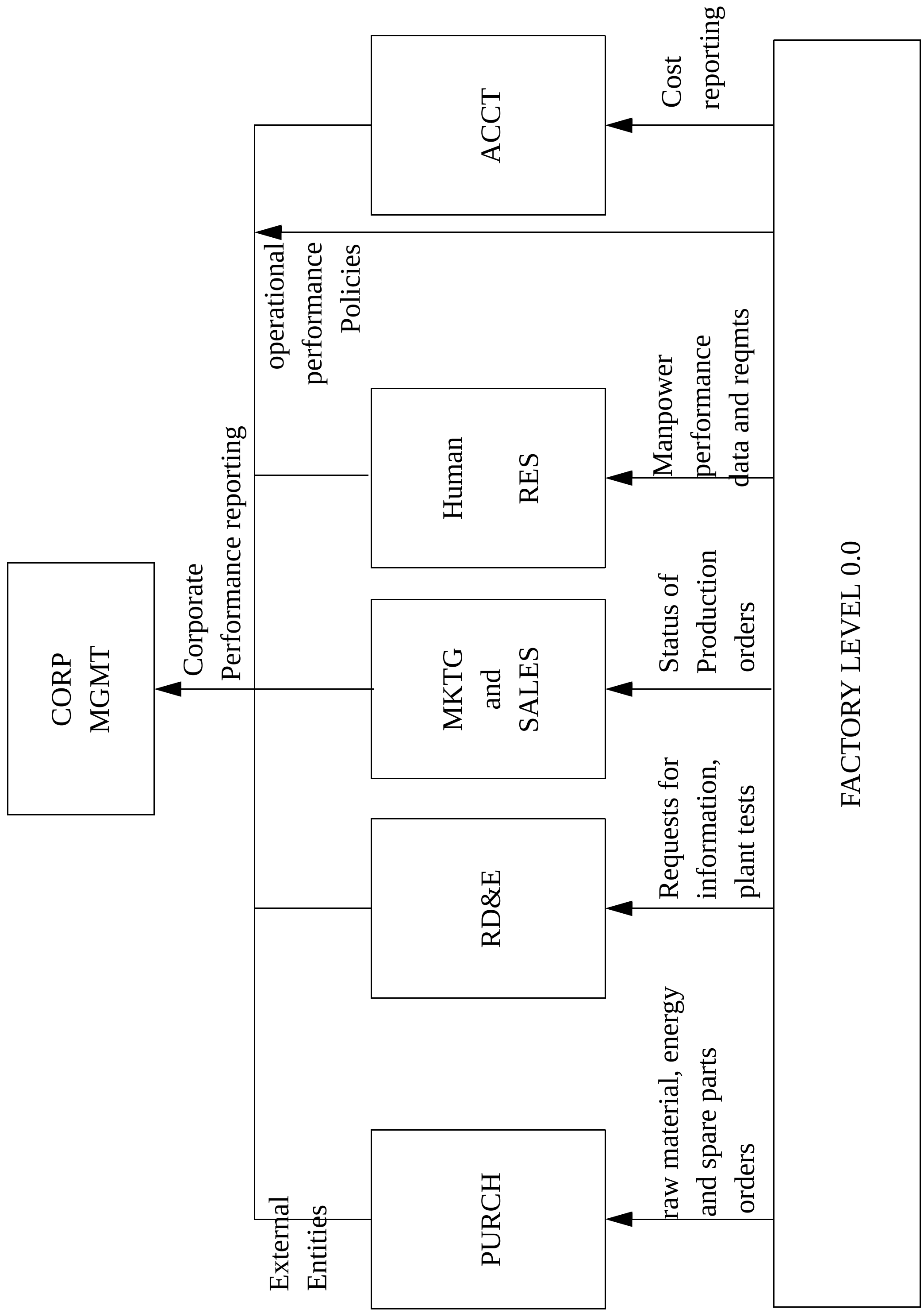
[source - find]

• Assumed functional hierarchy computer system structure for a large manufacturing complex



[source - find]

• Report interfacing to corporate management and staff functional entities from the factory



[source - find]

• The Shop Floor Production Model (SFPM):
[source - find]

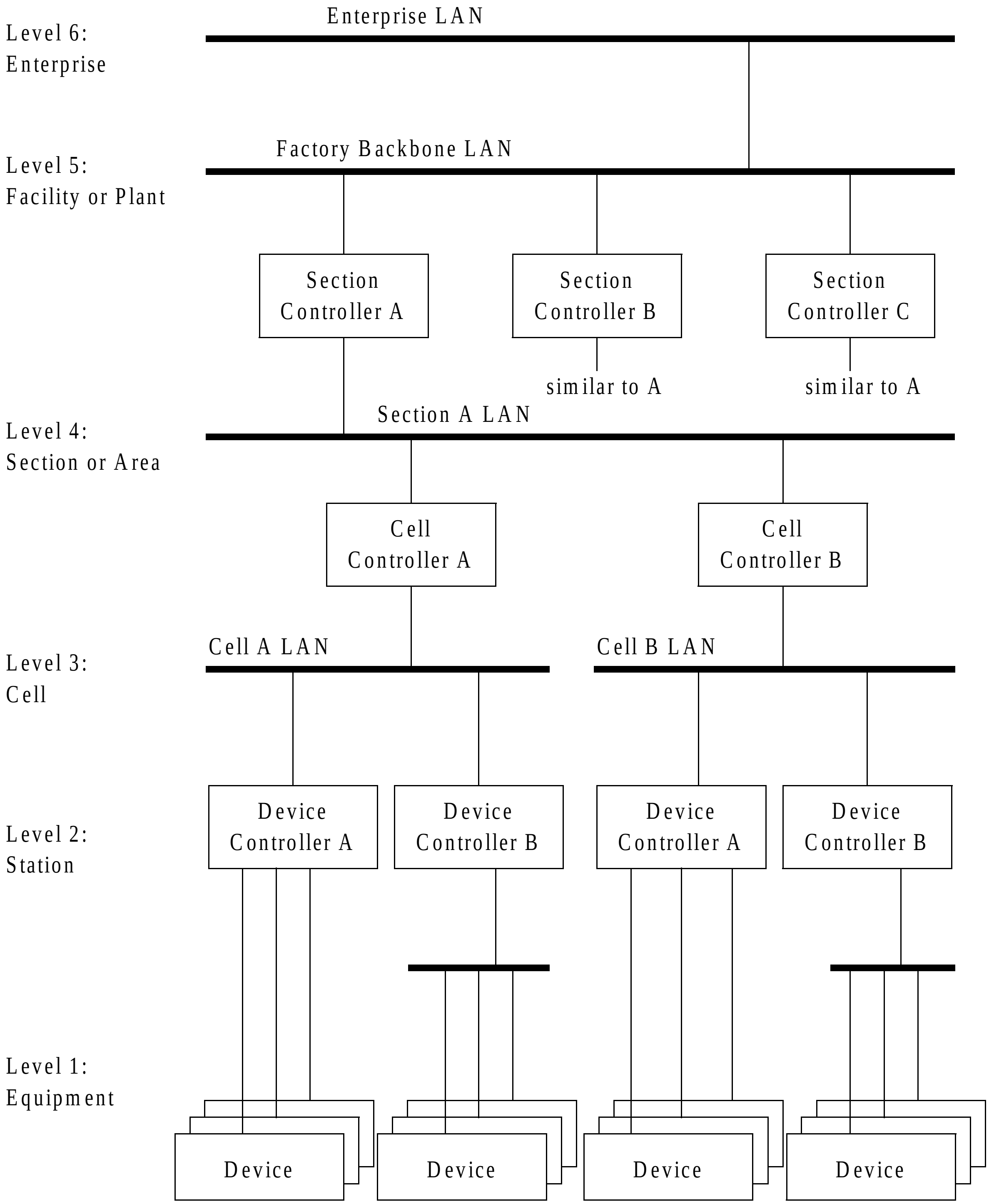
	Level	Sub-Activity	Responsibility
4	Section/Area	Supervise shop floor production process	Supervising and coordinating the production and supporting the jobs and obtaining and allocating resources to the jobs.
3	Cell	Coordinate shop floor production process	Sequencing and supervising the jobs at the shop floor production process
2	Station	Command shop floor production process	Directing and coordinating the shop floor production process
1	Equipment	Execute shop floor production process	Executing the job of shop floor production according to commands

The ISO Reference Model for Factory Automation adds a couple of layers
[source - find]

Level/Hierarchy	Area of Control	Responsibility	Basic Functions
6 / Enterprise	Managing the corporation	Achieving the enterprise's mission and managing the corporation	Corporate management Finance Marketing and sales Research and Development
5 / Facility or plant	Planning Production	Implementing the enterprise functions and planning and scheduling production	Product design and production engineering Production management (upper level) Resource management (upper level) Procurement (upper level) Maintenance management (upper level)

Level/Hierarchy	Area of Control	Responsibility	Basic Functions
4 / Section or area	Allocating and supervising materials and resources	Coordinating production and obtaining and allocating resources to jobs	Production management (lower level) Procurement (lower level) Resource management (lower level) Maintenance management (lower level) Shipping Waste material treatment
3 / Cell	Coordinating multiple machines and operations	Sequencing and supervising shop floor jobs and supervising various supporting services	Shop floor production (cell level)
2 / Station	commanding machine sequences and motion	Directing and coordinating the activity of the shop floor equipment	Shop floor production (station level)
1 / Equipment	Activating sequences and motion	Taking action on commands to the shop floor equipment	Shop floor production (equipment level)

• A LAN (Computer Network) Hierarchy for Shop Floor Control [source - find]



• Typical Architecture for Manufacturing Components [update]

Item	Equipment	Workstation	Cell
EXAMPLES Hardware	Lathe, Mill, T-10 Bridgeport Series I IBM 7545 Robot	Robot tended Machine Center, Cartrac Material Handling System	Variable Mission System, Several Integrated workstations
Controller Hardware	Mark Century 2000, Accuramatic 9000, Custom-single-board system.	Allen-Bradley PLC-5, IBM-PC, etc.	Windows NT, SUN workstation, etc.
Type Controller	Single-board processors, Machine tool controller, Servo-Controller, etc	PLC, PC, Minicomputer	PC, Microcomputer, Super-MiniComputer
Language Application	Assembler, Part programming, Robot programming, etc.	C, Ladder logic, Pascal and other sequential languages	C, LISP, FORTRAN, and other high level languages
Memory/Size Requirements	8k-128k RAM plus custom ROM, EPROM, etc.	32M RAM, >1M Hard Drive	128M RAM, >1Gigabyte Hard drive
Response Time	$< 10^{-3}$ sec	< 1 sec	< 20 sec
Machines/ Interconnects	1-1 connect	1-many 1-[1,8] Machine tools, 1-[1-50] Material handling	1-many 1-[1-15] workstations

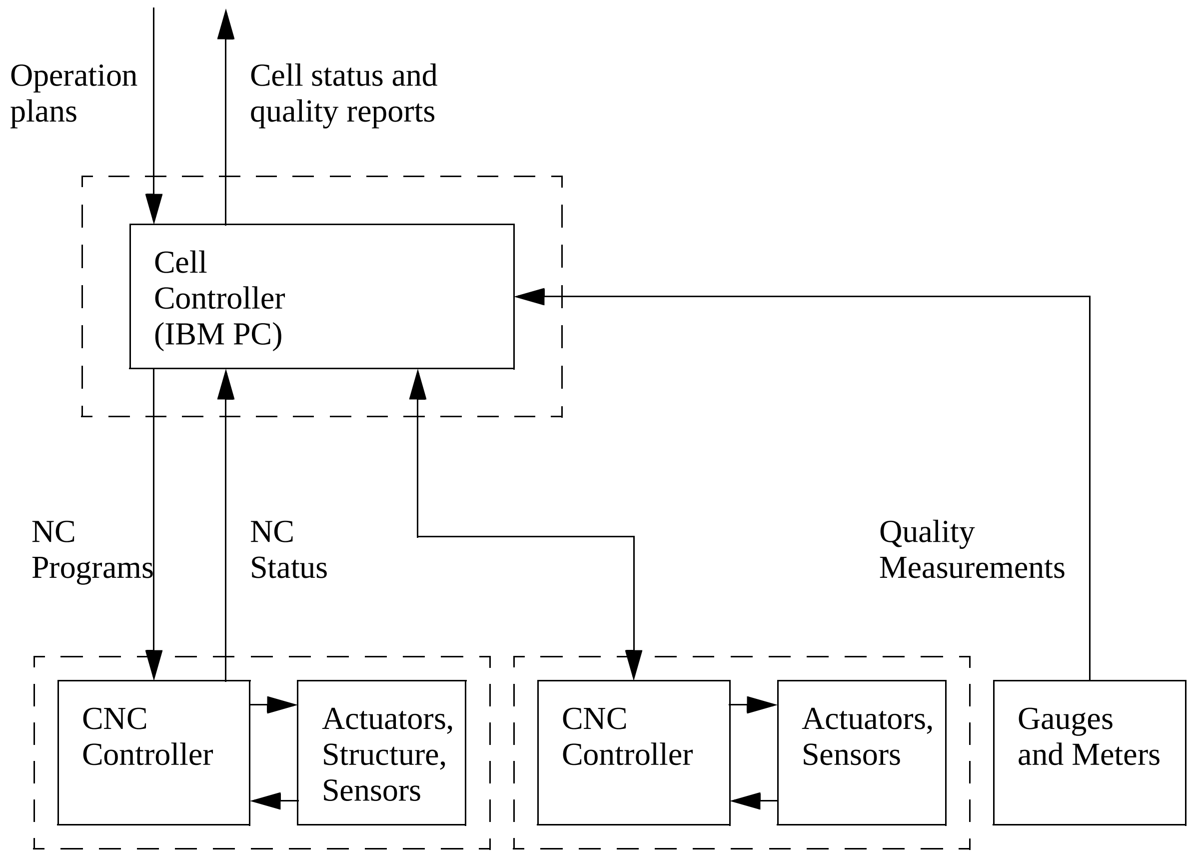
• Functional Breakdown of Control Architecture

	Equipment	Workstation	Cell
Planning	Tool selection, parameter specification, tool path refinement, GMT code, tool assignment to slots, job setup planning	•Resource allocation jobs •Batch splitting and equipment load balancing	Batching, Workload balancing between workstations, Requirements planning Task allocation to workstations

	Equipment	Workstation	Cell
Planning Horizon	Milliseconds - Minutes	Minutes - Hours/Days	Hours - Days/weeks
Scheduling	•Operation sequencing at individual equipment	•Sequence equipment level subsystems •Deadlock detection and avoidance •Gantt chart or E.S. based scheduling •Buffer management	•Assignment of due dates to individual workstations •Look ahead ES/simulation based scheduling •Optimization based tech •Batch sequencing
Control	•Interface to workstation controller •Physical control (motion control at NC and robot pick and place level) •Execution of control programs (APT, AML, etc.)	•Monitor equipment states and execute part and information flow actions based on states •Synchronize actions between equipment (eg. robot & machine while loading/unloading parts) • Ladder logic execution	Organizational control of workstations, Interface with MPS, generation of reports, etc.

• In all of these models we must consider the value of the information being passed. At the low level control stages, information that is more than a few seconds old may be completely worthless, while the same information at the higher level may be valuable for quality tracking months later.

• We can draw part of a simple flow chart that illustrates a simple CIM system. The elements shown include a PLC, NC machine, and stand alone sensors. These are all integrated by a single computer running cell control software.



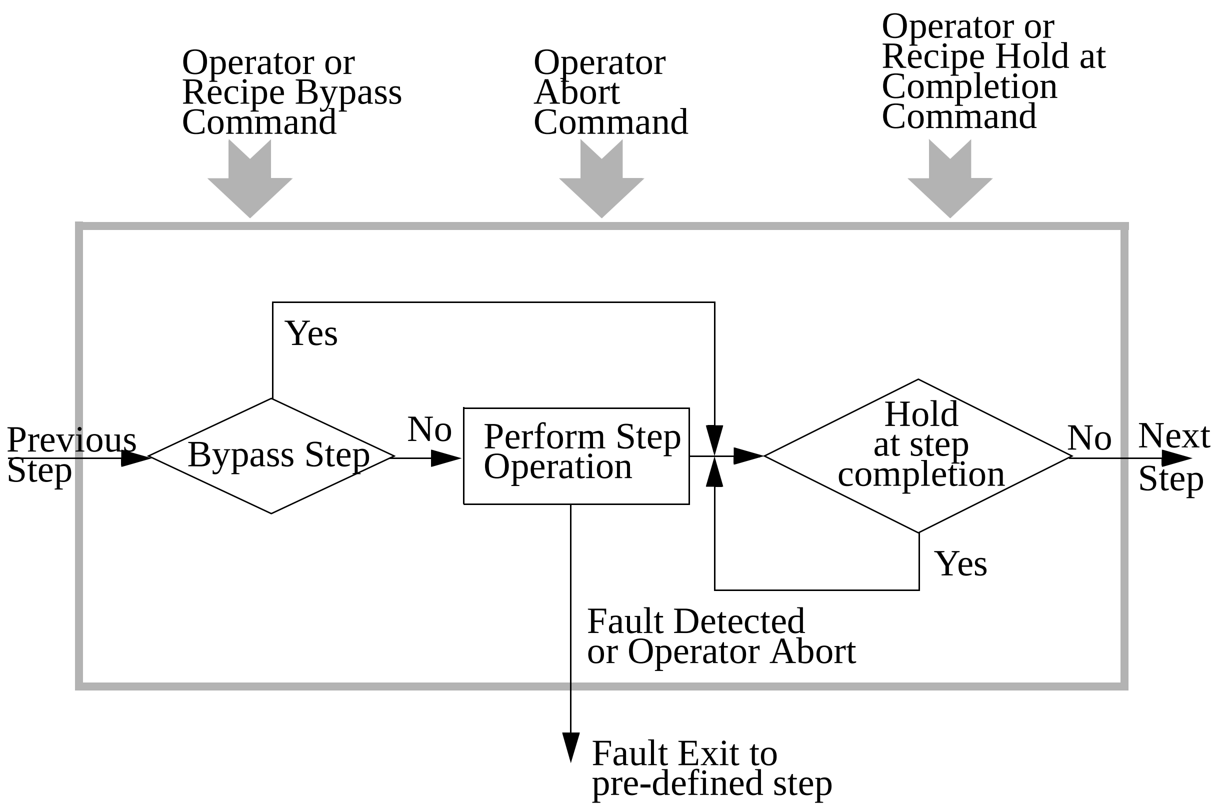
6.3 COMPUTER CONTROLLED BATCH PROCESSES

• The nature of Batch processes,
- Batch processes deal with discrete quantities of raw materials or products.
- batch processes allow the tracking of these discrete quantities of materials or products
- batch processes allow more than one type of product to be processed simultaneously, as long as the products are separated by the equipment layout.
- Batch processes entail movement of discrete product from processing area to processing area
- Batch processes have recipes (or processing instructions) associated with each load of raw material to be processed into product.
- Batch processes have more complex logic associated with processing than is found in continuous processes
- Batch processes often include normal steps that can fail, and thus also include special steps to be taken in the event of a failure.

• The nature of steps in a batch process,

- Each step can be simple or complex in nature, consisting of one or more operations
- Generally, once a step is started it must be completed to be successful.
- It is not uncommon to require some operator approval before leaving one step and starting the next.
- There is frequently provision for non-normal exits to be taken because of operator intervention, equipment failure or the detection of hazardous conditions.
- Depending on the recipe for the product being processed, a step may be bypassed for some products.
- The processing operations for each step are generally under recipe control, but may be modified by operator override action.

• A typical process step



6.4 PRACTICE PROBLEMS

1. List 5 industries that are well suited to integration, and 5 that are not. Indicate why you think so.

2. In an automated factory there as many as six levels of control. Discuss the equipment available in the lab and how this relates to the 6 level model of factor floor control.

ans.

The lab equipment (right now) only satisfies the first couple of levels. You can argue that the ability to watch over the net is a supervisory function. Etc...

3. Information drives an automated factory from the initial entry of geometry in CAD, to the final production of parts with CAM. Discuss how data networks support this and the impact of open network standards.

4.

AQ:7. GROUP TECHNOLOGY (GT)

AQ:7.1 OVERVIEW

• Most product models use an exact definition of geometry, or other details

• It can be useful to have a more abstract representation of a part for some tasks,
  - Storage and recall of designs
  - Recall of process plans for similar parts
  - Classification of designs for analysis of production

• GT is used to identify subsets or families of similar parts for the purpose of realizing common features for improved design and process efficiency through standardization.

• GT codes can be used to represent products using any combination of geometry, manufacturing processes, and/or function.

• The advantages of such a system can be found in,
  1. Product design - Group technology allows similar designs to be recalled on the computer. Instead of starting from scratch again.
  2. Tooling and setups - standard tooling can be developed for a part family, and then standard setup procedures and times can be used.
  3. Materials Handling - Factory floor layout can be updated to reflect part families, and reduce part handling time.
  4. Production and Inventory Control - The use of GT to set up standard production techniques allows faster production, therefore less inventory, and Work in Process (WIP).
  5. Employee Satisfaction - Grouping of machines allows easier tracking of quality (and achievement).
  6. Process Planning - Standard plans can be developed for GT part families. The plans can then be altered to fit, instead of producing a new process plan.

• Problems with GT systems are,
  1. Not suited to a factory with widely varying products
  2. Can have a long setup time, and debugging
  3. There are no standard GT codes developed - each GT code application will probably be unique.
  4. A GT code may be hard for inexperienced users to read.

AQ:7.2 SOME DETAILS

• The GT code is made up of a string of digits which identify specific attributes of a part.

• If the digits of a GT code are unrelated, it is a polycode, and each digit may be looked up independently.

• If the digits of a GT code are related, it is a monocode, and they must be looked up in sequence.

• It is possible to have a hybrid GT code which is a combination of polycode and monocode.

• When selecting what the GT digits represent, the guidelines are,
  - They must differentiate products
  - Must represent non-trivial features
  - Only critical features should be encoded
  - Function should be encoded
  - Every digit should be significant

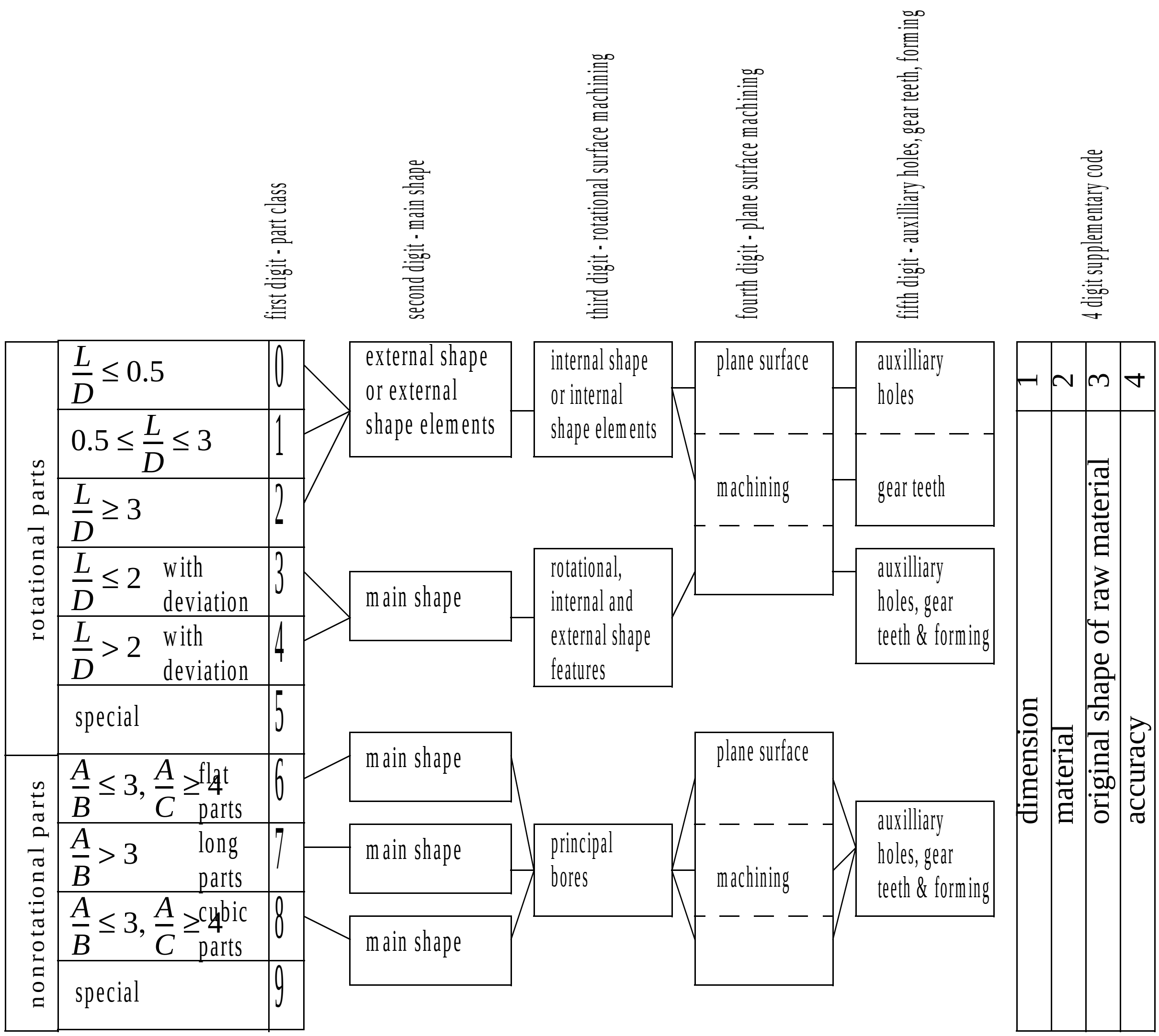
• Parts can be encoded using
  - process flow
  - tool axis
  - tolerance
  - function
  - material
  - shape.

AQ:7.2.1 Optiz Code

• One example system is the popular Opitz code, developed in a German university by H.Opitz.

• This code uses a sequence of 5 digits, 4 digits, and 4 letters, such as '11223 4455 ADEA'
  - The first five digits are the form code (identify shape). See the table for form codes.
  - The next four digits are the supplementary code - used to represent non-form details such as tolerances, materials, etc.
  - The last four letters are the secondary code, used to represent production operation types, sequences, or other functions chosen by the manufacturer.

• The Opitz code for a part is constructed from the first digit on, as shown in the tables below.

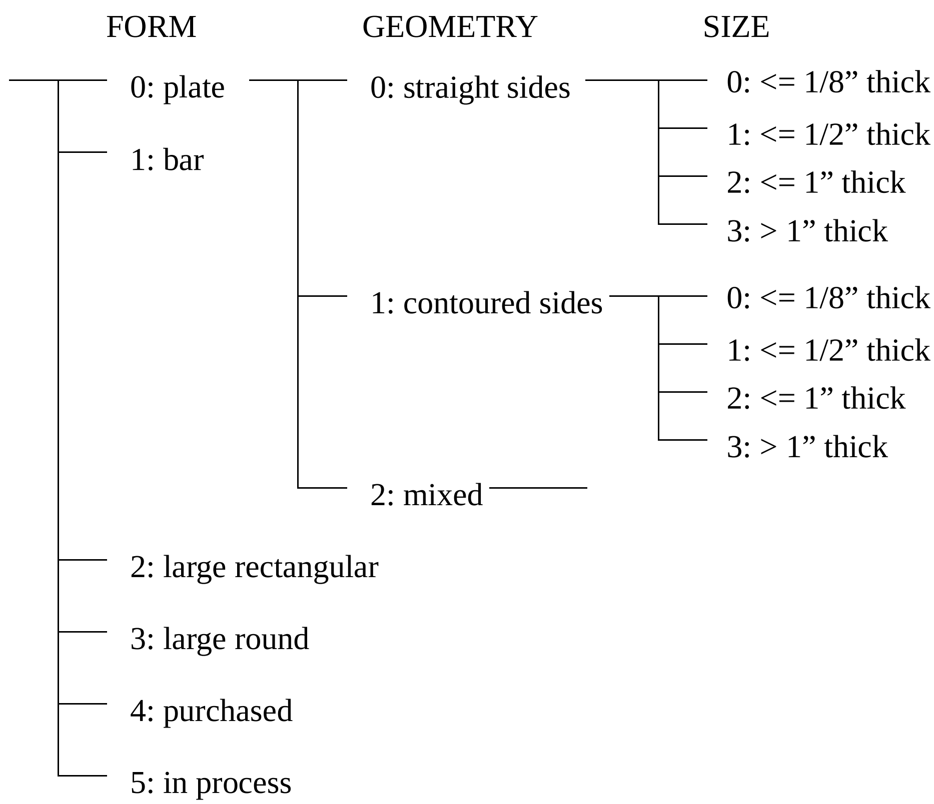


AQ:7.2.2 Decision Tree

• Decision trees are developed to be specific to typical product line, or manufacturing facility.

• To develop one of these trees we draw a tree that shows alternate possibilities for a part, and then number the options (care must be used to leave options not anticipated).

• Part of an example decision tree is given below. This can be expanded as it applies to a particular manufacturer or industry.



AQ:7.3 IMPLEMENTATION

• GT should be used when there are a large number of parts that can be divided into groups based upon geometry, function, and/or production.

• implementation is a multistage process,

1. Develop a GT code
2. verify the GT code by coding about 10-20% of the parts in the factory. A good random sample of parts should be used for reliable results.
3. The results of the coding should be reviewed. If too many parts have the same GT code, or there are not enough similarities between codes, then the code should be revised.
4. The remainder of the parts should be coded.
5. An examination of all the parts for the factory will allow the identification of patterns in production, or design. As a result standard production routings, or standard product designs may be selected.

AQ:7.4 GT MACHINE CELLS

• After identifying part families, a standard set of production steps can be identified.

• After identifying standard production steps, the factory floor can be reorganized to reflect a more rational layout of machines.

• Various ways to lay out machines for part families are,

- Single Machine Cell
- Group machine layout
- flow line design

• Single Machine Cells are suited to products which may be produced on a single machine, using a single process. This can also involve bringing two machines together. Such as a grinder, on a lathe.

• Group Machine Layout is suited to a small set of operations on a part which cannot be performed on a single machine.

• Flow Line Design - when parts in a family have a number of processes with the same sequence, this system may be set up with a transfer line.

7.5 REFERENCES

Ullman, D.G., The Mechanical Design Process, McGraw-Hill, 1997.

AG:8. COMPUTER AIDED PROCESS PLANNING (CAPP)

AG:8.1 OVERVIEW

• If we had an engine block, how would you manufacture it ?

• When deciding how to produce a product there are a number of factors to consider,
- Product geometry, material, tolerances, weight, etc
- Available processes/machine tools/skills
- Available tools and fixtures
- Inventory
- etc

• Requicha and Vandenbrande [1988] describe the process of process planning as,

> "A process planner and a set-up planner (often the same person) examine a part's blueprint and consult various files and handbooks to produce a process plan. A plan contains process specifications and information on fixtures and clamping devices to be used, and on set-up of the workpiece on a machine tool. Set-up specifications are typically conveyed through annotated sketches or engineering drawings."

• A process plan will vary from factory to factory, but there are some basic elements to be found on all. An example is shown below.

OPERATION SHEET

Part No.	*CLP023456-4-92-023*	Material	*steel 1040*
Part Name	*Widget*		
Orig.	*H.Jack*	Changes	
Checked	*W.H.ElMaraghy*	Approved	*D.Corrin*

No.	Operation	Machine	Setup	Time (hrs.)
0010	*Saw off and slug 1.75 dia. hole*	*Dept 12. Saw 3*		*.3*
0015	*R'Turn 6.00 dia. stock to 5.210/5.190* *R'Bore 1.75 dia to 2.00* *F'Bore 2.00 to 2.005/2.015*	*G.E. Turn Lathe*	*Hold in counter centrifugal Chuck*	*1.2*
0025	*Deburr all edges*			*5 mins.*

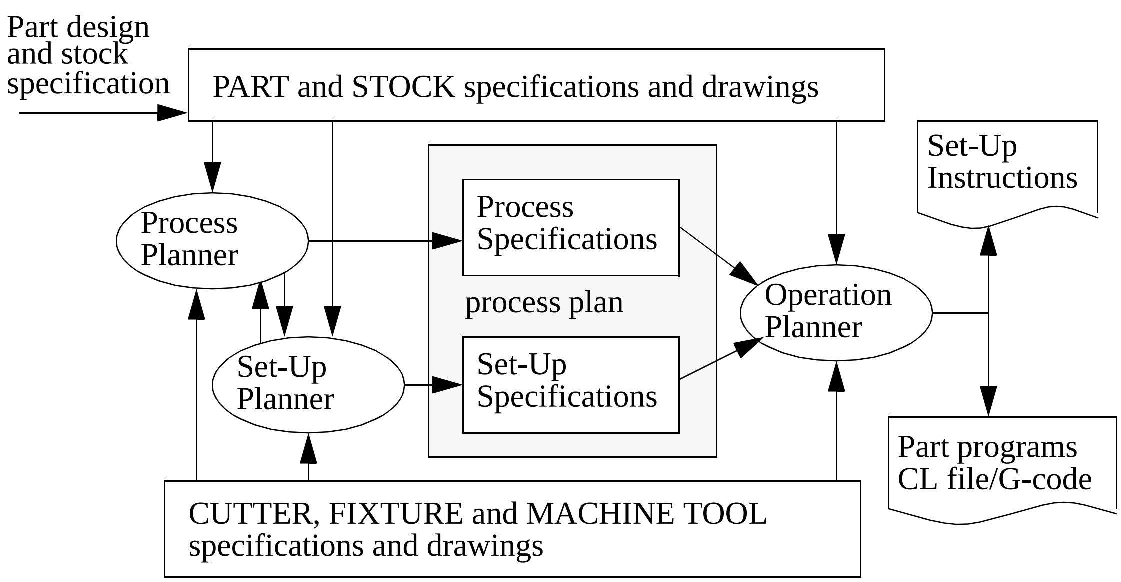
• Obviously a process plan is important when there is a high product mix, because it lets us know were to send the parts, and what to do with them. In a high volume setting, a process plan lets us decide exactly how something will be made before equipment is bought or moved.

• A Process Plan includes,
  - Part routings (Indication of where to send finished parts)
  - Bill of Materials (for each operation)
  - Work Orders (A description of what operations to perform at a work station).

• Every company uses process planning. In smaller companies the process planner may also be the craftsman who makes the product. In larger companies there may be large departments set aside to perform this function.

• As the size of a company grows, and so do the possible methods for manufacturing, and process planning become more difficult.

• A Diagram of the traditional Two-Stage Approach to Process Planning



• Depending upon who defines process planning, it may, or may not include operation planning.

• In their purest sense, the definitions are,
  - Process Planning - Choosing the technological means whereby a feature(s) of a product will be manufactured (eg. drilling, milling, or casting). Also known as high level process planning.
  - Operation Planning - Choosing the parameters of the operation which is used to create the feature(s). (eg. feeds, speeds). Also known as low level process planning.

AG:8.2 CAPP SOFTWARE

• There are few successful process planning software packages available today.

• There are two main categories of process planners - Variant and Generative.

• Variant process planners use existing process plans, then allow a user to edit the plan for their new parts.

• Generative process planners should create a new process plan, without the use of any existing plans. This does not imply that the process planner is automatic.

• Some of the process planning steps used for machining operations are,

1. Interpretation of part design data
2. Selection of machining processes
3. Selection of machine tools, and fixtures
4. Machining optimization
5. Decomposition of machinable volumes
6. Selection of machinable volumes
7. Generation of precedence constraints
8. Sequencing of machinable volumes

AG:8.2.1 Variant Process Planning

• Most successful variant systems depend upon Group Technology.

• The basic variant approach to process planning with GT is,

1. Go through normal GT setup procedures
2. After part families have been identified, develop standard process plans for each.
3. When a new product has been designed, get a GT code for each part.
4. Use the GT system to look up which part family is the closest match, and retrieve the standard plan for that part family.
5. Edit the standard plan so that values now match the new design parameters, and add or delete steps as required.

• Some benefits of the GT system are,

- It is well suited to medium to low product mixes
- It can be developed quickly for most companies
- Can be used with other CIM
- One program can be used in radically different industries

• Disadvantages are,

- GT codes can become obsolete quickly
- While it is fast to setup, it is slower for planning than generative systems

- More prone to error than generative systems

• These systems tend to get exact matches 2-7% of tries. A standard plan is used about 50% of time.

AG:8.2.2 Generative Process Planning

• Each plan is made from scratch
• The generative systems are poorly developed at this point in time, and tend to be research systems, or very limited domain
• These systems rely heavily upon the methods of Artificial Intelligence, or very complex algorithms.
• An example of a Generative system is the development of rules deciding which machines to use.

• Possible sources of input vary from system to system, but they are essentially,
  - Interpret designs from CAD directly (very difficult)
  - User defines features then answers questions about them
  - The user does design directly on the CAPP system.
  - The users creates a special product description file

• A rule example for a CAPP system called XPS-2 is shown below,

```
0010        EXECUTE MILL_HOLE FOR EACH BLIND_HOLE IF
            BLIND_HOLE.DIAMETER GT 25.,
            BLIND_HOLE.DEPTH LT 50. !
```

• This rule identifies the operation, the feature it is used on, and the two conditions for it to be used. When rules are used, the number of rules in the system becomes very large.

• Advantages,
  - Runs faster when planning
• Disadvantages,
  - Requires a more extensive setup

8.3 REFERENCES

Ullman, D.G., The Mechanical Design Process, McGraw-Hill, 1997.

AS:9. PRODUCTION PLANNING AND CONTROL

AS:9.1 OVERVIEW

• A design must be converted to a process plan before it may be produced.

• But, if we have thousands of process plans, and hundreds of customer orders, with dozens of parts in each, which machines do we use when to make the products? What parts do we need?

• Traditionally jobs have been scheduled on a first come, first served basis. This resulted in a lineup of various jobs waiting to be done at each work center.

• When jobs are not scheduled efficiently, we often will get jobs sitting half completed, while we wait for simple parts to be processed. This costs money, wastes time, takes up floor space, makes the customer unhappy, etc.

• Eventually computers were used to figure out how to schedule jobs so that parts were made before they were needed, and so that work was done on time.

• As computers were used more it also became obvious that strict schedules were a nice idea, but they don’t work. A schedule is only valid until the first breakdown.

• Newer control programs called Production Planning and Control (PPC) systems were used to generate schedules, and fix problems that came up.

• Most systems, manual, and automatic either push, or pull the work through the factory. If the work is pushed, then customer orders tend to drive the production. If the work is pulled, the factory often tries to satisfy some continuous demand, and when things are about to run out, more is produced.

• Regardless of which system is used, Scheduling is not exact, and never optimal, but you can get a near optimal schedule with the right tools and methods.

• Some of the traditional Production, Planning and Control subject include,
    1. Forecasting - Estimating the production demands using a horizon of a few month to a few years for long range planning.
    2. Production Planning - Matching needed production to available resources.

• Note: This is more of a CIM topic.

AS:9.2 SCHEDULING

• We often know well in advance what has to be produced

• We can use computer programs to come up with a 'near perfect' schedule for all jobs, ahead of time.

• These methods at the present time are not well enough developed to handle sudden disruptions on the shop floor (See next section on Shop Floor Control).

• Schedules are often made up weekly

*************** ADD DETAILS FOR MRP I and MRP II

AS:9.2.1 Material Requirements Planning (MRP)

• This is one very popular approach to planning

• Uses Master Production Schedules to determine how much of each product should be produced within given periods. Master Production Schedules are based on customer, or projected demand.

• The elements used by MRP to plan are,
  - Master Production Plan (Schedule)
  - On-hand inventories
  - Bill of Materials
  - Current of Purchased and Manufactured Orders
  - Rules for each part produced (including WIP)

• The rules about each step in production include,
  - Lead time
  - Order quantity per final part
  - Scrap rate
  - Buffer stock quantity
  - etc.

• MRP then tries to determine quantities required using the data input from the users, and a set of rules, such as,
  - Fixed Order Quantity - Product are produced as required using a prespecified lot size.
  - Economic Order Quantity - The cost of carrying inventory is weighed off against the cost of setup for one production run.

- Lot for lot - Lots are produced as required, any batch size.
- Fixed-period Order Quantity - Produce parts to cover more than a single order.

• Lot sizes required are subtracted from available stocks.

• The required production quantities are used to order from suppliers, etc, while considering lead times, and delays.

• You should note that this approach is concerned more with inventory minimization than with utilization of machines.

• While this system can lead to easy production scheduling, it is susceptible to errors in BOMs, routings, etc.

• Advantages,
  - improved Customer Service
  - better Scheduling
  - reduced inventory
  - reduced component shortages
  - reduced manufacturing costs
  - reduced lead times
  - higher production quality
  - less scrap, and rework
  - higher morale in production
  - improved communication
  - improved plant efficiency
  - improved competitive position
  - improved coordination of marketing and finance

• MRP II (Manufacturing Resources Planning) - A closed-loop MRP system that, at a minimum, includes detailed capacity analysis (see next section). Some MRP II systems include the business plan in the closed-loop system.

AS:9.2.2 Capacity Planning

• While MRP is concerned with determining how much should be produced, it is not concerned with how to produce it.

• Capacity planners attempt to determine how to assign jobs to machines, people, etc.

• Information used by capacity planners includes,
  - Planned orders (from MRP)

- Orders in process (order status)
- Routings, including setup and run time (from process plans)
- Available facilities
- Workforce availability
- Subcontracting potential

• There are some strategies used by the Capacity Planner to Assign jobs to machines,
  - Splitting of lots (batches) across identical machines
  - Splitting of lots to expedite a smaller quantity
  - Sequencing of lots to minimize setup times
  - Alternative routings that require different resources
  - Loading a facility by weight, volume, etc. (eg. heat treating)

• After jobs have been assigned to machines, the capacity of the machines must be considered.

AS:9.3 SHOP FLOOR CONTROL

• No factory is perfect, and a schedule can become invalid at any time because of,
  - Machine breakdown
  - Sudden material shortage
  - Workforce vacancy
  - Tool breakage
  - etc.

• What to do about it,
  - Wait and See
  - Try to find alternative production plans/parts
  - Ask engineering for replan
  - Bump other jobs
  - ?????

AS:9.3.1 Shop Floor Scheduling - Priority Scheduling

• Instead of scheduling before production (MRP and Capacity planning), a manufacturer may opt to do scheduling on the fly.

• Some of these methods include,
  - Earliest operation due date - soonest date. This gives time until due, but ignores processing time.
  - Order Slack - soonest date minus processing time. This gives the amount of time to play with.

- Shortest operation first - Do the quickest jobs first. This just clears out WIP faster.

AS:9.3.2 Shop Floor Monitoring

• It is important to know what is happening on the factory floor.

• To do this we must pay attention to obvious problems like machine operation, and hidden problems such as quality, and production quantities.

• Inspection covers a number of areas,
  - Inspection of raw materials
  - Inspection of manufactured product
    - preprocess
    - in-process
    - post process
  - Inspection of production process parameters
    - tools
    - fixtures
    - production machinery
  - Verification/calibration
    - inspection fixtures
    - Inspection gauges
    - Inspection machinery

AA:10. PLANNING AND ANALYSIS

AC:10.1 FACTORS TO CONSIDER

• There are a number of factors in a company which must be considered when evaluating the need for CAD/CAM/CAE/CIM/etc systems. Some of these are listed below,

external
- company crisis
- markets Niche/Global/Home/ etc.
- competition
- customer requirements

internal
- corporate objectives, mission and culture

technological
- available technology
- research & development

success factors
- the role of management
- worker security
- corporate organization
- unions
- middle management
- worker motivation
- training / worker abilities
- cash
- purchasing
- design engineering
- etc.

• Current popular planning strategies include,

Cost management
- direct costing
- effective capital investments
- space utilization

Cycle time reduction
- continuous flow manufacturing and vendor supply
- pull manufacturing
- business and process reengineering

Market driven quality
- defining market needs
- first to market

- agile manufacturing
- 6 sigma quality

Automation
- process
- warehouse
- information

CIM
- simplifying and automated processes
- increased information access

• We can draw a chart that illustrates the issues that might be encountered,

	Structure	Infrastructure
Macro	fiscal/tax monetary trade industrial capital market political structure labor organization	culture tradition religion values social behavior
Micro	business market plant/equipment - capacity - location - process technology vertical integration	measure and control workforce vendors management capital budget organization