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THE MANUFACTURING SYSTEM DEVELOPMENT GAME

by

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ABSTRACT

The Manufacturing System Development Game© is a comprehensive case study in developing a system for the manufacture of a new generation of multi-panel printed circuit cards. It explores a broad range of design and operational issues, requires extensive team effort and coordination on the part of the participants, and employs a variety of microcomputer-based analytical and information management programs. In the course of the Game, participants will

(a) structure a team approach for developing a large manufacturing system;

(b) apply basic manufacturing engineering and economic principles to the design of this system;

(c) focus on the crucial interfaces between functional areas, discovering how manufacturing and logistics problems can be avoided by the early involvement of different functional representatives in the design process; and

(d) gain experience in applying software tools that can ease data management and communication problems and can increase the analytical scope of the design phase.

Because a key objective of the course is to relate issues that arise in different functional areas, the Game has been designed to avoid deep technical issues in any particular area. Consequently, provided that participants have expertise in some area of manufacturing engineering and operations, they should be able to contribute to the activities and discussions in any of the functional areas. The Game is intended, in part, to broaden the experience and outlook of the participants.

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I. INTRODUCTION

I.A Background

Increased international competition during the past decade has forced United States-based manufacturing companies to re-evaluate their positions in the global economy. The invasion of new competitors into their once tightly controlled markets has caused these companies to respond to the changes in a variety of ways. Many companies first tried to maintain their market share and profits. They partially accomplished this goal through layoffs of both line workers and managers, through increased automation, and, in some cases, through plant closings. For the most part, these actions, while necessary, did not address fundamental problems and therefore provided only short term relief. Unfortunately, the economic climate and market place had permanently changed. Product life cycles shortened. In many instances the investments in manufacturing facilities required to produce these new products increased dramatically over those experienced previously. Also, customer service requirements increased in terms of both the timeliness of shipments and the quality of products. In addition, currency fluctuations, tax policy changes, and economic disruptions in various parts of the world caused managers to be extremely cautious when making capital allocation decisions. Often companies were overly careful and too concerned with short term profits. Consequently, they lost the edge in manufacturing technology and product innovation they once enjoyed.

Some companies have responded to the challenges of this new environment. In addition to cost cutting measures, they have examined their businesses and have appropriately restructured them. One common major goal in these restructuring efforts has been to change the way products are designed and manufactured. To be competitive, these companies realized that they had to design and test products in shorter periods of time. They designed products whose components could be manufactured inexpensively. These products have fewer parts, require fewer process steps, and have greater functionality and reliability. To achieve all of these competitive goals, the companies had to create a new environment in which the product, process, and manufacturing engineers had to work as a team in combination with the people in other areas, such as finance, marketing, procurement, and distribution functions. The IBM Proprinter is an example of a product that was designed, manufactured, and marketed in this new environment. Companies that are able to integrate the traditionally separate and often times conflicting activities into a more purposeful entity will survive and prosper in the changing global economy. Those that cannot will cease to exist.

The Manufacturing System Development Game© in which you are about to participate has been created to demonstrate both the necessity and complexity of a team approach to product, process and system design. In a simulated environment, your design team will create a plan for the design and manufacture of a new generation product called a multi-panel card. The game explores a broad range of design and operational issues, requires extensive team effort and coordination, and employs a variety of PC-based analytical and information management programs.

Specifically, the objectives of the Manufacturing System Development Game© are (1) to apply basic manufacturing engineering and economic principles; (2) to introduce a team approach for developing a large system; (3) to focus on the crucial interface between the design laboratory and manufacturing plant and to illustrate how manufacturing problems can be avoided by the early involvement of manufacturing engineers in the design process; and (4) to give experience in applying several PC-based programs to ease the data management problems and increase the analytical scope of a large manufacturing system's project.

I.B Play of the Game

The game encompasses a broad range of issues that must be addressed-too many for a single person to consider in detail. Because of the amount of information, the complexity of the issues, and the number of tasks that need to be completed, a group effort is essential. The skills and ideas of several people are required in order to design an effective manufacturing system plan. To meet the goals of the game, you will be organized into nine teams: Manufacturing System Architect (one or two students responsible for coordinating the overall project), Information System Development, Cost Engineering, Logistics Engineering, Facilities Engineering, Equipment Engineering, Industrial Engineering, Product Engineering, and Process Engineering.

The game itself is divided into two phases. In the first phase, the teams jointly develop a preliminary proposal for a manufacturing system that meets the objectives of the program and addresses all the basic issues. To accomplish this task, several alternative designs may have to be evaluated by each team before a final preliminary proposal is established. Once established, the proposal will be presented orally to a group of faculty members who will critique it and identify the issues that the students need to consider more fully. In the second phase, the basic scenario will be altered with new demand forecasts, new yield performance estimates, and new design options. The teams are to revise their proposal in light of the critique and the new information. The final proposal will be delivered both orally and in a written report.

I.C Information Flow

The United States manufacturing sector has not been lacking in new ideas but has often failed to implement them effectively. In order for an idea to be effectively incorporated into a product and system design, communication among teams is absolutely necessary. However, a common occurrence in a manufacturing environment is the lack of cooperation between the design laboratory and the manufacturing plant. An innovative yet intricate product design may turn out to be a logistical or manufacturing nightmare. Consequently, the product costs are often much higher than originally estimated. An improved organizational design would open lines of communication and allow ideas to flow smoothly, thus making the product design and manufacturing system activities work together much more effectively.

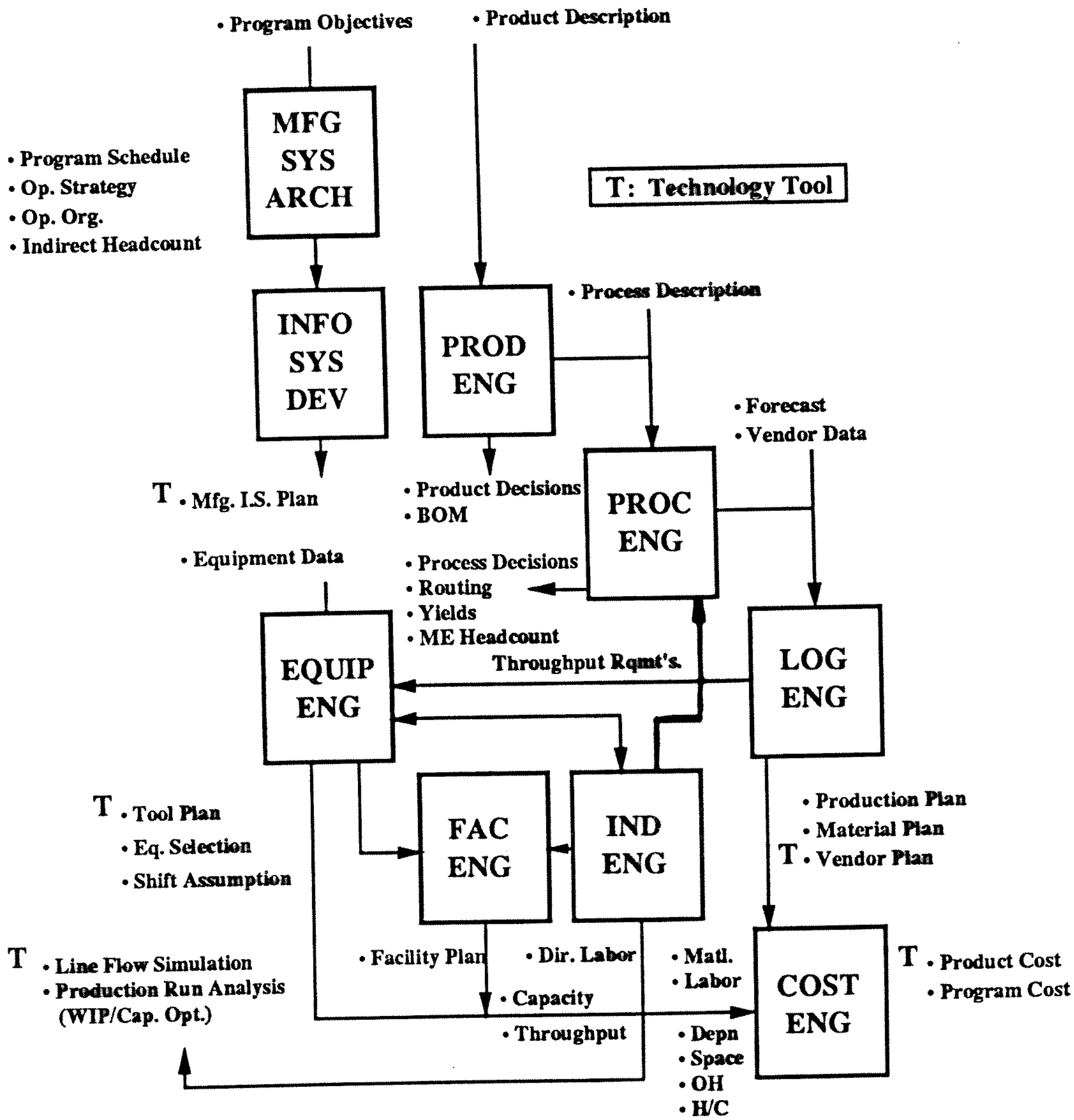


Figure I-1. Information Flows.

Properly organizing a system to accomplish this goal is a difficult task. Not only is it important to know what information is available, but also who requires it, when it is needed, and how it will affect decisions in the future. To illustrate the communication requirements associated with the design of a manufacturing system, we describe the basic flow of information that must occur among the different teams in the game. As you can see from Figure I-1, almost every decision made by one team requires information from other teams. Furthermore, each decision made by a team will affect decisions made by other teams.

There are several types of data displayed in Figure I-1. The first is static. Data such as the equipment parameters fall into this category. Some data are based on estimates and projections. An example of this type is the product forecast. Finally, some data are decision driven, such as the tool plan from the Equipment Engineers.

Technology tools, mostly in the form of LOTUS™ spreadsheets, are provided. In Figure I-1, a "T" denotes the availability of a technology tool to help manage the large amount of data. Figure I-1 should not be viewed as comprehensive in scope, but rather as a general guideline of how information must flow in the design process for the multi-panel card line.

To illustrate the interdependence of the teams, consider the problem of meeting the program objective of minimizing product cost. Since the major cost category is equipment depreciation, it is not possible to get even a ball-park estimate of product cost until the Equipment Engineers have developed a preliminary tool plan. The Cost Engineers are thus in the position to encourage the Equipment Engineers to provide them with some basic data to begin their analysis. The Equipment Engineers in turn cannot prepare a tool plan until they have a forecast of capacity requirements from the Logistics Engineers. The Logistic Engineers must develop a five-year production plan from the demand forecasts. But to translate that information into capacity requirements by sector they in turn need a yield plan from the Process Engineers. Very quickly you will discover the critical information flows. It is the job of the Manufacturing Architect to prepare a schedule for developing the final system proposal and to assure the timely flow of information among teams.

I.D Project Objectives

To conclude this introductory section we describe the objectives for the first part of the Manufacturing System Development Game©. They are relatively simple to state, but considerably more difficult to accomplish. The nine teams must cooperate to produce a preliminary plan for a manufacturing system. Each team must conduct its own required analysis and provide needed information to the other teams. Your design must integrate the efforts of all team members and all teams. The results of your efforts will be presented orally to faculty members at the conclusion of this phase. The design you present should:

1) Deliver the forecasted production quantities on time and starting at the earliest possible calendar time.
2) Achieve the highest possible process and product quality as soon as possible.
3) Achieve the lowest possible material cycle times.
4) Deliver the product at the lowest possible cost.

The above criteria are important dimensions to the evaluation of your design. However, they are not ranked by importance. Where tradeoffs exist, as between cycle time and cost, you must establish your own ranking.

II. MULTI-PANEL CARD ENVIRONMENT

II.A Background

The multi-panel card that you will design is an improvement on the old card panel technology first introduced in the Manufacturing Operations Game©. This section will briefly describe several key features of the old product line.

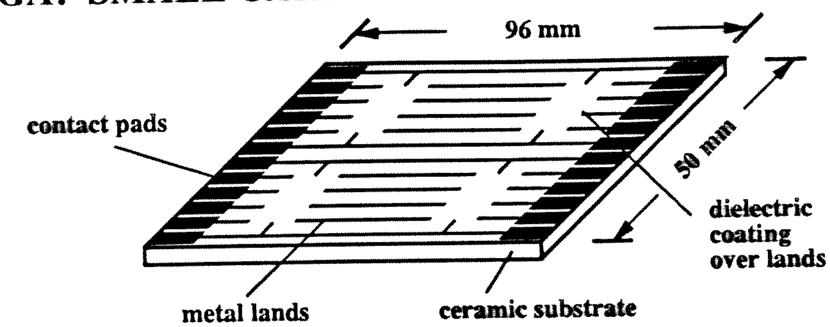
In the Manufacturing Operations Game©, the product that was manufactured was called a "card panel." There were two part types of card panels, part number GA and part number GD. The two products are very similar except that product GD is slightly larger and requires an additional processing step and, therefore, additional resources in terms of tools and people.

Both products are small ceramic substrates upon which a thin coating of chrome-copper-chrome metal is deposited. By a series of photo-masking and etching steps, the metal is etched away to form a pattern of conducting lines on the substrates. The additional step required for the GD product is the placement of several metal staples that serve as cross-overs and connect one set of lines to another (see Figure II-1).

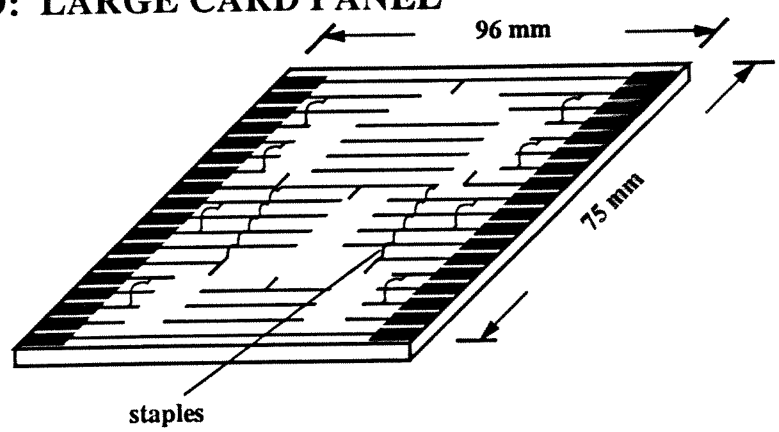
The card panels are produced by a series of operations grouped into six sectors. The sectors are Clean/Evaporate, Photo, Etch, Staple (GD only), Sputter, and Test.

Figure II-2 is a representation of the next generation of panel that will be produced in the Manufacturing System Development Game©, a multi-panel card. This section gives the product and process descriptions for this new line of products as well as an initial forecast for each part number in the product line.

GA: SMALL CARD PANEL



GD: LARGE CARD PANEL



larger panel has crossovers ("staples")

Figure II-1. Old Card Panels-GA and GD

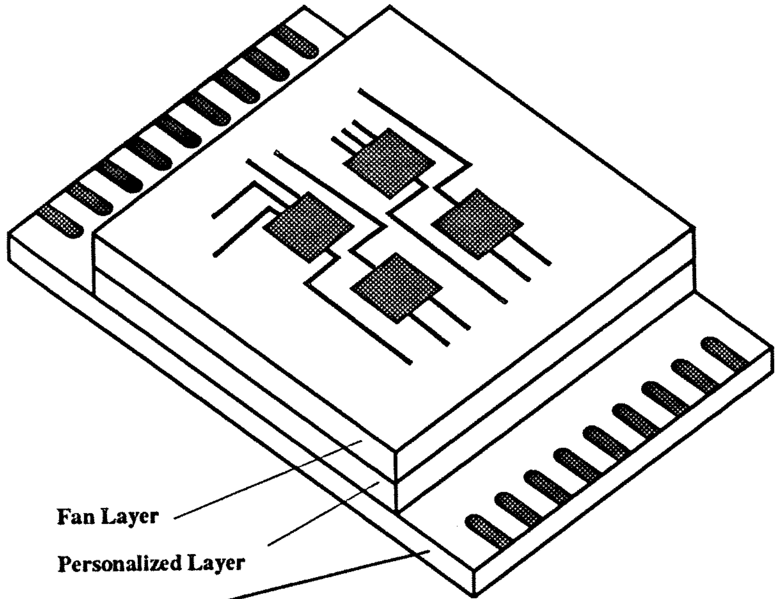


Figure II-2. Multi-Panel Card.

II.B Product Description for Multi-Panel Cards

New packaging technology has just emerged. This technology permits a new generation of products called multi-panel cards which are named MLC (multi layer ceramic) cards. These cards, which consist of several layers, were designed so that more circuitry could be placed on them than on cards in the previous generations. The new product (shown in Figure II-2) consists of three layers of ceramic, two of which are common to all models (the fan and the power). There are four possible versions of the third personalized layer (MA, MC, MD, and MF). There are two families of MLC cards, SMP and AMP. The part numbers MA, MC, and MD are grouped into the SMP family. The AMP family includes part number MF, the most advanced product. Each layer has a special type of circuitry applied to it, called land circuitry. Then the layers are stacked on top of each other and are heated in a hydrogen oven to bond the different layers together. Connections between the individual layers of circuitry are made through "via holes" which are filled with conductive material and are described in more detail in the Process Engineering description. Chips are added on the fan layer to provide additional circuitry (see Figure II-3).

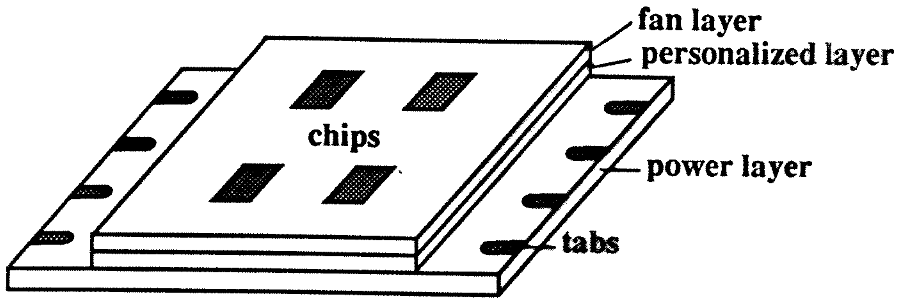


Figure II-3. MLC Card.

Protection for the chips is provided by placing a flange and a cover over them. A window shaped flange is attached to the top layer to create a well in which the chips lie. The cover includes a spring which makes contact with the chips. Fins on the outside of the cover increase the surface area exposed to the air and are used to dissipate heat. A cross-sectional view of the entire assembly is shown in Figure II-4.

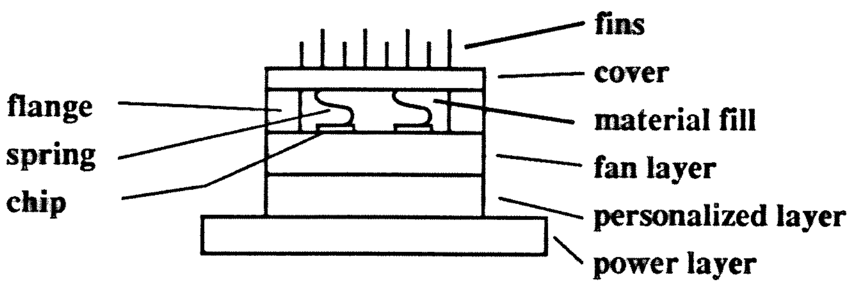


Figure II-4. Cross Sectional View.

The new MLC cards are compatible with the former "shoe box" technology at the next assembly level. Figure II-5 is a side view example of the "shoe box" technology. The individual panels are inserted sideways into a tongue and groove shaped motherboard. However, the thicker card size means that fewer cards can fit into existing motherboard designs.

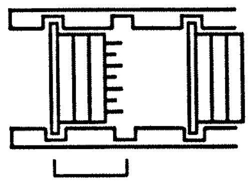


Figure II-5. "Shoe Box", Side View.

The Manufacturing System Development Game© focuses on the design of a manufacturing line to produce the MLC card panels from substrates. The addition of the chips and the cover as well as other assembly tasks take place after the cards leave this line. Likewise, drilling of the via holes, addition of the tabs and firing of the ceramic substrates are assumed to have occured prior to their entrance into this line.

II.C Process Description

In order to produce the new multi-panel ceramic cards, several process steps are required. The manufacturing process is divided into five sectors: substrate cleaning, panel assembly, top metal processing, flange assembly, and final testing. In each sector, one or more operations is completed.

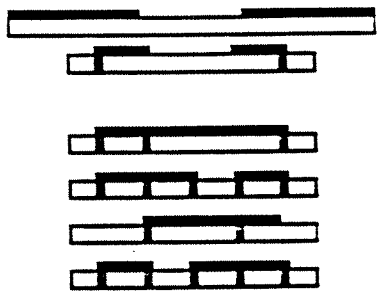
The operations are described, numbered and listed in Table II-1. In the first column of Table II-1, each operation is given a process routing number and a label. For example, in sector 1, Substrate Screening, there are five operations which are numbered 101-105 and named Inspect, Clean, Screen, Sinter, and Test. Notice there are two possible sets of operations given for sector 3. One of the design decisions to be made is to select a process routing. The Process Engineering team must choose between the top metal staple process and the top metal thin film process. Only one option may be chosen. These options are discussed in detail under the Process Engineering team descriptions. These operations are grouped into five sectors: Substrate Screening, Panel Assembly, Top Metal, Flange Assembly and Final Test. The center column depicts graphically what happens to the panels after each sector completes its operations. For example, in sector 2 the panels are assembled. The three layers, power, personalized, and fan, are stacked in that order and pressed. Finally, the last column lists what parts are required for each sector. As you can see, the operations in sector 3 apply only to the advanced multi-panel card (AMP), which is the only card that requires this technology.

MPC's which complete Final Test, in sector 5, are sent to the next manufacturing step, Chip Attach, in the so-called Module Assembly Line.

1. Substrate Screening

Family/P/N

101 Inspect
102 Clean
103 Screen
104 Sinter
105 Test



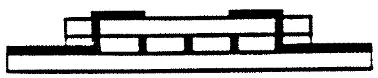
Common: PWR
FAN

Standard: MA
MC
MD

Advanced: MF

2. Panel Assembly

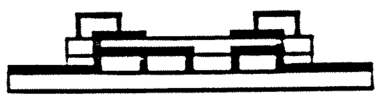
201 Substock
202 Assemble & Press
203 Sinter
204 Test



Stacked for Ass'y.
3 SMP P/N's
1 AMP P/N

3. Top Metal Staple Process

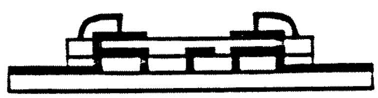
301 Staple Assembly
302 Reflow
303 Sputter
304 Test



Staple Process:
AMP only

Top Metal Thin Film Process

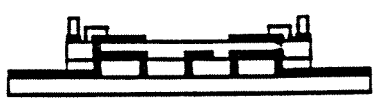
310 Sputter
311 Photo (Glass)
312 Glass Etch
313 Evaporate
314 Photo (Metal)
315 Metal Etch
316 Test



Thin film process:
AMP only

4. Flange Assembly

401 Flange
402 Brazing



Flange:

5. Final Test

501 Test

To: Chip attach in module line

Table II-1. Multi-Panel Product and Process Description.

The following is a brief description of the five sectors and their operations listed in Table II-1.

Sector 1

Inspect:	All substrates are visually inspected for transit damage.
Clean:	The substrates are given a chemical wash to prepare the surfaces for the thick film application.
Screen:	A thick paste is squeezed through a metal screen onto the substrate forming the land pattern. Each layer (fan, 4 personalized layers and power layer) requires a different pattern. The via holes are also filled with paste.
Sinter:	The substrates are treated in a hydrogen oven, sintering the paste to the substrate. The paste vehicle evaporates leaving the conductive land material bonded to the substrate.
Test:	This is a simple continuity test (probe and test) that takes no more time than loading and unloading the substrates into the test machine. There is some changeover time from one pattern to another.

Sector 2

Substock: A stocking point for the substrates before assembly.

Assembly: Depending on the part number, the three layers are stacked together in a semi-automatic operation.

Re-sinter: The assembled card is heated again in a hydrogen oven (at higher temperature) to bond the different layers together.

Test: A continuity test performed is similar to the one performed on the individual layers; however, the yield is much lower than for the individual layers.

Sector 3

Top Metal Options: One of the part numbers, corresponding to one of the personalized layers, will have the most number of chips attached. This product has a low forecasted demand but is pushing the limits of the current 3-layer MLC. It requires another layer. One way to add this needed layer is to use the staple technology-add some staples to the top layer (fan) to make the connections. This is the cheapest alternative because the stapler already exists and demand is low. The staple process may not be extendible to the denser, more advanced cards being developed in the laboratory. In the long run product engineers would prefer to see another layer added to the card using the thin film technology. The thin film option is expensive given current demand projections but the future of this product line lies with this technology.

Sector 4

Flange Assembly: The flange is manually soldered to the top layer.

Sector 5

Final Test: A final continuity test.

II.D Bill of Materials

A bill of materials (for both direct and indirect materials) has been structured for the various products. Table II-2 lists both the contents and the costs of material for the Screen, Top Metal and Flange sectors. For example, in the Screen sector, 0.00208 lbs. of paste are required per unit of SMP and costs $0.1/unit. Only the staple AMP ("STA AMP") or the thin film AMP (T.F. AMP) is found in the bill of materials column depending on which design option is chosen. The complete bill of materials can be found in the Materials Planning spreadsheet entitled BOM.WK1.

Sector	Material Name	Unit of Measure	Usage SMP	STA AMP	T.F. AMP	$/Unit
Direct Material						
Screen	Ceramic	ea.	1	1	1	.10
	Paste	lb.	0.00208	0.00208	0.00208	10
Top Metal	Staples	ea.		15		0.001
	Solder Flux	lb.		0.00625		8
	Dielectric Glass	lb.		0.00625	0.00625	24
	Aluminum Pellet	lb.			0.00625	10
Flange	Flange	ea.	1	1	1	0.35
	Brazing Preform	ea.	1	1	1	0.1
Indirect Material						
Screen	Cleaning Fluid	gal.	0.00167	0.00167	0.00167	8
Top Metal	Photo Resist	gal.			0.003	100
	Glass Etchant	gal.			0.001	10
	Metal Etchant	gal. gal.			0.001	15
Flange	Cleaner	gal.	0.005	0.005	0.005	8
	Brazing Flux	lb.	0.00625	0.00625	0.00625	16

Table II-2. Bill of Materials.

II.E Equipment Costs and Performance

To produce the new multi-panel cards, several different pieces of equipment are needed. Fortunately, some of the machines from the single layer card panel line can be used. Data on equipment costs and performance have been gathered into Tables II-3 and II-4. The last column of Table II-3 lists the book value or accounting cost of the presently available equipment. As you can see, the existing equipment has already been depreciated by a significant amount. Note that the electrical test system must be upgraded for multi-panel fixtures and this upgrade costs $50,000. This information is of value to the Equipment and Cost Engineers. The equipment performance table (Table II-4) gives the nominal capacity or running rate per hour. It also lists the mean time to fail (MTTF) and to repair (MTTR) for the machine tools as well as the process batch size and the setup time. MTTF is defined as the mean time a machine runs before a failure. This information is presented in greater detail in the four Equipment Planning spreadsheets entitled TOOL1.WK1, TOOL2.WK1, TOOL3ST.WK1, TOOL3TF.WK1 and TOOL4&5.WK1. The Equipment Engineering team should use these data to decide how many new machines are needed for the multi-panel card line.

Relevant Multi-Panel Sector and Operation		Tool Name	Quantity On Hand	Initial Capital Cost/Unit x$1000[1]	Current Book Value x$1000 (each)
1	(Vis. Inpection)	Microscopes	4	0.2	0
	(Cleaning)	In-line Cleaner	1	250	25
	(Testing)	Continuity Tester	1	100	10
2	(Mat. Handling)	Substrate Transfer System	2	20	2
	(Testing)	Continuity Tester		(see above)	
3	***Staple***				
	(Staple Assembly)	Assembly Tool	1	250	150
	(Reflow)	Reflow Furnace	1	75	8
	(Sputter)	Sputtering Chamber (1)	1	150	10
		Sputtering Chamber (2)	2	140	15
		Sputtering Chamber (3)	2	102	25
	(Testing)	Continuity Tester		(see above)	
3	***Thin Film***				
	(Sputter)	Sputtering Chamber (1)		(see above)	
		Sputtering Chamber (2)		(see above)	
		Sputtering Chamber (3)		(see above)	
	(Photo-Glass)	Photo Processor	1	250	25
	(Evaporation)	Continuous Evaporator	1	175	18
	(Metal Etch)	Metal Etcher	1	175	18
	(Testing)	Continuity Tester		(see above)	
5	(Final Test)	Electrical Test System	1	250	25[2]

[1]The design and debug costs are included.

[2]Requires $50K upgrade for multi-panel fixtures and programming changes.

Table II-3. Card Panel History: Equipment Costs.

Relevant Multi-Panel Sector and Operation	Tool Name	Process Batch Size	Running Rate (#/hr)	Setup Time (hrs)	MTTF (hrs/ fail)	MTTR (hrs/ fail)
1 (Vis. Inpection)	Microscope	1	667	0	333	20
(Cleaning)	In-line Cleaner	1	455	0	250	1
(Testing)	Continuity Tester	1	267	0	40	1.5
2 (Mat. Handling)	Substrate Transfer System	1	200	0	400	1.5
(Testing)	Continuity Tester		(see above)			
3 ***Staple***						
(Staple Assembly)	Assembly Tool	1	133	0.5	4.2	0.25
(Reflow)	Reflow Furnace	1	200	0	60	3
(Sputter)	Sputtering Chamber (1)	1	29	0	15	1
	Sputtering Chamber (2)	1	29	0	15	1
	Sputtering Chamber (3)	1	29	0	15	1
(Testing)	Continuity Tester		(see above)			
3 ***Thin Film***						
(Sputter)	Sputtering Chamber (1)		(see above)			
	Sputtering Chamber (2)		(see above)			
	Sputtering Chamber (3)		(see above)			
(Photo-Glass)	Photo Processor	1	143	0.1	10	0.75
(Evaporation)	Continuous Evaporator	10	400	0	15	1
(Metal Etch)	Metal Etcher	1	250	0.3	8.4	0.4
(Testing)	Continuity Tester		(see above)			
5 (Final Test)	Electrical Test System	1	500	0	33	1

Table II-4. Card Panel History: Equipment Performance.

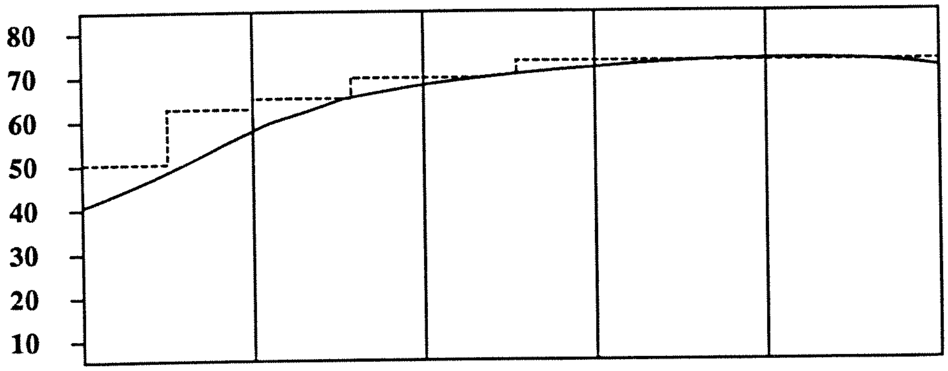
II.F Process Yields

Figure II-6 graphically depicts the actual and planned yield performance of the single layer card panel line of the Manufacturing Operations Game©. The data shows that the yield steadily increased until the third year, then leveled off. The actual yield, however, was for the most part below the planned yield.

Some current yield data on the new multi-panel card line are available from a pilot manufacturing line. Table II-5 lists the yield information. Note that there will be a slight difference in yield for the AMP depending on which top metal option is used. Also realize that the pilot line is a low volume, highly controlled line operating under laboratory conditions. The pilot line for the single layer card panel line significantly overestimated the yields that were actually experienced when the single layer card panel began operations.

Key ---- planned
—— actual

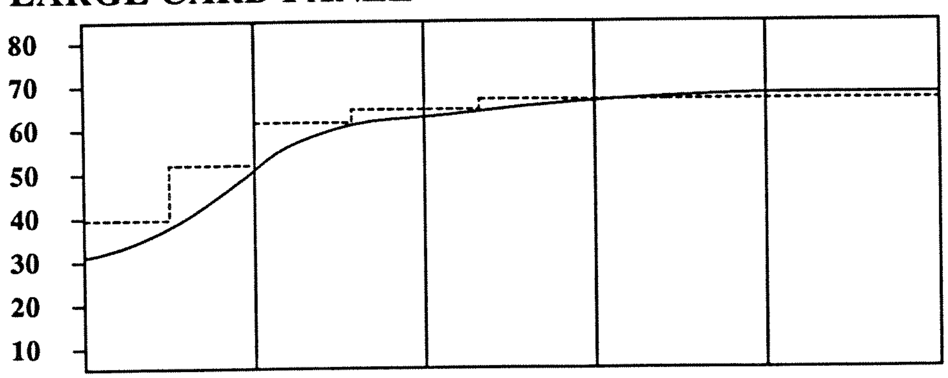
GA: SMALL CARD PANEL



Program Year 1st 2nd 3rd 4th 5th

Plan	50	65	69	72	72	75	75	75	75	75	75
Actual	40	48	72	68	71	72	73	75	75	74	73

GD: LARGE CARD PANEL



Program Year 1st 2nd 3rd 4th 5th

Plan	40	55	60	62	62	64	64	64	64	64	64
Actual	32	39	50	62	62	64	65	67	67	67	65

Figure II-6. Card Panel Yields.

Multi-Panel Phase 1 Data:
Pilot Line Current Yields, SMP P/N's.

Sector	Operation	Yield
Screening	Inspection	.98
	Cleaning	.99
	Screening	.95
	Sintering	1.00
	Test	.97
Assembly	Assemble & Press	.98
	Sinter	.98
	Test	.90
Flange	Flange Assembly	1.00
	Brazing	.98
Final Test	Test	.95
		.72

Multi-Panel Phase 1 Data:
Development Estimates of Top Metal Ultimate Yields.

Sector	Operation	Yield
Top Metal	Staple Process	.90
Top Metal	Thin Film Process	.95

Table II-5. Current Yield Information.

II.G Product Forecast

To conclude this section, Table II-6 lists the initial forecast for each multi-panel part number. These estimates were obtained from product forecasts for those products which are currently committed to use this new technology package.

Part Number	Year 1	Year 2	Year 3	Year 4	Year 5	Total
MA	72000	144000	168000	165000	99000	648000
MC	93000	180000	204000	216000	129000	822000
MD	105000	198000	207000	216000	150000	876000
SMP Subtotal	270000	522000	579000	597000	378000	2346000
MF	75000	90000	111000	144000	174000	594000
Total	345000	612000	690000	741000	552000	2940000

Table II-6. Product Forecasts.

III. TEAM DESCRIPTIONS AND RESPONSIBILITIES

This section describes the nine teams, their responsibilities, and gives some specific data and special situations. You should read all of the team descriptions to get a better idea of the problems that each team must resolve.

III.A Manufacturing System Architect (MFG. SYS. ARCH.)

This team must provide the overall management and control of the multi-panel program. It must develop the program schedule to be presented at the kickoff meeting using data and information from all the other teams. In addition, it must plan and orchestrate the phase review meetings to ensure that all issues are adequately covered, and it must develop the operating strategy for the multi-panel card line. Finally, it should provide the multi-panel card line operating organizational plan that will identify the required direct, indirect, and manufacturing engineering head count as an input to the cost engineering team for the product cost estimate.

The organizational plan should include the direct support functions such as manufacturing, manufacturing engineering, production control, quality control, etc. The MFG. SYS. ARCH. team must decide which of these functions will be part of the multi-panel operating organization and which ones will be organized at the site support level of the plant organization. Keep in mind the objective to reduce our non-technical head count from 45% to 30% of total site head count.

TEAM: **MFG. SYS. ARCH.**

SITUATION: **MULTI-PANEL OPERATION STRATEGY**

The primary activity of this multi-panel program focuses on the physical attributes of the manufacturing system. Assuming the plan is adopted, the successful operation of the line will depend not only on the excellence of its design but how effectively it is run. This part of the program directed by your team and with the support of the INFO. SYS. DEV. team will focus on a plan for managing the line. This operating plan will consider the following:

- What are the objectives of this manufacturing system? They relate to several key parameters. Delivery, cost and quality requirements are fundamental, of course, but managing the parameters which determine delivery, cost and quality are necessary as well. These secondary parameters may include, for example, equipment performance, WIP management, yield, and labor utilization. There are undoubtedly tertiary parameters which you may wish to consider as well.
- What type and form of organization will you choose? What skills do you require? What job scope should be assigned to individuals? What training is appropriate? These considerations will help determine the most effective organization.
- What is the process by which communication takes place and by which decisions are made? There are perhaps two levels of attention. First, you need day-to-day tracking of the line's status and the action necessary to keep performance close to objectives. Second, a longer range view is required to manage the implementation of procedures or equipment that are needed to improve operations, for example to increase capacity, to increase yield, or to increase equipment efficiency.
- How will automation in the future affect your plan?

This operating plan will be the basis for determining the information system plan.

TEAM: **MSA, COST ENG.**

SITUATION: **ORGANIZATION HEAD COUNT**

The cost engineering department has been asking you for the organization plan that will provide them with the head count of indirect employees by the planning calendar so they can determine the program costs. You need to establish organization charts (which may change over time) so that you can plan the number of people in the organization. The direct labor headcount is normally the responsibility of the industrial engineering team (see section III.G and Table III-12). However, if that team has difficulty meeting its schedule, you should assume responsibility for planning direct labor. The information that you have from finance about the salary rates to use is presented in Table III-1.

	Average Annual Salary
Managers of Managers	$50,000
Managers of People	$45,000
Professionals	$40,000
Technicians	$32,000
Direct Operators	$25,000

Table. III-1. Salary Planning Data.

III.B Product Engineering (PROD. ENG.)

PROD. ENG. is responsible for the design of the multi-panel product. It must quickly determine which of the alternative product designs for the flange will best meet the objectives for the multi-panel program. Then it must ensure that the design alternative that is selected is ultimately incorporated into the manufacturing system plan. (It may be helpful to model the flange design alternative using CATIA©.) The specifics of the flange design problem are given on the next pages. A final task of PROD. ENG. is to provide the bill of materials to LOG. ENG. for the production and material plans.

The technology tool used by PROD. ENG. is CATIA©.

TEAM: **PRODUCT ENGINEERING**

SITUATION: **FLANGE DESIGN PROBLEM**

The development pilot line has been successfully producing multi-panels with the "window frame" design (see Figure III-1). At the assembly operation a metal square called a window frame is pressed and sintered as a part of the multi-panel manufacturing line.

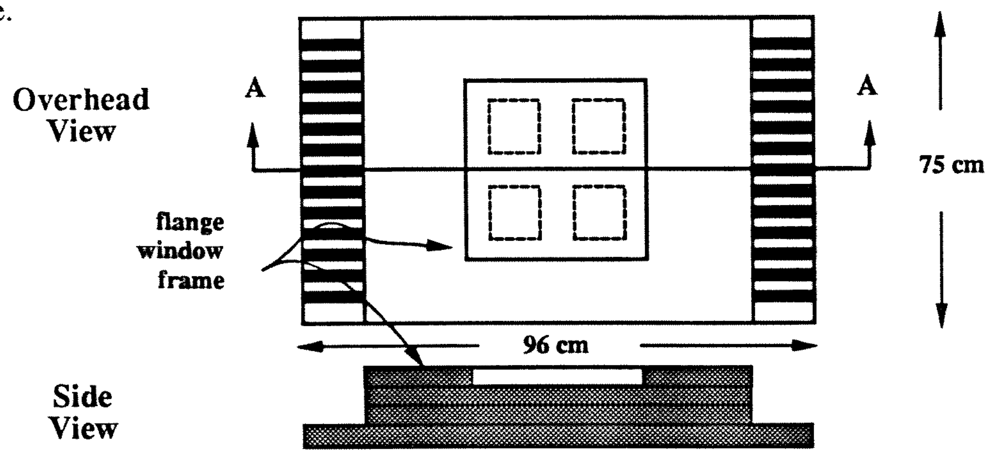


Figure III-1. Multi-panel with flange window frame.

At the end of the module assembly line, after the chips have been attached to the multi-panel, a Kovar metal cover is brazed to the window frame. Separate metal cooling fins are then brazed to the cover. The Kovar metal cover and the cooling fins are shown below in Figure III-2.

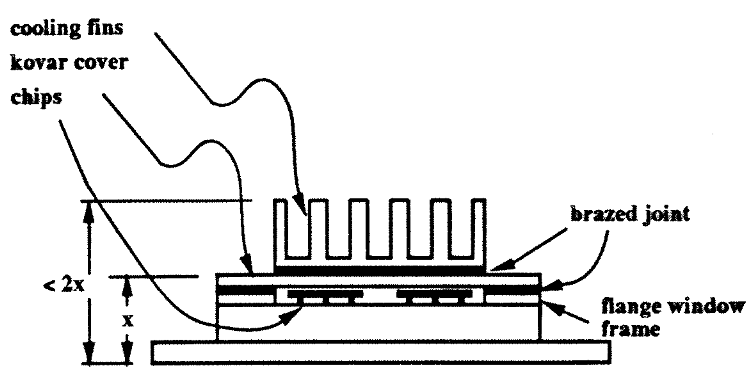


Figure III-2. Multi-panel module with Kovar cover and cooling fins.

There are several concerns with the present design:

(1) Although the flange window frame is quite cheap to buy and assemble, the plant manager feels that the number of process steps is excessive and an integrated design might be cheaper for the overall program.

(2) The plant quality assurance organization is concerned that the flange window frame inhibits the visual inspection of the chip-to-substrate joints. This could be a quality issue.

(3) The cooling fins are difficult to braze to the Kovar cover.

(4) Results from initial reliability tests are not yet available but the guarantee of a hermetically sealed module is fundamental to the success of the program.

Two *alternative designs* have been suggested:

(1) The *silo design* (Figure III-3) which was used with the old technology package has proven to be a very reliable seal. It also provides for disassembly and replacement of bad chips. It may, however, be more costly.

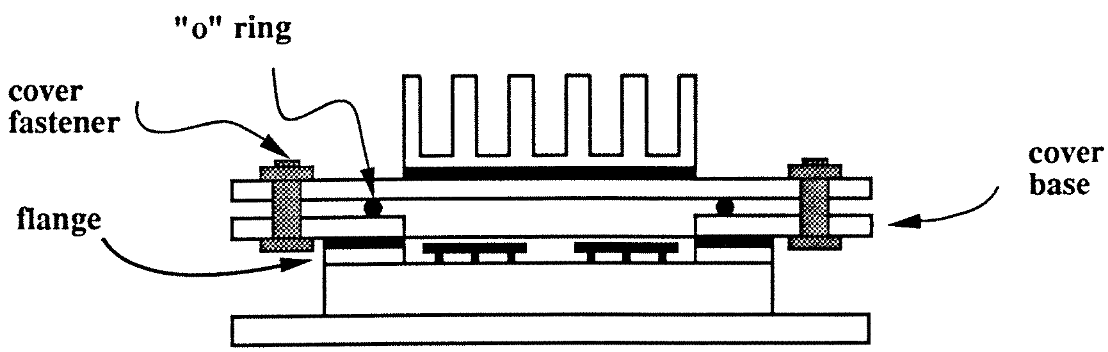


Figure III-3. Multi-panel module with silo detachable cover.

(2) The *formed cover* (Figure III-4) design would dissipate heat better; however, the forming operation appears to be more costly than the other options. Initial attempts to braze the cooling fins to the formed flange cause the flange to buckle slightly and therefore the viability of the module seal is tenuous. It does not appear to be possible to disassemble a brazed cover to replace bad chips. The

related costs are:

Item	Cost ($)
Plain Kovar Cover	0.01
Cover with holes	0.0125
Flange	0.001
Fasteners	0.0075
"O" ring	0.001

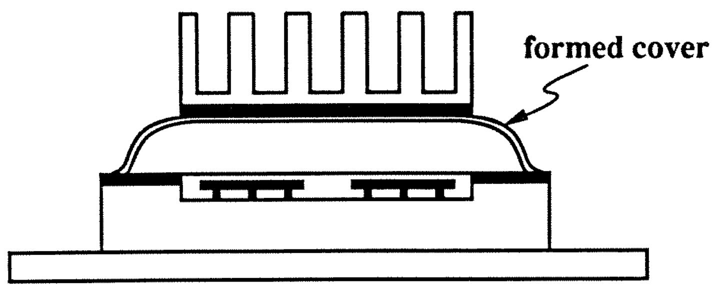


Figure III-4. Multi-panel frame with formed cover.

Product Engineering must finalize the product design as quickly as possible since it will affect the routing and therefore is fundamental to the whole manufacturing system design. Since our organization is responsible only to plan the multi-panel program and the flange design affects both our process and the module process, an out-of-pocket cost analysis must accompany this design analysis.

The design analysis should consider:

(1) The form of the design as it relates to chip clearance, overall package height and clearance with system assembly.

(2) The function of the product with respect to the thermal properties of the cover, cooling fins, and "O" ring.

(3) The manufacturability of the product in terms of the number of operations required in the routing and the potential for automation. Remember, our goal is to automate.

(4) The quality and reliability of the seal.

(5) The cost of our product, of the overall program, and of the inventory.

Finally, a requirement of this design analysis is to propose the final design on the CAD system using CATIA© so it is ready for release to manufacturing. Mapping of alternative designs on the 5080 using CATIA© may be helpful in visualizing the various alternatives.

III.C Process Engineering (PROC. ENG.)

One of the main responsibilities of PROC. ENG. is to determine whether the staple or thin film process will best meet the system's objectives. It should also ensure that the process alternative which is selected is incorporated into the manufacturing system plan. Once the alternative design is chosen, PROC. ENG. should provide a process routing and a yield plan over the program calendar for all concerned teams. The yield plan should be completed as soon as possible and given to LOG. ENG. for their production and material planning. In order to compute yields, the Process Engineers must also decide how many Manufacturing Engineers are needed.

PROC. ENG. should also examine the process which the pilot line is now using to determine which process steps can be modified to reduce manufacturing cost. You may wish to consider using sampling inspections rather than examining 100% of the parts or eliminating and combining test operations.

The PROC. ENG. team will use the yield model spreadsheet (YIELD.WK1) to help manage the data. This spreadsheet is described in the next section.

TEAMS: **PROC. ENG., MSA**

SITUATION: **ADVANCED MULTIPANEL (AMP) TOP METAL**

The design of the AMP is too dense to function with one layer of top metal conductors under the chips. There are two proposed processes for making this multi-panel part number.

The GD card panel successfully used a *staple assembly process* (Figure III-5) for the second layer. All of the equipment to perform the required operations is available from the old card panel line. It has been partially depreciated which would apparently lower the multi-panel program cost if you can use it. The development pilot line is using it successfully to produce the initial AMP engineering parts. Figure III-5 portrays a cross-section of the top portion of the assembly when the staple assembly process is used.

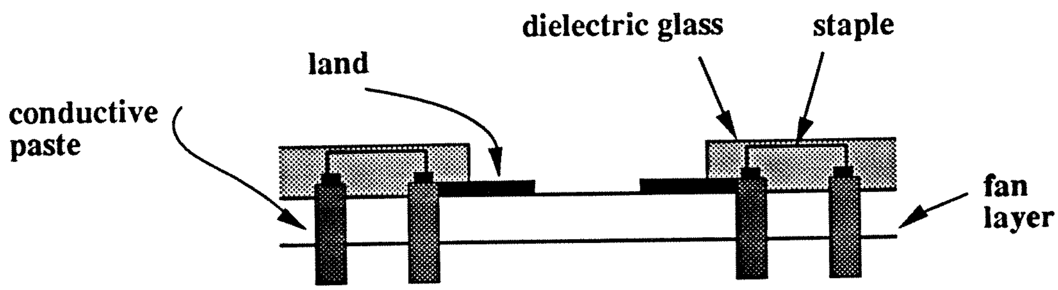


Figure III-5. Staple Assembly.

The alternative process which development is calling *Thin Film* (Figure III-6) has been proposed because it is a batch process whereas staples must be placed individually. Equipment is available from the card panel line for part of the thin film process. Figure III-6 shows a cross-section of the upper portion of the assembly when the thin film process is employed.

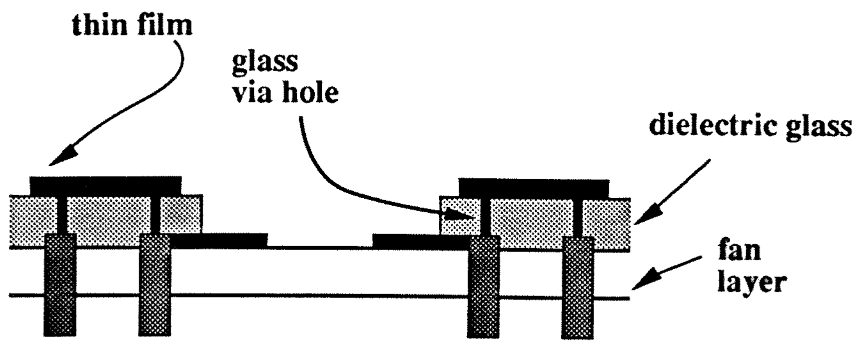


Figure III-6. Thin Film Assembly.

The staple process, although suitable for the first AMP part number, may not be extendible for follow-on part numbers which may be even denser. Product development is now setting up the thin film process in the pilot line. You cannot wait for a decision from development for your initial manufacturing system design. Therefore you must consider both processes in our planning process. The final decision will be important to you since it will affect program cost. Development needs our input to make the decision and therefore we intend to examine the following:

(1) The comparative cost of the program using either of these two alternative processes.

(2) The effect of each process relative to the number of process steps, inventory management, and continuous flow.

(3) You need to examine and present the arguments for extending the proven process of staple assembly to produce new complex part numbers versus the timing to move to the thin film process technology. Thin film may initially cost more but will ultimately provide needed functionality and cost leverage.

III.D Logistics Engineering (LOG. ENG.)

The LOG. ENG. team will provide a production plan. This plan should include the line build and start quantities for each part number over the program calendar. It must also provide the line target throughput at each sector of the routing for each part number consistent with the production build plan over the program calendar. The team must then provide an explosion of the production plan which will indicate the quantities of direct and indirect material required. Finally, it should exercise the vendor selection models to determine a desired vendor supply plan to support the multi-panel program.

There are five spreadsheets that LOG. ENG. should use: Production Planning (TPUT.WK1), Materials Planning (BOM.WK1), and the Vendor Selection Models (LP1.WK1, LP2.WK1, LP3.WK1). The contents and scope of these spreadsheets are described in the Technology Tool section.

TEAMS: **LOG. ENG.**

SITUATION: **VENDOR SELECTION**

The logistics engineering team is responsible for establishing contracts for the purchase of materials from vendors for the system's first year of operation. Certain materials such as ceramic and cleaning fluid are presently available under existing contracts at set prices, while others must be purchased separately from vendors under new contracts. Table III-2 shows what materials can be purchased from each vendor. Not all materials are available from each vendor. The vendors listed were selected based on quality of their materials and their level of service. Each is deemed to be exceptional in both categories.

It may not always be possible to purchase materials from the lowest cost vendor. Constraints of the following types exist:

(1) minimum annual purchase quantity of a particular material from a vendor;

(2) maximum total annual dollar amount of purchases from a particular vendor;

and

(3) maximum fraction of the annual unit material usage that can be purchased from a particular vendor.

The first type of constraint is imposed by the vendors. The second and third types of constraints are corporate policy constraints. These constraints exist so that a vendor does not become too dependent on our orders and we do not become too reliant on one or two suppliers of critical materials. Table III-3 contains data on the maximum total annual dollar volume that we will consider purchasing from each vendor. These numbers already reflect purchase commitments from other programs.

You need to critically examine the corporate policy constraints. If you believe they are detrimental to meeting your objectives for the manufacturing system, you should make a presentation to senior management that details how and why these policies should be changed.

VENDOR NAME	PASTE	PREFORM	PHOTORESIST	GL. ETCH	STAPLES	GLASS	ALUM	FLANGE	SOLDER	M. ETCH	CLEANER	B. FLUX
Bridge Chemical	x	x	x	x								
Candle Inc.	x	x	x	x								
Dandy Corp.	x	x	x	x								
FABTECH					x	x	x	x				
Metal Might					x	x	x	x				
Python					x	x		x				
Moore Chemical									x	x	x	x
Triple Jay									x	x	x	x
Daylight Inc.									x	x	x	x

x indicates that a material may be purchased from the corresponding vendor.

Table III-2. Material/Vendor Supply Relationship.

Vendor	Maximum $ Value
Bridge Chemical	999999
Candle Inc.	42250
Dandy Corp.	40250
FABTECH	999999
Metal Might	96600
Python	57500
Moore Chemical	17250
Triple Jay	14950
Daylight Inc.	999999

(**Note:** 999999 indicates there is no constraint.)

Table III-3. Vendor/$ Volume Constraints.

Table III-4 contains information pertaining to the maximum fraction of the annual unit consumption for each material that can be purchased from a given vendor.

Material	Max Fraction from a Single Vendor
paste	0.9
brazing preform	0.9
photoresist	1.0
glass etchant	1.0
staple	1.0
glass	1.0
aluminum	1.0
flange	1.0
solder flux	0.6
metal etchant	0.5
cleaner	0.4
brazing flux	0.4

Table III-4. The maximum fraction of annual material usage that can be purchased from a single vendor.

The minimum order quantity stipulated by vendors for certain materials is sometimes related to the quoted price. That is, the price a vendor charges for a material can depend on volume. Table III-5 contains the price break and minimum purchase volume information.

The objective is to provide a recommended plan for procuring the required materials for the first year. That is, the logistics engineering team must establish the vendors and procurement quantities for all materials. Once this is established, the material cost can be determined, using the Materials Planning Tool, and passed on to the cost engineering team.

Vendor	Material	Minimum Annual Qty.	Unit Price ($)	Minimum Annual Qty.	Unit Price ($)
Bridge Chemical	Paste	300	15	-	-
	Preform	0	0.17	45000	0.15
	Photoresist	0	150	25	140
	Glass Etchant	0	10	-	-
Candle Inc.	Paste	900	10	-	-
	Preform	25000	0.15	50000	0.14
	Photoresist	0	100	35	95
	Glass Etchant	0	11	-	-
Dandy Corp.	Paste	600	11	-	-
	Preform	60000	0.10	-	-
	Photoresist	0	105	25	98
	Glass Etchant	0	10	-	-
FABTECH	Staples	50000	0.0017	100000	0.001
	Glass	100	14	300	12
	Aluminum	100	11	300	10
	Flange	75000	0.40	125000	0.37
Metal Might	Staples	100000	0.0015	-	-
	Glass	100	13	200	12
	Aluminum	100	10.05	-	-
	Flange	200000	0.35	-	-
Python	Staples	110000	0.001	-	-
	Glass	0	24	-	-
	Flange	5000	0.43	-	-
Moore Chemical	Solder flux	0	8	-	-
	Metal etchant	0	15	-	-
	Cleaner	825	8.5	-	-
	Brazing flux	300	11	-	-
Triple Jay	Solder flux	0	8.5	-	-
	Metal etchant	0	15	-	-
	Cleaner	990	7	-	-
	Brazing flux	660	10	-	-
Daylight Inc.	Solder flux	0	10	-	-
	Metal etchant	0	17	-	-
	Cleaner	990	8.0	-	-
	Brazing flux	0	16	-	-

Revised 3/2/98

Table. III-5. Price break/minimum purchase volumes.

III.E Equipment Engineering (EQ. ENG.)

The Equipment Engineers should develop the tool plan for the multi-panel program. It should then provide a depreciation schedule from the tool plan as an input to COST ENG. for the product cost estimate. The team should also provide an initial set of shift assumptions to IND. ENG. for the line flow simulations. The IND. ENG. team will recommend average production run sizes to you.

EQ. ENG. will use the four Equipment Planning LOTUS™ spreadsheets (TOOL1.WK1, TOOL2.WK1, TOOL3ST.WK1, TOOL3TF.WK1, TOOL4&5.WK1) described in detail in the Technology Tool section.

Tables III-6 and III-7 give cost and performance equipment data for equipment that we do not currently have. The data of Tables II-3, II-4, III-6, and III-7 have been merged in the Equipment Planning spreadsheets.

TEAMS: **EQ. ENG., MSA**

SITUATION: **TOOL PLAN**

Relevant Multi-Panel Sector and Operation		Tool Name	Initial Capital Cost/Unit x$1000
1	(Screening)	Single Screener	52
		Tandem Screener*	81
	(Drying)	Drying Oven (1)	11
		Drying Oven (2)	26
2	(Assembly)	Assembly and Press	52
	(Sintering)	Batch Oven	22
		Continuous Furnace	102
3	***Thin Film***		
	(Glass Etch)	Glass Etcher	177
	(Photo-Metal)	Photo Processor	250
4	(Flange Assembly)	Manual Assembly	0
	(Brazing)	Brazing Furnace	81

* in-house project

Table III-6. New Process Tools: Equipment Costs.

TEAMS: **EQ. ENG., MSA**

SITUATION: **TOOL PLAN**

Relevant Multi-Panel Sector and Operation	Tool Name	Process Batch Size	Running Rate (#/hr)	Setup Time (hrs)	MTTF (hrs/ fail)	MTTR (hrs/ fail)
1 (Screening)	Single Screener	1	300	0.25	100	10
	Tandem Screener*	2	600	0.4	50	10
(Sintering)	Drying Oven (1)	100	100	0	200	5
	Drying Oven (2)	1000	1000	0	300	10
2 (Assembly)	Assembly and Press	1	200	0.1	400	1.5
(Sintering)	Batch Oven	500	150	0.25	300	5
	Continuous Furnace	10	500	0	300	5
3 ***Thin Film***						
(Glass Etch)	Glass Etcher	1	250	0.3	8.4	0.4
(Photo-Metal)	Photo Processor	1	143	0	10	0.75
4 (Flange Assembly)	Manual Assembly	1	200	0	1000	0
(Brazing)	Brazing Furnace	10	500	0	60	3

*in-house project

Table III-7. New Process Tools: Equipment Performance.

III.F Facilities Engineering (FAC. ENG.)

It is the responsibility of the FAC. ENG. team to provide a facilities plan for the multi-panel card manufacturing line. This plan should include the net productive square footage for both the manufacturing line and the supporting offices over the program calendar. Also, the FAC. ENG. team should develop a materials handling strategy that explores the possibilities for the use of robotics as a demonstration project. (The plant manager is particularly keen on this idea.)

FAC. ENG. should work closely with EQ. and IND. ENG. to develop a strategy for how the multi-panel manfacturing floor should be laid out. This strategy should include but not be limited to: equipment grouping considerations to optimize the use of operators, material flow considerations, material handling considerations, and space utilization.

An initial plan may have to assume the number and kind of tools used. Subsequent plans will have to be modified as line flow simulations are performed by IND. ENG. and the tool plan is modified by EQ. ENG. PROC. ENG. may also influence tool plan updates by modifying the process and PROD. ENG. will influence the tool plan by resolving product design issues.

The following information will enable a scaled layout to be produced from which the net productive manufacturing square footage can be determined.

TEAM: **FAC. ENG.**

SITUATION: **FACILITIES PLAN: EQUIPMENT REQUIREMENTS**

Sector	Operation	Tool Name	Tool Footprint (sq. ft.)
1	Inspection	Microscope on Work Bench	3 x 5
	Cleaning	In-Line Cleaner	4 x 38
	Screening	Single Screener	4 x 7
		Tandem Screener	6 x 7
	Drying	Small Oven	4 x 5
		Large Oven	10 x 5
	Test	Continuity Tester	5 x 5
2	Material	Automatic Transfer System[1]	Width 4 feet Length 5 or 10 units
	Assembly and Press	Assembly and Press Tool	4 x 7
	Sinter	Batch Sintering Oven (H_2)	10 x 5
		Continuous Sintering Furnace (H_2)	4 x 20
	Test	Continuity Tester	5 x 5
3	***Top Metal: Staple Process***		
	Sputtering	Sputtering Chamber	4 x 5
	Staple Assembly	Automatic Staple Tool	4 x 12
	Reflow	Reflow Furnace	4 x 20
	Test	Continuity Tester	5 x 5
	Top Metal: Thin Film Process		
	Sputtering	Sputtering Chamber	4 x 5
	Photo	Photoprocessing System	5 Stations each 4 x 10
	Glass Etch	Etch System	6 Stations each 4 x 7
	Evaporate	Continuous Evaporator	4 x 38
	Metal Etch	Etch System	6 Stations each 4 x 7
	Test	Continuity Tester	5 x 5
4	Flange Assembly	Assembly Work Bench	3 x 5
	Brazing	Brazing Furnace	4 x 20
5	Test	Electrical Test System	8 x 10

[1] Two systems available from the card panel line: one 5 ft. and one 10 ft. system. Capital cost for both was about $20,000.

Table III-8. Facilities Plan Equipment Requirements.

TEAM: **FAC. ENG.**

SITUATION: **FACILITIES PLAN: OFFICE REQUIREMENTS**

The MFG. SYS. ARCH. team is developing an organization plan which will indicate the number of employees. As a part of your facilities plan you should lay out the space required by people which should include, but not be limited to, office, break areas, aisles, etc.

The site standards for office space are as follows:

	Office Standard
Managers of Managers	12 x 12 sq. ft.
Managers of People	9 x 12 sq. ft.
Professionals (2/office)	9 x 12 sq. ft.
Technicians (4/office)	12 x 12 sq. ft.

Table III-9. Office Space Requirements by Category.

TEAM: **FAC. ENG.**

SITUATION: **FACILITIES PLAN: PLANT LAYOUT**

The multi-panel manufacturing line and the required support space must be contained within the existing card panel building. The present layout is illustrated in Figure III-7.

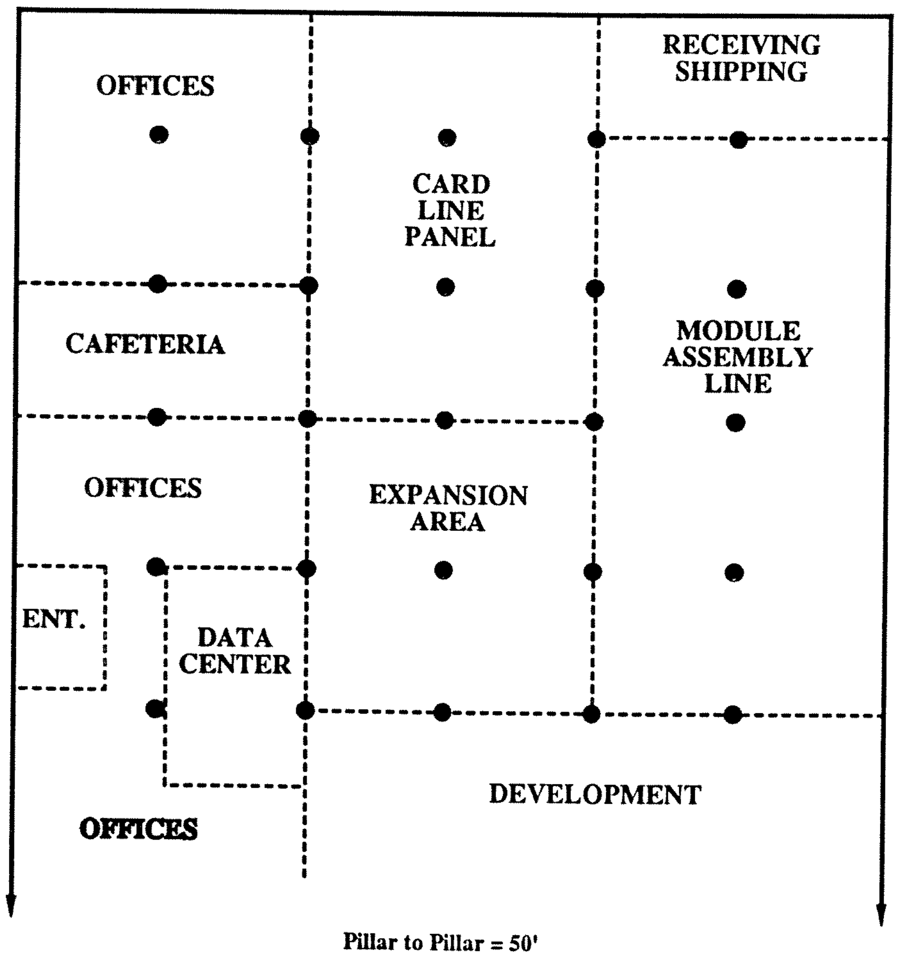


Figure III-7. Present Layout.

LINE LAYOUT

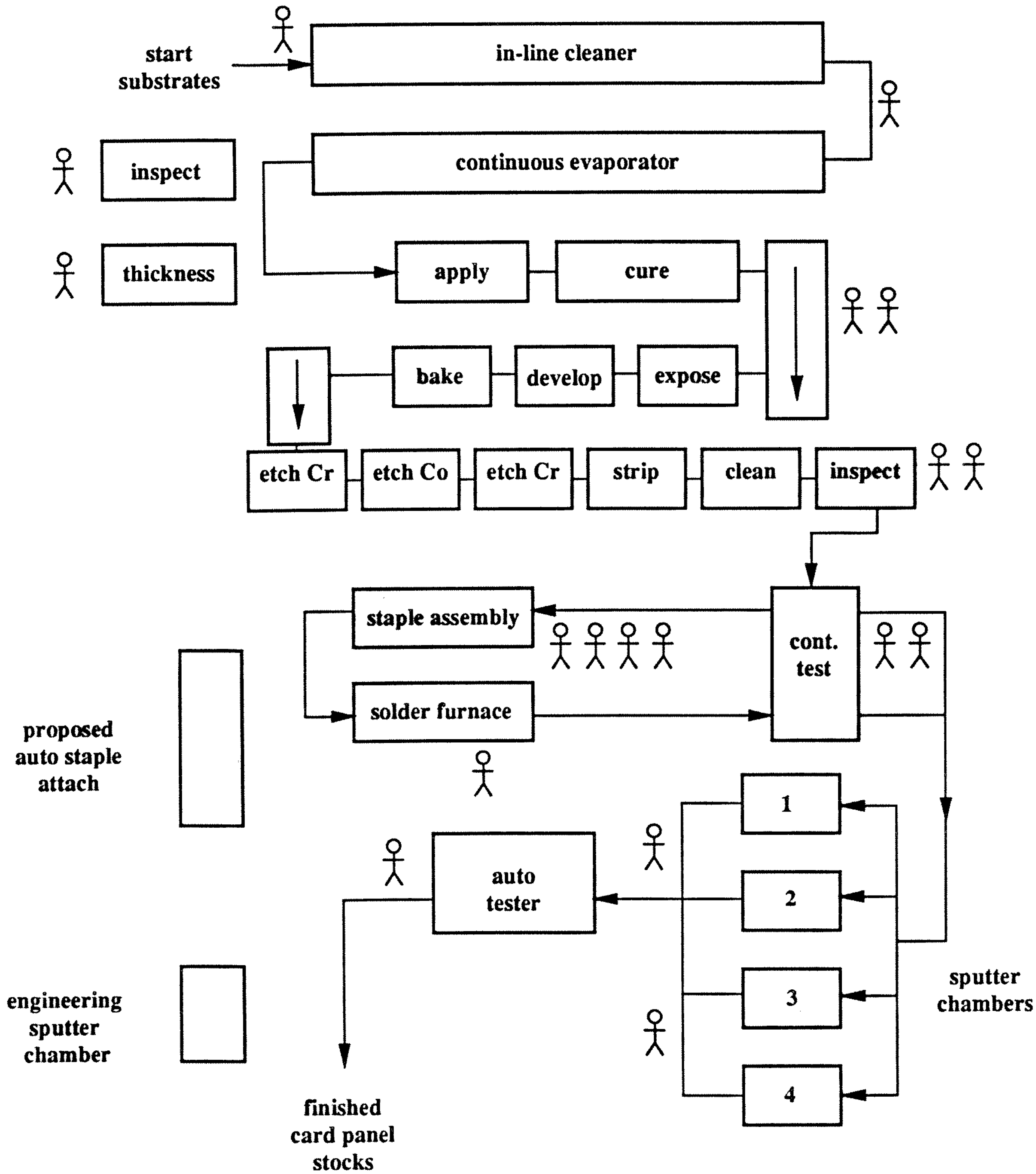


Figure III-8. Single Layer Card Line Layout.

General Plant Layout

Scale: 1 in. = 50 feet

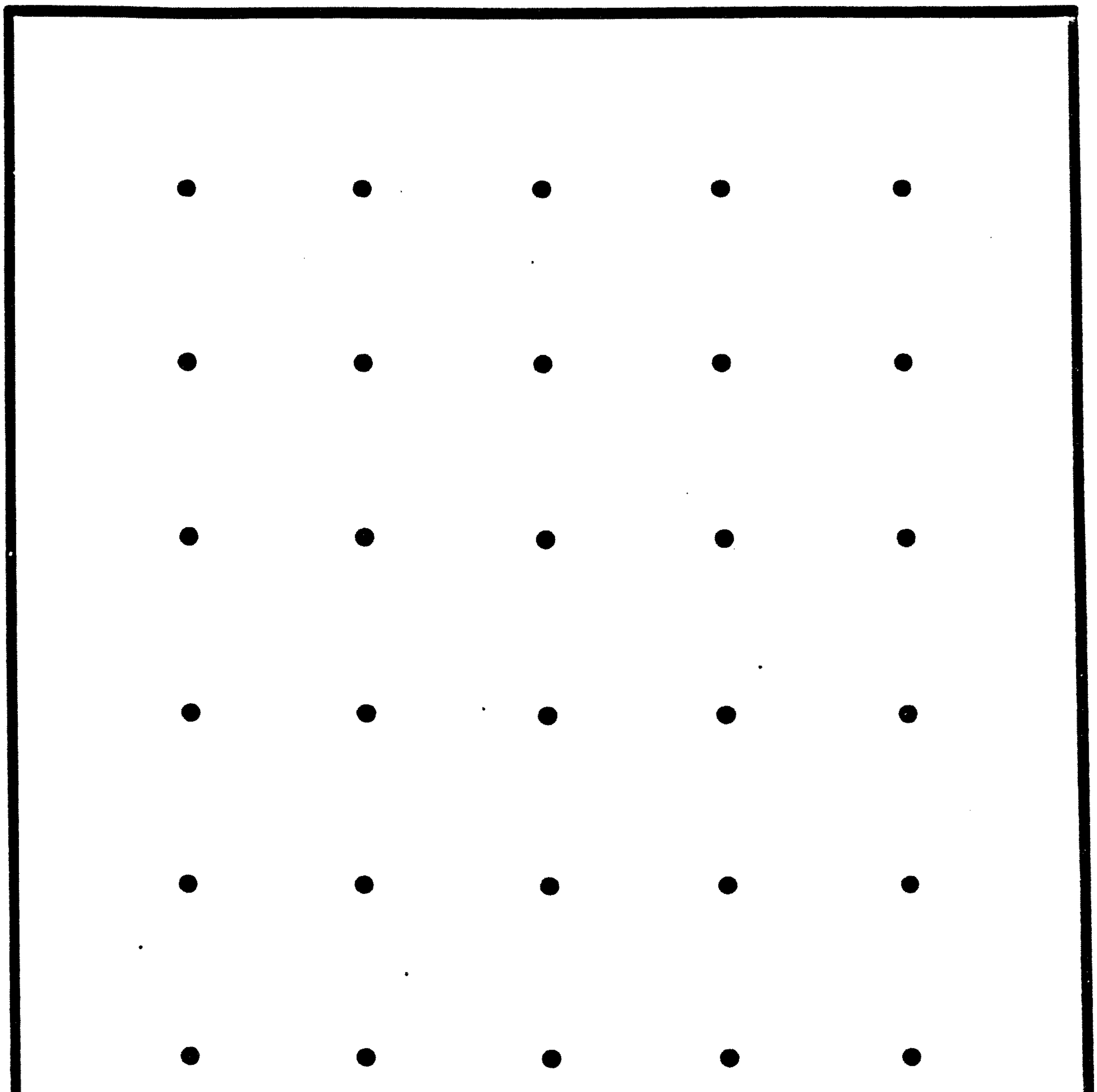


Figure III-9. Blank Layout Map for Plant.

Plant Layout Detail

Scale: 1 in. = 25 feet

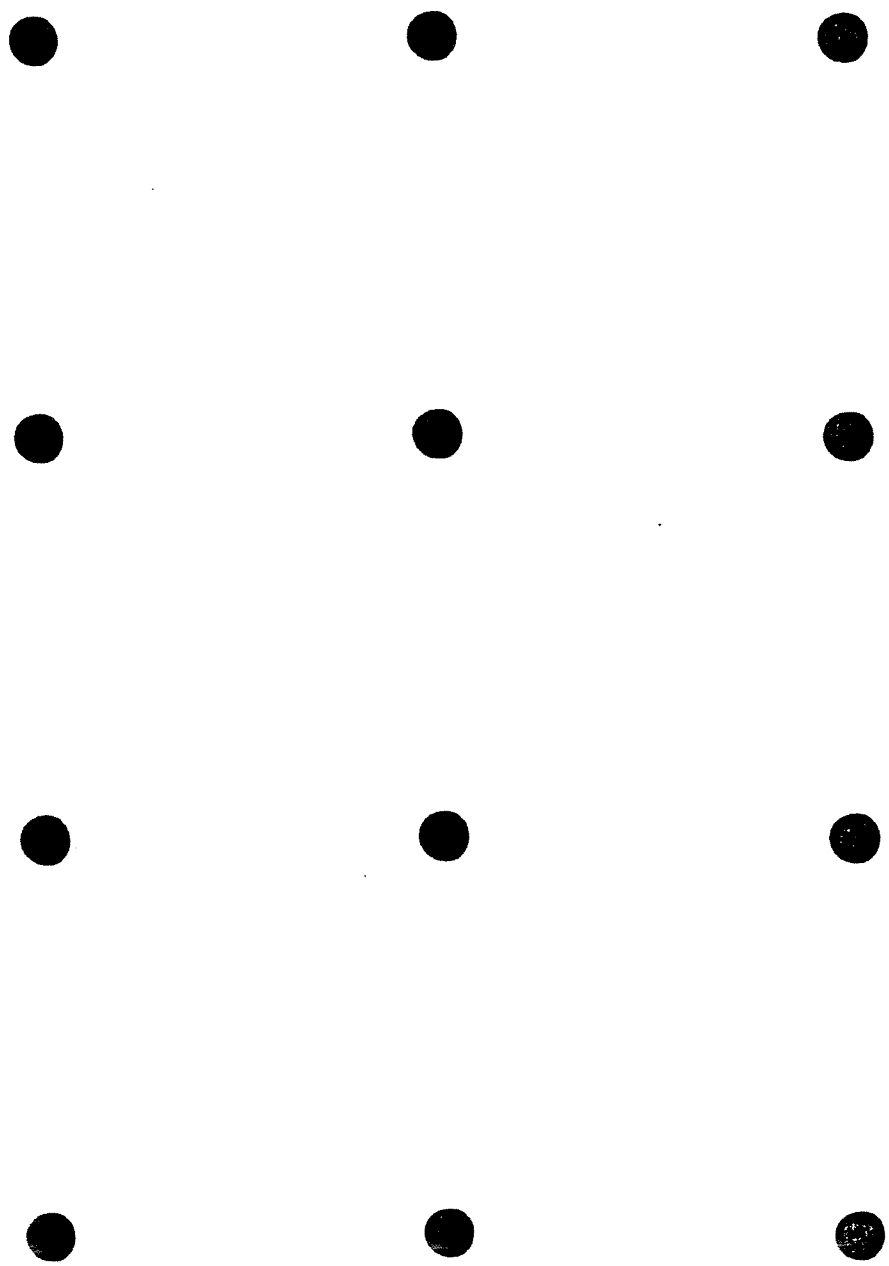


Figure III-10. Blank Layout Detail Map.

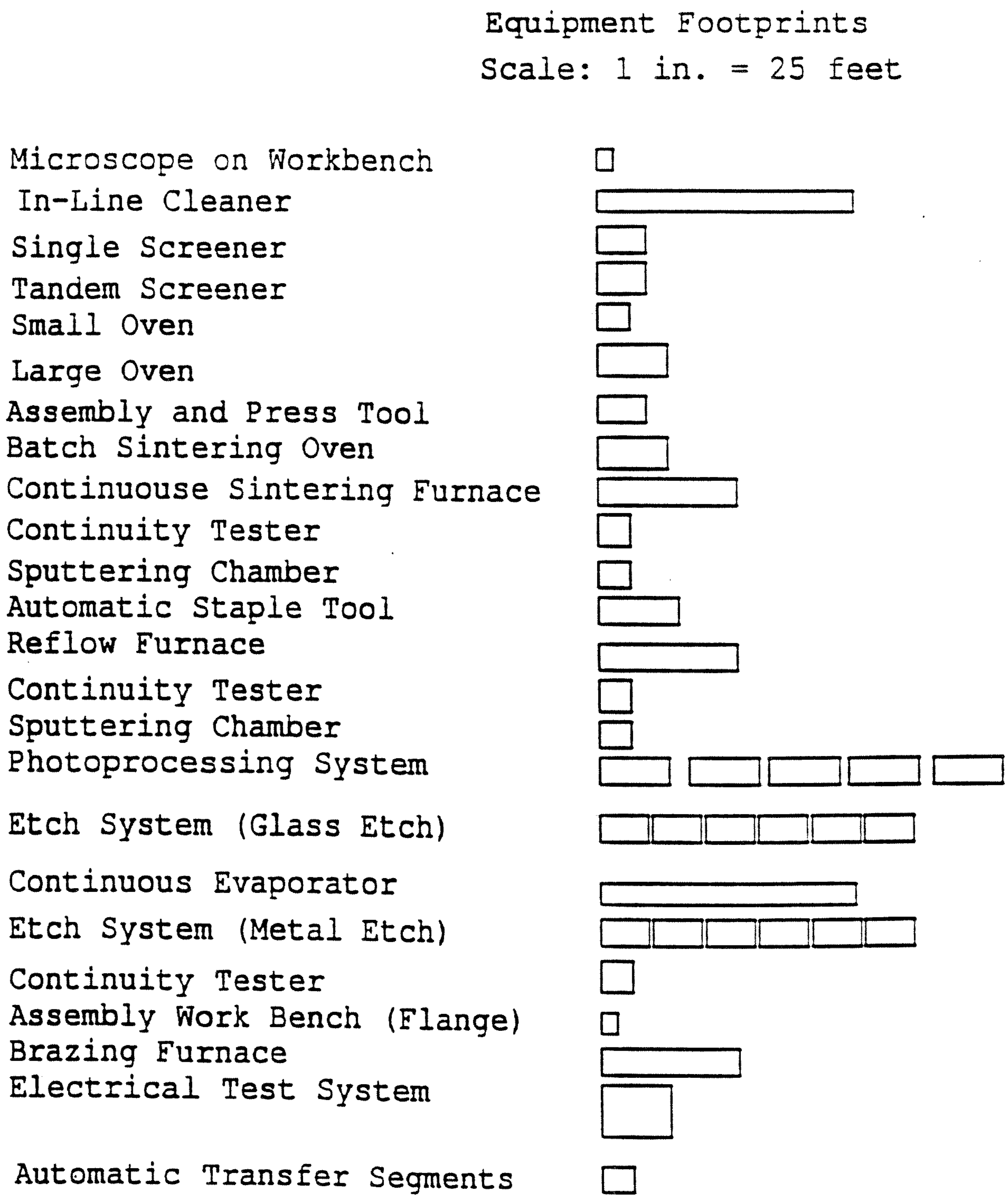


Figure III-11. Template for Layout.

III.G Industrial Engineering (IND. ENG.)

One of the responsibilities of the IND. ENG. team is to simulate the line flow to assess system performance. To do this the team should select calendar times that correspond to different conditions and simulate the activity in that period. The team must then analyze their line flow simulations to understand where capacities are underutilized with respect to the production schedule and the product cost estimate. Work-in-process inventory levels should also be analyzed. The central focus of the team is to estimate material cycle time in the line as a whole. This is believed to have a critical impact on product and process quality and is an important measure of responsiveness to customer demand. It is important that the IND. ENG. team provides feedback of their analysis to PROC. ENG., EQ. ENG., FAC. ENG., and other concerned teams for fine-tuning of their part of the multi-panel card manufacturing system plan. IND. ENG. should also analyze production run scheduling to determine desirable line scheduling objectives and feed results back to the concerned teams. The IND. ENG. team will use the Cycle Time Analysis LOTUS™ spreadsheet (CYCLE.WK1) described in the next section. The IND. ENG. team should use a line flow simluation package to analyze bottlenecks and buffer placement. IND. ENG. should develop a Gantt Chart schedule for planning production for various production requirements.

TEAM: **IND. ENG., EQ. ENG., M.S.A.**

SITUATION: **DIRECT LABOR PLANNING**

You have been given some information (Table III-10) from the EQ. ENG. group which indicates the amount of labor time involved in setting up and operating equipment. A spreadsheet has been developed which will enable you to plan the amount of direct labor required to support the program. It is incorporated in the BULLETIN.WK1 Technology Tool.

For your first pass when planning direct labor hours, you may make a rough estimate of the number of tools needed and the schedule on which they operate. When the tool plan is available, you can more accurately estimate direct labor requirements. Furthermore, while working with EQ. ENG. you can refine the estimates when the results of line flow simulations are known.

To determine set-up direct labor you can assume a set-up frequency which you may refine as you optimize production run size. Table III-10 lists labor requirements by tool.

Sector	Operation	Tool Name	Set-Up Time: Hrs.	Direct Labor Hrs. per Hr. of Operation
1	Inspection	Microscope	0	1.0
	Cleaning	In-Line Cleaner	0	0.2
	Screening	Single Screener	0.25	0.2
		Tandem Screener	0.4	0.3
	Sintering	Small Oven	0	0.1
		Large Oven	0	0.2
	Test	Continuity Tester	0	1.0
2	Assembly & Press	Assembly & Press Tool	0.1	0.2
	Sinter	Batch Sintering Oven	0.25	0.1
		Continuous Sintering Furnace	0	0.1
	Test	Continuity Tester	0	1.0
	Top Metal Staple Process:			
	Staple Assembly	Automatic Staple Tool	0.5	0.5
	Reflow	Reflow Furnace	0	0.1
	Sputtering	Sputtering Chamber	0	0.1
	Test	Continuity Tester	0	1.0
3	***Top Metal Thin-Film Process:***			
	Sputter	Sputtering Chamber	0	0.2
	Photo (Glass)	Photo Processor	0.1	0.2
	Glass Etch	Etcher	0.3	0.2
	Evaporate	Continuous Evaporation	0	0.2
	Photo (Metal)	Photo Processor	0.1	0.2
	Metal Etch	Etcher	0.3	0.2
	Test	Continuity Tester	0	1.0
4	Flange Assembly	Manual	0	1.0
	Brazing	Furnace	0	0.1
5	Test	Electrical Test System	0	0.4

Table III-12. Labor Information.

III.H Cost Engineering (COST ENG.)

First, the COST ENG. team should prepare an initial product cost estimate. It should be based on assumptions whenever input data are not yet available to develop a more accurate estimate. As more accurate information becomes available from other teams, COST ENG. must continually refine and update their product cost estimates. It should then relay these results to the concerned teams. Program cost analysis must also be performed. This analysis will include but will not be limited to: capital cost, inventory cost, and out-of-pocket costs. COST. ENG. also needs to determine an allocation scheme for some of the cost categories to allocate the costs to the different products in the program.

The Product Cost Planning LOTUS™ spreadsheet (COST.WK1) will be used by the COST ENG. team. For more information about this spreadsheet refer to the Technology Tool section.

III.I Information System Development (INFO. SYS. DEV.)

The responsibility of the INFO. SYS. DEV. team is to develop the manufacturing information system plan for the multi-panel line.

TEAM: **INFO. SYS. DEV.**

SITUATION: **MANUFACTURING INFORMATION SYSTEM PLAN REQUIREMENTS**

The primary activity of the multi-panel program focuses on the physical attributes of the manufacturing system. The manufacturing information system developed by this team is the basis for running the line. The information system must support the operating strategy developed by the MFG. SYS. ARCH. team. The approach to be used to develop this important plan is as follows:

- Work directly with the MFG. SYS. ARCH. in their development of the operating strategy.
- Work directly with each team to understand how they see the information needs of the functions they represent.
- Organize and analyze the requirements of the information system.
- Develop a plan for capturing key operating data and ensuring its accuracy.
- Develop a plan for users to have access to the data base.
- Develop report formats for those sets of information routinely required by the operating organization.

IV. TECHNOLOGY TOOLS

IV.A General Information

Several teams will use various PC-based software packages. Many of the tools are spreadsheets designed to reduce the burden of routine calculations. The following pages contain complete descriptions of each LOTUS™ spreadsheet. For the first few times you use a spreadsheet, it is recommended that you refer to this section to better understand the basis for each calculation. An important point to keep in mind is that the emphasis of the Game is not on the Technology tools themselves but on the challenge of developing a manufacturing system.

There are also several other optional software packages: XCELL©, DRAWPLUS©, and CATIA©. Refer to their User Manuals to learn more about them.

The following table lists each team that will use a Technology Tool in the Game.

Team	LOTUS Spreadsheets	Other Software Packages
M.S.A.	Bulletin	
Product Eng.		CATIA©
Process Eng.	Yield	
Logistics Eng.	Production Planning Materials Planning Vendor Selection Model	
Equipment Eng.	Equipment Planning	
Industrial Eng.		XCELL©
Cost Eng.	Product Cost Planning	
Facilities Eng.		DrawPlus©

Table IV-1. Software Packages.

TOOL: **LOTUS 1-2-3**

TEAMS: **LOG. ENG., EQ. ENG., IND. ENG., COST ENG.**

PURPOSE: **LOADING A 1-2-3 SPREADSHEET**

(**Note:** These directions are configuration dependent.)

(1) Put DOS diskette in "A" drive and turn machine on. Respond to date and time questions if you wish (otherwise, just hit <ret>).

(2) At the prompt A>, remove DOS diskette from "A" drive. Put 1-2-3 system diskette in "A" drive and the diskette with the tool spreadsheet in the "B" drive.

(3) Type lotus<ret>

(4) Use the left and right arrow keys to position the cursor at the 123 option. Hit <ret>.

(5) You should now have a blank spreadsheet displayed. Hit the following keys:

Key:	You Should See:
/ (accesses main menu)	
F(chooses file option)	worksheet...file...quit
D (chooses directory option)	retrieve save...directory
B: (select "B" drive)	

(6) Follow step 5 above, except type R for retrieve instead of D for directory. Use the left and right arrow keys to position the cursor at the name of the spreadsheet you want. Hit <ret>.

(7) You should now have the spreadsheet displayed on the screen. Use the arrow keys, <PgUp>, <PgDn>, and <Home> keys to position the cursor and to move to different screens.

TOOL: **LOTUS 1-2-3**

TEAMS: **LOG. ENG., EQ. ENG., IND. ENG., COST ENG., M.S.A.**

PURPOSE: **SPREADSHEET CONVENTIONS**

1. Most tables in the spreadsheets are labelled with a date and a revision number. Typically, you need only update the revision number of the first table in the spreadsheet and the rest of the tables are updated automatically. This feature is provided for your convenience, to coordinate your design activities. The M.S.A. team is responsible for instituting a standard that makes use of this feature.
2. Many of the tables in the spreadsheets are both wider and longer than the display screen. You can use the arrow keys, PgUp, PgDn, or the tab key to move the cursor to the desired position. The words "END OF SCREEN" will appear in the last column of each table.
3. Certain cells in each spreadsheet are protected: You are prevented from accidentally changing the value or formula in the cell. Other cells are unprotected. These show up as green highlighted numbers (color screen only). You are free to change these numbers. Typically, given data and formulas are protected; numbers that you are expected to change are unprotected. Spreadsheet protection is not seen as a guard against "cheating". An independent auditor will be employed to check for fraud. To turn off spreadsheet protection, type /wgpd.
4. In the large spreadsheets automatic recalculation has been turned off. Consequently, when you change a number the "CALC" reminder appears on the lower portion of the screen indicating that the spreadsheet needs to be recalculated to reflect the change. Hit function key F9 when you are ready to view the results of your changes. This permits you to make many changes before enduring the "WAIT" of recalculation.

TOOL: **LOTUS 1-2-3**

TEAMS: **LOG. ENG., EQ. ENG., IND. ENG., COST ENG.**

PURPOSE: **ELECTRONIC TRANSFER OF INFORMATION**

A considerable amount of information must be transferred between teams solving different aspects of the system development problem. Frequently, problems arise in the information transfer process because data are stored in different formats or quantities and are measured in different units. In the System Development Game, formats and units of measure have been standardized as much as possible. For example, time schedules are always presented with the same calendar (by quarter for years one and two and by year thereafter). Transfer of information is still tedious, however, if done manually. In those cases in which information must be transferred between spreadsheets, it is possible to perform the transfer electronically. This note explains the procedure for passing data from one Lotus spreadsheet to another. However, you do not need to read this note because the procedure has been completely automated with LOTUS macros. Those macros are described in the documentation for BULLETIN.WK1. Refer to this note only if you wish to by-pass the macros or to develop new spreadsheets.

By way of example, consider the problem of passing the table of daily throughput requirements from the Production Planning spreadsheet to the Product Cost Planning spreadsheet. The following instructions assume you have a two-disk system.

1) Place the Lotus disk in drive "A".

   Place the disk labelled Production Planning in drive "B".

2) Type a:<enter>, where <enter> is the enter key.

3) Type 123<enter>

4) Type /fdb:<enter>

5) Load the Production Planning Worksheet as follows:

   type /frtput.wk1<enter>

6) Page down until you are faced with the table entitled REQUIRED DAILY THROUGHPUT: SMP SUBTOTAL

7) Move the cursor to location C228, the beginning of the table

8) Give the table a name of your own choosing, e.g. tputsmp, as follows:

   type /rnctputsmp<enter>

   Now define the extent of the table by answering the "Enter range" prompt: move the cursor to N236 and hit <enter>. Note that we have included the build schedule in our definition of the table range.

9) Save the spreadsheet back to disk: type: /fs<enter>r

10) Remove the Production Planning disk and place the disk labelled Product Cost Planning in drive B.

11) Load the Product Cost Planning spreadsheet as follows:

    type /frcost.wk1<enter>

12) Turn off automatic recalculation: /wgrm

13) Page down until you are faced with the table entitled REQUIRED DAILY THROUGHPUT: SMP SUBTOTAL

14) Move the cursor to location D148, the beginning of the table. Note that the table has the same dimensions as the table in the Production Planning spreadsheet, including the location of the build schedule.

15) Remove the Product Cost disk and insert the Production Planning disk in B.

16) Copy the table from Production Planning spreadsheet to the active spreadsheet as follows: type /fccntputsmp<enter>tput.wk1<enter>

17) This should result in the table now appearing in protected mode (white characters). To unprotect the table, type /ru, move the cursor to O156, and hit <enter>. The table now appears in unprotected mode (yellow characters).

18) Convert the table from formulas to values:

    Position the cursor at D148, the beginning of the table. Type /rv. Now move the cursor to the end of the table, location O156, and hit <enter> twice. You may now hit F9, the CALC key, without fear of garbled answers.

19) Remove the Production Planning disk and insert the Product Cost Planning disk in drive B.

20) Save the updated cost spreadsheet as follows: type /fs<enter>r

There are many other examples of where you will need to transfer tables or portions of tables from one spreadsheet to another. The procedure in all cases is essentially the same. Make sure the table in the FROM spreadsheet has the same dimension (number of rows and columns) as the corresponding table in the TO spreadsheet. Assign a name to the table in the FROM spreadsheet and save the spreadsheet. Switch to the TO spreadsheet, turn off recalculation, and use the FILE COMBINE feature of LOTUS™ to bring in the desired table. Fix up the table by turning off protection and converting formulas to values. Finally, save the updated TO spreadsheet.

IV.B Production Planning

TOOL:	PRODUCTION PLANNING
TEAMS:	LOG. ENG.
PURPOSE:	TO DETERMINE THE THROUGHPUT RATES REQUIRED BY SECTOR TO MEET PRODUCT FORECAST
SPREADSHEET FORMAT:	SEE THE MAP ON THE FOLLOWING PAGE.
FILE NAME:	TPUT.WK1
INFORMATION FLOW:	YIELD DATA PROVIDED BY THE PROC. ENG. TEAM. THROUGHPUT DATA ARE REQUIRED BY THE EQ. ENG., LOG. ENG., IND. ENG., AND COST ENG. TEAMS.

	A-H	I-P	Q-X
41 60	Product Forecast		
61 80	Daily Build Rates		
81 100	Build Schedule		
101 120	Cumulative Production Plan		
121 140	Yield Plan: SMP		
141 160	Yield Plan: AMP		
161 180	Required Daily Throughput: MA		
181 200	Required Daily Throughput: MC		
201 220	Required Daily Throughput: MD		
221 240	Required Daily Throughput SMP: Total		
241 260	Required Daily Throughput: AMP		
261 280	Required Daily Throughput: Totals		

Figure IV-1. TPUT Spreadsheet Map.

TPUT.WK1, LINES 41-60

TABLE: Product Forecast

PURPOSE: To enter the forecasted demand schedules by year and by part type as input data for other calculations.

INPUTS: Forecasted annual demand rates for each part. This information is given.

OUTPUT: Subtotals of forecasted demand by year and by part across a five-year span.

REMARKS: There is a graph macro built in which allows you to view the product forecasts. Hit the "ALT" and "G" keys simultaneously and follow the menu at the top of the screen.

TPUT.WK1, LINES 61-80

TABLE: Daily Build Rates

PURPOSE: To enter the daily build rates by product for the period, given the product forecast.

INPUTS: The daily build rate by period for each part.

OUTPUT: Total daily build rates by period for both part groups.

EXAMPLE: Daily build rates are used to determine the build schedule (units/period).

Build schedule = daily build rate x days per period (units/period).

TPUT.WK1, LINES 81-100

TABLE: Build schedule: (units/period)

PURPOSE: To determine the number of units to be built in a period given the daily build rate and the number of days in that period.

INPUTS: None.

OUTPUT: The build schedule in units/period for each part in each time period.

EXAMPLE: Having the same daily build rate for quarters 1 and 2 in year 1 results in a different build schedule for these two quarters because the number of days per period is different.

REMARKS: You should be careful to note that there are not the same number of days per period. For instance, in year 1, quarter 1, there are only 57 days. For year 2, quarter 2, there are 63 working days.

TPUT.WK1, LINES 101-120

TABLE: Cumulative Production Plan

PURPOSE: To summarize the cumulative production, both forecast and plan.

INPUTS: None.

OUTPUT: The cumulative production, both forecast and plan, by year.

EXAMPLE: If the planned cumulative production is greater than the forecasted cumulative production in any year, the interpretation is that there will be a buildup of inventory in that year. If the plan is less than the forecast then we will draw down inventories.

REMARKS: You can view cumulative planned production versus forecasted demand with the graphing macro. Again, hit the "ALT" and "G" keys simultaneously to see the graph menu.

TPUT.WK1, LINES 121-160

TABLE: Yield Plan: SMP [AMP]

PURPOSE: To record the yield plan of good SMP [AMP] parts by sector.

INPUTS: The planned yield of SMP [AMP] for each sector in each time period. This information is provided by the PROC. ENG. Team.

OUTPUT: The overall yield for the production process, calculated as the product across all sectors of the planned yield for that time period.

EXAMPLE: Look at the column under year 1, quarter 1 for SMP. The screening process has a 89% yield, the panel assembly has a 86% yield, flange assembly has a 98% yield, and final testing has an 95% yield. Thus, the overall yield is 71% (0.89 x 0.86 x 0.98 x 0.95 = .71).

TPUT.WK1, LINES 161-220, 241-260

TABLE: Required Daily Throughput: MA [MC, MD, MF]

PURPOSE: To calculate the daily throughput requirements in each sector by part for each period.

INPUT: None.

OUTPUT: Required daily throughput (daily starts by sector). The daily throughput in sector 1 is multiplied by a factor of 3 because the assembly operation requires three substrates for each MPC.

EXAMPLE: Given the daily build rate of 290 units for MA and the following yields:

Screening	89%
Panel Assembly	86%
Flange Assembly	98%
Final Test	95%

The required starts into each sector are:

Screening	$1221 = \frac{362}{0.89} \times 3$
Panel Assembly	$362 = \frac{311}{0.86}$
Flange Assembly	$311 = \frac{305}{0.98}$
Final Test	$305 = \frac{290}{0.95}$

TPUT.WK1, LINES 221-240, 261-280

TABLE: Required Daily Throughput: SMP [AMP, Totals]

PURPOSE: To calculate the total daily throughput requirements by sector and period for the SMP or AMP sub-assemblies and the total throughput requirements.

INPUTS: None.

OUTPUT: Daily throughput rates for the SMP or AMP subassembly, or the total throughput rate.

EXAMPLE: The SMP subtotal is the sum of the MA + MC + MD requirements.

There is only one AMP part number. Consequently, the table for part number MF and the AMP subtotal is one and the same table.

The total required daily throughput is the sum of AMP + SMP requirements.

REMARKS: The graph macro allows you to view the required throughput by sector. Hit the "ALT" and "G" keys simultaneously to bring up the graph menu.

IV.C Materials Planning

TOOL:	MATERIALS PLANNING
TEAMS:	LOG. ENG.
PURPOSE:	TO DETERMINE THE TOTAL RAW MATERIAL REQUIREMENTS (VOLUME AND COST) OVER TIME
SPREADSHEET FORMAT:	SEE THE MAP ON THE FOLLOWING PAGE.
FILE NAME:	BOM.WK1
INFORMATION FLOW:	MATERIAL VOLUME REQUIREMENTS ARE NEEDED BY THE LOG. ENG. TEAM TO SOLVE THE VENDOR SELECTION PROBLEM. UNIT PRICES ARE THE RESULT OF THE SOLUTION TO THE VENDOR SELECTION PROBLEM. MATERIAL COST SUMMARIES ARE REQUIRED BY THE IND. ENG. TEAM TO DETERMINE ECONOMIC RUN SIZES.

	A-J	K-R	S-Z
41 60	BOM Direct Materials	Intermediate Calculations	
61 80	BOM Indirect Materials	Intermediate Calculations	
81 100	Summary By Sector		
101 120	Required Daily Throughput: SMP		
121 140	Required Daily Throughput: AMP		
141 160	Direct Materials Usage: Totals		
161 180	Indirect Materials Usage: Totals		
181 200	Direct Materials Cost by Sector (SMP)		
201 220	Indirect Materials Cost by Sector (SMP)		
221 240	Direct Materials Cost by Sector (AMP)		
241 260	Indirect Materials Cost by Sector (AMP)		

Figure IV-2. BOM Spreadsheet Map.

BOM.WK1, LINES 41-80

TABLE: Bill of Materials: Direct Materials [Indirect]

PURPOSE: To show where each material is needed, and the cost of each material per unit of SMP, AMP.

INPUTS: Price/Unit of Material.

The team decides what price to take based upon price/volume combinations provided. See vendor selection problem.

Qty/unit (AMP in Sector 3 only).

The quantity of material per unit is provided for each sector except for AMP in Sector 3. Refer to Table II-2 and discuss the issue with the Process Engineers. Input the data from Table II-2 corresponding to the staple or the thin film process decision.

OUTPUT: Cost of each material per unit of SMP, AMP.

This is determined by the (price/unit of material) x (quantity of material per unit of SMP (AMP)).

EXAMPLE: Glass is currently listed at a price of $24/lb. It is used in Sector 3.

No glass is used in SMP product. 0.0062 lbs. of glass are used per unit of AMP. Thus, the cost of glass per SMP is zero, and the cost of glass per AMP is $24 x .0062 = $0.149.

Verify that changing the price of glass to $20/lb. decreased the cost of glass per AMP from $0.149 to $0.124.

Note: After changing input values, you must hit the F9 key to recalculate the worksheet.

BOM.WK1, LINES 81-100

TABLE: Summary by Sector: $/unit

PURPOSE: To show the direct and indirect cost of materials per unit of SMP and AMP, by sector.

INPUTS: None.

OUTPUTS: The material costs per unit of SMP and AMP are summarized by sector based on the information provided in the Bill of Materials. No adjustment is made for yield. The IND. ENG. team will request unit material costs adjusted by yield. That is, they need to have an estimate of the total material cost incurred to make one good unit of SMP [AMP].

EXAMPLE: The direct material cost per unit of SMP for Sector 1 is the sum of the costs per unit of the material used in Sector 1.

BOM.WK1, LINES 101-140

TABLE: Required Daily Throughput: SMP Subtotal [AMP]

PURPOSE: To record the throughput required each day in each sector to meet the daily build schedule.

INPUTS: All daily throughput figures come from the production planning tool which is in the possession of LOG. ENG. team.

OUTPUT: None.

EXAMPLE: Consider quarter 1 of year 1 for SMP product:

4582 units in screening 1359 units in panel assembly 1169 units in flange assembly 1146 units in final test	must be started each day in order to meet the build schedule of 1088 units of SMP per day

BOM.WK1, LINES 141-180

TABLE: Direct [Indirect] Material Usage: Total by Material

PURPOSE: To show the raw material requirements needed by period in order to meet the daily build schedule.

INPUTS: None.

OUTPUTS: The columns summarize the raw material requirements for each period needed to produce the daily throughput required (SMP and AMP combined). These volumes, particularly the annual totals, are needed in solving the vendor selection problem.

EXAMPLE: The direct material usage of ceramic in year 1, quarter 1 is the SMP ceramic quantity per unit multiplied by the starts of SMP in year 1, quarter1 plus the AMP ceramic quantity per unit times the starts of AMP in year 1, quarter 1 scaled by the length of the period.

BOM.WK1, LINES 181-260

TABLE: Direct [Indirect] Material Cost: Total by Sector SMP [AMP]

PURPOSE: To display the material costs by sector and period such that the daily throughput requirements for each product are met.

INPUTS: None.

OUTPUT: The columns summarize the raw material costs for each period in order to produce the daily throughput required.

EXAMPLE: The total SMP Direct Material Cost for Sector 1 in year 1, quarter 1 is calculated as the required daily throughput of SMP in year 1, quarter 1 times the direct material cost per unit of SMP for Sector 1 scaled by the length of the time period.

IV.D Vendor Selection Model

TOOL:	**VENDOR SELECTION MODEL**
TEAMS:	**LOG. ENG.**
PURPOSE:	**TO AID IN THE SELECTION OF VENDORS TO SUPPLY MATERIALS WHILE SATISFYING THE COMPANY POLICY AND VENDOR-IMPOSED CONSTRAINTS.**
SPREADSHEET FORMAT:	**SEE THE MAP ON THE FOLLOWING PAGE.**

This tool consists of three spreadsheets, each covering a distinct group of vendors and materials.

File Name	**Vendors**	**Materials**
LP1.WK1	Bridge Chemical Candle Inc. Dandy Corp.	Paste Brazing Preforms Photoresist Glass Etchant
LP2.WK1	FABTECH Metal Might Python	Staples Glass Aluminum Flange
LP3.WK1	Moore Chemical Triple Jay Daylight, Inc.	Solder Flux Metal Etchant Cleaner Brazing Flux

For illustrative purposes, we will look at LP1.WK1.

	A-H	I-T	U-AF
41 60	Vendor and Product Parameters		
61 80	Team's Sourcing Decisions		
81 100	Feasibility Check: Team Decisions		
101 120	Optimized Sourcing Decisions		
121 140	Feasibility Check Optimal Decisions		
141 160 161 180 181 200	Mixed Integer Linear Programming Formulation		

Figure IV-3. LP1, LP2, LP3 Spreadsheet Map.

LP1.WK1, LP2.WK1, LP3.WK1, LINES 41-60

TABLE: Vendor and Product Parameters

Product Group A [B, C]

PURPOSE: To display the price and volume parameters for each material in Product Group A [B, C].

INPUTS: (1) Unit prices

(2) Minimum order size

The unit prices and minimum order sizes will change depending on the price breaks chosen.

(3) Volume required-the total units of each material required to satisfy the system's first year of operation. You will need to get this information from the materials planning tool.

OUTPUT: None

EXAMPLE: The maximum $ volume and maximum fraction of volume per vendor information are given, and are explained in the vendor selection task description.

LP1.WK1, LP2.WK1, LP3.WK1, LINES 61-80

TABLE: Decisions: Volume Sourced by Product by Vendor

PURPOSE: To allow the team to input a set of vendor sourcing decisions.

INPUTS: The units of each material you want to purchase from each vendor. Currently, these values are all set to zero.

OUTPUTS: (1) The dollar volume purchased from each vendor

(2) The total units of each material purchased.

This information will be used later to check the feasibility of the sourcing decisions you have made.

LP1.WK1, LP2.WK1, LP3.WK1, LINES 81-100

TABLE: Feasibility Check

PURPOSE: To show which constraints, if any, have been violated, based on the team's sourcing decisions.

INPUTS: None.

OUTPUTS: (1) Minimum order size check.

(2) Capacity check.

(3) Volume check.

(4) Maximum dependency check.

For each of these constraint types (see Vendor Selection Task Description), there are two possible values:

0 - the constraint is satisfied

ERR - the constraint is violated

At this point, there should be ERR messages in each of the volume check cells. This is because all of the sourcing decisions are initialized to zeros on the previous screen.

EXAMPLE: Go back to the sourcing decision screen [PgUp].

Change the sourced volume of preforms at Candle Inc. from 0 to 380,945 (thus satisfying the volume requirement).

Go to the feasibility check screen [PgDn].

First notice that the volume check constraint for preforms is now '0' instead of 'ERR'. Also, note that the decision to source all preforms has violated two other constraints:

<1> too much dollar dependency on Candle Inc.

<2> too high a fraction of preform volume is purchased from a single vendor.

LP1.WK1, LP2.WK1, LP3.WK1, LINES 101-120

TABLE: Mixed Integer Linear Program Solution

PURPOSE: To display one possible solution to the vendor sourcing problem, as calculated by a mixed integer linear program.

A mixed integer linear program has been set up to minimize the materials costs, subject to the company policy and vendor-imposed constraints.

To run the linear program, follow the instructions shown on this screen. (**Note:** These instructions are configuration dependent. See the MIP83 Manual or the instructors for help in running this optimization software if you have problems.)

The solution displayed on this screen has been generated by the integer program. The choice of whether or not to use this suggested solution is up to you.

INPUTS: None.

OUTPUTS: Sourcing decisions (generated by the integer program).

LP1.WK1, LP2.WK1, LP3.WK1, LINES 121-140

TABLE: Feasibility Check: Mixed Integer Linear Program Solution

PURPOSE: To show which constraints, if any, have been violated by the mixed integer linear program solution (see remarks below).

INPUTS: None.

OUTPUTS: The same as on the previous feasibility check screen.

REMARKS: Since this screen checks the feasibility of the mixed integer linear program solution, all values should be '0' (i.e. no violations) once the integer linear program has been run.

LP1.WK1, LP2.WK1, LP3.WK1, LINES 141-200

TABLE: Mixed Integer Linear Program Formulation

WARNING: **Do not change anything on these screens!**

Do not change any range names associated with this area of the spreadsheet.

IV.E Equipment Planning

TOOL:	EQUIPMENT PLANNING
TEAMS:	EQ. ENG.
PURPOSE:	TO ASSIST IN DETERMINING CAPACITY REQUIREMENTS AT THE OPERATION LEVEL SO THAT EACH SECTOR'S SCHEDULED THROUGHPUT REQUIREMENTS CAN BE ACHIEVED.
SPREADSHEET FORMAT:	FIVE SEPARATE SPREADSHEETS ARE REQUIRED TO DESCRIBE ALL THE OPERATIONS. SEE THE MAPS ON THE FOLLOWING PAGES. THE FIRST MAP IS THE SPREADSHEET LAYOUT FOR OPERATIONS IN SECTORS 1 AND 2. THE SECOND AND THIRD MAP IS THE SPREADSHEET LAYOUT FOR OPERATIONS IN SECTOR 3. THE FOURTH MAP IS THE SPREADSHEET LAYOUT FOR OPERATIONS IN SECTORS 4 AND 5.
FILE NAME:	TOOL1.WK1, TOOL2.WK1, TOOL3ST.WK1, TOOL3TF.WK1, TOOL4&5.WK1
INFORMATION FLOW:	YOU WILL NEED TO INTERACT WITH THE LOG. ENG. TEAM TO GET THE SECTOR THROUGHPUT REQUIREMENTS. RUN SIZE INFORMATION SHOULD BE OBTAINED FROM THE IND. ENG. TEAM, AND THEY SHOULD BE SUPPLIED WITH THE NUMBER OF TOOLS ON LINE AT EACH OPERATION. THE COST ENG. TEAM SHOULD BE SUPPLIED WITH THE DEPRECIATION SCHEDULE.

	A-I	J-T	U-Y
41 60	Sector 1 Operation 1 Tool Parameters		
61 80	Tool Acquisition	Tools on Line	Totals for Year
81 100	Operation Schedule		Totals for Year
101 120	Sector 1 Operation 2 Tool Parameters		
121 140	Tool Acquisition	Tools on Line	Totals for Year
141 160	Operation Schedule		Totals for Year
161 180	Sector 1 Operation 3 Alternative 1 Tool Parameters		
181 200	Tool Acquisition	Tools on Line	Totals for Year
201 220	Operation Schedule		Totals for Year
221 240	Sector 1 Operation 3 Alternative 2 Tool Parameters		
241 260	Tool Acquisition	Tools on Line	Totals for Year
261 280	Operation Schedule		Totals for Year
281 300	Sector 1 Operation 4 Alternative 1 Tool Parameters		
301 320	Tool Acquisition	Tools on Line	Totals for Year
321 340	Operation Schedule		Totals for Year
341 360	Sector 1 Operation 4 Alternative 2 Tool Parameters		
361 380	Tool Acquisition	Tools on Line	Totals for Year
381 400	Operation Schedule		Totals for Year
401 420	Sector 1 Operation 5 Tool Parameters		
421 440	Tool Acquisition	Tools on Line	Totals for Year
441 460	Operation Schedule		Totals for Year

461 480	Capacity Table Sector 1		
481 500	Depreciation Schedule Sector 1		

Figure IV-4. TOOL1 Spreadsheet Map.

	A-I	J-T	U-Y
41 60	Sector 2 Operation1 Tool Parameters		
61 80	Tool Acquisition	Tools on Line	Totals for Year
81 100	Operation Schedule		Totals for Year
101 120	Sector 2 Operation 2 Tool Parameters		
121 140	Tool Acquisition	Tools on Line	Totals for Year
141 160	Operation Schedule		Totals for Year
161 180	Sector 2 Operation 3 Alternative 1 Tool Parameters		
181 200	Tool Acquisition	Tools on Line	Totals for Year
201 220	Operation Schedule		Totals for Year
221 240	Sector 2 Operation 3 Alternative 2 Tool Parameters		
241 260	Tool Acquisition	Tools on Line	Totals for Year
261 280	Operation Schedule		Totals for Year
281 300	Sector 2 Operation 4 Tool Parameters		
301 320	Tool Acquisition	Tools on Line	Totals for Year
321 340	Operation Schedule		Totals for Year
341 360	Capacity Table Sector 2		
361 380	Depreciation Schedule Sector 2		

Figure IV-4. TOOL2 Spreadsheet Map.

	A-I	J-T	U-Y
41 60	Sector 3 (Staple) Operation 1 Tool Parameters		
61 80	Tool Acquisition	Tools on Line	Totals for Year
81 100	Operation Schedule		Totals for Year
101 120	Sector 3 (Staple) Operation 2 Tool Parameters		
121 140	Tool Acquisition	Tools on Line	Totals for Year
141 160	Operation Schedule		Totals for Year
161 180	Sector 3 (Staple) Operation 3 Alternative 1 Tool Parameters		
181 200	Tool Acquisition	Tools on Line	Totals for Year
201 220	Operation Schedule		Totals for Year
221 240	Sector 3 (Staple) Operation 3 Alternative 2 Tool Parameters		
241 260	Tool Acquisition	Tools on Line	Totals for Year
261 280	Operation Schedule		Totals for Year
281 300	Sector 3 (Staple) Operation 3 Alternative 3 Tool Parameters		
301 320	Tool Acquisition	Tools on Line	Totals for Year
321 340	Operation Schedule		Totals for Year
341 360	Sector 1 (Staple) Operation 4 Tool Parameters		
361 380	Tool Acquisition	Tools on Line	Totals for Year
381 400	Operation Schedule		Totals for Year

401 420	Capacity Table Sector 3 (Staple)		
421 440	Depreciation Schedule Sector 3 (Staple)		

Figure IV-5. TOOL3ST Spreadsheet Map.

	A-I	J-T	U-Y
41 60	Sector 3 (Thin Film) Operation 1 Alternative 1 Tool Parameters		
61 80	Tool Acquisition	Tools on Line	Totals for Year
81 100	Operation Schedule		Totals for Year
101 120	Sector 3 (Thin Film) Operation 1 Alternative 2 Tool Parameters		
121 140	Tool Acquisition	Tools on Line	Totals for Year
141 160	Operation Schedule		Totals for Year
161 180	Sector 3 (Thin Film) Operation 1 Alternative 3 Tool Parameters		
181 200	Tool Acquisition	Tools on Line	Totals for Year
201 220	Operation Schedule		Totals for Year
221 240	Sector 3 (Thin Film) Operation 2 Tool Parameters		
241 260	Tool Acquisition	Tools on Line	Totals for Year
261 280	Operation Schedule		Totals for Year
281 300	Sector 3 (Thin Film) Operation 3 Tool Parameters		
301 320	Tool Acquisition	Tools on Line	Totals for Year
321 340	Operation Schedule		Totals for Year
341 360	Sector 3 (Thin Film) Operation 4 Tool Parameters		
361 380	Tool Acquisition	Tools on Line	Totals for Year

381 400	Operation Schedule		Totals for Year
401 420	Sector 3 (Thin Film) Operation 5 Tool Parameters		
421 440	Tool Acquisition	Tools on Line	Totals for Year
441 460	Operation Schedule		Totals for Year
461 480	Sector 3 (Thin Film) Operation 6 Tool Parameters		
481 500	Tool Acquisition	Tools on Line	Totals for Year
501 520	Operation Schedule		Totals for Year
521 540	Sector 3 (Thin Film) Operation 7 Tool Parameters		
541 560	Tool Acquisition	Tools on Line	Totals for Year
561 580	Operation Schedule		Totals for Year
581 600	Capacity Table Sector 3 (Thin Film)		
601 620	Depreciation Schedule Sector 3 (Thin Film)		

Figure IV-6. TOOL3TF Spreadsheet Map.

	A-I	J-T	U-Y
41 60	Sector 4 Operation 1 Tool Parameters		
61 80	Tool Acquisition	Tools on Line	Totals for Year
81 100	Operation Schedule		Totals for Year
101 120	Sector 4 Operation 2 Tool Parameters		
121 140	Tool Acquisition	Tools on Line	Totals for Year
141 160	Operation Schedule		Totals for Year
161 180	Capacity Table Sector 4		
181 200	Sector 5 Operation 1 Tool Parameters		
201 220	Tool Acquisition	Tools on Line	Totals for Year
221 240	Operation Schedule		Totals for Year
241 260	Capacity Table Sector 5		
261 280	Depreciation Schedule Sectors 4 & 5		

Figure IV-7. TOOL4&5 Spreadsheet Map.

TOOL1.WK1,TOOL2.WK1, TOOL3ST.WK1, TOOL3TF.WK1, TOOL4&5.WK1

TABLE: Tool Design.

PURPOSE: To give general information about the different tools needed to run the line.

INPUTS: None.

OUTPUTS: The following data are given: Process time, process batch size, setup time, mean time to fail (MTTF) and mean time to repair a tool (MTTR).

EXAMPLE: The running rate is determined by dividing the process batch by the process time.

TOOL1.WK1, TOOL2.WK1, TOOL3ST.WK1, TOOL3TF.WK1, TOOL4&5.WK1

TABLE: Tool Plan (Sector, Operation, Alternative).

Tool Acquisition, Tools on Line.

PURPOSE: To describe characteristics of tool type and to record when each tool will go on-line.

INPUTS: The number of the month when a tool is needed on-line (maximum number of tools per type is five) setting "need on line by" to 99 is equivalent to saying the tool is not needed.

The following data are given: Time and cost to design and debug a tool, tool order lead time, and purchase cost. These data correspond to those found in the tables in equipment cost and performance.

OUTPUTS: Gives the tools on-line and tool operations schedule for this tool plan. (See appropriate titles section.)

Computes delivery-by and order-by times for each purchased tool accounting for the lead times needed to design and debug and to order and receive a tool.

EXAMPLE: Presently, we have two microscopes at the visual inspection station in sector 1. Suppose capacity constraints require us to add another microscope in month 18. Change the "need on line by" value for micro #3 to 18. Hit the F9 (calc) key to update the sheet. We now have a third machine added to the operation in month 18. (To see how the tools on-line and tool operations schedule were changed, see the tools on line table, described below.)

Special Cases Involving Tool Plans

ALTERNATIVES: When an operation has one or more alternative tools, the EQ. ENG. team has the option of using any combination of the alternative tools.

EXAMPLE: Sector 1, Operation 3 has two screening tool alternatives. If at some point in time another screener is needed, the EQ. ENG. team has the option of which type to add regardless of past acquisitions. Remember, however, five tools is the maximum amount for any tool type.

SECTOR 3: STAPLE VS. THIN FILM: At some point, the decision regarding top metal application must be made. Once made, the tool plan for the rejected processing sequence is unnecessary and no tools for that process need to be acquired. Notice, however, that both staple and thin film require sputtering chambers for the dielectric operation. If at present the staple process is implemented and we wish to change to the thin film process, we do not want to purchase new sputtering chambers. Simply transfer the tools from one tool plan to the other. Check other similar operations to see where tool replacements can be performed.

TOOL1.WK1, TOOL2.WK1, TOOL3ST.WK1, TOOL3TF.WK1, TOOL4&5.WK1

TABLE: Tool Operation Schedule

PURPOSE: To show the accumulation of tools through time; to show the effects that this accumulation has on the nominal capacity and the capital cost schedules.

INPUTS: The number of shifts per day and the average run size (determined by IND. ENG.).

OUTPUTS: Hours per day:

Calculated as 8 if the number of shifts per day is 1, calculated as 16 if the number of shifts per day is 2, and 22.5 if the number of shifts is 3.

Tool availability per day:

Calculated as hours per day multiplied by the availability which is $\frac{MTTF}{MTTF + MTTR}$.

Setups/day:

Calculated as run rate times tool availability per day divided by average run size.

Nominal Capacity:

Calculated as run rate times tool availability per day less the product of setups per day and setup time.

Nominal Capacity Schedule:

Calculated as the total number of tools on line times the nominal capacity per tool.

Capital Cost Schedule:

Calculated as the total cost (purchase plus design and debug) of all tools brought on line in that period.

EXAMPLE: (continued from Tool Plan) By adding a third microscope in the 18th month, we should have increased our capacity for that month. Follow the calendar to the right until the 18th month is reached (use the tab key). Notice that the 18th month falls in the second quarter of the second year, corresponding to when the tool's implementation begins. There are now three tools on line (W78), capacity has increased (P98), and a cost is incurred (P100). It is important to note that if a tool is requested at a time greater than 60 months, then it will not register and will not be implemented.

REMARKS: Capacity is grossly determined by the number of tools on line and the number of shifts. For operations with setup time, capacity can be fine-tuned by setting appropriate production run lengths (the longer the run, the less time spent in setup). Capacity can be further adjusted by planning for overtime (not considered in this spreadsheet). The EQ. ENG. team must work closely with the IND. ENG. team to determine capacity.

TOOL1.WK1, TOOL2.WK1, TOOL3ST.WK1, TOOL3TF.WK1, TOOL4&5.WK1

TABLE: Capacity Table (Sector)

PURPOSE: To reveal bottlenecks within a sector and to compare throughput requirements with the capacity over time.

INPUTS: Throughput requirements from LOG. ENG. team.

OUTPUTS: The capacity of a sector is the minimum nominal capacity across all operations in the sector.

REMARKS: There is a graphing macro built in to display visually the sector capacity vs. the throughput requirements. Simply hold down the "ALT" key, hit the "G" key and follow the menu at the top of the screen.

TOOL1.WK1, TOOL2.WK1, TOOL3ST.WK1, TOOL3TF.WK1, TOOL4&5.WK1

TABLE: Depreciation Schedule

PURPOSE: To show the depreciation schedule of the tools on line.

INPUTS: Depreciation method, either 1 for straight line or 2 for double declining.

OUTPUTS: Tools will be depreciated, starting at the time the tool is acquired, according to the selected depreciation method. The resulting schedule is found to the right of the tool name screen.

IV.F Cycle Time Analysis

TOOL:	CYCLE TIME ANALYSIS
TEAMS:	IND. ENG.
PURPOSE:	TO RECORD A PLAN FOR CYCLE TIME IMPROVEMENT. ALSO, PROVIDES A CALCULATOR TO DETERMINE PROCESS TIMES BY JOB FOR USE IN DEVELOPING A GANTT CHART OF MATERIAL FLOW.
SPREADSHEET FORMAT:	SEE THE MAP ON THE FOLLOWING PAGE.
FILE NAME:	CYCLE.WK1
INFORMATION FLOW:	THE CYCLE TIME SCHEDULE IS AN INPUT TO THE OVERALL SCORECARD; IT IS ALSO USED BY THE PROC. ENG. TEAM TO PLAN YIELD IMPROVEMENTS.

	A-H	I-P	Q-X
41 60	Process Times by Tool		
61 80	Process Times by Sector		
81 100	Manufacturing Cycle Efficiency Plan		
101 120	Cycle Time Plan		
121 160	Process Times by Tool (Detailed)		
161 180	Yielded Run Sizes		
181 220	Run Times by Tool and Job type		

Figure IV-8. CYCLE Spreadsheet Map.

CYCLE.WK1, LINES 41-60

TABLE: Process Times by Tool

PURPOSE: To record approximate process times for each possible tool.

INPUTS: None.

OUTPUTS: None.

CYCLE.WK1, LINES 61-80

TABLE: Process Times by Sector

PURPOSE: To compute ideal process times by sector.

INPUTS: None.

OUTPUTS: The process time by sector is simply the sum of the raw process times at the individual tools within the sector. No allowance is made for machine breakdown, for machine setup, for job run sizes, or for job queueing between stations. If there are choices of tools, the fastest process is selected for the purpose of this calculation only, regardless of the actual selection made by the EQUIP. ENG. team. Thus, these process times are ideal and serve as a goal or target for cycle time improvement.

CYCLE.WK1, LINES 81-100

TABLE: Manufacturing Cycle Efficiency Plan

PURPOSE: To record a plan for manufacturing cycle efficiency improvement.

INPUTS: Manufacturing cycle efficiency factors by product family and by time period. This plan is the responsibility of the IND. ENG. team. Manufacturing cycle efficiency is defined to be the ratio of raw process time to the total cycle time (all queue time plus process time).

OUTPUTS: None.

CYCLE.WK1, LINES 101-120

TABLE: Cycle Time Plan

PURPOSE: To compute the planned cycle times implied by the Manufacturing Cycle Efficiency Plan.

INPUTS: None.

OUTPUTS: The planned cycle times are the ratio of the total process time (computed by summing across sectors in the process time by sector table) to the planned manufacturing cycle efficiencies. This table is used by the PROC. ENG. team to estimate yield improvements. It is also used as one of the central inputs to the scorecard.

CYCLE.WK1, LINES 121-160

TABLE: Process Times by Tool

PURPOSE: To record detailed process times by tool for estimating job run times. Tools are identified by their process number. For each tool, the run rate, the setup time and the batch time are listed. Batch time is used for those operations that are cook operations: the time is independent of the number of units in the batch.

INPUTS: None.

OUTPUTS: Process time is the inverse of the run rate. It is a process time per unit. Cook operations have no process time.

CYCLE.WK1, LINES 161-180

TABLE: Yielded Run Sizes

PURPOSE: To compute estimates of run sizes by sector.

INPUTS: Sample yields and initial run sizes. The sample yields can be determined after discussion with the PROC. ENG. team. You need to decide what period in the planning horizon you are modelling. The initial run sizes are the run sizes that would be used in sector 1 of the process. Note that you would release jobs according to a cyclic schedule. For example, the initial run sizes that are currently listed correspond to a cyclic schedule in which **two** jobs each of power and fan layers are released for each set of jobs of MA, MC, MD, and MF. Hence the release schedule would be PWR, FAN, MA, MC, PWR, FAN, MD, MF, repeated as many times as necessary to meet throughput requirements. You are free to design a different release schedule and different run sizes.

OUTPUTS: With yield losses, average run sizes will decrease from one sector to the next. Accordingly, this table computes the yielded run sizes by multiplying the initial run size by the cumulative sample yields.

CYCLE.WK1, LINES 181-220

TABLE: Run Times by Tool and Job Type

PURPOSE: To compute job run times at different tools for each part type

INPUTS: None.

OUTPUTS: The run time for a job at a tool is given by the product of the yielded run size for that job type with the process time per unit for that tool plus the setup time. In the case of cook operations, the run time is simply the batch time, independent of the number of units in the job. These run times can be used to lay out a Gantt Chart schedule of the flow of jobs through the system. From this Gantt Chart, it is possible to get rough estimates of cycle time performance.

IV.G Product Cost Planning

TOOL:	PRODUCT COST PLANNING
TEAMS:	COST ENG.
PURPOSE:	TO CALCULATE TOTAL PROGRAM COST AND UNIT PRODUCT COST.
SPREADSHEET FORMAT:	SEE THE MAP ON THE FOLLOWING PAGE.
FILE NAME:	COST.WK1
INFORMATION FLOW:	MATERIAL COST FROM LOG. ENG. TEAM. DIRECT LABOR HEAD COUNT AND OVERTIME FROM IND. ENG. THROUGHPUT FROM LOG. ENG. TEAM. DEPRECIATION FROM EQ. ENG. TEAM. SPACE FROM FAC. ENG. TEAM. MANUFACTURING ENGINEERING HEAD COUNT FROM PROC. ENG. INDIRECT LABOR HEAD COUNT FROM M.S.A. TEAM.

	A-H	I-P	Q-X
41 60	Direct Material Schedule		
61 80	Indirect Material Schedule		
81 100	Supplies Schedule		
101 120	Direct Labor: Head Count		
121 140	Overtime (%)		
141 160	Daily Throughput SMP Subtotal		
161 180	Daily Throughput AMP Subtotal		
181 200	Direct Labor Total Direct		
201 220	Direct Labor Overtime		
221 240	Direct Labor Allocation: SMP		
241 260	Direct Labor Allocation : AMP		
261 280	Indirect Labor Head Count		
281 300	Indirect Labor Allocation: SMP & AMP		
301 320	Depreciation Schedule		
321 340	Space Report		
341 360	Site Overhead		
361 380	4th Element (Mfg. Eng.)		
381 400	Cost Summary: Total		
401 420	Cost Summary SMP		
421 440	Cost Summary AMP		

Figure IV-9. COST Spreadsheet Map.

COST.WK1, LINES 41-60

TABLE: Direct Material Schedule

PURPOSE: To record direct material cost summary

INPUTS: Total direct material cost by time period for SMP and AMP. This information comes from the LOG. ENG. team.

OUTPUTS: Total direct material cost.

COST.WK1, LINES 61-80

TABLE: Indirect Material Schedule,

PURPOSE: To record indirect material cost summary.

INPUTS: Total indirect material cost by time period for SMP and AMP. This information comes from the LOG. ENG. team.

OUTPUTS: Total indirect material cost.

COST.WK1, LINES 81-100

TABLE: Supplies Schedule

PURPOSE: To record supplies cost summary.

INPUTS: None. The supplies factor is a given.

OUTPUTS: The supplies expense is figured as a given percentage (the supplies factor) of direct materials taken from the Direct Material Schedule.

COST.WK1, LINES 101-120

TABLE: Direct Labor: Head Count

PURPOSE: To record the direct labor head count schedule by sector.

INPUTS: The number of direct labor employees by sector by time period. This information is provided by the M.S.A. Check to ensure that this information is consistent with whatever shift assumptions the EQ. ENG. team has made. That is, if they are planning two-shift operation of the line in a given period, they should report twice as many direct labor employees as they would for single shift operation. Three-shift operation means three times as many direct employees.

The labor rates are given. The wage and salary escalation schedule is also given.

OUTPUTS: Total direct labor head count by time period.

COST.WK1, LINES 121-140

TABLE: Overtime (%)

PURPOSE: To record the overtime schedule by sector.

INPUTS: The percentage overtime by sector by time period. This information is provided by the IND. ENG. team.

OUTPUTS: None.

COST.WK1, LINES 141-180

TABLE: Daily Throughput: SMP [AMP]

PURPOSE: To record the daily throughput schedules by sector and product group.

INPUTS: The daily throughput by sector by time period and the build schedule for SMP and for AMP. This information is provided by the LOG. ENG. team.

OUTPUTS: None.

COST.WK1, LINES 181-200

TABLE: Direct Labor: Total Direct Labor

PURPOSE: To compute total direct labor costs.

INPUTS: None. The utilization ratio is a given.

OUTPUTS: The direct labor cost for a particular sector in a particular time period is computed as the direct labor head count for that sector in that period, multiplied by the utilization ratio, multiplied by the labor rate for that sector, scaled by the length of the time period, multiplied by the wage escalation factor for that time period.

REMARKS: The utilization ratio is an acknowledgement that a portion of every direct labor employee's time is spent in activities not directly related to production.

COST.WK1, LINES 201-220

TABLE: Direct Labor: Overtime

PURPOSE: To compute the time portion of direct labor overtime.

INPUTS: None.

OUTPUTS: The "time" portion of "time-and-a-half" overtime is computed as the total direct labor cost from the previous table multiplied by the percentage of overtime for that sector in that period.

COST.WK1, LINES 221-260

TABLE: Direct Labor: SMP [AMP]

PURPOSE: To allocate direct labor costs to the product groups.

INPUTS: None.

OUTPUTS: Direct labor cost, including the "time" portion of overtime, is split between SMP and AMP sector by sector, time period by time period, based on the relative sizes of the total daily throughput rates for each product group in that sector and time period.

COST.WK1, LINES 261-280

TABLE: Indirect Labor: Head Count

PURPOSE: To record the indirect labor head count schedule.

INPUTS: The number of manufacturing managers and line technicians by time period. This information is provided by the M.S.A. team. The salaries for the two categories are given.

OUTPUTS: Total indirect head count by time period.

COST.WK1, LINES 281-300

TABLE: Indirect Labor: SMP & AMP

PURPOSE: To compute total indirect labor costs and to allocate these costs to the different product groups.

INPUTS: None.

OUTPUTS: ***Directs Doing Indirect:*** Calculated as total direct labor across all sectors for that time period (excluding overtime) divided by the utilization ratio and multiplied by (1 minus the utilization ratio).

Overtime: (the "half" portion of "time-and-a-half") Calculated as 0.5 of total overtime cost across all sectors for that time period.

Indirects: Calculated as the sum across indirect labor categories (mfg. managers and line technicians) of the head count for that category, in that time period, multiplied by the labor rate for that category, scaled by the length of the time period, and multiplied by the salary escalation factor for that time period.

Total: Total indirect labor costs by time period.

SMP [AMP]: Total indirect labor costs by time period allocated to the two product groups based on the relative sizes of the build schedules for that time period.

COST.WK1, LINES 301-320

TABLE: Depreciation Schedule

PURPOSE: To record the total depreciation schedule by sector.

INPUTS: The total depreciation on equipment by sector, by time period. This information is provided by the EQ. ENG. team.

OUTPUTS: Total depreciation by time period.

COST.WK1, LINES 321-340

TABLE: Space Report

PURPOSE: To compute the space charges for the manufacturing floor.

INPUTS: The number of productive square feet for the manufacturing floor. This information is provided by the FAC. ENG. team. The general occupancy costs, total net productive space, and general occupancy rate for the factory are given. The site overhead item is that portion of general site overhead allocated based on the head count in Maintenance and Facilities Engineering.

The general occupancy rate is the occupancy costs divided by the net productive space.

OUTPUTS: ***Program Occupancy Cost:*** Calculated as program space multiplied by the general occupancy rate.

Program Occupancy Schedule: Calculated as program occupancy cost times the period length.

COST.WK1, LINES 341-360

TABLE: Site Overhead

PURPOSE: To compute the site overhead charge for the program.

INPUTS: None. The site overhead rate is given.

OUTPUTS: ***Total Site Overhead:*** Calculated as the total manufacturing head count (directs plus indirects) multiplied by the site overhead rate, scaled by the length of the time period.

REMARKS: General site overhead is allocated by head count. It shows up in the **Space Report**, this report, and in the **4th Element** report.

COST.WK1, LINES 361-380

TABLE: 4th Element

PURPOSE: To record the manufacturing engineering head count and to compute total 4th element costs.

INPUTS: The number of managers, professionals and technicians by time period. This information is provided by the M.S.A. team. Salaries by category are given.

The overhead rate is given. It includes site overhead as well as special services.

The occupancy rate is given. See the Space Report for its derivation.

Office space which is that portion of the floor plan not related to production (offices and laboratories) provided by the FAC. ENG. team.

OUTPUTS: ***Total Head Count:*** The sum of the head counts by category.

Total Salaries: Calculated as the sum over salary categories of the head count in that category in that time period, multiplied by the salary for that category in that time period, multiplied by the salary escalation factor for that time period, scaled by the length of the time period.

Total Overhead: Calculated as the total 4th element head count in that period multiplied by the overhead rate and scaled by the length of the period.

Occupancy Cost: Calculated as the office space multiplied by the occupancy rate and scaled by the length of the period.

COST.WK1, LINES 381-400

TABLE: Cost Summary: Total

PURPOSE: To present a program cost summary by cost category by time period and to compute total program cost and unit product cost.

INPUTS: None.

OUTPUTS: Total costs by major cost category by time period.

Annual totals and program totals.

Direct Materials: Total direct material cost per time period for SMP & AMP. This information comes from the LOG. ENG. team.

Direct Labor: Total direct labor cost across all sectors.

Indirect Labor: Sum of indirect labor for SMP and AMP (direct doing indirect plus overtime plus indirects).

Depreciation: The total depreciation on equipment across all sectors by time period. This information is provided by the EQ. ENG. team.

Space: The program occupancy schedule (calculated as program occupancy cost times the period length).

Site Overhead: Total site overhead (calculated as the total manufacturing head count 'direct plus indirects' multiplied by the site overhead rate, scaled by the length of the time period).

4th Element: Total salaries plus total overhead plus occupancy cost.

(SMP daily throughput plus AMP daily throughput) multiplied by the days per period.

Unit Product Cost: Calculated as total cost divided by the length of the period and divided by the daily build schedule.

COST.WK1, LINES 401-440

TABLE: **Cost Summary: SMP [AMP]**

PURPOSE: To allocate program costs to the different product groups and compute unit product costs.

INPUTS: None.

OUTPUTS: Same as for **Cost Summary: Total**.

REMARKS: These tables are not completely programmed. Allocation of 1st and 2nd element costs (direct materials, direct labor, indirect materials, indirect labor) has already been described. The remaining cost categories have no pre-determined allocation technique. It is the responsibility of the COST ENG. team to decide upon an allocation technique for each of these categories and to program the calculations into this spreadsheet.

IV.H Yield Plan Model

TOOL: YIELD PLAN MODEL

TEAM: PROCESS ENGINEERING

PURPOSE: TO GENERATE A YIELD PLAN BASED ON A LEARNING CURVE MODEL AND TO DETERMINE M.E. HEADCOUNT.

SPREADSHEET FORMAT: SEE THE MAP ON THE FOLLOWING PAGE.

FILE NAME: YIELD.WK1

INFORMATION FLOW: THE BUILD SCHEDULE IS PROVIDED BY LOG. ENG. THE PLANNED CYCLE TIME IS PROVIDED BY IND. ENG. ONCE A YIELD PLAN IS DEVELOPED, YIELD INFORMATION MUST BE GIVEN TO LOG ENG. AND M.E. HEADCOUNT MUST BE GIVEN TO THE M.S.A.

	A-H	I-N	O-U
21 40	Estimated Initial Yields		
41 60	Manufacturing Engineering Headcount		
61 80	Weighting Factor Selection		
101 120	Build Schedule (Throughput Driven)		
121 140	Yield Plan: SMP (Throughput Driven)		
141 160	Yield Plan: AMP (Throughput Driven)		
161 180	Model Parameters (Throughput Driven)		
221 240	Estimated Initial Yields (Repeated)		
241 260	Cycle Time Performance		
261 280	Planned Cycle Counts		
281 300	Manufacturing Engineering Headcount (Repeated)		
301 320	Model Parameters (Cycle Time Driven)		
321 340	Yield Plan: SMP (Cycle Time Driven)		
341 360	Yield Plan: AMP Cycle Time Driven		
361 380	Yield Plan: SMP (Weighted Average)		
381 400	Yield Plan: AMP (Weighted Average)		

Figure IV-10. YIELD Spreadsheet Map.

YIELD.WK1, LINES 21-40, 221-240

TABLE: Estimated Initial Yields by Sector

PURPOSE: To guide the initial yield estimates.

INPUTS: Initial yields decided on by PROC. ENG.

OUTPUTS: None.

YIELD.WK1, LINES 41-60, 281-300

TABLE: Manufacturing Engineering Headcount

PURPOSE: To record the total headcount in Manufacturing Engineering by time period.

INPUTS: M. E. headcount by time period decided by PROC. ENG.

OUTPUTS: None.

YIELD.WK1, LINES 61-80

TABLE: Weighting Factor Selection

PURPOSE: To determine a weighting factor for the yield plan between the throughput and cycle driven models.

INPUTS: The weighting factor may be varied after discussion with the instructor. Both the throughput and cycle driven models are learning curve models but each takes a different view of what activity drives learning. The weighting factor registers the instructor's belief of which view should dominate.

OUTPUTS: None.

YIELD.WK1, LINES 101-120

TABLE: Build Schedule (Throughput Driven Model)

PURPOSE: To record the build schedule to be used to determine the throughput driven yield plan.

INPUTS: Build Schedule is decided by the LOG. ENG. team.

OUTPUTS: None.

YIELD.WK1, LINES 121-160

TABLE: Yield Plan for Throughput Driven Model: SMP [AMP]

PURPOSE: To compute the appropriate yield plan based on the initial yield estimates, the build schedule, and the number of ME's used in each period.

INPUTS: None.

OUTPUTS: The yield plan by product family for each time period.

Total yield: Let Y_t denote the yield in period t and let C_t denote the build schedule in period t. Then, for a general period t, t > 1, the yield model is:

$$Y_t = 1 - (1-Y_{t-1})\exp(-b_{t-1}C_{t-1}),$$

where b_t denotes the learning curve parameter that depends on the number of manufacturing engineers in period t. Observe that decreasing the build schedule or increasing the number of manufacturing engineers will increase the planned yield.

Yield by Sector: The total yield is allocated to the different sectors in logarithmic proportion to the sector yields of the previous period. The initial sector yields are input in the estimated initial yields table.

YIELD.WK1, LINES 161-180, 301-320

TABLE: Yield Model Parameters (Throughput or Cycle Time)

PURPOSE: To give the parameters used in the yield model.

INPUTS: None.

OUTPUTS: None.

REMARKS: This table summarizes the parameters used in the model for determining yields. The parameters actually used in the model depend on the number of ME's and the cumulative production as well as the initial yields. The yield model is typical of a learning curve model but is specific to the game environment.

YIELD.WK1, LINES 241-260

TABLE: Cycle Time Performance

PURPOSE: To record the data necessary to estimate the number of cycle counts per period.

INPUTS: The planned cycle times (hours/unit) provided by IND. ENG. The number of hours per day by period, provided by EQ. ENG. The user of this spreadsheet will need to request the IND. ENG. and EQ. ENG. teams to summarize the data since those teams typically deal at a greater level of detail than is needed here.

OUTPUTS: None.

YIELD.WK1, LINES 261-280

TABLE: Planned Cycle Counts

PURPOSE: To compute the planned cycle counts for each product family in each period.

INPUTS: None.

OUTPUTS: The number of cycle counts in a period is computed as the product of the number of days in the period, the number of hours per day, and the inverse of the cycle time (hours/unit).

initial sector yields are input in the estimated initial yields table.

YIELD.WK1, LINES 321-360

TABLE: Yield Plan for Cycle Time Driven Model: SMP [AMP]

PURPOSE: To compute the appropriate yield plan based on the initial yield estimates, the planned cycle counts, and the number of ME's used in each period.

INPUTS: None.

OUTPUTS: The yield plan by product family for each time period.

Total yield: Let Y_t denote the yield in period t and let C_t denote the planned number of cycles in period t. Then, for a general period t, t > 1, the yield model is:

$$Y_t = 1 - (1-Y_{t-1})\exp(-b_{t-1}C_{t-1}),$$

where b_t denotes the learning curve parameter that depends on the number of manufacturing engineers in period t. Observe that shortening the cycle time or increasing the number of manufacturing engineers will increase the planned yield. The cycle counts for the SMP product line is taken to be the sum of the cycle counts for both the SMP and the AMP families. Learning related to the AMP line is assumed to be equally useful on the SMP line. The cycle counts for the AMP line is taken to be the cycle counts for that line alone. Learning related to the SMP line is assumed to have little value for the more advanced product.

The above yield model is crude but it illustrates a relationship between cycle time and yield that is gaining currency in the semiconductor fabrication industry.

Yield by Sector: The total yield is allocated to the different sectors in logarithmic proportion to the sector yields of the previous period. The

YIELD.WK1, LINES 361-4000

TABLE: Yield Plan : SMP [AMP]

PURPOSE: To compute the appropriate yield plan based on a weighted average of the throughput driven model and the cycle time driven model.

INPUTS: None.

OUTPUTS: A yield plan based on the weighted average input by the PROC. ENG.

REMARKS: The graph macro allows you to view the yields over the program. Hit the "ALT" and "G" keys simultaneously and follow the graph menu.

IV.I Bulletin Board

TOOL:	BULLETIN BOARD
TEAM:	MANUFACTURING SYSTEM ARCHITECT
PURPOSE:	TO ACT AS A CENTRAL DATABASE FOR THE MANUFACTURING SYSTEM DEVELOPMENT. ALSO, TO ASSIST IN WORKFORCE PLANNING.
SPREADSHEET FORMAT:	SEE THE MAP ON THE FOLLOWING PAGE.
FILE NAME:	BULLETIN.WK1
INFORMATION FLOW:	ALL TABLES TO BE TRANSFERRED BETWEEN TEAMS ARE CAPTURED HERE. MACROS IN THE DIFFERENT TEAM SPREADSHEETS IMPORT OR EXPORT TABLES STORED HERE. BULLETIN ACTS AS THE DATA TRANSPORT MEDIUM AND CENTRAL DATABASE FOR THE MANUFACTURING SYSTEM DEVELOPMENT.

IN ADDITION, THE TOOL PLAN, SHIFT SCHEDULE, NUMBER OF SETUPS, AND THROUGHPUT PLAN ARE USED TO GENERATE THE DIRECT LABOR HEADCOUNT REQUIRED. THE M.S.A. IS RESPONSIBLE FOR ALL HEADCOUNTS IN THIS SPREADSHEET.

TO EXPORT OR IMPORT DATA FROM ANOTHER SPREADSHEET YOU MUST FIRST LOAD THE FLOPPY DISK ONTO YOUR HARD DRIVE. TO DO THIS TYPE:

\S	To enter the system (DOS)
LOAD	To load BULLETIN to hard drive
EXIT	To return to 1-2-3

TO EXCHANGE DATA BETWEEN SPREADSHEETS ACTIVATE THE APPROPRIATE SPREADSHEET (Note: Bulletin is NOT the appropriate spreadsheet). THEN TYPE *ALT-X* TO EXPORT, OR TYPE *ALT-I* TO IMPORT.

Rows	A-H	I-N	O-U
41 60	Yield Plan SMP		
61 80	Yield Plan AMP		
81 100	Required Daily Throughput : SMP		
101 120	Required Daily Throughput : AMP		
121 140	Required Daily Throughput : Total		
141 160	Throughput Capacity by Sector		
161 220	Tool Plan (Number on line)		
221 280	Shift Schedule (Shifts per day)		
281 340	Number of Setups (Setups per day)		
341 400	Depreciation Schedule by Operation		
401 420	Depreciation Schedule by Sector		
421 480	Labor Information by Operation		
481 540	Direct Labor Headcount by Operation		
541 560	Direct Labor Headcount by Sector		
561 580	Indirect Labor Headcount		
581 600	Cost Summary Total		
601 620	Material Schedule SMP & AMP		
621 640	Cycle Time Plan SMP & AMP		
641 660	Scorecard SMP & AMP		

Figure IV-11. BULLETIN Spreadsheet Map.

BULLETIN.WK1, LINES 41-80

TABLE: Yield Plan for SMP[AMP]

PURPOSE: To record the yield plan. to be exported to the TPUT spreadsheet to be used by the LOG. ENG. team.

INPUTS: The yield plan tables are taken from the YIELD.WK1 spreadsheet at at each revision made by the PROC. ENG. team.

OUTPUTS: These tables are exported to the TPUT.WK1 spreadsheet for use by the LOG. ENG. team.

BULLETIN.WK1, LINES 81-140

TABLE: Required Daily Throughput for SMP[AMP, Totals]

PURPOSE: To record throughput data to be used by the M.S.A. to calculate direct labor headcount.

INPUTS: The throughput tables are imported from the TPUT.WK1 spreadsheet at each revision made by the LOG. ENG. team..

OUTPUTS: The throughput tables are exported to the TOOL spreadsheets, used by the EQ. ENG. team, and to the COST.WK1 spreadsheet, used by the COST ENG. team.

BULLETIN.WK1, LINES 141-160

TABLE: Throughput Capacity by Sector.

PURPOSE: To record the throughput capacity.

INPUTS: The throughput capacity is imported the TPUT.WK1 spreadsheet at each revision made by the LOG. ENG. team.

OUTPUTS: A bar graph of throughput capacity and requirements for each time period may be viewed by selecting ALT-G.

BULLETIN.WK1, LINES 161-220

TABLE: Tool Plan by operation.

PURPOSE: To record the number of tools on line.

INPUTS: The tool plan is compiled by importing the tool plan for each sector from the sector-specific TOOL spreadsheets at each revision made by the EQUIP. ENG. team.

OUTPUTS: A printout of this table should be provided to the FAC. ENG. and IND. ENG. teams.

BULLETIN.WK1, LINES 221-280

TABLE: Shift Schedule by operation

PURPOSE: To record the number of shifts per day for each operation.

INPUTS: The shift schedule is compiled by importing the shift schedule for each sector from the sector-specific TOOL spreadsheets at each revision made by the EQUIP. ENG. team..

OUTPUTS: A printout of this table should be provided to the PROC. ENG., FAC. ENG. and IND. ENG. teams.

BULLETIN.WK1, LINES 281-340

TABLE: Number of setups by operation

PURPOSE: To record the number of setups per day to be used by the M.S.A. to calculate the direct labor headcount.

INPUTS: The setup schedule is compiled by importing the setup schedule for each sector from the sector-specific TOOL spreadsheets at each revision made by the EQUIP. ENG. team..

OUTPUTS: A printout of this table should be provided to the FAC. ENG. and IND. ENG. teams.

BULLETIN.WK1, LINES 341-420

TABLE: Depreciation Schedule by operation [Sector]

PURPOSE: To record the depreciation schedule for each operation and compute a sector summary report.

INPUTS: The depreciation schedule by operation is compiled by importing the depreciation schedule for each sector from the sector-specific TOOL spreadsheets at each revision made by the EQUIP. ENG. team..

OUTPUTS: The sector totals are computed by summing the depreciation schedules for all operations in the sector. This sector summary table is exported to the COST.WK1 spreadsheet.

BULLETIN.WK1, LINES 421-480

TABLE: Labor Information by operation

PURPOSE: To record the set-up time, the running rate, and the direct labor hours per hour of operation to be used by the M.S.A. to calculate the direct labor headcount.

INPUTS: These data are given.

OUTPUTS: None.

BULLETIN.WK1, LINES 481-540

TABLE: Direct Labor Hours Required by operation [sector]

PURPOSE: To calculate the direct labor hours required to be used to determine the direct labor headcount.

INPUTS: None.

OUTPUTS: The direct labor hours required are calculated as the throughput requirement (units/day) multiplied by the inverse of the running rate then again multiplied by the direct labor hours per hour of operation, plus the number of setups multiplied by the setup time. This sum is then divided by the utilization ratio to give the direct labor hours required by operation.

BULLETIN.WK1, LINES 541-560

TABLE: Direct Labor Headcount by sector

PURPOSE: To calculate the direct labor headcount.

INPUTS: None.

OUTPUTS: Total direct labor headcount by time period. This table is exported to the COST.WK1 spreadsheet. It is calculated by adding the direct labor hours required by sector and then dividing by the number of hours per shift.

BULLETIN.WK1, LINES 561-580

TABLE: Indirect Labor Headcount

PURPOSE: To record the number of employees classified as indirect labor. This includes the number of manufacturing managers, the number of line technicians and the 4th element (Manufacturing Engineering) which consists of managerial, professional, and technical positions.

INPUTS: The number of 4th element professionals (Manufacturing Engineering Headcount) is imported from the YIELD.WK1 at each revision made by the PROC. ENG. team. All the other headcounts are input directly by the M.S.A. team.

OUTPUTS: This table is exported to the COST.WK1 spreadsheet.

BULLETIN.WK1, LINES 581-600

TABLE: Total Cost Summary

PURPOSE: To record the Cost Summary.

INPUTS: This table is imported from the COST.WK1 spreadsheet at each revision made by the COST team.

OUTPUTS: None.

BULLETIN.WK1, LINES 601-620

TABLE: Material Schedule for SMP and AMP

PURPOSE: To record the schedule of direct and indirect materials by SMP and AMP.

INPUTS: The material schedule is imported from the BOM .WK1 spreadsheet each revision made by the LOG. ENG. team.

OUTPUTS: The material schedule is exported to the COST.WK1 spreadsheet, used by the COST ENG. team.

BULLETIN.WK1, LINES 621-640

TABLE: Cycle Time Plan for SMP and AMP

PURPOSE: To record planned cycle times for each product family.

INPUTS: The cycle time schedule is imported from the CYCLE.WK1 spreadsheet at each revision made by the IND. ENG. team.

OUTPUTS: The cycle time schedule is exported to the YIELD.WK1 spreadsheet, used by the PROC. ENG. team.

BULLETIN.WK1, LINES 641-660

TABLE: Scorecard for SMP and AMP

PURPOSE: Reports the process quality (%), manufacturing cycle time (hrs/unit), and the product cost ($/unit) for SMP and AMP along with the specified goal for each. These three dimensions capture key aspects of the system: process quality is the best predictor of product quality in this system; manufacturing cycle time is the best predictor of response time to changes in demand; and unit cost is the best predictor of customer value in this system.

INPUTS: The unit cost figures are imported from the COST.WK1 spreadsheet at each revision made by the COST ENG. team. The targets for each category are given. The targets are *perfection standards*: the best yield is 100%; the lowest cycle time is the sum of the process times assuming a production run size of 1 unit and no setup time; the lowest cost per unit is the variable cost per unit (direct labor and material costs assuming maximum efficiency and minimum price).

OUTPUTS: The process quality figures are equal to the sum over all time periods of the build schedule multiplied by the yield plan; this sum is then divided by the sum over all time periods of the build schedule. The manufacturing cycle time values are equal to the sum over all time periods of the build schedule multiplied by the cycle times; this sum is then divided by the sum over all time periods of the build schedule.

APPENDIX I. PHASE I DATA

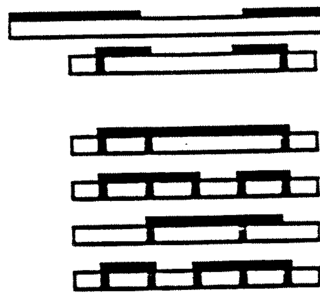
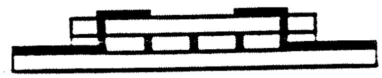
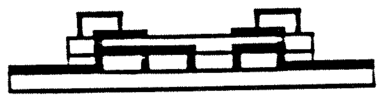
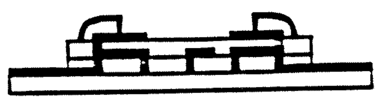
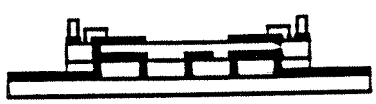
Process		Family/P/N
1. Substrate Screening 101 Inspect 102 Clean 103 Screen 104 Sinter 105 Test		Common: PWR FAN Standard: MA MC MD Advanced: MF
2. Panel Assembly 201 Substock 202 Assemble & Press 203 Sinter 204 Test		Stacked for Ass'y. 3 SMP P/N's 1 AMP P/N
3. Top Metal Staple Process 301 Staple Assembly 302 Reflow 303 Sputter 304 Test		Staple Process: AMP only
Top Metal Thin Film Process 310 Sputter 311 Photo (Glass) 312 Glass Etch 313 Evaporate 314 Photo (Metal) 315 Metal Etch 316 Test		Thin film process: AMP only
4. Flange Assembly 401 Flange 402 Brazing		Flange:
5. Final Test 501 Test		
To: Chip attach in module line		

Table A-1. Multi-Panel Product and Process Description.

(found on page II-8)

Sector	Material Name	Unit of Measure	Usage SMP	STA AMP	T.F. AMP	$/Unit
Direct Material						
Screen	Ceramic	ea.	1	1	1	.10
	Paste	lb.	0.00208	0.00208	0.00208	10
Top Metal	Staples	ea.		15		0.001
	Solder Flux	lb.		0.00625		8
	Dielectric Glass	lb.		0.00625	0.00625	24
	Aluminum Pellet	lb.			0.00625	10
Flange	Flange	ea.	1	1	1	0.35
	Brazing Preform	ea.	1	1	1	0.1
Indirect Material						
Screen	Cleaning Fluid	gal.	0.00167	0.00167	0.00167	8
Top Metal	Photo Resist	gal.			0.003	100
	Glass Etchant	gal.			0.001	10
	Metal Etchant	gal. gal.			0.001	15
Flange	Cleaner	gal.	0.005	0.005	0.005	8
	Brazing Flux	lb.	0.00625	0.00625	0.00625	16

Table A-2. Bill of Materials.

(found on page II-12)

Relevant Multi-Panel Sector and Operation	Tool Name	Quantity On Hand	Initial Capital Cost/Unit x$1000[1]	Current Book Value x$1000 (each)
1 (Vis. Inpection)	Microscopes	4	0.2	0
(Cleaning)	In-line Cleaner	1	250	25
(Testing)	Continuity Tester	1	100	10
2 (Mat. Handling)	Substrate Transfer System	2	20	2
(Testing)	Continuity Tester		(see above)	
3 ***Staple***				
(Staple Assembly)	Assembly Tool	1	250	150
(Reflow)	Reflow Furnace	1	75	8
(Sputter)	Sputtering Chamber (1)	1	150	10
	Sputtering Chamber (2)	2	140	15
	Sputtering Chamber (3)	2	102	25
(Testing)	Continuity Tester		(see above)	
3 ***Thin Film***				
(Sputter)	Sputtering Chamber (1)		(see above)	
	Sputtering Chamber (2)		(see above)	
	Sputtering Chamber (3)		(see above)	
(Photo-Glass)	Photo Processor	1	250	25
(Evaporation)	Continuous Evaporator	1	175	18
(Metal Etch)	Metal Etcher	1	175	18
(Testing)	Continuity Tester		(see above)	
5 (Final Test)	Electrical Test System	1	250	25[2]

[1]The design and debug costs are included.

[2]Requires $50K upgrade for multi-panel fixtures and programming changes.

Table A-3. Card Panel History: Equipment Costs.

(found on page II-14)

Relevant Multi-Panel Sector and Operation	Tool Name	Process Batch Size	Running Rate (#/hr)	Setup Time (hrs)	MTTF (hrs/ fail)	MTTR (hrs/ fail)
1 (Vis. Inpection)	Microscope	1	667	0	333	20
(Cleaning)	In-line Cleaner	1	455	0	250	1
(Testing)	Continuity Tester	1	267	0	40	1.5
2 (Mat. Handling)	Substrate Transfer System	1	200	0	400	1.5
(Testing)	Continuity Tester	(see above)				
3 ***Staple***						
(Staple Assembly)	Assembly Tool	1	133	0.5	4.2	0.25
(Reflow)	Reflow Furnace	1	200	0	60	3
(Sputter)	Sputtering Chamber (1)	1	29	0	15	1
	Sputtering Chamber (2)	1	29	0	15	1
	Sputtering Chamber (3)	1	29	0	15	1
(Testing)	Continuity Tester	(see above)				
3 ***Thin Film***						
(Sputter)	Sputtering Chamber (1)	(see above)				
	Sputtering Chamber (2)	(see above)				
	Sputtering Chamber (3)	(see above)				
(Photo-Glass)	Photo Processor	1	143	0.1	10	0.75
(Evaporation)	Continuous Evaporator	10	400	0	15	1
(Metal Etch)	Metal Etcher	1	250	0.3	8.4	0.4
(Testing)	Continuity Tester	(see above)				
5 (Final Test)	Electrical Test System	1	500	0	33	1

Table A-4. Card Panel History: Equipment Performance.

(found on page II-15)

Multi-Panel Phase 1 Data:
Pilot Line Current Yields, SMP P/N's.

Sector	Operation	Yield
Screening	Inspection	.98
	Cleaning	.99
	Screening	.95
	Sintering	1.00
	Test	.97
Assembly	Assemble & Press	.98
	Sinter	.98
	Test	.90
Flange	Flange Assembly	1.00
	Brazing	.98
Final Test	Test	.95
		.72

Multi-Panel Phase 1 Data:
Development Estimates of Top Metal Ultimate Yields.

Sector	Operation	Yield
Top Metal	Staple Process	.90
Top Metal	Thin Film Process	.95

Table A-5. Current Yield Information.

(found on page II-18)

Part Number	Year 1	Year 2	Year 3	Year 4	Year 5	Total
MA	72000	144000	168000	165000	99000	648000
MC	93000	180000	204000	216000	129000	822000
MD	105000	198000	207000	216000	150000	876000
SMP Subtotal	270000	522000	579000	597000	378000	2346000
MF	75000	90000	111000	144000	174000	594000
Total	345000	612000	690000	741000	552000	2940000

Table A-6. Product Forecasts.

(found on page II-19)

Relevant Multi-Panel Sector and Operation		Tool Name	Initial Capital Cost/Unit x$1000
1	(Screening)	Single Screener	52
		Tandem Screener*	81
	(Drying)	Drying Oven (1)	11
		Drying Oven (2)	26
2	(Assembly)	Assembly and Press	52
	(Sintering)	Batch Oven	22
		Continuous Furnace	102
3	***Thin Film***		
	(Glass Etch)	Glass Etcher	177
	(Photo-Metal)	Photo Processor	250
4	(Flange Assembly)	Manual Assembly	0
	(Brazing)	Brazing Furnace	81

* in-house project

Table A-7. New Process Tools: Equipment Costs.

(found on page III-21)

Relevant Multi-Panel Sector and Operation	Tool Name	Process Batch Size	Running Rate (#/hr)	Setup Time (hrs)	MTTF (hrs/ fail)	MTTR (hrs/ fail)
1 (Screening)	Single Screener	1	300	0.25	100	10
	Tandem Screener*	2	600	0.4	50	10
(Sintering)	Drying Oven (1)	100	100	0	200	5
	Drying Oven (2)	1000	1000	0	300	10
2 (Assembly)	Assembly and Press	1	200	0.1	400	1.5
(Sintering)	Batch Oven	500	150	0.25	300	5
	Continuous Furnace	10	500	0	300	5
3 ***Thin Film***						
(Glass Etch)	Glass Etcher	1	250	0.3	8.4	0.4
(Photo-Metal)	Photo Processor	1	143	0	10	0.75
4 (Flange Assembly)	Manual Assembly	1	200	0	1000	0
(Brazing)	Brazing Furnace	10	500	0	60	3

*in-house project

Table A-8. New Process Tools: Equipment Performance.

(found on page III-22)

Sector	Operation	Tool Name	Set-Up Time: Hrs.	Direct Labor Hrs. per Hr. of Operation
1	Inspection	Microscope	0	1.0
	Cleaning	In-Line Cleaner	0	0.2
	Screening	Single Screener	0.25	0.2
		Tandem Screener	0.4	0.3
	Sintering	Small Oven	0	0.1
		Large Oven	0	0.2
	Test	Continuity Tester	0.0	1.0
2	Assembly & Press	Assembly & Press Tool	0.1	0.2
	Sinter	Batch Sintering Oven	0.25	0.1
		Continuous Sintering Furnace	0	0.1
	Test	Continuity Tester	0.0	1.0
	Top Metal Staple Process:			
	Staple Assembly	Automatic Staple Tool	0.5	0.5
	Reflow	Reflow Furnace	0	0.1
	Sputtering	Sputtering Chamber	0	0.1
	Test	Continuity Tester	0.0	1.0
3	***Top Metal Thin-Film Process:***			
	Sputter	Sputtering Chamber	0	0.2
	Photo (Glass)	Photo Processor	0.1	0.2
	Glass Etch	Etcher	0.3	0.2
	Evaporate	Continuous Evaporation	0	0.2
	Photo (Metal)	Photo Processor	0.1	0.2
	Metal Etch	Etcher	0.3	0.2
	Test	Continuity Tester	0	1.0
4	Flange Assembly	Manual	0	1.0
	Brazing	Furnace	0	0.1
5	Test	Electrical Test System	0	0.4

Table A-9. Labor Information.

(found on page III-33)

VENDOR NAME	PASTE	PREFORM	PHOTORESIST	GL. ETCH	STAPLES	GLASS	ALUM	FLANGE	SOLDER	M. ETCH	CLEANER	B. FLUX
Bridge Chemical	x	x	x	x								
Candle Inc.	x	x	x	x								
Dandy Corp.	x	x	x	x								
FABTECH					x	x	x	x				
Metal Might					x	x	x	x				
Python					x	x		x				
Moore Chemical									x	x	x	x
Triple Jay									x	x	x	x
Daylight Inc.									x	x	x	x

x indicates that a material may be purchased from the corresponding vendor.

Table III-2. Material/Vendor Supply Relationship.

Vendor	Maximum $ Value
Bridge Chemical	999999
Candle Inc.	42250
Dandy Corp.	40250
FABTECH	999999
Metal Might	96600
Python	57500
Moore Chemical	17250
Triple Jay	14950
Daylight Inc.	999999

(**Note:** 999999 indicates there is no constraint.)

Table III-3. Vendor/$ Volume Constraints.

Table III-4 contains information pertaining to the maximum fraction of the annual unit consumption for each material that can be purchased from a given vendor.

Material	Max Fraction from a Single Vendor
paste	0.9
brazing preform	0.9
photoresist	1.0
glass etchant	1.0
staple	1.0
glass	1.0
aluminum	1.0
flange	1.0
solder flux	0.6
metal etchant	0.5
cleaner	0.4
brazing flux	0.4

Table III-4. The maximum fraction of annual material usage that can be purchased from a single vendor.

Vendor	Material	Minimum Annual Qty.	Unit Price ($)	Minimum Annual Qty.	Unit Price ($)
Bridge Chemical	Paste	300	15	-	-
	Preform	0	0.17	45000	0.15
	Photoresist	0	150	25	140
	Glass Etchant	0	10	-	-
Candle Inc.	Paste	900	10	-	-
	Preform	25000	0.15	50000	0.14
	Photoresist	0	100	35	95
	Glass Etchant	0	11	-	-
Dandy Corp.	Paste	600	11	-	-
	Preform	60000	0.10	-	-
	Photoresist	0	105	25	98
	Glass Etchant	0	10	-	-
FABTECH	Staples	50000	0.0017	100000	0.001
	Glass	100	14	300	12
	Aluminum	100	11	300	10
	Flange	75000	0.40	125000	0.37
Metal Might	Staples	100000	0.0015	-	-
	Glass	100	13	200	12
	Aluminum	100	10.05	-	-
	Flange	200000	0.35	-	-
Python	Staples	110000	0.001	-	-
	Glass	0	24	-	-
	Flange	5000	0.43	-	-
Moore Chemical	Solder flux	0	8	-	-
	Metal etchant	0	15	-	-
	Cleaner	825	8.5	-	-
	Brazing flux	300	11	-	-
Triple Jay	Solder flux	0	8.5	-	-
	Metal etchant	0	15	-	-
	Cleaner	990	7	-	-
	Brazing flux	660	10	-	-
Daylight Inc.	Solder flux	0	10	-	-
	Metal etchant	0	17	-	-
	Cleaner	990	8.0	-	-
	Brazing flux	0	16	-	-

Revised 3/2/98

Table. III-5. Price break/minimum purchase volumes.

TEAM: FAC. ENG.

SITUATION: FACILITIES PLAN: EQUIPMENT REQUIREMENTS

Sector	Operation	Tool Name	Tool Footprint (sq. ft.)
1	Inspection	Microscope on Work Bench	3 x 5
	Cleaning	In-Line Cleaner	4 x 38
	Screening	Single Screener	4 x 7
		Tandem Screener	6 x 7
	Drying	Small Oven	4 x 5
		Large Oven	10 x 5
	Test	Continuity Tester	5 x 5
2	Material	Automatic Transfer System[1]	Width 4 feet Length 5 or 10 units
	Assembly and Press	Assembly and Press Tool	4 x 7
	Sinter	Batch Sintering Oven (H_2)	10 x 5
		Continuous Sintering Furnace (H_2)	4 x 20
	Test	Continuity Tester	5 x 5
3	***Top Metal: Staple Process***		
	Sputtering	Sputtering Chamber	4 x 5
	Staple Assembly	Automatic Staple Tool	4 x 12
	Reflow	Reflow Furnace	4 x 20
	Test	Continuity Tester	5 x 5
	Top Metal: Thin Film Process		
	Sputtering	Sputtering Chamber	4 x 5
	Photo	Photoprocessing System	5 Stations each 4 x 10
	Glass Etch	Etch System	6 Stations each 4 x 7
	Evaporate	Continuous Evaporator	4 x 38
	Metal Etch	Etch System	6 Stations each 4 x 7
	Test	Continuity Tester	5 x 5
4	Flange Assembly	Assembly Work Bench	3 x 5
	Brazing	Brazing Furnace	4 x 20
5	Test	Electrical Test System	8 x 10

[1] Two systems available from the card panel line: one 5 ft. and one 10 ft. system. Capital cost for both was about $20,000.

Table III-8. Facilities Plan Equipment Requirements.