D264

August 1986

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Computer Aided Process Planning for Shipyards

U.S DEPARTMENT OF TRANSPORTATION
Maritime Administration
in cooperation with
Newport News Shipbuilding

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **AUG 1986**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **The National Shipbuilding Research Program, Computer Aided Process Planning for Shipyards**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**349**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

COMPUTER AIDED PROCESS PLANNING FOR SHIPYARDS

PREPARED BY:

BATH IRON WORKS CORPORATION
BATH, MAINE

AUGUST, 1986

A PROJECT OF

THE NATIONAL SHIP BUILDING RESEARCH

BY

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
SHIP PRODUCTION COMMITTEE PANEL SP-4
DESIGN/PRODUCTION INTEGRATION

FORWARD

The future success of the U.S. shiphuilding industry depends on quantum leaps in productivity. The application of group technology, process lanes, accuracy control and Computer Aided Process Planning (CAPP) are essential ingredients to such productivity increases.

Many U.S. shipbuilders believe that multiple ship contracts are necessary to gain learning curve advantages. This attitude must be replaced by the realization that learning curve advantages can be gained for interim products through the application of manufacturing process lanes that capitalize on the similar attributes of such interim products.

Group technology (GT) is applied to shipbuilding today using the Product Work Breakdown Structure (PWBS). This approach recognizes the inherent similarities in the products from various construction areas of a ship-yard on a macro level (i.e. erection and assembly/subassembly units). See the National Shipbuilding Research Program's, "Product Work Breakdown Structure", December, 1982. The next step to be taken in applying GT is to identity the similar characteristics inherent in the design of the various interim products, and to group these interim products into corresponding families. Manufacturing processes required to produce each family can then be determined. This 'will facilitate the implementation of process lane fabrication and assembly. The identification of distinct processes will also lead to the recognition of measurable parameters by which work content can be described. This relationship of interim product-s to their manufacturing processes and work content integrates readily with computer-processed scheduling, manning and budgeting, and statistical analysis for accuracy control. The future development of a group technology based manufacturing data base for shipyard interim products for the CAPP System will make possible the application of CAPP to the shipyard fabrication shops as is currently done with machined parts.

ACKNOWLDGEMENTS

This is the final report. of a project managed and cost shared by Newport News Shipbuilding for the National Shipbuilding Research Program under Maritime Administration Contract DTMA91-82-C-20018 . The program is a cooperative effort of the U.S. Navy, the Maritime Administration Office of Advanced Ship Development and Technology and the united states shipbuilding industry. Industry direction was provided by the Society of Naval Architects and Marine Engineers' Ship Production Committee Panel SP-4, Design Production Integration.

Principle research was conducted by R. L. DeVries, Bath Iron Works Corporation. Project team members were R. L. DeVries - Manager, M. A. Allen, M. L. Jasper and F. J. Barley.

Appreciation is expressed to F. A. Logan of Logan Associates for sharing his vast knowledge of CAPP with the team members and for providing many CAPP articles. Appreciation is also expressed to D. T. Koenig of General Electric Company for arranging the demonstration of a CAPP system in operation at. their Valley Forge, PA plant.

Special thanks are extended to D. H. Thompson and R. Crawford for their continued encouragement and support, to J. R. Phillips and S. A. Lever for their outstanding editorial support., and C. C. Brewer and K. H. Schenk for their endurance and skill in setting these words to type.

COMPUTER AIDED PROCESS PLANNING

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SECTION I
EXECUTIVE SUMMARY

Concept

One of the key elements of the 1930's concept of Group Technology (GT) is the classification of individual parts into families of parts with similar attributes. Prior to the advent of zone construction in shipbuilding similar products, such as frames, floors and shell plates, were presented on separate drawings, which resulted in the grouping of similar materials on each drawing. The assembly process followed a similar logical pattern using each of the drawings in each stage of construction. The introduction of zone construction has applied these GT concepts to the unit assembly process. Computer Aided Process Planning (CAPP) and its requirement to organize manufacturing data in a logical, structured manner has brought the shipbuilding industry back to the GT concept in the structural fabrication shop. The subdivision of a ship into manageable subsets of interim products allows for the further grouping of interim products into families requiring similar manufacturing processes.

Material Flow

This breakdown of parts into families (presented as a matrix in Figure III-3) is the tool that ultimately supports the effective implementation of a CAPP system. The Japanese concept that people cannot be controlled, so the material flow must be controlled, is an integral part of a CAPP system implemental ion project. The involvement of the Industrial Engineering Department in analyzing the interim product material flow can result in significant productivity increases. Providing the right material, to the right place, at the right time reduces shop congestion, improves safety and increases productivity.

The development of material flow layouts and process flow diagrams and their use are covered in Section IV.

Impact

Shipyard implementation of the CAPP system will impact all phases of shipbuilding. Although a few areas, such as detailed planning, will experience an increased workload, the total benefits to be derived from CAPP implemental ion far outweigh this increase.

CAPP's greatest impact on pre-production activities is the resultant highly structured approach to the development of database information. The general standards that are established result in overall improved communications and reduced costs. Specific benefits are also realized in: Estimating, Program Planning, Program Scheduling, Budgeting, Material Lift, Production Drawings, Shop Planning and Shop Scheduling.

In production activities, Material Handling will significantly improve as will Shop Level-Loading and Productivity. Of primary importance in these activities will be the increased accuracy of schedules, raw material pick lists and kitting lists.

Parameters

Accurate measurement of the amount of work to be accomplished in performing a specific task is the key to accurate budgeting and scheduling. The measurement tool for work content is a parameter. A parameter can also serve as a productivity measurement tool for shop management and an accurate estimating tool for new work. Dividing the parameter by the time required to accomplish a task results in an efficiency rate that will nearly be constant for similar interim products if the same methods are used. The efficiency rate becomes a quantity that can be observed over time and statis–tical analysis can be applied to analyze the results for the effects of methods changes, the need for individual training, the identification of problem areas, the effectiveness of shop floor supervision and the overall shop floor management. The computer software tools to implement a CAPP system in a shipyard are commercially available. There are systems available with varying levels of sophistication from stand alone systems, such as Prime Computer's LOCAM or Brigham Young University's D–CLASS, to systems designed to specifically support the scheduling accuracy needs of a Material Resource Planning system, such as the General Electric Company's CASA/CAMA system. These systems are generic in that they provide the data manipulation and decision processing software but require the input of an individual shipyard's decision logic, equipment capabilities, construction methods, material handling information and design data in order to function. The tools are available and only the implementation needs to be accomplished. The use of other supporting software tools and the identification of shipbuilding standards during this project have been a natural extension of the effort. The manipulation of the manufacturing data base for even a limited scope project is essential to limit transcribing errors and reduce program costs. However, the application of a scheduling software package is not practical during the start-up phase as a stabilized manufacturing database is considered necessary.

Implementation

The implementation of a CAPP system at a shipyard is a back-to-basics exercise. Applying time honored concepts, such *as GT,* Material Flow Analysis and Henry Ford's Production Line Technology, is necessary in order to establish the foundation on which to build a CAPP system. New terms, such as parameters, efficiency rates and statis–tical control, are surely present but the concepts are not new. A CAPP system implementation project simply requires that the project is approached in a structured, well planned, well managed manner and that size of the implementation effort is limited in scope for each implementation phase. The task to be completed is to capture the manufacturing data and decision logic used by the planners and shop floor management in their daily activities and then use today's computer technology to standardize the construction approach and provide the shop floor with the management and control information to effectively carry out the tasks.

Conclusions

The technology is in place, the tools are available and all that remains is a pilot implementalion project to prove the practicality and cost–effectiveness of a CAPP system in a shipyard environment.

The implementation of a CAPP system in a shipyard can result in a productivity increase of 10 to 40 percent. This is based on an IHI projected productivity increase of 20 to 40 percent for process lane implementation and productivity increases of 10 to 60 percent where similar CAPP systems have been implemented in related industries. Some specific areas in which this increase will be realized are:

- The recognition of interim product similarities results *in* a learning curve savings throughout single ship programs.

- The establishment of process lanes, capitalizing on interim product similarities, results in repeating processes that can be analyzed for process improvement, and the location of equipment.

- The analysis of raw material and interim product flow results in improved productivity and safety.

- The consistent control of data enhances the application of several technologies such as bar coding which results in improvements in providing and gathering data.

- The tiered development of data supports the application of design budgets during the design phase, and results in an auditable trail of the effects of engineering changes in design and methods and process changes in production.

- The process planning information feedback loops resulting from the approach required by a CAPP system results in the management information remaining current.

SECTION II
PROJECT DESCRIPTION

SECTION II
PROJECT DESCRIPTION

A. Project Objective

CAPP is a multiple definition acronym as is MRP II. The software vendor's definition is generally dependent on the sophistication of their software. The definitions range from a simple system of editing existing process plans that only describe how a product is made to a system that develops the process plan and, in addition, identifies and integrates inform- ation from other systems such that the worker on the floor has a complete set of documentation for the job he/she has to do including bill of matecials, kitting information, shipping information with all superfluous data deleted and a feedback system to management for statusing and level-loaded schedul- ing for each work station.

The primary objectives of the project were to:

- Examine previous documentation on the subject of Product Work Breakdown Structure (PWBS), Group Technology (GT), Process Planning and related subjects in order to capitalize on, and avoid duplication of, other completed endeavors.

- Identify the elements of the manufacturing data base neces- sary to support a Computer Aided Process Planning (CAPP) System in a shipyard.

- Focus on the product characteristics of structural fabrications that lend themselves to accuracy control and productivity improvement through statistical analysis.

- Standardize the products and processes of structural fabrication to the level of piece-manufacturing process-flow lanes.

- Identify potential off-the-shelf CAPP systems that could be applied in a shipyard environment.

- Promote integration of contract development processes with product and process standard- ization to ensure future improvement and savings across all shipbuilding disciplines.

B. Project Work Scope

A comprehensive study of the front-end and production operations which support process production was undertaken in order to evaluate and recommend effective implementation of CAPP systems in the shipbuilding industry. The project was subdivided into functionally oriented tasks that could be developed independently, as follows:

Task I Product and process definition and evaluation

Task II Impact analysis of product definition on front-end support and scheduling

Task III Refinement of products and budgeting and scheduling parameter identification

Task IV Evaluation of existing CAPP systems

, Task V Project enhancements and integration.

Thes tasks were further subdivided as follows:

Task. I - Product and Process Definition

o Standard interim products for structural and distributive system fabrications and small subassemblies were identified

Associated construction processes were identified

0 Product flows were defined

0 A model for product and process identification and for product scheduling was developed

Using in-process work sample schedule durations and budgets for various products and processes were applied and test

0 Managed and communicated detailed performance and problems.

Task II – Impact Analysis

0 Evaluated the effects of product and process definition on preproduct-ion and production activities such as estimating, planning, scheduling, budgeting, steel lift, lofting, and shop level-loading

0 Evaluated results of test application on in-process work

0 Modified model to reflect test results.

Task III - Refinement and Full Implemental ion

0 Refined standard interim product identification

0 Refined identified construction processes

0 Refined identified product flow

0 Defined parametric budget and schedule logic

0 Developed method for establishing parameters for estimating, scheduling and budgeting

0 Applied product related refinements and parametric budgeting and scheduling to in-process work and revised model accordingly

0 Managed and communicated detailed performance and problems.

Task IV – Evaluation of Existing CAPP Systems

- Through correspondence with government and private organizations, BIW ascertained the status of the present use and development of CAPP. Concurrently, a bibliography of the literature on CAPP was prepared. Visits to CAPP users in other industries were conducted.

- BIW organized all the gathered information into an interim report detailing current status, shipbuilding interest, and a CAPP bibliography.

- Two particular CAPP system were determined to be suitable for use in the shipbuilding industry, however, a test application of that system on BIW'S Process Flow Lane Project was not conducted due to insufficient funds.

Task V - Project Enhancements and Integration

- Investigated mini-computer scheduling systems for application to interim product detail scheduling

- Applied and tested computer-aided scheduling

- Recommended the development of design standards specifically related to product and process identification

- Continued overall system development by involving affected groups in making refinements and solving problems

- Developed final report.

These tasks were expanded by the contract to include all shipyard fabrication shops, demonstrating the applicability of the approach.

C. Project Approach

In reviewing the literature on existing CAPP systems it was apparent that most operable systems in use were those in machine shops. These systems relied heavily on the group technology concept of product similarities as they related to the manufacturing processes involved in their production. In addition, the systems promoted similar material flows for similar products and relied heavily on "feeds" and "speeds" data developed for each of the machines. It was decided that a similar approach to ship component fabrication was necessary in order to successfully implement a CAPP system. The primary focus of the project, therefore, was to identify the data base information necessary to support a CAPP system.

The first step in the process was to identify the types of products that were subjected to similar processes. Then all processes involved for each product were identified. The results of this effort are reported in Section III.

The next step in the process was to identify and analyze the flow path of the material for each interim product. In addition, the documentation necessary to control such flow was identified and reviewed. The results of this effort are reported in Section IV.

The impact on the various preproduction and production activities was then reviewed. The results are reported in Section V.

Work measurement quantities (referred to as parameters) that could be easily measured were then identified for each interim product to support scheduling and manhour budgeting efforts. The results of that activity are reported in Section VI.

In parallel with the above efforts, a literature search was conducted allowing greater familiarity with the CAPP system requirements. Also , computer system vendors were contacted to determine the availability and applicability of existing CAPP systems. The results of these efforts are reported in section VII.

As the project progressed the investigators continued to interface with other organizations to ensure that the CAPP program remained in step with other areas of technological advance. ment. Mini–computer scheduling systems were investigated to determine the applicability of such systems to the CAPP environment. The results of this effort are reported in Section VIII.

An implementation plan that can be followed by other shipyards in developing their own data bases is presented in Section IX.

Finally the conclusions reached in this study , and recommendations for future activities, are presented in Section X.

SECTION 111

INTERIM PRODUCT/CONSTRUCTION PROCESS DEFINITION

SECTION III
INTERIM PRODUCT/CONSTRUCTION PROCESS DEFINITION

A. Introduction

The implementation of automated process planning requires that the following factors be established in the manufacturing environment:

- o A consistent vocabulary
- o A clear identification of processes
- o A clear identification of products
- o A simple work content measurement tool
- o A measurable definition of shop process lane capacity.

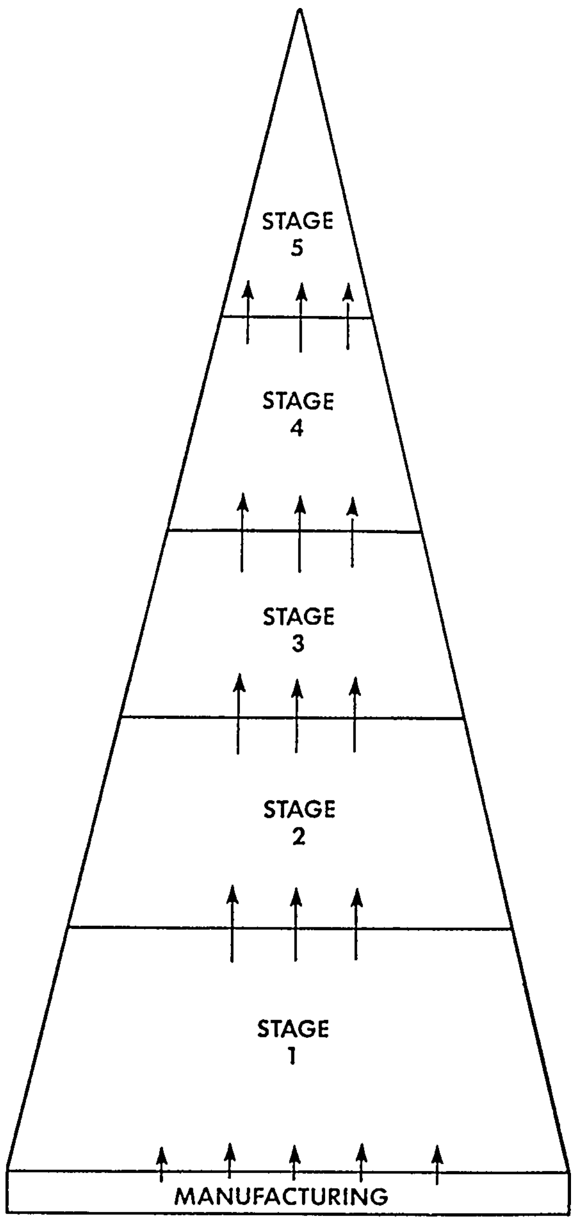
A lack of understanding of these factors would allow the majority of U.S. Shipbuilders to believe that automated process planning can only be applied to multiple ship construction programs and perhaps then only to a limited extent where unit similarity and series production can be applied. This opinion is reinforced through constraints imposed by the layout of fabrication shops and through the macro-level view of shipbuilding processes which obscures existing product/process similarities. Consequently, the implementation of any automated process planning system in a shipyard environment must be preceded by the development of a model that addresses each of these factors and by a training program which explains the model and the logic used to develop it. Once the model is developed, the manufacturing data can be quantified, training can occur and automated process planning can be implemented in the shipbuilding industry. This has already been done in many machine shop-type industries, such as cylindrical shaft and gear manufacturers.

Frank Logan, in his paper "The Five Stages to Automated Process Planning," describes the stages of process planning using a triangle with a base of the manufacturing data necessary to carry out the manufacturing processes involved (see Figure III-l). In the initial investigation of this project it was discovered that the only type of shop which had such repeatable data was the machine shop where the majority of time is expended in machine operations. Machine shops also benefit, from the significant amount of work which has been done to develop set-up time parameters. Consequently, the majority of existing Computer Aided Process Planning (CAPP) systems are designed for machine shop applications. The U.S. Army Missile Command System, CMPP, is an example of such a system.

In examining existing machine shop CAPP systems it was further discovered that manufacturing data is organized in a logical, structured manner which is easily related to the design, planning, budgeting and scheduling processes. Figure III-2 illustrates the basic concept. The classification of individual parts into families of parts with similar attributes is a key element of a philosophy developed in the 1930s known as Group Technology (GT). In the "stick building" era of shipbuilding, GT concepts were applied in shipyards as similar interim products were grouped on separate drawings, such as web frames, stiffeners, and shell plates. Similar materials were consequently grouped on each drawing and the assembly process followed a similar, logical pattern using each of the drawings in each stage of construction. With the advent of unit construction the assemblier was forced to deal with all of the drawings at one time since each unit was only a small part of each drawing. The evolution process continued and the unit drawing was developed to support the assembly shop personnel. In order to facilitate material control, raw materials were also grouped by unit. This resulted in small pieces of raw material having to be handled by fabrication shops to support the unit assembly process. This naturally reduced efficiencies in the structural fabrication shop and in most of the other fabrication shops as well. CAPP and the inherent requirement to organize manufacturing data in a logical, structured manner, has had the effect of bringing the shipbuilding industry full circle. Fabrication shops will once again see World War II type drawings for groups of similar interim products.

The recognition of the interim product similarities allows the fabrication shop to group such interim products and fabricate them using a process lanes approach. The resulting repetitive similar work results in learning curve savings. In addition, the processes for each process lane remain relatively constant and the processes can be analyzed for productivity improvement through the use of jigs and fixtures and/or new or improved technologies. Statistical analysis can also be used to determine the trends in quality and productivity and to monitor the effect of jigs and fixtures and/or new technologies that may be implemented.

FIGURE III-1
THE 5 STAGES OF PROCESS PLANNING



AUTOMATIC PROCESS PLANNING DRIVEN BY COMPLEX PART CODING AND MANUFACTURING LOGIC DECODING CAPABILITIES WITH LINKS TO CAD.

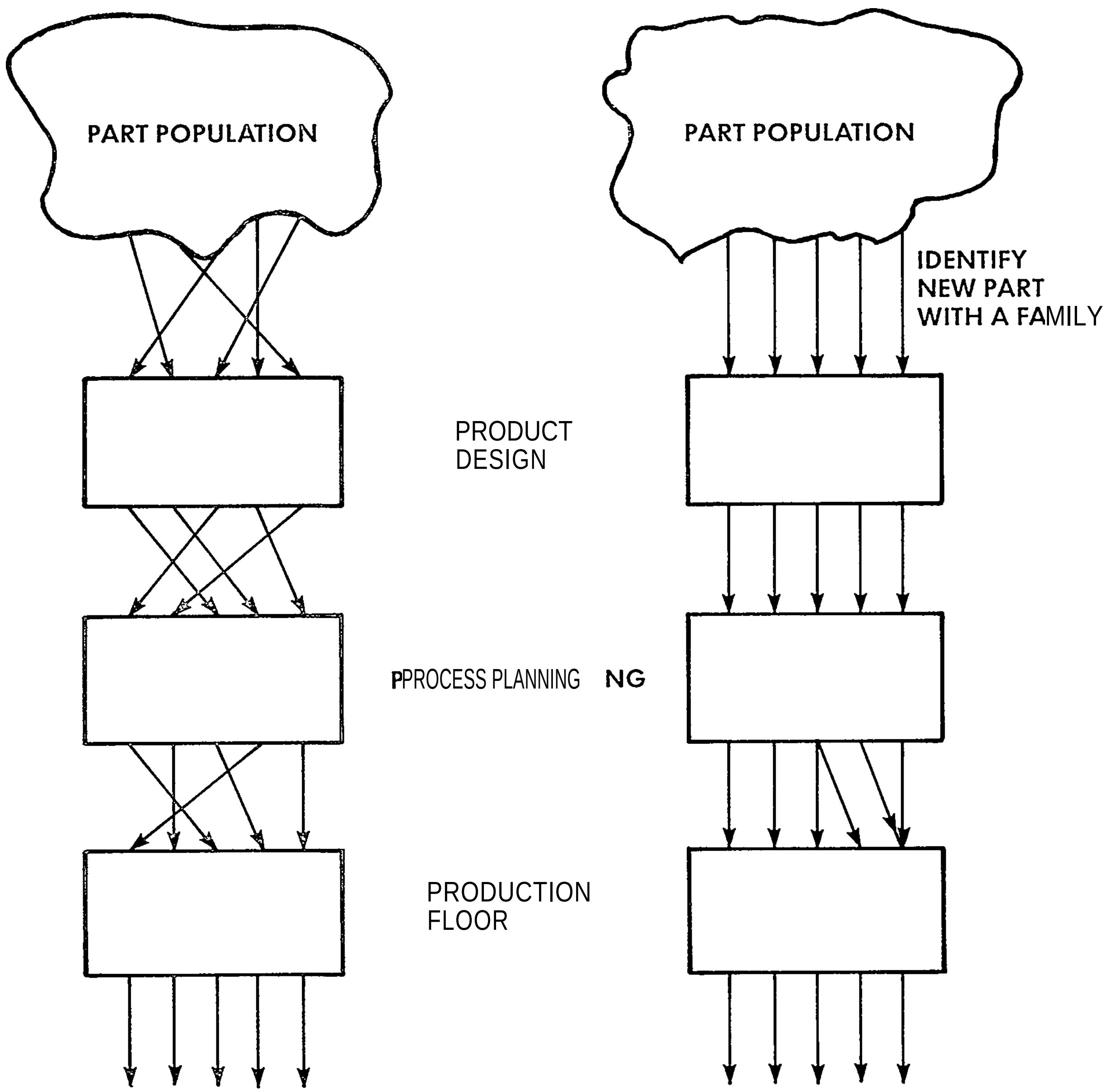
SEMI-AUTOMATIC PROCESS PLANNING DRIVEN BY SIMPLE CODING SYSTEMS WITH MANUAL ENTRY OF SOME DATA, E. G., DIMENSIONS.

FEATURE (ATTRIBUTE) DRIVE PROCESS PLANNING FROM GROUPS KEYWORDS AND SIMPLE AUTOMATIC SELECTION OF BASE PARAMETERS,

ENTRY LEVEL INTERACTIVE COMPUTER-AIDED TIME ESTIMATING AND METHODS PLANNING USING QUESTIONS AND/OR PARAMETER DRIVEN MANUFACTURING LOGIC WHICH HAS DIRECT ACCESS TO TIME/COST STANDARD DATABASE.

TRADITIONAL MANUAL PROCESS PLANNING USING PERSONAL EXPERIENCE TO DERIVE MANUFACTURING LOGIC AND EXTRACT TIME/COST STANDARD DATA AND WRITE OUT MANUFACTURING INFORMATION.

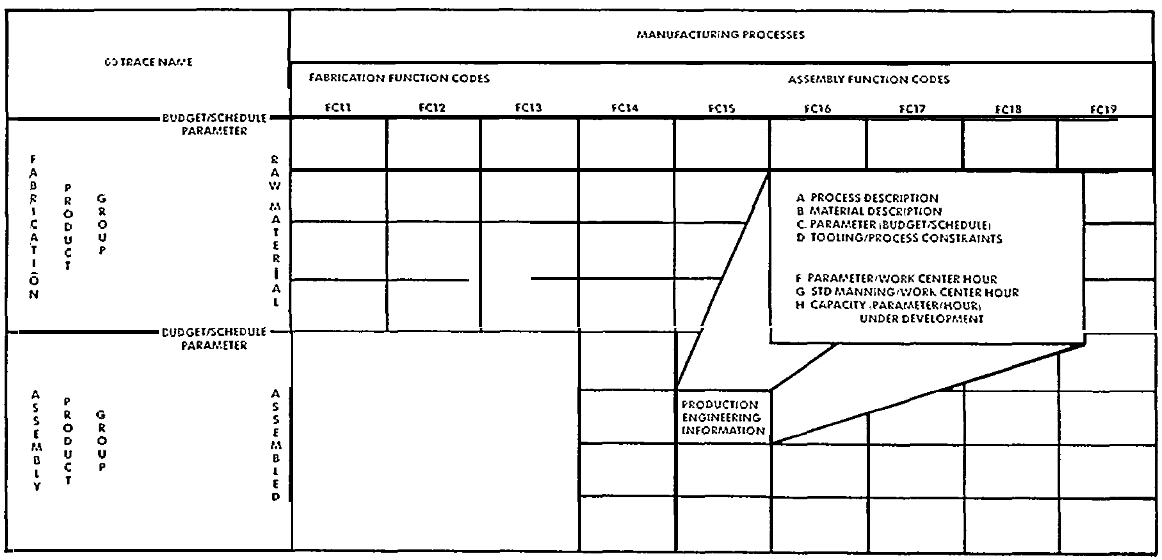
FIGURE III-2
STRUCTURED MANUFACTURING DATA



B. <u>Product/Process Matrix Logic</u>

The National Shipbuilding Research Program publication, “Product Work Breakdown Structure”, June 1986, has provided a useful organizational tool for analyzing the shipbuilding process. It subdivides a ship into manageable subsets of interim products. These interim products can be grouped into families that require similar manufacturing processes. These families of products can further be grouped by the shop or trade that has responsibility for their manufacture. BIW has elected to present this product/process information for the fabricating trades/shops in the matrix format shown below in Figure III-3:

FIGURE III-3
INTERIMPRODUCT/CONSTRUCTION PROCESS MATRIX



The products are subdivided into two categories: raw materials, including purchased components, and assemblies. The manufacturing processes were found to be similar for all trades and are also divided into two categories: fabrication and assembly.

Raw material is staged for the fabrication processes of cutting and bending. Fabricated components and purchased components are inspected and kitted for the assembly processes of assembly, joining, finishing, quality assurance, and kitting for a later stage in the construction process. These manufacturing processes are further defined by the following function codes:

- FC 11 QUEUE - Raw material sorting, moving, kitting, etc.
- FC 12 CUTTING - Burning, shearing, sawing, etc.
- FC 13 BENDING - Bending, forming, flanging, etc.
- FC14 Q&Qc - Fabricated material queue, kitting and quality control
- FC 15 ASSEMBLY - Assembly of parts
- FC 16 JOINING - Welding, brazing, bolting, etc.
- FC 17 FINISHING - Grinding, pickling, coating, etc.
- FC 18 QA - Quality Assurance
- FC 19 KITTING - Kitting for installation pallet/by Product Work Breakdown Structure

The product/process matrix is the tool for systematically identifying the Production Engineering Information required to support effective implementation of a CAPP System. The following Production Engineering Information will complete the matrix for each trade or fabrication shop:

- o Detailed Process Descriptions – Complete description of each of the different methods available should be provided. Included in this description should be the decision logic followed in determining which method is used.
- o Detailed Material Descriptions Complete descriptions of the raw materials that are normally processed by the shop should be provided. The information should include material type and maximum and minimum sizes.
- o Tooling and Process Constraints - The capacity constraints for each method described in the Detailed Process Descriptions as well as the handling constraints (size and weight) should be provided.
- o Work Content Parameters - Work content parameters (hereafter referred to as parameters) are a work measurement tool for determining the amount of labor required to complete a task. Examples include the number of pieces to be fitted, the linear feet of weld joint to be fitted, the weld pass length (number of passes X linear feet of weld joint) to be welded, number of pipe pieces to be installed, etc.
- o Efficiency Rates – Efficiency rates are calculated by

dividing the work content parameter value by the hours required to complete the task.

- o Standard Manning Levels - Standard manning levels are the number of persons that can efficiently be assigned to a task at a specific work site.

- o Capacity Stated as Parameter/Hour - Capacity for a work station is calculated by multiplying the Efficiency Rate by the standard manning level for each station.

C. Interim Product/Construction Process Matrices

Product/Construction Process matrices have been developed for each of the BIW fabrication shops. Included in the matrices is the Production Engineering Information covering the detailed process descriptions and the materials used by each shop. The basic data describing BIW'S facilities has been displayed. The balance of the BIW manufacturing data is considered proprietary, however, typical examples are provided to enable the reader to gain a clear understanding of the concepts involved.

MAA 4/12/85

D/34 HARDINGS

PRODUCT	QUEUE	CUTTING	BENDING	Q&QC	ASSEMBLY	JOINING	WELDING	QA	KITTING
PLATE	SQ FT								
PARALLEL EDGE PLATE PARTS NON PARALLEL PLATE PARTS INTERNAL PLATE PARTS	SEQUENCE SORT BLAST/PRIME CONVEY INSIDE STACK	MACH BURN MANUAL BURN SHEAR SAW PUNCH SHEAR	BEND ROLL LINE HEAT FLANGE PUNCH	TO BATH TO WEB LINE TO BULKHEADS TO FOUNDATION TO MISC SMALL PARTS TO COMPLEX 3 D				INSPECT STATUS REPORT	SORT TRESSEL STORE SHIP
SHAPES	LIN FT	—	—		—	—			—
ROLLED SHAPE INTERNAL PARTS PREFABBED SHAPE INTERNAL PARTS	SEQUENCE SORT BLAST/PRIME CONVEY INSIDE STACK	LAYOUT MANUAL BURN SHEAR	FRAME BEND LINE HEAT TWIST PUNCH DRILL STRAIGHTEN	TO BATH TO WEB LINE TO BULKHEADS TO FOUNDATION TO MISC SMALL PARTS TO COMPLEX 3 D				INSPECT STATUS REPORT	SORT TRESSEL STORE SHIP
WEBS & GIRDERS	—	—	—		WELD LENGTH	—	—		
WEBS & GIRDERS FROM SHAPES WEBS & GIRDERS FROM PLATES WEBS & GIRDERS FROM BOTH				FROM SHAPES FROM PLATES FROM MISC SMALL PARTS	LAYOUT POSITION TACK	JOIN TO BULKHEADS TO FOUNDATION TO COMPLEX 3 D	WELD INSPECT PICK UP	INSPECT STATUS REPORT	SORT RACK STORE SHIP
BULKHEADS, DECKS, & PLATFORMS	—	—			WELD LENGTH	—	—		
SINGLE PLATE BULKHEAD SINGLE PLATE BULKHEAD W/WEBS MULTIPLE PLATE BULKHEAD MULTIPLE PLATE BULKHEAD W/WEBS				FROM PLATES FROM SHAPES FROM MISC SMALL PARTS FROM WEBS & GIRDERS	JOIN PLATES LAYOUT FRAMING TACK	WEBS & GIRDERS TACK TO COMPLEX 3 D	WELD INSPECT PICK UP	INSPECT STATUS REPORT	SORT TRESSEL STORE SHIP
FOUNDATIONS	—	—	—		—	—	—		—
SIMPLE FOUNDATION FROM SHAPE SIMPLE FOUNDATION FROM PLATE SIMPLE FOUNDATION FROM BOTH COMPLEX FOUNDATION FROM SHAPE COMPLEX FOUNDATION FROM PLATE COMPLEX FOUNDATION FROM BOTH		LAYOUT MANUAL BURN PORT PLASMA	ROLL FLANGE SHEAR BEND DRILL	FROM PLATES FROM SHAPES FROM MISC SMALL PARTS FROM WEBS & GIRDERS	WELD LENGTH POSITION TACK	TO BULKHEADS TO COMPLEX 3	POSITION WELD INSPECT PICK UP	INSPECT STATUS REPORT	STORE PICK TRAILER SHIP
MISC SMALL PARTS		—	—		WELD LENGTH	—		—	
MISC SMALL PARTS FROM PLATE MISC SMALL PARTS FROM SHAPE MISC SMALL PARTS FROM BOTH				FROM PLATES FROM SHAPES	LAYOUT FIT TACK	TO WEB LINE TO BULKHEAD TO FOUNDATION TO COMPLEX 3	POSITION WELD INSPECT PICK UP	INSPECT STATUS REPORT	BOX OR PALLET STORE PICK TRUCK SHIP
DOORS HATCHES SCUTTLES	—	—	—		QUANTITY	—		—	—
(ANY DOOR, HATCH, OR SCUTTLE THAT IS >100 LBS SHOULD BE BUILT ON A TABLE IN FOUNDATION AREA)				FROM PLATES FROM SHAPES FROM MISC SMALL PARTS		LAYOUT POSITION TACK TURN BACKFIT	POSITION WELD POSITION WELD INSPECT PICK UP	INSPECT STATUS REPORT	STORE PICK TRAILER SHIP
COMPLEX 3 D ASSEMBLIES	—	—	—	—	WELD LENGTH	—	—		—
COMPLEX 3 D FROM PLATES COMPLEX 3 D FROM SHAPES COMPLEX 3 D FROM BOTH COMPLEX 3 D FROM BOTH INCLUDING WEBS, GIRDERS, BULKHEADS, MISC SMALL PARTS, FOUNDATIONS, OR ANY COMBINATION OF THESE				FROM PLATES FROM SHAPES FROM MISC SMALL PARTS FROM WEBS & GIRDERS FROM BULKHEADS		LAYOUT POSITION TACK TURN BACKFIT	POSITION WELD POSITION WELD INSPECT PICK UP	INSPECT STATUS REPORT	STORE PICK TRAILER SHIP

FIGURE III-4
STRUCTURAL FABRICATION
INTERIM PRODUCT/CONSTRUCTION
PROCESS MATRIX

MAA 4 12 85

U 15 PIPE SHOP

PRODUCT	QUEUE	CUTTING	BENDING	QA/QC	ASSEMBLY	JOINING	FINISHING	QA	KITTING
PIPE FERROUS NON FERROUS ALUMINUM	LIN FT DRAW	SAW	LAYOUT BEND	TO KITTING TO PIPE ASSEMBLY TO OUTFIT PACKAGE				INSPECT STATUS REPORT	KIT TRANSPORT
HOSE	LIN FT DRAW	SAW		TO KITTING TO HOSE ASSEMBLY TO OUTFIT PACKAGE				INSPECT STATUS REPORT	KIT TRANSPORT
HANGER MATERIAL	LIN OR SQ FT DRAW	CUT	BEND	TO KITTING TO HANGER ASSEMBLY TO OUTFIT PACKAGE				INSPECT STATUS REPORT	KIT TRANSPORT
WAVEGUIDE	LIN FT DRAW	SAW	BEND	TO KITTING TO WAVEGUIDE ASSEMBLY				INSPECT STATUS REPORT	KIT TRANSPORT
PURCHASED FOR ASSEMBLY	QUANTITY			TO PIPE ASSEMBLY TO HOSE ASSEMBLY TO WAVEGUIDE ASSEMBLY TO OUTFIT PACKAGE				INSPECT STATUS REPORT	KIT TRANSPORT
ASSEMBLED PIPE PIPE WITH 0-1 FITTINGS PIPE WITH 2-5 FITTINGS PIPE WITH 5 OR MORE FITTINGS				LIN FT FROM PIPE FROM PURCHASED FROM HARDINGS FROM MACHINE SHOP	LAYOUT FIT PREP BRAZE OR WELD		TEST INSPECT CLEAN COATINGS	INSPECT STATUS REPORT	KIT TRANSPORT
HOSE ASSEMBLY				LIN FT FROM HOSE MATERIAL FROM PURCHASED	LAYOUT ATTACH FITTINGS		CLEAN TEST	INSPECT STATUS REPORT	KIT TRANSPORT
WAVEGUIDE ASSEMBLY				LIN FT FROM WAVE GUIDE MATERIAL FROM PURCHASED	LAYOUT ATTACH FITTINGS	ASSEMBLE	TEST CLEAN PROTECT	INSPECT STATUS REPORT	KIT TRANSPORT
HANGER ASSEMBLY				QUANTITY FROM HANGER MATERIAL FROM PURCHASED	LAYOUT ASSEMBLE	WELD	CLEAN PRIME	INSPECT STATUS REPORT	KIT TRANSPORT
OUTFIT PACKAGE				LIN FT FROM PIPE FROM PURCHASED FORM HARDINGS FROM MACHINE SHOP FROM ASSEMBLED PIPE FROM HANGER ASSEMBLY FROM HOSE ASSEMBLY	LAYOUT ASSEMBLE WELD OR BRAZE	[illegible] ASSEMBLIES	TEST CLEAN PAINT	INSPECT STATUS REPORT	KIT TRANSPORT

FIGURE III-5
PIPE FABRICATION
INTERIM PRODUCT/CONSTRUCTION
PROCESS MATRIX

MAA 3 21/85

D 19 ELECTRIC SHOP

PRODUCT	FABRICATION: QUEUE	CUTTING	FORMING	Q&QC	ASSEMBLY: ASSEMBLY	JOINING	FINISHING	QA	KITTING
PLATE	SQ FT WEIGHT								
SHEET METAL PLATE EQ OR < 1/4"	RECEIVE RACK DRAW MOVE	LAYOUT CUT SHEAR SAW PUNCH	BEND DRILL	TO SMALL MANUFACTURED ITEMS COMPLEX MANUFACTURED EQUIPMENT TO KITTING				INSPECT STATUS REPORT	SORT BOX STORE SHIP
SHAPES	LIN FT, WEIGHT	—	—	—	—	—	—	—	—
ANGLE BAR PIPE FLAT BAR CABLE TRAY MATERIAL	RECEIVE RACK DRAW MOVE	LAYOUT CUT SHEAR SAW PUNCH	BEND DRILL	TO SMALL MANUFACTURED ITEMS COMPLEX MANUFACTURED EQUIPMENT TO KITTING				INSPECT STATUS REPORT	SORT BOX STORE SHIP
PURCHASED OR GF EQUIPMENT FOR ASSEMBLY	—	—	—	—	QUANTITY	—	—	—	—
PURCHASED EQUIPMENT CABLE ENTRANCE DEVICES	ATTACH ID TAG			FROM STORES	DRILL	ASSEMBLE	COVER	INSPECT STATUS REPORT	KIT
ELECTRICAL EQUIPMENT FOUNDATIONS	—	—	—	—	QUANTITY	—	—	—	—
CABLE TRAYS LIGHT LEGS TERMINAL BOXES DISTRIBUTION BOXES				(FROM PLATE) (FROM SHAPE) (FROM SHEET METAL SHOP) (FRM MACHINE SHOP) (FROM HARD NGS) (FROM SHOP INVENTORY) (FROM PIPE SHOP)	LAYOUT	TACK SCREW BOLT DRILL	WELD INSPECT PICK UP	INSPECT STATUS REPORT	SORT TAG BOX STORE SHIP
COMPLEX MANUFACTURED EQUIPMENT	—	—	—	—	QUANTITY	—	—	—	—
POWER PANELS				(FROM SHEET METAL SHOP) (FROM SHOP INVENTORY)	LAYOUT POSITION	JOIN HOOK UP TACK SCREW BOLT DRILL	POSITION WELD INSPECT PICK UP	INSPECT STATUS REPORT	SORT TAG BOX STORE SHIP
LABELS	—	—	—	—	QUANTITY	—	—	—	—
CABLE TAGS CONDUCTOR TUBING				(FROM SHOP INVENTORY)	KEYPUNCH PUNCH TAPE	CUT BEND		INSPECT STATUS REPORT	SORT TAG KIT SHIP
PRE-PLUG SPECIAL CABLE	—	—	—	—	QUANTITY	—	—	—	—
				FROM D/08 CABLE RM (FROM CONNECTOR INVENTORY)		HOOK UP		INSPECT STATUS REPORT	TAG KIT SHIP
INVENTORY	—	—	—	—	QUANTITY	—	—	—	—
CONNECTORS PLUGS VENDOR SUPPLIED CABLE				(FROM SHOP INVENTORY) (FROM STORES)				INSPECT STATUS REPORT	SORT TAG BOX STORE SHIP
CABLING BY DEPT 08 STORES	LIN FT	—	—	—	LIN FT	—	—	—	—
MAIN CABLE LOCAL CABLE	ROUGH CUT SPOOL MOVE	CABLE CUT	STRIPOUT CUT WIRE	TO ASSEMBLY COMPLEX MANUFACTURED EQUIPMENT TO KITTING	LABEL OR TAG		SPOOLING	INSPECT STATUS REPORT	SPOOL STORE SHIP

FIGURE III-6
ELECTRICAL FABRICATION
INTERIM PRODUCT/CONSTRUCTION
PROCESS MATRIX

MAA 3 21 85

D/17 SHEET METAL SHOP

PRODUCT	QUEUE	CUTTING	FORMING	Q&QC	ASSEMBLY	JOINING	WELDING	QA	KITTING
	FABRICATION				ASSEMBLY				
SHEET GOODS	SQ FT WEIGHT								
SHEET METAL PLATE 1/4" GRATING HONEYCOMB PANELS	PICK MOVE RACK PICK	LAYOUT WEDMATIC SHEAR NIBBLE SAW PUNCH BURN	BEND ROLL	TO VENTILATION TO FOUNDATIONS TO 2 D & LOW 3 D TO COMPLEX 3 D TO JOINER				INSPECT STATUS REPORT	SORT TRESSEL STORE SHIP
SHAPES	LIN FT, WEIGHT	—	—	—	—	—	—	—	—
FLAT BAR ANGLE BAR PIPE OR TUBING EXTRUSIONS CHANNEL DECK SHOES	PICK MOVE RACK PICK	LAYOUT MANUAL BURN SHEAR SAW PUNCH	FRAME BEND LINE HEAT TWIST DRILL	TO VENTILATION TO FOUNDATIONS TO 2 D & LOW 3 D TO COMPLEX 3 D TO JOINER TO KITTING				INSPECT STATUS REPORT	SORT PALLET BOX STORE SHIP
PURCHASED	—	—	—	—	QUANTITY	—	—	—	—
VENT VALVES COOLING COILS HEATERS & REHEATERS COMM EQUIPMENT				TO VENTILATION TO FOUNDATIONS TO 2 D & LOW 3 D TO COMPLEX 3 D TO JOINER				INSPECT STATUS REPORT	SORT PALLET BOX STORE SHIP
RECTANGULAR VENT	—	—	—	—	LIN FT	—	—	—	—
				(FROM SHEET) (FROM SHAPES) (FROM PURCHASED)	TACK/WELD PARTS WELD FLANGES ASSEMBLE HDWARE MOVE	JOIN ASSEMBLIES WELD ATTACH HDWARE INSPECT PICK UP	WELD INSPECT	INSPECT STATUS REPORT	SORT BOX
ROUND VENT	—	—	—	—	LIN FT	—			SHIP
				(FROM SHEETS)	ASSEMBLY	ATTACH HDWARE			
FOUNDATIONS	—	—	—	—	WEIGHT QUANTITY	—	—	—	—
SIMPLE FOUNDATION COMPLEX FOUNDATION				(FROM SHEET) (FROM SHAPES) (FROM PURCHASED) (FROM HARDINGS)	LAYOUT POSITION TACK	(TO 3 D ASSEMBLY)	POSITION WELD INSPECT PICK UP	INSPECT STATUS REPORT	SORT PALLET BOX STORE SHIP
2 D & LOW ASSEMBLY 3 D	—	—	—	—	WEIGHT QUANTITY	—	—	—	—
SEE LIST A				(FROM SHEET) (FROM SHAPES) (FROM PURCHASED) (FROM HARDINGS)	LAYOUT FIT TACK	JOIN TACK	POSITION WELD INSPECT PICK UP	INSPECT STATUS REPORT	SORT PALLET BOX STORE SHIP
COMPLEX 3 D ASSEMBLY	—	—	—	—	WEIGHT, QUANTITY	—	—	—	—
SEE LIST B				(FROM SHEET) (FROM SHAPES) (FROM PURCHASED) (FROM HARDINGS) (FROM 2 D & LOW 3 D)	LAYOUT POSITION FIT TACK	JOIN INSPECT PICK UP	POSITION WELD INSPECT PICK UP	INSPECT STATUS REPORT	SORT PALLET BOX STORE SHIP

2 D & LOW ASSEMBLY 3 D

ACCESS COVERS
AIR LISTS
BINS
CURTAIN PLATES
DECK COAMING
DRAFT MARKS
FIRE STATIONS
FLANGE SHIELDS
FLOOR PLATES
FIRE TIGHT COLLARS
GOOSENECKS
GAUGE BOARDS
HANGERS
LIGHT TRAPS
PANS
PENETRATIONS
PIPE BATTENS
SHEATHING
SHELVES
STOWAGES
VENT DAMPERS
VENT FLANGES
VENT SCREENS
VENT TERMINALS

COMPLEX 3 D ASSEMBLY

BENCHES
BERTHS
BOXES
COUNTERS
COUPLING GUARD
HOODS
LOCKERS
LOUVERS
SINKS
STOWAGES

FIGURE III-7
SHEET METAL FABRICATION
INTERIM PRODUCT/CONSTRUCTION
PROCESS MATRIX

MAA 4/12/85

D/25 CARPENTER SHOP

PRODUCT	QUEUE	CUTTING	FORMING	O&QC	ASSEMBLY	JOINING	FINISHING	QA	KITTING
LINEAL GOODS	LIN FT								
LUMBER WIRE ROPE ROPE STRAPS CHAINS TUBING	RECEIVE STORE DRAW MOVE	CUTTING SAWING	PLANING SANDING DRILLING MILLING BENDING SHAPING EDGE JOINTING	TO WOOD PRODUCTS TO LIFESAVING EQUIP TO RIGGING & HANDLING EQUIP TO HULL OUTFIT ASSEMBLY TO KITTING				INSPECT STATUS REPORT	SORT PALLET BOX STORE SHIP
SHEET GOODS	SQ FT	—	—	—	—	—	—	—	—
PLYWOOD CANVAS RUBBER FORMICA BENELIX ALUMINUM	RECEIVE STORE DRAW MOVE	CUTTING SAWING	PLANING SANDING DRILLING MILLING SHAPING EDGE JOINTING	TO WOOD PRODUCTS TO LIFESAVING EQUIP TO RIGGING & HANDLING EQUIP TO HULL OUTFIT ASSEMBLY	SEWING	ASSEMBLE		INSPECT STATUS REPORT	SORT PALLET BOX STORE
KEVLAR	SQ FT	—	—	—	—	—	—	—	—
	RECEIVE STORE DRAW MOVE	CUTTING SAWING		TO KITTING				INSPECT STATUS REPORT	SORT PALLET BOX STORE SHIP
INSULATION	SQ FT	—	—	—	—	—	—	—	—
ACOUSTICAL FIREPROOF SOUNDPROOF THERMAL	RECEIVE STORE DRAW MOVE	CUTTING SAWING		TO KITTING				INSPECT STATUS REPORT	STORE PICK TRAILER SHIP
PURCHASED COMPONENTS FOR ASSEMBLY	—	—	—	QUANTITY	—	—	—	—	—
FASTNERS FITTINGS TURNBUCKLES GLUE ADHESIVES				TO WOOD PRODUCTS TO LIFESAVING EQUIP TO RIGGING & HANDLING EQUIP TO HULL OUTFIT ASSEMBLY					
WOOD PRODUCTS	—	—	—	QUANTITY	—	—	—	—	—
CRIBBING & SHORING STAGING PLATFORMS & RAMPS LADDERS WOODEN GRATING STORES & CARGO BATTENS DAMAGE CONTROL SHORING POPPETS				FROM LINEAL GOODS FROM SHEET GOODS FROM PURCHASE FOR ASSEMBLY	LAYOUT POSITION ASSEMBLE	JOINING	COATING	INSPECT STATUS REPORT	SORT BOX STORE SHIP
LIFESAVING EQUIPMENT	—	—	—	QUANTITY	—	—	—	—	—
SAFETY NETS LIFELINES GRP RAILS STANCHIONS, SOCKETS				FROM LINEAL GOODS FROM PURCHASED FOR ASSEMBLY	LAYOUT ASSEMBLE TACK CRIMP BOLT	JOIN TACK CRIMP BOLT	POSITION WELD INSPECT PICK UP	INSPECT STATUS REPORT	BOX OR PALLET STORE PICK TRUCK
RIGGING & HANDLING EQUIPMENT	—	—	—	LIN FT	—	—	—	—	—
SLINGS				FROM LINEAL GOODS FROM PURCHASED FOR ASSEMBLY	SEWING SWEDGING BOLTING SPLICING	JOINING			KIT
OTHER HULL OUTFIT ASSEMBLY	—	—	—	QUANTITY	—	—	—	—	—
LADDERS ROPE & WOOD AWNINGS PROTECTIVE COVERS				FROM LINEAL GOODS FROM SHEET GOODS FROM PURCHASED FOR ASSEMBLY	LAYOUT POSITION ASSEMBLE	JOIN	FINISH	INSPECT STATUS REPORT	KIT

FIGURE III-8
MISCELLANEOUS FABRICATION
INTERIM PRODUCT/CONSTRUCTION
PROCESS MATRIX

MAA 4 12 85

D .9 OUTSIDE MACHINE SHOP

PRODUCT	QUEUE	CUTTING	BENDING	Q&OC	ASSEMBLY	JOINING	FINISHING	QA	KITTING
GRATING	LIN FT								
STEEL ALUMINUM DIAMOND PLATE	DRAW	SAW BURN		TO KITTING TO GRATING ASSEMBLY TO OUTFIT PACKAGE				INSPECT STATUS REPORT	KIT TRANSPORT
OPERATING GEAR MATERIAL	LIN FT	—	—	—	—	—	—	—	—
	DRAW	SAW		TO KITTING TO OPERATING GEAR ASSEMBLY TO OUTFIT PACKAGE				INSPECT STATUS REPORT	KIT TRANSPORT
SHAPES	LIN OR SQ FT	—	—	—	—	—	—	—	—
I BEAM ANGLE BAR FLAT BAR ROUND BAR	DRAW	CUT	BEND	TO KITTING TO GRATING ASSEMBLY TO OUTFIT PACKAGE				INSPECT STATUS REPORT	KIT TRANSPORT
WIRE ROPE	LIN FT	—	—	—	—	—	—	—	—
	DRAW	CUT		TO KITTING TO CO2 PULL ASSEMBLY				INSPECT STATUS REPORT	KIT TRANSPORT
PURCHASED FOR ASSEMBLY	—	—	—	QUANTITY	—	—	—	—	—
				TO GRATING ASSEMBLY TO OPERATING GEAR ASSEMBLY TO CO2 PULL ASSEMBLY TO OUTFIT PACKAGE				INSPECT STATUS REPORT	KIT TRANSPORT
GRATING ASSEMBLY	—	—	—	SQ FT	—	—	—	—	—
				FROM GRATING FROM PURCHASED FROM HARDINGS FROM SHAPES	LAYOUT ASEMBLE TACK	JOIN SECTIONS TRIAL FIT GRATING	WELD BOLT DISASSEMBLE	INSPECT STATUS REPORT	KIT TRANSPORT
OPERATING GEAR ASSEMBLY	—	—	—	LIN FT	—	—	—	—	—
				FROM OPERATING GEAR FROM D 07 MACHINE SHOP FROM PURCHASED	LAYOUT ATTACH FITTINGS			INSPECT STATUS REPORT	KIT TRANSPORT
CO2 PULL ASSEMBLY	—	—	—	LIN FT	—	—	—	—	—
				FROM WIRE ROPE FROM PURCHASED	LAYOUT ATTACH FITTINGS	ASSEMBLE		INSPECT STATUS REPORT	KIT TRANSPORT
OUTFIT PACKAGE	—	—	—	LIN FT	—	—	—	—	—
				FROM PURCHASED FROM HARDINGS FROM MACHINE SHOP FROM GRATING FROM SHAPES FROM GRATING ASSEMBLY FROM OPERATING GEAR ASSEMBLY	LAYOUT ASSEMBLE	BOLT ASSEMBLIES		INSPECT STATUS REPORT	KIT TRANSPORT
LABEL PLATES	—	—	—	QUANTITY	—	—	—	—	—
				FROM PURCHASED	LAYOUT PHOTO PRINT ENGRAVE TYPE PRINT		SHEAR CLEAN COATINGS	INSPECT STATUS REPORT	KIT TRANSPORT

FIGURE III-9
MISCELLANEOUS FABRICATION
INTERIM PRODUCT/CONSTRUCTION
PROCESS MATRIX

SECTION IV
INTERIM PRODUCT FLOW

SECTION IV
INTERIM PRODUCT FLOW

A. Introduction

The material in a fabrication shop spends more of its time in queue or moving from one work site to another than does material in a machine shop. The flow of material, as well as the queue time, must be known for each interim product family in order to assign schedule durations for each of these products. In addition, in a shop where Group Technology (GT) has not been applied to the recognition of interim product similarities, such products are generally handled as unique items and, hence, any data that may have been accumulated to record work site efficiencies or cycle time will vary widely. Once the flow path for "value added" work sites, for a particular interim product family, are established, the processes can be analyzed, and changes with known impacts can be accomplished to improve the productivity.

In developing data for a shipyard Computer Aided Process Planning (CAPP) system at BIW it was apparent in all shops, from a shop floor perspective, that the flow path options for material between actual work sites were nearly infinite. However, when viewed from a GT perspective, the problem became manageable. Once again, it was the application of an old technology to form the base for the CAPP triangle.

B. Interim Product Flow Logic

As in any Industrial Engineering analysis of a material flow problem, the present flow had to be determined. Using the fabrication plant layouts, the interim product flow paths were added. A natural result of this effort was the identification of "bottlenecks" and "multiple travel paths". The rearrangement of the facility and/or improved organization of material can frequently result in improved interim product flow. As a result of identifying the present material flow, a future material flow layout was prepared. This was simply a plant layout with an improved or hopefully "optimum" material flow indicated on the layout. The process of drawing such layouts resulted in the identification of travel distances, "value added work sites", travel times, handling frequencies and queue times. All of this information is essential for the development of an effective CAPP system.

In parallel with the material flow layout development, interim product flow diagrams were produced as an expansion of the interim product/ construction process matrices. Separate flow diagrams were developed for each interim product family with all potential process paths displayed. The flow diagrams were used to analyze the "value added" activities that occur for each product. The term "value added" refers to those processes which add to the worth of the interim product such as cutting a bar or plate to size, shaping a bar or plate, and/or joining two or more pieces together to form an assembly. This effort also identified "bottlenecks'* in the process flow. This was determined by applying the most probable manning and efficiency rates for a specific work site against the work to be completed at that site. The bottleneck is the work site with the longest cycle time.

C. Sample Interim Product Flow Diagrams

Completed material flow diagrams provided the information necessary to identify the "value added" points in the material flow. These points or work sites were identified on the flow diagram. Example diagrams are presented for the structural fabrication shop .

D. Sample Interim Product Flow Layouts

The following layouts are representative of the BIW fabrication process. It was readily apparent that learning curve efficiencies could be achieved over a short period of time by maintaining a consistent flow within a shop . It also became apparent that the supervisors of shop floor flow control had frequently made changes in a sincere effort to improve productivity without first analyzing the impact of such changes.

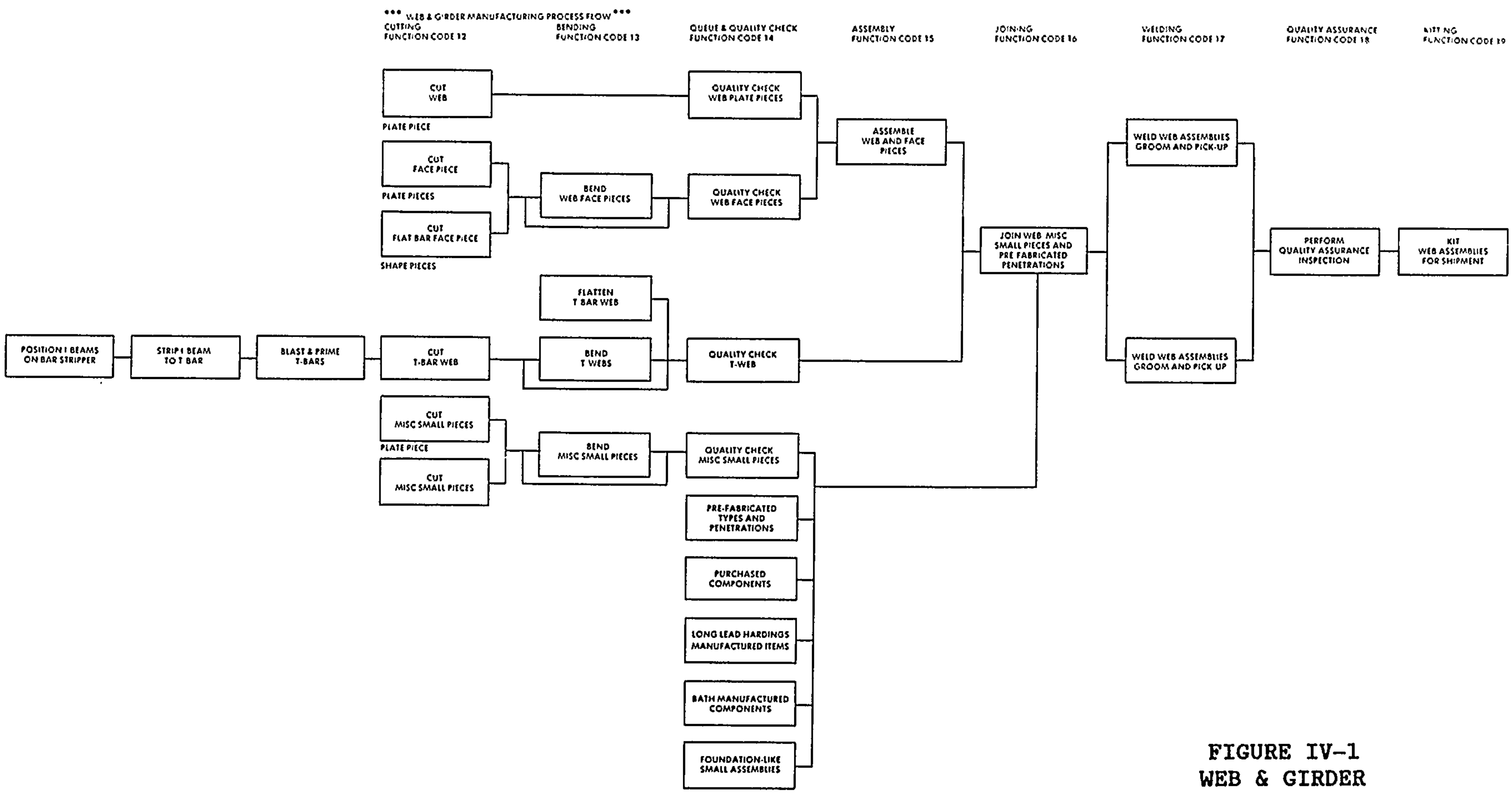


FIGURE IV-1
WEB & GIRDER
MANUFACTURING FLOW DIAGRAM

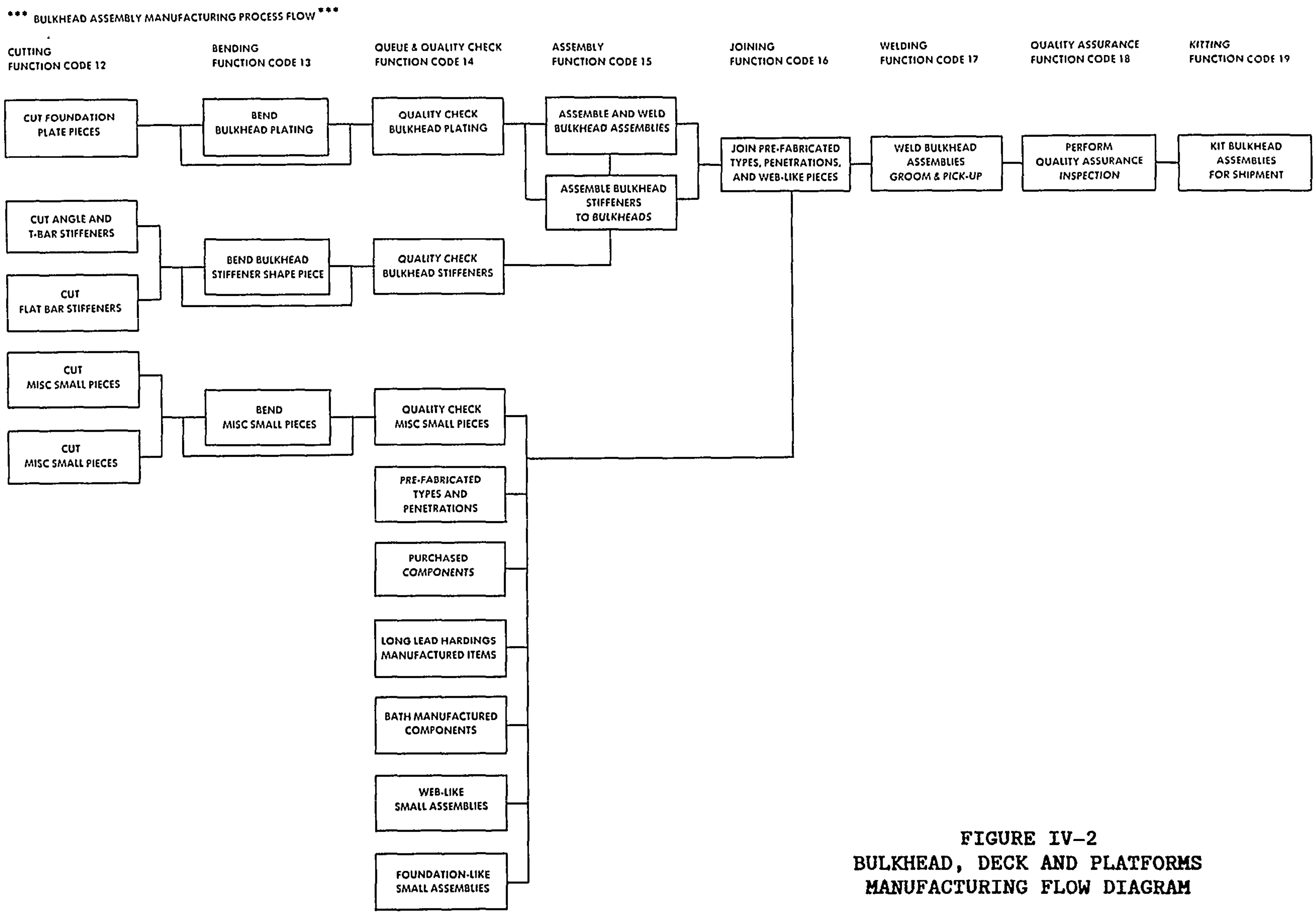


FIGURE IV-2
BULKHEAD, DECK AND PLATFORMS MANUFACTURING FLOW DIAGRAM

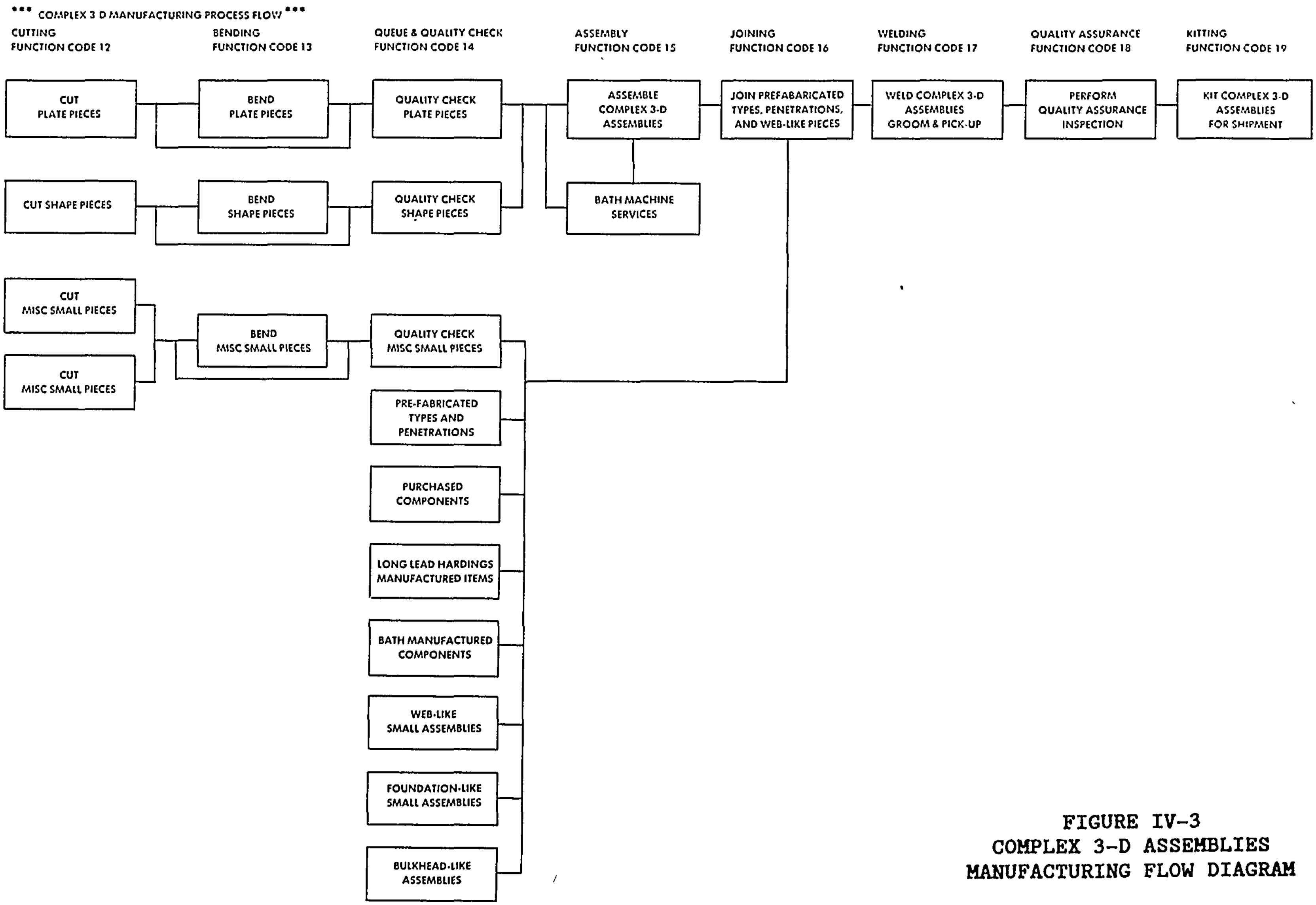


FIGURE IV-3
COMPLEX 3-D ASSEMBLIES
MANUFACTURING FLOW DIAGRAM

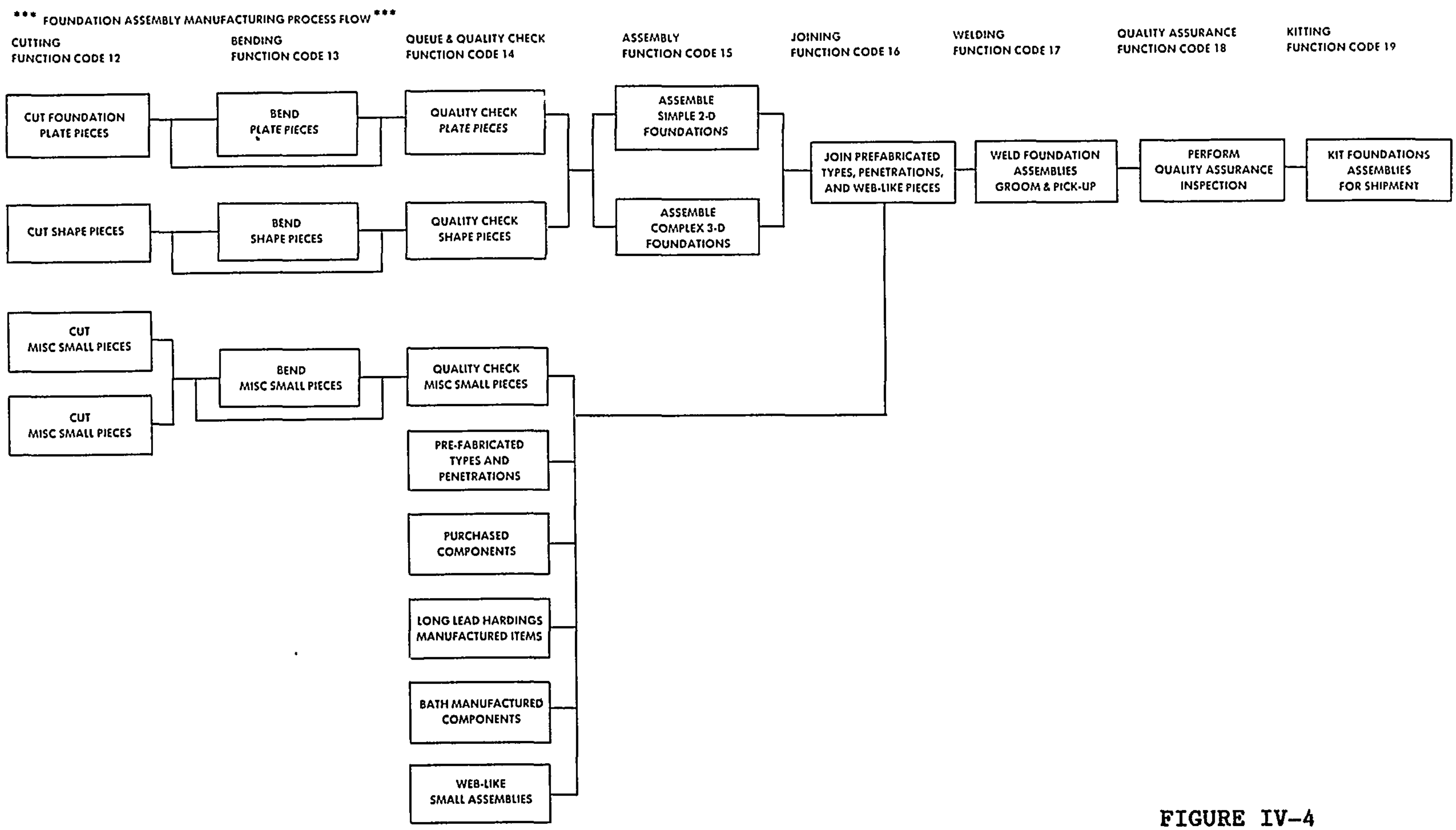
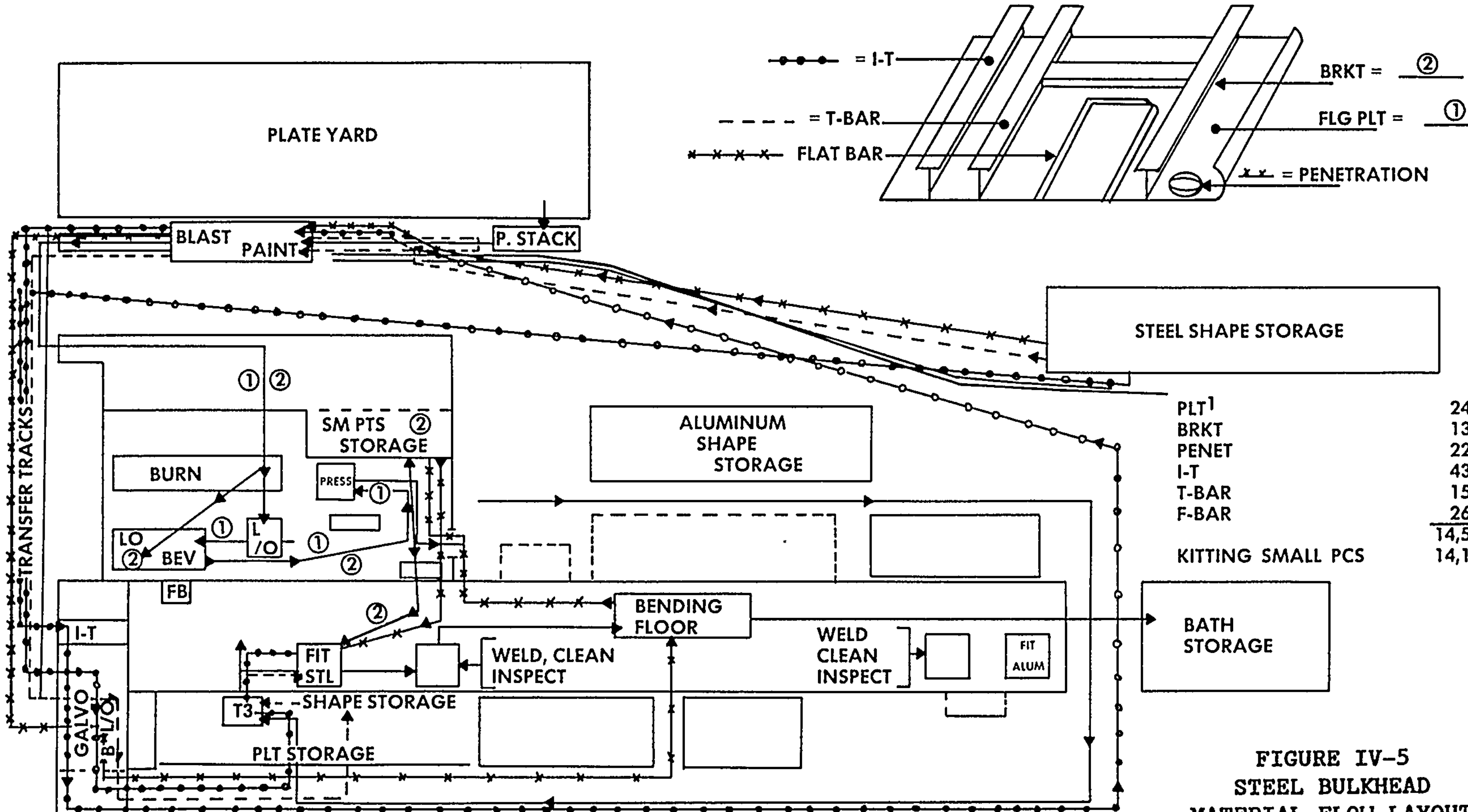


FIGURE IV-4
SMALL 3-D ASSEMBLIES
MANUFACTURING FLOW DIAGRAM

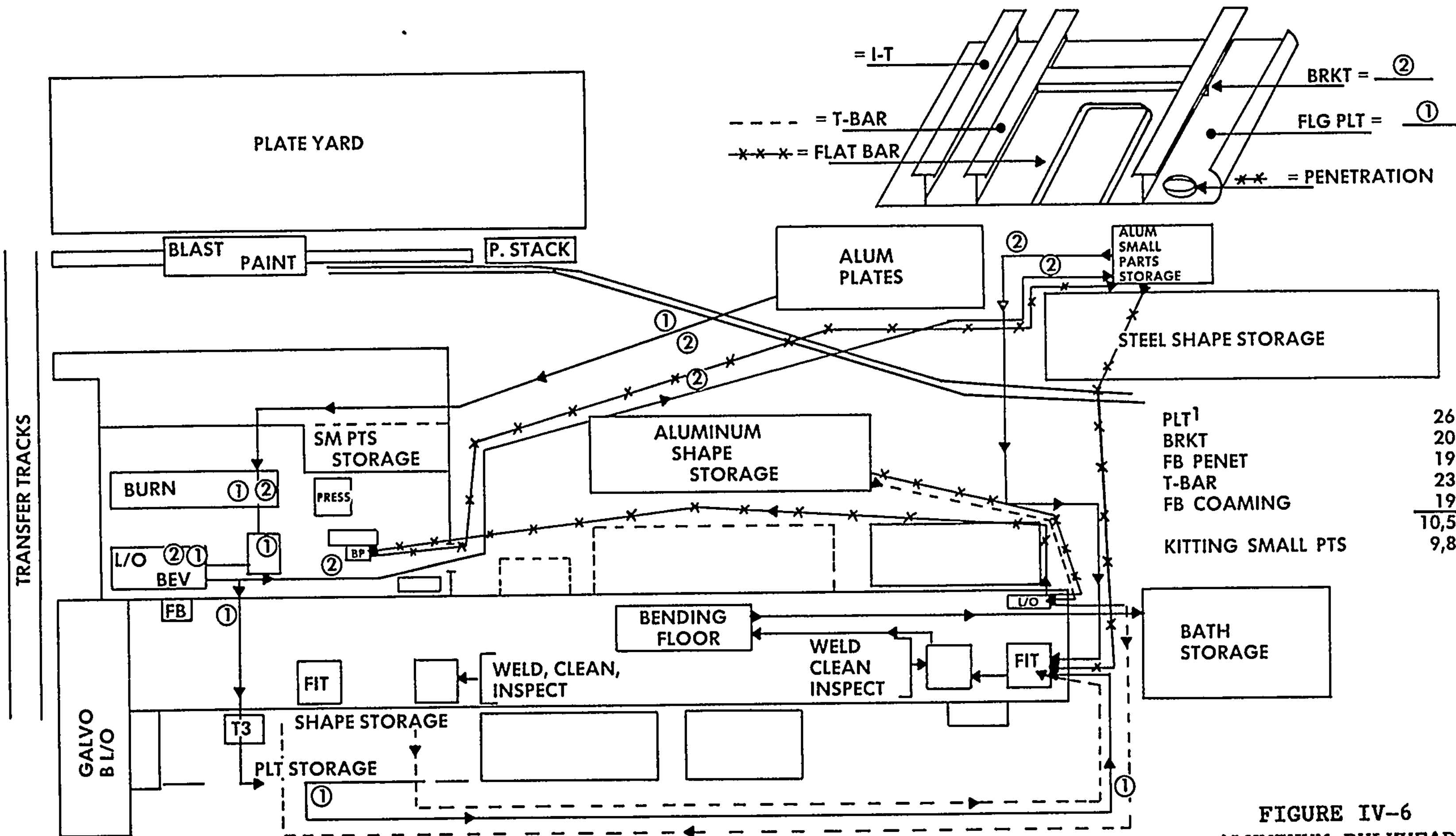
BHD - STEEL



PLT[1]	2400 FT
BRKT	1300 FT
PENET	2295 FT
I-T	4330 FT
T-BAR	1540 FT
F-BAR	2660 FT
	14,525 FT
KITTING SMALL PCS	14,125 FT

FIGURE IV-5
STEEL BULKHEAD
MATERIAL FLOW LAYOUT
(PRESENT)

BHD - ALUMINUM



PLT[1]	2635 FT
BRKT	2010 FT
FB PENET	1940 FT
T-BAR	2300 FT
FB COAMING	1940 FT
	10,525 FT
KITTING SMALL PTS	9,895 FT

FIGURE IV-6
ALUMINUM BULKHEAD
MATERIAL FLOW LAYOUT
(PRESENT)

T-WEB - STEEL

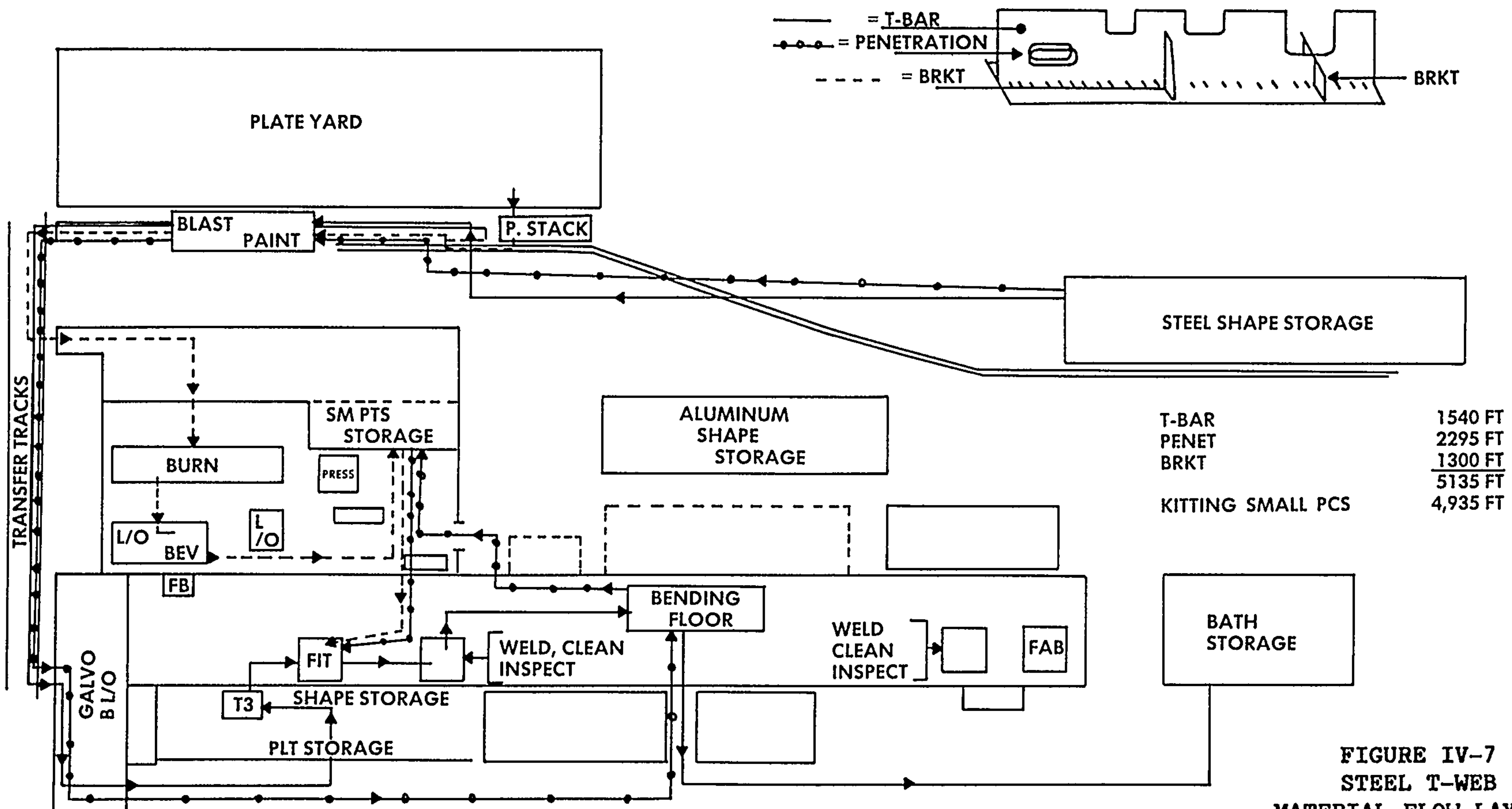


FIGURE IV-7
STEEL T-WEB
MATERIAL FLOW LAYOUT
(PRESENT)

T-WEB - ALUMINUM

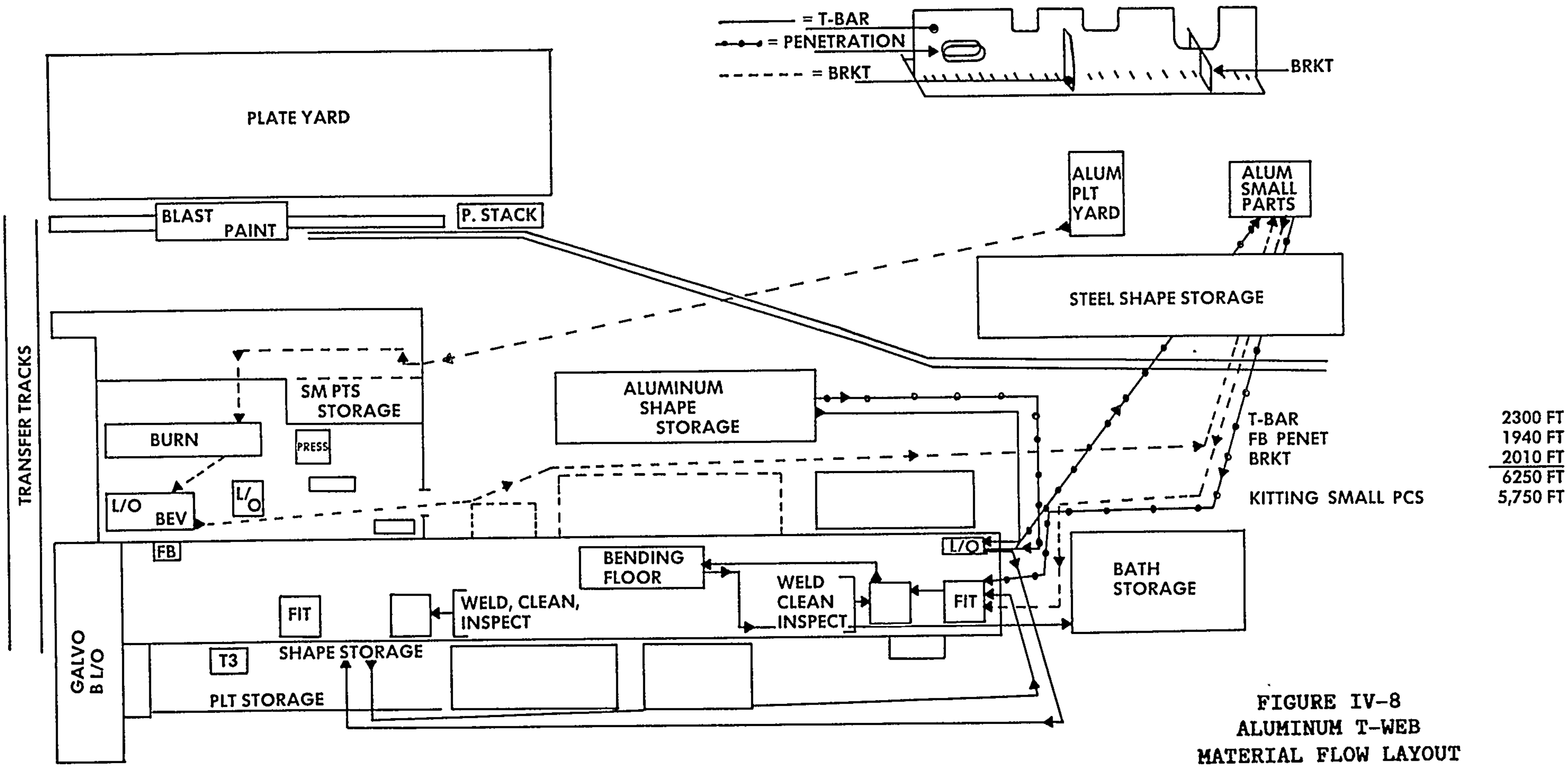


FIGURE IV-8
ALUMINUM T-WEB
MATERIAL FLOW LAYOUT
(PRESENT)

T-WEB, SHAPED - STEEL

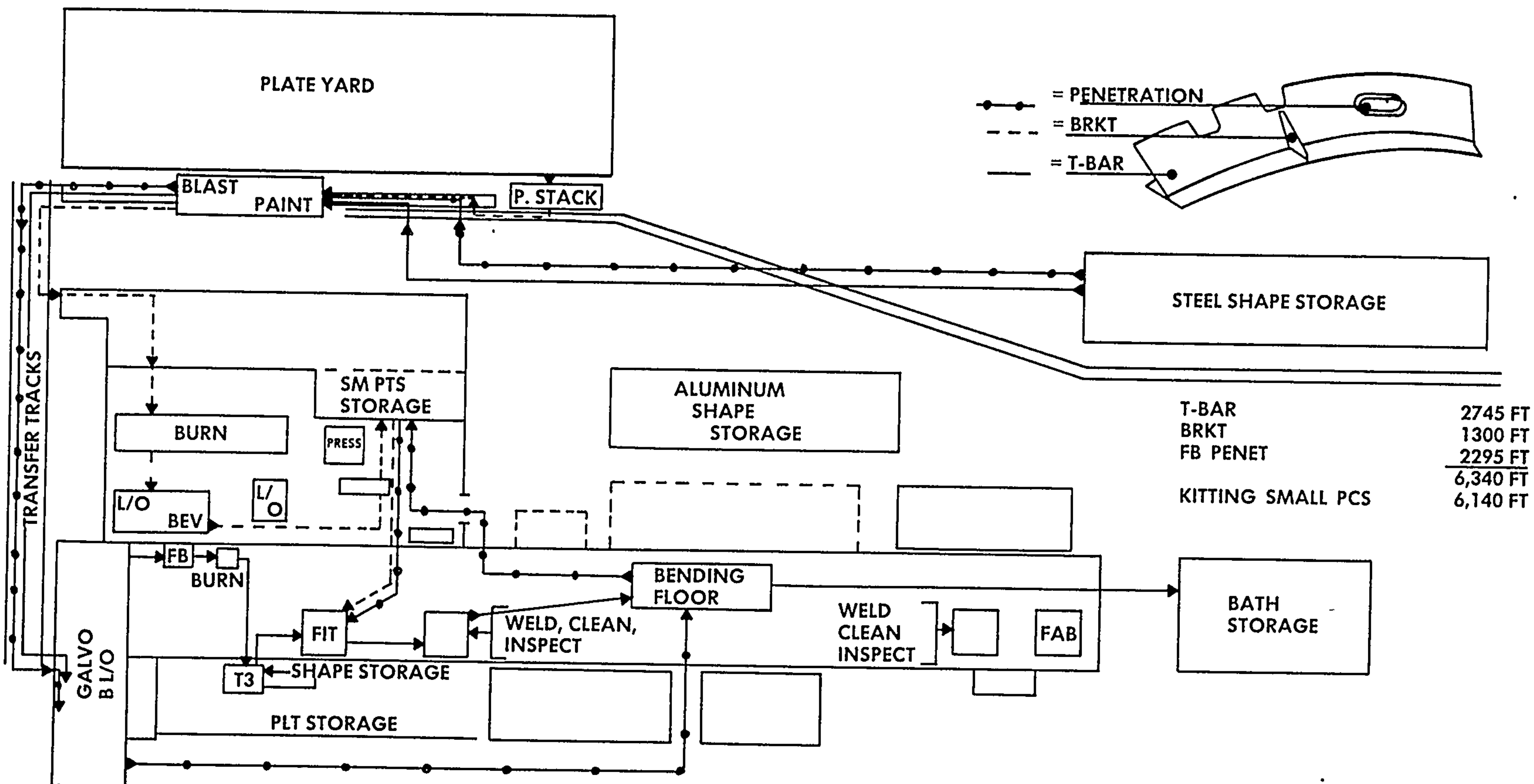


FIGURE IV-9
STEEL T-WEB SHAPED
MATERIAL FLOW LAYOUT
(PRESENT)

BUILT-UP WEB - STEEL

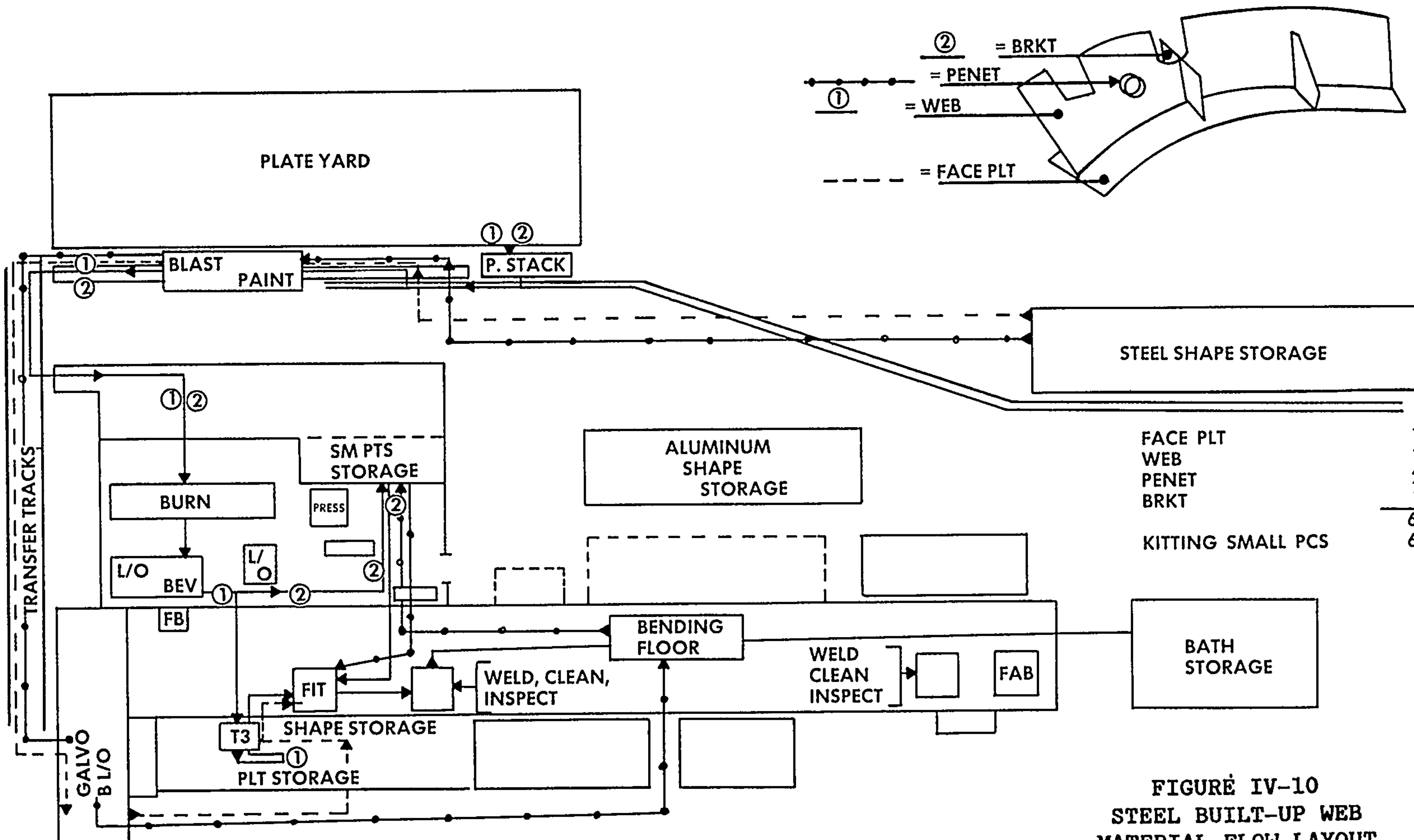


FIGURE IV-10
STEEL BUILT-UP WEB
MATERIAL FLOW LAYOUT
(PRESENT)

BUILT-UP WEB - ALUMINUM

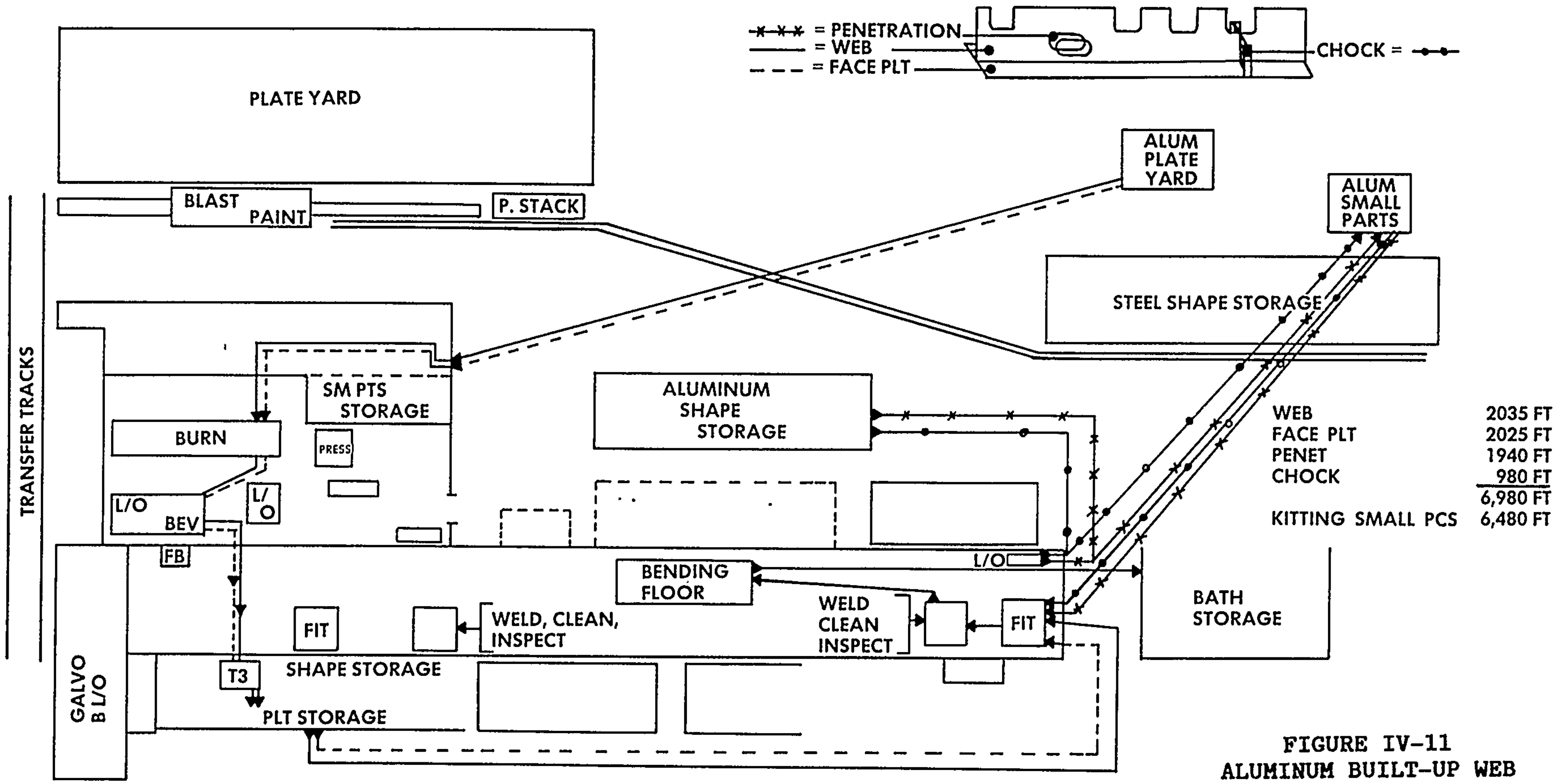
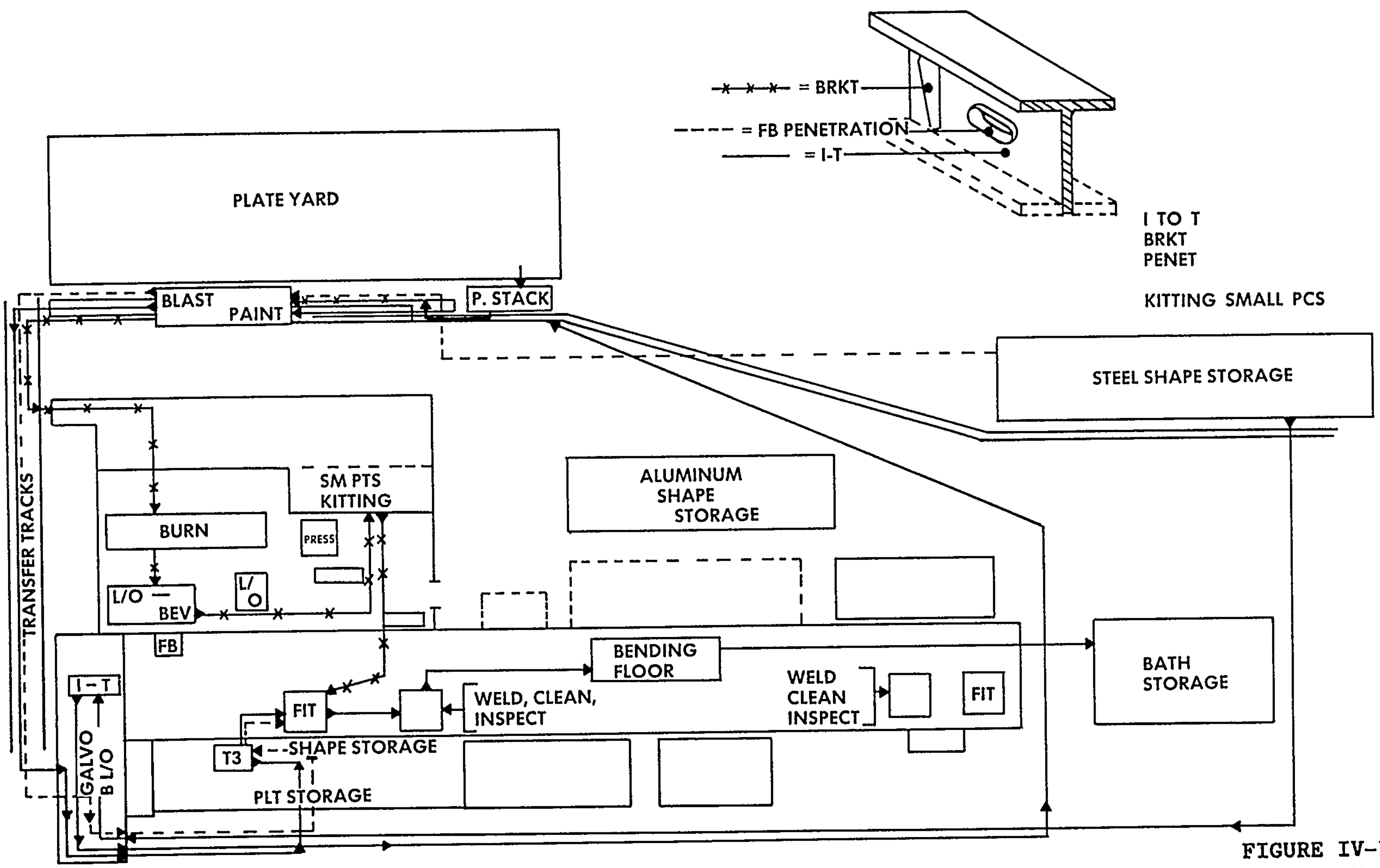


FIGURE IV-11
ALUMINUM BUILT-UP WEB
MATERIAL FLOW LAYOUT
(PRESENT)

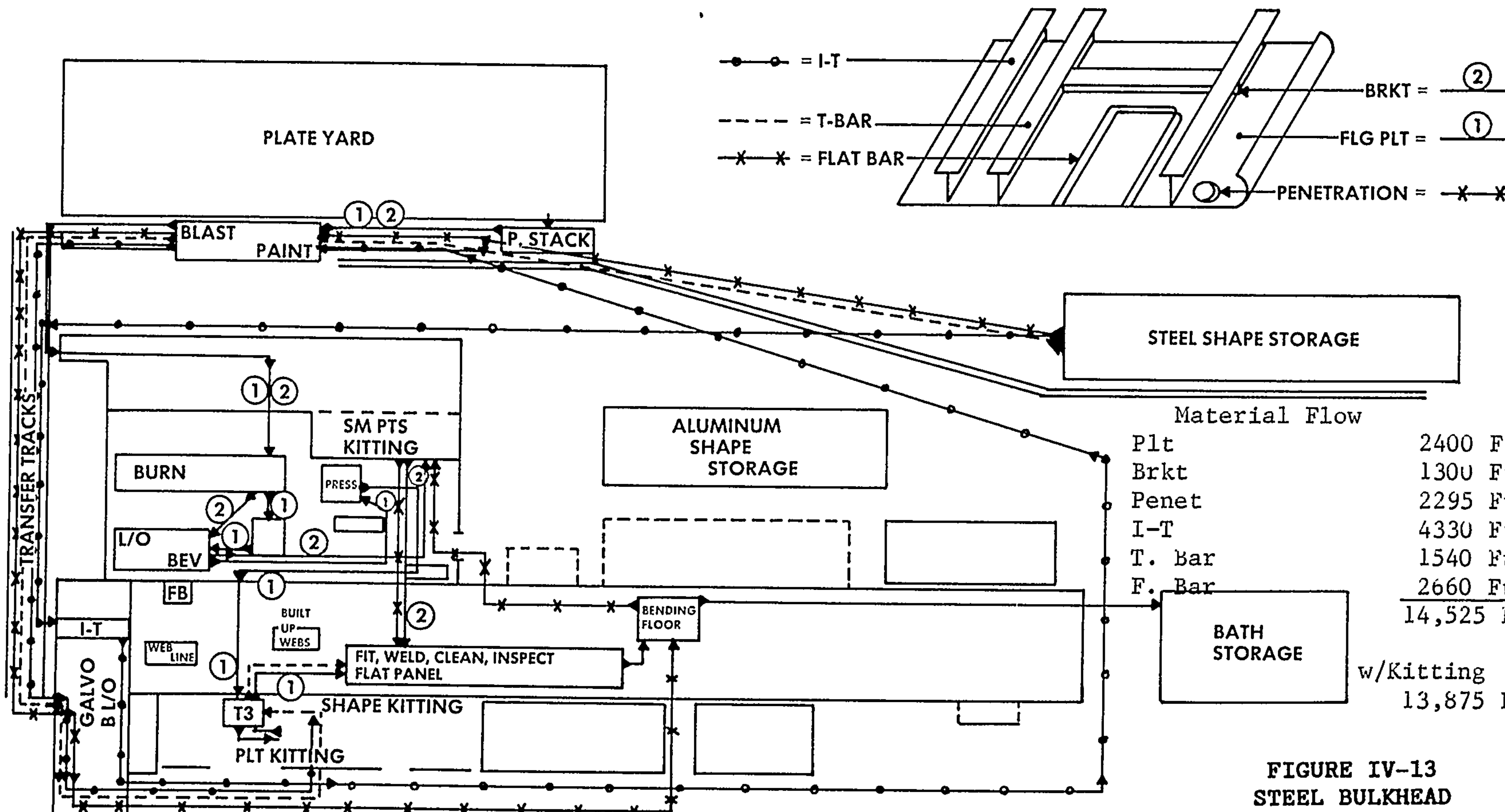
I TO T



I TO T	4330 FT
BRKT	1300 FT
PENET	2295 FT
	7,925 FT
KITTING SMALL PCS	7,725 FT

FIGURE IV-12
I TO T
MATERIAL FLOW LAYOUT
(PRESENT)

BULKHEAD
STEEL

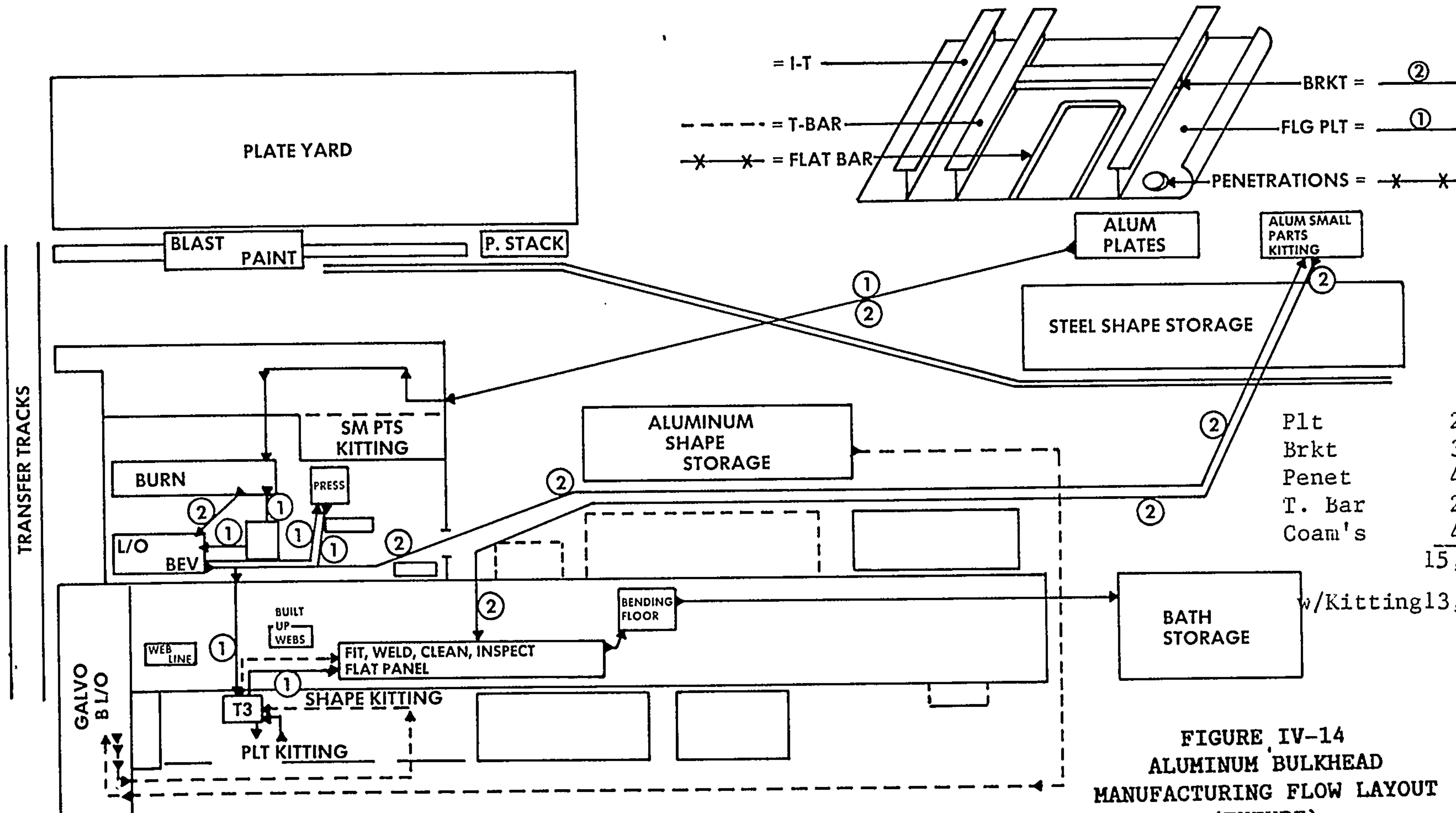


Material Flow

Plt	2400 Ft
Brkt	1300 Ft
Penet	2295 Ft
I-T	4330 Ft
T. Bar	1540 Ft
F. Bar	2660 Ft
	14,525 Ft
w/Kitting	13,875 Ft

FIGURE IV-13
STEEL BULKHEAD
MANUFACTURING FLOW LAYOUT
(FUTURE)

BULKHEAD
ALUMINUM



Plt	2085 Ft
Brkt	3060 Ft
Penet	4390 Ft
T. Bar	2000 Ft
Coam's	4390 Ft
	15,925 Ft
w/Kitting	13,195 Ft

FIGURE IV-14
ALUMINUM BULKHEAD
MANUFACTURING FLOW LAYOUT
(FUTURE)

T-WEB
STEEL

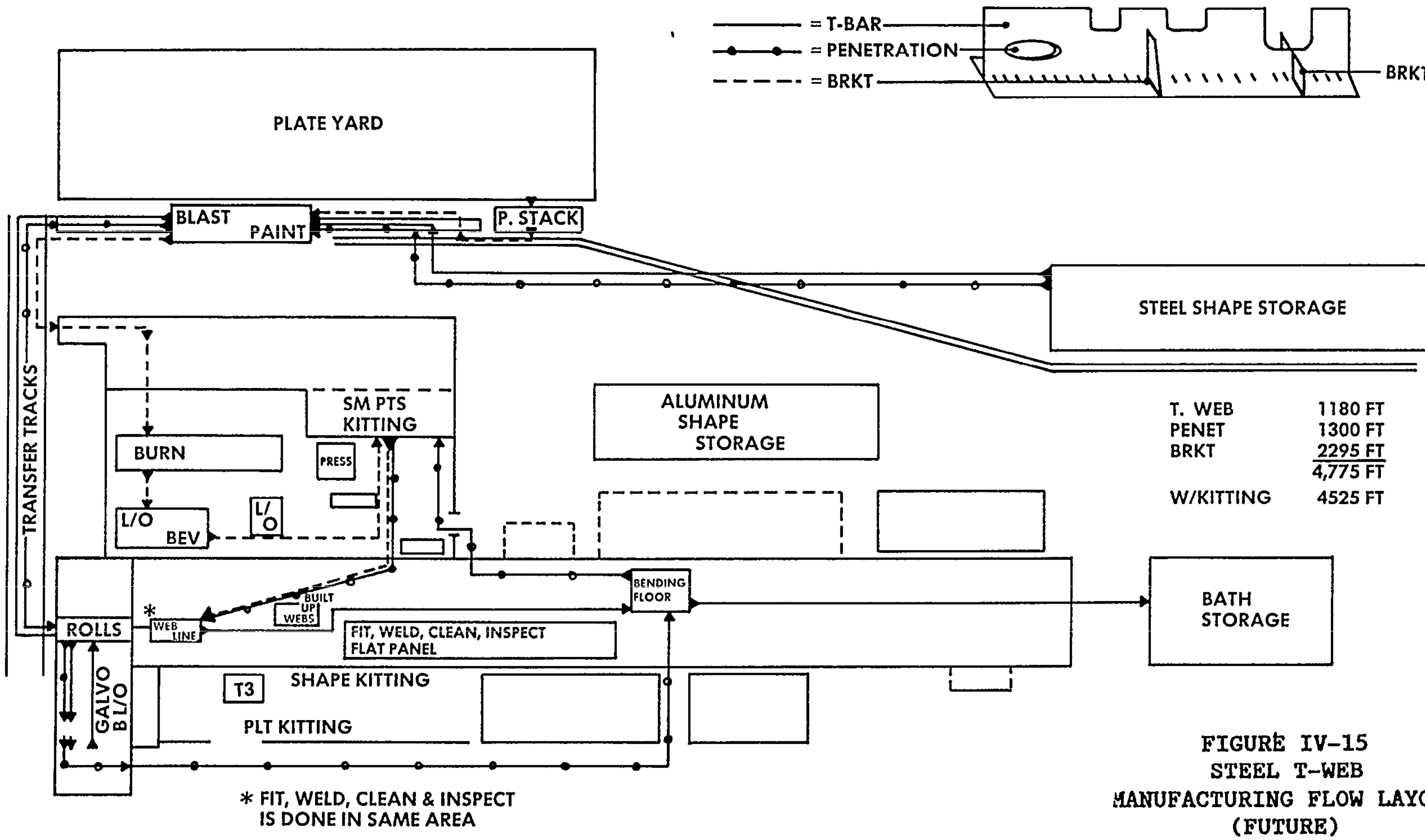


FIGURE IV-15
STEEL T-WEB
MANUFACTURING FLOW LAYOUT
(FUTURE)

T-WEB
ALUM

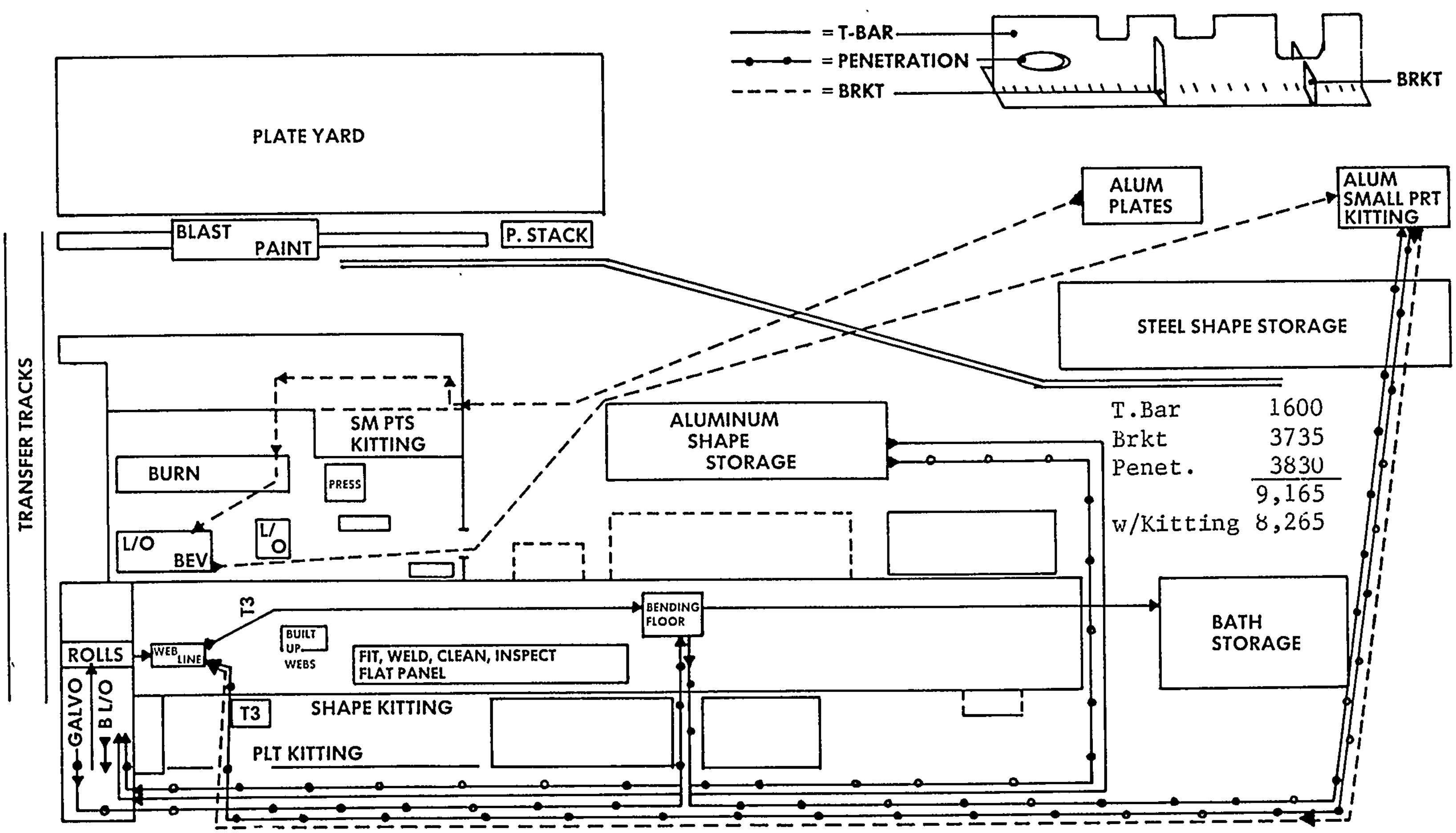


FIGURE IV-16
ALUMINUM T-WEB
MANUFACTURING FLOW LAYOUT
(FUTURE)

T-WEB, SHAPED
STEEL

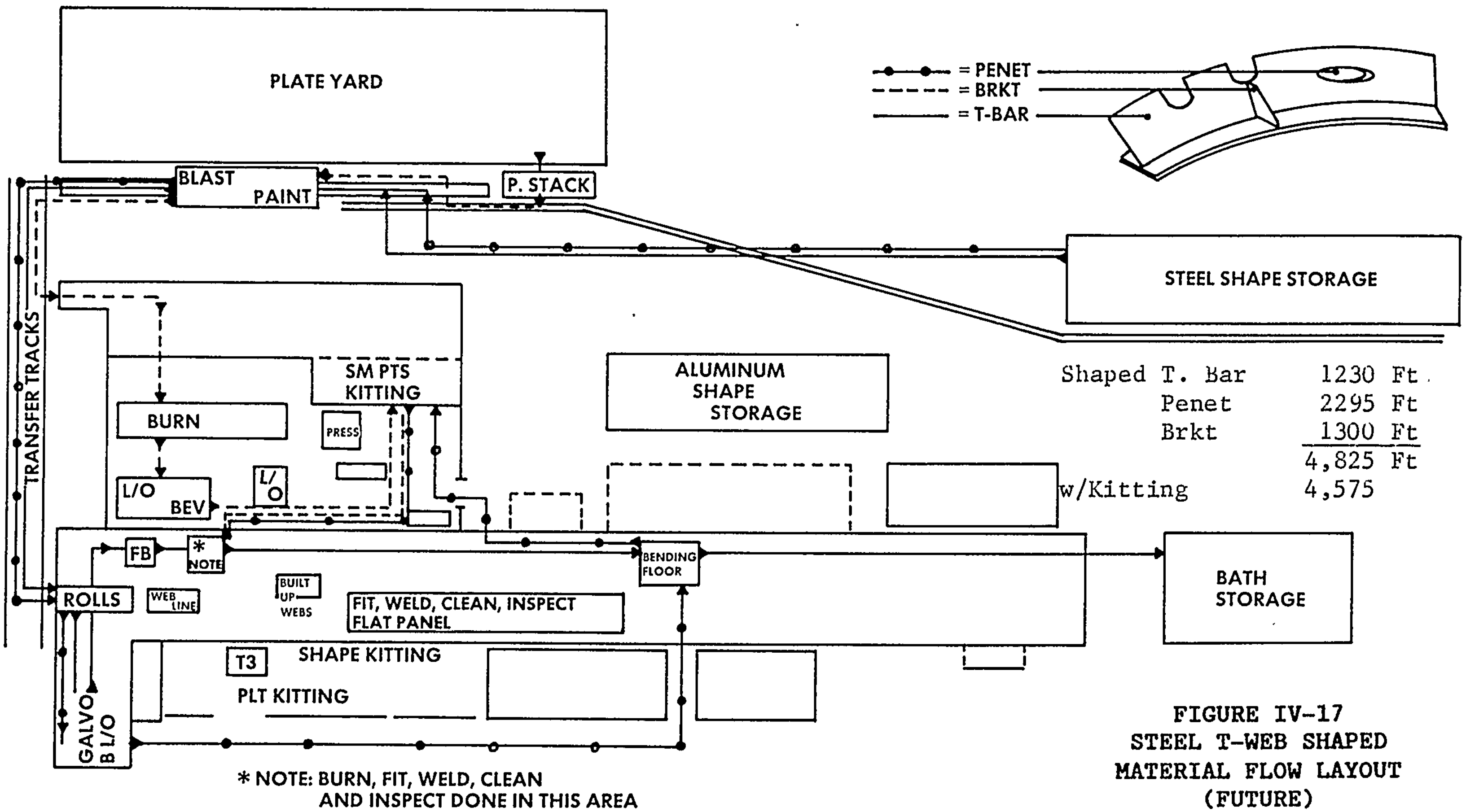
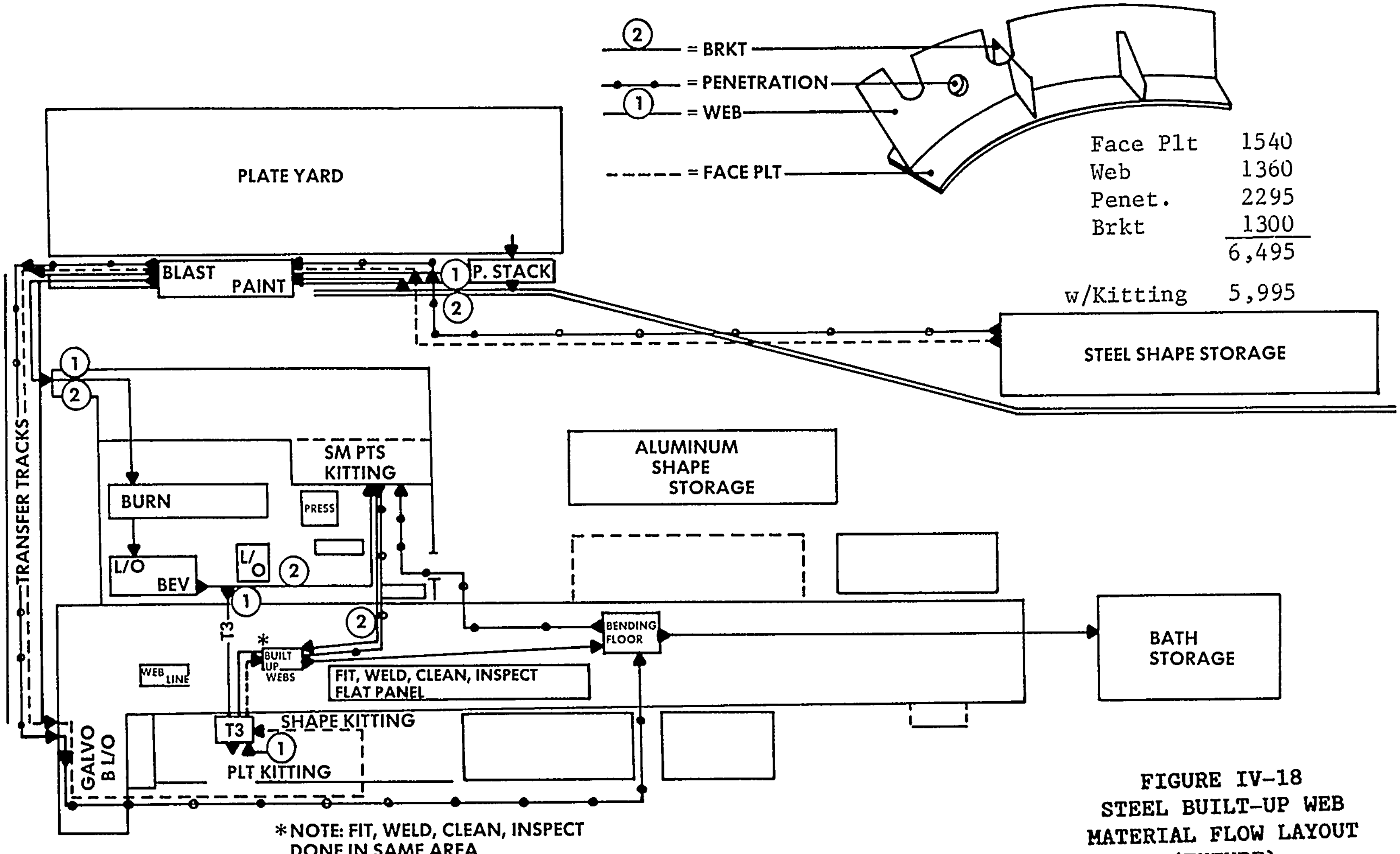


FIGURE IV-17
STEEL T-WEB SHAPED
MATERIAL FLOW LAYOUT
(FUTURE)

BUILT-UP WEB
STEEL



Face Plt	1540
Web	1360
Penet.	2295
Brkt	1300
	6,495
w/Kitting	5,995

*NOTE: FIT, WELD, CLEAN, INSPECT DONE IN SAME AREA

FIGURE IV-18
STEEL BUILT-UP WEB
MATERIAL FLOW LAYOUT
(FUTURE)

BUILT-UP WEB
ALUM

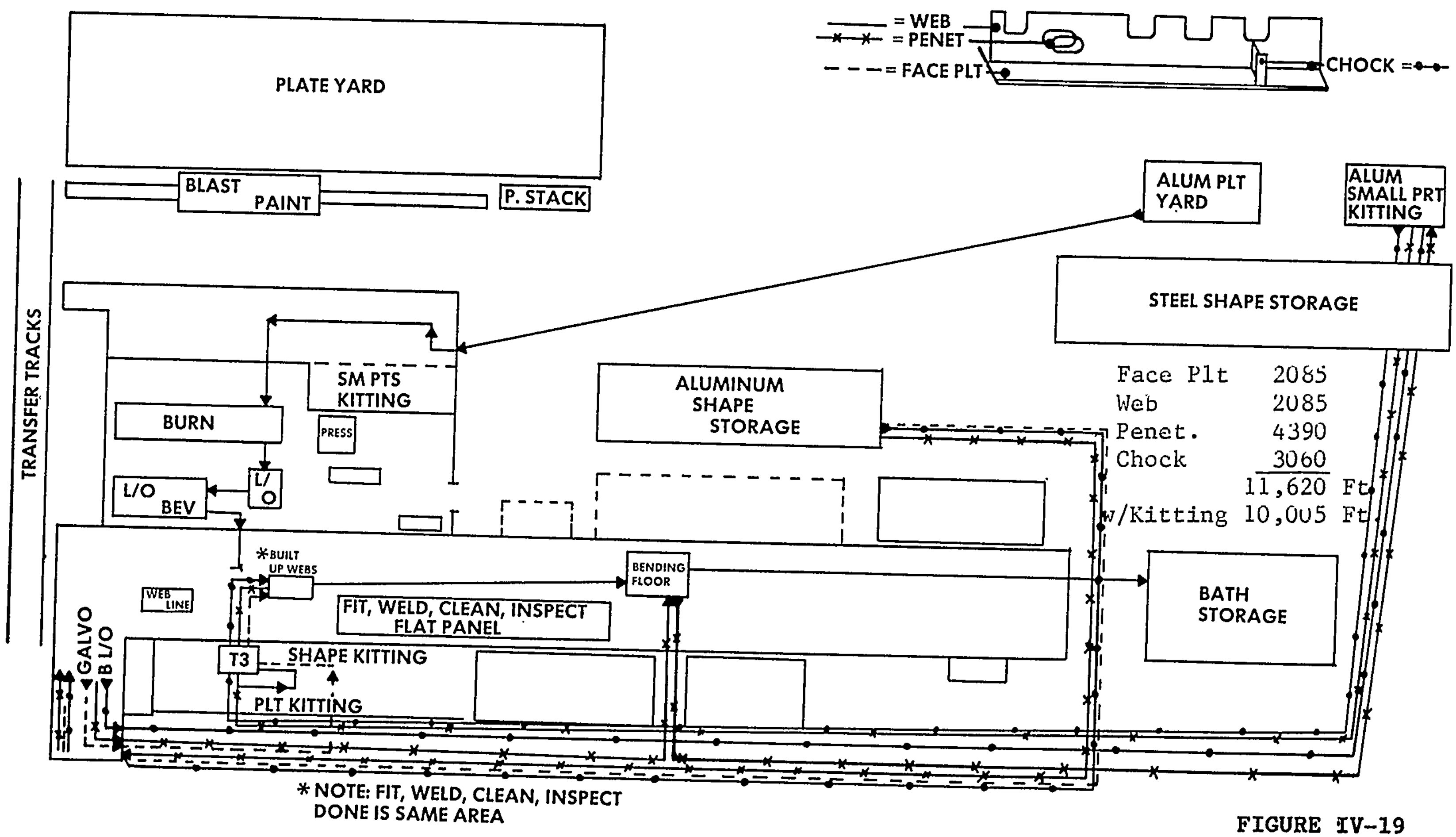


FIGURE IV-19
ALUMINUM BUILT-UP WEB
MATERIAL FLOW LAYOUT
(FUTURE)

I-T

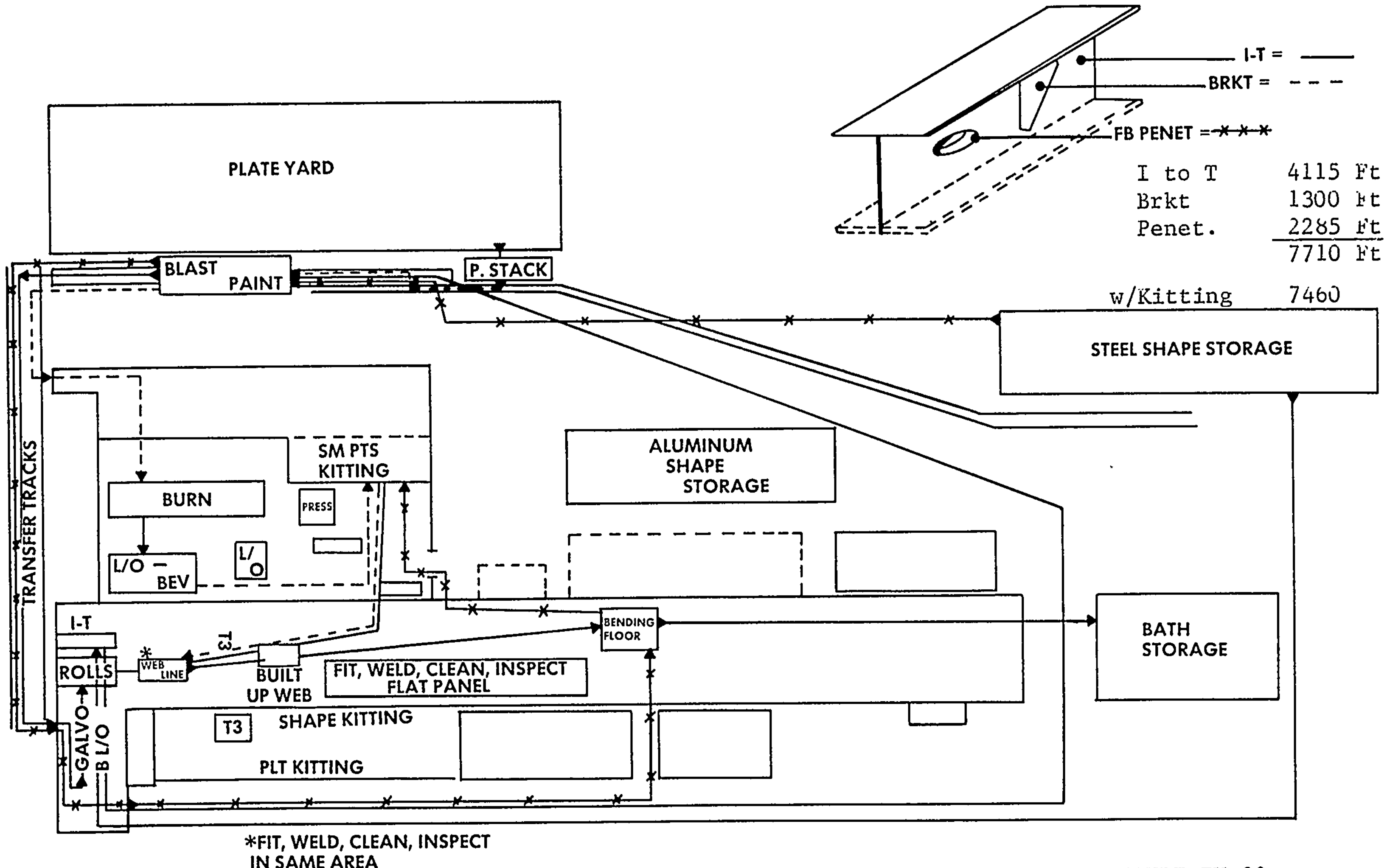


FIGURE IV-20
I TO T
MATERIAL FLOW LAYOUT
(FUTURE)

FIGURE IV-21
PIPE SHOP PROCESS FLOW DIAGRAM DESCRIPTION

Process 1 - 2

(1) Material is received through the West Door and moved to the (2) Stockroom for storage.

(2) Material is moved from the Stockroom out to the Floor (3) in Assembly Package kits for fabrication.

(3) Material is picked up by the mechanic and moved to the Fab bench area (15) or (33).

Process 10 - 20: Ferrous Pipe ±2.5″ & Non Ferrous Pipe ±4.5"

(10) Pipe enters Shop through West Door and is stored on the Rack (11) .

(11) Pipe moves from the Rack to the Cut Off Saw (12).

(12) Pipe moves from the saw to the Bending Area (13) for bending, or is left straight and moves to temporary storage (14).

(13) Pipe is bent and then joins the straight pipe in storage (14) or is moved outside to the Bent Storage Area (21).

(4,21) The mechanic moves the pipe for his job to the Fab Bench (15) to join the material. The bent pipe is first cleaned in the Pennsolve Tank and then moved to the Fab Bench (15).

(15) As Fabrication is in process, sections are moved to the Brazing Bench (16) for brazing.

(16) After brazing, sections are moved to the Sulphuric Acid Bath (17) for cleaning, and then back to the bench (15). This loop may occur several times for a pipe piece.

(15) Brazed joints are moved to the NDT station (18) for inspection and then returned to the bench (15).

(15) Finished pieces are prepared for storage and placed in a stack (19) for delivery to the Northward Flat (25).

Process 30 - 36: Ferrous Pipe ± & Non Ferrous Pipe ±4"

(30) Pipe is moved through the wall from the Pipe Yard to the Plasma Table (31) for cut and moved to Temporary Storage (32).

(32) Straight pipe moves to the Fab Bench (33) while the remainder moves to the bending area (13).

FIGURE IV-21
PIPE SHOP PROCESS FLOW DIAGRAM DESCRIPTION

(32) After bending, the pipe is moved back to the Temporary Storage area (32) and then on to the Pennsolve Tank (20).

(20) After cleaning, the bent pipe joins the straight pipe and the material at the fab bench (33).

(33) During the fab process, sections are placed in queue for welding (34) .

(34) Welded joints are inspected in the X-ray area (35) for P1 pipe & returned to the welding area for additional work or back to the bench (33) for continuation of the fab process. This loop may occur several times for each pipe piece.

(34) Non P1 pipe (P3, P3A) does not require X–ray inspection and is returned to the fab bench (33).

(33) Completed pieces are stacked (36) for collection and delivery to the North Yard Flat (25).

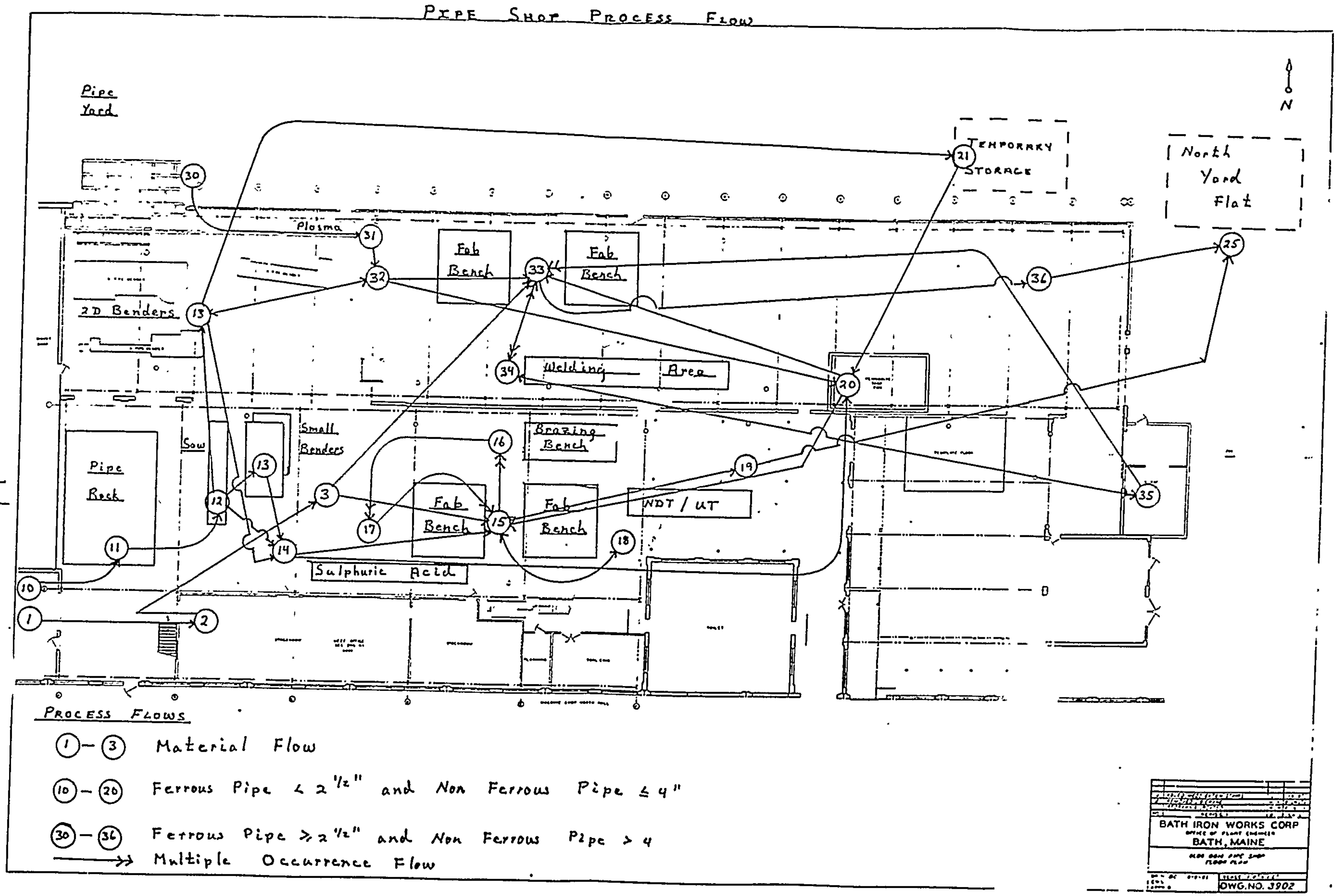


FIGURE IV-21
PIPE SHOP PROCESS
FLOW DIAGRAM
(PRESENT)

SECTION V
IMPACT ANALYSES OF COMPUTER AIDED PROCESS PLANNING

SECTION V
IMPACT ANALYSES OF COMPUTER AIDED PROCESS PLANNING

A. Introduction

As shown in Figure III–2, Computer Aided Process Planning (CAPP) has an impact on all phases of the shipbuilding process. Some work areas, such as detailed planning, will experience an increased workload due to the additional information developed to operate a CAPP system. However, the total benefits that a shipyard can derive from implementing CAPP far outweighs the workload increase in most areas. This section briefly describes the impact on each of the areas involved in the shipbuilding process.

B. Impact on Preproduction Activities

The greatest impact CAPP has on preproduction activities is that the discipline required to support information retrieval during the planning process results in a more structured approach to the development of that information. General standards relating to classification and coding of parts, subassemblies, assemblies and units are developed to provide a common language for all disciplines. This results in overall improved communications and reduced costs. Specific benefits for each area follow:

1. Estimating. Estimating departments primarily derive a benefit because using parameter values allows the estimate to be based on measurable work content. Current Efficiency Rate Returns from the various shops involved reflect current work practices thus providing up-to-date information for the estimating process. The work content data that is developed during the estimating process can be used to measure the design development against the estimated bid, and for the development of baseline budgets after contract award.

   In fact, data throughout the estimating, design and planning process becomes related. Thus, each step in the estimating, program planning, design, and detail planning process is a refinement of the data developed during the previous stage. The tiered development of data supports the application of design budgets during the design phase and enhances the capability of a shipyard to develop an auditable trail of the effect of both engineering changes in design and methods and process changes in production.

2. Program Planning. Computer Aided Program Planning can be applied in much the same manner as Computer Aided Process Planning. Each can use the same work content and efficiency rate data to develop program planning information such as facility loading, standard program plan language, unit sequencing, and preoutfit levels. BIW considers that manual or variant Computer Aided Program Planning would most economically serve the needs of a program planning office due to the text type nature of program plans.

3. Program Scheduling. Program scheduling has potentially the most to gain from the use of a CAPP system. The accuracy of the top level schedules can be significantly enhanced by

using the work content developed by estimating and the efficiency rate returns and projected manning for the various yard areas.

4. Budgeting. The development of budgets for the tasks to be completed in the various shipyard areas can become a computer exercise when the work content is broken down into the various stages of construction and the applicable efficiency rates are applied. of course, as the design matures and detailed drawings become available the work content values must be refined to reflect the work content on the detailed drawings. Changes in work content are then auditable as far back as the estimating process.

5. Material Lift. Material lift will see little impact from a CAPP system unless "Just In Time" material nesting on standard plates and shapes is implemented to suit process lane requirements and capabilities. The primary benefit of such implementation is the elimination of uniquely sized plates and multiple length shapes for each unit.

6. Production Drawings. Potentially, drawings for the fabrication floor could be grouped by interim product type or process. This could lead to an increase in the number of shop drawings that would be needed if unit relationships are maintained or to a decrease of fewer drawings, if the unit relationship was only maintained through an interim product identification code or number and interim products for each family, are grouped on a single drawing. The workload of the designer could increase if the responsibility for work content measurement was placed on the designer. This could have the additional benefit of making the designer aware of the production work content he may add to the drawing because of his approach to the design development. The traditional benefit of providing a design retrieval tool through the classification process is also present. The benefit of being able to retrieve similar past designs reduces the design time required because frequently an existing design or one with minor changes will satisfy the design requirements. This results in fewer designs to be manufactured and a higher level of productivity in the production shop as a result of learning curve benefits.

7. Shop Planning. The greatest benefit will be realized in shop planning. The planning process will be automated through the use of variant or generative process planning systems and the accuracy and consistency of the plan produced will be improved. In addition, the completeness and accuracy of the information provided as raw material pick lists, interim product kit lists and interim product work content will be significantly improved.

8. Shop Scheduling. The accuracy of the shop schedules will be significantly improved due to the "real time" information feedback on efficiency rates, problem areas, and identified bottlenecks.

c. Impact on Production Activities

1. Material Handling. Material Handling will significantly improve due to several factors:

   o Due to the grouping of products by families, raw material pick lists will be more accurate and timely to support the process lanes.

   o The development of material flow layouts will identify inefficiencies and bottlenecks, and will enhance the material flow.

   o Kitting lists can be related directly to the production schedule thus highlighting material problems prior to the commencement of work.

2. Shop Level-loading. The availability of work content information, and current returns of efficiency rates, coupled with manning projections will enable the planner to level-load the shop to a high degree of accuracy. In addition, shop production management can be made aware of varying manning requirements and, thus, respond accordingly.

3. Productivity. The increased accuracy of the schedules, raw material pick lists and kitting lists will improve productivity by having the right material available at the right time. In addition, the construction of similar interim products in a consistent manner will lead to increased productivity through learning curve efficiencies. Also, each step in each process can be analyzed for productivity improvements with changes being incorporated only after the improvements have been verified through simulation techniques.

SECTION VI

BUDGET AND SCHEDULE PARAMETERS DEFINITION

SECTION VI
BUDGET AND SCHEDULE PARAMETERS
DEFINITION

A. Introduction

One of the key elements of manufacturing data is the work measurement tool which BIW calls "parameter". A parameter is a measurable quantity that will reflect the work content of the interim product. Work content is a measure of the amount of work to be accomplished at a work station. An interim product is any of the products defined as a part of a family of products in the interim product/construction process matrices. The foreward of the Department of Defense MIL-STD-1567A Work Measurement states,

> "Experience has shown that excess manpower and lost time can be identified, reduced and continued method improvements can be made regularly, where work measurements programs have been implemented and conscientiously pursued.
>
> Active support of the program by all affected levels of management, based on an appreciation of work measurement and its objectives, is vitally important. Work Measurement and the reporting of labor performance is not considered an end in itself but a means to more effective management. Understanding the implication inherent in the objectives of the work measurement program will promote realization of its full value. It is important that objectives be presented and clearly demonstrated to all personnel who will be closely associated with the program.

The following are benefits which can accrue as a result of the employment of a work measurement program:

(a) Achieving greater output from a given amount of resources

(b) Obtaining lower unit cost at all levels of production because production is more efficient

(c) Reducing the amount of wasted time in performing operations

(d) Reducing extra operations and extra equipment needed to perform these operations

(e) Encouraging continued attention to methods and process analysis because of the necessity for achieving improved performance

(f) Improving the budgeting process and providing a basis for price estimating, including the development of Government cost Estimates and should-cost analyses

(g) Acting as a basis for the planning of long-term manpower, equipment, and capital requirements

(h) Improving production control activities and delivery time estimation

(i) Focusing continual attention on cost reduction and cost control

(j) Helping in the solution of layout and materials handling problems by providing accurate figures for planning and usage of such equipment

(k) Providing an objective and measured base from which management and labor can project piece-work requirements, earn-ings and performance incentives ." (See Appendix A.)

Without work content measurement tools , the accuracy of a Computer Aided Process Planning (CAPP) system would be considerably reduced and the plan would be soon abandoned due to shop floor congestion or under use as a result of inaccurate cycle times.

Many elements can be used for work content measurement. BIW'S selected elements are not presented as they are presently considered proprietary information. Example parameters are presented in Subsection B.

B. Budget and Schedule Parameters Logic

A parameter is simply a measurement of the work content in a task that needs to be completed. It may be the square footage of surface to be blasted or painted, the number of bolts to be installed, or the footage of weld to be deposited. Once the work content is determined the efficiency rate to accomplish the task can be determined by dividing the work content by the time required to complete the task.

Work Content = Efficiency rate X time

The efficiency rate is highly dependent on the method and stage of construction involved, however, for individual work stations it has proven to be very constant. Process changes at a work station or the addition of jigs and fixtures will change the efficiency rate. However, the change should be known in advance because a cost benefit analysis should be completed prior to incorporation of the change.

There are two types of efficiency rates as defined by MIL-STD-1567A. They are defined as follows:

"Type I Engineered Labor Standards. These are standards established using a recognized technique such as time study, standard data, a recognized predetermined time system or a combination thereof to derive at least 90% of the normal time associated with the labor effort covered by the standard and meeting requirements of paragraph 5.1. Work sampling may be used to supplement or as a check on other more definitive techniques.

5.1 Type I Engineered Labor Standards. All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level. For short operations, the accuracy requirement may be better met by accumulating small oper-ations into super operations whose times are approximately one-half hour. Type I standards must include:

a. Documentation of an operations analysis

b. A record of standard practice or method followed when the standard was developed

c. A record of rating or leveling

d. A record of the standard time computation including allowances

e. A record of observed or predetermined time system time values used in determining the final standard time.

Type II Labor Standard. All labor standards not meeting the criteria established in paragraph 5.1."

Type I standards are those similar to the MOST data compiled between 1979 and 1985 for the National Shipbuilding Research Program. Figure VI-1 is an example of such data. Some of these standards could remain applicable for future work in this area. Another example of Type I data is the numerically controlled cutting data available from the AUTOKON data base in the BIW mold loft. Figure VI-2 is an example of such data. For this project BIW chose to use Type II standards due to the availability of current data. It is noted that the parameter for both types of efficiency rates could be the same. The parameters selected for use at an individual shipyard will most likely be unique for that shipyard.

FIGURE VI-1
TYPE I PRODUCTION
STANDARD EXAMPLE

7.0 STANDARD TIME CALCULATION

7.1 Fitting Operations (Level Time) Factors for Hyde Assembly Shop

C. Shell Sub-Assemblies on 90° Diaphragm Mocks

Fitting Operation	our/Factor	"MOST" No.
Set, Regulate & Secure (flat assemblies) :		
Plates on Mock (mild steel plate)	1.5741ea.	12,30,40
(HY-80)	2.249/ea.	12,30,41
Stringers	.232/ea.	23,30
Webs	.214/ea.	13,30
Set, Regulate & Secure (radius shell assemblies) :		
plates on Mock (mild steel Plate)	2.814/ea.	11,12,16,30
(HY-80)	3.097/ea.	11,12,17,30
Stringers	.350/ea.	30,42
Webs	.214/ea.	13,30
Make up Fit & Tack (flat assys.) :		
*Shell Seams & Butts		
(mild steel plate)	.048/ft.	14,18
(HY-80)'	.099/ft.	15,19
Stringers to Shell (to mild steel	.023/ft.	24
(to HY-80)	.045./ft.	25
Webs to Shell (to mild steel)	.063/ft.	26
(to HY-80)	.098/ft.	27
Make up Fit & Tack (radius shell assemblies) :		
*Shell Seams & Butts		
(mild steel plate)	.048/ft.	14,18
(HY-80)	.099/ft.	15,19
Stringers to Shell (to mild steel	.028/ft.	43
(to HY-80)	.052/ft.	44
Webs to Shell (to mild steel)	.063/ft.	26
(to Hy-8")	.098/ft.	27

*lakeup of shell. seams also includes installation of strong backs.

Figure VI-2
Autokon Production Data

NESTED FORMAT = 4010 / 29

CUTTING INFORMATION

CONTOUR PART	TIME MIN : SEC	LENGTH FT-IN-16	SPEED IN/MIN
CUTTING	= 180=16	414-00-01	27.559
RAPID TRANVERSE	= 6 =15	102-07-14	196.850
MARKING	= 1= 9	2-07-14	27.559
REMAINING	= 0=11	0-05-05	27.559
65 PREHEATINGS	= 6=30		
TOTAL	= 194-21	519-09-03	

USED PLATE

AREA	WEIGHT	%/TOTAL
99.246	1595.671	66.164

NESTED FORMAT = 4010 / 34

CUTTING INFORMATION

CONTOUR PART	TIME MIN : SEC	LENGTH FT-IN-16	SPEED IN/MIN
CUTTING	= 198=10	455-01-11	27.559
RAPID TRANVERSE	= 11= 6	182-01-11	196.850
MARKING	= 1= 9	2-07-15	27.559
REMAINING	. 0=10	0-04-13	27.559
71 PREHEATING	= 7= 6		
TOTAL	= 217=41	640-04-02	

USED PLATE

AREA	WEIGHT	%/TOTAL
217.323	8149.612	62.092

The following is a list of example parameters that could be used by a shipyard:

Figure VI-3
Example Parameters

	Efficiency Rate	Parameter
Marking/Burning		
Numerical control marking and burning	H/PL	PL
Flame Planner	H/PL	PL
Telerex	H/PL	PL
CM-56 Parts Cutter	H/PL	PL
Manual marking	H/PL	PL
Manual burning	H/PL	PL
Profile cutting	H/P	P
Bending		
Profile bending	H/P	P
Plate bending	H/PL	PL
Small piece bending	H/P	P
Subassembly		
Fitting	H/FT	FT
Welding	H/FT	FT
Finishing	H/FT	FT
Others		
Material handling	H/Ton	Tons
Shot blasting	H/PL	PL
	H/P	P
Painting	H/PL	PL
	H/P	P
Others		
Flat		
Plate joining	H/FT	FT
Fitting	H/FT	FT
Welding	H/FT	FT
Finishing	H/FT	FT

Curved

Preparation	H/Ton	Tons
Plate joining	H/FT	FT
Fitting	H/FT	FT
Welding	H/FT	FT
Finishing	H/FT	FT

PIPE FABRICATION

Pipe	Lin Ft
Hose	Lin Ft
Hanger material	Lin Ft
Wave Guide	Lin Ft
Material handling	Qty
Fittings, flanges, etc.	Qty
Assembled pipe	Qty
Ferrous	Qty
Non-ferrous	Qty
Hose assembly	Lin Ft
Wave Guide assembly	Lin Ft
Hanger assembly	Qty

SHEET METAL FABRICATION

Sheet Goods	Sq Ft
Grating	Sq Ft
Honeycomb panels	Sq Ft
Plate 1/2"	Sq Ft
Sheet metal	Sq Ft
Shapes	Lin Ft
Angle	Lin Ft
Channel (Deck Shoes)	Lin Ft
Extrusions	Lin Ft
Flat bar	Lin Ft
Pipe or tubing	Lin Ft
Purchased for Assembly	Qty
Comm. equipment	Qty
Cooling coils	Qty
Dampers	Qty
Filter housings	Qty
Gauges	Qty
Heaters & reheaters	Qty
Terminal ends	Qty
Thermostats	Qty
Vent valves	Qty

Rectangular vent	Lin Ft
Round vent	Lin Ft

SHEET METAL FABRICATION

Foundations	Qty
Simple foundations	
Complex foundations	

2D & Simple 3D	Qty
Access covers	Qty
Cable protectors	Qty
Control panels	Qty
Deck coaming	Qty
Draft marks	Qty
Fire extinguishing fdns	Qty
Fire stations	Qty
Flange shields	Qty
Floor plates	Qty
Fume tight collars	Qty
Gooseneck	Qty
Grab rods	Qty
Guage boards	Qty
Hangers	Qty
Joiner curtain frames	Qty
Joiner curtain plates	Lin Ft
Ladders	Qty
Light traps	Qty
Orifice plates	Qty
Pans	Qty
Penetrations	Qty
Pipe battens	Qty
Protective covers	Qty
Sheathing	Sq Ft
Shelves	Qty
Stowages	Qty
Vent air lifts	Qty
Vent dampers	Qty
Vent flanges	Qty
Vent screens	Qty
Vent terminals	Qty

Exhaust Ducting Intakes/Uptakes	Special Estimate
Corten	Lin Ft
Expansion joints	Qty
Sheathing	Sq Ft

SHEET METAL FABRICATION

Complex 3-D Assembly	Qty
Benches	Qty
Berths	Qty
Bins	Qty
Boxes	Qty
Bulk stowages	Qty
Cabinets	Qty
Commissary equipment	Qty
Counters	Qty
Coupling covers	Qty
Drawers	Qty
Dressers	Qty
Hinged shelves	Qty
Hoods	Qty
Installation fixtures	Qty
Ladders	Qty
Lockers	Qty
Louvers	Qty
Priming chambers	Qty
Power & lighting panels	Qty
Racks	Qty
Service stands	Qty
Sinks	Qty
Stowages	Qty
Tanks	Qty
Reefer Construction	Special Estimate
Reefer boxes	Cubic Ft

ELECTRICAL FABRICATION

Purchased or GF Equipment	Qty
Electrical Equipment Foundations	Qty
Cable trays	Qty
Light legs	Qky
Terminal boxes	Qty
Distribution boxes	Qty
Complex Manufactured Equipment	Qty
Power Panels	Qty
Switchboards	Qty
Controllers	Qty
Pre-Plug Special Cable	Qty

MISCELLANEOUS FABRICATION

<u>Grating</u>	Sq Ft
Steel	Sq Ft
Aluminum	Sq Ft
Diamond plate	Sq Ft
Operating gear material	Lin Ft
<u>Shapes</u>	Lin Ft
I-Beam	Lin Ft
Angle bar	Lin Ft
Flat bar	Lin Ft
Round bar	Lin Ft
Wire rope	Lin Ft
Purchased for assembly	Qty
Grating assembly	Sq Ft
Operating gear assembly	Lin Ft
CO_2 pull assembly	Lin Ft
Outfit package	Special Estimate
Label plates	Qty

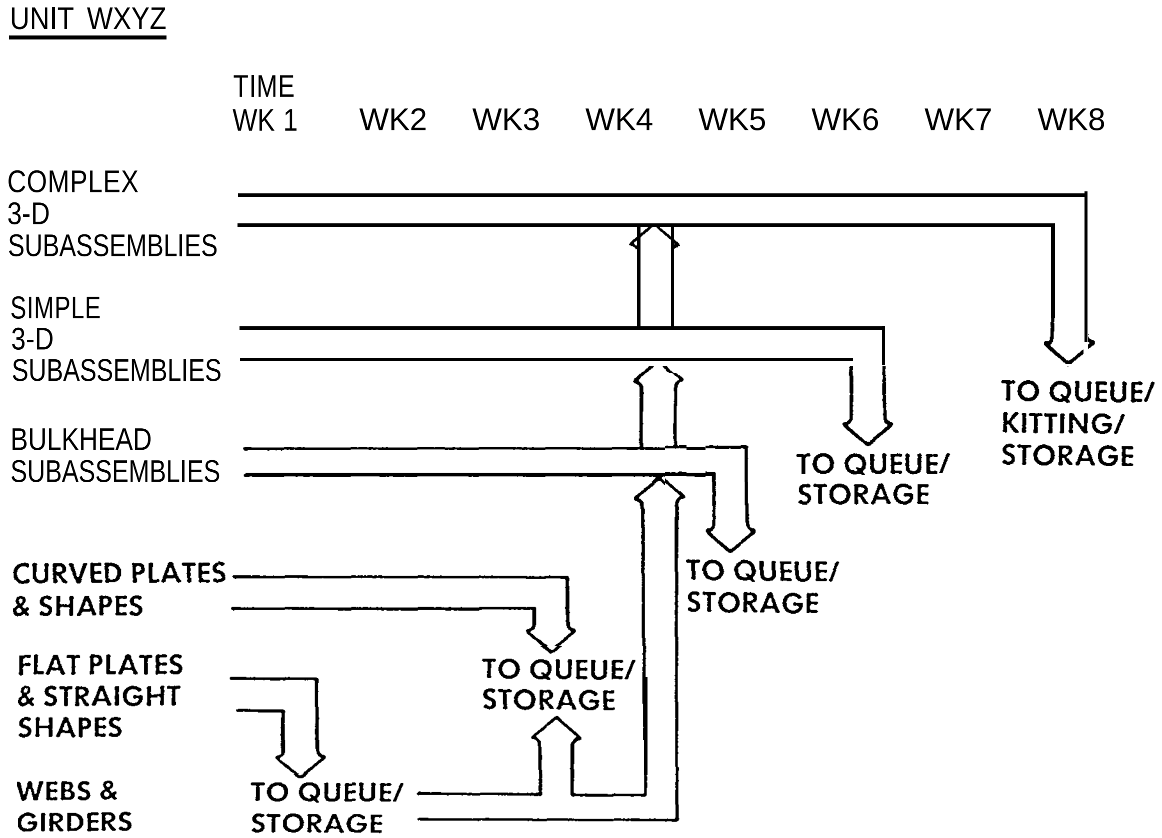
H = Hour
PL = Plate
Ton = Long Ton (2,240 lbs.)
Sq = Square

P . Piece
FT = Foot
Lin = Linear
Qty = Quantity

c. Structural Fabrication Scheduling

In reviewing scheduling and material flow the most significant factor observed was that "in-process" material remained in queue an inordinate amount of time in relation to the "value-added" time. (Value-added time is that period of time when work is performed on the interim product to increase its value.) The shop schedule, from the master schedule point of view, was a "window" of time for each unit. To control material and manage the process both the material and the interim products were managed by unit. In identifying interim products it became evident that the flow was as shown in Figure VI-4. The interim products remaining in queue resulted in shop floor congestion that hampered the productivity of the shop. Multiple flow paths and different construction approaches for similar products negated any learning curve benefits that could have been realized based on interim product similarities.

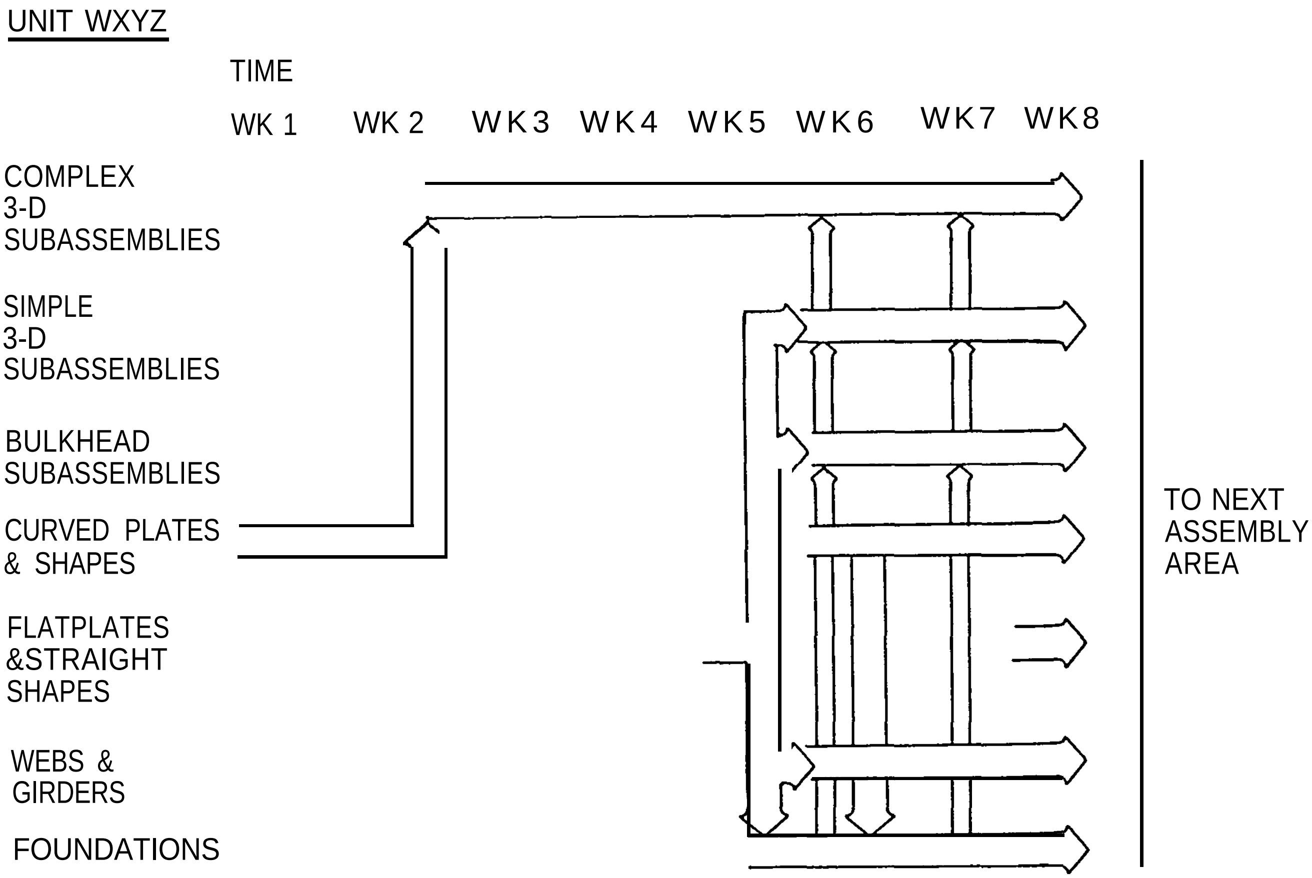
Figure VI-4
Unit Fabrication Schedule



If a problem with material availability arose the entire unit could be delayed even though its total "value added" time in the cycle could be short. When material problems arose during construction, the entire unit construction would halt for several weeks while waiting for a replacement.

With the recognition of the interim product/construction process relationship it was possible to further subdivide the unit into similar products and schedule the "value added" time in the shop. Figure VI-4 was revised as shown in figure VI–5.

Figure VI–5
Interim Product Fabrication Schedule



Integrating interim products across several units demonstrated that a process lane could be level-loaded based on relatively constant efficiency rate returns from each of the work centers.

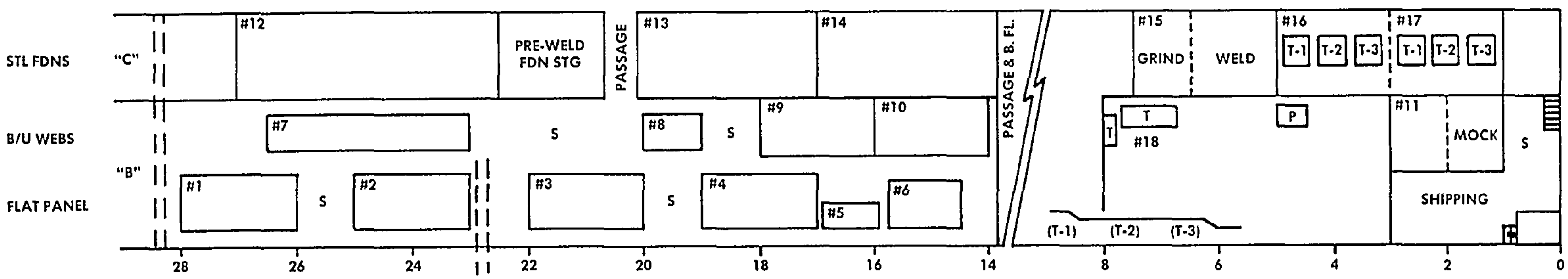
The manning level at an individual work site was the major factor responsible for meeting schedule needs. With the refinements in the work content measurement approach and efficiency rate returns it was discovered that not only were the schedules more accurate but the projected manning requirements accuracy was increased, thus allowing shop management to more effectively manage the effort.

To implement a scheduling process using the data discussed above it was decided to limit the effort to the subassembly process in the structural fabrication shop. This decision was based on the reasoning that the cutting and bending operations were relatively supportive of the subassembly process and were generally short term "value added" activities with fewer control problems.

To meet the dynamics of shop floor control it was decided to provide weekly updated schedules that covered a two week period. Examples of these schedules are shown in Figure VI-6. These provided a realistic schedule to each represented station in the shop.

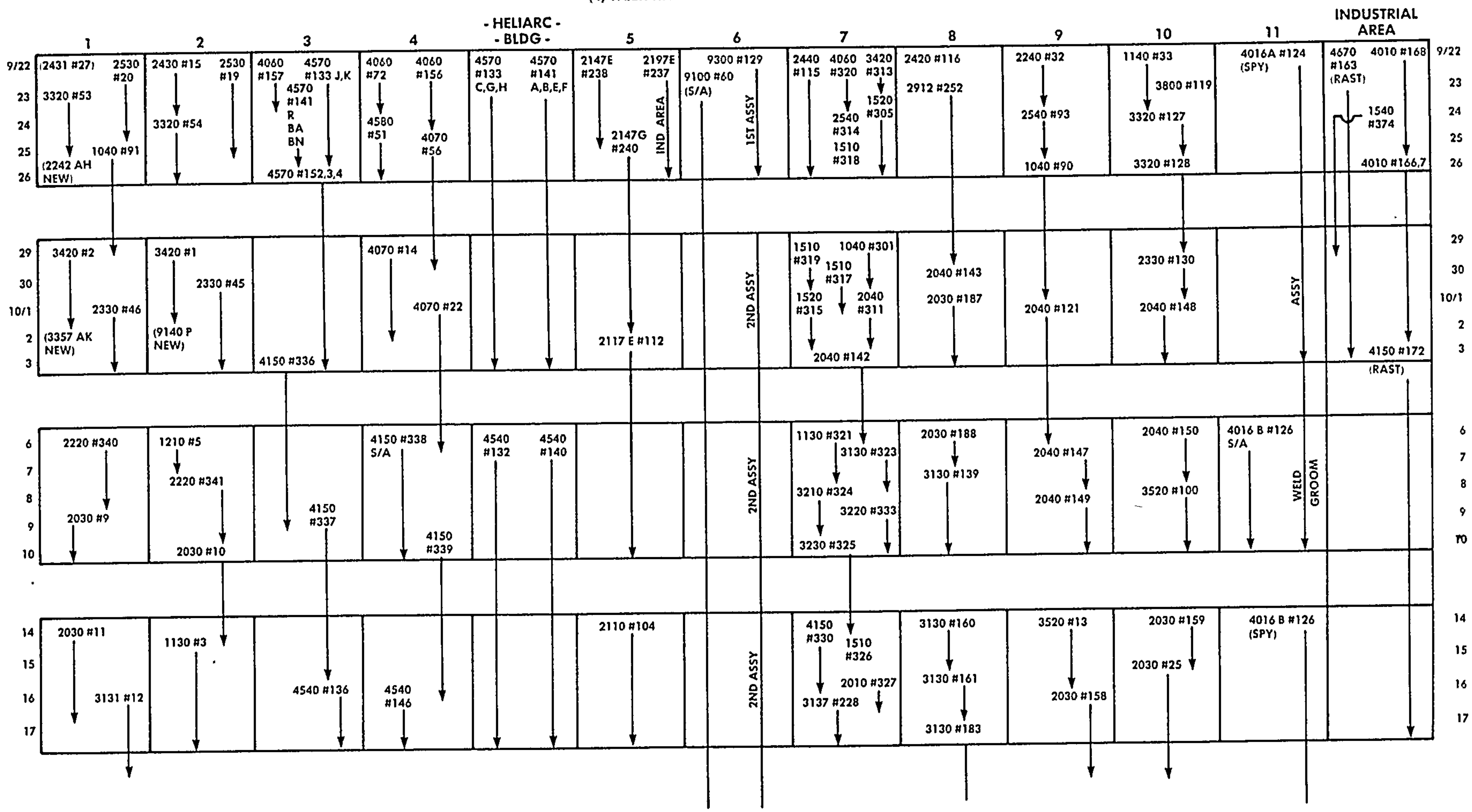
To meet the management needs for shop manning, a three month schedule was provided. Again, each work station is scheduled with a total shop integration to achieve the best possible Level-loading of personnel. These schedules continue to be refined as shop usage dictates.

1. 25' x 50' FLAT PANEL AREA
2. 25' x 50' FLAT PANEL AREA
3. 25' x 50' FLAT PANEL AREA
4. 25' x 50' FLAT PANEL AREA
5. 10' x 30' TABLE
6. 15' x 30' TABLE
7. B/U WEBB TABLES
8. RUDDER MOCK AREA
9. 25' x 50' MISC LARGE AREA
10. 25' x 50' MISC LARGE AREA
11. 25' x 50' MISC ALUM, MISC LARGE, SPY
12. MISC SMALL STL FIT AREA
13. MISC SMALL STL WELD AREA
14. MISC SMALL STL FIT & WELD AREA
15. MISC SMALL ALUM WELD & CLEAN AREA
16. MISC SMALL ALUM FIT AREA
17. MISC SMALL STL FIT & WELD AREA
18. INDUSTRIAL/MISC AREA, TABLES



(4) WEEK KIT PLAN BAY "B"

09/19/86



MLJ 9-22-86

HULL / UNIT	KIT #	9-22	9-23	9-24	9-25	9-26		9-29	9-30	10-1	10-2	10-3
1-4050	28 Z	REMAKES										
1-9533	131	↓										
1-4020	253A											
2-2140	239A											
2-2140	241											
2-2241.2	266											
2-2120	261 A											
2-3122,6,7,8	229							A'D KIT				
↓	230											
2-9506	103											
1-4410	280											
WO HPO-068												
1-3800 SZ	276											
2-2933 OP	231											
1-4010	352							JOBS -IT, U 2 H,J,K,L,M,N,R,T,U,V,AC			AD KIT	
2-2546,7,8	285											
2-9511	248											
1-4580	109											
1-2526 F	REV											
1-2236,7,8	282											
↓	282 A											
1-2765 B	REV											
420-9523 D	SS 801 B											
WO# 07-2276	2912 P											
2-9516	291											
2-9521 E	363											
1-9251 BF	NEW											
1-1546	374											
1-3358 W	NEW											
2-3310	221 A											
1-9546	196											+
2-2127,8	262											+
↓	263											+
2-3122,6,7,8	229 A											
1-1536,7,8	272 A											
1-1700 SZ	277											
1-4510	274											+
2-1131,2,6	297 A											
1-4010	352 A											
	351											+
	353											+
↓	354											+
2-2246,7,8	278											+
2-9511	247											
2-9514	286											+
420-9523 D	SS 718 718 A											
1-1511,2,3,4	299											+
1-1600 SZ	287											
2-1040	201											
2-2110	288											+
												+

SECTION VII
CAPP SYSTEMS EVALUATION

SECTION VII
CAPP SYSTEMS EVALUATION

A. Introduction

Further refinement of the product and process model for the structural fabrication shop resulted in a clear definition of the factors required in the manufacturing environment for a Computer Aided Processing Planning (CAPP) system. These factors are as follows:

- 0 A clear identification of product families
- 0 A clear identification of related processes
- 0 A consistent vocabulary
- 0 A simple coding scheme
- 0 A simple work content measurement tool
- 0 A measurable definition of shop process lane capacity
- 0 An accurate schedule based on shop capacity
- 0 A clear identification of required material flow control documentation
- 0 An identification of data base requirements.

The work carried out to develop and refine the interim product/process model described in the preceding sections led to the identification of the following required output from a CAPP system:

- 0 A process plan for the item to be manufactured based on "product family" characteristics. The process plan should group products with similar manufacturing process requirements in support of process flow lane concepts. There may be several process plans that presently exist in the individual planner's memory or personal data. These process plans should be accumulated and then combined for optimium effectiveness or combined and segregated to give the best combinations for the various scenarios that could exist. This task will enhance the completeness of the plans by expanding them to include step by step sequences, manning requirements, tool requirements, equipment control parameters, standard time information, technical data sources and charging instructions.
- 0 Assembly or construction drawings or sketches for each stage of the process. This requires that the design process be integrated with the process plan to maximize the effectiveness of the designer's output.
- 0 Raw material sorting and kitting instructions to direct the right pieces and parts to the right place at the right time. Raw material pick lists and the daily sequencing of raw materials into the shop are examples of raw material requirements output.
- 0 Piece, part, subassembly and assembly kitting instructions for each stage of the process. These instructions should include kitting information for the shop's products in support of the major assembly shops.

- Work content for each stage of the assembly process. The work content parameters used should only be at the level necessary to provide the information required to level-load the process lanes and to provide feedback to shop management for productivity monitoring. The work content information can be utilized along with the current efficiency rates for determining accurate budget values and schedule durations that reflect current methods and shop capabilities using a computer program that is a part of the CAPP software.

- A level loaded schedule for each of the stages in the process. This should be prepared on a short term basis only (e.g. two week schedule updated weekly) to support the major milestone schedule.

- Weekly product status and work station performance reports providing clear data to shop management. The data should enable shop management to make short term adjustments to the process plans to respond to problems and changes occurring on the shop floor.

The manually prepared documents currently used to control the flow of material at the structural fabrication shop are as follows:

- Freight Packing Slip - The packing slip received with the raw material from the shipping company.

- Sorting Instruction Sheet – Provides instructions to the material handlers in the plate yard as to the sequence of plates in each plate stack.

- Daily Sequence Sheet - Provides instructions to the material handlers in the plate yard for the sequencing of plates into the shop.

- Material Issue Requisition - Provides information to the material control system as to what material has been issued against a specific unit or charge.

- Material Transfer Document - Provides information to the material control system to identify material that had been allocated to one unit or charge but had been used on another unit or charge.

- Interdepartment Work Order - A request by one department to provide fabricated material for another department that does not have the capability to fabricate the required material within its own shop.

- Interdepartment Shipping Order - Document used to ship the material on an Interdepartment Work Order.

- Fabrication Shop Internal Shipping Order - Document used to ship loose pieces from the layout areas to the next work station.

- Material Storage Location Form – Document used by layout to ship loose pieces to a storage area.

- Retraction Document - Document used to control material from a storage area to a work station.

- Assembly Ordering Form - Document used to request all the pieces and subassemblies to complete an assembly.

- Left Off List - List of items that were not installed into an assembly because of some production constraint.

- Delivery Sheet - Document used to control movement of raw material between storage areas.

- Plate/Shape Loading Sequence Sheets - Document used to load a plate rack and shape rack for shipment of completed material to an assembly site.

- Short Range Order Form - Document used to control shipment of material to an assembly site.

- Long Range Order Form - Document used by the assembly shops to notify the fabrication shop of the future material requirements.

- Bill of Material - A list of all the material required for the assembly of a complete unit.

The required data bases identified for a CAPP system to automatically Supply the above lists in the structural fabrication shop include:

- Material Receiving Data Base
- Shapes Location Data Base
- Consolidated Shapes List Data Base
- Plate Stack Data Base
- Shop Schedule Data Base
- Daily Sequence Data Base
- Loft Summary (Piece and Part) Data Base
- Parameter Data Base
- Efficiency Rate Data Base
- Nest Data Base.

The proposed Consolidated Shapes List, Data Base and Shop Schedule Database allow for computer selection of the "shape process lane" items from the Loft Summary Data Base which are sorted by shape fabrication and/or layout area. Hard copy printouts of the data for the weekly or daily requirements are provided directly to the structural fabrication shop. Coupling this information with the structural shape location data base provides a pick list for the raw material handlers. This allows the raw material to be provided to the "shape process lane" area on a "just in time" basis. This information can also be integrated across contracts to allow similar materials to be processed concurrently.

The Plate Stack Data Base, based on a preplanned plate storage area, coupled with the Loft Summary Data Base and the Shop Schedule Data Base will provide a pick list (Daily Sequence Database) for the raw plate material handlers. Again, this information can be integrated across all contracts to allow similar grade and thickness material to be processed in batches. The nesting of parts, based on schedule requirements, just prior to shop fabrication can increase the usage of standard sized plates and reduce scrap costs. The Nest Data Base would need to be closely coupled with the material charging system to support cost charging against the proper contracts.

The Material Receiving Data Base provides a real time information source to determine the availability for the weekly update of the level loaded work station schedules.

The development and maintenance of these data bases provides consistent data control which facilitates the utilization of bar codes for gathering and entering data. Bar codes for recording charging data, material and interim product identification, kit inventorying, raw material control and material control input information can all be provided on the process plan and kitting documentation to allow for bar code data recording. This can increase data input efficiency by a factor of ten and decrease input error to nearly zero.

Group Technology (GT), as described in the National Shipbuilding Research Program report "Product Work Classification and Coding", is an essential element for product family identifications and for the development of a coding system that rationalizes and simplifies the data base information. Organizing the information by common attributes that are required by the users limits the size of the data bases. This organization occurs at the various stages of design and construction. In addition, structuring the information in a hierarchical fashion limits the amount of data that must be scanned by the computer to integrate the information for each stage of construction.

B. CAPP Bibliography and Abstracts

As a first step in evaluating existing CAPP systems a "CAPP Bibliography and Abstracts" report was developed. It was used as the knowledge base in the evaluation. The results are presented in Appendix B.

C. CAPP Evaluation Procedure

Bath Iron Works solicited five potential CAPP system vendors (see Appendix C) to determine their interest level in providing a demonstration project. The five vendors were:

- Prime Computer (LOCAM)
- General Electric (CASA/Cm)
- Westinghouse
- Computervision
- Brigham Young University

All vendors except Westinghouse expressed interest.

A follow-up letter (see Appendix D), which provided information on what Bath Iron Works uses to control material flow and a systems analysis of the structural fabrication shop, was provided to each of the vendors. Note: Proprietary data provided to the vendors in this letter has been deleted from Appendix D.

All four vendors responded that a system, meeting most of the Bath Iron Works output requirements, could be provided. A common prerequisite was that a group technology coding system based on products that are grouped into families would be required. These family groups are based on the group technology concept and interim product similarities. Prime Computer, General Electric and Brigham Young University responded with proposals for a demonstration project. The proposals are presented in Appendices E, F and G.

A procedure for conducting the evaluation of the proposals was developed. The procedure involved first developing weighted evaluation factors for the various requirements and then judging the proposals against these factors. The procedure and evaluation criteria are presented in Appendix H.

In addition, Bath Iron Works reviewed the U.S. Army Missile Command's CAPP system (CMPP) for cylindrical parts. This system is an extensively developed and implemented system for machine shops and is available, at no cost, from the U.S. Army Missile Command. See appendix I for a further description of the system.

D. CAPP Evaluation Results

As all proposals exceeded the available funding, it was decided that funds would be conserved to enhance the possibility of an implemental ion project as an extension of the present effort. Consequently, the evaluation was conducted by only the effected BIW departments and the cost of soliciting other shipyards for their input was avoided.

The results of this evaluation are as follows: (See Appendix H for definitions of each of the criteria.)

o Major Category Weighting Factors

A. Output Capability - 0.24
B. Vendor Support - 0.21
C. System Software - 0.15
D. Shipyard Supp't Req'd – 0.19
E. Other Sys Integration - 0.21
1.00

0 Subcategory Weighting Factors

A. Output Capability

A.1 Product Family Identification - 0.16

A.2 Process Plan - 0.14

A.3 Schedules - 0.15

A.4 Efficiency Rates - 0.09

A.5 Raw Mat'1 Lists – 0.13

A.6 Raw Mat'1 Costs – 0.04

A. 7 In-Process Mattl Lists – 0.15

A.8 Interim Product Statusing - 0.14

1.00

B. Vendor Support

B.1 Consultant Support - 0.27

B.2 Vendor Software – 0.17

B.3 Training - 0.29

B.4 Documentation – 0.27

1.00

C. System Software

C.1 Shipyard Sys Impact - 0.70

C.2 Supports Bar Code Data Collection and Transfer - 0.30

1.00

D. Shipyard Support

D.1 Manpower Req'd - 0.36

D.2 Ease of Use by Shipyard Personnel - 0.64

1.00

E. Integration Capability

E.1 Shipyard Computer Sys Integration - 0.50

E.2 Integration of CAPP System Modules - 0.50

1.00

The results of the evaluation of the three proposals are as follows:

Ranking	System	Score
1.	Prime Computer	1.12
2.	General Electric	0.86
3.	Brigham Young University	0.64

It is noted that the above results are effected by the fact that LOCAM had interfaced with BIW personnel on previous occasions and the evaluators were more familiar with the LOCAM system. In addition, the General Electric system assumed an interface with a Material Resource Planning system which would supply some of the required outputs. If the output available from a MRP system had been considered in the evaluation, General Electric's cASA/CAMA would probably have scored as high as Prime Computer's LOCAM. A re-evaluation by other shipyards is anticipated if additional work in this area is undertaken.

SECTION VIII
PROJECT ENHANCEMENTS

SECTION VIII
PROJECT ENHANCEMENTS

A. Introduction

The use of a personal computer (PC) to develop schedules in the shop planning office was believed to be an appropriate application at the beginning of the project. It was recognized early in the project development, however, that the manufacturing data base would need to be in place prior to such application if a reliable, accurate schedule was to be produced. The first potential enhancement investigated was Project p2 scheduling. See Appendix J for a summary description of this computer scheduling tool. It was determined that Project P2 operates most efficiently on work content budget values spread over time. The manufacturing data base and measurement parameters needed to be established before work content budgets could be established in place. It was decided that manual scheduling based on PC manipulated data would best suit this project.

The investigators interfaced with the other shipyard disciplines to remain abreast of related technology advancements and to identify standards that would have an impact on Computer Aided Process Planning (CAPP) implementation.

B. Computer Aided Scheduling

As discussed in Section Vl, two types of schedules were developed to support shop management: a two week schedule updated weekly, and a three month schedule, updated monthly. To assist in the scheduling effort, an IBM PC program was installed to manipulate the data. The program requirements were established as follows:

The IBM PC software is to maintain a data base describing the work content for each fabricated unit. There are 12 data elements in the data base with data base sort requirements as follows:

1. By unit/by kit in "Weld Comp" date sequence.

Example

Unit	Kit No.	Mat'1 Comp*	Weld Comp*	Fit Hours*	Weld Hours*
421-4330	197	6/01	6/22	48	33
	198	6/01	6/22	53	36
	199	6/01	6/22	67	46
422-2020	207	5/18	6/22	54	35
	208	5/18	6/22	91	59
	209	5/18	6/22	61	40

optional columns to be available on request.

2. By type of kit/by steel and then aluminum/by kit number in "Weld Comp" date sequence.

Example

Kit Type	Steel/ Alum.	Kit No.	Mat'1 Comp*	Weld Comp*	Total Assys*	Total Pieces*	Weld Footage*	Comments
B-1	S	207	5/18	6/22	3	208	557	Sub ASSY
		208	5/18	6/22	5	87	947	Sub AssY
		209	5/18	6/22	5	93	646	Sub ASSY
		12	6/08	6/29	4	145	1037	Sub ASSY
		13	6/08	6/29	7	68	666	
		14	6/08	6/29	3	119	1045	

Avg : Assys 5 Pieces 120 Weld ft 721 # of kits 6

*Optional columns to be available on request.

For each type of kit the total pieces and weld footage is added by the PC software and the averages are determined. This is selective by weld complete date; i.e. user enters "6/01" and "7/28" and the averaging will be for this period. A subset of this is to enter a parameter by kit type for pieces and weld footage and two new columns will appear for fit hours and weld hours.

A check of sequential kit numbers is made to identify missing numbers; i.e. user enters "1" and "30" and the system would identify which of the kits were not in the data base between 1 and 30, including 1 and 30. Station days for a particular product are determined by dividing the total pieces and weld footage by the average, and multiplying by a station days parameter. The results are presented in an additional column titled station days. The program for the IBM PC is presented in Appendix K.

The data developed by the program is then used to manually select units for the schedule such that the sequence will fully utilize the manning in each area.

c. Design Standards Recommendation

As the fabrication processes are examined from the production view point, problem areas will show a need for production oriented design standards. It is felt that these will generally be shipyard unique regarding details, however, the basic concepts are considered to be universal.

The first area requiring design standards is the frame bending operation. It was found that the accuracy of curved shell units varied significantly and, often, the curvature was less than required. In tracing the problem to its source it was found that when frames were formed the web or the flange would be rippled if bent beyond a certain point. After the bending operation the rippled pieces were shipped to a press to flatten the web or face plate. This frequently altered the frames' curvature. This suggests that for each material and frame size there are limiting curvatures that should not be exceeded. Beyond such limitations, built-up members should be called for or other design approaches should be followed. The same concept applies to other materials.

The adoption of a group technology classification and coding system, as presented in the National Shipbuilding Research Program "Product Work Classification and Coding", June 1986, also dictates the development of design related numbering standards. It must be kept in mind that facilities, processes and methods change, and the identifier that ties the code to a specific process should be applied during shop floor planning and scheduling. However, the identifier applied during the design phase should provide a link to the fabrication shop to simplify shop planning.

SECTION IX

COMPUTER AIDED PROCESS PLANNING SYSTEM IMPLEMENTATION APPROACH

SECTION IX
COMPUTER AIDED PROCESS PLANNING SYSTEM
IMPLEMENTATION APPROACH

A. Introduction

The implementation of a Computer Aided Process Planning (CAPP) system requires the development of a manufacturing data base which provides interim product/construction process relationships. The prerequisites of such an effort are the identification of similar interim product families and their related processes. Once the interim product/process relationships are defined, a consistent approach in applying the processes for producing the interim product must be achieved. When such consistency is achieved, the identification of work content parameters, process constraints and capacity standards can be achieved and the accumulation of data to operate a CAPP system can proceed. A Group Technology (GT) code to facilitate retrieval of the data is, of course, an essential element. As with any project, the procedural steps must be well planned in order for it to be properly managed. Of the utmost importance is ensuring that the project has a limited, manageable scope. Encompassing too many processes or too large a production area is a sure step towards failure.

B. Interim Product/Process Matrix Development

The interim Product/Process matrices presented in Section III are generic in nature and can be used as a first step. It is recommended that the grouping of interim products into families should be reviewed with both production and engineering departments to ensure full acceptance of the matrices. The systematic gathering of the Production Engineering Information can then proceed as follows:

- Detailed Process Descriptions: The different methods to accomplish each of the processes should be described including any parameter data that is pertinent to the operation. This data is equivalent to the “feeds and speeds” data in a machine shop. A shipyard’s maintenance shop is frequently a valuable source of data, as is the welding engineer’s office. The operator is an excellent source in obtaining opinions on the shop equipments’ true capabilities.

- Detailed Material Descriptions: The primary source for this information is the shop’s material clerk and the shop planner. Engineering personnel are also a reliable source, however, the list of materials should be reviewed with the shop personnel to delete any unique materials that the shop is not familiar with. This provides an automatic flag during the planning process to ensure appropriate procedures are invoked to control the fabrication processes.

- Tooling and Process Constraints: The predominate constraint often is material handling capacity. Capacity information is generally available from a shipyard’s industrial engineering office or the maintenance office. Work station operators are also an excellent source, especially for safety constraints.

- Work Content Parameters: Yard budgeters are the primary source for useful parameters. Frequently budgeters-will have historical data that they use in formulas for estimating the work content of a task. These formulas and the supporting data can frequently be introduced into the software for the selected CAPP system. The identified parameters should be reviewed with the shop floor supervision because they frequently have easy-to-use methods for determining work content and manning requirements. Being the ultimate user of work content parameter data, the shop floor supervisor should have a major input in its selection. See Section VI for sample parameters.

- Efficiency Rates: The initial collection of data for developing efficiency rates may be broad based depending on the method of labor return collection used in the shop. The start–up efficiency rates will generally be Type II labor standards. The start-up parameter used for the BIW Structural Fabrication shop was linear foot of weld for all assembly processes. The efficiency rate used covered all trades, for all processes, from start of assembly to completion of assembly. As the process lane was developed, the parameter for welders became weld pass length, and for fitters it became fit length or number of pieces. This decision depends on the type of interim product. Once the process lane becomes established, Type I labor standards can be determined. Data gathering can then be accomplished for independent steps in the total process. This is probably the first area in which computer assistance is mandatory in order to manage the resulting data base.

- Standard Manning Levels: The establishment of standard manning levels can initially be established based on assembly size. This effort should be coordinated with the shop floor supervisors. The data should be updated after process lane operations have become stabilized.

- Process Lane Capacity: Using efficiency rates and standard manning levels, the throughput capacity for each process can be determined. This will generally result in one process being a bottleneck for each process lane. These bottlenecks can be analyzed and modifications to each lane can be implemented to maximize capacity, if production output warrants the changes. If the bottleneck cannot be eliminated, the manning for the balance of the process lane must have some flexibility to shift personnel because the bottleneck capacity limits the process lane capacity. In addition, queue storage space for the input and the output of the bottleneck process will generally be required in order to effectively man the balance of the process lane.

c. <u>Process Lane Development</u>

The start-up of a process lane requires that a number of preproduction activities be established. The following is a list of the essential elements:

- The interim product/construction process matrix to determine which process lanes

- The determination of the parameters to be used to control the manning and scheduling of the process Lanes

- The determination of the work content in the interim products to be produced for a period of six to 12 weeks and related Type II efficiency rates to determine which lanes will require some flexibility to construct more than one type of interim product

- Interim product flow networks to determine cycle times and sample manning

- Process lane layout to determine work and storage area requirements, equipment locations and material flow.

The matrices and parameters were described in detail in Section IX, B. The remainder of these tasks are described as follows:

- Work Content Measurement

  Having determined suitable parameters for each of the interim products, the measurement of the work content can be accomplished. For systems such as AUTOKON, numerical control data burn lengths and burn time can be supplied directly from the system. Figure IX-1 is a sample AUTOKON output. For the interim products presented in Section C, manual determination of the parameter quantity is generally required. This can best be accomplished by a shop planner who is familiar with the general processes that occur in a shop.

- Interim Product Flow Network

  Section IV, D presents the structural fabrication interim product flow networks for Bath Iron Works. As is evident, the matrices are an expansion of the interim product/process matrix for each interim product family identified. The interim product flow networks can be developed once the basic interim product/construction processes relationships have been established. Using the work content parameter quantities and preliminary efficiency rates, flow networks can be used to simulate production runs of typical. interim products. This process can identify potential bottlenecks and indicate the areas in the plant layout where buffer storage sites are required. It is helpful to include the preferred manning and the efficiency rates applicable for each process on the network.

- Process Lane Layout

  The material flow, as it presently exists, will provide a valuable tool for determining the layout of actual process flow lanes. Current flow paths that are established due to handling capabilities and space constraints can be identified. The process lane layout can then be developed based on the current flow and the interim product flow networks. It may be necessary to first develop an ideal layout and then develop the best compromise based on a cost/benefit analysis of each suggested rearrangement of equipment and modification of the flow paths.

It must be recognized that there may be some flexibility required because of interim product quantities as well as changes necessary due to process refinements or improvements. Once the process lane has been put in place, changes should be controlled and implemented only when analysis substantiates that an improvement in total productivity will result.

D. Scheduling Implementation

The shop floor is a dynamic environment susceptible to equipment failures, material problems and manning variations. The schedule must be capable of adequately responding to such conditions. Therefore it is recommended that the shop floor schedule cover only a two week period and that it be updated on a weekly basis. This allows the shop floor supervisor to manage the work at hand and plan for the coming week. This also enables the scheduler to respond to shop floor problems by rescheduling problem jobs downstream and/or developing appropriate work-arounds.

As presented in Section VI, C the actual scheduling process is relatively simple once the work content is known, efficiency rates have been established and station manning levels become stabilized. Section VI provides a sample schedule package for the structural fabrication shop.

FIGURE IX–1
AUTOKON OUTPUT

Cutting Information

Contour Part	Time Min: Sec	Length Ft-In-16	Speed In/Min
Cutting			
Rapid Tranverse			
Marking			
Remaining			
65 Pre-Heatings			
Total	:194:21	519–09-03	

Raw Plate

Length Ft-In-16	Breadth Ft–In-16	Area Ft–2	Thick Inches	Density Lb/Ft‘3	Weight Lb
20-00-00	7–06-00	150.000	0.394	490.012	28937.738

Used Plate

Area	Weight	% Total
99.246	1595.671	66.164

Start/Enc Pos. (Rel. to Lower Left Corner)

Start-U Ft-In-16	StarL-V Ft–In–16	End- U Ft-In-16	End- V Ft–In-16
0-00-00	0-00-00	18–08-06	3–03-08

SECTION X
CONCLUSIONS AND RECOMMENDATIONS

SECTION X
CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The introduction of Computer Aided process planning (CAPP) to shipyards brings with it a structured discipline that can result in a significant productivity increase (10-40%). The following summarizes the areas where this saving can be realized:

- The recognition of interim product similarities results in a learning curve savings throughout a single ship program.
- The establishment of process lanes to capitalize on interim product similarities results in repeating processes that can be analyzed for process improvement through the use of jigs and fixtures and/or improved technologies.
- The manufacturing data from the "value added" work sites can be monitored using statistical control methods to determine trends in quality, productivity, manning requirements, and the effect of new technologies.
- The raw material and interim product flow paths, which become somewhat fixed because of process consistency, can be determined and analyzed to reduce redundant moves and improve safety.
- The location of equipment relative to raw material and interim product flow can be analyzed to improve productivity and safety.
- The manufacturing processes and sequencing stored in the individual planner's memories can be captured and stored on hard copy or in a data bank and the best combination of the individual approaches can be utilized in planning work. In addition the process plans become consistent for similar tasks because the individual preferences are removed from the process plans.
- The process plans contain improved and more complete information. The process plan information can become similar to that presently provided in machine shops, providing such information as step by step sequence, manning requirements, tool requirements, equipment control parameters, time requirements, kitting information, technical data sources, and charging and shipping instructions.
- Consistent data control enhances the application of bar code technology in providing and gathering data. Bar codes for recording charging data, material and interim product identification, kit inventorying, raw material control and material control system input information can all be provided on the process plan and kitting documentation to allow for bar code data recording. This can increase data input efficiency by a factor of ten and decrease input error to nearly zero.
- The manufacturing process planner is freed from routine

clerical duties and is able to concentrate on methods improvement and cost reduction changes to the process plans.

- The accuracy and consistency of process plans for new projects is improved, which results in a higher confidence level on the part of shop floor supervision and laborers. Budgets and scheduling information are no longer based on "inspired guesstimates" on the part of the budgeter and scheduler, but are based upon work content measurement and "real time" efficiency rate returns that reflect current methods and capabilities.

- Budgets and schedules can be computer based using work content- information and efficiency rates. Thus the budgeter can spend additional effort to determine actual work content and the scheduler can spend his valuable time resolving scheduling problems.

- Data throughout the estimating, design and planning process becomes related. Thus, each step in the estimating, program planning, design and detail planning process is a refinement of the data developed during the previous stage. The tiered development of data supports the application of design budgets during the design phase and enhances the capability of a shipyard to develop an auditable trail of the effect of both engineering changes in design and methods and process changes in production.

- Process planning information remains current due to the feedback loops which result from the structured approach required for a CAPP system.

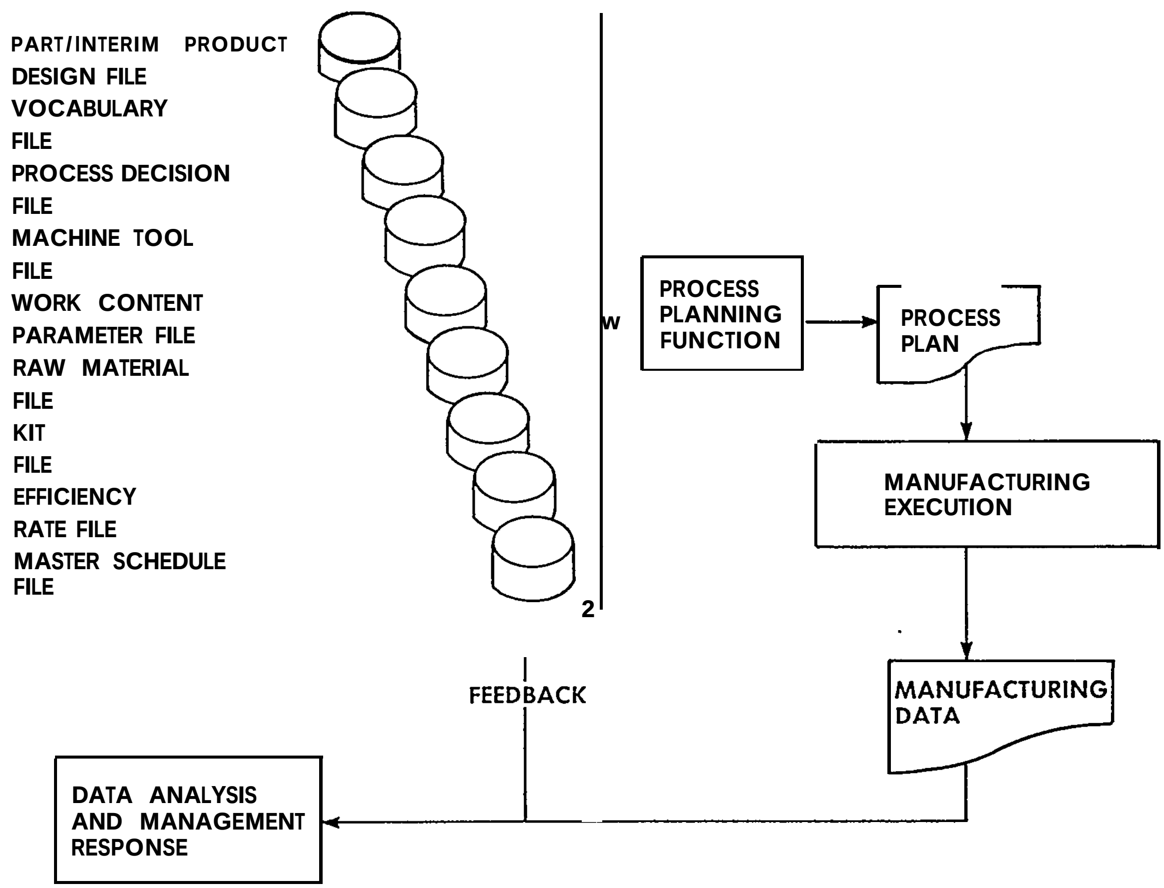
Investigation of CAPP systems revealed a common thread in all systems in that a GT code is necessary to efficiently manage the manufacturing data base. The National Shipbuilding Research Program report "Product Work Classification and Coding", June 1986, presents a useful approach to developing such a code. The investigation also revealed that the code may include many related attributes that may be required for only specific stages in the design/planning/manufacturing process. For instance, the functional attributes necessary for design development and customer approval are not necessary for fabrication and installation but may be necessary for system activation and testing. Thus the identifier carried by a product need only include elements to provide traceability through the manufacturing process. Portions of the code may be added or deleted at each stage. It also became apparent that process related attributes should be added as far downstream in time as data processing/scheduling will allow. Thus, it will be possible to react to the dynamics of shop floor problems and changing production requirements.

The code string expands based on the "first-touch" concept. This means that the first person in the process to logically require or identify a data string adds the related data to the interim product identifier. The computer software then operates only on that portion of the data string that is required for the process or stage for which the document is being provided.

Review of the commercially available CAPP systems revealed that the systems advertised had a wide range of sophistication from simple word processing manipulation of existing process plans to those that provide all of the recognized outputs in some form. The more sophisticated systems, such as General Electric Company's CASA/CAMA, tended to rely on other related programs to provide the necessary output, such as a Material Resource Planning System. Whereas others, such as LOCAM had the option of being a unique, stand alone system. It can definitely be concluded that there are commercially available CAPP systems that can be applied to the shipbuilding industry without having to develop a unique set of specifications and software. This is due in large part to the generic approach used in the basic, commerical CAPP software. Section 4.7 of the National Shipbuilding Research Program's "product Work Classification and Coding", June 1986, presents the D-Class approach to a shipyard CAPP system. Appendix E presents the LOCAM approach. Both approaches capture, in a data base, the manufacturing logic presently contained in the minds and "little black books" of planners and manufacturing engineers. Use of the computer and this decision logic, can now develop consistent, complete, process plans.

The CAPP system is best illustrated in Figure X-1.

FIGURE X-1
CAPP SYSTEM OPERATION



Design/schedule/manufacturing data is integrated through the use of CAPP system software to develop a process plan for each interim product. The results of the process plan are gathered and used to update the data base and to provide information for management action controlling the processes and providing additional feedback to the data base. The approach for each shop is identical with only the data base information changing, based on the parameters required by the interim products.

The cost of a CAPP demonstration project was found to exceed the $20,000.00 projected in the original proposal. Consequently, the funds originally earmarked for such a demonstration have not been used, these funds can be carried over into an implementation project as presented in the following recommendations.

B. Recommendations

The development of the structured data base information required for a CAPP system can be very beneficial to a shipyard as presented in the previous section. Although the actual approach taken by a shipyard for developing such a data base may vary, the basic framework presented in Section IX should be followed.

To further this project it is recommended that the SF-4 panel of the Society of Naval Architects and Marine Engineers fund a limited implementation project to demonstrate the usefulness of a currently operating CAPP system in the shipyard environment.

The project should include:

- The automated development of Type I time standards for a structural fabrication shop. (See Section VII for the description of a Type I time standard.) The "MOST" data developed during the various National Shipbuilding Research Program reports on "Work Management" will be used where applicable.
- The generation of GT Codes for the structural fabrication shop.
- The generation of process plans similar to those presented in Appendix L using a variant process planning system.
- The generation of process planning documents to support process lanes in a structural fabrication shop.
- The publishing of a report documenting the results of the implementation project and a projection of expected savings for the implementation of a CAPP system throughout the shipyard.

COMPUTER AIDED PROCESS PLANNING
FOR SHIPYARDS

APPENDICES

APPENDICES

Table of Contents

APPENDIX A

MILITARY STANDARD “WORK MEASUREMENT”, (MIL-STD-1567A)

MIL-STD-1567A,
11 **March** 1983
SUPERSEDING
MIL-STD-1567(USAF)
30 June 1975

MILITARY STANDARD

WORK MEASUREMENT

No Deliverable Data
Required by this Document

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DEPARTMENT OF DEFENSE

WASHINGTON DC 20301

WORK MEASUREMENT

MIL-STD-1567A

1. This military standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Recommended corrections, additions, or deletions should he addressed to Commander, Air Force Systems Command, ATTN: ALY, Command Standardization Office, Andrews AFB DC 20334.

FOREWORD

The purpose of this standard is to assist In achieving increased discipline in contractors' work measurement programs with the objective of improved productivity and efficiency in contractor industrial operations. Experience has shown that excess manpower and lost time can be identified, reduced, and continued method improvements made regularly where work measurement programs have been implemented and conscientiously pursued.

Active support of the program by all affected levels of management, based on an appreciation of work measurement and its objectives, is vitally important. Work Measurement and the reporting of labor performance Is not considered an end in itself but a means to more effective management. Understanding the implication inherent in the objectives of the work measurement program will promote realization of its full value. It is important that objectives be presented and clearly demonstrated to all personnel who will be closely associated with the program.

The following are benefits which can accrue as a result of the employment of a work measurement program.

(a) Achieving greater output from a given amount of resources.

(b). Obtaining lower unit cost at all levels of production because production is more efficient.

(c) Reducing the amount of waste time in performing operations.

(d) Reducing extra operations and the extra equipment needed to perform these operations.

(e) Encouraging continued attention to methods and Process analysis because of the necessity for achieving improved performance.

(f) Improving the budgeting process and providing a basis for price estimating, including the development of Government Cost Estimates and should cost analyses.

(g) Acting as a basis for planning for long-term manpower, equipment. anti capital requirements.

(h) Improving production control activities and delivery time estimation.

(i) Focusing continual attention on cost reduction and cost control.

(j) Helping In the solution of layout and materials handling problems by providing accurate figures for planning and utilization of such equipment.

(k) Providing an objective and measured base from which management and labor can project pfecework requirements, earnings and performance incentives.

While recognizing the benefits that may normally be expected from the requirement for a work measurement system, it is DOD Policy to selectively apply and tailor standardization documents to ensure their cost-effective use in the acquisition process. Each program office should carefully consider, within DOD and Service guidelines, benefits and costs *of* imposing MIL-STD-1567 on each specific acquisition. Contractors may propose document application and tailoring modifications with supporting rationale for such modifications.

The DOD Is committed to development and coordination with Industry of detailed application guidance to accompany MIL-STD-1567. The purpose of this guidance is to provide non-contractual information on when and how to use the document, the source of and flexibility inherent within specific document requirements, information on what is required to satisfy document requirements, and the extent of Government review and aPproval. The guidance is intended to promote consistency *in* application and interpretation of MIL-STII-1567 requirements. Until this guidance can be issued in the form of an "Application Guidance" appendix to MIL-STD-1567, or In a separate Military Handbook, the following applies:

(a) Use and correct application of appropriate predetermined time systems can be assumed to satisfy Government requirements for system accuracy.

(b) The contractor and the Government are encouraged to come to an early agreement (possibly in the form of a Memorandum of Understanding) of what constitutes an acceptable system satisfying the intent of this standard.

(c) Care should be exercised in the use of a work measurement system to ensure that the overall intent is not lost. Management understanding and attention to the manufacturing ciro-cess is necessary for increased productivity. work measurement provides one of the tools; however, misuse could result in reduced workforce motivation and productivity.

Feedback on the success or difficulties encountered (benefits and costs) In the application of this standard on specific contracts is encouraged. Contractor/industry and Government experience should be forwarded to the address indicated on page ii.

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MILITARY STANDARD

WORK MEASUREMENT

1. SCOPE

1.1 Purpose. This standard requires the application of a disciplined work measurement program as a management tool to improve productivity on those contracts to which it is applied. It establishes criteria which must be met by the contractor's work measurement programs and provides guidance for implementation of these techniques and their use in assuring cost effective development and production of systems and equipment.

1.2 Applicability. This standard is applicable to new/follow-on contracts, including modifications, as shown in paragraphs 1.2a, l.2b, 1.2c and 1.2.1 below. The dollar thresholds indicated are to be based on the current Five Year Defense Program (FYDP) budget submissions.

a. Full-scale acquisition program developments which exceed $100 million.

b. Production, which may include some types of depot level maintenance repair or overhaul, that exceeds $20 million annually *or $100* million cumulatively. It shall not be applied to contracts or subcontracts for construction, facilities, off-the-shelf commodities, time and materials, research, study, or developments which *are* not connected with an acquisition program.

c. This standard is not applicable to ship construction, ship system contracts which have low volume non-repetitive production runs, or service-type contracts.

1.2.1 Subcontracting. When this standard is applied to prime development or production contracts, it shall also be applied to related subcontracts and/or modifications which exceed $5 million annually or $25 million cumulatively. If it is determined by the prime contractor that such application is not cost effective or inappropriate for other reasons, the prime contractor may request the Government to waive the specific application. Requests for waivers shall be supported with the data used to make the determination.

1.3 Contractual Intent. This standard requires the application pf a documented work measurement system. This standard further requires that the contractor apply procedures to maintain and audit the work measurement system. It is not the intent of this standard to prescribe or imply organization structure, management methodology, or the details of implementation procedures.

1.4 Convective Actions. When surveillance by the contractor or the Government discloses that the work measurement program does not meet the requirements of this standard, a plan shall be initiated to expeditiously assure that corrective measures shall be implemented, demonstrated and documented. The contractor's system is subject to disapproval by the Government whenever it does not meet the requirements of this standard.

1.5 Documentation. The work measurement program shall include sufficient documentation to assure effective operation of the program and to provide for internal audits as required by paragraph 5.14. Documentatlon shall specifv organizational responsibilities, state policies, and provide operational procedures and instructions. The results of contractor system audits and plans for corrective actions shall be made readily available to the Government for review.

2. REFERENCED DOCUMENTS.

Not Applicable

3. DEFINITIONS.

3.1 Actual Hours. An amount determined on the basis of time incurred as distinguished from forecasted time. Includes standard time properly adjusted for applicable variance.

3.2 Earned Hours. The time in standard hours credited to a worker or group of workers as the result of successfully completing a given task or group of tasks: usually calculated by summing the products of applicable standard times multiplie by the completed work units.

3.3 Labor Efficfency. The ratio of earned hours to actual hours spent on same increments of work during a reportinq period. When earned hours equal actual hours, the efficiency equals 100%.

3.4 Methods Engineering. The analyses and design of work methods and systems, including technological selection of operations or processes, specification of equipment type, and location.

3.5 Operation Analysis. A study which encompass all those procedures concerned with the design or improvement of production, the purpose of the operation or other operations, inspection requirements, materials used and the manner of handling material, setup, tool equipment, working conditions, and methods used.

3.6 Predetermined Time System. An organized body of information, procedures and techniques employed in the study and evaluation of manual work elements. The system is expressed in terms of the motions used, their general and specific nature, the conditions under which they occur, and their previously determined performance times.

3.7 Realization Factor.

(a) A ratio of total actual labor hours to the standard earned hours.

(b) A factor by which labor standards are multiplied when developing actual/projected manhour requirements.

3.8 Subcontract. A contract between the prime contractor and a third party to produce parts, components, or assemblies in accordance with the prime contractor's designs, specifications or directions and applicable only to the prime contract.

3.9 Touch Labor. Production labor which can be reasonably and consistently related directly to a unit of work being manufactured, processed, or tested. It involves work affecting the composition, condition, or production or a product; it may also be referred to as "hands-on labor" or "factory labor."

NOTE : As used in this standard, touch labor includes such functions as machining, welding, fabricating, setup, cleaning, painting, assembling, functional testing of production articles and that labor required to complete the manually-controlled process portion of the work cycle.

3.10 Touch Labor Standard. A standard time set on a touch labor operation.

3.11 Type I Engineered Labor Standards. These-are standards established using a recognized technique such as time study, standard data, a recognized predetermined time system or a combination thereof to derive at least 90% of the normal time associated with the labor effort covered by the standard and meeting requirements of paragraph 5.1. Work sampling may be used to supplement or as a check on other more definitive techniques.

3.12 Type II Labor Standard. All labor standards not meeting the criteria established in paragraph 5.1.

3.13 Standard Time Data. A compilation of all elements that. are used for performing a given class of work with normal elemental time values for each element. The data are used as a basis for determining time standards on work similar to that from which the data were determined.

3.14 Touch Labor Normal/Standard Time. Normal time is the time required by a qualified worker, to perform a task at a normal pace, to complete an element, cycle or operation, using a prescribed method. The personal, fatique and unavoidable delav allowance added to this normal time results In the standard time.

3.15 Operation. (1) A job or task consisting of one or more work elements, normally done essentially in one lQcation; (2) The lowest level grouping of elemental times at which PF&D allowances are applied.

3.16 Element. A subdivision of the operation composed of a sequence of one or several basic motions and/or machine or process activities which is distinct, describable and measurable.

4. GENERAL REQUIREMENTS.

4.1 Genera!. Minimum requirements which must be met in the Implementation of an acceptable work measurement program are:

a. An explicit definition of standard time that shall apply throughout the jurisdiction of work measurement.

b. A work measurement plan and supporting procedures.

c. A clear designation of the organization and personnel responsible for the execution of the system.

d. A plan to establish and maintain engineered labor "standards to known accuracy.

A plan to conduct methods engineering studies to improve operations and to upgrade Type II labor standards to Type Engineered Labor Standards in accordance with requirement of paragraph 5.4.

f. A defined plan for the use of labor standards as an input to budgeting, estimating, production planning, and "touch labor" performance evaluation.

g. A plan to ensure that system data is corrected when labor standards are revised according *to* paragraph 5.11 below.

5. SPECIFIC REQUIREMENTS.

5.1 Type I Enqinee0red Labor Standards. All Type I standards must reflect an accuracy of ±10% with a 90% or greater confidence at the operation level. For short operations, the accuracy requirement may be better met by accumulating small operations into super operations whose times are approximately one-half hour. Type I standards must include:

a. Documentation of an operations analysis.

b. A record of standard practice or method followed when the standard was developed.

c. A record of rating or leveling.

d. A record of the standard time computation including allowances.

e. A record of observed or predetermined time system time values used in determining the final standard time.

5.1.1 Predetermined Time Systems. It is not the intent of this Military Standard to challenge the accuracy of those *predetermined* time systems whose inherent accuracy meets the requirements of paragraph 5.1. However, when a predetermined time system is used, it shall be incumbent on the contractor to demonstrate to the Government that the accuracy of the original data base has not been compromised in application or standards development.

5.2. Operations Analysis. Operations analysis is considered an Integral part of the development of a Type I Engineered Labor Standard. An operations analysis shall be accomplished and recorded prior to the determination of a Type I standard; and in the improvement of established labor standards.

5.3 Standard Data. The contractor shall take full advantage of available standard time data of known accuracy and traceability.

5.4 Labor Standards Coverage. The contractor shall develop and implement a Work Measurement Coverage Plan which provides a time-phased schedule for achieving 80% coverage of all categories of touch labor hours with Type I standards. (See 3.9, Touch Labor.)

5.4.1 Cost Trade-off Analysis. The Work Measurement Coverage Plan shall be based on cost trade-off analyses which consider the status and effectiveness of the contractor's existing work measurement program.

5.4.2 Initial Coverage. Type II Standards are acceptable for initial coverage. All Type II standards shall be approved by the organization(s) responsible for establishing and implementing work measurement standards and estimating when Type I Standards have not yet been developed.

5.4.3 Upgrading. The Work Measurement Touch Labor Coverage Plan shall provide-a schedule for upgradinq Type II to Type I Standards.

5.5 Leveling/Performance Rating. All time studies shall be rated using recognized techniques.

5.6 Allowances. Allowances for personal, fatigue, and unavoidable delays shall be developed and included as part of the labor standard. Allowances should not be excessive or inconsistent with those normally allowed for like work and conditions.

5.7 Estimating. The contractor's procedures shall describe how touch labor standards are utilized to develop price proposals.

5.8 Use of Labor Standards. Labor standards shall he used:

5.8.1 Budqets, Plans, and Schedules. As an input to developintg budgets, plans and schedules, when available.

5.8.2 Touch Labor Hours. As a basis for estimating touch labor hours when Issuing changes to contracts and as a basis for estimating the prices of Initial spares, replenishment spares and follow-on production buys, when available.

5.8.3 Measuring performance. As a basis for measuring touch labor performance.

5.9 Realization Factor. When labor standards have been modified by realization factors, major elements which contribute to the total factor shall be identified. The analysis supporting each element shall be available to the Government for review.

5.10 Labor Efficiency. A forecast of anticipated touch labor efficiency shall be used in manpower planning, both on a long-range and current scheduling basis.

[8] 5.11 Revisions. Labor-standards shall be reviewed for accuracy and appropriate system data revision made when changes occur to:

a. Methods or procedures

b. Tools, jigs, and fixtures

c. Work place and work layout

d. Specified materials .

e. Work content of the job

5.12 Production Count. Work units shall he clearly and discretely defined so as to cause accurate measurement of the work completed and shall he expressed in terms of completed:

a. End items

b. Operations

c. Lots or batches of end items

5.12.1 Partial Credit. In those cases where partial production credit is appropriate, the work measurement procedures shall define the method to he used to permit a timely and current production measure.

5.13 Labor Performance Reporting. The contractor’s work measurement program shall provide for periodic reportinq of labor performance. The report shall he preparerd at least weekly for each York center and be summarized at each appropriate management Ievl; it shall indicate labor efficiency and compare current results with pre-established contractor goals.

5.13.1 Variance Analysis. Labor performance reports shall be reviewed by supervisory and staff support functions. When a significant departure from projected performance qoals occurs, a formal written analysis which addresses causes and corrective actions shall be prepared.

5.13.2 Report Retention Performance reports and related variance trend analyses shall be retained for a six-month period.

5.14 System Audit. The contractor shall use an internal review process to monitor the work measurement system. This process shall be so designed that weaknesses or failures of the system are identified and brought to the attention of management to enable timely corrective action. Written procedures shall describe the audit techniques to be used in evaluating system compliance.

5.14.1 Scope of Audit. The audit shall cover compliance with the requirements of this standard at least annually. The audit, based upon a representative sample of all active labor standards and work measurement activities, shall determine:

a. The validtty of the prescribed method and the accuracy of the labor standard time values as validated against the data baseline.

b. percent of coverage by Type I and Type II labor standards.

c. Effectiveness of the use of labor standards for Planning, estimating, budgeting, and scheduling.

d. The timeliness, accuracy and traceability of production count reporting.

l The accuracy of labor performance reports.

f. The reasonableness and attainment of efficiency goals established.

g. The effectiveness of corrective actions resultinq from variance; analyses.

5.14.2 Audit Reports. A copy of the audit finding shall be retained in company files for at least a two-vear period and shall be made available to the Government designated representative for review upon request.

APPENDIX B

COMPUTER AIDED PROCESSING PLANNING
BIBLIOGRAPHY WITH ABSTRACTS

COMPUTER-AIDED PROCESS PLANNING

BIBLIOGRAPHY

WITH ABSTRACTS

FOR

SOCIETY OF NAVAL ARCHITECTURE AND MARINE ENGINEERS
PANEL SP-4

BY

BATH IRON WORKS CORPORATION
700 WASHINGTON STREET
BATH, MAINE 04530

COMPUTER-AIDED POCESS PLANNING

BIBLIOGRAPHY

Compiled by

Richard L. DeVries, Project Manager
Bath Iron Works Corporation
700 Washington Street
Bath, Maine 04530

ACKNOWLEDGEMENT

I would like to thank Cheri Tronolone for her patience and excellent organizational support in the preparation and typing of this bibliography.

COMPUTER-AIDED PROCESS PLANNING

BIBLIOGRPHY

WITH ABSTRACTS

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SECTION II

CAPP BIBLIOGRAPHY

ABSTRACTS OF CAPP RELATED ARTICLES

PRESENTED IN ALPHABETICAL ORDER BY TITLE

“A Complex Computer-Aided Process Planning and Optimization for Machine Production"

R. Kyttner, N. Shtcheglov and A. Kimmel
Technical University, Tallin (USSR)

SME Technical Papers (1979).

"A generalized technological process optimization schema for Computer-Aided Process Planning (CAPP) systems is described. The part-family oriented CAPP data base is designed. A special language to specify the user’s requirements for the CAPP system and a universal interpretative technological processor are proposed for an efficient implementation of the CAPP System.”

“A Computer-Aided Tolerance Control System (CATC)”

Rashpal S. Ahluwalia, Ohio State University
Andres V. Karolin, General Motors

Journal of Manufacturing Systems (1984), Volume 3, No. 2, Pages 153-160.

“Computer utilization in manufacturing systems is increasing at a rapid rate. Developments thus far have been diejointed. Much work needs to be done in the area of ir:egrating Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM). Tolerance control is an important component in the integration of CAD and CAM. Selection of design tolerances affects the buildability of a product. The selection of manufacturing processes and sequence of processes affects process tolerance stacking. Unexamined process tolerance stacking leads to scrap and rework. A Computer-Aided Tolerance Control (CATC) system is presented in this paper. This system is based on the tolerance chart technique. The CATC system is interactive and uses computer graphics for information display. The system can be used for Computer-Aided Process Planning (CAPP) and for CAD/CAM integration."

"A Computer-Integrated Manufacturing System for the Metalworking Industry"

Jose M. Pinte, Research Centre of the Belgian Metal-Working Industry, Heverlee, Belgium.

"A rapid and accurate information flow between all company divisions is the main condition for an efficient manufacturing process. This paper describes an integrated manufacturing system for the mechanical industry. It is based .on a unique and clearly defined data structure and information processing mainly occurs automatically. The main characteristics are: the general integration approach, including design, process planning function, which has been highly automated; and the use of a general normalized data base system (CODASYL) for the management of all data (geometrical and non-geormetrical)."

"A General and Flexible System for Information Handling and Decision Making"

Jorgen Jorgensen, CIM Consulting, APS
Leo Alting, Technical University of Denmark

SME Technical Papers (1984).

"Establishment of the information structure and handling of information, including initiation/flow of technical information, capture of existing know-how, and retrieval/utilization of information to support planning and decision making in various functions and engineering analysis, are major prerequisites for rationalization of an industrial enterprise and for an effective introduction of CAD/CAM and CIM. D CLASS TM is a multipurpose tree processor with a high level tree definition/application programming language, which can handle and support general important industrial functions. Examples of D CLASS TM as a basic software tool are described, including selection of parts, equipment and other types of inventory, generative process/assembly planning, and truly integrated and automated CAD/CAM application systems."

"A Knowledge-Based Approach to Generative Process Planning"

R. H. Phillips, University of Illinois, Chicago, Illinois
C. B. Mouleeswaran, Siemens Research and Support, Incorporated, Princeton, New Jersey.

"This paper describes a research effort to solve a real world problem using Artificial Intelligence (AI) concepts and knowledge based reasoning techniques. A prototype of a knowledge based expert system for manufacturing process planning is described. The system derives part geometry and other related information from a Computer-Aided Design (CAD) data base in the form of a descriptive language, and produces a detailed process plan to manufacture the part. The paper discusses the AI approach used, the concepts utilized to encode manufacturing logic in computers, the symbolic representation of mechanical parts, and the research contribution to Computer-Integrated Manufacturing (CIM)."

"A Management Overview of Group Technology"

Alexander Houtzeel and Carl S. Brown
Organization for Industrial Reseach, Incorporated

SME Technical Papers (1982).

Increasingly, batch manufacturers are investing in CAD/CAM technology to improve productivity. A common approach is to purchase stand-alone systems to perform specific tasks. However, isolated systems cannot reflect the impact of one activity or department on another, or take advantage of a company's total store of experience. Integration is the key to realizing the full potential of computerization. Group Technology, classification and coding are the tools necessary to integrate CAD and CAM. Because the implementation of an integrated system is a complex, inter-departmental task, it is necessary that top management understand and guide the process."

"A Review of Computer-Aided Process Planning Systems"

J. D. Burgess, Swinburne Institute of Technology

SME Technical Papers (1984).

"Current manual process planning methods lead to inconsistent process planning with resulting manufacturing inefficiencies. Computers are being used to assist the process planner. Current computer process planning systems are based on variant process planning techniques and use a coding and classification system to extract standard process plans. Artificial Intelligence and expert knowledge computer systems techniques are being explored to use generative process planning techniques for even greater efficiency. Some expert knowledge systems are currently being tested but are not yet suitable for commercial use."

"A Review of Computerized Machinability Data Base Systems"

P. Balakrishnan and M. F. DeVries
University of Wisconsin, Madison

Proceedings (1982), Volume 10, Pages 348-356.

"Computerized machinability data base systems are surveyed. Some two dozen systems were identified, their basic features characterized. Classification of system types, areas of application, data structure, output capabilities, and processing logic are among the details which were compared. Techniques used by the various systems to obtain recommended or optimum cutting conditions were analyzed. Integrated machinability systems in automated process planning schemes and numerical control programming languages were identified and their suitability for use in computer-integrated manufacturing facilities discussed. Limitations of the existing systems are noted and areas where further work is needed to enhance the reliability and suitability of these systems for use in automated manufacturing are suggested."

"A Software Library for the Design and Optimization of Computer-Integrated Manufacturing Systems"

Dr. Paul G. Ranky, Trent Polytechnic

SME Technical Papers (1984).

"Since the heart of advanced manufacturing systems is the distributed processing environment employing computer networks and sophisticated software, the author has created "the FMS software library" with the aim of providing modular software tools and turnkey computer programs for designing, simulating, controlling, implementing, testing and maintaining FMS and CIM systems. The paper gives an overview of this growing library, written in PASCAL and capable of running on over 30 different micro, mini, and mainframe computers, as well as discussing the FMS and robot maintenance and the three dimensional robot test program in more detail."

"A Strategy for Implementation of Hierarchical Control of CIM"

Forrest C. Gale, Defense Systems Management College

SME Technical Papers (1984).

"Hierarchical control architecture provides a unifying framework for the implementation of in–situ automation in existing functionally diverse process operations. Further, hierarchical control schema may offer the closest approach yet devised to an integrated theory of manufacturing because of the underlying structural emphasis on the manufacturing system functions of communication and control. This paper offers a strategy for implementation of hierarchical control of 23 geographically and operationally unique industrial operations all managed by one organization. System and attribute models of the resultant complex are devised and discussed as is the operation of the industrial engine thus devised."

"A System of Computer-Aided Process Planning for Machine Parts"

Dr. K. H. Tempelhof and Otto V. Guericke
Technische Hochshule (G.D.R.)

SME Technical Papers (1979).

"In this paper an Autotech-Programme System is discussed for the computer-aided planning of manufacturing processes for typical machine parts, such as shafts, flanges, housings, etc. The structure of the system, i.e., its subdivision into a basic system and a frame system, and its building-up from process modules are described. The possibilities and advantages of its application in the machine tool industry are shown. The example used is a large machine tool manufacturing plant."

"A Today's Look at the Automated, Integrated Factory of Tomorrow"

Robert L. Vaughn, Lockheed Missiles & Space Company, Inc.

SME Technical Papers (1983).

"This paper will discuss current company activities in areas that influence the "automated integrated factory" of tomorrow. Computers have already integrated engineering and manufacturing functions including design, tool design, planning, facilities layout, fabrication (NC, DNC, CNC) and inspection. Satellites have tied together this information to the mainframe computers of all corporate companies so as to act as one. Productivity factors of 39:1 are now being realized. Costs, machine performance and other pertinent information is tied together with a data base management information system to allow real adjustment in product flow. Robots with eyes, and soon with sensitive hands, are integrated into development. Workers talk to the computer while production is progressing and the automated material storage and retrieval system fills orders. Thousands of parts are being designed and manufactured without drawings. Tomorrow's factory is here today."

"An Aerospace CIM System"

Editorial Staff, Manufacturing Engineering

Manufacturing Engineering (1983), Volume 91, No. 4,
Pages 67-68.

“The General Electric Aircraft Engine Business Groups’s Computer-Integrated Manufacturing (CIM system is described.) The system is comprised of a network of several computerized manufacturing operations at three General Electric Plants. The system features direct numerical control, CAD/CAM, and Computer-Aided Process Planning.

“An Approach for Solving the CIM Gap Problem”

John Harried, LSF Automation, Limited, Mt. Clemens, Michigan
Samuel B. Holcman, Computer & Engineering Consultants, Limited, Southfield, Michigan.

“Large scale factory automation requires the integration of microcomputer technology at all levels of the plant hierarchy. At present, a CIM gap exists between the management_ decision support systems at the MIS level and the factory floor level where the “intelligent” controller and small microcomputers reign. This paper describes one approach for solving the CIM gap problem; this approach is based on combining color graphics man-machine interfaces, feedback control and MAP technology to achieve production monitoring and supervisory control at the workstation, cell and area management hierarchal levels. Emphasis is placed on control system architecture and MAP application interfaces .“

"An Approach to CAPP Cost Justification"

William D. Cochran, Garrett Turbine Engine Company

SME Technical Papers (1984).

"There are different methods to analyze and justify costs and benefits of a Computer-Aided Process Planning System. Discussed is one approach to justify cost of a CAPP system. Tools used for analysis are Group Technology and production flow analysis."

"An Approach to Computer-Integrated Manufacturing at Brigham Young University"

Dr. Dell K. Allen and Paul R. Smith
Brigham Young University

SMti Technical Papers (1983).

"Computer-ntegrated Manufacturing is being approached on both the conceptual level and the experimental level. Manufacturing has been defined to include all activities within the enterprise. Manufacturing activities have been classified and analyzed to identify basic functions to be performed. Data elements are being defined for supporting common and distributed data bases. The systems engineering integration model includes coordination, planning, scheduling, and control of various activities and processes. An eight-step integration approach is being followed for creating hardware and software to be used in a fully integrated minilab for research, teaching, and simulation purposes."

"An Award - Winning CIM System"

Editorial Staff, Manufacturing Engineering

Manufacturing Engineering (1983), Volume 90, No. 2, Pages 49-50.

"The CIM system of the Ingersoll Milling Machine Company, the 1982 CASA/SME Lead Award Winner, is described. The system is used to process both business and manufacturing information using an IBM-3033U computer that handles 121 alphanumeric and 30 graphics terminals and manufacturing equipment. George Hess, Ingersoll Vice President of Systems and Planning, outlines the key componets and processes of the system."

"An Integrated Group Technology Program"

W. Stephen Bucher, General Electric Company

SME Technical Papers (1979).

"The armament systems department of General Electric Company inihiated a fully integrated Group Technology Program in May of 1978. The objectives were to develop systems in both engineering and manufacturing that would exploit the similarities of parts. ASD'S program involves the tailoring of the MICLASS code and software through a rigorous analysis effort. Although payoff was not predicted until 1981, several operating systems are already utilizing the G.T.. code and retrieval program to generate documented savings. Future plans call for the implementation of a Computer-Aided Process Planning Program and interfacing classification and coding to the interactive graphics system."

●*An Integrated Process Architecture for Aircraft Remanufacturing"

Forrest C. Gale, Defense Systems Management College

SME Technical Papers (1983).

"The Navy organic aircraft remanufacturing complex is comprised of six large, geographically dispersed high technology production sites employing more than 26,000 personnel. This paper characterizes these unique and diverse operations, their embedded industrial processes, process elements, process flows, and the attendant process technologies. A new ideal state process flow and topological structure is postulated for the "aircraft depot of the future", utilizing a flexible hierarchical control architecture and an integrated support systems approach unique to this class of industrial operation. System design characteristics of the resultant production engine are described in detail, as in an arch-type attributes model for the resultant process complex."

"An Integrated System UtiLizing Solid Modeling Techniques for the Design and Manufacture of Mechanical Parts"

Harry E. Davine, General Electric Company

Proceedings (1982).

"An integrated CAD/CAM system is used for the design and manufacture of complex mechanical parts. A significant element of this integrated system is the use of solid modeling software. The system involves the design, analysis (thermal, structural, mass properties), documentation, numerical control programming, process planning, and assembly disciplines utilizing a common data base. Software and hardware, the integration of engineering and manufacturing functions, and the advantages offered by utilization of solid modeling techniques are discussed in detail. Examples of applications in addition to the engineering design and analysis disciplines include facility planning for a military training installation, process planning for complex parts of a shipboard weapons system, and operator aids for sequential machining operations on large castings."

"An Open Loop Adaptive Control Metholology"

W. J. Zdeblick, Metcut Research Associates
R. E. DeVor, University of Illinois

Proceedings (1979), Volume 7, Pages 300-306.

"An approach to macroeconomic analysis for process planning of machining operations termed, "Open-Loop Adaptive Control (OLAC)" is detailed. This approach shows that economic savings are made by recognizing the systematic effect tool wear has on process performance measures such as surface finishes and selecting cutting conditions over the tool change interval. The basic structure of a Long Run Cost (LRC) Model is summarized. Optimization procedures for cutLtng condition selection and tool change interval selection also are reviewed. The development of the Open-Loop Adaptive Control method is illustrated through the modeling of data from a turning experiment. A comparison of this methodology with several other macroeconomic optimization procedures is made."

"Application of Automated Process Planning and NC Programming"

LJ. Eversheim, B. Holz, and H. Zons
Technical University AACHEN

CAPP Computer-Aided Process Planning, (1985), First Edition, Pages 173-193.

InmM the recent years a rapidly increasing application of CAD/CAM systems is characteristic for the departments of process planning and NC programming. Most of these SyS-tems are concentrated on certain planning tasks or they are restricted by the parts spectrum that can be planned. There at the Laboratory of Machine Tools and Production Engineering (WZK) at AACHEN Technical University, the systems AUTAP and AUT.AP-NC were developed. The present report shows the structure and use of these systems which enable a complete process planning and NC programming for a wide parts spectrum, like disks, gears, shafts, sheet metal, etc.

Depending on the requirements of companies the systems can be applied in an interactive or batch mode. AUTAP and AUTAP-NC, which are part of an integrated system for generation of manufacturing documents are already used successfully in different German companies."

"Applications of Microcomputers in Manufacturing Management"

Dennis R. Stevenson, University of Wisconsin, Parkside, Kenosha, Wisconsin.

"Several areas are explored where microcomputers, using typical software, can be profitably applied toward management problems in smaller manufacturing shops. Target computers and software are defined, along with characteristics of the target shops. Traditional management theories are reviewed for applicability, and sample programs are presented for representative problems. It appears that this "small-end" use of computers represents a new and expanding area of importance for the general computer-aided manufacturing field."

"Applying Group Technology: A Case Study'*

Sundaram R. Meenakski, Tennessee Technology University

SME Technical Papers (1981).

'*Group Technology, classification and coding that leads to improvements in manufacturing productivity, can be successfully implemented in both job shop and batch–type manufacturing industries. The implementation of this concept *in* manufacturing not only increases productivity but also lends itself to computerization of manufacturing leading to CAM. Further, the planning and scheduling of manufacturing operations are made simpler. This paper describes a methodology developed to determine the feasibility of using the techniques of group technology, classification, and coding in a machine shop that manufactures to order. Quantity required, repeat orders, setup cost, design, and drafting costs are the considerations used in developing this methodology as well as ease of production planning and scheduling of jobs. (Available in microfiche only.)"

"Automated Manufacturing Planning and Engineering'*

N. W. Hopwood, Jr. and A. C. Friedemann
Ford Motor Company

SME Technical Papers (1981).

"The system development described in this paper involves the interactive use of a computer data base in the planning and operation of a high-volume, automotive component manufacturing operation. A discussion of the evaluation of process planning data and systems software development are presented."

"Automated Process Planning the Key to Automating Manufacturing Support"

R. H. Jackson, Rockwell International--Tulsa Division

SME Technical Papers (1978).

*'Automated planning is not only a tool for increased productivity and better quality in the process planning function, but can be the key element in automating the entire 'design translation" process. The goal of this concept is to provide a computer-aided, manufacturing system that applies standards, orders tools, orders materials, and issues shop orders per schedule automatically upon completion of the planning function."

"*Automated Testing: A Systems Approach"

Howard S. Fogelson, IBM Corporation

SME Technical Papers (1983).

*'Rapid changes in technology, coupled with the need for high quality and competitive pressure to drive costs down, are major challenges that must be faced by manufacturers of data processing products. Automated product testing is a methodology to meet and overcome these challenges. The most effective automated test process can be achieved by integrating product testing with other manufacturing operations via distributed data processing computer systems. The description of a systems approach to automated testing illustrates how direct labor costs can be reduced by almost 100%, while simultaneously achieving 100% accuracy of the test process."

"Building Blocks for Automation"

Gary L. Renick, APPLICON

SME Technical Papers (1984).

"A fully integrated manufacturing environment is built with two key disciplines; product design, and manufacturing engineering. Within these disciplines, many functional tasks are enhanced and automated with CAD/CAM technologies. Basic requirements of factory automation, such as part geometry, Group Technology, process planning, facility design, and device programming are defined. These ingredients, when integrated via common data bases, aid both product design and manufacturing engineering when designing for automation. Integrated applications performing Group technology, process planning, facility design, device programming along with geometric modeling, form the foundation for Computer-Integrated Manufacturing."

CAD/Generative Process Planning with TIPPS”

Tien-Chien Chang, Purdue University
Richard A. Wysk, Pennsylvania State University

Journal of Manufacturing Systems (1983), Volume 2, No. 2,
Pages 127-135.

“Two approaches to Computer-Aided Process Planning are defined variant and generative. The variant approach retrieves existing plans for a similar part while the generative approach synthesizes plans from built–in knowledge. The generative approach to process planning is normally considered more complex and the more automated of Lhe two approaches. This paper discusses a generative process planning system called Totally Integrated Process Planning System (TIPPS). TIPPS uses a Computer-Aided Design (CAD) model as direct input, eliminating part coding or description from the planning process. Currently, TIPPS is capable of planning prismatic parts with one access direction. Relevant issues encountered in constructing a generative process planning system as well as the TIPPS design philosophy are discussed. Process planning using TIPP’S is illustrated. This paper also discusses future research directions in automated process planning."

“CADMAC, Next Step on the Path to CIM”

Chris Schroeder, Infodetics.

“Companies are expending great effort to link the components of CIM: CAD, CAM, Group Technology, BOMS, MRP, automated materials handling and assembly, and technical publications systems. In addition to establishing links between diverse computer systems, CIM is now poised to integrate the paper based documentation of manufacturing areas that have not yet been automated. The CADMAC (Computer Assisted Document Management and Control) system is a logical first step in linking CAD/CAM files and manually prepared documents in a single data base and bringing many of the long sought benefits of CAM today.”

"CAM and Computer Speech Recognition"

Edward R. Guididas, Lockheed Electronics Company, Inc.

SME Technical Papers (1982).

"Lockheed Electronics Company, Inc. has combined two high technology concepts, Computer-Aided Manufacturing and computer speech recognition, into a single application for office paperwork automation. The specific task involves the creation of shop work orders using a person's voice as the method of entering data into the computer. This paper describes the system's hardware configuration and the details of how the system operates."

"CAM Integration of W.P., CAD, 4M, and MRP"

Robert R. Clifford, Singer Company

SME Technical Papers (1984).

"Integration, through communication, of modern tools used by industrial and manufacturing engineers in support of product fabrication, is discussed. Research into linking of word processing, Computer-Aided Design, automated labor standards and manufacturing resource planning is undertaken. The project was initiated to reduce the non-recurring or preparation time needed to begin product fabrication, and to modernize the process."

"CAM I Automated Process Planning"

C. H. Link, Computer-Aided Manufacturing-International

SME Technical Papers (1977).

"This presentation provides a description of how the CAPP system operates. The coding and classification requirements for data base construction, initialization and use of CAPP are also explained."

"CAM-I Automated Process Planning"

C. H. Link, Computer-Aided Manufacturing-International

SME Technical Papers (1978).

"This presentation provides a brief description of how the CAPP system operates. It contains comments about the systems that are released, additional studies completed, or modules that are under development."

"CAM–I's CAPP System"

Richard N. Claytor, Computer–Aided Manufacturing–International

SME Technical Papers (1976).

"CAM-I is a not-for–profit industrial research and development organization dedicated to the application of the computer to the solution of manufacturing problems. The process planning program is one of CAM-I's manufacturing software development projects. Experts have worked for two years to specify a basic process planning system for machined parts planning. The specifications have recently been com–pleted, and, a contract awarded to McDonnel Douglas Automa–tion for the development of the "Machined Parts Process Planning Creator Module". This paper describes the contract work, the anticipated mode of operation of the system, and the benefits expected from use of the system."

"CAM-I's Experimental Planning System, XPS-l"

Charles F. Sack, Jr., United Technologies Research Center

SME Technical Papers (1983).

"CAM–I'S Process Planning Program is developing an advanced process planning system for general parts. As a first phase, CAM-I has selected United Technologies Research Center to develop a prototype system called XPS-1. The system will demonstrate basic generative planning techniques and provide a framework for additional advanced capabilities. XPS-1 provides a data dictionary and relational data base for defining and entering required product data, and an english-like language for defining processing logic. The logic is applied to the product data to produce a sequence of work elements and/or classification code. The plan output may be passed to a variant planning system or text editor."

"CAPP: Critical to CAD/CAM Success"

Robert E. Harvey

CAPP: Computer-Aided Process Planning (1985), First Edition, Pages 15-17.

"Computer-Aided Design (CAD) and Computer-Aided Manufacturing have increased the responsiveness of design and manufacturing to the needs of the marketplace. However, the link to convert the complex geometries produced by CAD into efficient instructions to be carried out by CAM must also be computerized to prevent a bottleneck in the flow of information. Process planners in many industries are a dying breed, as most of the companies experience is walking out the door with the retirees. Computer-Aided Process Planning (CAPP) is the tool to preserve a firm's design and manufacturing history by capturing the knowledge of the retiring process planner, before he walks out the door, and removes the bottleneck in the flow of information."

"Communicating Product Definition and Support Data in a CAE/CAD/CAM Environment"'

A. Kader Elgabry, General Electric Company
Schenectady, New York.

"The overall problems of communicating product data between and within engineering and manufacturing environments is addressed and the related interface and control issues are discussed. Product definition data (geometric and non-geometric definition of product parts and assemblies) and product support data (derived from product definition and used for product analysis, planning, production, and control) are the data components covered. Current exchange formats and interface standards for product data are outlined, and their major features discussed. Future trends in communicating product data, and their anticipated impact on CAE/CAD/CAM users and vendors, is discussed."

"Computer-Aided, Fully Generative Process Planning"

Robert M. Smith, CAPP of New Jersey

Manufacturing Engineering (1981), Volume 86, No. 5, Pages 98–99.

"A fully generative process planning computer would create the required manufacturing specifications without human intervention. Such a system is not yet available, but limited applications have been developed. Full scale development may be the next major addition to the discipline of Group Technology."

"Computer-Aided Material Selection, Design for Production and Tool/Die Design"

Jorgen Jorgensen and Leo Alting

SME Technical Papers (1983).

"Computerized engineering disciplines and methods for integration of design and manufacturing are major prerequisites for the long-range goal of Computer-Integrated Manufacturing (CIM) - and generally for design of better products at competitive costs. A number of computer-aided engineering application modules can provide an integration and support of important mechanical design and manufacturing activities. The applications include information storage and retrieval for parts and equipment, material selection, process selection, design for production, tool and die design, process planning, time estimating, and equipment selection. The modules can significantly improve the capabilities of standard CAD/CAM systems."

Computer-Aided Milling Operation Planning Program (CAMOPP)”

Stephen A. Pellegrino, General Electric Company
Inyong Ham, The Pennsylvania State University

Proceedings (1983), Volume 11, Pages 484-489.

“Milling operation planning can be defined as the planning of milling cutter tool paths. It involves the selection of the milling cutters capable of generating the part’s geometric features, the specification of the cutting parameters based on a production optimization objective, and the sequencing of these cuts based on the part’s metallurgical characteristics, mechanical properties, and fixturing constraints. The factors that influence operation planning decisions are described and the Computer–Aided Milling Operation Planning Program (CAMOPP) which was developed as an exploratory software package in the area of process planning for non-rotational parts is reviewed.”

“Computer-Aided Part Design for Economical Fabrication by a Forging Computer-Based Factory Automation"

C. Poli, University of Massachusetts
W. A. Knight, University of Oxford, England

Proceedings (1984), Pages 35-38.

“A research program to initiate the development of a series of software tools to aid a designer in the design of products for economic manufacture by such processes as forging, molding and casting is described. At a later stage, this work can lead to the integration of product design with computer–aided work planning and process design, together with the CAD/CAM design and production of the dies required for the process.”

"Computer-Aided Planning of Robotic Assembly"

Shimon Y. Nof, Purdue University

SME Technical Papers (1983).

"This paper reviews seven related research projects on planning robotic assembly systems under a framework of computer–aided facility planning: (1) Further development of RTM, the robot time and motion method; (2) Performance evaluation of robotic assembly cells; (3) Simulation package for robot systems, SINDECS-R; (4) Facility planning with an expert system based on prolog; (5) Optimal plans for bin picking and part insertion; (6) Coordination of assembly cells with cooperating robots, and (7) Economic evaluation of alternative assembly technologies in the woodworking industry."

"Computer-Aided Process Planning (CAPP)"

C. H. Link, Computer-Aided Manufacturing–International

SME Technical Papers (1977).

"This presentation provides a brief history and description of how the CAPP system operates. The coding and classification requirements for data base construction, initialization, use of CAPP, and its relationship to numerical control, geometric modeling and shop floor control."

"Computer Aided Processing Planning"

Dell K. Allen and Paul R. Smith, Brigham Young University

The National Shipbuilding Research Program, "Product Work Classification and Coding, June 1986

"The problems and needs of processing planning are presented along with two basic approaches for computer assisted process planning. Characteristics of the variant and generative approaches for process planning are discussed. The use of decision tables and trees is explored as applied to generative process planning. Implementation of logical decision trees by means of a unique tree handling system is explained and typical generated process plans are shown.

KEYWORDS

Generative, process-planning, decision, tables, trees, computer-aided, DCLASS, variant, selection, and sequencing.

"Computer-Aided Process Planning and Productivity"

Kjell B. Zandin, H. B. Maynard and Company, Inc.

SME Technical Papers (1982).

"One of the biggest causes of declining productivity in U.S. industry is the lack of integrated process planning in the factory. The computer can introduce efficiency and accuracy to this production refinement by making it possible to plan entire sequences automatically. Maynard's MAYCAPP system enables less skilled planners to produce reliable information more quickly. Skilled industrial or manufacturing engineers will be able to devote more time to productivity improvements and spend less time on routine paperwork. Finally, the family of parts concept will reduce the number of parts, the number of tools needed to produce those parts and the number of standards to measure the work."

"Computer - Aided Process Planning for Aircraft Engine Rotating Parts"

Vijay A. Tipnis, Tipnis Associates, Inc.
S. A. Vogel, Metcut Research Associates, Inc.
C. E. Lamb, General Electric Company

SME Technical Papers (1979).

"The basic philosophy of the system is to complement the process planner's experience with extensive computer/graphics aids and machining technology validation programs so as to enable him to interactively arrive at the most cost-effective process plans for aircraft engine rotating parks. The system is a part of the overall master CAM plan being implemented in the rotating parts operation of General Electric Aircraft Engine Group."

"Computer-Aided Process Planning: Past, Present and Future"

Harold J. Steudel, Department of Industrial Engineering, University of Wisconsin–Madison, Madison, Wisconsin

CAPP: Computer–Aided Process Planning (1985), First Edition, Pages 3–14.

"The role of process planning in small-batch, discrete parts metal working industries and the impact of the computer in automating this important, but tedious job are discussed. The nature, advantages, and limitations of the manual, variant, and generative approaches to process planning are presented along with a review of the progress to date for each approach. A major thrust of the paper is to discuss approaches and strategies for structuring manufacturing methods and data in decision logic formats applicable to developing generative type automated planning systems. Although no particular approach is promoted, the paper provides an overview and information useful for approaching the task of designing a generative type system. Some detailed discussion on part coding schemes and structuring decision logic for generative type planning systems is also presented. The paper concludes with a brief discussion of the future of Computer–Aided Process Planning and the role that the microcomputer will play in that future."

"Computer-Aided Production Engineering: The Integration of CAPP, Engineering and Manufacturing"

Gayle L. Berry, Garrett Turbine Engine Company

SME Technical Papers (1984).

"Computer-Aided Production Engineering (CAPE) is a strategic direction to integrate information, logic, and engineering functions of design, process planning, and production. The system design process used has been a contributor to the success in implementation of initial modules of CAPE. Phased approaches to development and implementation are key elements in the CAPE program, as are technical elements which specifi-tally address GTEC'S individual environment."

"Computer-Aided Scheduling: A Heuristic Model"

A. Conti, M. Carbo, and G. Manfrinato, Dalmine S.P.A.

Proceedings (1981), Volume 9, Pages 475-482.

"A heuristic model for production planning of plants consisting of a main line feeding a series of secondary lines via intermediate storages is presented. The way in which the results provided by the model are evaluated is explained, and an account is given of a procedure for its profitable employment in practice as a duly inserted component of the information system. Lastly, an actual case in which the model and its method of utilization were investigated and elaborated is described."

“Computer-Aided Selection of Feeds and Speeds”

Robert N. Stauffer, Manufacturing Engineering

Manufacturing Engineering (1979), Volume 82, No. 5,
Pages 53-55.

“A software package developed by the General Motors Manufacturing Development Group gives the process engineer quick access to the best available information on feeds and speeds. The data base covers pertinent characteristics of the workpiece, machine, cutting tool, and type of machining operation. General Motors Delco Product Division has improved both productivity and quality with the program.”

"Computer-Aided Tolerance Analysis"

Andres V. Karolin, General Motors Corporation

SME Technical Papers (1984).

“Tolerances are fundamental to manufacturing. Choice of design tolerances affects the products suitability for construction. Selection of manufacturing processes and sequence of processes affects tolerance stacking. Tolerante stacking has an effect on product quality. Unexamined tolerance stacking leads to scrap and rework thereby increasing product costs. Computer-Aided Tolerance Analysis (CATA) is presented in this paper. It is based on the “tolerance chart” technique. CATA is interactive and uses computer graphics for information display.”

"Computer-Assisted Process Planning: A First Step Towards Integration"

Alexander Houtzeel, Organization for Industrial Research

Proceedings (1980), Volume I, Pages 801-806.

"Computer-Assisted Process Planning can be a first step toward the integrated use on computers in the design and manufacturing process to improve productivity in batch manufacturing. The key to the process of integration is a part feature recognition method to analyze the retrieved manufacturing processes and arrive at least–cost designs consistently linked to "best" manufacturing processes. Major problems are incompatible computers, software, and people. (available in microfiche only.)"

"Computer-Based Manufacturing Shop Floor Control System at Kingsport Foundry and Manufacturing Corporation"

E. A. Ring, Kingsport Foundry and Manufacturing Corporation
Dr. Timothy J. Greene, Virginia Polytechnic Institute and State University

SME Technical Papers (1983).

"SEQUEXEC, a computer-based, manufacturing shop floor control system, was developed for and successfully implemented at Kingsport Foundry and Manufacturing. This facility specializes in casting and machining make-to-order, one-of–a-kind products. The products must meet stringent due date requirements within a limited capacity system, because the products are unique and prototypical. Accurate cost estimation and labor reporting is critical. SEQUEXEC provides a priority sequencing mechanism for all machine centers based on due date (slack) criteria. This mechanism is designed to be used by machine operators and supervisors. SEQUEXEC provides: capacity and manpower planning information, labor reporting and job cost tracking, actual–to-standard time analysis, and aggregate shop efficiency performance measures, A shop floor control system's capabilities, strengths and weaknesses, as well as the difficulties involved with its development and implementation are detailed."

"Computer-Integrated Manufacture in the Australian Defense Industry"

Vincent A. Bond, Small Arms Factory

SME Technical Papers (1984).

"This paper presents the integrated information control approach which has been devised within the Small Arms Factory. The overall architecture of five interrelated systems, designed using Structured Analysis and Design Technique (SADT), is presented. In particular, the use made of production inventory management and Group Technology principles is described. The history, development, and present state of implementation is shown. The place played by commercially available computer hardware and software packages is described and illustrated for solid modeling, process planning and manufacturing control."

"Computer-Integrated Manufacturing: Opportunities and Barriers"

Thomas L. Adams, Battelle Columbus Laboratories

SME Technical Papers (1983).

"Computer-Integrated Manufacturing (CIM) is a concept in which manufacturing management, engineering, and production functions would be integrated for handling by a hierarchical system of computers. The opportunity is right for manufacturing firms to implement CIM due to the availability of individual building block technologies; government-sponsored CIM development programs in the U.S., Japan and the downstream economic benefits of CIM. However, heavy capital requirements and long-term phase--in are barriers to CIM. The barriers are overcome by extensive up-front planning and engineering. Human skills required in the CIM facility include adaptation, reasoning, acute senses and dexterity."

"Computer-Managed Process Planning: A Bridge Between CAD and CMM"

Charles F. Sack, Jr., United Technologies Research Center

Proceedings (1982).

"Automated process planning plays a key role in integrating design and manufacturing functions. The Computer–Managed Process Planning System (CMPP) deals with high technology machined cylindrical parts. Its goals are to improve productivity through reduced planning lead time, improved accuracy, and standardization. CMPP functions include: (1) generating a sequence of operations, (2) selecting dimensioning reference surfaces, (3) determining machining dimensions and tolerances, and (4) producing process plan documentation. CMPP is generative, interactive, and manufacturer independent. It also provides interfaces to accept part designs from CAD systems and to pass information to CAM systems."

"Computerized Assembly Process Planning"

Robert. Waterbury

CAPP: Computer-Aided Process Planning (1985), First Edition, Pages 109-112.

"Lockheed-Georgia is using group technology and family–of-parts classification and coding techniques to bring some of the benefits of mass production to batch manufacturing. Lockheed applies Group Technology concepts to divide parts into coded families based upon such similarities as size, shape, materials and manufacturing processes. Lockheed Process Planners use a specially-developed Computer-Aided Process Planning System know as Assembly Genplan to assist in the development of process plans enhancing the production process through the standardization of methods and processes utilizing such Group Technology codes. Improved process planning document quality and consistency are major benefits."

"Computerized Procedure for Optimization of Machining Conditions"

Mikell P. Groover, Lehigh University
Marlene Velnich, IBM Corporation

SME Technical Papers (1981).

"A self–adaptive procedure for making evolutionary improvements in machining conditions is discussed. This procedure, based on the use of search strategy, uses a terminal located near the machine tool to transmit operating results to and obtain instructions from, a centrally located computer. Some of the experience acquired in using the system is documented."

"Computerized Process Planning for Metal Cutting"

J. I. Eigomayel, Purdue University
R. H. Phillips, University of Illinois

Proceedings (1980), Volume 8, Pages 266-270.

"Production planning is one of the most time-consuming and costly operations of the manufacturing cycle, and hence it is vital that this activity be automated for efficient Computer-Aided Manufacturing Systems to be implemented. Procedures were developed for developing a computerized process planning system for machining metal components that are produced in a discrete part batch manufacturing environment."

Concept of Integrated CAD/CAM System for Metal Parts”

Dr. W. Eversheim, H. Fuchs, and D. Prior
Technical University AACHEN

SME Technical Papers (1979).

“A lot of investigations and developments have been made in the field of Computer-Aided Design and Computer–Aided Planning during the last years. Each of the realized CAD and CAP systems fulfills special demands and is characterized by a certain range of application. However, even if these solutions cover the requirement of special tasks, an integration of several existing systems has not yet been realized. Therefore, the needs of an integrated CAD/CAP system had to be found out and according to the results a conception for the integration of existing systems could be designed. The present report shows the procedure for investigating the main problems in designing and planning of aerospace parts. According to the requirements of aerospace companies, CAD and CAP systems have been analyzed, also the coupling possibilities of systems have been regarded. As a result of this study, a recommended solution of an integrated CAD/CAP system will be presented.”

“Conceptual Overview of Steam Turbine Generator’s CIM System”

Ken W. Emery and John F. Snyder
General Electric Company, Schenectady, New York.

“General Electric’s Turbine Generator’s CIM System links all business functions from quotation to shipment of the finished product. Key integrated modules consist of order entry, MRPII, automated design, generative automated process planning, and factory management.”

"Design of the Manufacturing Systems for the 80's"

Roy W. Smolens, Honeywell Information Systems

Proceedings (1980), Volume I, Pages 443-449.

"Manufacturing operational improvements have been achieved by some manufacturing organizations through the use of computerized systems for MPS, MRP, CRP, shop loading, etc. Improvements also have been achieved by use of factory data collection equipment and on-line inquiry capabilities to speed information retrieval cycles and provide rapid feed-back of operational information. These successes tend to be limited. Many studies have been performed examining the information needs in manufacturing businesses. They have identified two specific trends which establish the form and format for manufacturing control system designs during the 80s. These two trends, how implementation can be achieved - bottom-up, not top down will be discussed. (Available in Microfiche only.)"

"Development and Use of Machinability Data for Process Planning Optimization"

Vijay A. Tipnis and Michael Field, Metcut Research Associates
Moshe Y. Friedman, Technion

SME Technical Papers (1975).

"During process planning for a Computer-Aided Manufacturing System, the selection of cutter paths, tools, workpiece material, cutting fluid, and operating conditions, such as speed, feed and depths of cut, should be made so as to minimize the total manufacturing cost."

"Development of an Integrated Planning and Control Model for Discrete Production Systems"

Dr. M. Fazle Rabbi and Dr. Eui H. Park
North Carolina A&T_ State University

SME Technical Papers (1984).

"The Material Requirement Planning (MRP) system is designed to provide detailed planning information for effective shop floor control. Ignoring part similarity and unrealistic assumptions, such as fixed lead time and resource availability, make MRP less effective as a production planning technique. Presented is a network-based method that considers the missing key elements from MRP by adapting critical path method and Group Technology to make systems more effective and realistic. A heuristic model which can be implemented on computers is presented with an example."

"Development of Computer-Aided Generative-Type Process Planning System for Prismatic Parts in Machining"

K. Iwata and N. Sugimura, Kobe University

Proceedings (1983), Volume 11, Pages 476-481.

"A computer-aided generative-type process planning system was developed to realize the integrated CAD/CAM system. The system determines the optimum sequence of the machine tools based on the models of the finished part and the blank part which are constructed by the CAD system.
through case studies, that the system developed was effective for wide spectrum of prismatic parts."

"Development of Manufacturing Logic and Its Use in Generative Process Planning'"

Edward J. Adlard, Metcut Research Associates, Inc.

SME Technical Papers (1981).

"The CAM systems group at Metcut Research Associates has developed a method of acquiring manufacturing logic and integrating it into a flexible software module for generative process planning. This has been accomplished by first developing a procedure for obtaining the manufacturing routing logic resident within a particular company; and second, utilizing a generalized software module based on decision rule logic to develop process planning information. Examples of how data is gathered and put in a form that can be stored for use in the generative process planning software are presented. (Available in microfiche only.)"

"Development of Non–Part Family Type Computer-Aided Production Planning System"

K. Iwata, Kobe University, Japan
Y. Kakino, Kyoto University, Japan
F. Oba, University of Osaka Pref., Japan

SME Technical Papers (1979).

"Development of automatic production planning systems is one of the most fundamental and important problems to realize complete integrated manufacturing software system in machine shops. A prototype non-part family type computer-aided production planning system named CIMS/PRO has been developed and reported here. The input data are described by the CIMS/DEC to prepare the geometrical and technological information of the finished part and blank part. The CIMS/PRO system automatically generates candidates of feasible machining sequences, machine tools and clamping methods. Cutter location data can also be produced by CIMS/PRO."

"Dynamic Scheduling for FMS"

Khosrow Hadavi, Siemens Corporate Research & Technology Laboratories, Princeton, New Jersey.

"A production planning and scheduling environment is introduced. The model is based on a hierarchial network of constraints that is changed dynamically either by the users or the shopfloor or both. Whenever a new order arrives it is treated as a goal to be realized in the existing levels of constraints ranging from organizational goals to machine availability. Various levels of management can interact with the system dynamically and change the constraints as appropriate. Other components of the proposed environment are user interface, knowledge acquisition tool, data base interface, real time interface, and fuzzy/uncertain decision making. A prototype of the model is currently under development for a circuit board manufacturing site."

"Economic Models for Process Planning"

V. A. Tipnis and Steven A. Vogel, Metcut Research Associates
H. L. Gegel, Wright-Patterson Air Force Base

Proceedings (1978), Volume 6, Pages 379–387.

"Economic models are needed to create cost–effective process plans, especially with the computer--aided and computerized process planning system. Based on rigorous generalized economic models for material removal process, macro- and micro-economic models were developed for process planning. The macro-economic model is applicable to the cost estimation and preplanning stage when information about the part and process are not available, and when a cost-effective process sequence must be selected. The micro–economic model is used for selection and optimization of operating conditions at each work station. These models were developed for analyzing process operating condition alternatives encountered in the machining of an airframe structure from a titanium forging. The application of the micro–economic program to the airframe structure demonstrated significant time and cost savings. These models are applicable to all material removal processes."

"Electronic Signoff: A Successful Manufacturing Implementation"

Wayne E. Thomas, Garrett Turbine Engine Company

SME Technical Papers (1984).

"An electronic data base process planning system can replace a current paper system. Part of this implementation is an on-line electronic sign-off and notification system described from concept through implementation. Requirements and user concerns are discussed. Features are described including provisions for expediting release, and for visibility. The system, as implemented, including the revision cycle, sign-off status, and release control is described."

"Engineering Systems at Grumman Aerospace Corporation"

Jacob D. Rosenbaum, Grumman Aerospace Corporation

SME Technical Papers (1977).

"The paper will describe engineering computerized systems associated with air vehicle design and how they are integrated to handle a design project. The systems include GEMS (Grumman Engineering and Manufacturing Systems), RAVES (Rapid Aerospace Vehicle Evaluation System). In terms of applications, these systems encompass a diversity of tasks covering the spectrum of design analysis activities including on-line interactive graphic applications via IBM 2250 scopes, time sharing graphic applications, and conventional batch IBM processing. The integration and visibility into this process requires an unprecedented degree of control and planning. The systems and organization required to perform this function will be addressed."

"Expert System Model of the Design Process

Fatih Kinoglu, Don Riley, Ph. D, and Max Donath, Ph. D
Control Data Corporation St, Paul, Minnesota.

"Semi-generative process planning is based on the identification and modification of existing process plans from previous similar designs. It is based on identification and matching of similar design features, typically referred to as classification of part families. This paper presents an attempt to develop an expert system model of the design process which can then automatically generate a classification code, providing a basis for the development of a process plan in a semi-generative fashion. Implementation of the model is in the LISP language on a personal computer."

"Factory Scheduling: Link to Automation"

Shyamal K. Ganguly, Intergral Computer Systems, Incorporated, Putnam, Connecticut.

"The age-old problem of manufacturing control is addressed. The lack of a system which reports on what all machines are doing currently, and predicts what they should be doing at a later time., plagues the entire industry, small and large manufacturers alike. This paper forwards ideas of data collection from various production machines in real–time, and analyzes how the state of the shop floor can be continually monitored by a group of micros placed in a proper hierarchy and connected to a supermicro or a mini. Methods of summarizing the data to help in optimization of shop scheduling are presented. Shop categories include: build to stock; assemble to order; build to order; and engineer to order."

"Factory Simulation: Approach to Integration of Computer-Based Factory Simulation with Conventional Factory Planning Techniques"

J. B. Comly, B. Keramati, and General Electric Corporate Research & Development in Schenectady, New York

Proceedings (1982).

"The R&D status of integrating hierarchical computer simulations, financial models, graphics interfaces is discussed as are data bases with conventional planning techniques to make a working environment for factory simulation. This system could be used to plan the evolution from an existing plant to a modern and flexibly automated one, while minimizing the disturbance and risk to ongoing manufacturing operations during the changeover. The characteristics desired for the simulations are given, and are compared with characteristics of some existing computer–based simulators. The kind of graphic input and output desired are discussed, and are compared with the current state–of-the--art. A scenario is to be drawn to increase the flexibility, speed and number of "what if" combinations to be explored. The R&D status of each computer tool is discussed."

"Financial Justification of State-of-the-Art Investment: A Study Using CAPP"

Stephen Evans and Peter J. Sackett
School of Engineering, University of Bath, Bath, United Kingdom

CAPP : Computer-Aided Process Planning (1985), First Edition, Pages 47-50.

"Accounting practice heavily influences the investment decisions made in manufacturing engineering, and highly profitable state-of–the-art computer-based technologies may lie outside the classical scope of accounting appraisal methods. This work describes the problems and illustrates a solution to financial justification of these projects. The identification and agreement of effect and objective by both engineers and financial controllers is of paramount importance when clear and direct cost savings are not visible."

"Generating A Manufacturing Data Base: An Overview of Requirements"

Dr. Bertil N. Colding, Sandvik, Inc.

SME Technical Papers (1981).

"This paper surveys different modules with solution examples that are used interactively in an integrated total system. Modules for order preparation, scheduling, operation planning, machining data planning, adaptive control, monitoring and control, and the dynamic optimized control of a Computer Integrated Manufacturing System (CIMS) are discussed. Particular emphasis is placed on cost and performance optimization in the areas of machining economics and the entire manufacturing system. The concepts of the "machining productivity mountain" and the "manufacturing productivity mountain" are briefly described."

"Generative Process Planning System Automated CAD/CAM Link"

Thomas J. Drozda, Manufacturing Engineering

Manufacturing Engineering (1982), Volume 89, No. 5, Page 69.

"An interactive computerized process planning system for cylindrical parts selects operation sequences and performs sophisticated tolerance stackup analysis. The software has three major components: The data base system, part input system, and process planning system. The new process planning system is designed to automate the link between CAD and CAM systems."

“Group Layout of a Miscellaneous Part Shop for Higher Productivity”

D. T. Koenig, Canadian General Electric Company
Dr. Inyong Ham, The Pennsylvania State University
T. Gongaware, General Electric Company

SME Technical Papers (1982).

“This paper describes the cooperative process undertaken to relocate a miscellaneous part shop. It also examines implementation of Group Technology concepts for higher productivity through the joint efforts of industry and university. Group Technology is best justified for design and production planning and control applications which are not investment intensive, but are engineering intensive."

“Group Technology Characterization Code”

Don N. Norwood, Advanced Manufacturing Technology
Dr. Randyl L. Vaughn, Vought Corporation

SME Technical Papers (1981).

This paper describes the U.S. Air Force ICAM Group Technology Characterization Code (GTCC) Program and discusses the Group Technology Support Software (GTSS) system being developed as part of this program. The GTCC program has provided a scheme for structuring manufacturing, group technology information and the GTSS is a mechanism of processing this information."

"Group Technology: Key to Manufacturing Process Integration"

CAPT Dan L. Shunk, Wright-Patterson AFB

SME Technical Papers (1979).

"In a survey conducted by Computer-Aided Manufacturing-International of most critical manufacturing technology needs, aerospace companies listed Group Technology (GT) as their number one priority. In engineering design and manufacturing planning, properly applied GT has the potential to: reduce new parts inventory by at least 25%, substantially reduce in–process inventory, cut the cost of part programming by 50%, and provide the key to generative process planning. With all of this potential, one might expect a concerted rush to apply this simple, yet powerful concept; however, even though it has been around for more than 50 years, GT has only begun to be applied in american industry. There have been basically two reasons for this: (1) the absence of a strong accepted theoretic foundation, and (2) the absence of a standardized implementation approach. Within the Air Force program for Integrated Computer-Aided Manufacturing (ICAM), both of these barriers are being overcome. This paper explores the background and potential of GT and the Air Force approach to maximize its benefits."

"GT and CAPP: Productivity Tools for Hybrids"

S. J. Schwartz and M. T. Shreve
Westinghouse Defense and Electronics Center, Baltimore, MD

CAPP : Computer-Aided Process Planning (1985), First Edition, Pages 102–108.

"Improved productivity in the production of hybrids can be obtained through the application of Computer--Aided Process Planning (CAPP) and Group Technology (GT). At Westinghouse Defense and Electronics Center in Baltimore, Maryland, these concepts have been applied to the design and fabrication of thick film substrates and multichip hybrid packages.

The concepts of CAPP and GT have been applied to hybrid production by optimizing process knowledge and capturing it in algorithmic form using D CLASS (Decision Classification Information System) developed by Brigham Young University and additional internally developed software. This captured knowlege allows the user to obtain a detailed process plan complete with time standards, documentation requirements, and tooling in approximately 50% of the time required by conventional methods.

Through regular meetings with design engineering, product attributes and cost drivers were identified and converted to a decision tree structure. By classifying and coding existing designs the data base can be searched for specific product attributes with the potential of reducing the number of redundant designs. Feedback to the designer on expected factory costs can now be easily obtained by using the process planning software.

By using optimized routings with improved time standards, productivity gains have been achieved while improving feed-back to the design engineer. Additional benefits such as design and manufacturing standardization, reduced process planning learning time, and improved schedules will be addressed in this paper."

"GT-Based Generative Process Planning"

Joseph Tulkoff, Lockheed–Georgia Company

SME Technical Papers (1983).

"The Lockheed-.Georgia Company produces a variety of military and commercial cargo airplanes. The production of these aircraft depends on their manufacturing blueprints or process plans, detailing each step of fabrication. What is done in planning represents chaos or order on the factory floor. All types of aircraft parts are process planned, including machined parts, sheet metal, extrusions, plastics, tubing, and wiring. Lockheed's Generative Process Planning System, or genplan, is fully implemented, interactive computer–integrated process planning system used by process planners, preplanners, producibility engineers, time standard engineers, and quality assurance engineers. It creates and maintains operation sheets, and provides automated labor standards and quality assurance planning and verification data. More than 50 CRTS and 25 printers are networked from the host computer to serve the total needs of all process planning and associated functions. Productivity breakthroughs have been gratifying. Overall efficiency and quality were greatly enhanced and the part planning release cycle time was reduced by 75%."

“Hierarchical Control for Robots in an Automated Factory"

James S. Albus, Anthony J. Barbera, and National Bureau of Standards in Washington, D.C.

SME Technical Papers (1983).

"A hierarchical architecture for real-time sensory–interactive control of robots, machine tools, inspection machines, and materials transport and inventory systems is described in this paper. Computer–aided design, Computer-Aided Process Planning, and management information systems makeup the top level in the hierarchy, where the highest level goals are selected and the longest range planning horizons exist. Commands and goals generated at this highest level are decomposed through a series of levels (shop, cell, workstation, and equipment) until at the lowest level there are generated a series of drive signals to individual actuators on robots, machine tools, and other equipments. Feedback from sensors and from the control hierarchy itself are used at all levels to produce real-time goal seeking behavior."

“High-Level Planning and Control: An IDEF Analysis for Airframe Manufacture"

Gerald T. Mackulak, Arizona State university

Journal of Manufacturing Systems (1984), Volume 3, No. 2, Pages 121-134.

U“This paper presents and overview of a High–Level Planning and Control System (HLPCS) designed to permit CAD/CAM integration of the manufacturing processes of a generic airframe manufacturing facility.”

"How to be Fully Operational in Half the Time"

Robert E. Crowley, SDRC

SME Technical Papers (1981).

"This paper outlines a method of reducing by one-half the time required to select a Computer-Aided Design (CAD) system, train the operators, and create a data base. The techniques are simple and the time saved in achieving full production more than pays for the costs involved."

"TMPAC7 -- An Integration Framework for Planning and NC Manufacturing"

Sheila L. Cotler, Computer Aided Manufacturing International, Incorporated, Arlington, Texas.

"The integrated Manufacturing Planning and Control Technology (IMPAC) Project is a major software development effort. Its objective is to develop an integrated system to generate process plans and NC programs starting with a solid product model. Technologies of part feature recognition, expert. system process planning, and advanced NC tool control are used. The process will be fundamentally automatic, with minimal human assist. The goal is to demonstrate and deliver prototype software, promote its ultimate commercialization, and develop module and interface specifications which may become a foundation for future industry standards."

"Improved Process Design: The Often Overlooked Element in the CIM Investment Equation"

Steven A. Kruger, Arthur Andersen and Company

SME Technical Papers (1984).

"The cost advantage that many Japanese manufacturers have over the U.S. competitors is large and growing. To reverse this trend, U.S. manufacturers must dramatically improve their production processes. Small-scale, incremental improvernents are no longer sufficient for many U.S. manufacturers. Objectives of 75% or more reduction in individual setup costs, 9070 reduction in work-in–process inventory and 25% increase in direct and indirect labor productivity must be aggressively pursued. The paper reviews the results of two projects in the U.S. where these objectives were achieved."

"Improving Productivity Through Classification and Coding"

A. Ray Thompson, Boeing Commercial Airplane Company

SME Technical Papers (1976).

"Piece/part design classification and coding provides many opport-unities to achieve productivity improvements. Beginning with simple order grouping to reduce setup and throughput time, it culminates in a orderly, integrated computer–aided engineering and manufacturing system that includes design, process planning, manufacturing, and business control."

"Integral Link Between Geometric Modeling and CAM Applications"*

A. Kader Elgabry, General Electric Company

SME Technical Papers (1984).

"The integral link between CAD geometric modeling and some key CAM applications such as NC, tooling, process planning and quality control is explored. The major requirements for these applications with respect to the geometric modeling function are specified, and the resulting demand on data base management and display capabilities is discussed. Trends for use of solid modeling in CAM applications are outlined. Effects of interface between the geometric modeler and the applications it supports on the user interface are addressed."

"Integrated Control of Factory Operations"

C. Zodrow, Westinghouse Electric Corporation

SME Technical Papers (1977).

"Fully automated manufacturing complete control from order entry to delivery has been a dream since the first production line was put into operation. We can come very close, today. No new technologies are called for. Instead, all we need to do is integrate already existing elements, linking sub-systems of control into a unified whole. In fact, this has actually been done. This is the ultimate in Computer-Aided Manufacturing. CAM has been defined as the use of computer equipment to, in any way, assist the operation and management of manufacturing operations. This includes product planning and design, material management, fabrication, production and quality control."

"Integrated Generation of Drawings, Process Plans and NC Tapes"

Dr. W. Eversheim and H. Fuchs
Technical University of AACHEN

Germany, SME Technical Papers (1979).

"Highly automated machining processes in the field of manufacturing engineering cause increased demands in the planning areas with regard to organization and planning accuracy, especially in single part and small batch production. Electronic data processing offers to the designer and planner a welcome relief from data intensive and repetitive jobs. The main aim of rationalization in design and process planning is the exact and rapid availability of all necessary manufacturing documents such as drawings, process plans and NC tapes. Therefore, an EI)P system for integrated design and process planning has been developed at the Laboratory of Machine Tools and Production Engineering (WzL) at the Technical University of AACHEN. This system can be applied to different workpieces, for instance, sheet metal parLs, shafts, gearwheels, disks, etc. The planning system is based on a central workpiece data file, storing all geometrical and organizational data of every planning task."

"Integrated Manufacturing Information and Control System"

R. E. Nepal, P. D. DeMint, and E. J. Klages, Martin Marietta Energy Systems, Incorporated, Oak Ridge, Tennessee.

"The Integrated Manufacturing Information Control System (IMICS) applies group technology principles to automate the generation and distribution of manufacturing information. The Computer–Aided Design resident. product definition is accessed by a generative process planning system that creates a process plan, text, and graphics for procedures and all information necessary for numerical control generation. The part programs are complied, post-processed, verified, and distributed on demand. The distribution function is performed by an enhanced distributed numerical control system. Modules have been added to allow automatic time collection, advanced monitoring, in-process dimensional inspection, and step-by--step electronic procedures."

"Integrated Manufacturing Planning and Control Systems"

David L. Judson, U.S. Air Force

SME Technical Papers (1980).

"Current deficiencies in planning systems for production are impacing the implementation of "leading edge" technology for planning by preventing optimal material, equipment and tool requirements planning, capacity planning, process and alternative process plans, schedules, shop floor loading and order release systems. If an Integrated Computer-Aided Manufacturing System is to be successfully implemented in the actual manufacturing environment an evolutionary technical baseline for planning standard and an Integrated Planning Systems (IPS) is imperative in the near future."

"Intgrated Process Planning at General Electric's Aircraft. Engine Group'

Steven A. Vogel, Metcut Research Associates, Inc.
Diane I)awson, General Electric Company

Proceedings, Volume I, Pages 729-741.

"The CAM systems group at Metcut Research developed an integrated process planning system for rotational parts for the Aircraft. Engine Group of the General Electric Company. The system utilizes group technology as a primary technique to organize and process the manufacturing data in the process planning data base. Functions such as cost estimation, development of routing sheets, selection of tooling, feeds and speeds, graphical verification of NC tapes, and graphical composition of operation instructions can be performed by the system. Hardware to support the system includes a di.git.izing tablet and plotter. This paper describes the capabilities of the system and presents actual computer outputs. (Available in microfiche only.)"

"lntegrating CAD and CAM: Future Directions"

Dr. Edwin N. Nilson, Pratt & Whitney Aircraft

CAPP : Computer–Aided Process Planning (1985), First Edition, Pages 197–213.

"while most aerospace companies have moved into Computer-Aided Design via the implementation of interactive drafting along a broad front, Pratt & Whitney Aircraft took a very different approach. This was to establish a complete interactive design/ design analysis system for each of selected projects extending from preliminary design through the complete part description in an integrated data base. For these, drawings, where still required, are produced automatically. A similar approach is now being employed in extending this concept into manufacturing, carrying selected parts all the way through production. Interactive tool design, NC programming, and, in the future, process planning, are carried out against the engineering design data base where detailed part descriptions are available.

This distinctive approach in integrating CAD/CAM for selected projects has some significant advantages over concentrating upon the general application of interactive drafting, NC programming, and now process planning. We were able to show dramatic lead-time and cost reductions quickly; the approach is rapidly accepted by management and by rank-and-file; it can be applied as widely as feasible and does not entail blanket application; the power of the integrated design/manufacturing data base is effectively displayed."

"Integrating CAD and CAM Through Automated Process Planning"

Tien-Chien Chang and Richard A. Wysk, Department of Industrial Engineering, The Penn State University, University Pack, Pennsylvania

CAPP : Computer-Aided Process Planning (1985), First Edition, Pages 158--I72.

"Computer-Aided Process Planning is an important function in the Integration of CAD and CAM. There are two approaches in Computer-Aided Process Planning - - variant and generative. The generative is more suitable to CAD/CAM integration because it can synthesize a process plan. The success of developing a generative process planning system is dependent on the CAD interface and process capability analysis. The direct interface with CAD eliminates the tedious data preparation for a process planning system (i.e., it eliminates coding). The process capability analysis provides an information base for process and sequence selection. This paper presents a generative process planning system –- TIPPS (TotaLly Integrated Process Planning System). TIPPS uses a boundary representation from a CAD data base for a part. A user applies the crosshair cursor on a graphics terminal and a menu display to specify surfaces to be machined. The system then utilizes the information stored in a process knowledge base to determine manufacturing processes, sequence, cutting parameters and time estimation. The geometric modeling, process modeling, decision mechanism and a planning example are discussed."

"Integrating CAD and CAM with Production Control Systems"

Rex Swensen, IBM Australia LTD.
Melvyn Llewelyn, The Tyree Westinghouse Group of Australia

SME Technical Papers (1984).

"Over recent years, many CAD/CAM systems have been offered on the market. Most are turnkey systems and stand alone from other formal systems in the organization. Most of these systems are predominantly CAD oriented with little facility to integrate data flow with the production of planning and control systems of the organization. This paper explores the range of Integration possible, but with emphasis on bills of material data. Two approaches to the design process are reviewed: Drafting oriented design and automated design using decision tree processing. The facilities required in the CAD system to support such integration are defined, with a scenario to illustrate their use. Finally, a short case study is included to illustrate the decision tree approach."

"Integrating Design, Process Planning and Numerical Control Through the Use of Standard Programs and the Computer (CIM)"

Willard Burge, Eaton Corporate Manufactuing Systems Engineering

Proceedings (1982).

"In the area of Computer-Integrated Manufacturing, Eaton has taken standard software packages and linked them to form (for one family at present) a complete chain that starts with the designer and ends with a complete part. By linking two computers, four terminals, and four software packages, a designer, by answering questions from the computer, generates a dimensional drawing of the part and a process routing telling how to make the part. If an NC machine is chosen, a NC computer-assisted tape generation program is written and sent to another computer to produce an NC tape and a plot verification. All of this is accomplished by a designer inputting design information into a computer program. This program integrates the computer capabilities and the manufacturing engineering knowledge to accomplish the design engineers tasks."

"Integration of CAD and CAM: Fact, Fiction or Dream"

Richard J. Clayton, Digital Equipment Corporation

Proceedings (1981).

"In its simplest form, integrating CAD and CAM means useful information is easily transferrable between design and manufacturing. As a manufacturing company begins to acquire computer power in Computer-Aided Design and in Computer-Aided Manufacturing (process control, or production management or scheduling), it becomes timely and appropriate to more effectively utilize this resource by focusing on the integration of these two activities. This integration is a system designed function which includes planning, architecture, data bases, and processors. The integration and standardization of these networks and data bases is a most important management leadership function toward productivity making use of CAD and CAM throughout the enterprise."

"Integration of WIP Handling Systems with Process Automation"

Terry L. Glude, SYSTECON, Inc.

Proceedings (1980), Volume I, Pages 809-814.

"Although there are many applications of automated Work-in-Process (WIP) Handling Systems in industry, relatively few WIP systems have been totally integrated with the material handling systems and process automation that they support. However, the techniques are now becoming available to allow such total integration initially, or at least to make strategic planning for future integration advisable in planning new installations. This paper describes some examples to state of-the-art WIP systems that interface with external handling systems and/or process automation. In addition, guidelines are given for planning and designing such systems. (Available in microfiche only.)"

"Least Cost Estimating with Group Technology"

H. G. Smart, VSI Corporation

Journal of Manufacturing Systems (1982), Volume 1, No. 1, Pages 99-110.

"A 22-digit alphanumeric Group Technology System was established for the aerospace group of VSI Corporation. In addition, the planning for least cost processing planning generation has been completed using the Group Technology (GT) system. The GT system is also being used for classical applications such as tooling, reduced setups, process plans, identifying duplicate parts, etc., in addition to the planned least cost method. The least cost method uses a unique empirical production standards system in conjunction with GT code for its implementation."

"Machinability Data Base for End Mi11 Application"

Dr. William J. Zdeblick/Jeff Lindberg, Metcut Research Assoc.
L. J. Hawkins, General Dynamics, Fort Worth

SME Technical Papers (1981).

"The rapid growth of Computer–Aided Manufacturing (CAM) and Computer-Assisted Process Planning (CAPP) systems have required the computerization of machining technology. Once an art, relying heavily on machinist experience, machining has become a science, with its theories, models and data. As machining experience declines in today's factories, particularly in numerical control operations, the computerized machinability data base becomes a necessity. This paper describes an end milling data base developed for General Dynamics, Fort Worth Division. The data base's functions include recommending the correct cutting tool, determining the optimal size and number of cuts and specifying machining parameters (speed and feed) for each cut."

"Managing for Automation in the 1980s"

Michael Radnor, J. L. Kellogg and Atul Wad
Northwestern University

SME Technical Papers (1983).

"U.S. industry, including the consumer electronics industry, has suffered from a piecemeal approach to adopting automation, resulting in poorer productivity than some foreign competitors who have made more successful use of automated processes. Rather than viewing it as simply the acquisition of new equipment, the adoption of automation must be regarded as a system-wide, interrelated process involving different functional areas requiring close working relationships throughout the entire manufacturing process including product and process design, componentry selection, scheduling, R&D, quality control, and marketing. Automation decision--making must be a strategic, integrated process which recognizes the system-wide reverberations of each increment change."

"Manufacturer Cuts Costs with Low-Cost Computer, Off-the-Shelf Software"

Glennn C. Hartwig, Manufacturing Engineering

Manufacturing Engineering (1981), Volume 86, No. 5, Pages 86-87.

"Since investing in its computer manufacturing software, ACDC Electronics, Oceanside, California, has been able to put the bulk of its manufacturing inventory and planning data on-line. Real-time data management increases production efficiency and eliminates expensive inventory overstocking problems."

“Manufacturing Forum: Wanted; Shopwise Engineers”

Thomas J. Drozda, Manufacturing Engineering

Manufacturing Engineering (1984), Volume 92, No. 4, Page 57.

“William C. Missimer (Pratt & Whitney) believes that a major weakness of the U.S. manufacturing complex is the acute shortage of shopwise engineers. He states there are not enough designers who know process planning nor enough manufacturing engineers who can design new processes and methods. Missimer recommends getting designers away from their CAD screens, drafting boards, and offices for awhile and putting them on the shop floor. Only by working side by side with production people can they learn to understand the limitations and problems confronting shop people.”

“Microcomputer-Assisted Process Planning Basic Programming Solutions for Manufacturing"

J. E. Nicks, Ferris State College

Book (1982) First Edition, Pages 227-249.

“This chapter titled, "Microcomputer-Assisted Process Planning”, defines and explains how a smaller company can use the microcomputer to assist in automating the process planning routine. From a concept standpoint, this chapter is the most important in the entire book. A second objective is to explore the major differences between group technology and Microcomputer-Assisted Process Planning."

"Minicomputer-Based System Aids Process Planners"

Editorial Staff, Manufacturing Engineering

Manufacturing Engineering (1979), Volume 83, No. 4, Page 73.

"This article describes the operational functions of MIPLAN, a production oriented, Computer–Assisted Process Planning System developed by the Organization for Industrial Research, Incorporated."

MIPLAN: Inplementation at Union Switch and Signal"

James F. Lesko, Union Switch & Signal

CAPP: Computer-Aided Process Planning (1985), First Edition, Pages 57-63.

"The "MIPLAN Computer-Aided Process Planning System" is an approach to process planning that addresses the problems of standard work flows and route sheets, methods standardization, machine utilization, and the decreasing experienced work force. The prerequisite for the MIPLAN system is classification and coding of parts. The MIPLAN system can be further enhanced by linking it with a computerized time standards module. The coding system used for MIPLAN can also be used for analysis of design standardization, design retrieval, obsolescence, capacity planning and Group Technology."

"New CAPP System Offers Extended Features"

Gary Garcia, Manufacturing Engineering

Manufacturing Engineering (1980), Volume 85, No. 3,
Pages 74–75.

"The extended features offered by Planning Institute's PI-CAPP, an enhanced version of CAPP (CAM-IS Automated Process Planning System) is discussed."

"New Robotic Systems Change the Electronic Assembly Factory"

James A. Henderson and Robert N. Hosier
Westinghouse Electric Corporation

SME Technical Papers (1984).

"Hierarchical system design of total factory control systems and advanced technologies of computer–controlled robotics have established a new look in assembly of electronic systems. Discussion of the new automated factory, and the robotic systems which are providing this factory of the future, centers on the Electronic Assembly Plant at College Station, Texas. There, the robotic and automated systems which will produce printed wiring assemblies (both through–hole and surface mounted), electrical wiring harnesses, and the integrated material handling and kitting needed are going into production. Material resources planning, fully integrated factory scheduling and reporting, and systems for material acquisition and inventory control are addressed."

"NULISP: An Assembly Line Balancing System"

N. A. Schofield, Nottingham University

SME Technical Papers (1975).

"The NULISP (Nottingham University Line Sequencing Program) package can help the industrial engineer to produce a breakdown of a complete assembly operation into work stations whose work content is balanced between operators. The flexibility of the NULISP package enables it to be used for the day to day sequencing in tasks on a flow line production system and to aid the designer in planning the positioning of facilities and setting of team sizes for future production lines. The complete assembly is specified to the computer as a set of tasks with associated times, technological precedence relationships and line restrictions. The desired production rate may be specified in terms of a cycle time or range of team sizes and the NULISP system will then produce a balanced line, splitting the tasks between work stations so as to minimize the total idle time for the job. Thus, savings can be made in the time taken to produce realistic balanced lines and resulting decreases in line idle time can lead to large cost savings during the lifetime of a product."

"On Designing, Operating and Selling Integrated Manufacturing Systems"

Dr. J. Hatvany, Computer and Automation Institute (Hungary)
A. Tari, Sepel Iron and Steel Works, Hungary

SME Technical Papers (1979).

"Integrated manufacturing systems, comprising groups of computer-controlled machine tools, automatic workpiece transport, on-line computer scheduling, advanced process planning, a shared data base and possibly a link to CAD, has passed beyond the experimental stage. What problems arise when these systems are removed from the domain of the research and development teams that first design them? How can they be integrated into the work-a--day operational routine of an engineering factory? How can tenders be prepared for delivering further systems, without involving research people of the highest qualifications each time? How can new systems be designed, delivered and installed to customers without incurring exorbitant overheads?"

“On Scheduling in a Group Technology (GT) Environment

Raj Vaithianathan, Assistant Professor, Kansas State University
Keith L. McRoberts, Professor, Iowa State University

SME Technical Papers (1981).

“Traditional research in scheduling has concentrated on developing optimal and optional tending heuristic algorithms for nxm job shop and flow shop problems. Relatively no work has been conducted in the area of scheduling within a GT cel1. This paper examines the GT cell environment from a scheduling perspective and in relation to a job and flow shop and presents a modified approach to scheduling within a GT cell that implicitly takes advantage of common setups and part family coding structures."

“Process Planning at Sikorsky”

Harry Waldman, CAD/CAM Technology

CAD/CAM Technology (1983), Volume 2, No. 2, Pages 13-17.

“At Sikorsky Aircraft, Stratford, Connecticut, a 3 million dollar software program is used to standardize the machining of cylindrical parts for helicopters. Sikorsky Aircraft process planners also used a software program called Computer Managed Process Planning (CMPP) while working on a new helicopter program called the Seahawk. Planners found that the software is reducing lead-times, improving the accuracy of process plans, and standardizing the machining of gears for the main module (or main transmission) of this very complex flying machine."

"Process Planning: CAD/CAM Integration and Innovation"

Dr. Khalil Taraman, Editor

Book (1985) First Edition, Pages 185-228.

"This chapter presents a survey of Computer-Aided Process Planning. Process planning, as the vital link between design and production, is also explored.

"Process Planning in Transition"

Donald B. Wechsler, CAM-I

CIM Technology (1984), Volume 3, No. 4, Pages 31-32.

"Computer-aided Manufacturing-International is addressing the issue of how to automate part representation and recognition tasks in order to facilitate automated process planning. A prototype process planning software system called the Experimental Planning System-1 (XPS-1) contains the structures to accommodate part data provided in terms of features. CAM-1 also developed XPS–E as a high-level, system architecture for the kmowledge based version of a proposed process planning logic system. Under the XPS-E framework, alternate plans are immediately made available for evaluation."

“Process Planning in the Computer Age"

Lockheed--Georgia Company, Marietta, Georgia

CAPP: Computer–Aided Processing Planning (1985), First Edition, Pages 51-54.

“Planning for technological innovation represents perhaps the best way American manufacturing can compete in today’s challenging environment. Yet, today too few companies plan for new technology. Even worse, these companies are not prepared to change or stretch their organizations to manage it.

Too few companies have as their goal market domination or quality and pricing leadership. This causes short–term return–on-investment objectives and very little investment in new manufacturing technologies. Inevitably, this leads to a loss of market, compounding the problem even further.

Too many decisions on plant investments are made with emphasis on cost reduction and capacity. Moreover, they tend to be made piecemeal, one chunk of hardware at a time."

“Process Planning: The Vital Link Between Design and Production"

Frank A. Logan, Logan Associates

SME Technical Papers (1983).

"The advent of computer-aided systems for drafting/design and for manufacturing control (i.e., production scheduling and MRP) has had a significant impact on the productivity and efficiency of many manufacturing organizations. However, in most organizations, the vital link between design and manufacturing process plans still is managed by cumbersome manual methods. In addition to occupying large amounts of technical and clerical time, these methods are generally inadequate in creating and maintaining the up–to–date, viable manufacturing engineering information data base needed in today’s organization. This paper examines the traditional methods of process planning, and its inability to address the demands placed on it in today’s modern manufacturing organization. The components of a Computer--Aided Process Planning (CAPP) system are examined, and their manufacturing system described. The paper concludes that, without effective CAPP, the potential benefits of computer-aided design/drafting and manufacturing control will never be fully realized."

"Production Control in Highly Automated Manufacturing Systems"

W. Eversheim and W. Fromm
Technical University of AACHEN

SME Technical Papers (1983).

"The high investment costs of automatic manufacturing systems demand an optimal utilization of the machinery. This cannot be achieved by the normal capacity planning systems, as they do not consider a number of conditions, which are specific to highly automated manufacturing systems. These conditions are the maximum overlapping of the tool sets needed, the minimization of setup times and the usage of the same jigs for succeeding orders. For achieving these tasks an EDP system is necessary, which considering the above conditions, calculates the best order sequence for the machine tools. The control and monitoring of the manufacturing processes are the task of the operative control system. The flow of information from the rough planning level down to the level of realization of control tasks is shown. The jobs to be done on each planning and control level, as well as the hard and software solutions, will be demonstrated by means of a practical example."

"Production Planning for Group Technology Manufacturing"

Gerald R. Graves, Louisiana State University, Baton Rouge, Louisiana.

"This paper is concerned with production planning in a Group Technology manufacturing environment. An aggregate planning methodology for improving the associated benefits is presented. The methodology uses a cost model which is linear programming formulation and includes labor, material, burden, and inventory costs, and demand and capacitiy constraints. The uses, benefits, and limitations of the model are illustrated with an example. The methodology is intended for use in conjunction with a material requirements planning system."

"Production Technology Abroad, June 1978"

Dr. Moshe M. Barash, Purdue University

Manufacturing Engineering (1978), Volume 80, No. 6, Page 31.

"Dr. Barash discusses a Soviet NC steel bender; a book written in Russian which deals with the parqueting problem; Computer-Aided Process planning for cold forging; and a new design for twist drills."

"Prospects for Process Selection Using Artificial Intelligence"

Dana S. Nau, Computer Science Department, Maryland University, Maryland, and Tien-Chien Chang, School of Industrial Engineering, Purdue University, Indiana

CAPP: Computer-Aided Process Planning (1985), First Edition, Pages 214-228.

"One problem facing modern industry is the lack of a skilled labor force to produce machined parts as has been done in the past. In the near future, this problem may become acute for a number of manufacturing tasks. One such task is process planning. Since process planning requires intelligent reasoning and considerable experiential knowledge, almost all existing Computer-Aided Process Planning systems require a significant amount of supervision by an experienced human being.

There is some prospect that "expert computer system" techniques from the field of Artificial Intelligence may be successfully used to automate (at least partially) several of the reasoning activities involved with process planning. This paper discusses some current prospects for automating a process planning task known as process selection. These ideas are currently being considered for use in the Automated Manufacturing Research Facility project at the U.S. National Bureau of Standards, and steps are being taken to implement them in an expert computer system."

"Quality Control Essential for CIM Success"

Troy Koon and David Jung
ITT Advanced Technology Center

SME Technical Papers (1983).

"The factory information system (FIS) that collects and distributes raw data is emphasized. The FIS is the mechanism that provides an avenue for quality control information to be integrated throughout the organization. The freedom of input of quality control information enables the fine-tuning of the overall factory system to occur. It is this fine tuning of quality that enables CIM to flourish. Quality is addressed in areas relating to: data, design, process planning, gauging availability and production process."

"Quantitative Design Tools for Computerized Manufacturing Systems"

J. J. Solberg, Purdue University

Proceedings (1978), Volume 6, Pages 409-413.

"Computerized manufacturing systems offer the potential for achieving mass production levels of productivity in batch-type discrete parts manufacturing. To achieve such success, however, many critical design decisions must be properly made. This paper reports on a mathematical model which is of particular value in determining the consequences of design decisions in the early phases of planning a system. The model is easy to use, requires little data, and provides a wide range of steady-state performance measures. Use of the model in the design process is illustrated."

"Real-Time Assembly Planning and Control"

Asbjorn Rolstadas, NTH-SINTEF

SME Technical Papers (1975).

"One of the problems of assembly of mechanical products is connected to parts supply. Often shortage of parts is detected after the assembly has started. An on-line interactive data system based on a dedicated minicomputer can reduce the damage of such problems significantly by controlling any stock movement, relating accepted orders after product explosion to actual stock, predicting possible shortage at an early stage and ensuring that no assembly is started unless it can be carried through without shortage. Such an on–line system will consist of three modules: stock control, order entry, and assembly planning."

"Real-Time Simulation Eliminates the Risk of Industrial Automation"

Max W. Hitchens, HEI Corporation

SME Technical Papers (1984).

"Automation presents risks in conception, design, fabrication, installation, and operation of a warehouse or manufacturing system. Risks are caused by inexperience, miscommunication, perception limits, and human error. Applying a real-time simulation to all phases of an automated project eliminates the causes of risk. A real-time simulator is a computer system capable of animation, design simulation, system emulation, and diagnostic monitoring. Real-time simulation is a tool which enables each step of the automation process to be checked, and errors corrected."

"Selection Criteria for Manufacturing LANs"

Rajendra Melville and George Koshy, Booz, Allen & Hamilton, Incorporated, Lexington, Massachusetts.

"In an effort to improve productivity, an increasing number of American manufacturers are automating their facilities. A key to this effort is a Local Area Network (LAN) that will transfer data efficiently between the various components. This paper identifies issues that affect manufacturing communications, discusses the available LAN technologies and their attributes, and develops an approach to selecting the best communications technology to meet a user's needs."

"Shop Floor Scheduling and Control"

L. J. Baringer, D. J. Bulger and G. R. Johnston
IBM Corporation, General Systems Division

SME Technical Papers (1975).

"The role of production control has taken on added importance in today's manufacturing, including the NC machining environment. Assisted by a computer, production control has become a dynamic tool in the production process by providing better control of work flow, machine use, and parts inventory. Included as part of the output from the computer-aided system are daily and weekly reports that provide the information required by both management and people using the system."

"Software System for Flexible Manufacturing of Printed Circuit Boards in a Small-Lot Production Environment"

Frank Salamone, GTE: Communication Systems Division

SME Technical Papers (1985).

"Discussed is a software system which generates required manufacturing documentation and soft tools for low cost assembly of printed circuit boards. The brain of the system compares manufacturing alternatives to determine the most cost--effective assembly process. Its output is sent to post-processing for generation of machine instructions, setup instructions and visual aids. Topics discussed are: CAD/CAM interaction, manufacturing libraries, cost comparison program/process determination, automated component preparation instructions, automated operator instructions/ visual aids, and automated generation of pattern programs."

"Strategic Planning for Productivity"

Robert W. Baeder, General Electric

SME Technical Papers (1981).

"The strategic planning process normally used for business planning can be applied effectively for automation and productivity planning. The strategic planning process involves situation assessment, identification of key issues and development of the strategy and programs. This process views the factory broadly as three arenas: requirements planning, design and production. The broad productivity objectives should not only include cost but should also include improved quality, shortened design cycle and reduced investment intensity. The application of the strategic planning process can greatly improve the odds of success of automation systems planning."

“System Performance in Work Center Control Environment”

Thomas L. Wicklund, Honeywell, Incorporated, Golden Valley, Minnesota.

“The Work Center Control (WCC) System, when in operation with many connected pieces of shop floor equipment, is a data communications intensive system. Communication be tween the central host computer and the work stations is the single most important function of the WCC computer, employing networking, complex protocols, data verification, and other concepts that strain the resources of the host computer system. Techniques of performance measurement and some results that have been found by Honeywell are discussed."

“The Automated Factory in the '90s”

M. David Freedman, Consultant

CAD/CAM Technology (1983), Pages 11–12.

Within the next decade, it may be possible to realize the automatic factory. The result: CAM that depends less on the kinds of computer systems used and more on the degree of functional integration. The factory of the future is discussed in relation to marketing and sales, production, tooling, process and materials planning, shop-floor control and management.”

“The Automated Factory: What it Will Take”

Robert N. Stauffer, Manufacturing Engineering

Manufacturing Engineering (1983), Volume 91, No. 3, Pages 42-43.

“Robert J. Eaton, Vice President of General Motor’s Advanced Product and Manufacturing Engineering Staff, describes the factory of the future and its two major components, the Computer Integrated Production Facility (CIP) and the CAD/CAM system. It is important to understand how their various elements fit together and what new developments are still required. A substantial R&D effort is needed in such areas as peer communication, a graphics exchange standard, an automatic system for tracking engineering changes, a data base of manufacturing design criteria, off-line programming of robots, and an “expert” system for generative process planning.”

"The Control Structure in CAM Systems”

Oyvind Bjorke, Norwegian Institute of Technology

Technology of Machine Tools (1980), Volume 4, Page 7.2-1 7.2-19.

“The control structure in CAM systems is the organization of data processing before and during the execution of the individual actions. Such actions may be motion of tools within machine tools, motion of workplaces between machine tools, etc. Each of these actions is the result of a chain of planning steps that goes into greater detail as the time of execution approaches. Some steps are automatic, others are influenced by human decisions. Together they form an interwoven structure controlling machine actions. (Available by volume and in microfiche only.)”

"The New Role of Group Technology in Factory Automation"

Edward J. Adlard,Litton Integrated Systems Technology,
Florence, Kentucky.

"Group Technology (GT) has been practiced for many Years in operating batch manufacturing plants. It was first applied manually to code and classify parts and for machining cells for parts manufacturing. GT coding and classification were applied in a manual mode for design retrieval. With the development of the computer came a renewed interest in GT. Coding and classification were again used for design retrieval, but this time the power of the computer was used to perform the lengthy design data base searches. At the same time, GT was being used in manufacturing to help automate the process planning activity and to assist in forming automated manufacturing cells. Today, a new level of application of GT is being explored in the implementation of large-scale factory automation projects. This paper presents a brief history of group technology and discusses its new role in factory automation."

"The Problems of Using CAD-Generated Data for CAM"

Ann E. Meister, Consultant

SME Technical Papers (1983).

"A primary justification for a CAD/CAM system is its use as a common data base by engineering and manufacturing. This data base should provide all the information required for both activities. In reality however, it frequently does not. Contributing factors include the absence of appropriate standards and procedures in areas such as drawing control and tolerancing practices. In numerical control applications, problems arise from geometric deficiencies as well as inefficient tool path generation capabilities. The systems lack automatic access to the information required for group technology, process planning, and quality control. As a result of all this, problems arise because there is continuing human intervention in tasks which should be automated. This paper discusses these problems and suggests workable solutions."

“The Process Planning System of Lang Engineering Works”

Peter Hoffmann and Arpad Garzo
Lang Engineering Works, Budapest, Hungary

CAPP : Computer--Aided Process Planning (1985), First Edition, Pages 113–119.

"The process planning system of Lang Engineering Works, Budapest, is based on the variant approach. Process chart parameters can be input either by the operator or can be picked by the system from stored charts or from files of global parameters of complex products. Generated process charts can be both manually edited and computer processed. A generator kit allows generating process planning programs for any particular problem using problem specific information only. The paper describes applications of and experiences with the system.”

“The Road From Variant to Generative Process Planning”

Alexander Houtzeel, Organization for Industrial Research

SME Technical Papers (1983).

“There are currently two main roads to generative process planning through artificial intelligence, in which the computer totally recognizes parts and how to manufacture them; or through new multiple coding and classification systems which are used to create highly refined data bases of part. and manufacturing capability information. This paper demonstrates that the latter road is now open to practical implementation. It describes how new multiple coding classification systems, fully integrated with Computer-Assisted Process Planning and Group Technology systems can now be used for effective generative process planning. There are currently two main roads to generative process planning through artificial intelligence."

"Three Keys to Electronics Manufacturing in the '80s"

R. P. Claggett, Western Electric Corporation

SME Technical Papers (1979).

"Electronics manufacturing in the 80's is changing for Western Electric due to the rapid change in semiconductor technologies. The consequent is faster turnover in product offerings. Semiconductor manufacturing requires the most rapid change in processes and requires the highest degree of flexibility. Increased chip capabilities require new chip packages. New techniques must be found to assemble the packages to a PWB on a production basis. The assembly of equipment systems is requiring a higher degree of intel-ligent automation."

"Trends in the Robotics Industry"

Laura Conigliaro, Bathe Halsey Stuart Shields, Inc.

SME Technical Papers (1982).

"Timing, technology, and end-user awareness and need have combined to catapult the robotics industry into its most dynamic state ever. This paper examines some of the pre-sent and future trends within this extraordinarily dynamic, though infant, industry."

"understanding the Impact of Computer-Integrated Manufacturing"

Stephen J. Gondert, Computervision

Manufacturing Engineering (1984), Volume 93, No. 3,
Pages 67-69.

"The advantages of and possibilities *in* Computer-Integrated Manufacturing (CIM) are discussed. The ultimate goal of CIM is to link automated manufacturing functions such as numerical control, process planning, materials requirement planning, and CAD/CAM, and then further integrate these with the traditional MIS data processing functions such as financial accounting, inventory control, and payroll. The centralization of this information creates an extremely powerful resource for the entire company. Other advantages include lowered manufacturing costs, elimination of errors, and improved communications. This article also addresses the fundamentals, necessary hierarchy, future directions, data exchange, and obstacles to implementation of CIM."

"Update on CAM Technology"

Editorial Staff, Manufacturing Engineering

Manufacturing Engineering (1917), Volume 78, No. 4, Page 58.

"Some observations on a CAM-1 seminar are noted in this article. Training programs, CAM--I projects, future plans, and contracts to SOFTECH were discussed."

Utilization of Artificial Intelligence in Manufacturing”

David Liu, Hughes Aircraft Company

SME Technical Papers (1984).

“Advanced technology is being developed in both engineering and manufacturing. The present marketplace demands greater product variety and shorter product. life cycles. A software system that incorporates producibility into product design and automates support activities in manufacturing is discussed. Based on disciplines of artificial intelligence, full color pictorial manufacturing instructions are generated from the engineering data base.”

"Westinghouse Technology Modernization for Electronic Assembly”

James A. Henderson, Westinghouse Manufacturing Systems & Technology

SME Technical Papers (1985).

“A new facility for assembly of electronics sub-systems makes use of the latest technologies in computer systems, materials handling, and process automation. The new facility focus is on development of automated production for printed wiring assemblies (PWA) and electrical wiring harnesses used throughout the sensor systems (e.g. radar, electro–optical) produced for the Air Force, Army, and Navy. Three key projects supported are: materials accountability and robotic kitting (MARK), standard electronic assembly system (SEAS), and robot–enabled assembly of cable and harnesses (REACH). Major portions of these projects are in use in the new Electronic Assembly Plant (EAP) in College Station, Texas. Improvements in productivity, quality, and product cost are realized through combining process automation and integration of both product baselines and production facility (with material accountability and handling automation from Materials Requirements Planning (MRP) through shop floor control).”

APPENDIX C

SAMPLE LETTER SENT TO PROSPECTIVE CAPP SYSTEM VENDORS DATED AUGUST 19, 1985

W Bath Iron Works corporation A congoleum Company
1'
700 WASHINGTON STREET, BATH, MAINE 04530. (207) 443-3311

August 29, 1985

Computervision Corporation
201 Burlington Road
Bedford, Massachusetts 01730
Attn: Mr. Jcn Atwood

Dear Sir:

bath Iron works has been funded and has initiated a Computer Aided Process Planning (CAPP) project under tne auspices of the Maritime Administration/U.S. Navy/shipbuilding industry sponsored Society of Naval Architects and Marine Engineers (SNAME) to develop a system capable of generating manufacturing process plans and related schedule, manning and level-loaded shop information eased on interim product attributes- The system will include the front end documentation required to support the use of process lanes (flexible product work centers) in the affected shops.

As a part of the project bath Iron Works is funded to review existing Computer Aided Process Planning systems to determine if any such software is suitable for use in the shipbuilding industry. Bath Iron Works is interested in determining the applicability of your Multi-Class/Multi-CAPP. Our initial interest would be in the structural outfit fabrication shop processes where parts are cut from raw stock and then assembled with other fabricated . parts or purchased items to form small subassemblies or “pieces”. Later applications would involve the installation phases of ship construction where the pieces, suoassemolies and parts are assembled to form assembly units `and, finally, the completes ship. In summary, the effort parallels a machine shop System with Speeds, feed rates, tool type, machine types, etc. replaced with parameters, efficiency rates, queue times, etc. One key aspects of the software should be its utility in terms of operational simplicity.

The original proposal and the first quarterly report on this project are enclosed for your information.

If you are interested in becoming a part of this project, please submit a

demonstration should include variant and/or generative process plan development, level-loaded schedules based on Bath Iron Works and Ccmputervision developed time standards, mannning requirements and examples of the associated supporting documentation based on an active Bath Iron Works contract.
"Webs and Girders" and "Bulkheads, Decks & Platforms", presented on page II-5 of the enclosed quarterly report.

Bath Iron Works is in the process of developing flew diagrams for each of the process lanes (product centers) along with process descriptions, associated constraints, material flow diagrams, parameters and efficiency rates for each of the process lanes. The above information will be provided to the subcontractor as required. The proposal should include approximately 80 hours to review and comment on the BIW developed information.

The proposals received by BIW will be reviewed and presented to the SP-4 Panel of SNAME with a recommendation to the panel as to the preferred proposal. Wcrk is expected to commence about 1 January 1986 with a completion date of 1 May 1986. There is, however, no guarantee that any proposals will be accepted; if accepted, there is no guarantee the the proposal will be implemented.

The Bath Iron Works contract includes funding of approximately $20,000.00 for the demonstration project and review effort. However, as this is an R&D effort and the company selected will receive considerable exposure in the shipbuilding industry, it is expected that about one half of the cost of the demonstration project will be borne by the selected company. If you are interested in submitting a proposal please contact me at 207/443-3311 ext. 3854 for additional information. The proposal will be required at Bath Iron works no leter that October 11,1985.

Sincerely,

R. L. DeVries

Richard L. DeVries
Shipbuilding CAPP Project Supervisor

RLD: j
PPC-795/6227C

cc: Baxter Barham
Newport News
4101 Washington Avenue
Newport News, Virginia 23607

APPENDIX D

REQUEST FOR PROPOSAL LETTER SENT TO RESPONDING VENDORS
DATED SEPTEMBER 26, 1985

September 26, 1985

PRIME Computer
1 Speen Street
Farmington, MA 01701
Attn: Mr. Bill Hession

Dear Sir:

As promised in our August 29, 1985 letter regarding the CAPP demonstration project, additional information has been compiled to assist you in your development of a proposal. As an additional item, I would encourage you to provide a price for installing your system at the Hardings Plant for

The additional data provided is as follows:

Hardings Material Flow - present. and Future

Form 26

Inter-department Work Order

Hardings Plant Internal Shipper (Form 239-1)

BIW Corporation Material Storage/Locator Form/EOS/EOU (Form 239)

Sorting Instructions (Form E513-1)

Material Transfer Document (Form 113A)

Material Issue Requisition (Form 114)

Merchandise Material Requisition (Form 112B)

Delivery Sheet (Form 308A)

Plate Loading Sequence Sheet

Bar Rack Loading Sequence Sheet

Material Requirements (Form E-349)

Scheduled Work for Production

Bill of Material

Shipping Document

Retraction

Assembly Ordering Form

Left Off List (Form F-326)

List of Documents Used at Hardings

Steel Information and Control Project, Study Report and Recommendations

It should be noted that a coding system for structural material is presently being developed. This code is primarily focused at identifying the parts uniquely. It is presently felt that a group technology code, to further enhance the computer sort of material flow control data and development of standard process plans, is necessary.

In addition to the data bases mentioned in the Steel Information and Control Project, a parameters (work content) data base is considered necessary. Presently the identified parameters are weld length and number of pieces. Burning machine travel length and burn time are presently generated by AUTOKON and are available from the Loft.

It is envisioned that the demonstration project would identify when the various information required to form the necessary data bases would have to be provided and by whom.

be limited to, the following: a) Process Plan for each stage of fabrication and assembly at Hardings (Potentially a standard process plan for the entire family of parts would be applicable at some stages.); b) Plater and Shape Location Documentation;
d) Kit Contents for each stage of construction; e) Short Term (3 months) Schedule based on work content with level loaded process lanes; f) Shipping Instructions; g) Assembly completion Statusing; h) parameter performance Reports; i) Area Work Content Loadingly by day for the next two weeks each week.

The above would include innovative ideas on form format and content and should stress check-off type documentation for shop floor statusing versus manual entries.

A direct interface with the Hardings Plant planning and operations personnel, to determine their documentation needs, will most likely be necessary. A desk area at the Hardings Plant can be made available for that purpose.

Thank you for your interest. Please contact me at (202) 692-7660 or (703) 979-2030 if you have any questions.

Sincerely,

Richard L. DeVries
Shipbuilding CAPP
Project Supervisor

cc: Baxter Barharm
Newport News Shipbuilding
& Drydock Company
4101 Washington Avenue
Newport News, VA 23607

HARDINGS MATERIAL FLOW DOCUMENTS

A. Hardings Planning Office/D-12

- Freight Packing Slip
- Sorting Instructions Sheet
- Daily Sequence Sheet
- Material Issue Requisition (Merchandise)
- Material Transfer Document
- Inter-department Work order
- Inter-department Shipper

B. Layout/Burning Plate/Shape Area

- Hardings Plant Internal Shipper
- Material Storage/Locator Form
- Daily Sequence Sheet
- Inter-department Work Order
- Inter-department Shipper
- Material Issue Requisition (Merchandise)

C. Bending Floor/Plate Shop

- Hardings Plant Internal Shipper
- Material Storage/Locator Form
- Inter-department Work Order
- Inter-department Shipper
- Daily Sequence Sheet
- Material Issue Requisition (Merchandise)

D. Assembly Area/(CPO)

- Hardings Plant Internal Shipper
- Material Storage/Locator Form
- Inter-department Work Order
- Inter-department Shipper
- Retraction Document
- Assembly Ordering Form
- Left Off List

E. Shipping/Storage Area

- Delivery Sheet (Change of Raw Material Storage)
- Retraction Document
- Rate/Shape Loading Sequence Sheet
- Short Range Order Form
- Long Range Order Form
- Bill of Materials
- Freight Packing Slip

APPENDIX E

LOGAN ASSOCIATES CAPP DEMONSTRATION PROJECT
LOCAM PROPOSAL DATED OCTOBER 8, 1985

Logan Associates

59 Village Brook Lane, #4
Natick, Massachusetts 01760

Telephone: (617) 478-2898
Telephone: (617) 655-2191
Facsimile: (617)879-0698
Telex: 948477 (HQ FMHJ)

October 8 1985

Mr Richard L De Vries
Shipbuilding CAPP Supervisor
Bath Iron Works Corporation
700 Washington Street
Bath, Maine 04530

Dear Dick,

Re: Proposal for a CAPP Demonstration Project

I have pleasure in enclosing our proposal for implementing a CAPP Demonstration Project based on the LOCAM system.

AS you will see, I listed the objectives you had set out, and against this I have described a series of work segments which must be completed to achieve these.

Obviously, scaling down the objectives, or accepting a lower level of demonstration feasibility would affect the work content and naturally the project cost.

I note your comments re the limits on your budget and that you consider this to be an R and D exercise. However, as I have said in the proposal, we can demonstrate several running APP systems, especially at GE–STG, Schenectady, fulfilling exactly your requirements.

It is my firm belief, and GE's also, that my staff have now had more experience world-wide, in this particular field. And so we should - having had a team working with GE since the beginning of 1983.

Taking this into account, and considering that we are supplying you, on loan, software to the value of $200,000 and hardware of some $90,000, it is not unreasonable to expect a fair price for our highly professional services. Whatever happens, after the demonstration project is completed, Bath Iron Works would have gained extremely valuable insights into our advanced CIM strategy.

I trust that you will understand my position and I look forward to being able to work with you on this project.

Yours sincerely,

Frank A. Logan

Frank A Logan
President

PROPOSAL FOR A LOCAM DEMONSTRATION SYSTEM

TO BE INSTALLED AT THE

HARDINGS PLANT, BATH IRON WORKS CORPORATION

BATH, MAINE

CONTENTS

SECTION 1.0 INTRODUCTION

This proposal for a demonstration CAPP system has been, prepared in reply to the letter from Bath Iron Works Corporation, dated August 29 1985, and signed by Richard L Devries, Shipbuilding CAPP Supervisor; also his subsequent letter of September 26.

1.1 In support of these letters the following information was also supplied:

- Copy of BIW'S Proposal for Project #11
- Hardings Material Flow, present and future
- Form 26, Partial Shipment to Bath
- Inter-departmental Work Order
- Hardings Plant Internal Shipper (Form 239-1)
- BIW Material Storage/Locator (Form 239)
- Sorting Instructions (Form E513-1)
- Daily Sequence Sheet
- Material Transfer Document (Form 113A)
- -Material Issue Requisition (Form 114)
- Merchandise Material Requisition (Form 112B)
- Delivery Sheet (Form 308A)
- Plate Loading Sequence Sheet
- Material Requirements (Form E349)
- Scheduled work for Production
- Bill of Material
- Shipping Document
- Retraction
- Assembly Ordering Form
- Left off list (Form F-326)
- List of documents used at Hardings
- Steel Information and Control Project Study Report

1.2 Based on the letters and the additional information supplied it is understood that the CAPP demonstration system should have the following objectives:

- applicability to structural and outfit fabrication at Hardings
- operational simplicity
- variant and/or generative process planning capability

-production of level load schedule,
-initiate documentation for manufacturing control,
- focus on ‘Webs & Girders’ and ‘Bulkheads, Decks and Platform’ family groups,
-identification of information requirement – when it should be produced and by whom.

1.3 Bath Iron Works is in the process of developing flow diagrams for each process lane, with process descriptions, associated constraints, material flow diagrams, parameters and efficiency rates for each process lane.

This information to be reviewed with CAPP contractor during the system implementation.

1.4 Other points raised in the letters, are :

BIW is currently developing a coding system for structural material,

a group technology code to enhance material flow is considered necessary,

a parameters (work content) database is required,

the various output formats as specified in the letter dated September 26,

rationalization of format and content of existing output documents,

that the demonstration system be implemented at Hardings plant.

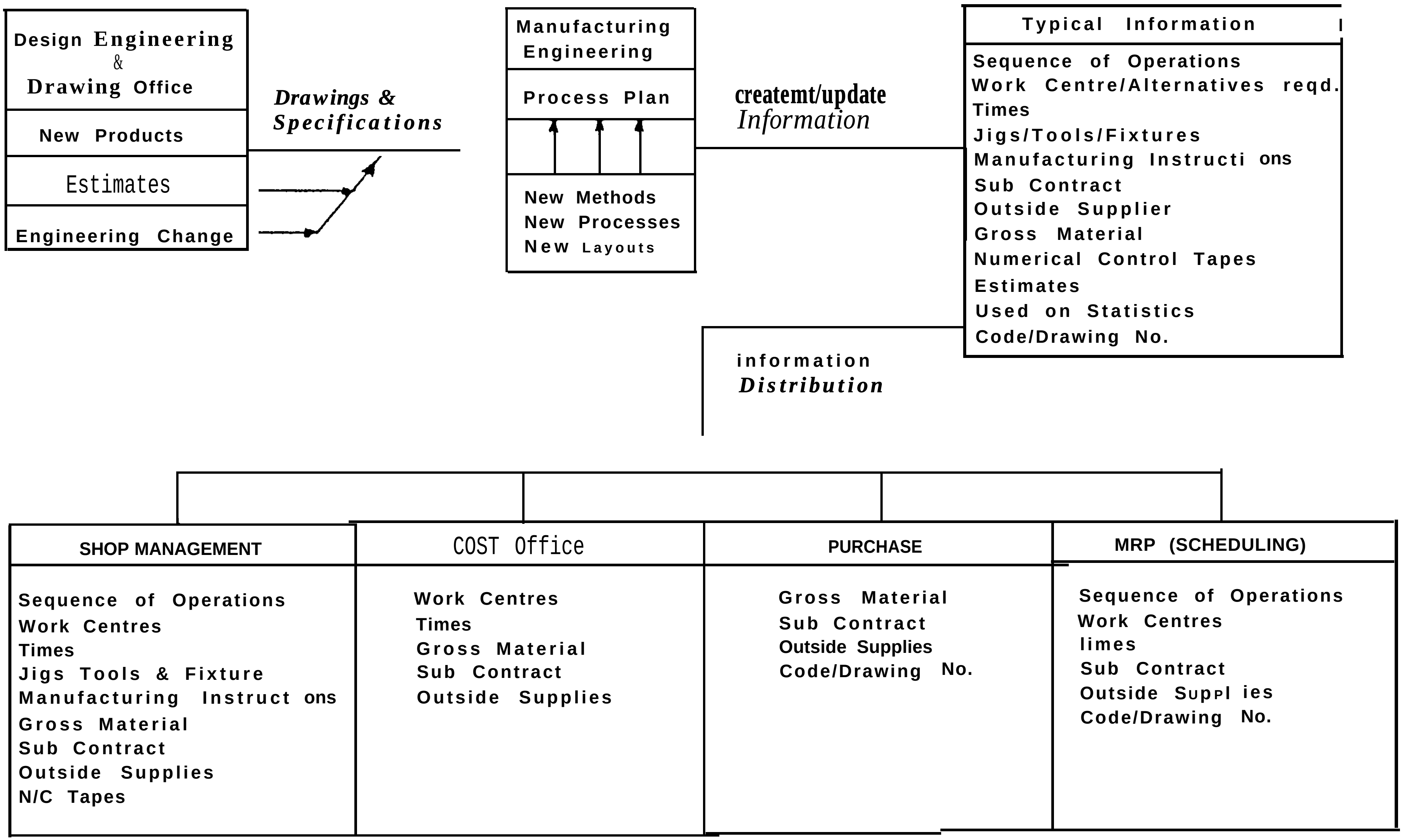
1.5 To conclude this introduction, the mechanics of process planning are:

1.5.1 the methodical translation of engineering requirements (contained on drawings and specifications) into detailed technical manufacturing requirements of material, labor and equipment,

1.5.2 the detailing, at a minimum, manufacturing sequences (flow) by work centre, cycle times, resource usage and tooling requirements,

can be no effective production scheduling (level loading), cost or performance control.

It is the vital link between engineering and actual manufacture, (see Figure 1).



SCHEMATIC DISTRIBUTION FLOW FOR MANUFACTURING ENGINEERING INFORMATION

Fig 1

SECTION 2.0 TRADITIONAL PROCESS PLANNING - BIW

From a previous visit by Frank A Logan to the Bath plant and discussions with Richard L DeVries and other members of BIW staff, it appears that BIW use traditional technical/clerical process planning techniques.

2.1 The above observation is re–inforced by a study of the documents supplied (see Section 1.1.) with their wealth of hand-written detail, translating engineering requirements into manufacturing control data.

2.2 Traditional process planning is characterized by the following:

2.2.1 Process planners study drawings, the text, views, notes, dimensions, etc. searching for key information.

2.2.2 They select this key information, based on previous experience, and use it to drive their personally held manufacturing logic.

2.2.3 From their experience they lay out a routing by work stations.

2.2.4 This application of personally held logic enables them to reference base data for calculation purposes (or take an inspired guesstimate).

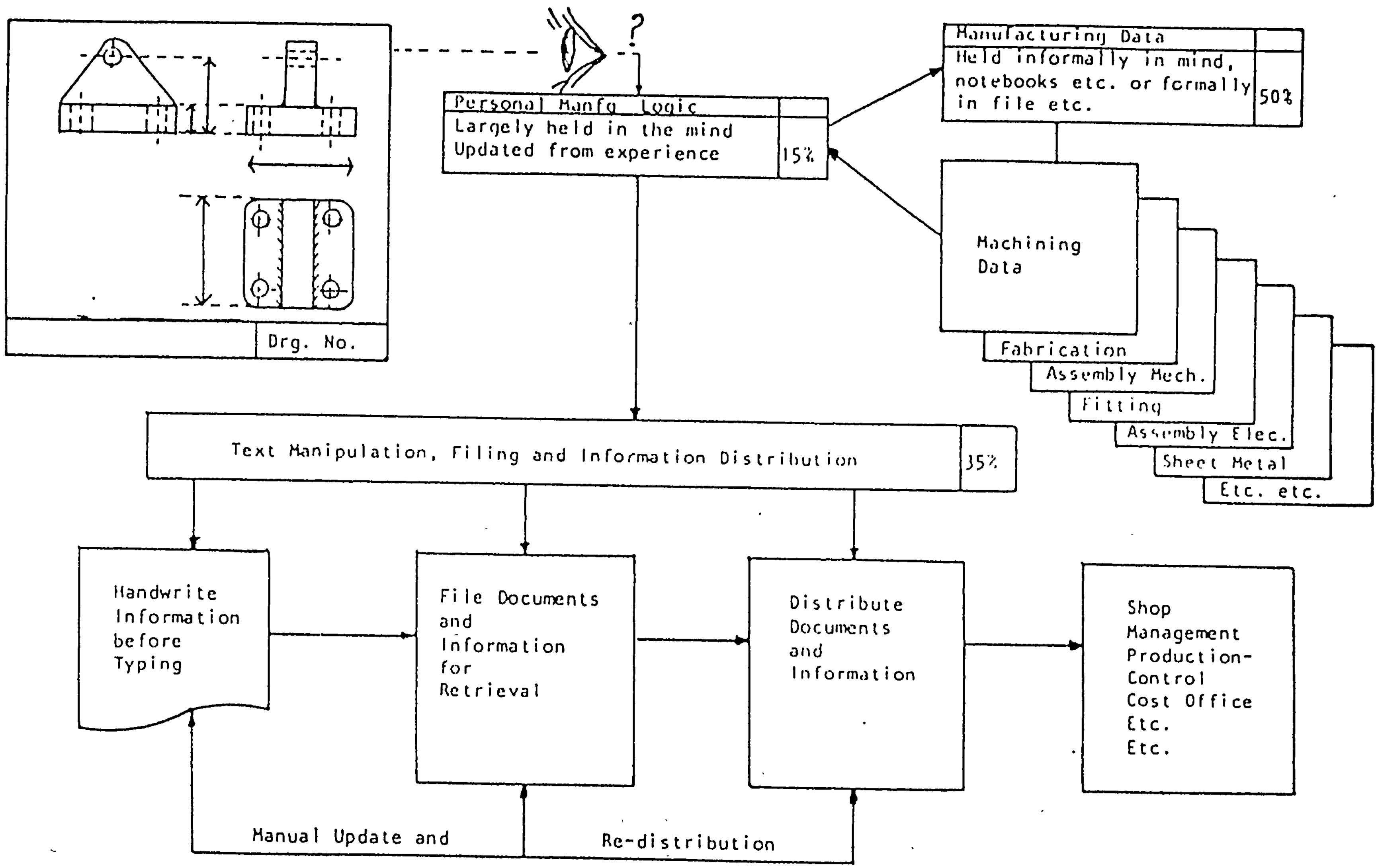
2.2.5 Steps 2.3.1 to 2.3.4 are processed interactively until the planner is either satisfied, or, more likely, runs out of process planning time.

2.2.6 During these interactive steps he is likely to involve other planners or foremen in the decision making process.

2.2.7 He handwrites variable process planning information on various process planning documents.

2.3 To summarize: traditional process planning is carried out by time-served technicians with intimate knowledge of manufacturing techniques, machines, equipment and level of plant skills. They visualize and analyze alternative methods and operation sequences using differing levels of tooling aids to achieve the lowest unit cost consistent with engineering requirements (see Figure 2).

2.4 Disadvantages of Traditional Process Planning: All the disadvantages of this traditional approach stem from the very high dependence upon technical/clerical activities, both in the preparation of process plans and the planning engineer's



STAGE 1 SCHEMATIC VIEW OF TRADITIONAL PROCESS PLANNING Fig 2

need to interact with related activities.

More specifically the disadvantages are:

- manufacturing logic is individual - it resides in the planer’s mind.
- this individual logic has to be recalled and re-processed for every process plan, a laborious process which is often short-circuited by guess-work,

  results are often incomplete or inconsistent,

  extended pre-production lead times,

  estimates for new products or processes are suspect until proven right,

  scarce manufacturing skills are locked into clerical planning routines rather than concentrated on methods improvement and cost reduction programs,

  supervision and shop floor operatives have little respect for the targets set by process plans due to inconsistency and inaccuracy,
- process planning information is often out of date. The whole planning cycle is subject to frequent information updates:
  * Engineering changes to product design
  * Alternative material and processes
  * Changes to manufacturing quantities

Process Planning is at a crisis; its present structure can only operate with high level skills and where progress chasers provide the push and pull on work-in-progress to meet manufacturing schedules. These conditions are dying. Modern ❑ manufacturing systems based on computers, such as Flexible Manufacturing and Production Scheduling, demand more timely and accurate process plans if they are to be effective.

.5 Yet, even within the cumbersome technical/clerical routines of the traditional approach, manufacturing logic does exist; planners plan every day using input data, which they observe on a drawing or specification, to drive their personal logic.

To move towards a CAPP environment, Planners require an ‘expert system’ which allows them to define their rules and data without having to depend on computer analysts or programmers.

SECTION 3.0 LOCAM – AN EXPERT SYSTEM

LOCAN is an expert system. It has evolved to its present format over a considerable period of time. (See enclosed 'Historical Development of the LOCAM System').

3.1 Its evolution has been guided by the following concepts:

* Free the planner from routine clerical activities,
* Use existing company manufacturing data, for example, synthetic time standards and process data for machining, welding, assembly, etc.,
* Perform all calculations,
* Generate descriptive user defined documentation and data files,
* Be applicable to all types of manufacture,
* Be capable of extension or up–date by manufacturing. engineers, to reflect changing manufacturing processes and equipment.

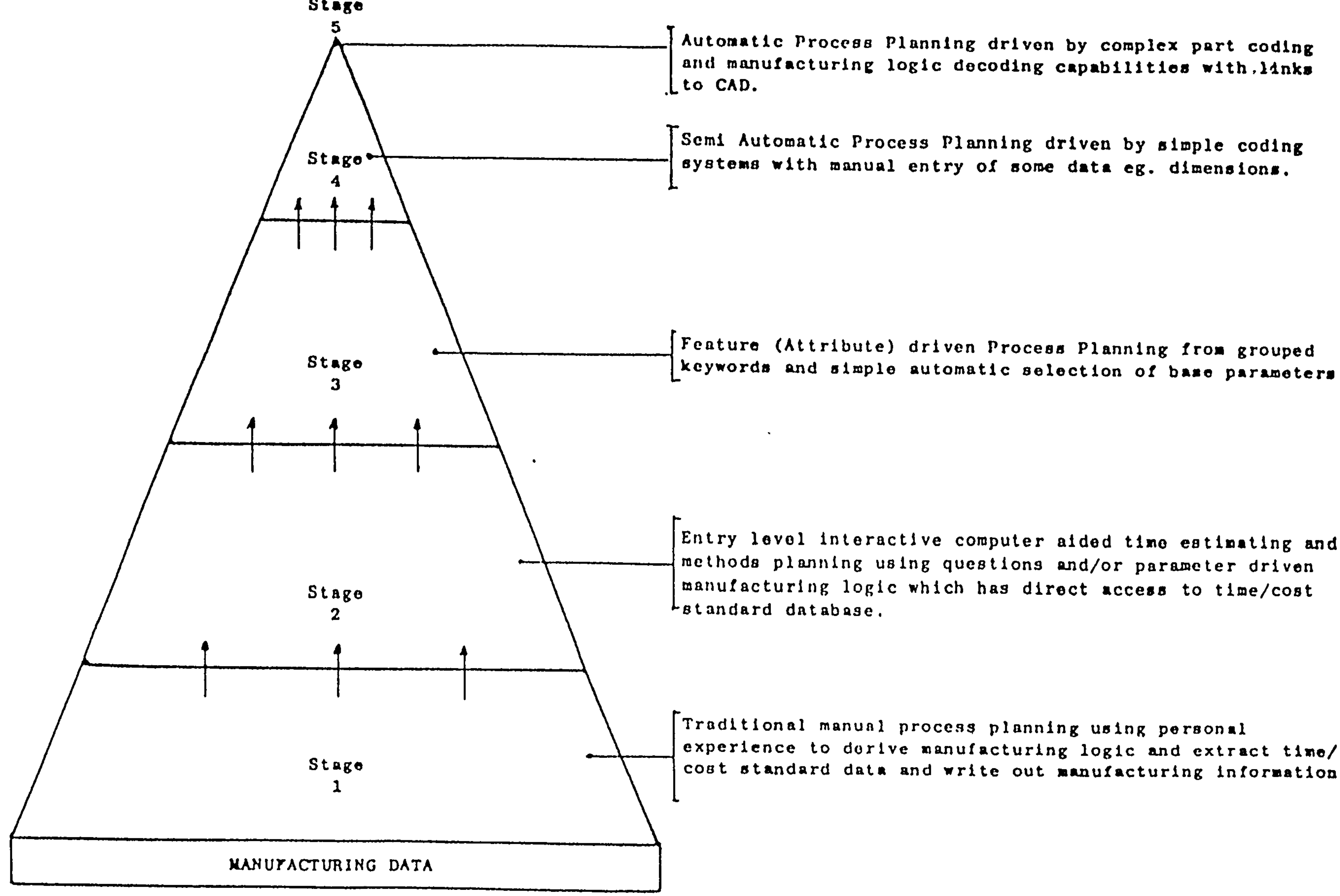
3.2 These concepts demanded that LOCAM be rule driven, that is, an expert system. The user is provided with tools to introduce and change his own rules (manufacturing logic) and the manufacturing database which interacts with these rules.

The users are able to introduce and modify rules and data without the need to be, or call upon, computer specialists.

3.3 Above all, LOCAM as an expert system, is able to operate at a number of levels (see Figure 3). It is capable of evolution through these levels as more complex rules and expertize are added to the the system.

3.4 Stage 1, Traditional: A pre-requisite to any 'expert system' is to have access to 'expertize' . BIW already has a wealth of experience residing in the minds of, amongst others, its manufacturing engineers and foremen.

3.5 Stage 2, Entry Level LOCAM: This interactive entry level has powerful utilities to create and maintain manufacturing data and logic. Typically this logic and data will support Operational Detail Planning. That is, once the planner has selected an operation and a work center, his program will display appropriate Questions and/or request Keywords with parameter values.



THE 5 STAGES OF PROCESS PLANNING

Fig 3

He is relieved of all data look-up and calculations and the detailed instructions, with times. Also the process plan is generated automatically. See Figure 4.

At this level, routing information, can be passed directly into MRP systems.

3.6 Stage 3, Features: The use of Features enables the user to group questions and/or Keywords with variable parameters to be stored for future recall and expansion. They reduce the input requirements very considerably, but their most important role is establishing the link to a Part Description Code that will ultimately be used to generate Automatic Process Planning. See Figure 5.

3.7 Stage 4, Semi Automatic: The two previous stages have been concerned with inputting information to generate text and times for each operation in the routing sequence. The linking logic, that is, selecting the next operation, being carried out by the process planner. Stage 4 is concerned with further developing this logic (increasing the expertise) to automatically select operations and their associated Features.

The first step, based on broad family groups, is to define, using LOCAM, Decision/Action program, the selection process; this builds Decision/Action Tables, (see Figure 6).

These tables can be driven interactively by answering the appropriate questions, or the input requirements can be established as a Manufacturing Code. In the latter case, if this code is generated by a Drafting Section or CAD-system, Semi Automatic planning is possible.

At this stage, no dimensional or functional data is included in the Code; these questions are answered interactively the user, (see Figure 7).

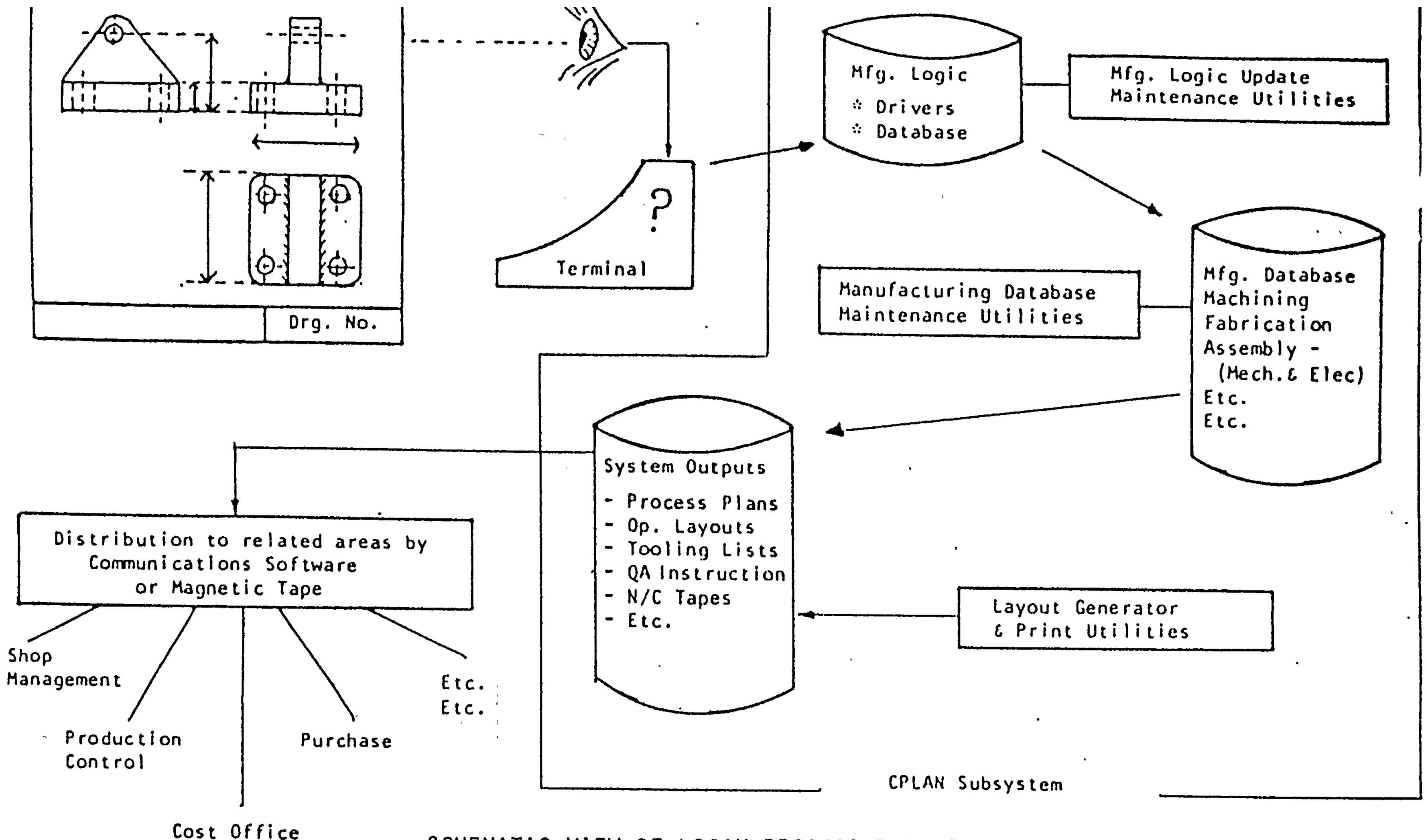
3.8 Stage 5, Automatic Planning: To progress to this stage requires the definition of a Part Description Code. Typically, this contains all manufacturing information, organised by elements as under:

#1 Drawing/Part Reference Numbers and Revision

#2 Shape Code

#3 Manufacturing Code (see 3.7 above)

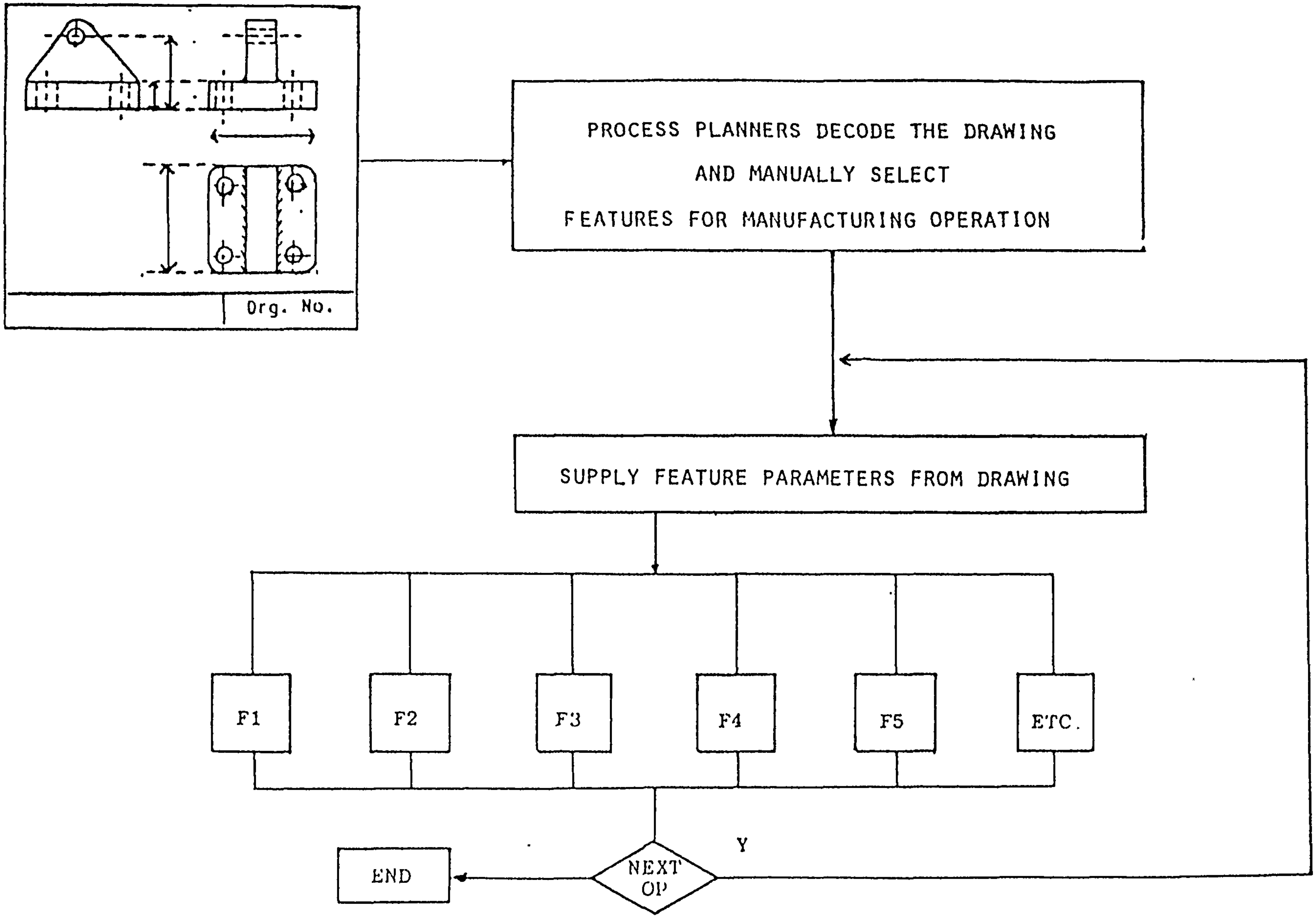
#4 Labeled dimensional information
Standard notes numbers (with parameters)
Reference drawing numbers.



SCHEMATIC VIEW OF LOCAM PROCESS PLANNING

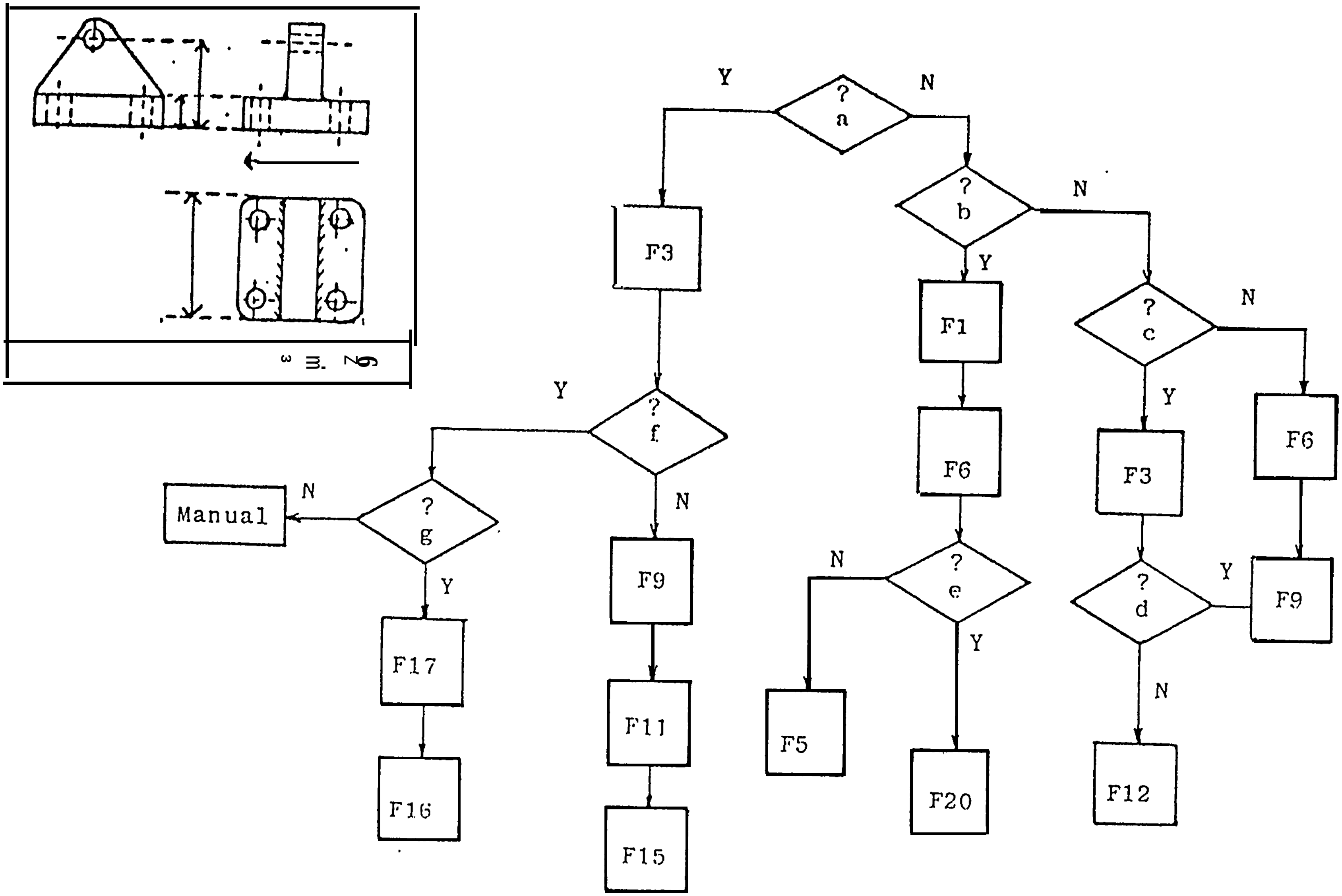
ENTRY LEVEL: STAGE 2

Fig.4



STAGE 3: INTERACTIVE USE OF FEATURES

Fig.5

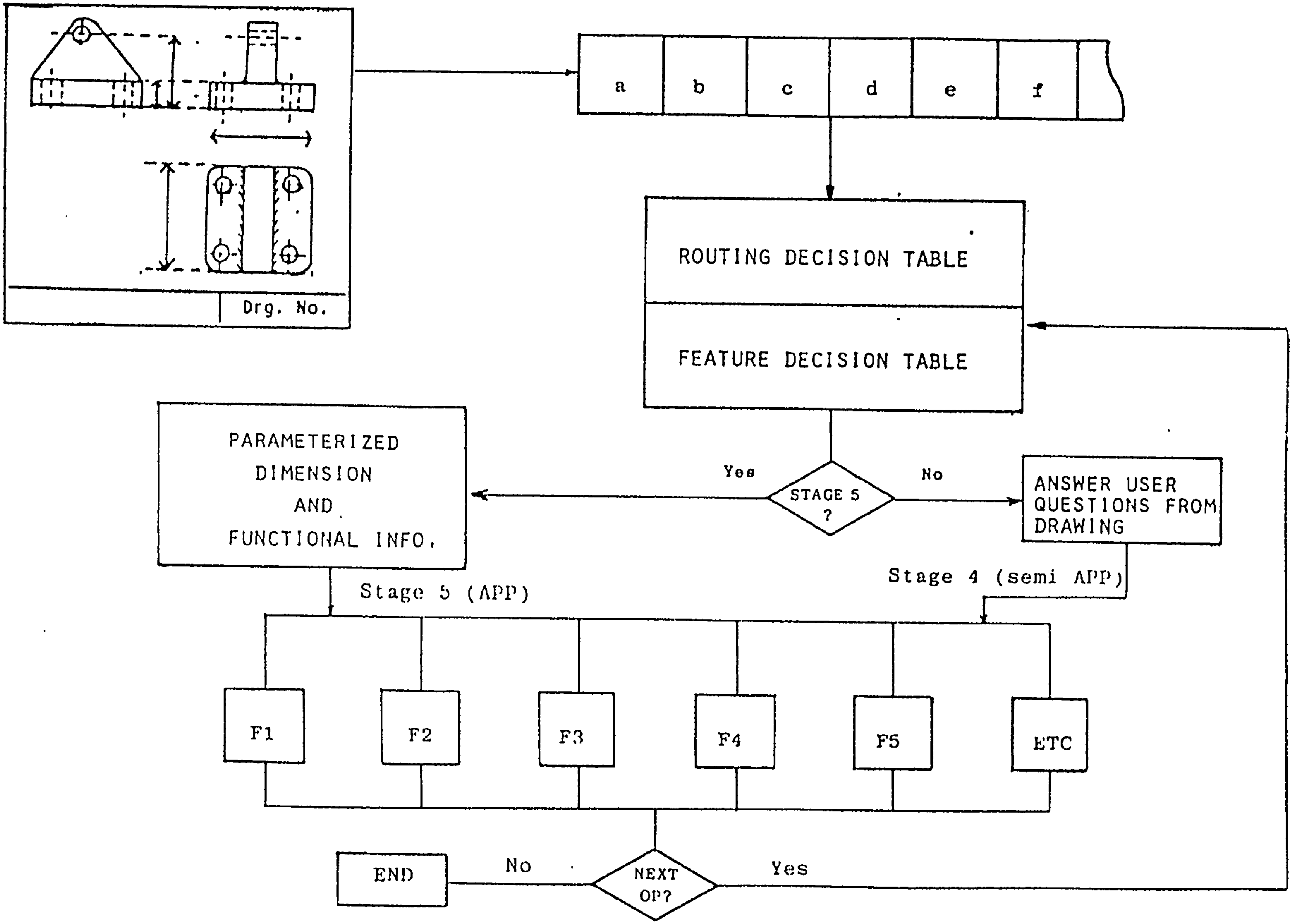


FLOWCHARTING MANUFACTURING LOGIC FOR FEATURE SELECTION

Fig.6

The Part Description Code is de-coded through Locam APP Library Routines and driven automatically-through Stage 3 {Feature expansion) and Stage 2 (Detailed Operation Planning), see Figure 7.

3.9 It is the intention of this proposal to provide these well tested and proven techniques for the demonstration project at BIW.



STAGES 4 & 5: SEMI AND AUTOMATIC PROCESS PLANNING

Fig.7

SECTION 4.0 PROPOSAL. for A LOCAM DEMONSTRATION SYSTEM

This proposed implementation of a LOCAM demonstration system into the Hardings Plant is based on the installation of:

A Prime 2250 Super Mini Computer with four terminals, line printer magnetic tape drive, and adequate memory and disk storage capacity; plus Primes operating system, Fortran77, EMACS Editor and Midasplus file management. This will be supplied by Prime Computer Inc, as agreed with Tom Buffington and Bill Hessian.

LOCAM Software comprising:

Standard Driver Library
Automatic Process Planning Library
" " " Database Utilities
Decision/Action Logic Definition Program
Standard Database Utility Programs
" Coding and Classification
Manufacturing Information Management
Work Analysis

In addition, subject to BIW having a copy of GKS Kernel. Drafting routines, a copy of the LOCAM Automatic Flow-charting program would be provided. If this, and a plotter are not available, Logan Associates will produce Logic Flow-charts off-site.

4.1 The above computer system and LOCAN software will be provided on a loan basis for four months from January 1 to April 30 1986. In the case of LOCAM software, BIW's and any other organization participating in the demonstration system would be required to sign a non-disclosure agreement with Logan Associates.

4.2 It is proposed that the demonstration project should be organized into the following segments:

4.2.1 Segment # 1: Five days intensive formal training in LOCAM Entry Level (Stage 2) concepts and use of database utilities, Layout formatter for documents and data files. It would include development of a simple LOCAM Driver program for a valid BIM operation type, such as welding.

4.2.2 Segment#2: A series of half day workshops for non–manufacturing engineering staff on LOCAM concepts including the evolution to fully automated process planning. This segment is intended for those staff who would interact in the development of the total demonstration system.

4.2.3 Segment #3: Guided application in the development of a LOCAM Entry Level (Stage 2) Driver for manufacturing operations used by the family group 'Webs and Girders'. This will produce documentation in conjunction with Segment #4.

4.2.4 Segment #4: Definition of documents and/or data files required. This will include rationalization of the existing paperwork and, in conjunction with Segment #3, using the Manufacturing Information Management to create a suitable database to create and maintain the necessary information. This segment would also explore the interface with other database facilities, such as Materials, etc.

4.2.5 Segment #5: Creation of Level load schedules would be proved in conjunction with Segments #3 and #14.

4.2.6 Segment #6: Use of LOCAM Decision/Action program to capture manufacturing logic as the initial step in creating a Part Description Code for fully Automated Process Planning would be tested. This would be carried out in conjunction with BIW'S projects for flow definition, group technology and coding.

The automatic flowcharting facility would also be demonstrated on-site, if possible.

4.2.7 Segment #7: Implement the use of LOCAM Features based on workpiece attributes to the Driver developed at Segment #3. These Features will also relate to the operations defined within flow diagrams that are defined at Segment #6.

4.2.8 Segment #8:

#3 and #7.

4.2.9 Segment #9: Define in conjunction with Ship Design/Detailing, a format of Part Description Code. This will include the manufacturing code from Segment #6, together with dimensional and note data.

4.2.10 Segment #10: Explore, define and demonstrate the links from Ship Design through Process Planning and Fabrication to delivery to Bath shipyard facilities based on automated process planning, (LOCAM Stage 5).

4.3 Such a progam, carried out in conjunction with Bath Iron Works, would realise all the objectives set out in Section 1.0. In addition, Bath Iron Works staff would have the necessary experience to continue the implementation across their total facility with little or no further involvement from Logan Associates staff.

4.4 The project would also establish clear guide lines for similar implementations of CAPP into the shipbuilding industry.

4.5 The Decision/Action and Flowcharting capability to be used in Segment #6 is currently being expanded. This work, at our expense, is being carried out in conjunction with General Electric Steam Turbine Generators, Schenectady, New York.

The intent is to be able to capture any logic, from turbine design, downwards. The existing Decision and Action Tables created by the program will reference Command Blocks.

At the highest level, logic will be displayed through IDEF flowcharting concepts, using a hierarchical structure.

Lower levels, involving definitive decision making flowcharts will follow their current style, based on existing program flowcharting conventions.

An important addition will be the use of Command Blocks. These Blocks will hold groups (with variability) of LOCAM Keywords, Commands, etc., operating system commands, or program language macros.

Both we, and General Electric, see this latter item as a move towards automatic computer programming of logic definable situations.

4.6 It is expected that the above facility will be available for demonstration at BIW during the proposed project

4.7 In the event that this proposal is accepted, Logan Associates would, in conjunction with BIW, develop a Segment Implementation Table. This would be used for project control by a joint steering group consisting of both BIW and Logan Associates staff.

SECTION 5.0 DEMONSTRATION PROJECT COSTS

The costs for this project have been arrived at on the following basis:

5.1 Logan Associates standard daily billing rate is, for:

Consultants	$ 700
Senior Consultants	$ 800
Vice Presidents and above	$ 950

All work a minimum 8 hour day. Travel time is not charged direct to the client.

5.2 The above daily rates include an allowance for hotel and subsistence. Travel, airfare and/or automobile costs are not included and are normally charged at cost to the client.

5.3 Based on Logan Associates experience from past implementations of similar projects, we would expect to bill, based on the work segments previously defined, as under:

segment #1	5 days	@ $800 per day	=	$ 4,000
Segment #2	2 "	@ $950 " "	=	1,900
segment #3	5 ".	" @ $800 " "	=	4,000
Segment #4	6 "	@ S800 " "	=	4,800
segment #5	3 "	@ $800 " "	=	2,400
segment #6	5. "	@ $800 " "	=	4,000
segment #7	3 "	@ $800 " "	=	2,400
segment #8	'4 "	@ S800 " "	=	3,200
segment /9	5 "	@ $950 " "	=	4,750
segment #10	5 "	@ $950 " "	=	4,750
Project Management	5 "	@ $950 " "	.	4,750
Total	48 days			$40,950
15 trips Boston/Bath/Boston		say -		S 600
Total Project Costs				$41,550

5.4 It is not Logan Associates normal practice to discount Consulting services. We appreciate that you have a limited budget and that you consider this to be an R and D exercise.

5.5 However from Logan Associates perspective, it is not R and D; there are alread LOCAM systems in place in major engineering companies, linking CAD and Factory Management systems, and running Automated Process Planning.

5.6 In addition, Logan Associates are able to offer consulting staff who have unriva experience in this field.

5.7 Notwithstanding the comments in 5.4 to 5.6, we would be prepared to undertake th project at a fee of $33,000 on the following conditions:

a BIW CAPP team of 3 qualified staff are available to work with Logan Associates on the project.

that the number of days in any segment is not exceeded. This will require that any co-operative effort with BIW staff (excluding the CAPP team) is extremely concentrated as to both effort and specific timing.

HISTORICAL DEVELOPMENT OF LOCAM

Logan (computer Aided Manufacturing) Ltd, trading as Logan Associates, was founded some eleven years ago in the United Kingdom, by Frank Logan. It is an international consulting company dedicated to implementing CIM solutions in close co-operation with client companies.

LOCAM, the computer aided process planning system developed by the company, is a mature product. Frank Logan started initial work in this area in the mid 60's when he managed the tooling and manufacturing engineering facilities in an automotive component manufacturing company.

A conference paper and technical article (copies attached) describing this early work were published in 1969. They were:

CAD as a Tooling Aid
Part Programming, Is it Really Necessary ?

The early work was the forerunner of prototype LOCAM projects implemented from 1972 in Italy, France and the UK, with LOCAM culminating in 1978 as an embrionic expert system implemented at GEC Large Electrical Machines, Rugby, England.

The attached article describing this and other early LOCAM implementations was published in the Production Engineer, June 1981.

At the beginning of 1982 the company began to market LOCAM in the USA and during that year were able to take GE Medium Steam Turbine Generators, Lynn, MA and Pitney Bowes, Stamford, CT, to visit a number of UK installations. GE Large Steam Turbines visited the UK in 1983. These three companies subsequently implemented LOCAM.

The current client list shows LOCAM installations from 1978 to the present day. These range across a variety of industries and, indeed, size of company; the smallest with some 50 direct shop floor employees, to thousands in the largest.

Naturally, there have been many system enhancements during this period, and toda we are justly proud to have LOCAM as a key component in the Computer Integrated Manufacturing system at General Electric Steam Turbine Generators, Schenectady, New York. This CIM implementation won the SME LEADS Award for 1984.

The experience gained over these years of effort has enabled Logan Associates t develop powerful software systems, and perhaps even more importantly, to build a team of experienced consultants who are able to investigate, report, and join implement, with client staff, the complex integration of Computer Aided Draftin Process Planning and Factory Management Systems.

The structure of the LOCAM system and the philosophy behind its design and appl ation are described in the enclosed:

Process Planning via Manufacturing Codes

The Automated Link Between Design and Manufacture

Product Bulletin

Schematic Flowchart

As already mentioned, Logan Associates have been closely involved, over the las two years, with GE Steam Turbine Generators at Schenectady, New york, in their CIM project, which is described in the enclosed articles:

Conceptual View of Steam Turbine Generators.CIM System

General Electric - CIM in Action

General Electric’s CIM System Automates Entire Business Cycle

In Europe, we are also implementing a similar system at Sandvik (UK) Ltd. This

Agency, as-part of its CAD/CAM awareness program. Under this agreement, Sandvi and Logan Associates are making presentations to industry, at six monthly inter vals. The object of these presentations is to illustrate the project developme and steps involved in implementing CIM.

The articles listed below describe the first two of these presentations:

The Challange of CIM – A User’s Viewpoint

Seminar Agenda, Nov/DEc. 1984
Information Flow; the Key to CIM
Flexible Manufacturing Systems

Seminar Agenda, April/May 1985
CIM ; Its Tangible Benefits and Future Environment
Support for Computer Aided Manufacturing

That is our story to date, but already the future beckons as we develop and implement new prototype tools for the LOCAM system. For example:

- Part Description Code Generators, programs which will enable parametric drawing Features to be recalled at the drafting stage to automatically produce recognition codes.

- Decision and Action programs, to give more powerful aids by which the expert (or often a group of experts) can define the rules. This is being coupled with an automatic flowchart generator to give graphic representation of the Decision/Actions involved.

- Automatic N/C Part Programming using Family Part Program Generators driven by CAPP.

- Vertical Integration techniques to link ‘islands of automation’, often running ,on differing computer systems. This is more than ‘networking’ but solving real problems of connecting systems into a cohesive whole. These techniques have already been implemented at GE STG and Sandvik (see penultimate paragraph in the article, ‘A glimpse of the CIM Future’).

Above all, will be the need for education of company staff in these new technologies and the dramatic impact that they are having on company structures. As an example, I enclose a copy of a paper given by John Snyder of GE-STG at an SME conference in January this year, entitled:

CIM : EVOLUTION OR REVOLUTION

APPENDIX F

BRIGHAM YOUNG UNIVERISTY CAPP DEMONSTRATION PROJECT, D-CLASS PROPOSAL DATED OCTOBER 8, 1985

Brigham Young University
CAM Software Laboratory

October 8, 1985

Mr. Richard DeVries
Bath Iron Works
Dept. 84
700 Washington
Bath, NE 04530

Dear Richard:

Enclosed is a proposal for the DCLASS System as you requested. As I discussed with you earlier, our approach would be a consultant to you rather than have us create a demonstration system for you.

We hope this is suitable for your needs. If you have further questions, please do not hesitate to call.

Sincerely,

Howard Millett

Howard Millett
Software Manager

HM:ph

Enclosure

- PROPOSAL -

BATH IRON WORKS CORPORATION

ON TIIE DCLASS SYSTEM

Introduction

The DCLASS System was developed at Brigham Young University and stands for Decision Classification Information System. The software is a general purpose tree handler which can handle any type of a classification system or any type of product line that may need decision making capabilities. The hierarchal tree structure can be used for:

- classification and coding schemes
- variant process planning
- generative process planning
- cost estimating
- time standards
- trouble shooting
- electronic component selection
- electronic assemblies
- design retrieval
- medical blood gas analysis
- etc.

Because the user can define the tree, the DCLASS System may be used for any decision making environment.

The DCLASS System prototype was developed in 1977 by Ron Millett. In 197S a DCLASS production system was developed and was first tested by Boeing Aircraft and Cincinnati Milicron. In 1980, the first DCLASS Users Conference was held. The DCLASS Users Group submits to the CAM Software Research Laboratory proposed enhancements and corrections to the DCLASS System. Since 19S0, approximately 200 enhancements submitted by DCLASS Users have been implemented.

The Product

As stated in the introduction, the DCLASS System is a general purpose tree handler which can create any hierarchal tree structure. This can include high level decision making capabilities. The DCLASS Users Group held the Sixth Annual DCLASS Users Conference in March of 1985. The most recent version of DCLASS to be released is 4.0 and contains approximately 33,000 lines of FORTRAN source code.

DCLASS is capable of being interfaced to other systems. This can be done in three ways: (1) a program or data base may input data to DCLASS which will allow DCLASS to make automatic decisions; (2) at any point in the tree DCLASS can call a FORTRAN subroutine for calculations or data base interaction, and then return to that branch of the tree; during this time data can be passed back and forth by way of variables or keys; (3) when

DCLASS in finished with a traversal, data can be passed to other programs for system analysis, calculations, report generators, data base interaction, or other user defined tasks.

A utility called TREEDRAW can draw the tree structure which can be printed on a standard computer printer. This tree structure can be very easily understood by semi-skilled personnel. Some of the features that DCLASS is capable of handling are: variable entry, arithmetic expression computation, and if-then decision making.

There are currently 80 companies using DCLASS at over 230 system installations. DCLASS is supported on the following computer systems:

HP3000	MP E
IB34	CMS or TSO
IBM PC-XT	DOS
IBM PC-AT	DOS
VAX	VMS
APOLLO	Domain/Aegis

Some of the most important attributes of DCLASS are the flexibility to customize to any given product line, the powerful decision making capabilities of an expert system, the interface of DCLASS to other systems or report generators, the ease of running DCLASS, and the creation of application trees by non-computing technical personnel.

By building the tree logic, valuable information can be captured from your best technical personnel. Not only will information be saved before personnel retire but it can be done much faster, more accurately, and with less duplication.

Proposal

Since BYU is an educational institution with very limited knowledge in ship building, we would like Bath Iron Works to be heavily involved in the project. We would prefer to act as a consultant rather than be the primary group that builds the system.

There are two (2) main reasons going this direction: 1) our over all philosophy has been to teach people to fish rather than do the fishing for them, and 2) experienced DCLASS users suggest that about 75% of the work is gathering the data form personnel. We feel that with our consultation, your personnel can create a demonstration that will be customized to their specialized situation.

We would suggest the following arrangements:

a. BYU would loan to Bath Iron Works for one (1) year a DCLASS System on the IBM PC-XT. If Bath Iron Works is not a licensed DCLASS User at the end of one (1) year, all DCLASS software and materials would be returned to BYU.

b. BYU consulting services would be $500 per day.

c. We would suggest two (2) people from Bath Iron Works be assigned to the project full time. We would suggest that one should be a programmer that knows FORTRAN.

d. We would suggest that they come to BYU for training and consulting on the following schedule:

January	2 weeks
February	1 week
March	1 week
April	1 week
May	1 week

By coming to BYU, we can take advantage of the expertise of five of our full time staff during the consulting period. When the personnel are at Bath Iron Works, further testing, modifying, and data collecting should take place.

The first three days of consulting would be primarily dedicated to DCLASS training. The remaining consulting would help in building tree logic for projects such as generative process planning, time standards, feeds and speeds, etc.

APPENDIX G

GENERAL ELECTRIC CAPP DEMONSTRATION PROJECT
CASA/CAMA PROPOSAL DATED DECEMBER 5, 1985

GENERAL ELECTRIC

INDUSTRIAL SALES DIVISION
GENERAL ELECTRIC COMPANY • ONE UNIVERSITY OFFICE PARK, 29 SAWYER ROAD
WALTHAM, MASSACHUSETTS 02254 • (617) 647-7200

December 5, 1985

Mr. R. L. DeVries
Bath Iron Works Corp.
700 Washington Street
Bath, ME 04530

Subject: CAPP Demonstration Project
GE CASA/CAMA

Dear Dick:

We are pleased to provide the following CAPP demonstration project proposal in response to your letters dated August 29 and September 26, 1985.

General Electric Co. Corporate Engineering & Manufacturing has developed a methods, time standards and planning modular system -- Computer Aided Station Analysis/Computer Aided Manufacturing Analysis (CASA/CAMA) -- as part of its overall approach to computer integrated manufacturing (CIM). The CASA/CAMA modular approach was designed to comply with MIL STD 1567A which requires all direct labor to be planned via engineered time standards with greater than 90% accuracy. The approach of linking methods and time standards to process planning assures that the intent of the MIL STD 1567A is complied with.

General Electric has been using CASA/CAMA in its aerospace businesses as well as in commercial businesses in its various formats for over three years with outstanding results. This system is playing a significant role in allowing General Electric to achieve its productivity improvement goals.

CASA/CAMA is a dynamic approach to providing methods, time standards, and planning to manufacturing operations. CASA/CAMA develops event sequences and process times for all manners of manufacturing activities as well as sequencing for materials introduction. Specifically, CASA/CAMA builds up process times and instructions from micro-elements of work, based on principles of motion economy, through operations sequencing and development of micro-times to accomplish planned tasks. In addition, it has the capability of evaluating different options for completing manufacturing tasks; e.g., evaluating for the optimum, “best method” of performing the task. CASA/CAMA also links database elements together in a Group Technology Classification Coding System for east of retrieval, improved planner/methods engineer productivity, and scheduling requirements inputs. CASA/CAMA provides the necessary sequencing and cycle time data for MRP-II systems and, as such, is an important element in establishing a CIM system.

CASA/CAMA can perform the following functions (as listed in your September 26, 1985 letter):

Process plan for each stage of fabrication and assembly at Hardings.
Plate and Shape Location Documentation.
Kit Contents for each stage of construction.
Shipping instructions.

The output available from CASA/CAMA can be electronically transferred to an MRP-II system which can perform the remainder of the functions listed in your letter. However, integration of the CASA/CAMA output to our MRP-II system is not part of this proposal. Specifically, the following functions (or an equivalent) would be performed by the MRP-II:

Plate and Shape Daily Sequence Sheets
Short Term Schedule
Assembly Completion Status
Parameter Performance Reports
Area Work Content Loading (by day for next two weeks)

General Electric Company Corporate Engineering and Manufacturing would provide sufficient training and complementation support to allow BIW to conduct the CAPP demonstration project. The following hands-on, training would be conducted at BIW:

Basic CAPP education/GE standard data training (scientific time standards) -- 2 weeks.
CASA training -- 4 weeks.
Process plan/group technology training (CAMA) -- 3 weeks.

We would also provide approximately 15 days of implementation support during the course of the demonstration project in addition to the training described above.

CASA/CAMA has been designed to run on the DEC/VAX system and the price quoted for purchase of this system by BIW is based on a DEC/VAX installation. If BIW wishes to install CASA/CAMA on another computer hardware system, General Electric will be happy to amend this proposal to accommodate that request.

Should you be interested in learning more about CASA/CAMA's capabilities, we can arrange for a demonstration at Corporate Engineering/Manufacturing in Bridgeport, or at one of our plants outside Philadelphia.

The price for installing CASA/CAMA in the Hardings location is S225,000. However, we recognize your budget for performing this demonstration project is limited. As such, we are prepared to provide the support described above for a fee of $20,000 to be paid upon the initial installation of CASA/CAMA at the Harding site, with the remainder to be paid after the successful conclusion of the pilot demonstration.

The completion of the following activities constitutes the successful conclusion of this contract. General Electric Company will expect the full payment of $225,000 from BIW at that time.

Installation of ORACLE relational data base management system in one of BIW'S DEC/VAX computers.
Installation of CASA/CAMA system in one of the BIW'S DEC/VAX computer.
Completion and acceptance of bench mark activities.
Assist BIW in demonstration of CASA/CAMA system to clients for maximum of 15 man days.
Provide GE Time Standard training for 10 days for a maximum of 8 people.
Provide CASA/CAMA user training for 5 days for a maximum. of 8 people.
Provide up to 20 man days of computer programmer time for a site specific program modifications. Estimate of man days required for modifications to be made by General Electric.

It will be BIW'S responsibility to install the necessary computer hardware within three months of contract acceptance. Otherwise, BIW will agree to pay General Electric prorated costs at $45,000 per month commencing month four after signing of this contract and continuing until all fees have been paid in full.

It is also BIW'S responsibility to make their personnel available within the first three months after signing this contract for training and specific requirements documentation purposes. In the event that BIW cannot comply with this requirement, the same provision for payments mentioned above will apply.

It is BIW'S responsibility to arrange for all their customer demonstrations within 120, ,days after the system is deemed operational per acceptance (by G.E. & BIW) of bench marks noted in this contract. General Electric will expect payment in full at the end of the above 120 days if all bench marks are complied with. General Electric will still fulfill its obligation to supply 15 man days assistance in demonstrating the system to BIW clients even after payment has been received.

BENCH MARKS

CASA :

Automatically generate time standard and associated text via input of GE time standard code.
Retrieve existing standard with full or partial drawing number.
Password security control.
Automatic on-line help during standard development.
Input detail material for the standard.
Free format text input in footnote section.
Automated time standard revision tracing.
Generate management reports.
- Department level standards listing.
- History report.
- Cover sheet report.
- Full,department level standard report.
- Distance matrix report.

CAMA

Generate process plan from operations built up in CASA level.
Variant planning - Generate new process plan by retrieving and editing predefine process plans.
Generation of Group Technology Classification and Coding.
Store/retrieve process plans by G.T. code or drawing number.
Password security control.
Generation of process planning documents.
- Traveler sheet.
- Process planning cover sheet.
- Alteration/notice control sheet.
- Planning instructions.

For your planning purposes, the following DEC/VAX equipment is necessary for installation of CASA/CAMA and must be solely dedicated to this use. The cost of this equipment will be borne by BIW and is not included in this proposal.

RECOMMENDED COMPUTER HARDWARE CONFIGURATION: (All computer hardware to be supplied by BIW)

CPU	MAIN MEMORY	DISK STORAGE	CONCURRENT USERS
VAX 11/730	2MB	200MB	4
VAX 11/750	4MB	300MB	6
VAX 11/780	8MB	900MB	15
VAX 11/785	12MB+	900MB & UP	OVER 15

The exact system selected is dependent on the number of concurrent users and number of plannings to be stored on the system. General Electric will provide guidance to BIW in selection of the computer hardware system.

Terminals should be DEC VT-240/241's operating at communication speeds of 9600 baud or higher.

SOFTWARE REQUIRED:

VAX VMS VERSION 4.X
ORACLE DATA BASE MANAGEMENT SYSTEM
FRIL LICENSE

supplied by
General Electric Co.

It is the General Electric Company's intention to provide Bath Iron Works with a leading edge, advanced state of art, Computer Aided Process Planning system tailored for shipyard use.

Regards,

J. M. Fredrickson
Sales Engineer
Marine & Defense Facilities
Sales Operation

JMF/mad
JFMA001

APPENDIX H

CAPP EVALUATION PROCEDURES AND EVALUATION CRITERIA

CAPP EVALUATION PROCEDURE

PURPOSE

The purpose of this paper is to prepare CAPP evaluators. Evaluators will be asked to establish the relative importance of BIW criteria developed for evaluating CAPP system vendor proposals. The CAPP project supervisor established a project team evaluation criteria (see Section 3), and utilized the procedures, developed by the business systems managers for MRP evaluation process, as the basis for CAPP proposal evaluation process.

Evaluators from each area will assist by completing evaluations. The evaluation input will be used to produce the comparative weight of each criteria. Further documentation will be written using these weights as guidance. Proposals from vendors will be judged using the weighted criteria.

SCOPE

This paper will cover four topics:

I. What is CAPP?

II. Explanation of the factors BIW will use for evaluation.

III. Explanation of the procedures BIW will use for the evaluation phase.

IV. Explanation of the method for weighing factors.

I. WHAT IS CAPP?

CAPP is a multiple definition acronym as is MRP II. The software vendor's definition is generally dependent on the sophistication of their software. The definitions range from a simple system editing existing process plans that only describe how a product is made to a system that develops the process plan and, in addition, identifies and integrates information from other systems such that the worker on the floor has a complete set of documentation for the job he/she has to do including bill of materials, kitting information, shipping information with all superfluous data deleted and a feedback system to management for statusing and level-loaded scheduling for each work station.

The CAPP demonstration project is focused on the "web and girder" and "bulkhead" process lanes at Hardings using the broader definition of CAPP. The expected integrated output from the system is as follows:

- o Product family identification of the products for the structural fabrication shop.
- o A process plan for each stage of fabrication and assembly in the shop.

- o Short term (three months) schedules based on work content level-loading each work station.*
- o Work station work content loading by day for a two week period, updated weekly.*
- o Work station performance reports.*
- o Raw material availability and location information.*
- o Daily sequencing requirements for raw material.*
- o. Kitting contents for each stage of construction.*
- o Product family kitting instructions for the products leaving each stage of construction.
- o Family product completion statusing.*
- o Kit contents and shipping instruction for products to the major assembly points.*

  * These outputs could be from some source such as MRP II, COPICS, etc.

Consequently, the system must integrate information from existing systems such as MIS, the LOFT, AUTOKON, SIMPL, 04, the master schedule, etc.

One of the primary goals is to eliminate the extensive manual transcribing of data that presently is necessary at Hardings.

As the project is scheduled to be a short term (6 months), near term (to start in February 1986) effort, the system must deal with the present "technology available at BIW.

The CAPP project will demonstrate many of the facets of MRP 11 such as scheduling, tiered bills of material, shop floor control, work in-process control, statusing, etc. However, the CAPP project will not deal with the purchasing end of the process. CAPP will only operate on the material availability information that is in the present MIS system.

II. DEFINITIONS OF MAJOR FACTORS - CAPP EVALUATION

The methods to be employed in selecting the CAPP demonstration project vendor will be similiar to those utilzed in selecting the MRP II system. However, the proposals are in-house and hence the development of a specification around the selection criteria cannot occur.

A. Output Capability - The outputs the system can provide and the ability to utilize information from other sources. These outputs are of primary concern to the structural fabrication shop detail planning and shop floor management. The actual output format and content will be determined during the development of the system at the structural fabrication shop.

B. Shipyard Support - The level of shipyard support to be provided.

C. BIW Support - The level of BIW support required during the development and demonstration effort.

D. System Software - Technical Features - The technical features of the software are those of particular interest to the systems department. These features relate to the performance of the system on the computer. The efficiency of data storage, batch processing time and volume of data limitations are examples of technical features.

E. Integration Capability - Ability to integrate the subsets of information and programs within the system and the ability to integrate with other computer systems.

Refer to the following brief descriptions of the factor details to assist in the evaluation process.

A. Output Capability

1. Product Family Identification - Ability to identify the shop's interim products and final products and related shop processes.

2. Process Plan - Ability to provide process plan for each product type.

3. Schedules - Ability to process labor data at the work product level and provide level-loaded long term (3 months) and short term (2 weeks) process lane schedules.

4. Efficiency Rates - Ability to provide work station efficiency rates.

5. Raw Material – Ability to provide identification of raw material location and sequencing requirements.

6. Raw Material Cost - Ability to provide raw material usage data feedback to MIS.

7. In-process Material - Ability to provide kitting information at each stage of construction.

8. Product Statusing - Ability to provide status of in-process products.

B. Vendor Support

1. Consultant Support - What level of vendor support will be provided for development of the data bases and system output?

2. Computer Programs - What vendor computer programs will be provided by the vendor for the project?

3. Training - What training will the vendor provide to shipyard personnel?

4. Documentation -What user information documenting the steps to be followed will the vendor supply?

C. Shipyard Support

1. Manpower - What level of manning must be provided to support the project?

2. Useability by Shipyard Personnel - Ease of data input and retrieval.

D. System Software - Technical Features

1. Shipyard System Impact - The impact the CAPP project will have on existing shipyard systems.

2. Supports Bar Code Data Collection and Transfer -The ability of the system to use bar codes for data collecting and transfer.

E. Integration Capability

1. Shipyard Computer Systems Integration - The ability of the system to integrate with other shipyard computer systems.

2. Change Processing - The system's built-in ability to process change information so that change is reflected in all appropriate files or tables in the system.

3. Integration of System Modules - How well the system can pass information from one part of the system to another. Is it a complete system, or is it a result of patching together independent modules?

III. Procedure

Four functional areas of BIW are defined as being impacted by the project. The personnel assigned to the review team reflect the voting weights:

Hardings Shop Floor Control -2
Hardings Detail Planning -2
CAPP Project -1
Systems -1

Each functional area may have as many evaluators as appropriate, however, a composite score for the area will be produced and weighted according to the chart above.

The team discussed the project at a meeting in the Hardings' Conference Room on Friday, December 2, at 8:00 AM. It was concluded that the procedure would be modified per comments received and then routed to the participants for weighing the evaluation factors. The weighing of the evaluation factors is to be completed and returned to R. L. DeVries by December 18, 1985. The proposals will then be distributed for review with the scoring to be provided to D. H. Thompson by 1:00 PM on Thursday, January 2, 1986. A joint review of the scoring will be held at 2:00 PM in the Hardings' Conference Room on Friday, January 3, 1986.

IV. METHOD FOR WEIGHING EVALUATION FACTORS

Matrices will be used to compare evaluation factors to determine relative importance. In each matrix, each component will appear down the side and across the top. Each component is compared to each other and rated as more important (l), less important (0), or equally important (both 1). Do not use 2 zeros. Individual weights are totalled across a line and a percentage rank is computed. An example is presented below:

	Vend	Soft	BIW	Cost	Output	Total %
A Vendor Support	. .	R 1	T 0	X 1		
B System Software	S 0	. . .				
C BIW Support	U 1		. .			
D Output Capability					. . .	

On line A,

if Vendor Support is more important than System Software, put l in box R and O in box S.

if Vendor Support is less important than BIW Support, put O in box T and l in box U.

if Vendor Support and Cost are equally important, put l in both box X and Y.

Continue in a similar manner for each line, and fill in the total for each line.

The question of relative importance is judged by which component the evaluator feels is more important for the CAPP system to have to meet Hardings' needs.

	A	B	C	D	E	TOTAL
A OUTPUT CAPABILITY						
B VENDOR SUPPORT						
C SYSTEM SOFTWARE						
D SHIPYARD SUPPORT						
E INTEGRATION CAPABILITY						

OUTPUT CAPABILITY

	1	2	3	4	5	6	7	8	TOTAL
A.1 PRODUCT FAMILY IDENTIFICATION									
A.2 PROCESS PLAN									
A.3 SCHEDULES									
A.4 EFFICIENCY RATES									
A.5 RAW MATERIAL									
A.6 RAW MATERIAL COST									
A.7 IN-PROCESS MATERIAL									
A.8 PRODUCT STATUSING									

VENDOR SUPPORT

	1	2	3	4	TOTAL
B.1 CONSULTANT SUPPORT					
B.2 VENDOR SOFTWARE					
B.3 TRAINING					
B.4 DOCUMENTATION					

SYSTEM SOFTWARE - TECHNICAL FEATURES

	1	2	TOTAL
C.1 SHIPYARD SYSTEMS IMPACT			
C.2 SUPPORT BAR CODE DATA COLLECTION AND TRANSFER			

SHIPYARD SUPPORT

	1	2	TOTAL
0.1 MANPOWER	. . . .		
0.2 USEABILITY BY SHIPYARD PERSONNEL		. . . .	

INTEGRATION CAPABILITY

	1	2	TOTAL
E.1 SHIPYARD COMPUTER SYSTEM INTEGRATION			
E.2 INTEGRATION OF SYSTEM MODULES			

Item	Score	Statement
A.1 Product Family Identification	4	The system incorporates the applicable product families that the shop normally segregates the work into utilizing group technology concepts.
	3	The system has a predetermined work breakdown that can be modified to accommodate the type of work problems the shop encounters.
	2	The system recognizes the need to segregate work into similar work problems.
	1	The system does not address product families.
A.2 Process Plan	4	The system captures the planning logic the shipyard uses in developing process plans and utilizes that logic to automatically generate process plans through questions that are answered through a multiple selection process by the operator.
	3	All existing process plans are stored in the system and through a coding process similar plans are retrived and edited.
	2	Common text are entered into the system and individual process plans are developed using the standard text.
	1	The process plan for each product family must be input each time.
A.3 Schedules	4	Schedules are developed using work content parameters, efficiency rates and queue times to level-load each work station.
	3	Schedules are developed using work content to level-load each process lane.
	2	Schedules are developed using standard durations.
	1	Major milestones are utilized to establish schedules.

Item	Score	Statement
A.4 Efficiency Rates	4	The system develops efficiency rates for each station based on work content and returns from each station.
	3	The system develop efficiency rates for each process lane based on work content and returns from the process lane.
	2	The system reports the labor expenditure on a weekly basis for each process lane.
	1	The system does not have the capability to report labor returns.
A.5 Raw Material	4	The system reports raw material availability for any given schedule window and provides a pick list on a daily basis integrating product families across all units and all contracts.
	3	The system reports raw material availability for any given schedule window and provides a pick list on a daily basis integrating product families across all units of a contract.
	2	The system provides a pick list on a daily basis integrating product families across all units of a contract.
	1	The system provides the raw material availability for a two week advance period.
A.6 Raw Material Cost	4	The system provides direct feedback to the MCS of all material drawn for use.
	3	The system provides a report of all material used on a daily basis.
	2	The system provides a report of all material used on a weekly basis.
	1	The system does not have the capability to report material used.

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Item	Score	Statement
A.7 In-Process Material	4	The system utilizes bar codes to input in-process material status and provides on-line access to product location information.
	3	The system utilizes bar codes to input in-process material status and location and provides daily reports of product location.
	2	The system has a direct entry capability to input in-process material status.
	1	The system does not address in-process material.
A.8 Product Statusing	4	The system provides "real-time" on-line status by product.
	3	The system provides a daily statusing by product families.
	2	The system provides weekly statusing by product families.
	1	The system does not provide statusing information.
B.1 Consultant Support	4	The vendor supplies experienced system analyists for the entire project. (40 man days or more).
	3	The vendor supplies experienced system analysts for a limited period during the project (20 man days or less).
	2	The vendor supplies unspecified level of experience analysts for the entire project (40 man days or more).
	1	The vendor supplies unspecified level of experience analyists for a limited period during the project (20 man days or less).
B.2 Vendor Computer Programing	4	The vendor will provide modules that have been utilized previously to support a similar project.
	3	The vendor will provide modules that have been developed for a similar project but that have not been proven in service.
	1	The vendor will develop software to support the project.

Item	Score	Statement
B.3 Training	4	The vendor supplies hands-on training at BIW for operators for 40 manhours or more.
	3	The vendor supplies hands-on training at BIW for operators between 20 and 40 manhours.
	2	The vendor supplies training at the vendor's site.
	1	The vendor does not supply training.
B.4 Documentsation	4	The vendor supplies complete user documentation and system description documentation.
	3	The vendor supplies complete user documentation and summary system documentation.
	2	The vendor supplies complete user documentation.
	1	The vendor supplies limited user documentation.
C.1 Shipyards System Impact	4	No additional hardware is required.
	3	The vendor supplies all additional computer hardware.
	2	BIW must acquire a small computer system (under $50, 000) for the project duration.
	1	BIW must acquire major equipment upgrades (over $50 ,000) to support the project.
C.2 Supports Utilization of Bar Codes	4	The system utilizes bar codes for data entry.
	3	The system will be extended in the future to utilize bar code terminals.
	1	The system does not utilize bar codes.
D.1 Manpower Required to Support Project	4	One person full, time for the duration of the development phase.
	3	Two persons full time for the duration of the development phase.
	1	Three more persons full time for the duration of the development phase.

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Item	Score	Statement
D.2 Useability of the System by Shipyard Personnel	4	The system can be operated by all shipyard personnel when properly trained.
	3	The system can be operated by most personnel when properly trained with less then 6 months of experience.
	2	The system can be operated by most personnel when properly trained, following 6 months of closely supervised experience.
	1	The system can be operated only by highly trained computer system personnel.
E.1 Shipyard Computer System Impact	4	The system can be integrated with all the shipyard related systems with minimal interfacing effort.
	3	The system can be integrated with the major shipyard computer systems with minimal interfacing efforts, however, it is not comparable with some of the minor related systems.
	2	The system can be integrated with the majority of the shipyard systems but with difficulty.
	1	The system is not comparable with most of the shipyard systems.
E.2 Integration of System Modules	4	The system modules have been integrated for a similar project that is in operation.
	3	The system modules have been integrated for a similar project but operating experience has not been obtained.
	2	The system modules need to be integrated for the project and the proposal contains as plan for their integration.
	1	The system modules have never been integrted and there is no plan in the proposal that address such integration.

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APPENDIX I

COMPUTERIZED PRODUCTION PROCESS PLANNING FOR MACHINED CYLINDRICAL PARTS

R81-945220-23

Computerized Production Process Planning for Machined Cylindrical Parts*

SUMMARY

Production process planning is a major manufacturing cost driver. The activity occupies a crucial position in the design/manufacturing data flow network. For these reasons, there is great industry interest in computerized process planning systems.

Computer Managed Process Planning (CMPP) is an advanced system for process planning of machined cylindrical parts. CMPP is generative, automatically making process decisions. An interaction capability offers optional review and modification of these decisions. CMPP is manufacturer-independent. Logic and data specific to particular workshops is incorporated into the system data base. CMPP executes data base logic and uses data base parameters in the execution of standard process planning procedures. An English-like, CMPP-executable process planning language is used to input manufacturing logic to the data base.

The CMPP software system has three major components: data base maintenance, part data input, and process planning. Data base modules include a compiler for the English-like process planning language. Part input software uses interactive techniques to collect detailed part data and construct part models. In the process planning module, the data base and standard planning procedures are applied to individual parts. Process decisions are made, perhaps with user intervention. Four major functions are performed: generation of a summary.of operations, selection of dimensioning reference surfaces, determination of machining dimensions and tolerances, and output of process documentation.

CMPP attains maximum usefulness when integrated into a larger CAD/CAM environment. There are three primary links between CMPP and other systems: 1) use of part data from an engineering data base, 2) output of process documents to a graphics system, and 3) output of workpiece geometries for use in tool design, numerical control programming, and other manufacturing service activities.

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*The work described herein was partially sponsored by the U.S. Army Missile Command under Contracts DAAK40-76-C-1104 and DAAH01-80-C-0945.

CMPP offers benefits in process planning, other manufacturing services, and the shop. Case studies and estimates indicate process planning labor savings of 25% - 45%. Savings in other manufacturing services depend on their use of CMPP-output geometry. Shop savings result from use of improved, standardized processes.

INTRODUCTION

Process planning is the activity which specifies how a product will be made. It is therefore a major determinant of manufacturing costs. In some industries, the cost of process planning itself is substantial. The manufacture of high technology machined parts is one such industry.

Process planning occupies a crucial position in the overall design/fabrication network (Fig. 1). It is “driven” by design engineering and “drives” the other manufacturing services as well as the production activity.

The economic importance of process planning provides a motive for computer aided process planning technology. This technology has the potential to standardize and optimize process plans as well as reduce planning costs. The rapidly increasing use of computer aided design (CAD) and computer aided manufacturing (CAM) systems provides a second motive. As Fig. 1 suggests, the synergistic benefits of integrating CAD and CAM systems depend heavily on the use of computer aided process planning.

For several years United Technologies Research Center has been developing an advanced process planning system for machined cylindrical parts. This system, Computer Managed Process Planning (CMPP), is implemented at three divisions of United Technologies Corporation. The characteristics and capabilities of CMPP are described below. The system’s place in an integrated CAD/CAM environment is discussed. Finally, CMPP benefits and economic considerations in its use are considered.

CHARACTERISTICS

CMPP deals with machined cylindrical parts. Four types of cylindrical surfaces are supported-: diameters, faces, tapers, and circular arcs (Fig. 2). Parts may have noncylindrical features such as slots, gear teeth, and holes. The system’s handling of these features, however, is less complete than for the basic cylindrical geometry.

CMPP is a generative process planning system. That is, process decisions are generated from programmed logic and the system data base. There is no dependence on previously stored process plans, nor is the user required to input decisions.

Manufacturer independence is a key CMPP characteristic. Logic and parameters specific to a manufacturer are incorporated into the system's local data base. To a large extent, the system thus acts a s executor of l local data base. The degree to which this is true varies among system functions. A functional module may perform strictly as a data base executor, use data base parameters in a standard procedure, or be independent of the data base.

Local logic is provided to CMPP using a technique called "process decision modeling". Figure 3 illustrates-the process decision modeling methodology. An English-like, problem-oriented Computer Process Planning Language (COPPL) is used to state manufacturing practice for families of parts (Fig. 4). COPPL process decision models are compiled into CMPP-executable form, stored in the data base, and executed for individual parts during process planning.

The COPPL language uses an open-ended vocabulary of manufacturing terms. (Vocabulary terms are underlined in Fig. 4). This vocabulary can be extended to include terms required by a particular manufacturer. Each vocabulary term has a "definition" which is comprehensible to the process planning system. Use of the term in a process decision model causes the definition to be invoked during process planning. At present most vocabulary definitions are small Fortran routines, but simpler definition methods are known and partially implemented.

CMPP, though generative, offers extensive user interaction. The user may choose to review some or all system decisions. If he does so, interactive displays such as Fig. 5 show decisions and allow the user to modify them. CMPP also has a flexible Suspend/resume capability. A user can suspend a planning session, saving system status, and then resume from the point of suspension or an earlier point.

CMPP utilizes detailed part data. A complete finished part description is input to the system. The requireddata includes functional dimensions, tolerances, surface finishes, material, hardnesses, plating requirements, etc. A description of the raw material is also required. Using the finished part as a target and the raw material as a starting point, CMPP determines intermediate workpiece status on an operation by operation basis.

CAPABILITIES

CMPP software has three major components: data base system, part input system, and process planning system. The data base system builds local files of manufacturing logic and parameters. The part input system constructs models of finished parts and the raw materials from which they are made. The process planning system applies data base contents and its own logic to produce process plans for parts.

The data base consists of four files (Fig. 6). The Vocabulary File lists and classifies vocabulary that may be used in process decision models. The Process Decision Model File holds the CMPP-executable form of COPPL models. This file is built and maintained by the COPPL compiler. It contains two types of process decision models. One type is used to generate summaries of operations for parts. The other determines dimensioning reference surfaces, locating surfaces, and clamping surfaces.

The two remaining data base files describe machines and their capabilities. The Machine Tool File lists machines and groups them by type and location. The Cut Parameter File contains information on the stock removal and tolerance capabilities of the machines. This data includes “normal” and minimum stock removal values, “normal” tolerances, and control parameters for tightening normal tolerances as necessary to meet blueprint requirements.

The part input system receives part data and constructs computer models for use in process planning. The system consists of two files and two processors (Fig. 7). An interactive module collects part data using displays such as that in Fig. 8. Partial or tentative data is stored in the Part Input File. Upon request, input data is converted into a part model and stored for process planning use.

The interactive part input module and file are designed to facilitate the use of local engineering data bases. An interface module (Fig. 7) would convert part data into the card image format used by the Part Input File. This interface module would generally be interactive, since most engineering data bases contain graphic and text data requiring human interpretation. The part input module would be used to provide any data not obtained via the interface.

The CMPP process planning system performs four technical functions (Fig. 9):

1. Generates a summary of operations.

2. Selects dimensioning reference surfaces, clamping surfaces, and locating surfaces.

3. Calculates machining dimensions and tolerances.

4. Outputs process documentation.

A summary of operations is usually generated by executing a process decision model. Fig. 4 shows an excerpt from a summary of operations model. When executed for a particular part, the model determines operations in sequence. An operation description, machine type, setup orientation, and list of cut surfaces are generated for each operation. Fig. 5 shows the interactive screen which displays this data and allows user modification.

A summary of operations can also be produced without a process decision model. In this mode, a display similar to Fig. 5 is used to interactively specify each operation.

Once a summary of operations has been determined, CMPP identifies dimensioning reference surfaces, clamping surfaces, and locating surfaces for each machining operation. This function is generally performed by executing a process decision model. Interaction may, however, be used instead of a process decision model. Fig. 10 illustrates the COPPL dialect used for reference surface selection. Fig. 11 exemplifies results of the logic in Fig. 10.

The third CMPP planning module determines machining dimensions and tolerances. This is done by executing a standard tolerance charting procedure (Ref. 7) which has been enhanced in several ways. Input to the procedure includes finished part dimensions and tolerances, raw material dimensions and tolerances, machining cuts, and reference surfaces. The Cut Parameter File provides the necessary data on local machine tools and machining practice.

The tolerance charting procedure first determines machining tolerances. If “normal” machine tolerances are not sufficient to assure that blueprint tolerances are satisfied, tolerances on selected cuts are tightened within machine limitations. Impossible situations are reported for interactive solution.

After machining tolerances are established, nominal stock removals, stock removal tolerances, and nominal machining dimensions are determined. Inadequate stock removal situations are diagnosed for interactive correction.

The process planning system’s final module produces process docummentation. A summary of operations or routing sheet is printed. One or more dimensioned workpiece sketches (Fig. 12) are produced for each machining operation.

INTEGRATION

CMPP'S usefulness is enhanced by integration into a larger CAD/CAM environment. Two or three interfaces are needed to accomplish this integration.

An interface to an engineering data base will reduce the cost and increase the reliability of part input to CMPP. Depending on the nature of the engineering data base, this interface may be automatic or interactive and may provide complete or partial part information. The data provided would be read into CMPP'S Part Input File.

CMPP does not determine all information that is normally put on operation sheets. It does not, of course, produce documents in local format. Moreover, automatic posting of dimensions on operation sketches does not always yield aesthetically pleasing results. Therefore it is desirable to direct CMPP output documents to a graphics editing system for production of shop documents.

Workpiece geometries determined by CMPP are potential input to a number of CAM systems -- NC programming, time standards, automated inspection, etc. Ideally, this data would be output by CMPP to a manufacturing data base that is shared by various CAM functions. Depending on a variety of factors, the interface required may or may not be the same as the interactive graphics interface discussed above.

BENEFITS

CMPP benefits can be divided into three areas -- process planning, other manufacturing services, and the shop.

Benefits within process planning are in labor saving, lead time reduction, and surge capability. Labor savings are substantial -- United Technologies experience indicates 25%-45% reduction in labor to produce a new process plan. This experience is in general agreement with surveys and studies of expected savings reported ir: Ref. 3.

In many companies the process planning workload is subject to surges as major new products approach production. This is characteristic of the production cycle for major defense items. CMPP, with its orientation toward generation of new process plans, is especially useful in reducing planning labor and lead times during these surge periods.

Benefits in manufacturing services “downstream” from process planning depend upon the systems integration discussed above. No experience data is available, nor have quantitative studies been conducted. Potential labor savings and reliability improvements are felt to be substantial.

Benefits in the shop result from use of improved, standardized processes. As a generative system, CMPP applies standard company practice to produce a standard process plan. The system does not explicitly optimize processes through use of time and cost functions. There are, though, inherent tendencies toward optimization in the use of process decision models, which should incorporate best local practice. Furthermore, the procedure for calculating machining tolerances has strong optimizing effects.

Savings due to improvement and standardization of process plans are very difficult to quantify. This has not been done on an experience basis. An industry survey (Ref. 3) suggests that shop savings might be on the order of 5%.

It should be noted that CMPP economics depend heavily on the nature of a company’s operations. The frequency and work content of cylindrical parts process planning requirements are the best indicators of potential benefits. The company’s commitment to integrated CAD/CAM systems is a second major factor.

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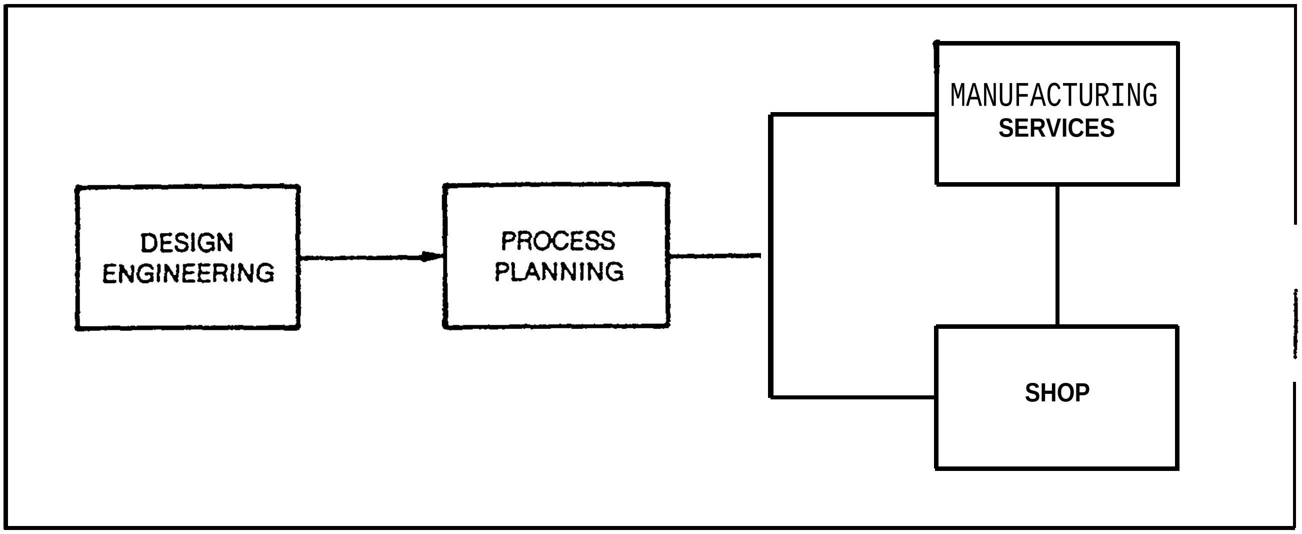


FIGURE1. THE CENTRAL ROLE OF PROCESS PLANNING IN Manufacturing DATA FLOW.

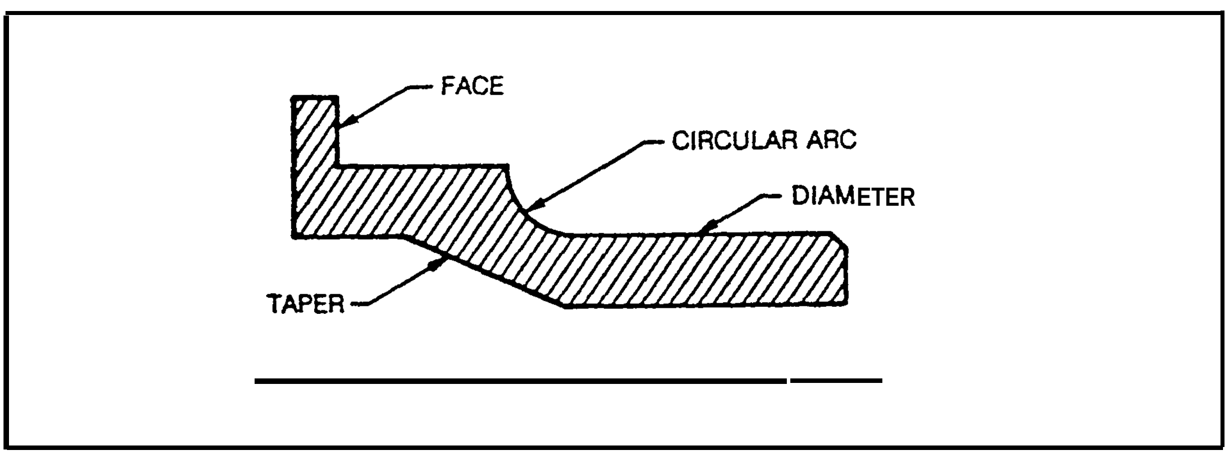


FIGURE 2 CYLINDRICAL SURFACES SUPPORTED BY CMPP.

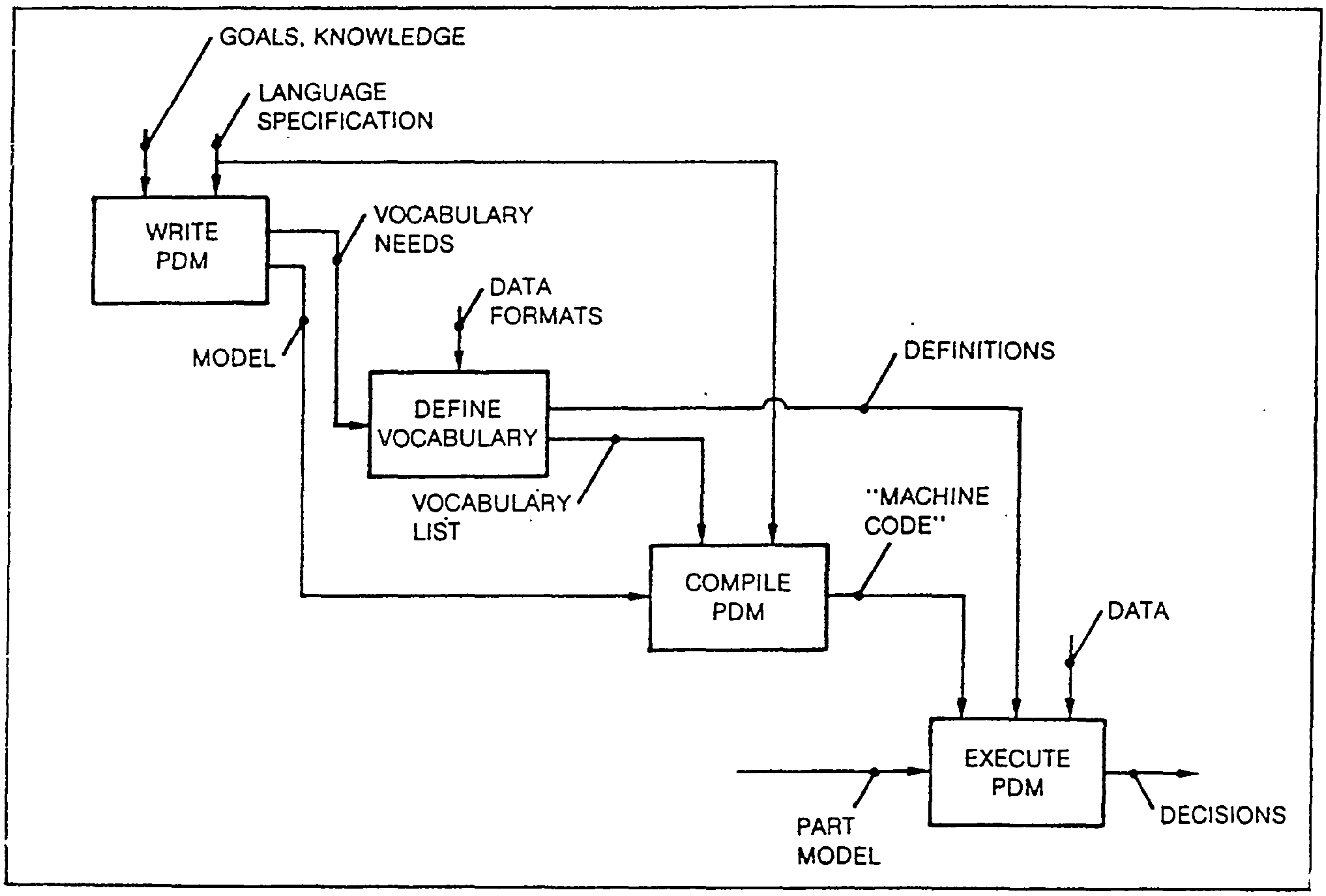


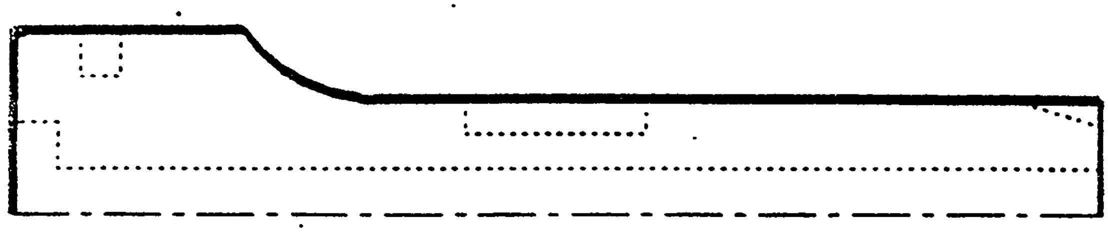
FIGURE 3. CMPP PROCESS DECISION MODELING (PDM) MECHANISM.

```
0010   DRAU MATERIAL AT MC0100 (BENCH), MT0102 (BENCH 001001)  $
                                                                              N
       THE NEXT STATEMENT UILL ORIENT (SETUP) THE PART SO THAT THE LONGEST    N
       OD OF THE PART IS OPEN TO THE RIGHT SIDE -- THIS UILL BE THE NORMAL    N
       ORIENTATION.                                                           N
                                                                              N
0020   ORIENT PART FOR LONGEST OD SETUP  $
                                                                              N
       THE NEXT OPERATION IS PROGRAMMED TO SHAPE THE PART IN NORMAL           N
       ORIENTATION.  OPEN AND SEMIOPEN (STEPPED) DIAMETERS, THE FREE END      N
       AND THE CUT-OFF END UILL BE CUT.  DIAMETERS UILL BE CUT ONLY IF        N
       THE RESULTING STEP SIZE (SHOULDER) IS AT LEAST .040.  ALSO, THE        N
       OPERATION MUST RESULT IN AT LEAST ONE DIAMETER BEING AS LONG AS        N
       .250 OF THE PART LENGTH.                                               N
                                                                              N
0030   TURN OUTSIDE SURFACE ON MC0400 (AUTOMATIC BAR MACHINE) IN NORMAL IF
                                                                              N
            SURFACE IS AN OPEN DIAMETER,
             SURFACE IS EXPOSED (OR)
                                                                              N
            FEATURE IS A SEMIOPEN DIAMETER,
             FEATURE IS EXPOSED (OR)
                                                                              N
            SURFACE IS AN END (AND)
                                                                              N
         PROUIDING THE FOLLOUING CONDITIONS ARE SATISFIED:
                                                                              N
            MINIMUM DIAMETER SEPARATION (0.040) ,
            RESULTING LONGEST DIAMETER (0.25)  $
                                                                              N
0040   HEAT TREAT IN MC0200 (FURNACE), MT0201 (FURNACE 2700) TO SPECIFIED     *
    *   HARDNESS PER PMP510  $
                                                                              N
       THE NEXT THREE STATEMENTS ARE PROGRAMMED TO GRIND THE LOCATING OD      N
       FOR A DEEP HOLE OPERATION AND TO DRILL THE DEEP HOLE (THRU BORE)       N
       USING EITHER AN EJECTOR DRILL OR GUN DRILL.                            N
                                                                              N
0050   GRIND THE LONGEST OD ON MC0500 (CENTERLESS GRINDER)  $
                                                                              N
0060   DRILL THE THRU BORE UITH MC0600 (GUN DRILL) IF
                                                                              N
            DIAMETER DIMENSION IS .LE 0.787  $
                                                                              N
0070   DRILL THE THRU BORE UITH MC2300 (EJECTOR DRILL) IF
                                                                              N
            DIAMETER DIMENSION IS .GT 0.787  $
```

FIGURE 4. A PORTION OF A COPPL PROCESS DECISION MODEL. THIS TYPE OF MODEL GENERATES A SUMMARY OF OPERATIONS FOR A PART. VOCABULARY TERMS ARE UNDERLINED.

```
UTC V3.0 CMPP SYSTEM.  ACCEPT/MODIFY GENERATED OPERATION          (#201)
PARTNO: 300000-XX                 USER: GCM                DATE: 05-11-81
PROCESS MODEL: 01        RULE NO.:    32

OP.   20  DESCRIPTION: TURN
MACH. CLASS 1:    400 BAR MACHINE                  MACH. CLASS 2: (NONE)
MACH. TOOL SPECIFIED: (NONE)
```



```
LCDGRDGRTRDFD
EH0RA0RHAE000
0000001111111
1234890356987
X X XX    X
TYPE C/R TO ACCEPT OPERATION; OR TYPE AN OPTION, AND REQUIRED DATA:
1,NEW OP.DESCRIPTION   2,MACHINE CLASS NUMBER (1 OR 2),CODE
3,MACHINE TOOL CODE   4,LIST OF ADDED CUTS  5,LIST OF DELETED CUTS
6 (CHANGES SETUP)   7 (DELETES OP.)   8 (INSERT OP. BEFORE THIS)
9 (SHOW MACHINE DATA)   10 (TERMINATE PLANNING)   11 (CHECKPOINT)
>
```

FIGURE 5. A CMPP INTERACTIVE DISPLAY. PROCESS DECISIONS ARE REVIEWED AND MODIFIED USING SUCH DISPLAYS AS THIS ONE. THE OPERATION SHOWN WAS GENERATED BY RULE 30 OF THE PROCESS DECISION MODEL IN FIGURE 4.

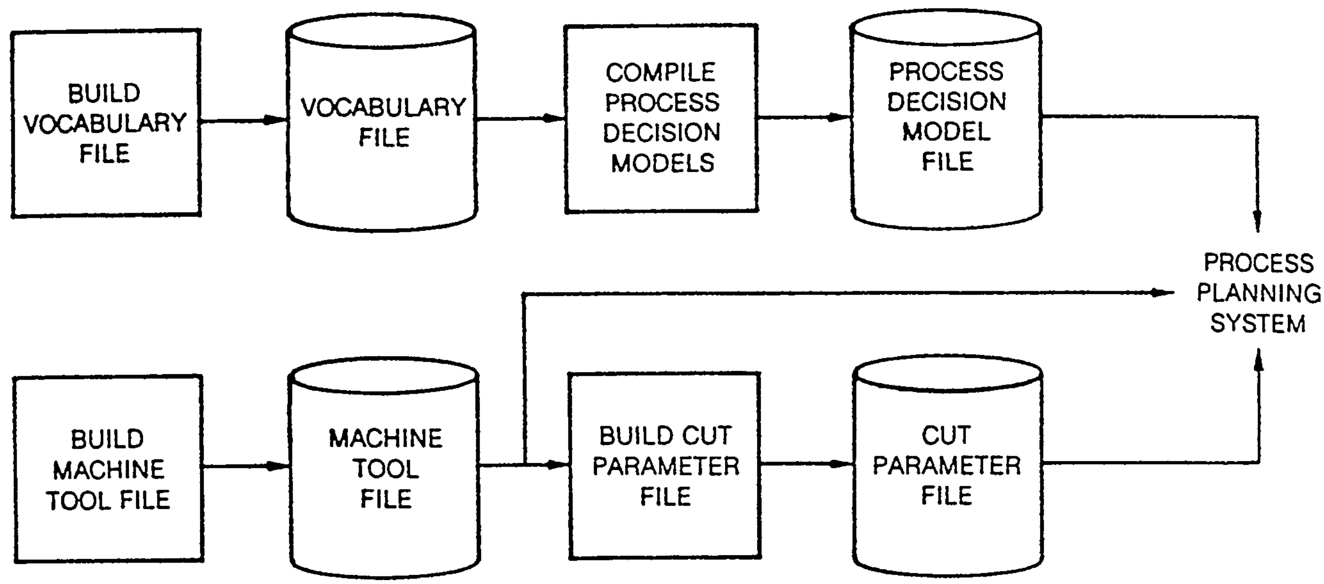


FIGURE 6. CMPP DATA BASE SYSTEM.

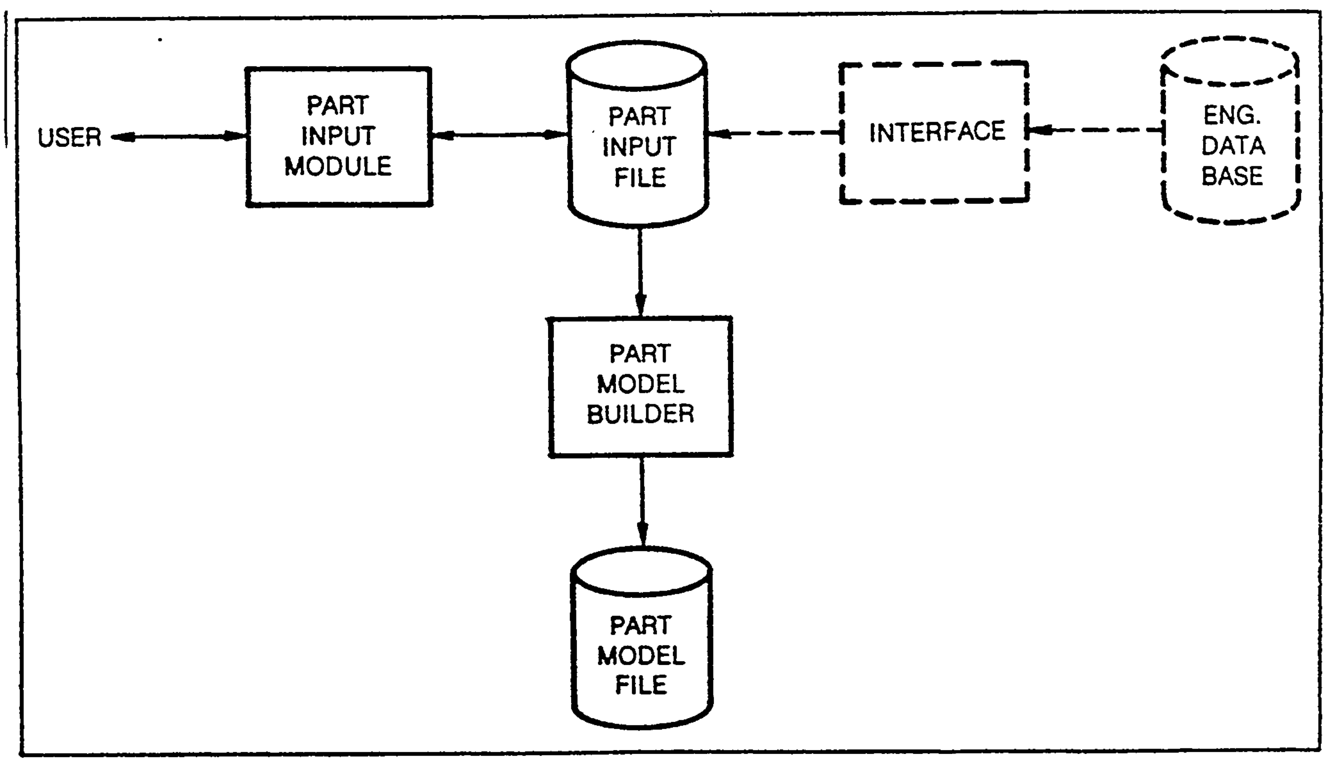
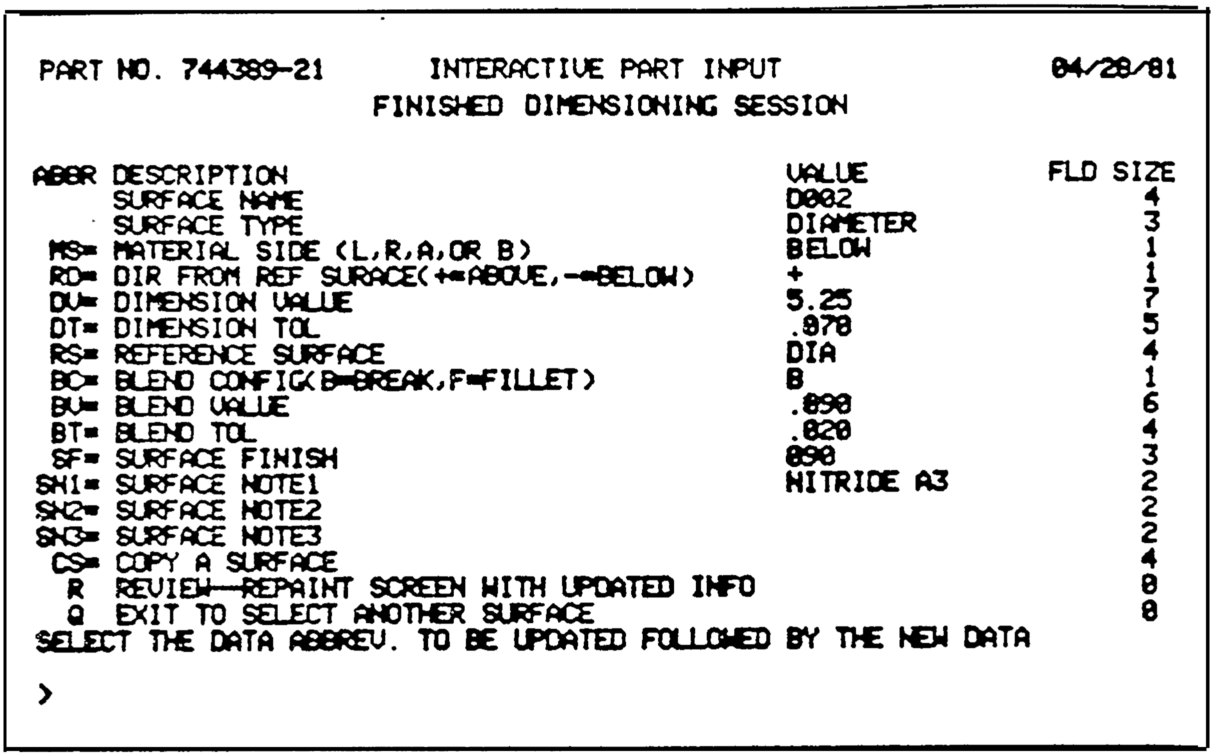


FIGURE 7. THE CMPP PART INPUT SYSTEM. DASHED LINES INDICATE OPTIONAL LOCAL ELEMENTS.



```
PART NO. 744389-21        INTERACTIVE PART INPUT                        04/28/81
                       FINISHED DIMENSIONING SESSION

ABBR DESCRIPTION                                     VALUE           FLD SIZE
     SURFACE NAME                                    D002                   4
     SURFACE TYPE                                    DIAMETER               3
 MS= MATERIAL SIDE (L,R,A,OR B)                      BELOW                  1
 RD= DIR FROM REF SURACE(+=ABOVE,-=BELOW)            +                      1
 DV= DIMENSION VALUE                                 5.25                   7
 DT= DIMENSION TOL                                   .070                   5
 RS= REFERENCE SURFACE                               DIA                    4
 BC= BLEND CONFIG(B=BREAK,F=FILLET)                  B                      1
 BV= BLEND VALUE                                     .090                   6
 BT= BLEND TOL                                       .020                   4
 SF= SURFACE FINISH                                  090                    3
SN1= SURFACE NOTE1                                   NITRIDE A3             2
SN2= SURFACE NOTE2                                                          2
SN3= SURFACE NOTE3                                                          2
 CS= COPY A SURFACE                                                         4
  R  REVIEW--REPAINT SCREEN WITH UPDATED INFO                               0
  Q  EXIT TO SELECT ANOTHER SURFACE                                         0
SELECT THE DATA ABBREV. TO BE UPDATED FOLLOWED BY THE NEW DATA

>
```

FIGURE 8. AN INTERACTIVE DISPLAY FOR INPUT OF PART DATA.

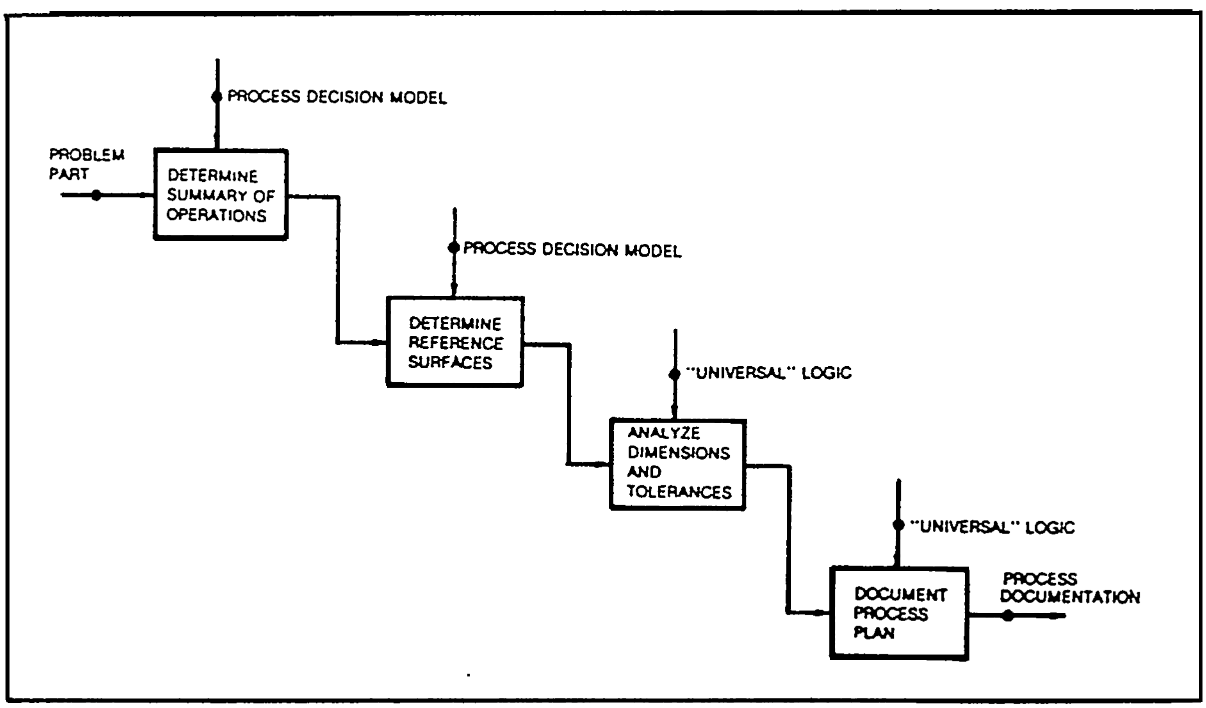


FIGURE 9. **MAJOR TECHNICAL MODULES OF THE CMPP PROCESS PLANNING SYSTEM.**

```
 0010  DO 20 IF OPERATION IS TURNING, ELSE 130 $
N
 0020  CLAMP ON THE LONGEST UNEXPOSED OD $
N
 0030  LOCATE ON A VERTICAL SURFACE IF
           SURFACE IS AN END,
             SURFACE IS NOT CUT (OR)
           SURFACE IS A FLANGE SIDE,
             SURFACE IS NOT EXPOSED $
N
 0040  DIMENSION THE EXPOSED END:
         REFERENCE THE MOST DISTANT VERTICAL CUT IF
            HEIGHT IS .GT .100;
         OTHERWISE, REFERENCE THE OTHER END $
N
 0050  DIMENSION A FLANGE SIDE IF
           FLANGE THICKNESS IS .LT .300:
         REFERENCE THE OTHER FLANGE SIDE IF
           SURFACE IS KNOWN $
```

FIGURE 10. PROCESS DECISION RULES FOR SELECTING DIMENSIONING REFERENCE SURFACES, LOCATING SURFACES, AND CLAMPING SURFACES.

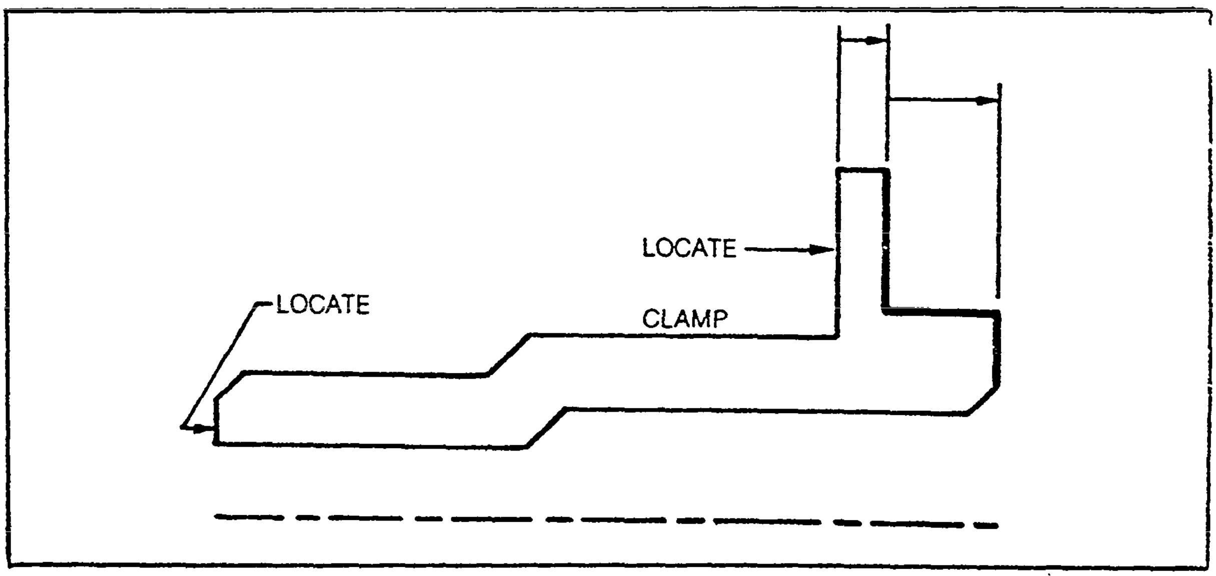


FIGURE 11. EXAMPLE OF PROCESS DECISIONS RESULTING FROM THE LOGIC OF FIGURE 10. ARROWS POINT FROM REFERENCE SURFACE TO CUT SURFACE.

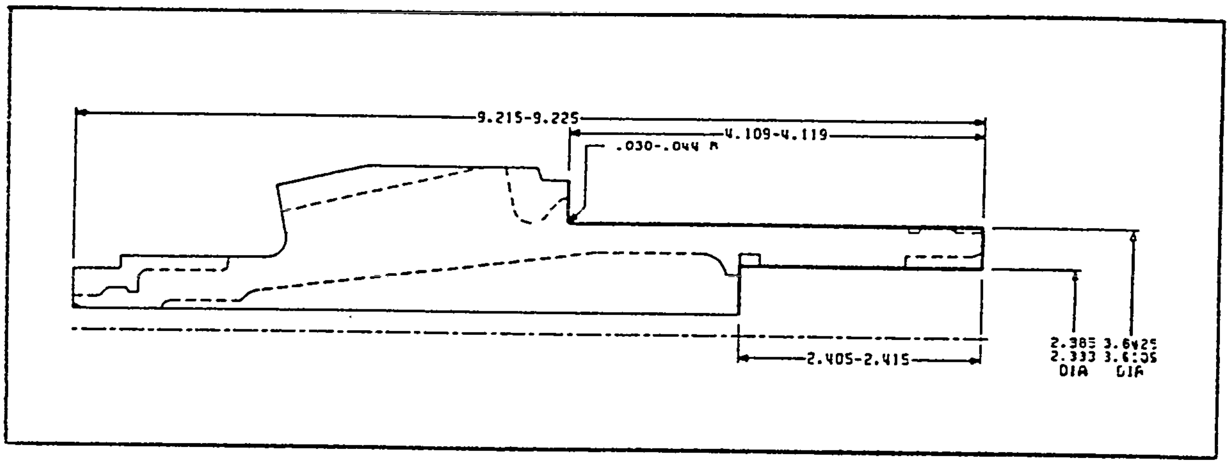


FIGURE 12. DIMENSIONED OPERATION SKETCH OUTPUT BY CMPP.

APPENDIX J

PROJECT II SCHEDULING PROGRAM DESCRIPTION

Overview of PROJECT/2

PROJECT/2 is a tool for the project planner who uses a computer in conjunction with project planning and control. A command language consisting of English language words eliminates the need for a knowledge of computers or programming. The only essential prerequisite to the successful use of PROJECT/2 is an understanding of the subject matter (network based project scheduling) and the conventions and specific terminology of the PROJECT/2 command language. A brief exposure, measured in hours, to the command language provides sufficient background for successful, independent use of PROJECT/2.

Project planning and control is a dynamic process which must match the real world conditions where unpredictable calamities occur, and where planning proceeds with the project and is not merely a startup function. To assure its success, PROJECT/2 provides many special features which economically allow network logic to be refined to adapt to management's latest thinking. PROJECT/2 has been programmed with careful attention so that each feature minimizes price per run costs to permit frequent interaction with PROJECT/2 for replanning, reporting, and scheduling. Either activity-on-arrow or activity-on-node networks can be used.

PROJECT/2 provides scheduling and control procedures and algorithms that go well beyond the basic early start, late start calculations. Incorporated within the PROJECT/2 processors are some of the most sophisticated new techniques available at this time.

The Network & CPM Schedule Processor stores basic network data and checks the network logic. The current schedule is automatically updated as actual progress is reported. The Multicalendar feature permits different activities within the same project network to operate on calendars with different workweeks and holidays. It also allows the user to vary the calendar during the life of the project. Up to 100 different work calendars can be defined for any project. The Microscheduling feature allows the user to schedule durations in hours and minutes, or optionally as several specific shifts per day. Multicalendar Microscheduling has proved especially useful in planning large plant shutdowns such as nuclear power station outages.

The Target Processor provides benchmark or target schedules for comparison to the current schedule or any other schedule. The target schedules are "frozen," rather than being updated like the current schedule. up to 50 target schedules may be saved.

The Resource & Cost Allocation Processor assigns resources and costs to activities and distributes them over the schedules. Cashflow and resource usage graphs may be produced for any time interval and over any period of time. There is no practical limit to the number of resources assigned to each activity. Output may be in tabular, histogram, and S-curve format.

The Project Cost Processor (PCP) views an entire project as a hierarchical (tree-like) structure. PCP can operate on four different multilevel work breakdown structures per project. It provides the user with maximun flexibility in assigning and manipulating costs, resources, quantities, and accounting periods. Information may be entered into PCP from several different sources: the PROJECT/2 network data base, direct input, or existing in-house files. The powerful and easy to use PCP Report Writer enables the user to custom design all printed output.

The Resource Constraining Processor computes schedules based upon resource limitations, time constraints, and activity resource assignments. PROJECT/2 is the first scheduling system to offer four methods of resource constrained scheduling: parallel, serial, wide window, and strictly serial.

The Network Graphics Processor produces high quality plotter-drawn network diagrams, bar charts, histograms, S-curves, and project calendars. Plots may be zoned by codes or total float. Only three simple commands are necessary to produce plotter output.

The Multiproject Processor combines two or more individual projects into one large project. Multiproject allows for company-wide cashflow projections, resource usage, and resource leveled schedules.

PROJECT/2 also has a unique Interactive Processor. The BROWSE feature enables TSO users to view any part of any stored report with or without hard copy output. QWIKNET™ allows the planner to create and update the network logic on a graphic display screen. As the network appears on the screen, PROJECT/2 commands are automatically generated and stored ready to update the PROJECT/2 data base.

PROJECT/2 is easy to "grow into." Users can start by using simple command forms and limited types of data. As they become familiar with the capabilities of PROJECT/2, they can use more complex forms of the commands and add new data without repeating any previous work.

One of the features that makes PROJECT/2 unique among network scheduling systems is the heavy commitment Project Software & Development, Inc. (PSDI) has made in the area of customer support services. To assist PROJECT/2 users, PSDI provides a complete package of services including technical assistance by telephone, in-house consultation, PROJECT/2 schools, plotting services, and a newsletter published three times a year. In addition, PSDI maintains a constant dialogue with all users both to communicate information on the latest PROJECT/2 developments and applications, and to obtain feedback for further enhancements of the system.

Introduction to Scheduling

Summary

Two commonly used systems for network-based project scheduling and control are activity-on-arrow and activity-on-node (precedence) networks. In both systems a network is a graphical representation of the project plan. It shows the interrelationships among the various activities. Each activity represents a task or work item that has to be performed in order to complete the project. The difference between the two methods is the way in which activities are represented in the networks. In activity-on-arrow networks each activity is represented by an arrow. In activity-on-node networks each activity is represented by a node or box.

In activity-on-arrow networks all preceding activities must be complete before an activity can be started. Dummy activities are often required to show sequential relationships.

In activity-on-node networks precedences are used to indicate the sequential relationships between activities. Precedences consist of a precedence relationship and a lag value. There are four types of relationships: Start-to-Start, Start-to-Finish, Finish-to-Finish, and Finish-to-Start. Lag values indicate the number of workperiods an activity is to be delayed. They can be positive, negative, or zero.

Once an appropriate level of detail is decided upon, activities and their interrelationships can be identified and the network diagram constructed. When constructing a network one should consider grouping together activities that are similar, i.e., show all activities that occur on one floor or are the responsibility of one department, to make the diagram easier to read.

Once a network has been defined, time and resources required by the activities may be added. PROJECT/2 can determine the total time required to reach project completion, as well as the individual time characteristics of each activity. The individual time characteristics of each activity are: early start, early finish, late start, and late finish. The early start and early finish are calculated in the Forward Pass. The late start and late finish are calculated in the Backward Pass.

Three types of float are associated with each activity. They are: Total Float, Free Float, and Direct Float. The chain of activities with the least amount of Total Float is known as the critical path. The critical path is important because it is the chain of activities that controls the overall project completion time.

Constraints are used to restrain the start or finish of an activity to more closely simulate what will actually happen. There are three types of constraints: Not Earlier Than, Not Later Than, and On. Not Earlier Than constraints affect only the Forward Pass. Not Later Than constraints affect only the Backward Pass. On affects both the Forward and Backward Passes. In the Forward Pass, On is replaced by Not Earlier Than, and in the Backward Pass, On is replaced by Not Later Than. Constraints may or may not impact the project schedule, depending upon network logic.

Although a great deal of benefit is gained from the additional effort spent in planning a project when network-based scheduling systems are used, delays can also be avoided by properly monitoring a project under way. A proper reporting cycle must be established so that problems will be discovered before it is too late to take corrective action.

Command Language and Operating Environment

Summary

The user communicates instructions and data to PROJECT/2 via English-like commands, which may be punched on cards or keyed at a data terminal. The Command Language is free format, i.e., the required symbols can begin anywhere on an input line as long as each item is separated from others by one or more blank spaces or commas. However, the ordering from left to right must follow the command General Forms as presented in the manual.

Commands are processed in the sequence in which they are input. The Command Language permits the user to shorten most words to their first three letters, and some abbreviations are used. Dates are input as shown below and most General Forms permit the entry of the project workday that corresponds to a calendar date.

```
month day year     (number number number)
month day year     (word number number)
day month year     (number word number)
```

Each command General Form shows the required words with the necessary letters underlined. If "ignorablell words are used, at least the overlined letters must be included. Optional features of commands are shown enclosed in parentheses or braces.

Each General Form requires one of three formats: Simple, Tabular, or Data List.

```
PRINT SCHEDULE                     a Simple Command

ADD PRECEDENCES
  30 60
  55 24                            a Tabular Command
  62 70
LAST

REMOVE ACTIVITIES 20, 30 LAST      a Data List Command
```

Basic Network Input and Output

Summary

Network Input,

Before a schedule can be created by PROJECT/2, the basic network data must be stored using the STORE NETWORK command. For each activity, the user must supply an activity number, description, and duration. Codes and cost may also be supplied. PROJECT/2 processes this information, checks for errors, and then stores the information.

Schedules cannot be created until a calendar has been defined. To define a calendar, the project start date must be supplied using the ASSIGN START comnand. The length of the workweek and holidays may be supplied using the

a 5 day workweek, beginning on Monday, is assumed. No holidays are assumed. The holidays and project calendar can be displayed by using the PRINT HOLIDAY and PRINT CALENDAR commands.

Constraints may be assigned to the project completion time and/or to individual activities. Constraints are assigned to the project completion by using the ASSIGN FINISH command. Activity constraints are assigned by using the ASSIGN CONSTRAINTS command. Constraints may be displayed by using the PRINT CONSTRAINTS command.

Activity descriptions can be expanded by using the ASSIGN LISTS command. Lists can be displayed by using the PRINT LISTS command.

Network Output

Once a network has been created and stored, various reports and schedules can be output. Four reports have been designed to aid in the verification of network data. They are produced by the commands,

PRINT NETWORK
ANALYZE OPEN ENDS
ANALYZE NETWORK NOFLOW
PRINT RELATIONSHIPS

Normally, one or more of these reports is required to debug the basic logic that has been input via the STORE NETWORK command.

After the basic logic has been debugged and a calendar specified, reports can be generated that display all or part of the different project schedules. Commands that display the schedules are:

PRINT PLANNING SCHEDULE
PLOT PLANNING SCHEDULE
PRINT WORKING SCHEDULE
PLOT WORKING SCHEDULE
ANALYZE NETWORK
PRINT PREDICED STATUS

Other reports allow the user to determine the overall status of all projects on a particular DD2 or the status of any individual project on the DD2. These reports are produced by the following commands:

```
LIST PROJECT STATUS
PRINT STATUS
```

Basic Network Modifications

Summary

PROJECT/2 provides the user with the ability to easily update or modify a network without having to store the entire network again.

The ASSIGN NAME command should be the first PROJECT/2 command in every PROJECT/2 run except runs that begin with a STORE NETWORK command. The ASSIGN NAME command identifies the project to which subsequent commands in the run apply. The project must have been previously established with a STORE NETWORK command.

Activities may be added to and removed from the network using the ADD ACTIVITIES and REMOVE ACTIVITIES commands.

Precedences may be added and removed using the ADD PRECEDENCES and REMOVE PRECEDENCES commands. Lags may be changed using the CHANGE LAGS command.

Activity information, e.g., durations, descriptions, and codes, may be changed using the CHANGE ACTIVITY BLOCK and EDIT ACTIVITIES commands. Activity constraints may be reassigned using the ASSIGN CONSTRAINTS command or removed using the REMOVE CONSTRAINTS command. Individual List items may be replaced by adding another List item with the same List reference number using the ASSIGN LISTS command. List items may be removed using the REMOVE LISTS command.

Calendar specifications can also be easily modified. The project start date and length of the workweek can be changed by reassigning the information using the ASSIGN START and ASSIGN WORKWEEK commands, respectively. Holidays can be added using the ASSIGN HOLIDAYS command and can be removed using the REMOVE HOLIDAYS command.

The project finish constraint may be modified by reassigning it using the ASSIGN FINISH command, or it may be removed using the REMOVE FINISH command.

Codes

Summary

Codes are used to control the output on PROJECT/2 reports. Three 9-digit numeric codefields are provided. They are called the Code, the Bcode, and the Ccode. Within each codefield, the code values are referenced by digit position. Digit position is determined by counting from the leftmost non-zero digit of the largest code number. If an activity with a larger number of digits than previously existed is entered, the digit positions of all other activity codes are changed.

Code values are assigned to activities in the STORE NETWORK command and the ADD ACTIVITIES command. They are changed by the CHANGE ACTIVITY BLOCK and EDIT ACTIVITIES commands.

Codesets are combinations of the various codefield digits. A codeset can be up to nine digits long. Order is important in a codeset.

Codesets may have descriptions associated with them. The descriptions are used as headings on subreports, as zone descriptions on plots, and as labels on summarized reports. Codeset descriptions are assigned using the ASSIGN DESCRIPTIONS command.

Once code descriptions have been stored they can be printed and/or removed from the network using the PRINT DESCRIPTIONS and REMOVE DESCRIPTIONS commands.

Activity Cost Accounting

Summary

Basic PROJECT/2 includes three cost types: estimated costs (budget), target costs - and actual and revised costs.

Estimated Costs (Budget) are the user's best estimate in advance. They may be input directly and/or computed based on resource assignments. Estimated Costs can be input on a per activity basis through the STORE NETWORK and ADD ACTIVITY commands. They may also be input individually using the ASSIGN COSTS command. Estimated Costs can be computed based on the resources required for each activity by using the ASSIGN COSTS BY RESOURCE PRICES command. Costs may be removed by using the REMOVE COSTS command.

Target Costs, like Target Schedules, are used for comparison with other costs for a project. Unlike Target Schedules, however, there is only one Target Cost per activity per network. Target Costs may be based on either the Budget or Latest Revised Estimate (LRE) and are input using the ASSIGN TARGET COSTS command. Target Costs are output by the PLOT CURVES, PRINT ACTUAL COST, and PRINT ACTUAL MANHOUR commands.

When work actually begins on the project, it is possible to start accounting for actual costs incurred and revising the estimates for costs in the future. The Latest Revised Estimate (LRE) is used for this task. Each activity has a three-component LRE composed of Actual Cost to Date, Obligations, and Estimate to Complete (ETC). LRE data may be input directly with the REPORT PROGRESS command. Estimates to Complete may be automatically computed using the ASSIGN ETC command.

The Actual Cost and Progress Report presents the net effect of data that is reported using the REPORT PROGRESS and ASSIGN ETC commands. This report shows the Budget, Latest Revised Estimate, Percent Complete Costwise and Timewise, and the deviations from the Budget. It is output using the PRINT ACTUAL COST command. PROJECT/2 can also output information concerning manpower usage. This report is similar to the Actual Cost and Progress Report; it is generated by issuing the PRINT ACTUAL MANHOUR REPORT command.

Cash flow projections may be made by using either the PRINT COSTS or PLOT CURVES command. The PRINT COSTS command has an option (ES/LS) that allows the user to generate Early Start and Late Start S-curves. The PLOT CURVES command prints up to eight cost curves on one sheet of paper.

Resource Planning

Summary

The following steps must be followed in resource planning and scheduling using PROJECT/2:

1. Define a Resource Library.
2. Assign resources to activities.
3. Generate resource usage reports.
4. Determine the problem resources and/or activities.
5. Impose resource limits (availabilities).
6. Generate Resource Constrained (leveled) Schedules.
7. Examine the results.

A Resource Library is established by using the DEFINE RESOURCE LIBRARY command, a "global" command that is independent of the projects on the dataset. Once a Resource Library has been defined, all resources in the Library may be used by any project on the dataset. The Resource Library contains the following information for each resource:

- Description
- Reference number
- Resource type (optional)
- Unit of measure (optional)
  Cost escalation points (optional)

Resources are assigned to activities by using the ASSIGN RESOURCES command. The DAILY option of this command is useful when many activities have the same per-day quantity of one or more resources, but are of varied duration. Resources may be removed from activities by issuing the REMOVE RESOURCES command.

Once resources have been defined in the Library and assigned to activities, two classes of output reports may be generated. Resource allocation reports provide the user with reports on how resources have been assigned. Resource usage reports distribute projected resource usage over a given time period. Resource allocation reports are output by the PRINT RESOURCE ALLOCATION command and the PRINT BILEVEL command. Resource usage reports are generated by either the PRINT RESOURCE USAGE or PRINT RESOURCE MULTIPLE command.

Output Control

Summary

PROJECT/2 has been designed to give the user great flexibility in tailoring output reports to meet specific requirements. The user can indicate the conditions that should be met by the activities to be included in the report, the order in which the activities should be printed, how the report should be page broken, the time frame, and an interval time.

The General Form for an output command with all of the output options is:

ommand * { interval / range } (select) (sort)

where:

command - a PROJECT/2 output command, e.g., PLOT SCHEDULE

interval - indication of the span of time to be used in reports that distribute cost or resources over time such as tabular listings, histograms, etc., e.g., EVERY WEEK instead of the default of every day.

range - specification of a time frame for those reports that distribute cost or resources over time such as tabular listings, bar charts, histograms, etc., e.g., BETWEEN JAN 15 1981 AND MARCH 30 1981.

select - description of the conditions that must be met by the activities to be included in the report, e.g., SELECT ACTIVITIES WITH NODES GT 1000.

sort - order in which the activities should appear in a report, e.g., SORT BY ES.

All of the output options are not available in every command. The user should check the General Form of each specific command to find out which options are available for that command. When several output options are used in the same command, the sequence in which they can appear (from left to right) is:

1. Interval and/or range in any order
2. Select
3. Sort

Any or all options may be omitted but the above order must always be maintained.

Many PROJECT/2 reports may be summarized by codesets chosen by the user. Outputting data by such summary groups of activities can decrease the printed volume considerably. The SUMMARIZE BY codeset option is shown in the General Form of each command that can produce summarized output.

If the same set of activities is used several times, the subset can be assigned as a Group by using the ASSIGN GROUP command. The use of Groups is more efficient because the selection process is performed only once.

In addition to the options listed above, a report can be controlled by the EJECT command. The EJECT command segments activity oriented reports into subreports according to the code numbers assigned to the activity. Three steps must be followed when ejecting a report: (1) issue the EJECT ON... command, (2) make the primary sort on the output command the same as the eject code, and (3) issue the EJECT OFF command.

Three titles can be input using the ASSIGN TITLE commands if the user wishes to have titles printed on report headings.

Various SET commands allow the user additional flexibility in specifying the data that is to be printed on output reports, e.g., the printing of Lists, constraints, and workdays may be inhibited.

Reporting Progress

Summary

The user conveys activity status information to PROJECT/2 by issuing a REPORT PROGRESS command. Any of the following activity progress data can be reported:

START, FINISH, OCCURRENCE (for events), Percent Complete (PC), Remaining Duration (RD), Days Complete (DC), Actual Cost (AC), Obligation (OBL), and Estimate to Complete (ETC).

PROJECT/2 classifies progress data into one of three categories, depending on the information reported at the Data Date and the status of the activity prior to the REPORT PROGRESS command. The three categories are:

- Initial Reporting - the first time progress information is reported on an activity, or when a start is re-reported.
- Subsequent Reporting - progress information already exists for the activity and is being updated with new progress data.
- Active Activities - incomplete activities, with reported starts from a prior Data Date, for which subsequent progress data is not reported on the current Data Date.

Once progress has been reported, PROJECT/2 automatically computes additional information about the activities. This additional information depends upon what information was reported, if any, and the REPORT PROGRESS command header card options. No header card options affect Initial Reporting.

The options that affect Subsequent Reporting are: RECALCULATE PC and RECALCULATE RD. When only a Percent Complete is reported PROJECT/2 does not normally recalculate a Remaining Duration, and vice versa. If the RECALCULATE option is used, then a new Percent Complete or Remaining Duration is calculated.

The options that affect Active Activities are FIX and SLIDE. If progress is not reported on an Active Activity then FIX assumes that the activity continued on schedule (its Early Finish does not change); therefore the activity may be automatically "completed." SLIDE assumes that no work was performed on the activity (its Remaining Duration does not change).

Once progress information is reported, PROJECT/2 calculates a Current Schedule based on the latest network logic and progress information. Each time progress information is reported the existing Current Schedule is destroyed and a new Current Schedule is calculated. When progress information is reported it remains on file until it is removed using the REMOVE PROGRESS command or updated, even though the Current Schedule may be destroyed.

The Current Schedule may be used in place of the Original Schedule on all Planning and Working Schedule reports. The user controls the schedule to be output by issuing the USE ORIGINAL or USE CURRENT command.

After progress has been reported, the user can direct PROJECT/2 to consider the Full set of project activities or a Brief set, defined as all of the activities that have not been completed as of the most recent Data Date. Any command whose General Form includes the select option will operate on the Full or Brief set of activities. The user chooses the Full or Brief set by issuing the command,

$$\underline{\text{USE}}\begin{Bmatrix}\underline{\text{ORI}}\text{GINAL}\\ \underline{\text{CUR}}\text{RENT}\end{Bmatrix}\ \left(\begin{Bmatrix}\underline{\text{FULL}}\\ \underline{\text{BRI}}\text{EF}\end{Bmatrix}\right)$$

As progress information is reported, data may be reported that conflicts with basic network logic. PROJECT/2 accepts information that conflicts with network logic. However, the network logic is modified through the introduction of negative lags to account for these inconsistencies. The Current Schedule Exception Report is output following reported progress data to show the violations of network logic.

Target Schedules

Summary

PROJECT\2 allows the user to save schedules, known as Target Schedules, and to compare them with the Current Schedule on a per activity or summary basis. Once created, a Target Schedule is "frozen." Logic changes and new progress dates do not alter the Target Schedule dates. Up to 50 Target Schedules can be saved.

Target Schedules are created using the CREATE TARGET SCHEDULE command. The user must have reported progress and established a Current Schedule and a Data Date before using the CREATE TARGET SCHEDULE command. A Target Schedule may be based upon the Original Schedule, Current Schedule, or a Resource Schedule. Once a Target Schedule has been created, a description may be associated with it by using the ASSIGN DESCRIPTION FOR TARGET SCHEDULE command.

A Target Schedule may be modified by using the ASSIGN TARGET DATES command. The ASSIGN TARGET DATES command allows the user to modify the dates associated with individual activities within a Target Schedule. Target Schedules may be deleted by using the REMOVE TARGET SCHEDULE command.

Target Schedules may be output in either tabular or bar chart format. The PRINT TARGET SCHEDULE command is used to generate tabular output, and the PLOT TARGET SCHEDULE command is used to generate bar chart output. If a comparison on a summary level is desired, the PRINT TARGET SUMMARIZE and/or PLOT TARGET SUMMARIZE commands are used. The Target Schedule Start and Finish dates printed on output reports are controlled by the user through the Working Schedule Mode.

The PRINT CURRENT STATUS command provides information about the actual status of the project over a future period of time as compared to the Target Schedule for that period. This command automatically generates three subreports, showing activities that must be completed, must be in progress, and may be in progress.

Resource Constrained Scheduling

Summary

Resource constrained schedules are computed based upon resource limitations, time constraints, and activity resource assignments.

By examining resource usage reports, a user can determine problem resources and/or activities. Resource limits are imposed via the ASSIGN RESOURCE AVAILABILITY command.

Resource leveled schedules are produced by the CREATE RESOURCE SCHEDULE command. Schedules produced in the Original mode include all activities; schedules produced in the Current mode constrain only the Brief set of activities. Resource leveled schedules may be resource-limited or time-limited. If the FORCE option is not used a resource-limited schedule is obtained; however, the job duration will probably increase. If the FORCE option is invoked a time-limited schedule will be produced. Forcing at criticality zero maintains the project completion date; however, resource limits may be exceeded. A CUTOFF DURATION may be specified, after which the scheduling process ignores all resource constraints. Before resource scheduling begins, feasibility tests are performed to avoid wasted computer runs; OVERRIDE may be specified to override the PROJECT/2 feasibility tests. Secondary resource availability is not considered unless the SECONDARY CRITICALITY option is used. The DEBUG and BOTTLENECK options provide useful output concerning the resource constraining process; if omitted, PROJECT/2 prints only informatory notes showing the progress of the scheduling algorithm. A description can be associated with each Resource Schedule by using the ASSIGN DESCRIPTIONS FOR RESOURCE SCHEDULE command.

Resource Constrained Schedules may be output using the PLOT RESOURCE SCHEDULE command. They can also be output on any report that prints dates based on the Working Schedule (PRINT WORKING SCHEDULE, PLOT WORKING SCHEDULE, PRINT RESOURCE USAGE, PRINT COSTS, etc.). A Resource Schedule can be used as a Working Schedule through the USE RESOURCE SCHEDULE command. A Resource Schedule, active as the Working Schedule, is "deactivated" using the ASSIGN ES, LS, FR MODE command, Data Base changes (Add or Remove activities), or at the end of the run.

A Target Schedule can be created based upon a Resource Schedule by using the CREATE TARGET BASED ON RESOURCE SCHEDULE command. When a Resource Schedule is active as the Working Schedule it replaces the Current Schedule in all Target Reports.

Network Graphics

Summary

Only three PROJECT/2 commands (DRAW.. .; ENDIPF; and POST.. .) are required ko produce plotter-drawn network diagrams and bar charts.

The DRAW NETWORK command produces a network drawing for all selected activities in the network. Four time scales are available for plotting network diagrams; they are: LOGICAL, COMPRESSED, DISCRETE, and LINEAR. If a time scale is not included in the DRAW NETWORK command PROJECT/2 chooses LOGICAL. Activity related information shown on each network diagram is as follows: the activity number, description, duration, percent complete, total float, and working schedule start and finish dates.

The DRAW SCHEDULE command produces plotter-drawn bar charts for all selected activities. Time scales on bar charts are specified by using the standard PROJECT/2 interval option. The PRINT option allows the user to specify the information to be printed on a bar chart.

A number of other draw options are available to modify the output produced by DRAW commands. If draw options are not included in a DRAW command then it is a simple (one line) command. If draw options are included then it is a tabular command (consisting of a header card, data cards, and a LAST cutoff card).

The ENDIPF command closes the intermediate plot file (IPF). The command is required and must be included between the DRAW command(s) and the POST command(s).

Actual plot output is generated by using the POST command. The POST command reads the coded information placed on the IPF by the DRAM command and produces output for the plotter specified by the user. The size of the plot generated by the DRAW command may be modified by using the SCALE option in the POST command.

The vertical placement of activities on the plot is controlled by the ASSIGN ZONE command. If zones were assigned BASED ON codeset, any previously assigned descriptions for the codesets are used as zone descriptions. Zones assigned by total float are labeled to indicate float groupings. Zone assignments carry over from run to run and may be inhibited by using the SET ZONES OFF command or may be deleted by using the REMOVE ZONES command.

APPENDIX K

CAPP PROJECT, IBM P/C SCHEDULE DATA, SOFTWARE PROGRAM

CAPP PROJECT, IBM P/C, SCHEDULE DATA SOFTWARE PROGRAM

The CAPP Project schedule data software program utilizes Revelation, a data base management and business-oriented applications soft ware tool from COSMOS Inc. The program consists of two sets of files called Location Table and Kit Tracking Table. The main menu is presented on page J-2 and the report menu is presented on page J-3.

The data entered for the location table is the numerical location information shown on sheet 1 of Figure VI–6 and the location name and the types of kits that the location can process. The process lanes kit information file contains all the data about each individual kit

```
* * * MAIN MENU FOR PROCESS LANES SYSTEM * * *          LANES
            14:12:33  22 JAN 1987

        1. MAINTAIN HARDINGS LOCATIONS
        2. KIT DATA MAINTENACE
        3. REPORT SUBMENU
        4. LOG OFF REVELATION

USED TO UPDATE LOCATION INFOMATION AND VIEW KIT CROSS-REFERENCE.
F5=Toggle MAIN/LAST menu   Ctl-F5=TCL   F9=END menu    Retrn=Run menu option
```

```
* * * REPORT MENU FOR PROCESS LANES SYSTEM * * *          LANES
                  14:15:16  22 JAN 1987

              1. LIST LANES FILES
              2. LOOK AT A DICTIONARY
              3. SELECT WELDING COMPLETIONS
              4. THE TEST RPT
```

F5=Toggle MAIN/LAST menu   Ctl-F5=TCL   F9=END menu   Retrn=Run menu option

LOC * * * DATA MAINTENANCE FOR LOC TABLE * * * (I-1)

01 LCC
02 LOC.NAME
03 KIT

LOCATION ? ..

KIT * * * PROCESS LANES KIT TRACKING * * *

```
01  HULL
02  KIT
03  UNIT
04  SUB A
05  S.A
06  TYPE
07  LOC
08  MAT.COMP
09  WELD.COMP
10  FIT.HOURS
11  WELD.HRS
    TOT.HRS
12  TOT.ASSY
13  TOT.PIECES
14  WELD.FOOT
15  COMMENTS
```

HULL ? ....

APPENDIX L

SPACECRAFT OPERATIONS, CASA/CAMA SYSTEMS DEMONSTRATION

SPACECRAFT OPERATIONS

CASA/CAMA SYSTEMS

DEMONSTRATION

TSD INDUSTRIAL ENGINEERING

CASA III/CAMA

AGENDA

- INTRODUCTIONS

- OVERVIEW OF CASA/CAMA
  - WHAT IS CASA?
  - WHAT IS CAMA?

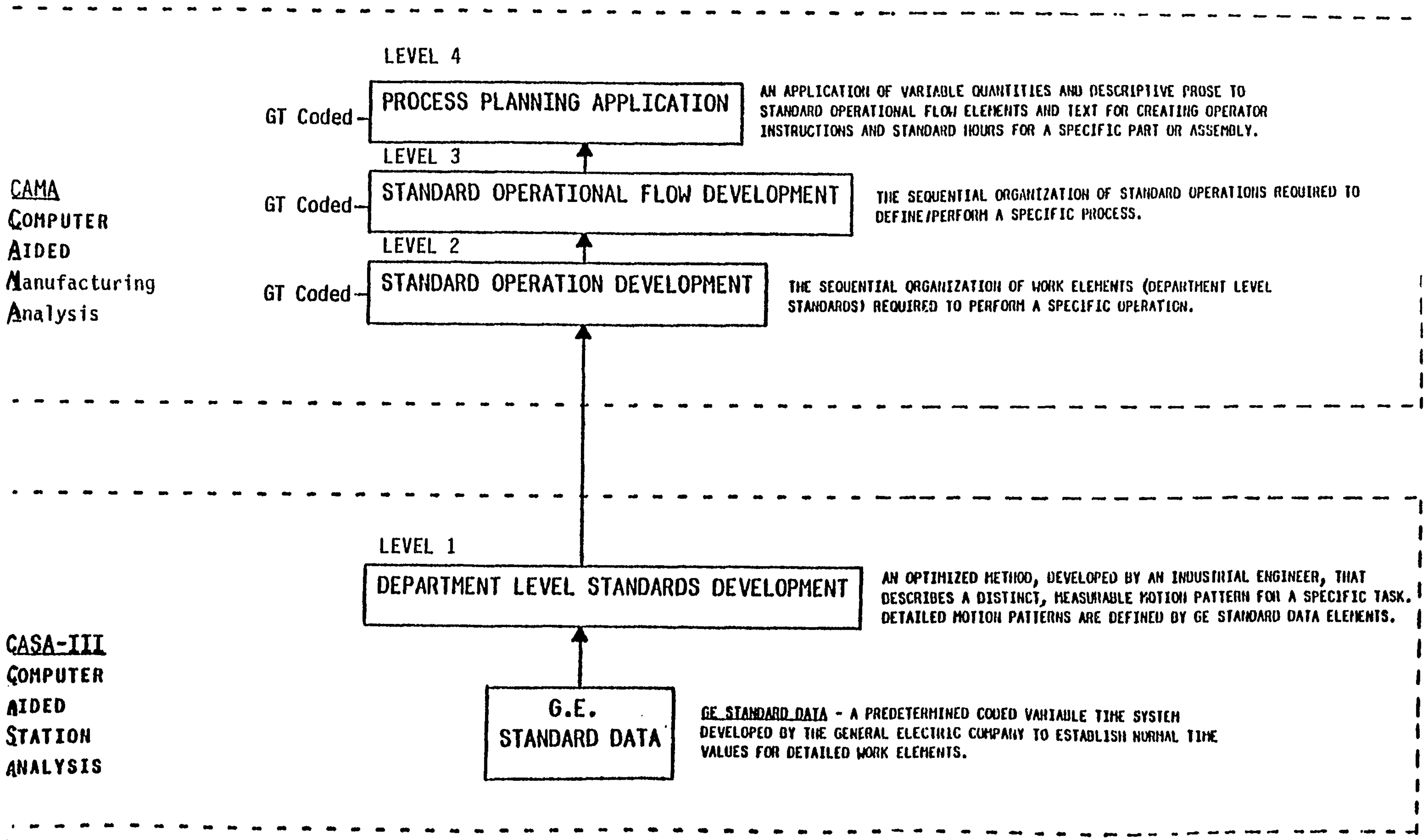
- CASA DEMO
  - OVERVIEW OF LOGIC CAPABILITIES
  - DEPARTMENT LEVEL STANDARDS GENERATION
  - TEXT/METHOD BUILDING
  - HISTORICAL DATA
  - QUERY SCREENS
  - DISTANCE MATRIX SCREEN

- CAMA DEMO
  - OVERVIEW OF LOGIC CAPABILITIES
  - STANDARD OPERATION DEVELOPMENT
  - STANDARD OPERATION FLOW DEVELOPMENT
  - PROCESS PLANNING
    - DEVELOPED FROM DEPARTMENT LEVEL STANDARDS
    - DEVELOPED USING "FREE FORMAT" INPUT
  - OUTPUT REPORTS
    - COVER SHEET
    - BILL OF MATERIAL
    - AN CONTROL
    - PROCESS PLANNING DETAIL
  - QUERY SCREENS
  - MASS UPDATE CAPABILITY

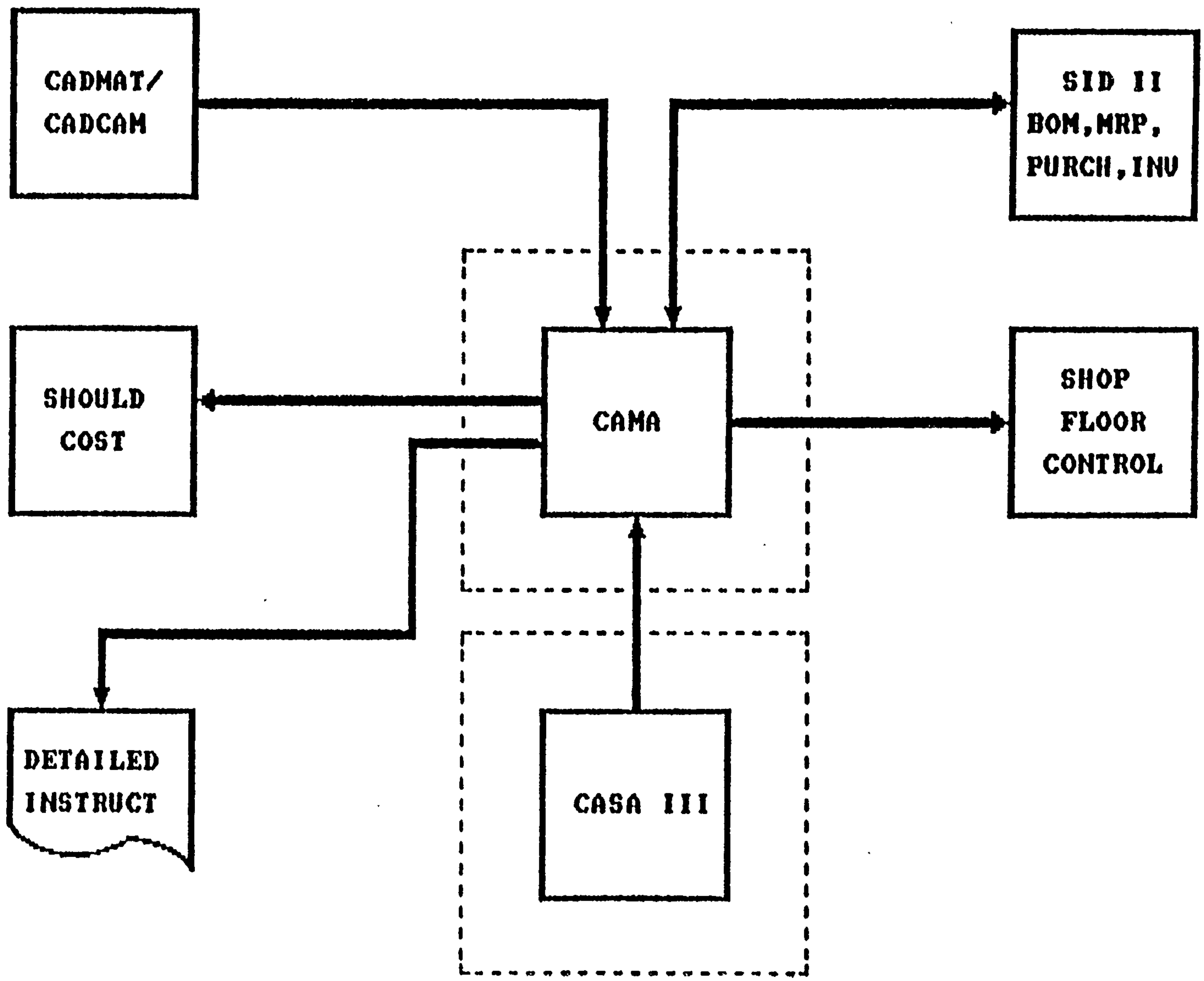
- GT CODING
  - BACKGROUND
  - DEMONSTRATION

- CONTINUE DISCUSSION OF SYSTEMS/QUESTIONS AND ANSWERS

I S D CASA III/CAMA OVERVIEW WITH GT CODING SCHEME



SYSTEMS OVERVIEW



HAF
5/6/85

CASA

Computer Aided Station Analysis

Advanced
— Methods and Measurements —
for the Future

Industrial Engineering
Applications Consulting

CASA

Computer Aided Station Analysis

- **"CASA" Objective** - Productivity Improvement
  - **—I.E. Analyst**
    - Computerize the Methods and Measurement Activity
    - Emphasize Methods Development/Work Simplification
    - Utilize Accepted Engineered Standards Techniques
  - **—Direct Labor Work Force**
    - More and Better Methods with Accurate Measurements

CASA

Computer Aided Station Analysis

- **Will Result In:**
  - — Greater and More Effective Industrial Engineering Effort
  - — Lower Direct Labor Cost
  - — Improved Shop Floor Control
  - — Increased Capacity
  - — Better Labor Load Planning
  - — More Accurate Inputs for Master Scheduling
  - — Improved Accuracy of Forecast

CASA

Computer Aided Station Analysis

. **Basic Features - All CASA Systems**

— **Computerized Logic - Provides:**
  - Ž **Disciplines in Meth. & Meas. Development**
  - Ž **Accurate Measurements**

— **M.T.S./G.E. Standard Data Base - Company-wide Acceptance**

— **Simplified Coding - Easy to Learn**

— **Application - Broad Plant Spectrum**

— **Flexibility for Method Optimization**

— **Hard Copy Documentation/Permanent Disk Storage**

— **High Level Acceptance - Operators - Managers**

— **Multilevel Application**
  - ● **Universal Data (Plant Data)**
  - Ž **Operational Standards**

– Supports **"CAPP"/"M.R.P."/Shop Floor Control Systems**

CASA
Computer Aided Station Analysis

- Benefits **with CASA**
  - — **Engineered Methods and Standards**
  - — **Full Documentation - Current and Historical**
  - — **Improvement in I.E. Effectiveness**
    - Ž **New Methods Development**
    - Ž **Maintenance of Methods and Standards**
    - Ž **Introduction of New Models**
  - — **10-3O% Productivity Improvement**
    - Ž **Emphasis on Good Methods and Adequate Training**
  - **- INCREASE CAPABILITY** FOR STANDARDS AUDITING

CAMA

COMPUTER AIDED MANUFACTURING ANALYSIS

ADVANCED

- PLANNING AND STANDARDS -

FOR THE FUTURE

INDUSTRIAL ENGINEERING

APPLICATIONS CONSULTING

CAMA

COMPUTER AIDED MANUFACTURING ANALYSIS

- "CAMA" OBJECTIVE - FULLY INTEGRATED COMPUTERIZED PLANNING AND STANDARD TIME SYSTEM
  - SUPPORT LABOR (PLANNER)
    - CAPABILITY OF GENERATING OPERATOR INSTRUCTIONS BASED ON ENGINEERING METHODS
    - UTILIZE EXISTING PLANNING/STANDARDS
    - EMPHASIZE USE OR STANDARD STATEMENTS/PROCESS FLOWS
    - GENERATE STANDARD REPAIR (REWORK) INSTRUCTIONS
    - SUPPLY COMPUTER DRIVEN MANUFACTURING SYSTEMS SOURCE DATA.
  - DIRECT LABOR FORCE
    - INCREASED PRODUCTIVITY WHEN PLANNED TIME AND INSTRUCTIONS ARE CONSISTENT.
    - MORE ACCURATE MEASUREMENT BASE (IMPROVED OPERATOR MOTIVATION)

2288A

CAMA

COMPUTER AIDED MANUFACTURING ANALYSIS

- WILL RESULT IN:
  - GREATER AND MORE EFFECTIVE PLANNING EFFORT
  - LOWER DIRECT LABOR COST
  - IMPROVED PRODUCT QUALITY
  - REDUCED DEFECTS
  - IMPROVED MANUFACTURING SYSTEMS DATA SOURCE
- BASIC FEATURES:

  COMPUTERIZED LOGIC - PROVIDES:
  - STANDARDIZED PROCESS SEQUENCE AND OPERATIONS INSTRUCTIONS.
  - CONSISTENT INSTRUCTIONS BASED ON ENGINEERING METHODS.
  - ACCURATE PLANNED TIME BASED ON ENGINEERED APPROACH.
  - MASS UPDATE CAPABILITY
  - STANDARD REPAIR (REWORK)
  - ELECTRO/MECHANICAL/ASSEMBLY GROUP TECHNOLOGY
  - ACCEPTANCE OF EXISTING PROCESS PLANS

2288A

CAMA

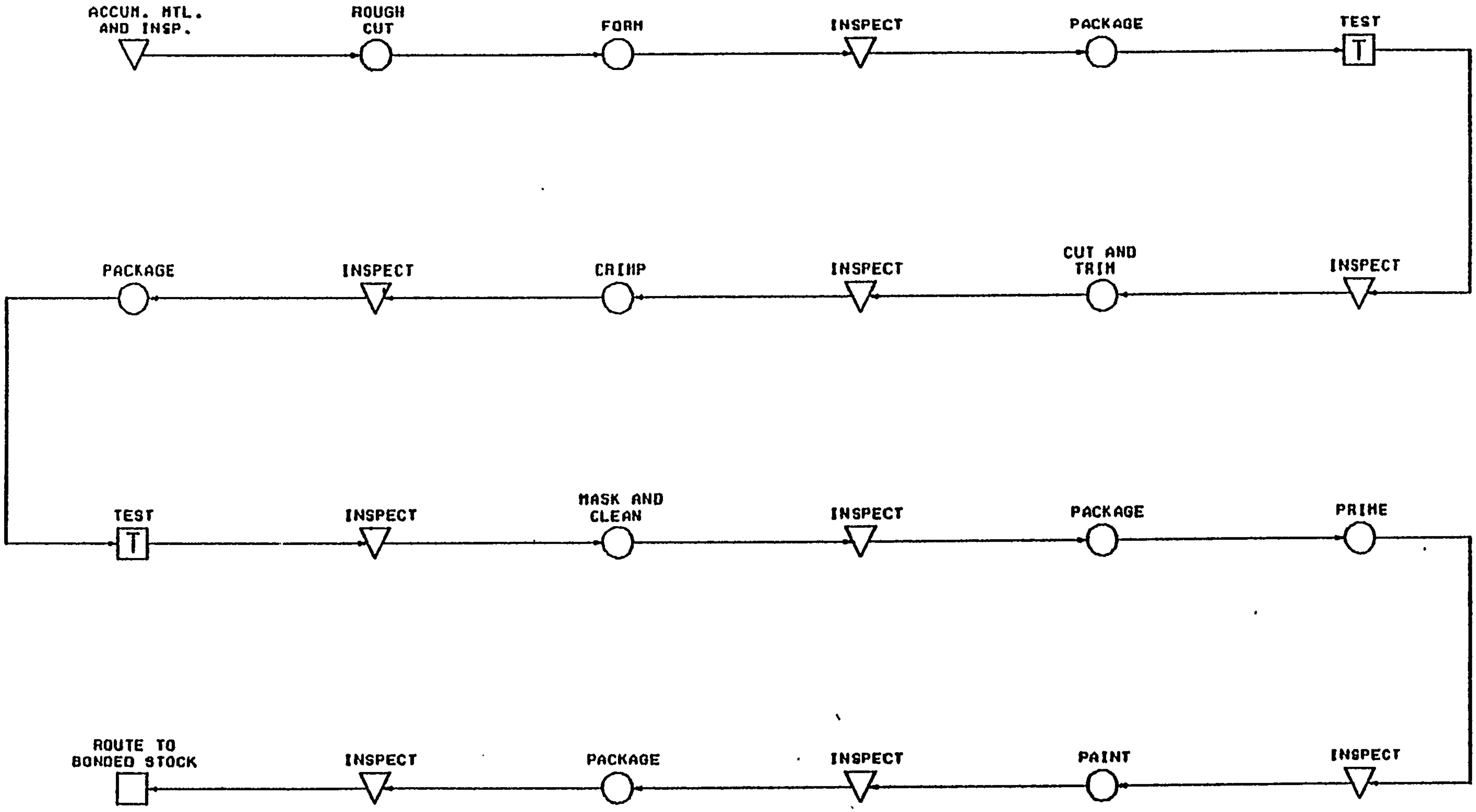
COMPUTER AIDED MANUFACTURING ANALYSIS

° BENEFITS WITH CAMA

- OPERATOR INSTRUCTIONS DRIVEN BY ENGINEERED METHODS AND STANDARDS
- COMPLETE STANDARDIZATION OF PROCESS SEQUENCE AND OPERATION TEST
- 40 - 50% IMPROVEMENT IN PLANNING EFFECTIVENESS
  - ° NEW PLANNING DEVELOPMENT
  - ° MAINTENANCE OF EXISTING PLANNING
  - ° VARIANT PLANNING DRIVEN FROM SAME BASE
    - ° PROTOTYPE
    - ° DEVELOPMENT
    - ° PRODUCTION
- 10 - 30% PRODUCTIVITY IMPROVEMENT
  - o EMPHASIS ON STANDARD OPERATOR INSTRUCTIONS WITH OPERATORS FOLLOWING CONSISTENT METHODS.

2288A

TYPICAL COAX CABLE FLOW



GE-TSD SPACE DIVISION

MANUFACTURING PROCESS PLANNING

OPER. NO.	METHOD DESCRIPTION	Q.C. CODE	TOOL	REF. DOC.	OPER. STAMP	HOURS SETUP	HOURS RUN EA.	WORK STAT.
10	ACCUMULATE MATERIAL AND ROUGH CUT TO LENGTH -- VERIFY REVISION STATUS OF PAPERWORK ACCUMULATE COAX CABLE MATERIAL ROUGH CUT COAX TO LENGTH note: rough cut length = 25 inches STAMP AND DATE PLANNING FILL OUT PRE-PUNCHED LABOR VOUCHER					0.04	0.02	731
20	FORM COAX CABLE --------------- FORM SEMI-RIGID COAX CABLE note: form coax per sample 47J191345P1-EXAMPLE STAMP AND DATE PLANNING FILL OUT PRE-PUNCHED LABOR VOUCHER					0.06	0.18	731
23	INSPECT COAX FOR CLEANLINESS, SHAPE AND I.D. -- 1. Shape and size of cable is like sample group number. 2. Physical damage and cleanliness. 3. Identification sleeving installed properly, is legible and correct.	I				0.03	0.09	Q7

DWG. NO.	NAME	PLANNER
COAX-PLAN-1	COAX ASSEMBLY EXAMPLE	M_ROURKE

SHEET 1 OF 2

GE-TSD SPACE DIVISION

MANUFACTURING PROCESS PLANNING

OPER. NO.	METHOD DESCRIPTION	Q.C. CODE	TOOL	REF. DOC.	OPER. STAMP	HOURS SETUP	HOURS RUN EA.	WORK STAT.

TOTALS BY WORK STATION (Hours, Each)

Work Station	Setup Time	Run Time	Cycle Time	Total Time
731	0.10	0.20	0.00	0.30
Q7	0.03	0.09	0.00	0.12
TOTALS ›››	0.13	0.29	0.00	0.42

DWG. NO.	NAME	PLANNER	
COAX-PLAN-1	COAX ASSEMBLY EXAMPLE	M_ROURKE	SHEET 2 OF 2

IN-PROCESS TRAVELLER

DWG NO. 47D259930G1-P	SER/JOB NOS		NAME PWB ASSY
N.H.A. 47E259900G1	12345	123456E	AN 8 / PLNG. REV 1

IN-PROCESS ALTERATION CONTROL

JOB QTY 1 | S/L

AN	PLNG REV	REMARKS	MFG	QC

"THIS SHEET MUST BE USED IN CONJUNCTION WITH THE D.P.S. PACKAGE & ALL REFERENCED MSI'S, METHOD SHEETS AND ENGINEERING SPECS."

MATERIAL LOG

	S/U	HRS EA	CYCLE
MFG	2.74	12.12	11.35
Q C	0.98	2.02	0.00

DWG NO.	NAME	LOT/SERIAL NO.	DWG NO.	NAME	LOT/SERIAL NO.

OPER NO.	WORK STA.	OPERATION INSTRUCTION	REFERENCE DOCUMENTS	NR	STAMP DATE	STAMP MFG/Q C	PLND.TIME S/U HRS	PLND.TIME HRS EA.	CYCLE/ CURE HRS.
01	Q7	INSPECT ACCUM.	MSI249770				0.08	0.17	0.00
10	771	VACUUM BAKE PWB, TIN & FORM COMPONENT LEADS	MSI238658				0.15	1.50	2.00
20	771	INSTALL P1 CONN., SOLDER, CLEAN, SECURE WITH HDWE.,TORQ	MSI238658				0.14	0.67	0.00
39	Q7	INSPECT IN PROCESS	MSI249770 MS P6				0.08	0.17	0.00
30	771	BOND SHIELDING PLATES TO BOTTOM OF IC'S.	MSI239945 MS P6				0.12	0.05	2.00
40	771	BOND INSULATORS AND IC'S TO PWB.	MSI236945 MS P6 MSI238658				0.56	0.69	2.00
50	771	TRIM, SOLDER, CLEAN IC LEADS	MSI238658				0.49	6.34	0.00

MFG PLNG/ DATE	Q C E/ DATE	FINAL ACCEPT STAMP/DATE	SHEET 1 OF

DWG NO. 47D259930G1-P	SER/JOB NOS 12345 / 123456E	NAME PWB ASSY

IH035

IN-PROCESS TRAVELLER (CONTINUATION SHEET)

OPER NO.	WORK STA.	OPERATION INSTRUCTION	REFERENCE DOCUMENTS	NR	STAMP DATE	STAMP MFG/Q C	PLND.TIME S/U HRS	PLND.TIME HRS EA.	CYCLE/ CURE HRS.
60	771	INSTL: Q'S, CAPS, R'S, TRIM LEADS, CLEAN	MSI238658				0.43	2.35	0.00
70	771	MARK & ID ASSY., MARK KEYING ON PWB EDGE	S32534CL7A MSI249770				0.15	0.14	0.50
73	Q7	INSPECT	S30146 MS P6 MSI238658 MSI249770				0.08	0.17	0.00
75	TC	TEST					0.50	1.00	0.00
83	Q7	INSPECT	MSI249770				0.08	0.17	0.00
99	Q7	INSPECT IN PROCESS	171A4425 MS P17				0.08	0.17	0.00
90	741	BOND DAMPERS	171A4425 MS P17				0.17	0.13	2.00
100	741	BOND SHIELDING PLATES, STAKE COMPONENTS, SEAL P1 CONN.	MSI236945 MS P8				0.21	0.11	2.00
110	741	MASK, CONF. COAT, UNMASK, CLEAN, ESD PACKAGE PWB.	MSI236935 MS P7 MSI249770				0.32	0.14	0.85
117	Q7	INSPECT FINAL	171A4627,MSP6, P7,P8,P17,MSI2 36935,S30146, MSI249770				0.08	0.17	0.00

NOTE - APPLY FINAL ACCEPT STAMP ON 1ST SHEET

SHEET 2 OF

GE-TSD SPACE DIVISION

PRIME PLANNING COVER SHEET

JOB NO.	DRAWING DESCRIPTION	TRAVEL TAG	WIRING DIAGRAM NO.	REV	AN
123456E	PWB ASSY	Y	N/A	1	8

REWORK CD	SEQ NO	DRAWING NUMBER	AN	MATRIX NO	VEHICLE	JOB QTY	PLC	SERIAL NO.
		47D259930G1-P	8	12345	1234	1	AD	12345

PROGRAM:	DATE REQD	PC CD	MFG SHOP ORDER NUMBER	INSP SHOP ORDER NUMBER	TEST SHOP ORDER NUMBER	S/S NUMBER
DSCS-III			123456789012	123456789012	123456789012	12345

PLANNER	EXT.	ORG. RELEASE	MFG WS	PLN HRS	INSP WS	PLN HRS	TEST WS	PLN HRS	
M. ROURKE	1234	21-NOV-85	771	13.78	Q7	1.50	TC	1.50	CYCLE/CURE HRS 11.35
QUALITY CONTROL	**EXT.**	**ORG. RELEASE**							
D. SPERRING	4321	21-NOV-85	741	1.08					TOTAL HRS/JOB 29.21
PRODUCTION CONTROL	**EXT.**	**SHOP RELEASE**							
S. DRUID	6543	19-DEC-85							

HANDLING REQUIREMENTS
STANDARD
ESD*
WHITE GLOVES REQUIRED

VERIFY PLANNING RELEASE
DATE LESS THAN 3 WEEKS ________

NON – CONFORMANCE REPORT INFORMATION

IN-PROCESS INSPECTION		TEST		FINAL MECH.		FINAL ACCEPTANCE STAMP DATE

REASON FOR REWORK IF APPLICABLE (NOTE: ENTER "RWK CODE" ABOVE – LEFT OF DWG NO.)	NR NO./OTHER

SHEET 1 OF 1

*NOTE: IF ELECTRO STATIC DISCHARGE SENSITIVE DEVICE, HANDLE THIS ASSEMBLY PER MSI 249770/251160

GE-TSD SPACE SYSTEMS DIVISION

ALTERATION CONTROL SHEET

ALTERATION CONTROLS

AN NO.	PLN. REV.	AFFECTED VEH OR S/N	AFFECTED PT. OR GR.	AFFECTED OPERATION	REMARKS	IE INIT.	MFG DATE	MFG INIT	QC DATE	QC INIT
6		B8 & SUBS	G1	ALL	P/L & DWG CHGE., REWRITE: OI, ESD ADDED.	MGR	10-SEP-85	MGR	10-SEP-85	SEC
7		B9 & SUBS	G2	30, BOM	AN-7 ADDS F/N 7 TO BOM.	MGR	10-SEP-85	MGR	10-SEP-85	SEC
8	1	B9 & SUBS	G2	20, 30	INCORP. AN-8 & MCR 85-92 TO UPDATE TORQUE CALLOUT NOTE 11	MGR	06-SEP-85	HEJ	03-SEP-85	SEC

DWG. NO. 47D259930G1-P
PHANTOM ASSY.

NAME PWR ASSY

NO. REV. VEH OR S/N PT. OR GR. OPERATION

PLANNER M. ROURKE

SHEET 1 OF 1

GE-TSD SPACE DIVISION

MANUFACTURING PROCESS PLANNING

OPER. NO.	METHOD DESCRIPTION	Q.C. CODE	TOOL	REF. DOC.	OPER. STAMP	HOURS SETUP	HOURS RUN EA.	WORK STAT.
01	INSPECT ACCUM.	I				0.08	0.17	Q7
10	VACUUM BAKE PWB, TIN & FORM COMPONENT LEADS	OI				0.15	1.50	771
20	INSTALL P1 CONN., SOLDER, CLEAN, SECURE WITH HDWE.,TORQ.	OI				0.14	0.67	771
39	INSPECT IN PROCESS	IP				0.08	0.17	Q7
30	BOND SHIELDING PLATES TO BOTTOM OF IC'S.	IP				0.12	0.05	771
40	BOND INSULATORS AND IC'S TO PWB.	OI				0.56	0.69	771
50	TRIM, SOLDER, CLEAN IC LEADS					0.49	6.34	771
60	INSTL: Q'S, CAPS, R'S, TRIM LEADS, CLEAN					0.43	2.35	771
70	MARK & ID ASSY., MARK KEYING ON PWB EDGE					0.15	0.14	771
73	INSPECT	I				0.08	0.17	Q7
75	TEST	T				0.50	1.00	TC
83	INSPECT	I				0.08	0.17	Q7
99	INSPECT IN PROCESS	IP				0.08	0.17	Q7
90	BOND DAMPERS	IP				0.17	0.13	741
100	BOND SHIELDING PLATES, STAKE COMPONENTS, SEAL P1 CONN.	OI				0.21	0.11	741
110	MASK, CONF. COAT, UNMASK, CLEAN, ESD PACKAGE PWB.					0.32	0.14	741
117	INSPECT FINAL	I				0.08	0.17	Q7

DWG. NO.	NAME	PLANNER	
47D259930G1-P	PWB ASSY	M_ROURKE	SHEET 1 OF 2

GE-TSD SPACE DIVISION

MANUFACTURING PROCESS PLANNING

OPER. NO.	METHOD DESCRIPTION	Q.C. CODE	TOOL	REF. DOC.	OPER. STAMP	HOURS SETUP	HOURS RUN EA.	WORK STAT.

TOTALS BY WORK STATION (Hours, Each)

Work Station	Setup Time	Run Time	Cycle Time	Total Time
Q7	0.50	1.00	0.00	1.50
771	2.04	11.74	6.50	20.28
741	0.70	0.38	4.85	5.93
TC	0.50	1.00	0.00	1.50
TOTALS ›››	3.74	14.12	11.35	29.21

DWG. NO.	NAME	PLANNER	
47D259930G1-P	PWB ASSY	M_ROURKE	SHEET 2 OF 2

GE-TSD SPACE DIVISION

PRIME PLANNING COVER SHEET

JOB NO.	DRAWING DESCRIPTION	TRAVEL TAG	WIRING DIAGRAM NO.	REV	AN
123456E	PWB ASSY	Y	N/A	D	8

REWORK CD	SEQ NO	DRAWING NUMBER	AN	MATRIX NO	VEHICLE	JOB QTY	PLC	SERIAL NO.
		47D259930G1	8	12345	1234	1	AB	12345

PROGRAM:	DATE REQD	PC CD	MFG SHOP ORDER NUMBER	INSP SHOP ORDER NUMBER	TEST SHOP ORDER NUMBER	S/S NUMBER
DSCS-III			123456789012	123456789012	123456789012	12345

		EXT.	
PLANNER	MG ROURKE	2231	ORG. RELEASE 09-SEP-85
QUALITY CONTROL	D SPERRING	5210	ORG. RELEASE 10-SEP-85
PRODUCTION CONTROL	ALAN TONESEN	9032	SHOP RELEASE 11-SEP-85

MFG WS	PLN HRS	INSP WS	PLN HRS	TEST WS	PLN HRS
771	13.78	Q7	1.50	TC	1.50
741	1.08				

CYCLE/CURE HRS	TOTAL HRS/JOB
11.35	29.21

HANDLING REQUIREMENTS

- STANDARD
- ESD*
- WHITE GLOVES REQUIRED

VERIFY PLANNING RELEASE DATE LESS THAN 3 WEEKS ________

NON – CONFORMANCE REPORT INFORMATION

IN-PROCESS INSPECTION		TEST		FINAL MECH.		FINAL ACCEPTANCE STAMP DATE

REASON FOR REWORK IF APPLICABLE (NOTE: ENTER "RWK CODE" ABOVE – LEFT OF DWG NO.)	NR NO./OTHER

SHEET 1 OF 1

*NOTE: IF ELECTRO STATIC DISCHARGE SENSITIVE DEVICE, HANDLE THIS ASSEMBLY PER MSI 249770/251160

GE-TSD SPACE SYSTEMS DIVISION

ALTERATION CONTROL SHEET

ALTERATION CONTROLS

AN NO.	PLN. REV.	AFFECTED VEH OR S/N	AFFECTED PT. OR GR.	AFFECTED OPERATION	REMARKS	IE INIT	MFG DATE	MFG INIT	QC DATE	QC INIT
6		B8 & SUBS	G1	ALL	P/L & DWG CHGE., REWRITE: OI, ESD ADDED.	MGR	10-SEP-85	MGR	10-SEP-85	SEC
7		B9 & SUBS	G2	30, BOM	AN-7 ADDS F/N 7 TO BOM.	MGR	10-SEP-85	MGR	10-SEP-85	SEC
8	1	B9 & SUBS	G2	20, 30	INCORP. AN-8 & MCR 85-92 TO UPDATE TORQUE CALLOUT NOTE 11	MGR	06-SEP-85	HEJ	03-SEP-85	SEC

DWG. NO. 47D259930G1
PHANTOM ASSY.

NAME PWR. ASSY

NO. REV. VEH OR S/N PT. OR GR. OPERATION

PLANNER ROURKE

SHEET 1 OF 1

GE-TSD SPACE DIVISION

MANUFACTURING BILL OF MATERIALS

TITLE	DWG. REV.	DWG. A.N.	PLANNING REV STATUS	B.O.M.
PWB ASSEMBLY	D	8	1	47D259930G1

OP. NO	REF.DES. /ITEM NO	SEQ	IDENTIFICATION NUMBER	NOMENCLATURE	QUANTITY	REV.	A.N.	UM	JOB/LOT NUMBER	SERIAL NUMBER	WEIGHT	INSP. STAMP
10	1	00	47D264988G1	PWB D&T HARD COUNTER	1.000			EA				
10	R2	00	47E263882P1	RESISTOR	1.000			EA				
10	R3	00	47B263678P1	RESISTOR	1.000			EA				
10	R4	00	47B262746P2	RESISTOR	1.000			EA				
10	R5	00	47B263676P1	RESISTOR	1.000			EA				
10	R6	00	47B263676P2	RESISTOR	2.000			EA				
10	C1	00	47B262745P1	CAPACITOR	1.000			EA				
10	C2	00	47B262739P1	CAPACITOR	1.000			EA				
10	Q1	00	47B242328P2	TRANSISTOR	1.000			EA				
20	P1	00	47B263677P1	CONNECTOR,PWB 110PIN	1.000			EA				
20	11	00	47B263681P1	SCR 2-56 X 5/16	1.000			EA				
20	12	00	47B242303P1	NUT HEX SELF LOCKING	1.000			EA				
30	7	00	47D259930P22	SHIELD	4.000			EA				
30	22	00	171A4629TY4	COMPOUND	0.000			PT				

MODEL MO EFFECTIVITY		TITLE	B.O.M. #
MODEL MO EFFECTIVITY	FROM 000009 THRU 000015	PWB ASSEMBLY	47D259930G1

SHEET 1 OF 1

GE-TSD SPACE DIVISION

MANUFACTURING PROCESS PLANNING

OPER. NO.	METHOD DESCRIPTION	Q.C. CODE	TOOL	REF. DOC.	OPER. STAMP	HOURS SETUP	HOURS RUN EA.	WORK STAT.
01	INSPECT ACCUM. --------------- INSPECT: 1. VERIFY PREVIOUS Q.C. ACCEPTANCE & PARTS PER BILL OF MATERIAL. 2. RECORD JOB/LOT NO. & AN AS REQ'D. ON BILL OF MATERIAL. 3. ESD PACKAGING/DAMAGE. ** NOTE : SUPERVISOR TO NOTIFY COGNIZANT PLANNER IF M/S "A" IS INCOMPLETE.	I	MSI249770 #4030 (3M)			0.08	0.17	Q7
10	VACUUM BAKE PWB, TIN & FORM COMPONENT LEADS --------------- INSTALL STANDOFFS TO (4) PWB CORNERS & CLEAN PWB. VACUUM BAKE PWB FOR 2 HRS. @ 145 +/- 5 DEG. F. AND 28.5 IN. Hg. MIN. TIN COMPONENT LEADS. FORM COMPONENT LEADS PER PLNG. FORMING TOOL MATRIX.	OI	TDL1258 MSI238658 TDL1804 SOLDER POT M/S "A"			0.15	1.50	771
20	INSTALL P1 CONN., SOLDER, CLEAN, SECURE WITH HDWE.,TORQ. --------------- INSTALL P1 CONNECTOR TO PWB WITH ALIGNMENT PINS. SOLDER PER DWG. NOTE 10 & VIEW "A". CLEAN CONNECTIONS. REMOVE ALIGNMENT PINS & SECURE P1 WITH (ITEMS 9 & 10) HDWE. & TORQUE 2-3 IN.-LBS. PER DWG. NOTE 11.	OI	TDL1447 MSI238658 CALIBRATED TORQUE DRIVER			0.14	0.67	771
39	INSPECT IN PROCESS --------------- 1) SHIELDING PLATES BONDED TO BOTTOMS OF U5 & U9	IP	DWG NOTE 16			0.08	0.17	Q7

DWG. NO.	NAME	PLANNER	
47D259930G1	PWB ASSY	M_ROURKE	SHEET 1 OF 6

GE-TSD SPACE DIVISION

MANUFACTURING PROCESS PLANNING

OPER. NO.	METHOD DESCRIPTION	Q.C. CODE	TOOL / REF. DOC. / OPER. STAMP	HOURS SETUP	HOURS RUN EA.	WORK STAT.
	(continued) 2)VERIFY CURE TIMES, TEMP. & MIX SHEET NO. RECORDED. 3) ESD HANDLING/ DAMAGE/ CLEANLINESS		MS P6 MSI 249770			
30	BOND SHIELDING PLATES TO BOTTOM OF IC'S. ------------------------------------ CLEAN PWB & PARTS TO BE BONDED & BOND (IT.22) SHIELDING PLATES TO BOTTOMS OF IC'S U5 & U9 USING (IT.7) CMPD. PER DWG. NOTE 16. NOTE: USE WEIGHT TO MAINTAIN POSITION & THIN BOND LINE RECORD MIX SHEET NO. ____________	IP	MSI 236945 MS P6 TDL 1631	0.12	0.05	771
40	BONDING: INSULATORS TO PWB, IC'S TO INSUL., IC'S TO PWB. ------------------------------------ 1) CLEAN & BOND (IT'S 6 & 8) INSULATORS TO PWB* (41)PLCS. USING (IT.7) COMPOUND PER DWG. NOTES 9 & 16. 2) CLEAN AND BOND IC'S TO INSULATORS OR PWB* (41) PLCS. & CLEAN AND BOND IC'S TO PWB (5) PLCS USING (IT.7) CMPD. INSERT LEADS OF AXIAL MOUNTED IC'S INTO PWB (15) PLCS. & TRIM LEADS OF PLANAR MOUNTED IC'S & POSITION ON BOARD (31) PLCS. NOTES: 1)* USE INSULATORS IF IC'S HAVE METAL BASE 2) CENTER EACH INSULATOR AT RESPECTIVE I.C. POSITION 3) OBSERVE PIN #1 ORIENTATION 4) TACK SOLDER LEADS OF PLANAR MOUNTED IC'S (4) CORNERS TO MAINTAIN POSITION	OI	MSI 236945 MS P6 DWG NOTES 9,16, & 18 DWG NOTE 17 MSI 238658 DWG. NOTE 18	0.56	0.69	771
50	TRIM, SOLDER, CLEAN IC LEADS ------------------------------------ ADJUST IC LEADS & TRIM PROTRUSIONS .060 MAX SOLDER IC LEADS & CLEAN CONNECTIONS		DZM 0584 OR EQUIVALENT MSI 238658	0.49	6.34	771

DWG. NO.	NAME	PLANNER
47D259930G1	PWB ASSY	M_ROURKE

GE-TSD SPACE DIVISION

MANUFACTURING PROCESS PLANNING

OPER. NO.	METHOD DESCRIPTION	Q.C. CODE	TOOL / REF. DOC. / OPER. STAMP	HOURS SETUP	HOURS RUN EA.	WORK STAT.
60	INSTL: TRANSISTORS, CAPS, RESISTORS, TRIM LEADS, CLEAN. NOTE: TACK SOLDER INSTALL REMAINING COMPONENTS TO PWB PER THE FOLLOWING SUGGESTED SEQUENCE: 1) Q1, Q2 & C1 THRU C9 SPACING DIMENSION PER DWG NOTE 13 2) RESISTORS (34) PLCS TRIM COMPONENT LEAD PROTRUSIONS .060 MAX SOLDER COMPONENT LEADS (COMPLETE) TO PWB SOLDER FILL ALL UNUSED PWB PLATED THRU HOLES THOROUGHLY CLEAN SOLDER CONN'S & PWB ASSY.		MSI 238658 M/S "B" DZM 0584 OR EQUIVALENT	0.43	2.35	771
70	MARK & ID ASSY., MARK KEYING ON PWB EDGE MARK KEYING ON PWB EDGE PER DWG. DIMENSIONS & DWG. NOTE 12 REF. F/D ZONE 1-G-5 MARK ID ASSY PER DWG. NOTE 2 & F/D ZONE 2-F-5 INCLUDING JOB NO. & LATEST APPLICABLE AN ESD PACKAGE & ROUTE TO INSP.		S32534CL7A MSI 249770 #4030(3M)	0.15	0.14	771
73	INSPECT 1)ORIENTATION OF PARTS / P1 CONN. HDWRE. SECURE 2) SPACING DIMENSION PER DWG. NOTE 13 3).244 MAX. HEIGHT DIMENSION PER F/D ZONE 1-G-11 4).060 MAX. COMPONENT LEAD PROTRUSION 5)KEYING MARKING PER DWG. DIM'S. & DWG. NOTE 12 6)BONDING OF IC'S & INSULATORS TO PWB PER DWG. NOTES 9,16,17,18 7)VERIFY CURE TIMES & TEMP & MIX SHT NO. RECORDED @ OP 40 8)ID PER DWG NOTE 2 INCLD'G JOB NO & LATEST APPLICABLE AN 9)SOLDER PER DWG. NOTE 5 10)ESD PACKAGING/ DAMAGE/ CLEANLINESS	I	S30146 S32534CL7A 171A4627TY2 MS P6 S32534CL7A MSI 238658 S30146 MSI249770 #4030 (3M)	0.08	0.17	Q7

DWG. NO.	NAME	PLANNER	
47D259930G1	PWB ASSY	M_ROURKE	SHEET 3 OF 6

GE-TSD SPACE DIVISION

MANUFACTURING PROCESS PLANNING

OPER. NO.	METHOD DESCRIPTION	Q.C. CODE	TOOL / REF. DOC.	OPER. STAMP	HOURS SETUP	HOURS RUN EA.	WORK STAT.
	(continued) 11)AIR FORCE MANDATORY (SOLDER)						
75	TEST	T			0.50	1.00	TC
83	INSPECT -------- 1)VERIFY TEST ACCEPTANCE 2)ESD PACKAGING/ DAMAGE/ CLEANLINESS	I	MSI 249770		0.08	0.17	Q7
99	INSPECT IN PROCESS ------------------ 1)FAYING SURFACES OF P1 & (IT.19) DAMPERS ABRADED 2)BONDING OF (IT'S 18&19) DAMPERS PER DWG DIM'S & NOTE 14 & DAMPERS NOT EXTENDED BEYOND STEP IN CONN. (F/D ZONE 1-B-10) 3)VERIFY CURE TIMES, TEMP. & MIX SHT NO. RECORDED	IP	171A4425 MS P17		0.08	0.17	Q7
90	BOND DAMPERS ------------ LIGHTLY ABRADE FAYING SURFACES ONLY OF P1 & (IT.19)DAMPERS CLEAN PWB & (IT.'S 18 & 19) DAMPERS & BOND DAMPERS TO PWB & P1 CONN USING (IT.20) ADH PER DWG DIM'S. & NOTE 14.	IP	#180 GRIT AL/OX PAPER 171A4425 MS P17 TDL 1631		0.17	0.13	741
100	BOND SHIELDING PLATES, STAKE COMPONENTS, SEAL P1 CONN. -- CLEAN & BOND (IT.22) SHIELDING PLATES TO TOP OF U5 & U9 USING (IT.13) CMPD. PER DWG. NOTE 16. STAKE RADIAL LEAD COMPONENTS Q1,Q2, & C1 THRU C9 USING (IT.13) CMPD PER DWG. NOTE 15. SEAL P1 CONNECTOR (BOTH SIDES) TO PWB (TO ASSURE THAT CONFORMAL COATING DOES NOT RUN THRU CONN. SHELL TO MATING AREA) USING (IT.13) CMPD.	OI	MSI 236945 MS P8 M/S "B"		0.21	0.11	741

DWG. NO.	NAME	PLANNER	
47D259930G1	PWB ASSY	M_ROURKE	SHEET 4 OF 6

GE-TSD SPACE DIVISION

MANUFACTURING PROCESS PLANNING

OPER. NO.	METHOD DESCRIPTION	Q.C. CODE	TOOL / REF. DOC.	OPER. STAMP	HOURS SETUP	HOURS RUN EA.	WORK STAT.
110	MASK, CONF. COAT, UNMASK, CLEAN, ESD PACKAGE PWB.				0.32	0.14	741
	MASK P1 CONNECTOR MATING AREA & BD. EDGES TO BE FREE OF COATING PER DWG DIMS. & DWG. NOTE 7		MSI 236935				
	CONFORMAL COAT PWB ASSY & DAMPERS (BOTH SIDES PWB) USING (IT.12) COMPOUND PER DWG. NOTE 6		MS P7				
	REMOVE STANDOFFS & MASKING, CLEAN ASSY & ESD PACKAGE		MSI 249770 #4030 (3M)				
117	INSPECT	I			0.08	0.17	Q7
	1) SHIELDS BONDED TO U5 & U9 PER DWG. NOTE 16 2) RADIAL LEAD COMPONENTS STAKED PER DWG NOTE 15		171A4627 MSI 236935 S30146				
	3) CONFORMAL COATING PER DWG. NOTE 6 4) P1 CONN. MATING AREA & AREAS FREE OF COATING PER DWG. & NOTE 7.						
	5) VERIFY CURE TIMES, TEMP. & MIX SHT. NO.'S RECORDED		MS P7 & MS P8				
	6) ASSY BUILT & IDENT. TO LATEST APPLICAABLE AN						
	7) ESD PACKAGING/ DAMAGE/ CLEANLINESS		MSI 249770				
	8) AIR FORCE MANDATORY (FINAL)						
	ROUTE TO STOCK						

DWG. NO.	NAME	PLANNER	
47D259930G1	PWB ASSY	M_ROURKE	SHEET 5 OF 6

GE-TSD SPACE DIVISION

MANUFACTURING PROCESS PLANNING

OPER. NO.	METHOD DESCRIPTION	Q.C. CODE	TOOL	REF. DOC.	OPER. STAMP	HOURS SETUP	HOURS RUN EA.	WORK STAT.

TOTALS BY WORK STATION (Hours, Each)

Work Station	Setup Time	Run Time	Cycle Time	Total Time
Q7	0.50	1.00	0.00	1.50
771	2.04	11.74	6.50	20.28
741	0.70	0.38	4.85	5.93
TC	0.50	1.00	0.00	1.50
TOTALS ›››	3.74	14.12	11.35	29.21

DWG. NO.	NAME	PLANNER	
47D259930G1	PWB ASSY	M_ROURKE	SHEET 6 OF 6