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This document describes an approach for achieving computer integrated manufacturing in the 1995 aerospace enterprise using the concepts developed in the SRD and SS. The aerospace enterprise (factory) is described as a total system and broken down (using System Engineering Methodology) into its component parts; goals are reviewed; operating environment is discussed; its principles of operation are defined; and its functions are described. Detailed discussions of the major factory components are presented in Sections 4.0 and 5.0. These components are discussed from the physical view (people, production

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) tools and equipment, facilities, and computer communications networks) in Section 4.0 and the logical view (common database and the logical processes used to manipulate data/information) in Section 5.0. Section 6.0 describes a conceptual framework for an integrated aerospace enterprise in 1995. This framework is based upon concepts previously developed and as such represents a hypothetical view. The point is made that a different description is possible if the actual realities of a specific enterprise are use as opposed to the generic concepts used by the coalition.

MMR110512000

ICAM Conceptual Design for Computer-Integrated Manufacturing

CONCEPTUAL FRAMEWORK DOCUMENT

Task "B"
Establishment of the Factory of the Future Conceptual Framework

February 1984

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Prepared for:

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AIR-FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
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Richard R. Preston — July 25, 1984

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FOREWORD

This Conceptual Framework Document, was developed under Air Force Contract #F33615-81-C-5119, Project Priority 1105, entitled "ICAM Conceptual Design for Computer Integrated Manufacturing." This contract was sponsored by the Computer Integrated Manufacturing Branch, Manufacturing Technology Division, Materials Laboratory, Air Force Wright Aeronautical Laboratories, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, 45433. This project was administered under the technical direction of Captain Richard R. Preston.

This document, Volume II, Part 6, of the Final Technical Report, contains the Factory of the Future Conceptual Framework.

The results of this project have been achieved by a coalition of companies organized and managed under the leadership of the prime contractor, Vought Corporation, with Mr. Don L. Norwood providing primary overall contract leadership and management responsibility (TASK A). Other Task leaders were:

1. Mr. Robert L. Moraski, Vought Corporation, responsible for leadership and management of the Factory of the Future Conceptual Framework Thrust (TASK B).

2. Mr. Frank E. Sullivan, Northrop Corporation, responsible for leadership and management of the Integrated Composites Center Conceptual and Preliminary Designs (TASK C and TASK E).

3. Mr. Robert H. Wettach, General Electric Company, responsible for leadership and management of the Quality Assurance Modeling and Analysis Thrust (TASK D).

The other major participating companies of the coalition were:

- D. Appleton Company, Inc. (DACOM)
- General Dynamics/Fort Worth
- Hughes Aircraft Company
- Illinois Institute of Technology Research Institute
- SofTech, Inc.

In addition to the major coalition participants, the following companies served as reviewing participants:

- Battelle Columbus Laboratories
- Boeing Aerospace Company
- Boeing Commercial Airplane Co.
- Boeing Military Airplane Co.
- Cincinnati Milacron Incorporated
- GE Aircraft Engine Business Group
- Grumman Aerospace Corporation
- Lear Siegler, Inc. Astronics Division
- Lockheed Georgia Company
- Lockheed Missiles & Space Company
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- Rockwell International Corporation
- Sikorsky Aircraft

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CONCEPTUAL FRAMEWORK DOCUMENT - FACTORY OF THE FUTURE

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SECTION 1.0

INTRODUCTION

1.1 BACKGROUND

This project is part of the U.S. Air Force's Integrated Computer-Aided Manufacturing (ICAM) program. ICAM is a program that addresses the needs and requirements related to state-of-the-art technologies, economies, design and manufacturing complexity as correlated with aerospace industry trends. The specific task for the coalition team was to postulate concepts for the computer integrated aerospace factory in 1995 - the conceptual framework.

Although the ICAM Life Cycle is a total systems approach, our coalition task addressed only the first phase (Understand the Problem) of this four-phased approach to modernizing manufacturing. See Figure 1-1. Results of this work are described in detail in the following ICAM Life Cycle Documents:

	ICAM LIFE CYCLE							
	NEEDS ANALYSIS	REQUIREMENTS DEFINITION	PRELIMINARY DESIGN	DETAIL DESIGN	CONSTRUCTION & VERIFICATION TEST	INTEGRATION VALIDATION & TEST	IMPLEMENT AND USE	MAINTAIN AND SUPPORT
TASK B DELIVERABLE	UNDERSTAND PROBLEM		FORMULATE AND JUSTIFY SOLUTION		BUILD AND INTEGRATE SOLUTION		IMPLEMENT AND MAINTAIN SOLUTION	
SCOPING DOCUMENT (SD)	X							
NEEDS ANALYSIS DOCUMENT (SAD)	X							
STATE-OF-THE-ART DOCUMENT (SAD)		X						
SYSTEMS REQUIREMENTS DOCUMENT (SRD)		X						
SYSTEM SPECIFICATION (SS)		X						
CONCEPTUAL FRAMEWORK DOCUMENT		X						

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NOTE: THIS FIGURE SHOWS THE RELATIONSHIP OF THE TASK "B" ESTABLISH FACTORY OF THE FUTURE CONCEPTUAL FRAMEWORK DELIVERABLES TO THE ICAM LIFE CYCLE. THIS MATRIX IS OFFERED TO CLARIFY PRECISELY WHAT TASK "B" WILL AND WILL NOT PROVIDE. SPECIFICALLY, THERE WILL BE ONLY A CONCEPTUAL DESIGN (THE FRAMEWORK) FOR THE FACTORY OF THE FUTURE PRODUCED. ALL EFFORTS IN THIS TASK ARE AIMED AT A CONCEPTUAL FRAMEWORK, NOT A DETAIL DESIGN FOR THE THE FACTORY OF THE FUTURE.

Figure 1-1. FoF Conceptual Framework Effort Relationship to the ICAM Life Cycle.

- o <u>Scoping Document (SD 110512000)</u>
  - Defined the boundaries of the Factory of the Future (FoF) Conceptual Framework to include the total aerospace enterprise, not just the production floor.
  - Identified the six major generic functions for an aerospace enterprise.

- o <u>Needs Analysis Document (NAD110512000)</u>
  - Identified over 400 specific needs necessary to enhance aerospace enterprise operations.
  - Categorized the needs into seven need groupings for ease of understanding.
  - Discussed seven major considerations for implementing technology to achieve computer integrated operations in 1995.

- o <u>State-of-the-Art Document (SAD110512000)</u>
  - Identified state-of-the-art and emerging computer technology that should be applied to 1995 aerospace enterprises.
  - Presented a discussion on the application of computer integrated manufacturing at Ingersoll Milling Machine Company which is considered an industry leader in the field.

- o <u>System Requirements Document (SRD110512000)</u>
  - Addressed the transition from the "AS IS" aerospace environment to the "TO BE" environment envisioned in 1995.
  - Translated the deficiencies in aerospace enterprise operations identified in the NAD into "TO BE" conceptual requirements for 1995.

- o <u>System Specification (SS 110512000)</u>
  - Based upon conceptual improvements and requirements from the SRD, established performance requirements for the 1995 aerospace enterprise.
  - Provided a departure point from which to initiate selected conceptual system designs.

1.2 <u>CONCEPTUAL FRAMEWORK - FACTORY OF THE FUTURE OBJECTIVE</u>

This document represents a deviation from the Life Cycle documents prescribed by the ICAM Documentation Standards. That deviation was mandated by the scope of the work addressed, i.e., the aerospace Enterprise (not a specific aerospace application system) and this fact that the project only involved the first phase of the ICAM Life Cycle. This project stopped short of preliminary design.

In this document, the coalition describes an approach for achieving computer-integrated manufacturing in the 1995 aerospace enterprise using the concepts developed, in the "Understand the Problem" phase of the ICAM Life Cycle. The aerospace Enterprise (factory) is described as a total system in Section 3.0: its goals are reviewed, its operating environment is discussed, its principles of operation are defined, its functions are summarized (IDEFØ models) and its major components are identified.

The definition of the major factory components are discussed in detail in Sections 4.0 and 5.0 These components are described from a physical view (people, production tools and equipment, facilities, and computer communication networks) and from a logical view (the common data base and logical processes used to manipulate data/information).

The coalition chose to address the components of the factory as a system from a physical and logical view for the following reasons:

- To curb the tendency towards addressing the FoF in terms of specific applications (capabilities) e.g., MRP I and II, CAD/CAM, flexible machining, integrated sheet metal center, group technology, etc.

- To stress that the factory is more than an accumulation of physical resources used to produce product.

In short, the coalition wanted to shift the traditional thought process of equating factory with shop floor. The coalition wanted the factory to be thought of in terms of the total Enterprise of which the physical factory floor is but a small portion

Section 6.0 describes a 1995 integrated aerospace Enterprise based upon the concepts developed by the coalition. It must be stressed that this is a hypothetical view of an aerospace Enterprise. Different descriptions (of integrated aerospace operations in 1995) are possible as the actual realities of specific manufacturing enterprises are addressed as opposed to the generic concepts used by the coalition.

Of major importance in this document, apart from the description of a conceptual 1995 aerospace Enterprise, is the analysis and methodology that went into developing the conceptual framework. The coalition believes that the methodology developed will prove valuable in other efforts aimed at developing computer-integrated operations for manufacturing enterprises.

SECTION 2.0

EXECUTIVE SUMMARY

2.1 COALITION APPROACH

As stated in Section 1.0, the work of the coalition addressed the entire aerospace Enterprise and not a specific aerospace application system, e.g., scheduling, shop floor control, etc. Figure 2-1 shows a conceptual view of a 1995 aerospace Enterprise organized in four tiers: Executive Management; Business Development and Resource Management; Technology Development and Product Support; and the factory floor. The conceptual framework described in this document focuses primarily on the top three tiers. This approach was selected because the coalition believed that adequate emphasis was being placed on the factory floor by other projects being conducted by ICAM, CAM-I, etc.

After selecting this approach, it soon became apparent that manufacturing had to be viewed from a different perspective, that of the person responsible for the operation and profitability of the Enterprise (aerospace factory), i.e., the General Manager, Vice President of Operations, President, etc. The result of taking this perspective is shown in Figure 2-2. Of vital importance in this approach is the need for:

- o Improved translation of strategic business plans into tactical and operational plans for the Enterprise
- o Effective management of technological change
- o Integrated management of time and resources
- o Improved decision support.

2.2 OVERVIEW

Pursuing this perspective of manufacturing as a business Enterprise and not just as the production floor led to:

- o The description of an aerospace Enterprise as a total integrated system as described in Section 3.0
- o The development of a methodology to describe the conceptual framework

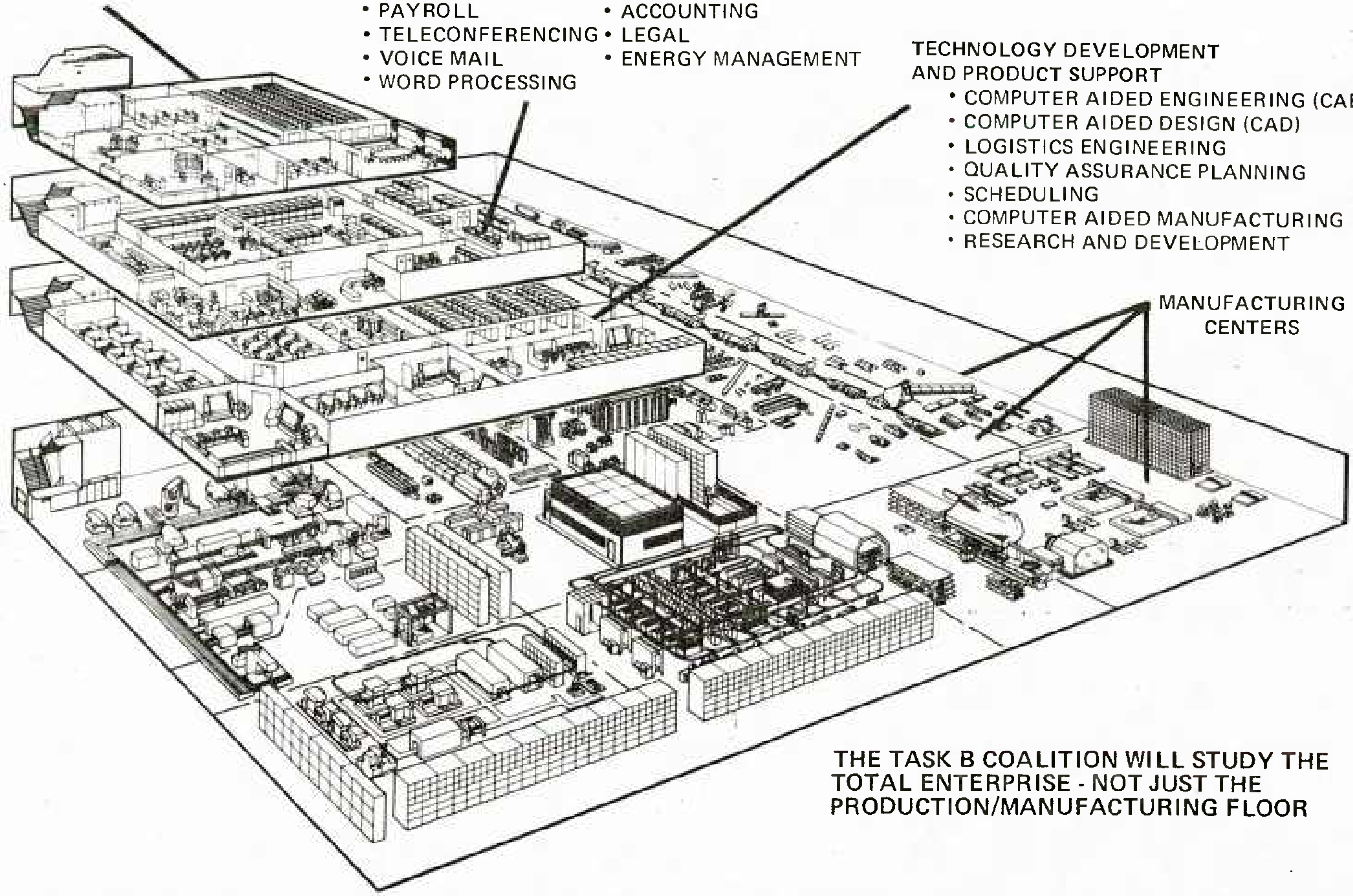

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Figure 2-1 1995 Aerospace Enterprise

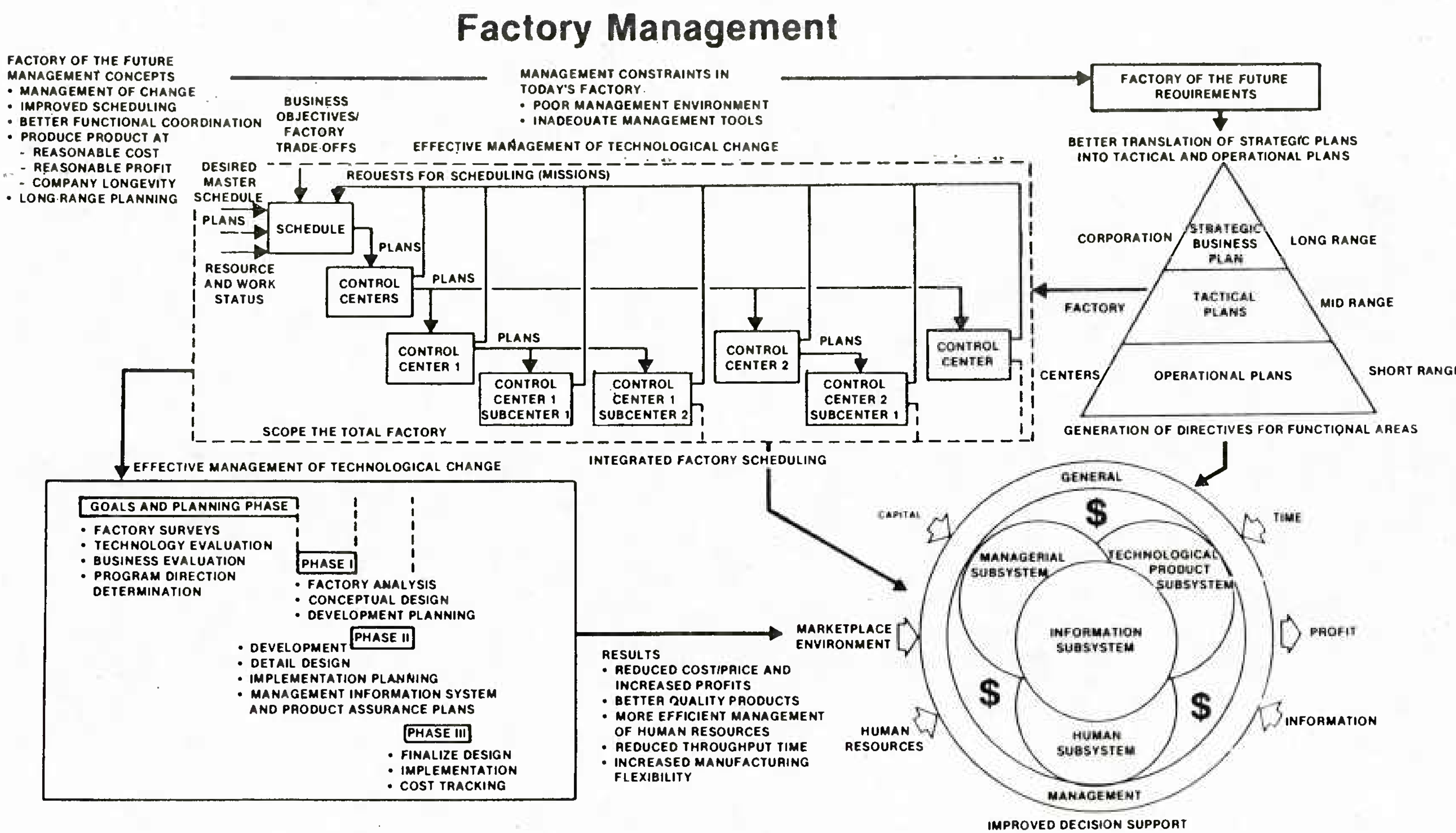

Figure 2-2 FoF Perspective

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- o The description of major factory components from a physical point of view and a logical point of view
  - Physical view (Section 4.0)
    - o people
    - o production tools and equipment
    - o facilities
    - o information processing and communication network
  - Logical View (Section 5.0)
    - o common data base
    - o logical processes

- o The presentation of a computer integrated aerospace Enterprise framework (Section 6.0).

2.2.1 Total Integrated System

The aerospace Enterprise is described as a sophisticated, complex, social-technical system that is dynamic and self-regenerative. It is an evolutionary, growing system that is never in a "static state." ("Static-state" is generally assumed whenever single factory applications are developed.)

In general, a system consists of one or more component parts that produces some form of desired output from a set of inputs. Thus, it is possible to take many views of the aerospace Enterprise as a system. From the owner's point of view, the Enterprise receives investments as input and produces a return on that investment as output. The customer views the Enterprise as receiving weapon system requirements as input and producing the weapon system and support services as output. Engineers see the role of the Enterprise as one of applying science and technology to the development of improved products or systems. The manufacturer's view is that of a system which receives raw materials and produces usable, finished goods. The view of the 1105 coalition is that of the General Manager who, in addition to all the above views, sees the Enterprise as a system to acquire and use resources.

Five goals for improving the aerospace Enterprise were identified. They are:

- o Reduce product cost
- o Improve product quality
- o Improve Human Resource Management
- o Reduce lead time
- o Improve manufacturing flexibility.

After establishing these goals, the coalition then examined the cyclic changes and strategic changes which are the essence of the FoF operating environment. Cyclic changes are those that expand or contract Enterprise activities but leave its nature intact. Examples of cyclic changes are:

- o Sales changes (up or down)
- o Labor force changes (adequate or inadequate)
- o Inventory (too much or too little), etc.

Strategic changes are those that transform the structure of the Enterprise, i.e., make it different. Examples of strategic changes are listed below and discussed in the text of this document.

- o Changes in products
- o Changes in markets
- o Changes in product/process technology
- o Changes in available resources.

External interfaces of the aerospace Enterprise are addressed and their use as an information source is discussed. Examples include:

- o The parent corporation or owners
- o Customers
- o Competitors
- o Government agencies
- o Suppliers
- o Society in general.

Operating concepts are examined and summarized in terms of what will be different in the 1995 aerospace Enterprise. Seven key points are made:

- o Strategic leveraging of computer-based manufacturing technology to assure competitiveness will become commonplace.

- o Information will be recognized and managed as the shared resource which integrates the Enterprise.

- o Humans will be recognized as a critical resource.

- o Application of computer-based technology will result in more formal definition and standardization of the design and manufacturing planning process.

- o Quality Assurance will be an integral part of every process.

- o Processing of materials will become more continuous flow oriented.

- o Short-term ROI will no longer be the major parameter for decision making.

Basic business functions are defined and related to the FoF/AO diagram for clarity. These functions are to:

- o Organize, direct and control the Enterprise
- o Acquire business
- o Develop and apply product and process technology
- o Acquire resources
- o Convert raw materials into finished goods
- o Provide product support services.

These functions are not essentially different from the functions being performed by today's Enterprises. However, the way the functions will behave differently and their relative importance in the future are discussed in this document.

2.2.2 Aerospace Enterprise System Components

With the conceptual description of a 1995 aerospace Enterprise determined, the next step was to define the components of this total integrated system. The coalition chose to address the components for the aerospace Enterprise as a system from a physical and logical point of view. (Sections 4.0 and 5.0, respectively.) The physical view includes people, production tools and equipment, facilities, and computer communication networks. The logical view includes the common data base and the logical processes used to manipulate data/information.

This approach was taken for the following reasons:

- o First, to curb the tendency towards addressing the FoF in terms of specific applications (capabilities) e.g., MRP I and II, CAD/CAM, flexible machining, integrated sheet metal center, group technology, etc. These are specific applications of technology and evolve over a period of time, e.g., MRP I became MRP II, NC now consists of CNC and DNC, etc. The total view of the factory, and especially the FoF, is much larger than these individual applications. It is the human integration of these capabilities that determines the factory system.

- o Second, to stress that the factory is more than an accumulation of physical resources used to produce product. While these physical resources (people, production tools, equipment, facilities, and the information processing communication network) are essential, they alone cannot produce a product. It is human reasoning (logic) developing specific capabilities (procedures and techniques) to achieve a goal, (e.g., build a part, build an assembly) and the transfer of these procedures and techniques as information to integrate the operations of the physical components that is the other essential element. This is the 95% of manufacturing operations related to data processing that is often cited by authorities (e.g., James F. Lardner and Joseph Harrington, Jr.).

- Third, to emphasize that there is more to integrating the Enterprise (factory) than the merging of shop floor applications and subsequent reduction of direct labor. True computer integration involves all aspects of Enterprise operations from marketing through product support. It is in these other areas that the true potential for improving productivity reside since direct touch labor now accounts for less than 10% of product cost.

2.2.3 Computer Integrated Aerospace Enterprise

Building upon the description of the total integrated aerospace system concept and its components, one potential version of the 1995 aerospace Enterprise is presented in Section 6.0. Figure 2-3 is a graphic representation of this framework. It must be reaffirmed that this is a hypothetical view. Different views (of integrated aerospace operations) are possible as the actual realities of specific manufacturing Enterprises are addressed rather than the generic concepts used by the coalition.

Each center of the framework is described in terms of:

- The activities it performs
- Its major internal and external interfaces
- The information it generates for the common data base
- The physical resources it requires:
  - People
  - Production Tools and equipment
  - Facilities
  - Computer communications network.

2.2.4 Methodology Used

Of major importance in the document, apart from the conceptual description of a 1995 aerospace Enterprise, is the analysis and methodology that went into developing the conceptual framework. The coalition believes that the methodology developed will prove valuable in individual company efforts aimed at establishing computer integrated operations for a manufacturing Enterprise.

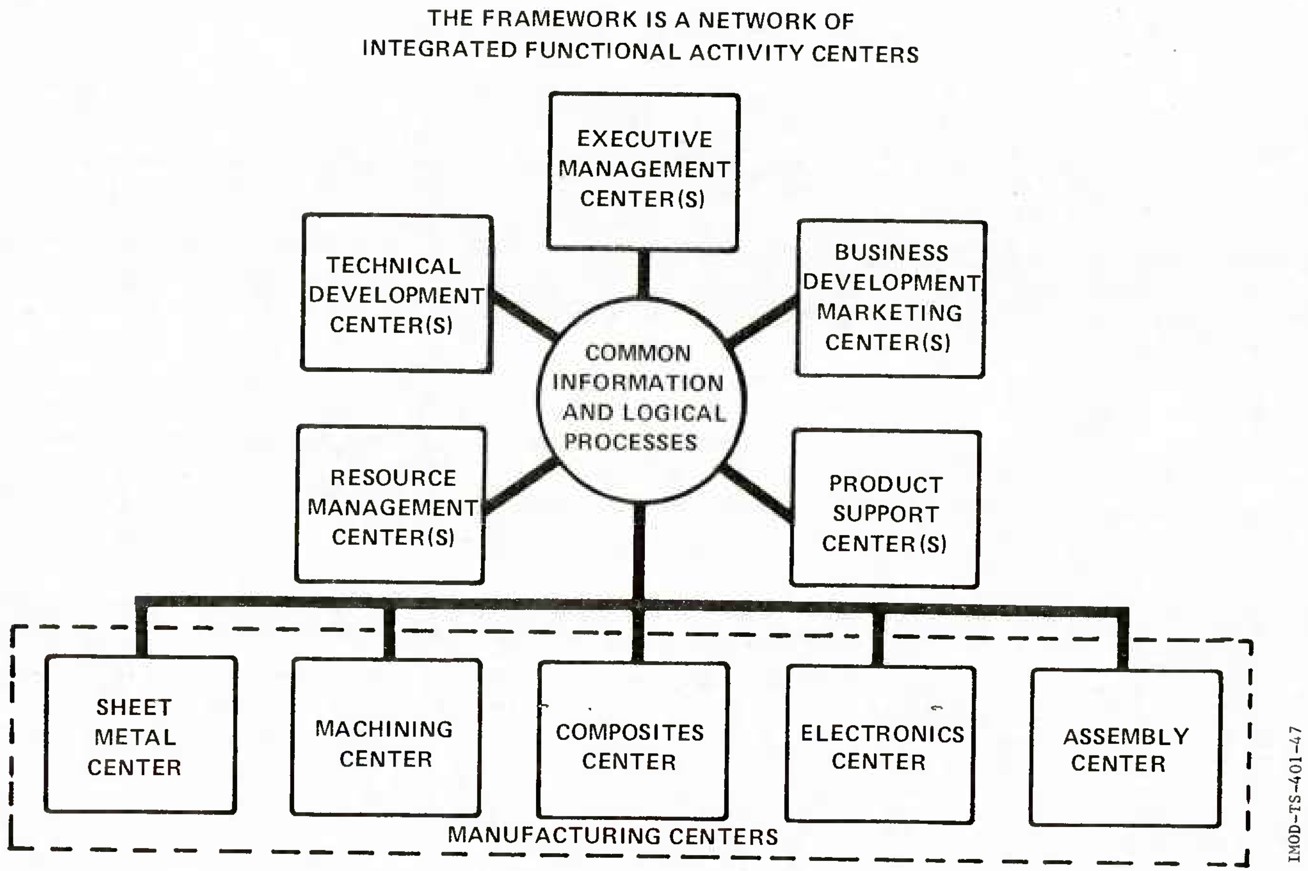


Figure 2-3 Conceptual Framework

To obtain a full understanding of the methodology requires a detailed study of this document, specifically Sections 3.0 and 5.0, as well as a thorough understanding of the Systems Specifications, System Requirements Document, State-of-the-Art Document, and Needs Analysis Document. These documents can be obtained upon written request from AFWAL/MLTC Wright-Patterson Air Force Base, Ohio 45433.

2.3 IMPLICATIONS OF THE CONCEPTUAL FRAMEWORK

Throughout this document, it has been suggested that American manufacturers need to change the way they conduct business operations. This is not meant to imply that the current approach has not been successful - it has for nearly two hundred years. In point of fact, this approach has been too successful and has led to self-complacency. After all, why argue with success.

This current "mind set" was established by the industrial revolution with its new sources of power and mechanical devices. It was subsequently reinforced by Fredrick Taylor and generations of cost-conscious managers. As a result, the factory is viewed as a productivity machine for transforming materials into products. As a productivity machine, the factory is planned for minimum direct labor costs and governed by the principles of industrial engineering and concepts of efficiency. This seductive and habitual pattern of current practice is directly causing today's problems and all but stopping any innovations that can lead to the Factory of the Future.

What is needed to change this current "mind set" is a new perspective of the relationship between the factory, and corporate strategic planning. In today's highly competitive, international, environment, the Enterprise must adopt new technology or become uncompetitive. This demands the strategic leveraging of manufacturing technology, the recognition of technological opportunities, and aggressive management of evolutionary change.

Our present problems will persist and continue to worsen should the concepts in this document be totally ignored and traditional methods continue. We must overcome our natural inclination to do it "efficiently" and stress doing the right things "effectively." Doing things "effectively" transports our efforts to achieve productivity above the factory floor to <u>all</u> organization levels. To put it succinctly, we must get off the direct labor route to efficiency (it only accounts for 10% of production costs) and take the uncharted indirect labor and materials cost route to effectiveness.

Application of the concepts discussed in this document will provide the opportunitiy to do things "effectively." It will not be a smooth effort as there will be many pot holes and detours along the way. Nevertheless, we must attempt the journey or face the worsening of our current problems of:

- Poor quality
- Increasing overhead and indirect costs
- Work force tensions and conflict
- Increasingly long lead times
- Excessive inventory
- Skilled worker shortages
- Inability to attract outstanding young people into the factory.

SECTION 3.0

THE AEROSPACE ENTERPRISE

3.1 CONCEPTUAL FRAMEWORK SCOPE

In developing this conceptual framework for a 1995 aerospace Enterprise (factory), the first step was to establish the boundaries of the effort. The boundaries are expansive when compared to the typical computer integrated manufacturing effort that generally deals with a single factory floor application. Figure 3-1 (FoF/AO "Operate An Aerospace Manufacturing Enterprise) and Figure 3-2 (Factory of the Future Functional Framework) are two visual explanations of the scope of the Factory of the Future (FoF) Conceptual Framework.

Viewed from this perspective, the factory is described as a sophisticated, complex social-technical system that is dynamic and self-regenerative. Consequently, the factory is an evolutionary growing system that is never in a "static state." Incidentally, "static state" is generally the conditional assumption made when single factory applications are developed.

A system, in general, consists of one or more component parts which produces some desired output from a set of inputs. There are many views of the manufacturing enterprise as a system. From the viewpoint of the owners, the FoF system receives investments as inputs and produces a return on that investment as an output. From the customer's point of view, the FoF system receives weapon system needs as input and produces weapon systems and support services as output. The design engineer primarily sees the FoF's role as applying science and technology to the development of increasingly sophisticated products. The manufacturing view of the enterprise is a system which converts raw materials into finished goods. The view of the 1105 project is that of the General Manager's who, in addition to all of the above views, sees the manufacturing enterprise as a system to acquire and use resources. See Figure 3-3.

The traditional view of the manufacturing enterprise system only recognized the ability to respond to changes in customer needs. The technology and resource structure were considered static. The increasing rate of technological changes and international competitive pressures means that the FoF must not only respond to new customer inputs but must also be flexible enough to dynamically reconfigure itself to leverage both product and process technology. This means that both human and physical resources must be aggressively acquired and organized in a flexible manner.

FACTORY OF THE FUTURE GENERIC FUNCTIONS

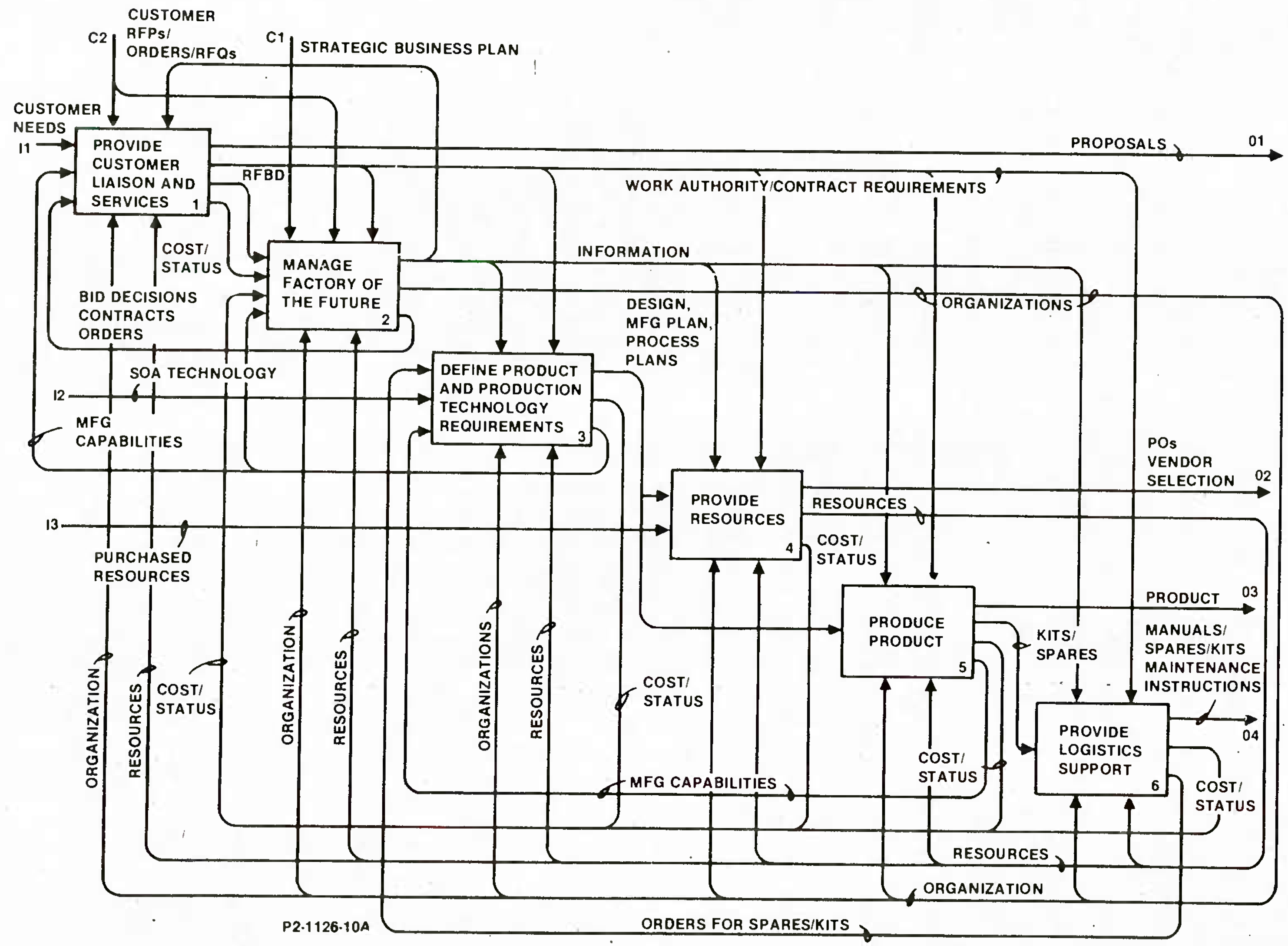


Figure 3-1 Factory of the Future Generic Functions

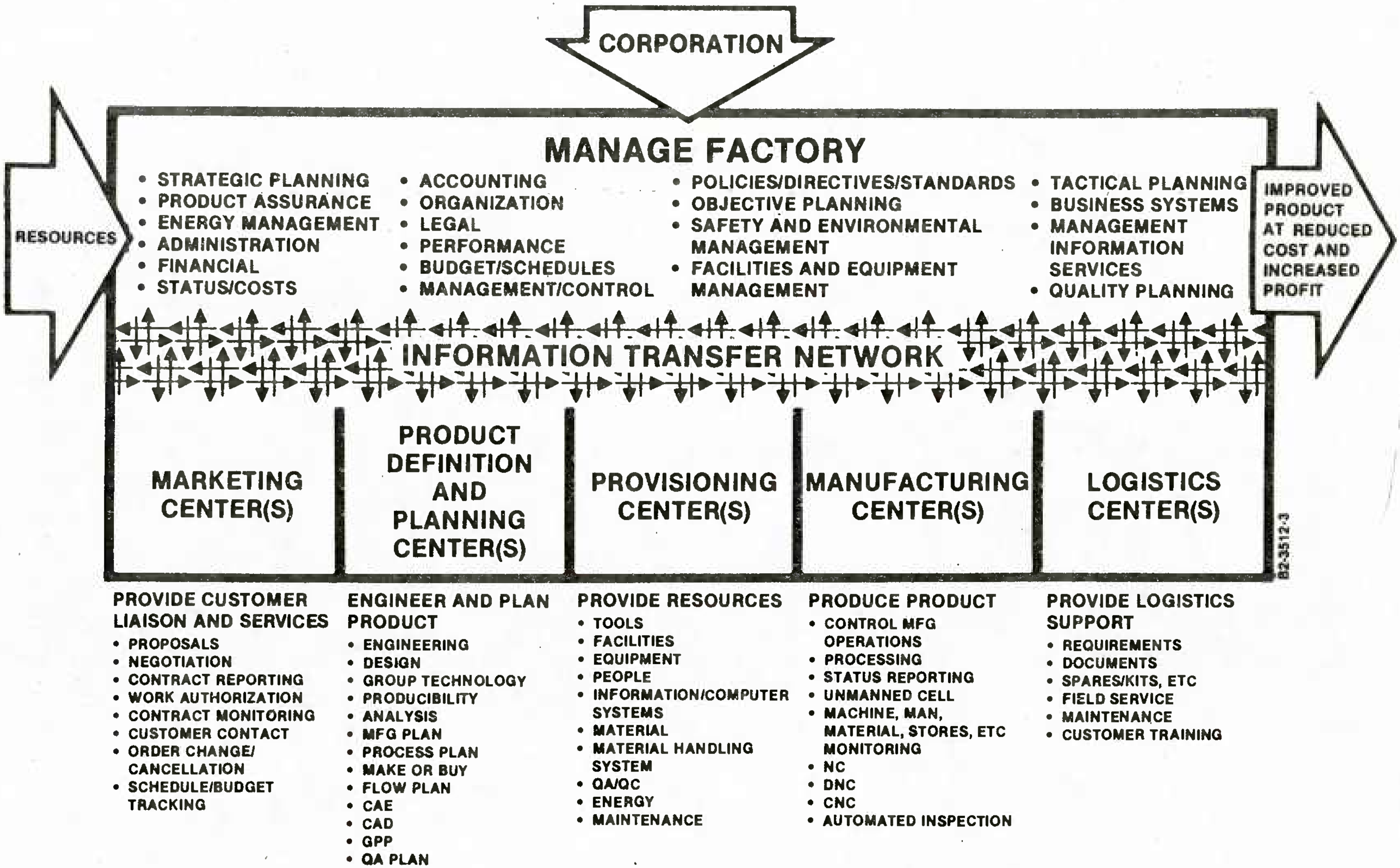


Figure 3-2 Factory of the Future Functional Framework

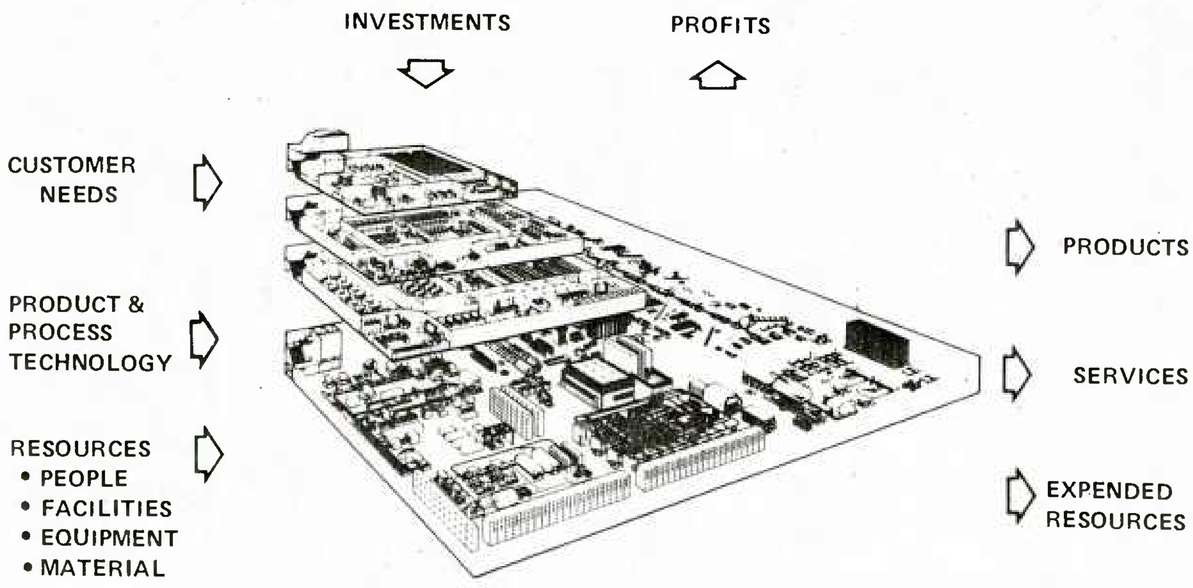


Figure 3-3 The General Manager's View of the FoF System

The six depicted functions of the FoF (Figure 3-1) describe, in a general way, the Enterprise activities:

- o Acquire and manage business (nodes A1 and A2)
- o Acquire and apply technology (Node A3)
- o Acquire, organize and use resources (Node A4)
- o Convert raw materials into products (Node A5)
- o Provide product support and services (Node A6)
- o Direct and control enterprise activities (Node A2)

The remaining paragraphs in this section will develop the conceptual framework around these six activities.

3.2 <u>Aerospace Enterprise Goals For 1995</u>

Although the goals (the performance objectives) for the FoF can be rather simply stated, achievement of these goals is not a simple matter. Success will require not only the implementation of new technology (product and process) but new concepts for: organizing and managing the Enterprise; assessing managerial and worker performance; and resource management. In general, the goals for a 1995 aerospace enterprise are to:

- o Reduce product cost
- o Improve product quality
- o Improve human resource management

- o Reduce time from customer order to product delivery
- o Improve manufacturing flexibility.

Paragraphs 3.2.1 through 3.2.5 discusses these goals to provide additional clarity.

3.2.1 Reduce Product Cost

Every business enterprise stresses reducing cost as one of its major goals. The major elements of product cost are:

- o Manhours/machine-hours per unit of production at some burdened rate
- o Material costs
- o Material carrying costs
- o Overhead expenses.

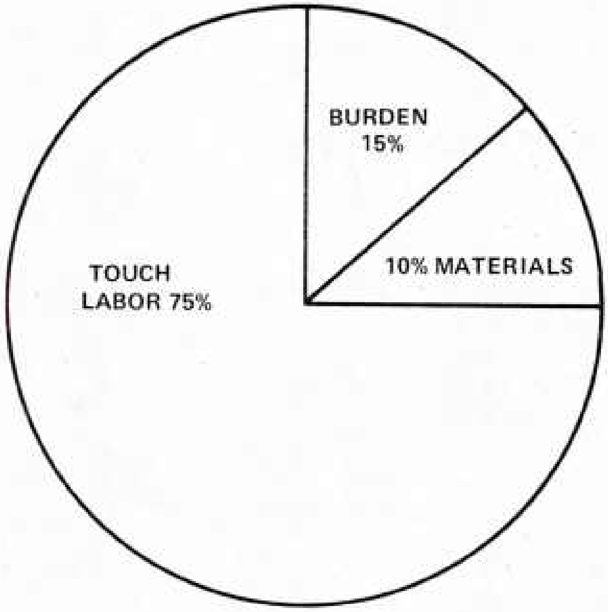
Studies have shown that 75% of past cost reduction programs have focused on direct labor (touch labor). However, when direct labor is unburdened, it accounts for less than (10% of the product cost in most companies). See Figure 3-4. Indirect labor (burden) typically outnumbers direct labor by a ratio of 3.5 to 1 and may account for over 35% of the product cost. Material cost is the major contributor to product cost. It typically represents 55% of the cost. This means that cost reduction in the FoF must not solely focus on replacing shop floor labor through automation, but must concentrate on making knowledge workers more productive and improving its interface with suppliers.

Cost reduction goals are usually stated as a percentage e.g., reduce system cost by 15%.

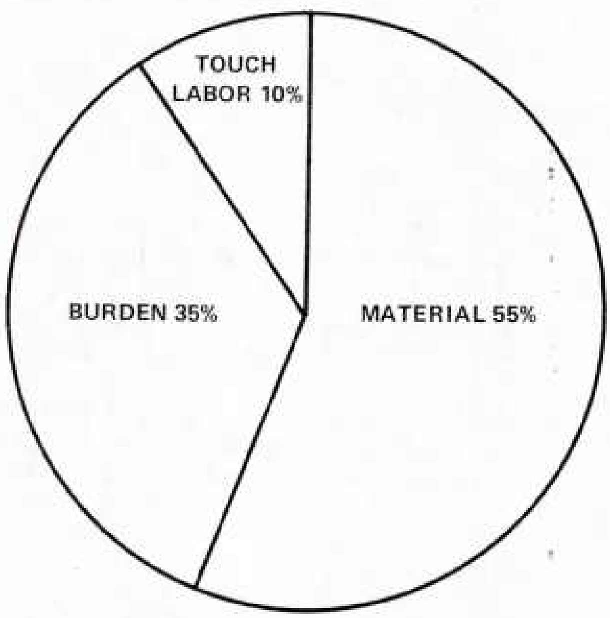
One salient point must be made with regard to reducing costs. In non-government related business, the key incentive in reducing cost is the subsequent increase in profit if costs are, indeed, reduced. Doing business with the government on a cost-plus-fixed-fee or firm-price (with a specified fee) does not provide an incentive to reduce cost. Reducing cost under these conditions would result in an Enterprise making less, not more, profit. There is DoD activity underway to address this condition, (the Industrial Modernization Incentive Program, IMIP) but until additional new approaches to contracting are in place, there is really no incentive to reduce cost for defense-related aerospace business.

3.2.2 Improve Product Quality

Improving product quality is an essential goal in the production of aerospace systems and is the responsibility of all personnel from top executive levels to those on the shop floor. Providing quality products not only ensures customer satisfaction, but enhances Enterprise image and profits. Doing



WHERE WE CURRENTLY ATTACK THEM



WHERE THE COSTS REALLY ARE:

IMOD-TS-401-9

Figure 3-4 Approaches to Product Cost Reduction it right -in the long run- costs less than doing it over. Goals for improving quality must be established as part of the long-range plan for an Enterprise, and these goals should be monitored by executive management.

While product improvement goals are initiated at executive level, the achievement of these goals is the responsibility of all in the enterprise, i.e., shop floor to the executive suite. Specific goals to improve product quality can be stated as follows:

- Shift the Quality Assurance focus to address early integration of Product Assurance
- Reduce cost to rework
- Reduce average number of final product defects
- Increase mean time between failures
- Reduce mean time to repair
- Reduce number of design related engineering change orders
- Reduce process plan errors
- Improve "checks and balance" activities for systems development.

3.2.3 Improve Human Resource Management

The improvement of employee attitudes and their perceptions of the Enterprise is a key objective. No matter what the current literature states, the 1995 aerospace enterprise, or any manufacturing enterprise (for that matter), will still be composed of people. People are the essence of the Enterprise, the main essential resource. Without people, there would be no Enterprise.

Professor Wickham Skinner, Harvard Business School, asserts the old notion that man can and will adapt to mechanization is no longer acceptable. He states that this notion is challenged by society on ethical grounds and besides it simply fails to work today. Therefore, he believes that if the human consequences of technological change are not anticipated, no amount of pay will overcome the degradation in quality, productivity and employer-employee relations.

Goals for improving employee attitudes and perceptions can not be quantified. They can only be described as desired traits between employer and employee and between employee and employer - a two-way street. It is relatively easy to describe these desired traits. Achievement, however, can be extremely difficult. Success or failure rests upon the attitudes and perceptions of employees and employers about one another. As a result, if there is distrust, suspicion of motives, or apprehension regarding results on the part of employees or employers, the Enterprise will encounter some traumatic experiences.

Success in this area calls for mutual trust and the achievement of supportive actions to ensure the success of the Enterprise and gainful employment for all. These actions must replace the mutual distrust and antagonistic actions so typical in our current environment. Paragraph 4.1 provides a more detailed discourse on this subject. Objectives for improved Human Resource Management can be stated as follows:

- o Improve employee attitudes (this means all levels of employees)
- o Improve tenure/length of employment
- o Decrease fluctuations in employment caused by layoffs and rehiring
- o Increase the productivity of all employees
- o Reduce the number of strikes
- o Provide training to upgrade employee skills - this includes retraining to operate/maintain new production systems/equipment

3.2.4 Reduce Time From Customer Order to Product Delivery

Long lead-times are the bane of the aerospace industry. Some aerospace systems have taken as long as 8 to 10 years from concept to first item delivery. There are many reasons for this situation, and they pertain to the approval/procurement cycle as well as to the purely technical problems encountered when developing new concepts into workable reliable weapon systems.

The Factory of the Future, if totally integrated, should be able to reduce lead times significantly. However, effective reduction of lead times will require the wholehearted cooperation of both government and industry to streamline the entire approval/procurement/build cycle. Assuming this total cooperation, realistic goals for reducing lead times could be stated as follows:

- o Reduction of average span time from contract initiation to first article rollout

- o Reduction of average production span time

- o Increased average inventory turnaround

- o Improved vendor/supplier lead time consistent with product delivery schedule.

3.2.5 Improve Manufacturing Flexibility

The improvement of manufacturing flexibility is essential if the aerospace factory is to remain competitive and viable in the

1995 time period. The key to this flexibility is computer integrated manufacturing (CIM). This implies, in our view as a coalition, more than integrated shop floor operations. It is the integration of the manufacturing enterprise from executive management down to the shop floor.

Computer integration is the key according to authorities in the area, e.g., James F. Lardner (VP, Deere and Co.) and Joseph P. Harrington Jr. (Arthur D. Little). They base their opinions on their assertion that, in the ultimate analysis, what we are manufacturing is a series of data processing operations.

In the 1995 aerospace factory, the key to flexibility will be the use of computer technology to logically integrate and automate the functions of the Enterprise. Specific flexibility goals are to:

- o Provide greater design flexibility without increased manufacturing cost
- o Provide greater manufacturing planning flexibility with decreased tooling and equipment cost
- o Produce parts in smaller quantities without increased equipment setup cost
- o Minimize the need to make facility and equipment modifications to produce new parts and products
- o Reduce the time required to adopt new product and process technology.

3.3 FACTORY OF THE FUTURE OPERATING ENVIRONMENT

Change is the essence of the operating environment the FoF faces just as change is the environment of the factory of today. Change in markets, change in product technology, change in process technology, change in employee attitudes, change in government policies and regulations, etc. Change impacts the Enterprise two ways:

First, there is change that expands or contracts the activities of the Enterprise e.g., increasing sales/decreasing sales, increasing profits/decreasing profits, adequate labor/ inadequate labor, excess inventory/inventory shortages, etc. These changes are cyclic and leave the nature of the Enterprise intact. They create short term havoc but have little or no impact on Enterprise stability.

Second, there is change that transforms the Enterprise structure making it different than before; in other words, strategic change. At one time our Enterprises were managed by this change. Beginning about the mid fifties, forward-looking Enterprises began focusing on external strategy approaches to better cope with and manage changes. However, the impact of external change on the internal structure of the Enterprise was ignored. A basic assumption was that the internal structure did not need to change in response to external conditions. It was not until the late 1970's that it became apparent that the internal structure of the enterprise must be adaptable to cope with a turbulent and changing world. Examples of strategic changes include:

- o Changes in products
- o Changes in markets
- o Changes in product/process technology
- o Changes in available resources

3.3.1 Product Technology Change

Changes in the product can range from the use of different materials to building products that have a totally new design and mission profile. Examples of new technologies being considered for future aircraft include:

- o Propulsion
  - High thrust to weight factor engines
  - Low fuel consumption turbofan engines
  - Advanced applications of turboshaft engine driven propellers
  - Vectoring/reverse thrust nozzles
  - Electronic controls
  - Composite engine parts

- o Air Frame/Materials/Structures
  - Composite airframes
  - Increased strength and corrosion-resistant aluminum and steel
  - Aluminum-lithium alloys

- o Configuration/aerodynamics/flight controls
  - Improved airframe-stores integration
  - Artificial stability (active controls)
  - Integrated flight/fire/propulsion controls

- o Avionics
  - Very high speed integrated circuits (VHSIC)
  - Integrated comm/nav/ident functions
  - Advanced man/machine/sensor/information processing interfaces

Future aircraft mission profiles will include greater fuel efficiency, payload, and range. Transatmospheric vehicles which are intended to become an aeronautically-configured, spaceship-like machines that can perform various missions in either low earth orbit or in the atmosphere while operating much like a conventional aircraft are also envisioned. In addition to product advancements for both commercial and military markets, many aerospace companies will be faced with continued product diversification, e.g., shifting from aircraft to motor vehicles or ships.

It is apparent that product related changes will impact the internal structure of the Enterprise. Use of new materials will require new design techniques, new machine tools, different labor skills, different quality control procedures, etc. Changes in product lines will have essentially the same impact.

3.3.2 Market Changes

In the aerospace industry, market changes can be brought about by any or all of the following:

- o Shifts in DoD product requirements
- o Changes in DoD procurement policies
- o Shifting to and from military to commercial products
- o Shifting from national to international suppliers
- o Demand for new products
- o Technological break-throughs in:
  - Product
  - Process

Although a detailed forecast of the military weapon systems market is beyond the scope of this report, some current trends which emphasize the need for flexibility in the FoF should be noted. Current trends in changes to DoD procurement policies include:

- o Increased emphasis on industrial technology modernization to reduce weapon system costs

- o Procurement of fewer weapon system platforms with longer life and greater flexibility (thus making maintainability, flexibility and product support major procurement issues)

- o Continued emphasis on improving product quality and reliability

- o A shift from single-year procurement to multi-year procurement

- o Increased international marketing of weapon systems

- o Increased requirement for international coproduction programs

- o Shorter lead time for product development.

Long-term Air Force plans for product requirements include:

- o Chemical and biological missions
- o Enhancements to the penetration capability of the B-1B, ALCM missile, and FB-111 through the 1990's
- o Tactical modernization to protect the current fleet of Air Force tactical aircraft beyond the year 2000
- o An electro-optical infrared counter-countermeasures for highly sensor-sensitive air-to-ground missiles
- o An Advanced Tactical Fighter (ATF)
- o An Advanced Technology Bomber (ATB)
- o A transatmospheric vehicle (TAV).

Each of the above market shifts requires that the internal structure of the Enterprise be adaptable. Shifts in product requirements could result in new organizations being created to supplement or replace current organizations. Shifting from military to commercial products could also have the same result. From this, it is obvious that external changes in market conditions have significant impact on the internal structure of the enterprise.

3.3.3 Changes in Process Technology

Product and process technology advances often go hand-in-hand. Examples of emerging process technology include:

- o Laser cutting and measurement
- o Powder metal forming
- o Superplastic forming
- o Titanium sandwich panel fabrication
- o Graphite and epoxy composite manufacturing
- o Metal matrix composite manufacturing
- o Advanced techniques for manufacturing integrated circuits.

In many cases, it is probably less apparent that changes in process technology can impact internal structures. After all, manufacturing is manufacturing, isn't it? For example, consider composites manufacturing: different manufacturing environment almost laboratory clean when compared to a machine shop; totally different quality control procedures and techniques; time sensitive materials with a finite not infinite shelf life and so forth.

Composite manufacturing not only requires different facilities, it requires people with different mind sets. That is, people who adapt to new procedures for developing designs and product manufacturing in composites. Different shop skills are also required to accomplish composites manufacturing. The key point to remember is that changes in process technology can also significantly impact the manufacturing activities of the enterprise. In turn, this will affect the internal structure.

3.3.4 Changes in Available Resources

In addition to changing markets, products and process technology, the availability of resources will have a major impact on the FoF. This includes human as well as physical resources. As new technology evolves, certain skills will become critical. For example, the demand for software development engineers is expected to greatly exceed the supply in future years. Therefore, the Enterprise must aggressively seek to satisfy its requirement through training programs, development of automated software generation techniques, or other means. Demographics, work ethics, and union demands are all major considerations for adapting to the availability of human resources.

The availability and capability of office and production equipment must also be considered in strategic and tactical plans. Strategic leveraging of advanced capabilities will be the key to maintaining a competitive edge. This includes computer and communications equipment, robotics, flexible manufacturing systems, etc.

The aerospace industry has already developed a complex structure of subcontracting and the use of support services. As the product and process technology continues to grow in sophistication, no one company will be able to provide all the necessary capabilities. Fewer prime contractors and less vertical integration are expected in the future. This means the FoF system must have an effective means to deal with subcontractors and service organizations since they already account for over 50% of the product cost. Many companies must also make the necessary adjustments to shift from a prime contractor to subcontractor role.

Only 5% of the labor force is expected to be required for manufacturing by the end of century. Service industries, on the other hand, will experience major growth. The FoF will purchase many of its services from outside the company rather than perform them in-house. The old problem of the "not-invented-here" syndrome must be dispelled if there is to be a FoF.

3.4 AEROSPACE ENTERPRISE EXTERNAL INTERFACES

Paragraph 3.3 discussed how change could impact the manufacturing enterprise. This paragraph will address the external interfaces that must be established by the manufacturing enterprise to identify and prepare for impending changes. Contact must be made and maintained with the following entities:

- The parent corporation or owners
- Customers, both military and commercial, including:
  - Program Management Offices (PMO/SPO)
  - Logistics Commands and depots
- Competitors
- Federal, state, and local government agencies, including:
  - DCAs
  - EPA
  - OSHA
  - IRS
- Society, through:
  - Public relations campaigns
  - Community development projects
  - Charities and "not-for-profit" organizations
  - Professional organizations
  - Potential employees
  - Unions
- Suppliers, including:
  - Subcontracotrs
  - Vendors of materials, tools, equipment, facilities and software
  - Service organizations
  - Financial institutions
  - Libraries, broadcasting companies and other external information sources

Essentially, these contacts will provide an information source that will cause the enterprise to change or assist the Enterprise in preparating to change. Effective contacts may also permit the enterprise to influence or mitigate pending changes.

A primary requirement for the establishment and maintenance of this information is direct electronic communication. Section 4.0, paragraph 4.4 discusses the required Information Processing and Communication Network in detail. In many cases instant communication is mandated. Communication and information exchange on this basis can be followed up by personal contact and other methods.

The information collected must be analyzed, evaluated and confirmed. It should, once processed, provide input to the preparation of the long-range and short-range goals of the Enterprise and help in their achievement. Data that impacts future operations should be communicated to all appropriate parties as soon as it is confirmed. Without this communication, our technical and production people could be preparing to implement the right systems and procedures for the wrong missions. The criticality of maintaining active external interfaces increases as the pace of change increases. The increasing application of computer-based technologies to achieve integrated manufacturing operations will greatly increase the pace of change. As a result, external interfaces become an important element in the drive to enhance the productivity of aerospace operations.

3.5 FOF OPERATING CONCEPTS

In order to develop a framework for the FoF, fundamental changes in the way the Enterprise will do business must be identified. The key changes can be summarized as follows:

- Strategic leveraging of manufacturing technology must become a primary concern of the overall strategic business plan. The company can no longer be totally controlled by market demands and short-term ROI.

- Information must be recognized and managed as a shared resource which integrates the Enterprise. Optimizing the availability of information must be considered over the optimization of computer usage.

- Humans must be recognized as a critical resource. Humans can no longer be forced to fit a particular job; instead, a flexible structure must exist which maximizes talent and creativity. Computers and equipment must be viewed as an extension of man's mental and physical capabilities.

- Formal definition and standardization of the product design and manufacturing planning process will become more important as more and more computer-based technology is applied.

- Quality assurance must be an integral part of every process whether the output of that process be physical or information. Product quality must be built-in. It cannot be inspected in.

- Processing of materials must be a continuous flow rather than batch-oriented with more investment in equipment and less investment in inventory. Equipment must be oriented to provide maximum flexibility and minimum throughput time.

- o Short-term ROI can no longer be the only parameter for decision-making. Long-term return on assets (ROA) and competition must be the drivers for decisions. The Enterprise can no longer be satisfied with simply improving the efficiency of the old way of doing business.

During the establishment of the FoF Conceptual Framework, specific operating concepts began to evolve. As these concepts matured, it was possible to relate them to the seven Needs Categories established during the needs analysis phase of the ICAM Life Cycle.

As these concepts are discussed below, bear in mind that they are describing the issues that must be addressed to integrate aerospace operations.

3.5.1 Concepts For Managing the Factory

Concepts for managing the factory can cover, and in fact do cover, all facets of the FoF. For purposes of this subparagraph, the concepts discussed here will be limited to those dealing with scheduling, resource allocation, the assessment of technology and its implementation. Other facets of management are addressed as follows: the concepts for management of information are addressed in subparagraph 3.5.2; concepts for managing human resources are addressed in subparagraph 3.5.5; concepts for materials management will be found in paragraph 3.5.6; and concepts for financial management are discussed in paragraph 3.5.7.

Of critical importance for integrating the FoF is scheduling to meet contractual obligations. Successful accomplishment of this activity will require a full range of computerized or computer-assisted tools to generate schedules. This includes establishing the master schedule and all detailed schedules as well. This scheduling capability should:

- o Assess business objectives and evaluate constraints to achieve consistency in all enterprise operations
- o Identify potential cost and schedule trade-offs between the enterprise and customer throughout the product life cycle
- o Assist the manager in enforcing schedules and priorities between functions to avoid suboptimization
- o Make full use of the following technologies:
  - Artificial Intelligence
  - Group Technology
  - Common data base
  - Neutral data communication languages.
  - Computer Simulation

Hand-in-hand with scheduling for productive operations is the need to effectively allocate resources and track their use. Effective resource allocation requires the following capabilities:

- o Establishment of optimal resource allocation targets for all enterprise activities
- o Identification of resource deficiencies and potential schedule impacts
- o Reallocation of resources to avoid detrimental schedule impacts
- o Identification of resources and activities that could create bottlenecks
- o Determination of the impact potential resource allocation will have on all enterprise activities requiring the same resources
- o Make full use of the following technologies:
  - Artificial Intelligence
  - Group Technology
  - Common data base
  - User friendly computer language.
  - Computer Simulation

The assessment and implementation of technology to achieve the envisioned capabilities of the FoF is a critical management function. The key questions are: What technologies can best satisfy enterprise goals and objectives? How much will lead time and product cost be affected? Will our manufacturing flexibility be increased? Will product quality be improved? Will our competitive position be enhanced? Effective answers to these questions require that the following capabilities be realized:

- o Accurate, up-to-date access to information on current technological advances, innovations, applications, etc.
- o Automated tracking and retrieval of information relating to industry-sensitive research and development efforts
- o A disciplined-consistent approach to technology assessment that is supported by computer-aided decision support tools.

3.5.2 Information Resource Management Concepts

In the ultimate analysis, manufacturing is a series of information processing steps. This is true whether or not the factory is manually integrated, computer integrated or in some halfway integrated state. As we move towards integrating the factory through a common but distributed data base that provides all the information required to manage and operate the enterprise, the physical objects which were primarily use to convey information (e.g., templates, master models, etc.) will be replaced with electronically stored information. As this transition occurs, information will be recognized as an essential company resource rather than the private resource of a department or individual.

This will mandate the management of information as a key company resource. In fact, as it is automated, it becomes the critical resource. Just like raw material or purchased items, information must be supplied to users when it is needed, where it is needed, and in the form it is needed.

Information will become, then, an essential requirement in the operation of the aerospace enterprise. As a result, the communication, management, and control of information will provide the key for integrated factory operations. Actually it is appropriate to make the following points:

- o No information - no integration
- o Wrong information - chaos
- o Late information - cost impact.

To ensure the success of Information Resource Management, the following capabilities must be in place:

- o A fully automated, intelligent data dictionary to support the formal definition of the Enterprise information structure

- o Automated tools and techniques for the dynamic structuring of information to support various application views of enterprise information i.e., a neutral data base

- o Standards, procedures and supporting computerized tools to develop user applications which share common information

- o Consistent, timely and accurate communication of information between all users of enterprise information

- o Automated support for human decision-making; this support could be based upon artificial intelligence technology

- o A friendly, interactive, natural command language that can be used with minimal training

- o Storage of large amounts of information in an efficient and flexible manner

- o Dynamic access to information by all users.

3.5.3 Concepts for Product Definition and Planning

Product definition and planning encompasses the key activities of product design and planning for manufacturing. As such, the concepts address issues associated with concept design through detail design, process planning, tool design and inspection, plans and all facets in between. In short, this entails the treating of design and manufacturing planning as a single activity in the FoF.

In other words, the merging of the functions of design engineer, manufacturing engineer, industrial engineer, tool designer, NC programmer is relevant. There is evidence of a strong trend in this direction made possible by the increasing use of CAD/CAM, Group Technology, and computer-aided process planning. Key factors driving this trend are: the potential for reducing cost and lead times through improved and better coordinated designs which result in fewer engineering changes and quality rejects; the possibility of reducing the massive amount of paper presently required to produce product; and the creation of a single unified engineering/manufacturing data base which can be used by all enterprise activities to form the nucleus of the common data base for the enterprise.

Achievement of the above stated goals for Product Definition and Planning requires the following capabilities:

- o 3D Geometric Modeling
  - Solid
  - Wire frame
- o Interactive graphics with a common exchange format, e.g., IGES or PDDI
- o Group Technology applications to support:
  - Part family development
  - Storage and retrieval of similar part information
  - Use any applicable classification and coding systems
  - Assembly planning
  - Process planning
  - NC programming
  - Organization of data for the common enterprise data base
- o An automated/generative process planning system that can generate the process plan from the geometric model of the part with minimal or no human intervention
- o A common data base of manufacturing/engineering information
- o A rapid means of handling engineering changes and maintaining configuration control.

3.5.4 Concepts for Product Assurance

Total quality assurance in the FoF is the driving element behind Product Assurance Concepts. Segments of quality assurance are inherent in all phases of Enterprise operations; consequently, the essence of total quality assurance is the control and coordination of these various segments to assure product reliability. Accordingly, it is apparent that total quality assurance in the Enterprise is the responsibility of all members from the chief executive to those on the shop floor.

The key factor in control and coordination is information. Currently, the transmission and sharing of this information is achieved through a massive manual effort that requires hard copy documentation. As a result, there are generally numerous delays in providing current quality information. In the FoF, this slow cumbersome system must give way to the use of automated procedures and electronic documentation.

Achievement of total quality assurance in the FoF will require the following:

- Designing quality into the product and manufacturing process vis-a-vis inspection and rejection of defective products, processes, and procedures
- Reduction/elimination of postprocess inspection through the maximum use of automated on-line inspection
- Enhanced control of the manufacturing process through the use of flexible manufacturing cells and building to ship sets or batch sizes of one
- Integration of quality assurance information with all Enterprise activities, e.g., design, finance, etc.
- Development of on-line/real-time Configuration Management procedures.

3.5.5 Concepts for Human Resource Management

The FoF will not be achieved without the cooperation of the essential Enterprise resource - its people. Concepts in the area of Human Resource Management address preparing for, adapting to, and contributing to the changes in the Enterprise that will be brought about by development of the FoF. Implicit in this are the need for: different management approaches, revised benefit programs and enhanced recruiting and placement procedures. Anything that leads to acceptance and understanding of the need to establish the FoF must be investigated, analyzed, and adopted as appropriate.

Specific concepts to be considered for enhanced Human Resource Management include:

- o Incorporating Human Resource needs into the strategic plans for the Enterprise
- o Methods for preparing management to deal with better educated, better trained and more sophisticated personnel
- o Providing a methodology to ensure that Human Resource considerations are incorporated into new system designs
- o Establishing in-house training programs to meet the needs of the FoF with current employees as much as possible
- o Developing Human Resource requirements 7 to 10 years in the future
- o Creating reward and incentive programs that support the development of new technologies, systems, and procedures for the FoF
- o Developing a cooperative relationship between the Enterprise and workers to:
  - Create capital and increase productivity to improve job opportunity, job security and pay
  - Improve competitive position of the Enterprise
  - Tie wage increases to realistic considerations of productivity growth, inflation and market conditions.

3.5.6 Concepts for Materials Management

Procurement, storage, movement and allocation of raw materials, subcontracted components, work-in-process, tools and equipment are as essential to the FoF as they are to the factory of today. The benchmark for successful Materials Management is providing the right materials, components and subcontracted items at reasonable cost, with the desired quality, in the proper amount, at the needed place and at the right time. This is essential for the control of resources used in production and product support activities. Control is essential as these costs may represent over 50% of the total contract price.

Concepts for the achievement of those results call for capabilities in:

- o The effective selection of vendors, suppliers and subcontractors
- o Near real-time communication with vendors, suppliers, and subcontractors

- Advanced strategic planning for material requirements
- Control of materials inventory at the enterprise level and at the vendor level
- Establishing of production facilities with flexible equipment
- Control and management of materials at the Enterprise level.

3.5.7 Concepts for Financial Management

The use of financial comparisons as the great equalizer to assess true production costs is paramount in today's factory. Every aspect of the Enterprise's operations are dollarized for analysis. In turn, this dollarized analysis is used almost exclusively to make decisions from determining salaries to the acquisition of new production capabilities.

However, there are two major drawbacks to this approach. First, the exclusive focus on financial aspects for decision-making overemphasizes short-term results; as a result, decisions which involve technology acquisition and implementation that have long payback periods are usually shunted aside or denied. This seriously degrades the competitive position of the Enterprise. Second, the current approach to basing costs on direct labor is rapidly losing validity. today, direct labor represents around 10% of total product cost and continues to decrease as more and more automated systems are brought on-line. Consequently, the continuing practice of basing costs on direct labor is leading to inaccurate cost estimates.

This condition cannot be permitted in the FoF. First of all, direct labor could be entirely eliminated from some functions in the FoF. Secondly, maintaining the Enterprise's competitive position will become, essentially, a matter of technologically upgrading manufacturing capabilities. These two conditions present different and challenging requirements for financial analysis and management. Meeting this challenge will require enhanced or new capabilities for:

- The collection, storage and manipulation of financial data
- Flexible and easy-to-use tools to forecast and estimate financial information
  - Customer profiles
  - "What if" simulations and forecasts
  - Parametric estimating
  - Access to manufacturing cost data, etc.

- o Dynamic financial analysis of the Enterprise to include:
  - Analysis of production rate changes
  - Tools to analyze time dependent and probablistic events
  - Automatic calculation of ROI/ROA using known and probablistic parameters
  - Analysis of productivity improvements, investments and other changes.

- o More accurate, timely, and efficient methods of general accounting

- o Optimizing asset allocations

- o Optimizing the acquisition of capital

- o Tracking inventory, purchased items, finished items, work-in-process and adding value to each item

- o Financial input to resource allocation decision-making to include the cost of under-utilization.

3.6 FUNCTIONAL REQUIREMENTS

In order to operate, the manufacturing Enterprise must perform the basic functions of a business. These basic functions for the FoF will not differ greatly from the basic functions of current aerospace companies. However, the way these functions are performed and their relative importance must change in order that the Enterprise may react favorably to the dynamic environment described earlier. The future approach to performing the functions of the Enterprise must implement the new concepts described in the previous section in such a way that all the activites of the Enterprise are highly integrated, yet flexible and easy to change.

The basic functions of a manufacturing Enterprise are to:

- o Organize, direct and control the Enterprise

- o Acquire business

- o Develop and apply product and process technology

- o Acquire resources

- o Convert raw materials into finished goods

- o Provide product support services.

Each of these basic functions is discussed further in the following paragraphs. Figure 3-5 shows a model of the FoF activities. A more detail model is shown in Appendix A.

3.6.1 Enterprise Management

This function corresponds to the executive management responsibilities of the manufacturing Enterprise and is represented by the A2 node, Manage Factory/Programs, in Figure 3-5. Business goals, objectives and requirements are given to the Enterprise's executive management by the owners or parent corporation of the Enterprise. Strategic, tactical, and operational business plans must be developed to satisfy the requirements of the owners. These business plans must take into account current and projected market opportunities, product and process technologies, resource availability, and current on-going activities. Based on an approved business plan, business controls are generated to orchestrate the activities of the other major functions of the Enterprise. These business controls include organizational relationships and responsibilities, resource allocations at a gross level (including budgets and manpower) and goals, policies, and directives for internal Enterprise functions. Each time new owner requirements are received or there is a projected or actual shift in markets, technology, or resource availability the business plans and controls are adjusted. The management and coordination of major programs which may involve multiple customers and/or products are viewed as part of the function of organizing, directing, and controlling the Enterprise.

3.6.2 Business Acquisition

In order to function as a business, the Enterprise must have customers. The acquisition of customers or business is represented by the A1 node, Provide Customer Liaison and Services in Figure 3-5. Based on the strategic and tactical business plans, the Enterprise must identify market needs, develop and execute promotional and sales efforts, respond to specified requests for proposals, and negotiate, execute and administer sales contracts. This business acquisition function must take current and future product and process technology as well as resource availability into account. In the FoF, more emphasis must be placed on strategic leveraging of technology, which means the Enterprise must actively seek new markets which match the technology profile of the company rather than just responding to demands of current customers. The major outputs of the function are proposals and other communications with the customer and customer/market requirements which must be satisfied by the other major Enterprise functions.

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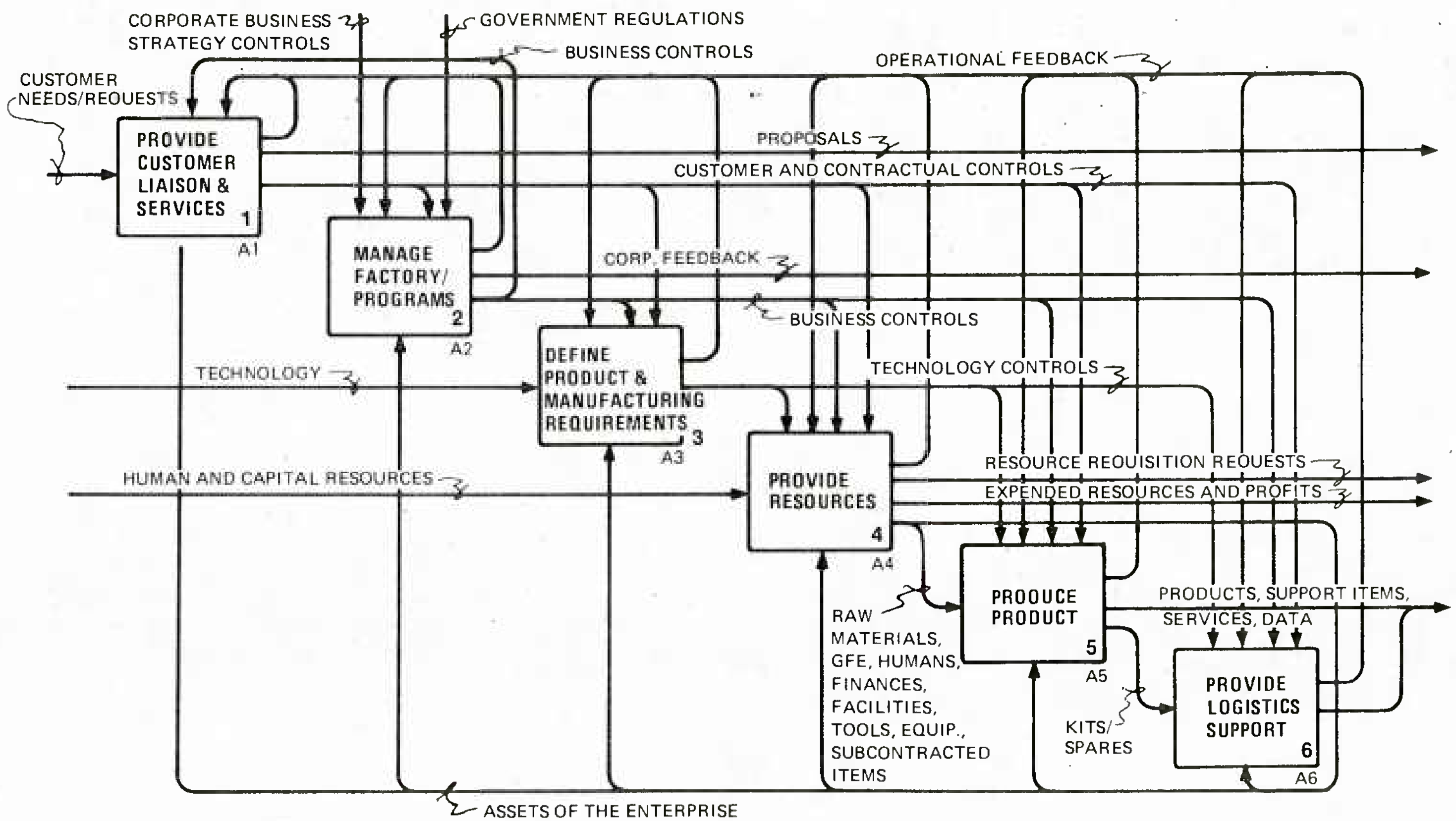

NODE: FOF/AO	TITLE: OPERATE AN AEROSPACE MANUFACTURING ENTERPRISE	NUMBER:

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Figure 3-5 Operate an Aerospace Manufacturing Enterprise

3.6.3 Product and Process Technology Development

Technology will become a major driver for the structure and activities of the FoF. The development and application of both product and process technology is represented in Figure 3-5 by the A3 node, Define Product and Manufacturing Requirements. Technology development in the past has focused on product development within the context of a business plan and specific customer requirements. In the FoF, the development of new technology may actually preceed a specific business objective and marketing plan. An example of this new-found importance of technology is being demonstrated by the current race to develop the fifth generation computer.

Technology development in the FoF will also give greater emphasis to process technology. Process technology is used here in a broad sense to include management and control processes as well as physical processes. Aerospace companies have traditionally emphasized product technology and have developed process technology only as needed to support specific product requirements. However, in the FoF environment, products will change more rapidly. Flexibility will only be gained by focusing development of process technology with applicability to multiple products, both current and future. The electronics industry serves as an example of the changing role of process technology, in that future advancements for the development of integrated circuits is primarily dependent upon technological breakthroughs in techniques for manufacturing electronic chips.

Given the business objectives, market/customer needs, and the availability of resources, existing technology is acquired from outside the company, further developed, and applied to specific products and processes within the company. The resulting output is a technical definition of current and future products and processes which serve both as inputs to marketing and business management activities and as technical controls for resource acquisition, manufacturing, and product support. For this function to be performed effectively in the FoF, current CAD/CAM technology must be further developed and integrated with the other business functions.

3.6.4 Resource Acquisition

The first step in converting plans and ideas into reality is the acquisition of the required resources. This function is represented by the A4 node, Provide Resources in Figure 3-5. Resources from the Enterprise perspective include information, finances and people as well as physical resources such as facilities, office equipment, production equipment, tools and materials. These resources, once acquired, become the mechanisms to carry out the Enterprise activities. The acquisition of these resources is controlled by business objectives, customer requirements, and technology developments. With the exception of materials, resources have traditionally been viewed as static. However, in the FoF environment, the individual life cycle of each resource must be recognized and managed. The organizational relationship and application of these resources must be managed dynamically.

As discussed previously, treating information and people as resources is critical to achieving the integrated FoF. The objective of Enterprise management must be to maximize the long term return on its assets, including information and people.

3.6.5 Conversion of Raw Materials into Products

The conversion of raw materials into finished goods is the heart of any manufacturing Enterprise. This conversion function is represented in Figure 3-5 by the A5 node, Produce Product. Using the available resources, this function converts raw materials and vendor supplied components into finished goods based on the business objectives and controls, customer requirements, and technological specifications of the products and processes. The results of the conversion are either supplied directly to a customer in fulfillment of a sales contract or as spares for logistics support. The conversion processes consist of fabricating, assembling, storing, moving, inspecting, and testing of materials. These processes may be applied to items which are subsequently used as tools or equipment as well as items which are ultimately delivered to a customer.

Traditionally, many elements of this conversion process have had fixed controls or were based on "hard-coded" information. A template, for example, is hard-coded information defining the shape of a part. In the FoF, controls on the conversion process must be "soft-coded" to allow fast and easy changes. Numerical control data, for example, represents soft-coded control information. (Although manual handling of punch tapes still possess some of the limitations of "hard-coded" controls.)

In addition, more intelligence and real-time decision-making must be implemented on the shop floor. Ultimately the detailed control instructions for a piece of equipment should be generated on the shop floor based on the supplied part specification rather than the current laborious creation of detail control instructions in the manufacturing planning stage.

3.6.6 Product Support Services

Even after a product has been built and delivered, the obligations of the Enterprise may continue for years in the form of product support. This function is depicted by the A6 node, Provide Logistics Support, in Figure 3-5. Similar to the conversion function, product support is controlled by business directives, customer requirements and technological product and process specifications. Process specifications in this case refer to maintenance and repair processes. The output of this function includes spare parts, field support, customer training, and product documentation. Customer feedback on product performance and reliability is also obtained and provided to the Enterprise by this function.

Product suport will become increasing more information-intensive in the FoF. Electronic documentation of design and manufacturing data will be the key to improved logistics support. This improved logistics support will become more and more critical as the life expectancy, mission variability, and cost of weapon systems increase. Design information for the B-1B which is being generated today, for example, will be required for logistics support in the year 2000, and beyond. Thus, an integrated data base of product and process definition information will be as important for logistics as for the design and manufacturing functions. This also implies the need for electronic communication of geometry and textual information between the Enterprise and customer depots. Eventually, this communication link may be extended to the product itself via on-board computers and sensors.

3.7 COMPONENT IDENTIFICATION

In developing a framework for the computer-integrated Factory of the Future, we viewed the total manufacturing Enterprise as a system. We established our improvement objectives for the system in terms of reduced product cost and increased profits, improved product quality, increased human satisfaction, reduced response time, and improved manufacturing flexibility. We have also identified the expected trends in future stimuli to the factory system, including customer demands and technology advancements. These stimuli are received and responded to through the factory's interface with corporate level management, government regulators, customers, subcontractors, vendors, external information sources and society.

All systems should be based on sound principles of operation. Therefore, we identified, in previous sections, the principles of operations for the Factory of the Future. We emphasized those principles which differ from the operating philosophy of today. The application of these principles to the specific aerospace environment led to the definition of activities which must be performed to make the FoF functional.

The overall functioning of the FoF as a system can be viewed from many perspectives. From a corporate management point of view, the manufacturing Enterprise can be defined as a mechanism to convert capital investments into capital gains. (As stated previously, our objective was not just to produce short-term profits, but to provide for long-term survivability and growth.) In order to produce these capital gains, the manufacturing Enterprise was viewed as a system to convert raw materials and energy into products which can be sold to customers. Integral to this material conversion function is the capability of the Enterprise to convert basic technology into applied technology.

Traditionally, the focus of technology development has been on incorporating new technology into the product being produced. However, the FoF must place strategic emphasis on the continual acquisition and application of new manufacturing technology. At one time, the structure of the "factory system" was viewed as being relatively static with its output only being affected by customer needs. Now we see a very dynamic "factory system" which is continually changing and restructuring itself to provide a competitive advantage by leveraging manufacturing technology as well as product technology. This dynamic FoF system can be viewed as a mechanism to acquire, use, and release physical resources, e.g. facilities, production tools and equipment, and computer systems. It can also be viewed as a mechanism for acquiring, using, and releasing human resources.

With these concepts in mind, the FoF system was defined in terms of components which comprised the total system. These components were defined from two views, physical and logical. (See Figure 3-6). Physical components have a material existence. They are perceptible through the senses and subject to the laws of nature. From the physical view, the FoF components are humans, facilities, material processing tools and equipment, and an information processing and communications network. Logically viewed, components are abstract. They represent the knowledge base of the Enterprise - the information and the procedures and techniques used to perform company activities.

The logical components of the FoF must be reflected in the physical components. However, they are treated separately to allow for the definition of a logical CIM framework which is independent of the many possible physical implementations. The relationship between the logical and physical components is defined by the activities of the FoF. Figure 3-7 illustrates

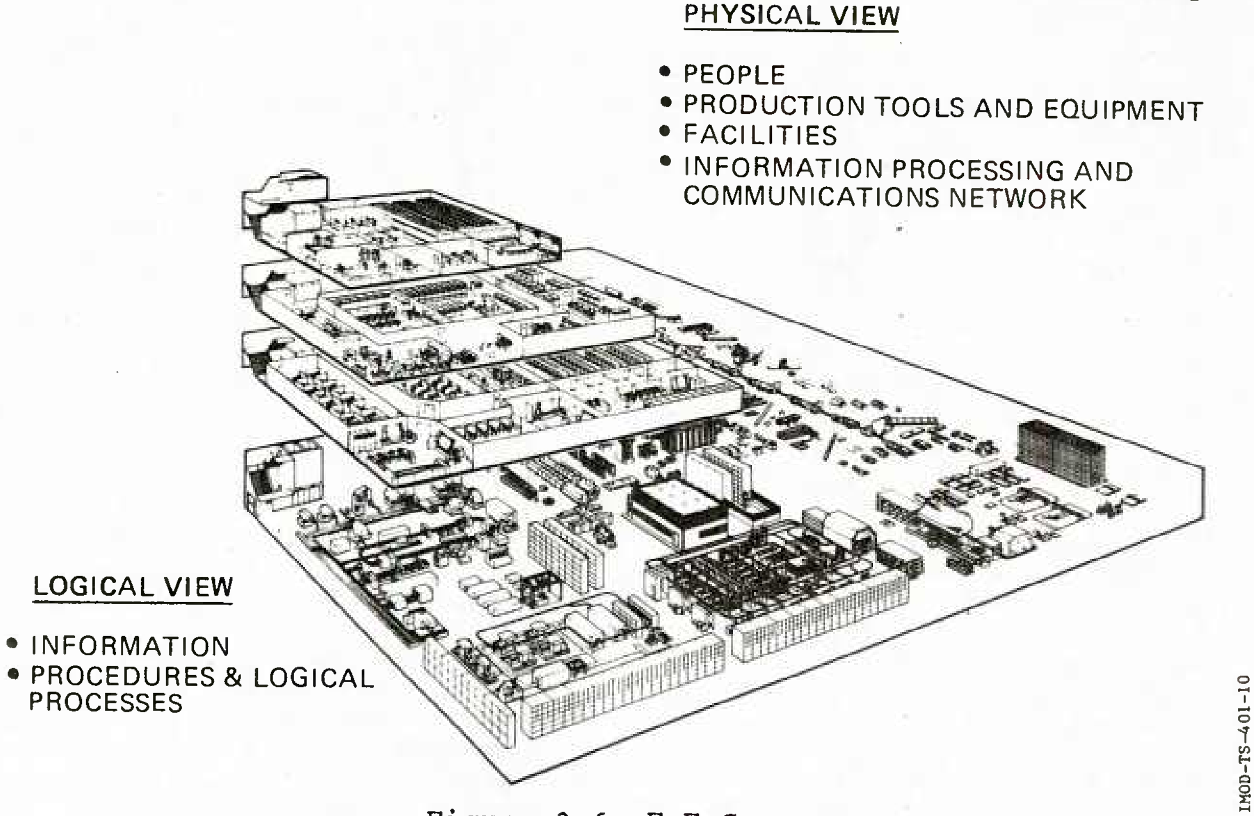


Figure 3-6 FoF Components

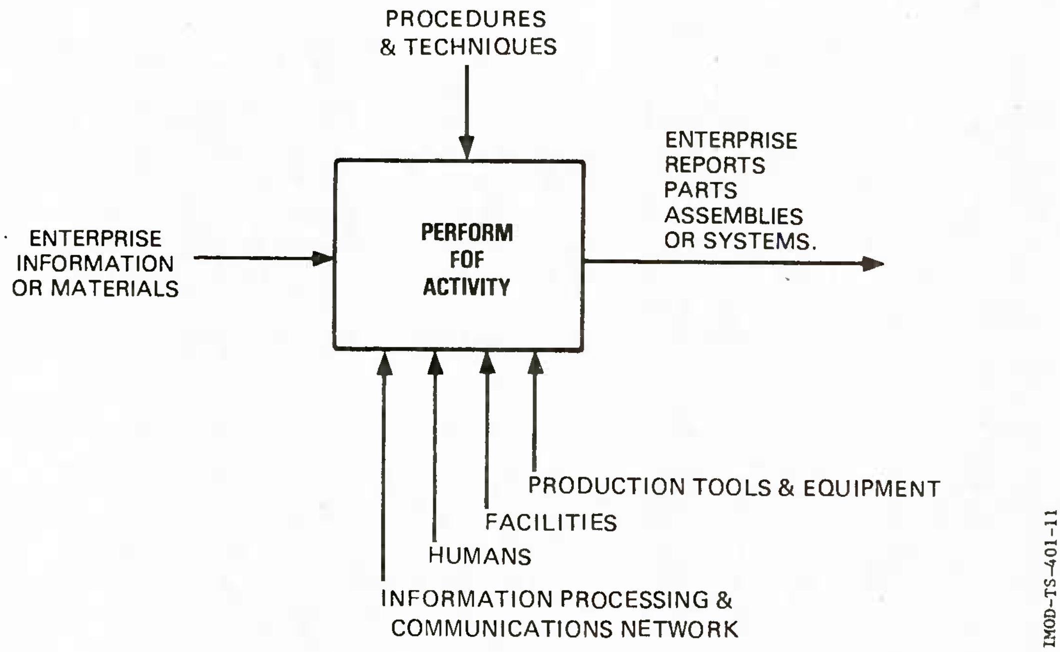


Figure 3-7 Component Relationships

that each FoF activity receives information as an input and produces information as output. The activity itself is controlled by the appropriate procedures and techniques. The mechanisms for the activity are some subset of the physical components. These include the mechanisms for input and output of the activity related information and the execution of the controlling procedures and techniques. (Although not shown in Figure 3-7, some activities may process physical items, e.g. raw material, as well as information.)

Components are distinguished from subsystems in that a component need not necessarily possess all the characteristics of a system. However, subsystems, such as an MRP subsystem or a computer-aided process planning subsystem, may be viewed as a subset of the FoF components, (i.e., a traditional MRP system corresponds to a portion of the FoF logical and physical components).

3.7.1 Identification of Physical Components

The following paragraphs briefly describe the physical components of the FoF and the roles they play in today's factory and the roles they will play in the Factory of the Future..

3.7.1.1 Humans

The human component of the FoF includes managers, technical personnel, business professionals, skilled technicians and craftsmen, office workers and general laborers. People are the most complicated component of the factory. They will be as essential to the FoF as they are for the Factory of Today (FoT). Humans cover a broad range of functions. They can perform both material and information processing functions. The human powers of sensing and reasoning are of particular importance to their role in the factory system. The other components of the FoF can be viewed as an amplification of the physical and logical capabilities of humans. The power of human resources has been further enhanced through the application of specialization and organization.

The role and organization of humans in the FoF must be redefined to take advantage of the latest advancements in material processing equipment and information processing techniques. Many previously human-performed functions will be totally automated; greater emphasis will be placed on enhancing human creative powers by taking advantage of computer-stored information processing and analysis logic. Computer-based communications will become the primary means for interaction between humans and other factory components. As a dynamically changing system, the FoF will impact individual employees and the life cycle of human organizations in order to achieve the goals of the system.

3.7.1.2 Facilities

The facilities component of the FoF includes real-estate, buildings, and general purpose support systems such as energy and environmental control. Facilities must house and sustain the other physical components; humans, production equipment, office equipment, raw material and computers. The types of facilities include: office, production, laboratory, warehouse, training, and repair. Facilities are generally considered to be fairly static in their configuration. However, the FoF will require the maximum degree of flexibility possible.

The FoF facilities layout and organization must consider the flow of both materials and information. Key issues include the optimal size of production facilities and the geographical relationships with both suppliers and the customer. The application of Group Technology will have a major impact on the internal facilities layout.

3.7.1.3 Production Tools and Equipment

The production tools and equipment component of the FoF include various devices, both fixed and mobile. They are used to move, store, evaluate, or alter material. The material which is processed by the equipment may become part of the final product, or may be subsequently used as a tool or equipment. The function of altering materials includes various forms of fabrication and assembly; evaluation includes various forms of monitoring, testing and inspecting. The equipment may have different degrees of sophistication ranging from manual operation to computer-based intelligence. The FoF will provide a framework by which the sophistication level of equipment may be increased in an evolutionary fashion which may eventually eliminate the need for human intervention between the manufacturing control structure and the equipment processing.

The life cycle for individual pieces of equipment, including maintenance and calibrating, will be managed by the FoF system. (In addition, the grouping and organization of equipment into production cells and centers must be planned and managed). Equipment for material alteration and evaluation will be physically integrated through automated material storage and moving equipment. It will be logically integrated through a factory-wide communication's network. Key issues for the FoF include considering material and information flow so that products are produced efficiently and with a high degree of quality. However, flexibility must be maintained to adjust to changes in products, technology and shifts in production volumes.

3.7.1.4 Information Processing and Communications Network

The information processing and communication's network includes various devices which store, communicate, and process information. These devices may have a varying degree of sophistication, ranging from paper-based to electrical-based to computer-based. Despite the major advancements which have been made in computer technology, the flow of most of the information in a typical company today is non-automated and relies heavily upon humans to integrate information. The FoF framework must provide an effective means of evolving toward a high degree of computer-based integration of information and the physical components and activities they support.

The information processing and communication's network component is viewed separately from the information and processing logic which it supports. While the processing logic and information itself reflects the logical aspect of the company, past, present, and future, the information processing and communication's network is merely a mechanism for coding and manipulating the information. The network may be implemented in many ways depending upon the particular needs of the company and computer technology employed.

The configuration of the information processing and communication's network must be managed and allowed to change dynamically to take advantage of advancements in computer technology. The key issues include acquiring and outputting information to and from the other physical components, integrating the flow of information within the communications network, sharing and maintaining stored information, and defining and executing information processing logic.

3.7.2 Identification of Logical Components

The following paragraphs briefly describe the components of the FoF and their roles in the Enterprise from a logical point of view:

3.7.2.1 Enterprise Information

The Enterprise information component is the logical definition of informational entities, attributes, and relationships which are required to carry out the functions of the FoF. This information represents the knowledge base of the company. Information is associated with the attributes or characteristics of each Enterprise resource and its past, present, and future life cycle events. Information is also defined by the past, present, and future logical and physical relationships between resources. Of particular interest is information which is common to more than one user, either human or non-human. The Enterprise information may be symbolically represented and manipulated by the information processing and communication's network or by humans. Information may also be manifested by other physical components, such as a template which represents the geometry of a part.

To define a framework for the FoF, it was necessary to define the logical information component of the factory. The key issues were: (1) What type of information is needed to run an aerospace manufacturing enterprise? and (2) What is the relationship of this information to the physical components and activities of the FoF?

3.7.2.2 Logical Processes

The logical processes component is the definition of the logic by which common information is processed in order for the company to operate. These processes reflect management policy and guidelines as well as the operating technological capability of the company to process, manipulate, store, retrieve and use information. Many of the logical processes can be defined independently of the information by which they operate. This defines the common logic for information processing which will support a variety of activities. This common processing logic may be combined in an hierarchical fashion to form higher level processing logic with a much broader scope.

The logical processes of the factory may be initiated and controlled directly by humans, or they may be automated through computers. The information processing and communication's network will make these automated procedures and techniques readily available to users along with the common information on which the procedures will operate. The framework for the FoF will allow for a high degree of automated procedures and techniques with the flexibility necessary to carry out the activities of the Enterprise. The key issues are identification of standard procedures and techniques and their relationship with common information, factory activities, and physical components.

SECTION 4.0

PHYSICAL COMPONENTS

4.1 PEOPLE

Probably the most important and complex physical component in the FoF will be people. Contrary to the literary comment about "peopleless" factories, we know that people will continue to play vital roles in overall factory operations in 1995.

People will be required to:

- Analyze and act upon information made available by the numerous computer-aided systems that support Factory operations
- Program, monitor, and repair the various automated machines and robotic equipment that assist in producing the product
- Accumulate knowledge and develop logic trees and algorithms that will establish the expert knowledge systems and provide the basic foundation for artificial intelligence applications
- Handle those problems or situations that are unstructured and do not lend themselves to computer analysis
- Integrate external as well as internal stimuli that affect the overall operation of the enterprise
- Advance technology as an ongoing activity.

In short, no matter how sophisticated and automated factory operations become, people will remain the ultimate mechanism to execute the functions of the Enterprise. All other components of the FoF Framework support the human effort. Figure 4-1 depicts a breakdown of the people component categories. The remainder of this section describes the makeup of the four categories of the people component and the integration of Human Resource Management in overall Enterprise strategy formulation and implementation.

4.1.1 Managerial

Every person in the Factory is a decision maker. Effectiveness can be increased by helping people make better decisions and by implementing these decisions efficiently. To provide that help to people at the operating level, a hierarchy of supervisors and managers has been established. These people fall into two Managerial categories within the FoF Framework.

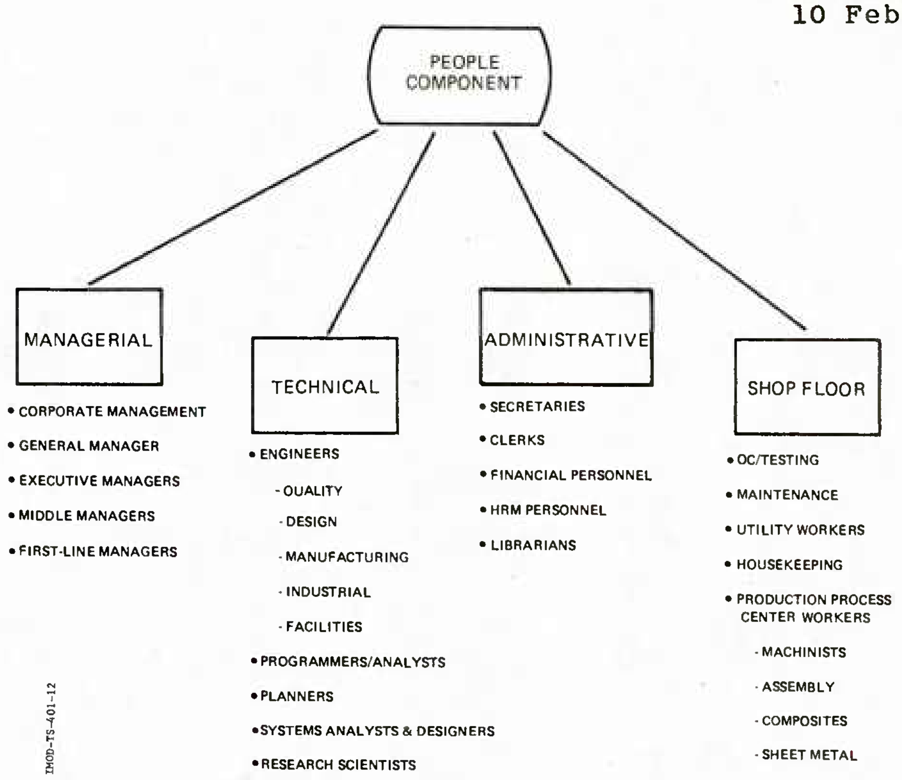


Figure 4-1. People Component of the Factory of the Future Framework

- o Those who make and execute decisions on operating matters that have been planned by Managers at higher levels - these decision-makers are administrators or supervisors.

- o Those who decide "what" shall be done (how resources shall be used). They make integrated decisions to attain balanced and optimum use of resources in achieving corporate goals - these are managers or executives.

4.1.1.1 <u>Managers/Executives</u>

Managerial characteristics for the FoF are essentially the same as those required of managers today, i.e., the ability to make decisions, leadership, integrity, intelligence, foresight, flexibility, and open-mindedness. However, four additional managerial characteristics will become increasingly important for 1995. They are:

- o Being conceptual, strategic thinkers. They must have the ability to react to any type of major change - economic, political, or social - early enough to favorably impact the business of the Enterprise.

- o Being able to cope with social forces that require changes not only in business strategy but in structure, policies, and management style.

- o Understanding government and governmental regulation and having some capacity to influence governmental actions.

- o Being able to cope with internal forces in managing human resources.

4.1.1.2 Administrators/Supervisors

Administrator/Supervisors make daily operating decisions. They are middle level managers through first level supervisors. Anticipated conditions in the FoF will require more extensive technical and social skills on their part. This will be brought about by:

- o Increased use of artificial intelligence based capabilities, office automation, common databases, and decision support

- o Integrated use of communications networks

- o The increasing number of knowledge workers and technical specialists.

In this environment, social skills and the ability to communicate upwards and downwards are essential prerequisites. It is also expected that extensive use of matrix type organizations will be made to manage large technical programs. Consequently, they must become adept at handling people with diverse talents and personalities.

4.1.2 Shop Floor

The Shop Floor category will be comprised of people we normally refer to as blue collar workers. These include laborers, production process workers (i.e., machinists, assembly workers, composites workers, sheetmetal workers, etc.) and maintenance workers. They normally populate the production centers and, in the final analysis, execute the instructions from Technical and Managerial people to fabricate, assemble, test and deliver the product.

We believe that many employees (such as machinists) who are classified as shop floor personnel in today's environment will be elevated to the Technical level in the FoF environment. An analogy of this phenomenon concerns the numerical control (NC) parts programmer and the NC machine operator. The parts programmer must exercise the skill and expertise of a machinist in developing the NC parts program, whereas the NC machine operator serves as more of a machine monitor rather than a machinist. In the FoF, the NC programmer will find that his tasks will center around developing logic and procedural guidelines for the machining knowledge base for an artificial intelligence application. Using the appropriate input data, the NC parts program can then be generated automatically.

Inspection or Quality Control is another area where present skills will be relegated to off-line programming. The "inspector" will simply monitor the output from NC coordinate measuring machines or some other type of electronically-controlled inspection device. For the most part, inspection of fabrication operations in the FoF will be in-process - that is, it will take place during the actual fabrication process. However, the certification of process equipment and its recalibration will become more important as we progress towards CIM in the 1995 Aerospace Enterprise.

Excluding assembly, most Shop Floor people will perform set-up and monitoring tasks for highly automated material handling devices. These will, in turn, support automated machine tools in a cell or FMS arrangement. As noted earlier, while these machine tools will be unmanned, humans will nonetheless serve as monitors to resolve those problems that cannot be resolved by automation.

Therefore, a higher level of technical skills will be required of the Shop Floor worker in the FoF. He must understand and monitor significantly larger portions of the production process, plus have a more integrated perspective of his job and its relationship to the entire production process. While much has been written concerning retraining the labor force for the automated factory, most experts agree that skills training must coincide with attitudes and thinking regarding the integrated nature of the work process. Conventional attitudes are deeply embedded in the cultural fabric of both labor and management and will not be easily transformed to meet the requirements of an automated factory. Thus, the retraining of personnel could become a critical factor in achieving successful factory operations in 1995.

4.1.3 Administrative

The people that comprise the Administrative category include secretaries, staff assistants, clerks, financial personnel, and Human Resource Management (HRM) personnel. These personnel deal more with the overall business operations of the factory as opposed to having specific product-oriented responsibilities. While they use the same physical and logical components as Technical people (knowledge, workstations, common data, etc.) to accomplish their tasks, they normally act in support of the Managerial, Technical, and Shop Floor people.

Typical duties of Administrative personnel include typing, dictating, filing, retrieving files, operating calculators and communicating. Traditionally these tasks have been accomplished through a number of separate manual (pencil and paper) and electrically supported (telephone, typewriter) devices. While there are also more challenging positions such as finance, legal, accounting, data librarians, etc., oftentimes those jobs become repetitious, boring and in some cases demoralizing. This is generally due to redundancy of tasks and inability to access needed data. Many of these frustrations will be alleviated in the FoF environment. Administration will make extensive use of office automation techniques such as word processing, electronic mail, voice processing, and automated calendaring, all from a single workstation. Expansion of automation to the office will be instrumental in increasing morale, productivity, and resourcefulness as more information is developed to support the Enterprise.

Once most of the activities of a job are centered on the knowledge workstation the nature of the office can be transformed in another way. There will no longer be any need to assemble all workers at the same place and time. Portable terminals and computers, equipped with appropriate software and facilities for communication, can create, in essence, a virtual office anywhere the work happens to be: at home, in a hotel, even in an airplane. The remote workstations can communicate electronically with the central office and, thus, extend the range of places where written and numerical material can be generated, stored, retrieved, manipulated, or communicated.

Micro-computer technology will make the locale or office work analogous to that of the telephone. Because of the almost universal distribution of telephones, it will no longer be necessary to go to the Enterprise office to call a coworker or customer, write or dictate a memorandum, read mail, or retrieve a file. Even in today's environment, workstations and ancillary electronic devices of an automated office are being linked to external terminals and personal computers. This will be even more prevalent in the 1990 timeframe. Administrative-type jobs will no longer be tied to the office; they will be tied to the worker personally.

4.1.4 Technical

The people within the Technical category include: engineers (i.e., design, manufacturing, industrial, facilities); data processing types such as programmer/analysts and database administrators, systems analysts and designers; scientists; and manufacturing technologists. With the exception of data processing types, the category for technical people will be comprised primarily of those that perform research, product definition and manufacturing planning activities in today's factory.

A major role for Technical people in the FoF will be in building and maintaining expert knowledge bases for artificial intelligence applications. These expert knowledge bases will essentially consist of processing logic and techniques necessary to perform various functional activities such as detail design, process planning, NC programming and facilities layout. It will be the task of the people in the Technical category to structure the logic and processing techniques for these expert knowledge bases so that when fed the appropriate input data, the algorithms can process the application in question automatically.

The people in the Technical category will carry much of the burden for making the FoF a reality. In this environment, knowledge and knowledge workers will become dominant. Obviously, knowledge has always been necessary for production; knowledge of how to perform each step in the production process, and knowledge of how to link these steps into a whole so that a planned product emerges. In the Factory of Today, this knowledge lies hidden in the minds of those workers who use it; however, in the FoF one of the tasks of Technical people (knowledge workers) will be to extract this knowledge, document it in a form that can be manipulated by the computer, then transfer it to the factory common data base where anyone with a need may access it.

Since Technical people are primarily responsible for providing Product Definition and Planning information, their roles become significantly more important as the factory environment becomes more automated. Many of the support workers and production workers as well as the automated equipment will be working directly from information and through systems supplied by the Technical people. The entire operation of the Enterprise will be more structured, leaving little opportunity for the discontinuity, confusion, and inefficiency which is commonplace in today's factories. Some of the primary responsibilities of the Technical people will include:

- Documenting manufacturing processes (this includes engineering as well as classical manufacturing processes) for appropriate computer manipulation

- Assembling of necessary data on materials, vendors, products, production processes (machining, composites, sheet metal, assembly, etc.)

- Encoding manufacturing know-how in expert knowledge systems

- Conducting research to improve product/process technology

- Maintaining, servicing, and monitoring knowledge information systems.

The integration of information, hardware, telecommunications, software and production tools and equipment will become the responsibility of Technical people. In the final analysis, they are the ones who will implement CIM once management makes the commitment to develop "their" Factory of the Future.

4.1.5 Human Resource Management

We have identified the roles of the FoF People component in terms of four basic categories (Managerial, Technical, Administrative, and Shop Floor); however, the integration of the People component with other factory elements can be more adequately discussed in terms of Human Resources Management (HRM). The effectiveness of People as valuable and essential contributors to the overall effectiveness of the Enterprise largely depends on the management of human resources becoming an indispensable consideration in formulating and implementing the Enterprise's strategy. On the operational level, HRM must satisfy immediate company needs and desires. On the strategic, level HRM must reflect the long-term goals and objectives of the Enterprise.

There are three basic things that HRM must do in the FoF to operate on the required strategic level to best serve Enterprise objectives. They are:

- Encourage strategic thinking within the different activity units of HRM. Managers must be educated to the realities of corporate planning. They must constantly monitor trends (and technological advancements) in terms of their consequences on the company's human resources.

- Link the activities of HRM functions to the strategic plans of the company. Interaction with executive managers preparing strategy is essential.

- Build a sufficient information base to provide necessary HRM projections to support the business and corporate plans.

The 1105 Task B System Requirements Document notes that a key element for facilitating the integration of Human Resources and new technology or new systems development and implementation is an activity called: "Conduct HR Research and New Program Development." While this may provide guidance in a manager's effort to boost productivity, humanize work content, or introduce new management techniques, the primary objective is to reduce the trauma experienced by employees who are affected by new technologies or systems implementation. To accomplish this, the principal requirement will be to represent the "human factor" in the design, development, and implementation of new technologies and systems. Although some attempts to consider the human element in system implementation have been made, such an undertaking in the Factory of the Future is mandatory. Some of the tasks included in this activity include:

- Analyzing and designing the content of new jobs to provide challenging work
- Developing an approach for introducing new technology to the workers; developing and providing appropriate mechanisms to facilitate implementation
- Determining skills requirements for new systems
- Assessing the retraining of existing workers for jobs created by new systems, versus hiring skilled personnel
- Determining the number of displaced employees (where displacement means employee reassignment)
- Coordinating the absorption of displaced employees
- Assessing the necessary training requirements - this will involve:
  - Training present workers to handle jobs related to new systems
  - Retraining displaced workers;
  - Familiarizing those involved with new equipment, new technologies, and new systems
- Coordinating with the Staffing and Compensation function in determining new job classifications and salary levels
- Developing and using positive reinforcement programs to overcome the natural resistance to change
- Providing the communication link between Systems Design and Implementation teams and the affected employees; coordinating employee participation in system design.
- Stressing use of an implementation timetable that is purposefully gradual
- Defining, in detail, jobs to be performed and the environment in which they will be performed
- Defining, in detail, the future state (new systems), the present state (existing systems), and planning and defining the transition phase between the two

- o Translating the technical language of computer specialists into information that can be clearly and easily understood by persons lacking special knowledge of the area
- o Ensuring that employee suggestions and comments are used in the development of new systems
- o Scheduling demonstrations (even at incremental stages if necessary) of new equipment and systems as soon as feasible
- o Arranging and conducting regularly scheduled meetings and shop floor "rap sessions" to disseminate pertinent information to all concerned employees and to gather their thoughts and suggestions on new systems
- o Advising Staffing and Training functions regarding testing for their ability to handle new technology jobs.

4.1.5.1 Training

There is no question that the manner in which an Enterprise handles training and retraining of employees will determine the ultimate success of the FoF. CIM will bring about a change in job content and structure, and the vast majority of these jobs must be filled through retraining existing personnel. Training will be required for all levels of personnel. It is not just for the employee who must operate new machines, utilize new systems, and/or interact with new data processing tools to carry out new job responsibilities.

Basically, two types of education are needed. The first involves making employees aware of the need for further education and training; the other involves the actual education and training program. If employees are made aware of the importance of taking advantage of educational and training programs, they will seek such training, thus making the impact of new technology implementation much less traumatic.

The major differences that will set apart Training in the FoF from Training in the FoT will be that of increased interaction with Human Resource Planning and with functions outside of HRM. The training-prior-to-need aspects of mid- and long-range planning are also of major importance.

Training will become an essential requirement within HRM. It will involve more employees than ever before. The assistance of computer-aided instruction will become mandatory. The current reactive mode of operation must succumb to a well-planned, detailed, and constantly-reanalyzed and reoriented function. Training activities must:

- o Develop and constantly refine mid- and long-range training requirements, in coordination with functional management and Human Resource Planning. This will include:
  - Development of an interface to new technology and systems implementation to determine inherent training needs. These will include determining the most appropriate method for handling displaced employees, the best approach in gathering the necessary skills to complement the new technology, and department-specific reorientations.
  - Familiarization with the overall strategic business plan for the company.

- o Ensure that training's plans are in concert with the overall strategic business plan for the company

- o Offer classes to train workers in a variety of skills/subjects during slack working periods

- o Provide internal retraining for displaced workers

- o Educate all employees regarding:
  - Communications skills (upwards and downwards)
  - Further acceptance of responsibility and decision-making capabilities, in light of new management styles
  - Computer installations and computer literacy.
  - Career development, self-education, and skill development

- o Operate training courses designed to develop skills of employees displaced due to technology implementation.

- o Educate management regarding:
  - Improving skills in dealing with people
  - New technology and its impact upon management's job and its effects on power base and structure
  - Equipment and process technology for which they are responsible.

- o Introduce <u>extensive</u> programs to develop the computer literacy of management, including "expert systems."

4.1.5.2 <u>Unions/Management Cooperation</u>

Both unions and management must understand their own vulnerability. They must steer away from their current adversarial stances towards a more cooperative relationship of recognizing their mutual interdependence. Management and union leaders must work toward accepting the following facts:

- o The worker's welfare depends on capital formation and productivity. This largely determines how many jobs there can be, how secure they can be, and how well paid they can be.

- o Collective bargaining must be aimed at improving the competitive position of the Enterprise.

- o Wage bargaining must be linked to realistic considerations such as productivity growth, inflation rate, and domestic and international market conditions.

- o Efforts to negotiate various types of job security provisions in exchange for work rule changes, introduction of technology, and productivity improvements will become more commonplace. Unions must be willing to give up rigid work rules that lead to overmanning and inefficiency by:

  - Enlarging jobs by adding duties and eliminating unneeded jobs
  - Combining jobs or job classifications where feasible, allowing journeymen to perform helper's duties, and permitting equipment operators to run more than one machine.
  - Allowing employees to rotate jobs; permitting pay for knowledge instead of function, and allowing management to change crew structure and scheduling to cope with production changes and new technology
  - Reducing use of seniority as a selection criterion

- o Unions will attempt to introduce "Technology Stewards." Some see these stewards as a liaison between management and the shop floor, preparing the work force for introduction of new, more productive equipment. Others see them acting as the union representative in systems design.

- o The growth of participative management techniques must continue.

- o There must be renewed interest in negotiating profit sharing and cost reduction sharing agreements.

- o There must be increased emphasis on cooperative efforts during the life of a labor agreement, especially where the interests of both parties are at stake.

4.1.6 Summary

The types of people in the aerospace enterprise have been identified and their roles in 1995 have been postulated. Subparagraph 4.1.5 presented concepts regarding approaches that could ease the transition and, hopefully, avoid the trauma so frequently experienced in modernizing enterprise operations. These approaches stressed:

- o Long range planning for personnel needs
- o Developing in-house training and retraining programs
- o Revised and more flexible benefits
- o Inproved employer-employee communication
- o Employee involvement in system design
- o Union/Management cooperation.

In effect, we attempted to show that the FoF will impact employees at all levels - from the CEO down. Perhaps the greatest impact will be on middle level managers and their subordinates as efforts proceed to improve indirect labor productivity through the use of computer technology.

4.2 PRODUCTION TOOLS AND EQUIPMENT

This physical component of the FoF framework consists primarily of tools and equipment that support the various production centers (i.e., machining, composites, sheet metal, assembly). What differentiates these physical components from those associated with telecommunication and data processing equipment is that the former acts upon "material" while the latter acts upon "information." It is the integration of information handling and processing components with physical components which act upon material that demands emphasis in the FoF. Rather than perform simple move, store and process operations, Production Tools and Equipment in the mid 1990's factory will also:

- o Monitor and provide adjustments to correct deviations during the material alteration process and, in fact, perform in-process Quality Control.

- o Collect discrete processing and machine status information during the material alteration process so that historical data may be accumulated for future analysis and comparison.

- o Feed processing and machine status information back to a higher level controller (i.e., cell, Flexible Manufacturing System (FMS), or Center Level Controller) providing timely status information to support management decisions and give management overall Enterprise visibility.

- o Perform limited information processing at the machine control console for such things as adaptive control and post-processing NC centerline data.

- o Provide an automatic redundant switching capability so that if a given critical circuit goes out (which would normally shut down the machine) the production equipment can detect the defective circuit, switch to a backup and continue the operation.

Flexible manufacturing-type arrangements will be more extensive in the FoF. These arrangements effectively integrate the elements of computer-controlled machines, robotic material handling devices, and remotely guided vehicles for material handling (delivery to and from workstations). Each component is linked via computer programs and electronic controls that specify what will happen at each stage of the manufacturing sequence. Flexible manufacturing allows the Enterprise, even in today's environment, to consider vastly different strategies. Under assembly line "hard" automation, the greatest manufacturing economies are realized only through mass production. With flexible manufacturing, similar economies will become available at a wide range of production levels. Flexible manufacturing applications will permit small batch or even single unit production to be conducted efficiently. (Diversity such as this permits making different products to be manufactured on the same line thus augmenting productivity).

While physical appearances of production equipment today and that of 1995 may seem similar, the difference in capabilities will be significant. The main difference will center around the integration of various information handling and telecommunications components coupled with sensory feedback devices. This area will provide the advances in reduced production cycle times, in-process quality control, and management information visibility of the production process to provide the capability to outperform FMSs in factories of today. In fact, just as CAD/CAM integration has provided synergistic effects in design and manufacturing planning operations, the coupling of information handling components with production equipment will produce similar effects at the process level. Production equipment will begin to take on such semblances of intelligence as self-diagnosis, corrective QC action, and self-configuration. This will all take place without direct human intervention at the process level.

In a typical FoF scenario, most of the information that drives production equipment will have undergone validation, quality assurance, and machine instructions processing in upstream Product Definition and Planning activities. The resultant information that enters a production center, then, will be ready to produce the product. However, there will still exist external elements outside the control of the earlier Product Definition and Planning activities which generate production instructions. These external elements may cause deviations from the previously computed machine instructions. Thus, FoF production equipment must be capable of:

- Monitoring the actual process with the previously defined instructions
- Determining if self correction adjustments are required and if those adjustments are within its (the machine's) capabilities
- Making corrective adjustments if possible
- Ceasing processing while simultaneously notifying the control computer when the problem is such that self-corrective adjustments cannot be made
- Accomplishing all of the above actions within milliseconds.

In short, production equipment in the 1995 factory must be capable of going far beyond the common process monitoring techniques that typify today's equipment. For example, there are machines in today's factories that monitor and compare actual positions with programmed positions. If there is a deviation that exceeds a given tolerance value, the machine stops. In the FoF, machines must take the next step. They must make appropriate adjustments to compensate for the deviation (provided said deviation falls within the machine's capacity for adjustment) and continue the process operation, without human intervention.

Ongoing research in alternate manufacturing machining processes such as powder metallurgy, water jets, and lasers etc. could result in a significant change to production equipment in the 1995 timeframe. Nevertheless, production equipment that primarily does milling, drilling, bonding, forming, and cutting will still be required. Again, the main emphasis in production center operations will be to take advantage of computer technology (e.g., artificial intelligence) to drive, monitor, control and feed back information from production machines.

In discussing production equipment in a FoF environment, it seems more appropriate to talk about the equipment in terms of cellular production systems as opposed to individual pieces of equipment. We are more concerned about the control structure of the cell than specific characteristics of the various pieces of equipment that make up the cell. Thus, the control aspects of the following subsystems are of particular interest:

- o Tool-motion subsystems that move perishable tools from resharpening and tool preset areas to tool magazines of individual machines.

- o Workpiece-motion subsystems which move raw materials from staging areas to processing areas, move the workpiece between, and in and out of, individual machines, and move processed parts to stock, another process area, or to assembly.

- o Fluid-and-chip removal subsystems which move chips from the area of creation to an area where the chips may be accumulated for recycle or destroyed. This subsystem also involves cleaning and recycling of fluids.

- o Tool monitoring subsystems which monitor the development of wear and of tool-failure situations.

- o Workpiece monitoring subsystems which monitor changes in workpiece characteristics such as shape, dimensions, and surface finish.

Most of these subsystems will be integrated with the cell controller which analyzes the reported data and takes appropriate actions. (See Figure 4-2). In some cases, such as workpiece and perishable tool monitoring subsystems, analyses must be made continuously at each individual machine where corrective action will take place rather than at some higher level cell controller.

4.2.1 Maintenance

The need to have Production Equipment and Tools operational and available for production will be of paramount importance in the FoF. Just-in-time production philosophies, integration with other components, and the increased complexities of the equipment itself will place tremendous additional pressures upon maintenance operations to meet the requirements for Production Equipment and Tool availability. Maintenance technology and maintenance information systems must advance at the same pace and be incorporated into production manufacturing technologies. FoF maintenance operations will make common use of:

- o Laser Technology - This will be used extensively to check machine installations for flatness, alignment and linear motion. In addition, checks for repeatability, backlash, endplay or screwball wear, which are fairly commonplace,

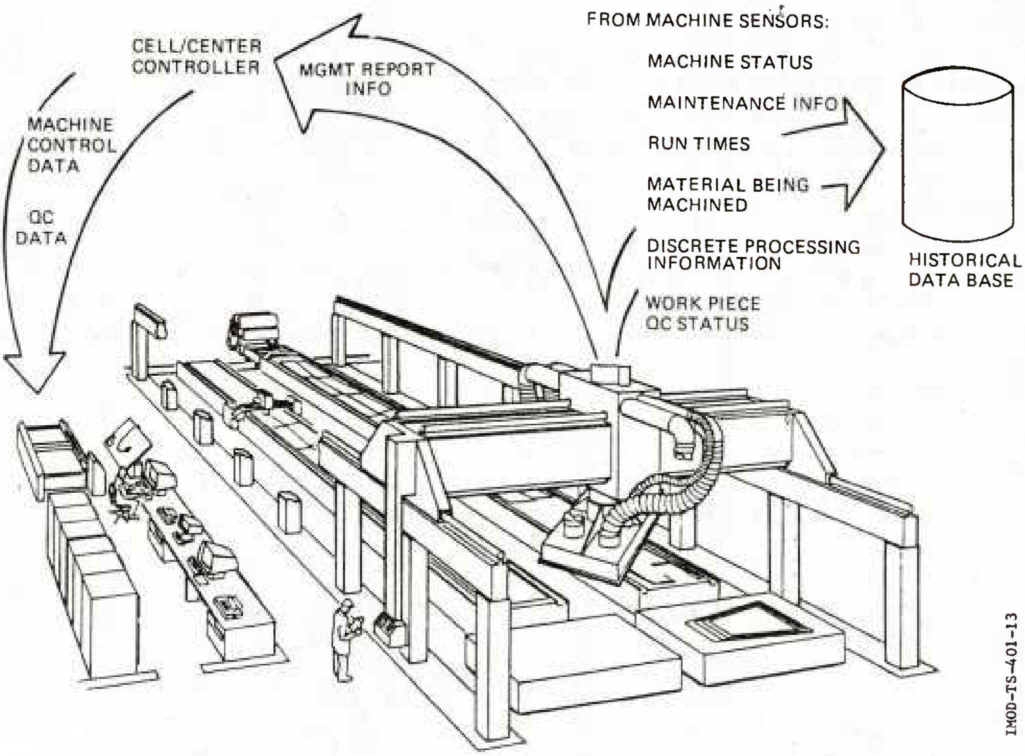


Figure 4-2 Intelligent Production Equipment With Processing Feedback

will be made easier, faster, more complete and more accurate than with methods used today. Those checks which are virtually impossible without laser technology, e.g., checking pitch and roll on transfer lines up to 100 feet long or in vertical alignment of high-rise storage areas (a typical dimension may be 80 feet high by 400 feet long) will be made quickly and accurately with lasers.

- <u>Vibration Analysis</u> - This will be used extensively in identifying stress points caused by poor alignment and improper balance. It will aid significantly in preventing premature component failure, particularly in bearings, belts, shafts and motors. Vibration analysis will be a vital part of preventive maintenance.

- <u>Infrared Scanning</u> - This technique will be used extensively in preventive maintenance to detect hot spots on equipment in operation. These hot spots will help identify potential failures.

As noted earlier, the effectiveness of the FoF is highly dependent upon the accumulation and dissemination of accurate and timely information. Despite the sophistication of the design and planning systems, if the production equipment is inoperative, the product cannot be made. Thus, effective maintenance management is imperative; it will consist of the following basic components:

- Equipment History - consisting of readily available equipment information such as:
  - Machine identification
  - Manufacturer
  - Model
  - Purchase date
  - Cost
  - Date installed
  - Installation cost
  - Location
  - Specifications

- Preventive Maintenance - consisting of a schedule and record of periodic inspection or checking of existing equipment. The intent is to uncover conditions leading to production stoppages or harmful equipment degradation and the correction of such conditions while they are still minor. An example of data elements that may comprise a preventive maintenance (PM) schedule are:
  - Calibration/certification data
  - Equipment identification
  - Job number
  - Craft code
  - Description of PM function
  - Frequency
  - Intended start date

- Maintenance Work-Order Generation to:
  - Provide authorization for the expenditure of labor and material in the performance of the work
  - Furnish records on operations performed
  - Provide formal documentation of other information such as material used, other work required, etc.

4.2.2 Quality

Despite the attention given Quality Assurance during the design and planning activities, there still remains the need for Quality Control during the actual production process. It would be remiss to discuss Production Equipment without mentioning the integration of Quality Control with the information handling and discrete data gathering components of such equipment. Since humans will have progressively less intervention at the process level, it becomes correspondingly more important to have computer-based, Quality Control components which support data gathering, analyses, and adaptive decision-making capabilities integrated into the process operation. Some of the basic functional requirements that these Quality Control components must satisfy include:

- o Incorporating measurement procedures and tolerance limits for the relevant process variables
- o Providing for process equipment software quality checks
- o Providing a mechanism for producing Quality Control data reports (i.e., periodic reports for product history and exception reports for immediate analysis)
- o Providing for immediate detection of abnormal situations and alternative courses of action to be taken during process
- o Establishing lot traceability to determine the process path of each lot
- o Improving the understanding of the cause/effect relationship which characterizes the process
- o Determining the source or cause of abnormal situations (for process variables or defects data).

In addition a historical repository of cause/effect and corrective action for non-conformance hardware will assist in preventing repeat occurrences of the failure.

Throughout much of the discussion on Production Tools and Equipment, various components were mentioned as being integrated with information handling elements of production equipment. In keeping with the philosophy of the Factory common data base (discussed in the logical components section of this document) and the logical components of which it is comprised, it should be noted that these components and elements may appear as subsystems to the user. In reality, the logic and appropriate processing techniques will be assimilated, as required, by the user or process in question. Although the resultant assimilation may have the guise of a system or subsystem (i.e., maintenance management system, QA information system), in actuality, there will be less of a defined boundary environment (due to coding structure) than in today's segmented software systems.

While all of the components of the factory are vitally important, it would seem that Production Tools and Equipment are the real bottom-line for any manufacturing concern because a manufacturing Enterprise must still produce a product. Despite how superior a design might be, or how well laid out production plans are, even despite the integration of information throughout the factory, in the end, the product must be manufactured. But, if production equipment is not as fine-tuned and well-honed as other aspects of the FoF, then all else is academic.

4.3 FACILITIES

4.3.1 Introduction

Facilities are the structures which enclose the personnel, machines, products or materials of the Enterprise. These structures include all permanent equipment such as environmental controls, communication lines and outlets, material handling equipment and waste control equipment. Facilities also include maintenance and procurement of facility equipment.

Developing facilities for computer-controlled manufacturing operations, material handling and storage systems, and control and information systems is a formidable task. Much of today's automation is not living up to its original projections for improved productivity and quality at lower costs. More often than not, inadequate facilities planning is the cause. Poor planning for automated facilities can be attributed to two main causes: First, the constantly changing and unpredictable factory environment; second, a lack of perspective on what is actually required for a totally integrated facility.

4.3.2 Computer Technology Trends

Looking at aerospace manufacturing in 1995 highlights certain significant trends in facilities design pertaining to the use of computers in the factory. At that time, the computer will affect everything in facilities construction and modification from design to controlling lights, heat, ventilation, air conditioning and facilities analysis.

The trend in computer technology is toward smaller and faster computers. For example, fixed-storage capacity quadruples every two years and microprocessor power doubles every four years. As a result, there is an ever-increasing use of computers to improve the flexibility, productivity and profitability of factory operations. This means that future facilities will have to house more computers which will require more electrical loads with a high degree of regulation and surge control to accommodate the increase. Computers must also communicate with one another and to humans; consequently, communication lines will be an inherent part of every facility design. Therefore, as new buildings are built the wiring for communications will be a requirement as stringent as the need for electrical control.

Fault-tolerant systems, another trend in hardware design, can sustain an error or hardware failure without interrupting processing. This advance is particularly significant in batch-type factories where high-volume flexible manufacturing systems depend upon on line computer systems 24 hours a day for location and delivery of material.

These computer trends highlight the need for manufacturing facilities that can provide: environmental control, wiring for communications, material movement etc., and be readily adaptable to meeting changing product and process requirements.

4.3.3 Planning for Integration

Facilities planning consists of two major activities: (1) determining the location of the facility - relative to the location of customers, vendors, and other facilities - and (2) the design for integrating the facility.

Planning for the integration of a facility can be directed at an existing facility or the building of a new facility. The proper method for planning an automated facility (even when only specific areas will be initially automated) is to develop a plan for the totally integrated facility. The facility plan can then be adjusted to automate the initial implementation areas while still maintaining the capability to fully integrate the rest of the facility at some later time.

4.3.4 Modularity and Flexibility

As with planning for integration, planning for modularity and flexibility can be in either a new facility or an existing facility. Some of the factors to be considered before modifying an existing facility are:

- o Will the foundation allow relocating of current machine tools?
- o Can the material handling system be easily rerouted and upgraded?
- o Can additional electrical outlets be installed?
- o Can network communication lines be installed?
- o Is the cost of these changes more than the cost of a new facility designed for modularity and flexibility?

Traditional concepts of facility expansion do not lend themselves to modularity or flexibility. To ensure a facility design that permits easy expansion and change, a strategic plan for that site/facility must be developed. With this plan as a basic departure point, modularity and flexibility can be emphasized throughout the design process. Several concepts that provide for modularity and flexibility are discussed in the following paragraphs.

4.3.5 Spine

The spine concept, as shown in Figure 4-3, consists of a central spine through which the various services (e.g., electricity, compressed air, telephone, local area networks, water, material handling) travel. Connected to the primary systems located within the spine are individual feeder systems that supply facility services, material handling and communications for the various cells. For future changes, only the feeder systems require expansion. The spine concept provides the opportunity to independently expand each cell without affecting any other cell, thereby maximizing facility modularity. Figure 4-4 illustrates the expansion of a spine facility.

An extra advantage of the spine concept is that less space is needed for the production area and it is less cluttered. Tools and materials are stored in the spine. These stored items can be classified as to their process and function and be retrieved as required for production operations.

4.3.6 Group Technology

Establishing a flexible production capability means creating a design that will permit a product change with little or no change to the components of the facility. One key to flexibility is the Group Technology cell concept used in manufacturing. Group Technology is a technique for manufacturing small to medium lot size batches of parts with similar processes. These parts are produced in a committed small cell of machines grouped together physically, specifically tooled and scheduled as a unit. Given the unpredictability of the future, a definite potential for increased efficiencies and flexibility exists through planning facilities that consist of Group Technology cells. The basic theory of Group Technology can also be applied to areas where moving machines and processes are prohibitive, such as paint processing. In this case, special ventilation and environmental control devices require that this process be housed in one area. By retrieving items classified and coded by paint processing attributes, batches of similarly painted items (color, primer, mask) could be grouped for processing together.

Another Group Technology approach is the virtual cell. This cell would still be scheduled as a unit but would be physically

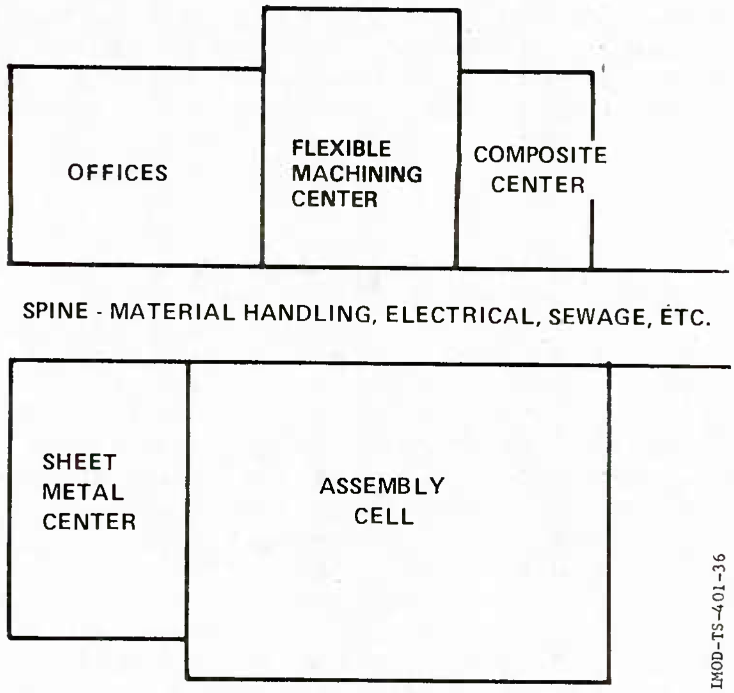


Figure 4-3 Site Plan for a Spine Facility

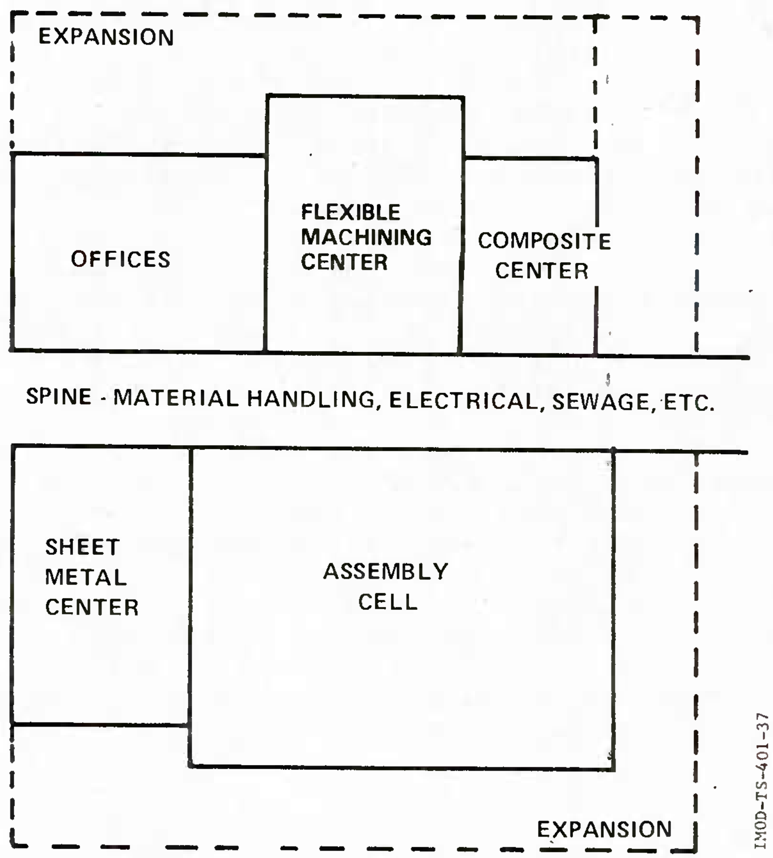


Figure 4-4 Expansion of a Spine Facility

separated. The logical connection of the processes in the cell would be linked by a material handling system that would have smart AGVs (automatically guided vehicles) to determine the optimal routes between processes. These optimal routes would be determined dynamically depending on current conditions of schedules and traffic. One advantage of a virtual cell would be the quick-grouping of the processes for the cell. Also if a process in the cell is not operating, alternative processes could be brought into the cell without affecting the schedule of the cell.

The Group Technology cell layout is demonstrated by the Japanese just-in-time (JIT) production system. Cells in a JIT system are shaped in a "U" to allow maximum flexibility of the human operator or assembler. An example of a U-shaped factory is shown in Figure 4-5. In the U-shaped GT cell, the operators operate multiple machines or assembly stations depending on the output needed from that cell for that day. As the output is increased, operators are added; fewer stations are operated by a single person. As the output is decreased, operators are removed and the remaining operators becomes multifunctional. This concept is illustrated in Figure 4-6.

The advantages of using multifunctional workers are illustrated in Figure 4-7. This example shows that by having fewer workers, productivity can be improved. It is also obvious that more machines will be needed to accomplish the same output. The Japanese approach is to buy smaller machines and develop special fixtures to reduce setup time. An example of the Japanese JIT layout philosophy is demonstrated in Figure 4-8.

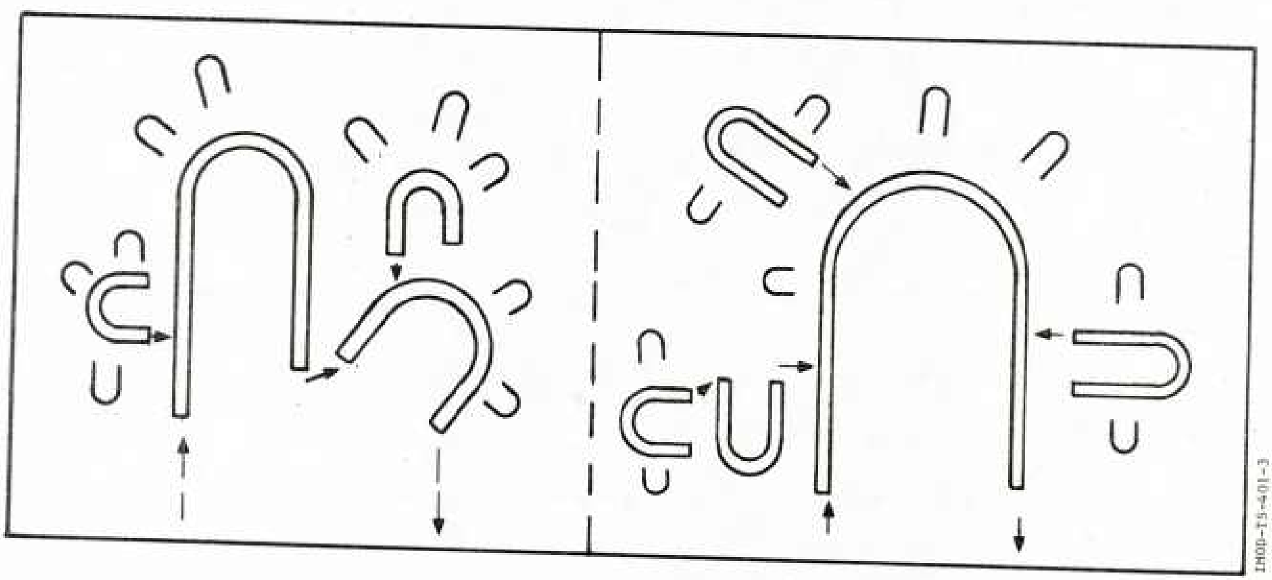
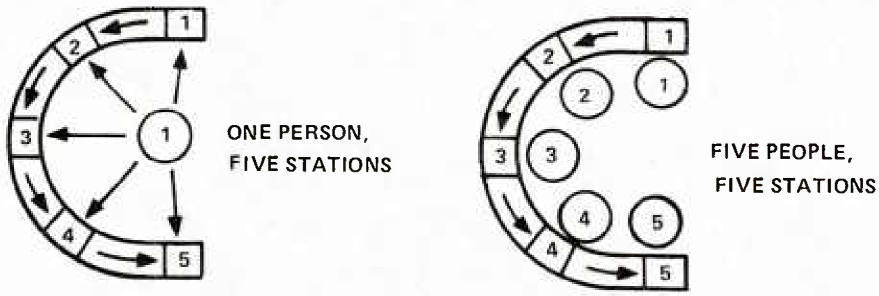


Figure 4-5. Factory U Shape Layout

SOME BENEFITS OF U-SHAPED LINES

SHORT LINES - U SHAPE YIELDS GREAT BENEFITS

- PROBLEM SOLVING OPPORTUNITIES CONTINUALLY REVEALED BY JIT PRODUCTION ARE BEST EXPLITED BY TEAMS IN G. T. CELLS.
- FLEXIBLE STAFFING--FOR SCHEDULE CHANGES AND FOR WORKER VARIETY, E.G.:



LONG LINES - U SHAPE YIELDS MODERATE BENEFITS

- SENSE OF BEING ON A TEAM
  - CATALYST FOR PROBLEM-SOLVING
  - ONE LINE (TEAM) MAY COMPETE WITH ANOTHER (OR WITH ITS OWN PAST PERFORMANCE)

FLEXIBLE STAFFING--FOR SCHEDULE CHANGES, E.G.:

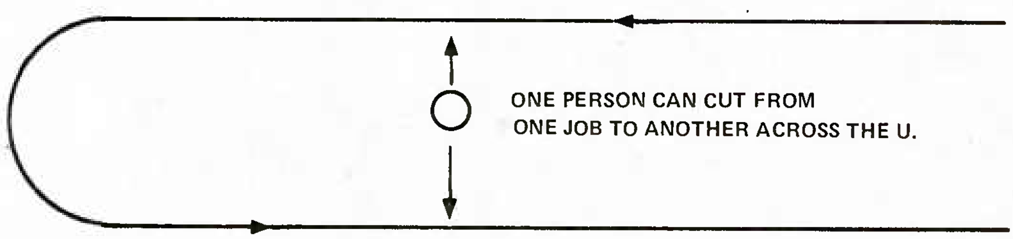


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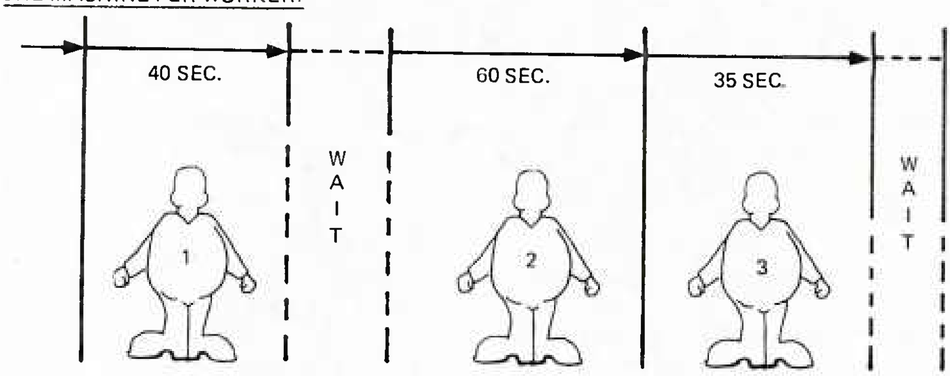
Figure 4-6. Benefits of U-Shaped Lines

MULTI-MACHINE PROCESSING

ONE MACHINE PER WORKER:

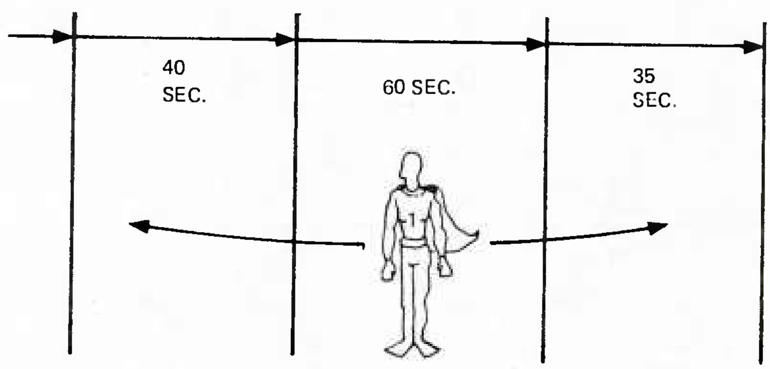


CYCLE TIME = 60 SEC.

HOURLY OUTPUT = 3600 SEC'/HR $\frac{\text{3600 SEC./HR.}}{\text{60 SEC.}}$ = 60 PCS.

OUTPUT PER WORKER = 60/3 = 20 PCS./HR.

THREE MACHINES PER WORKER:



CYCLE TIME = 135 SEC.

HOURLY OUTPUT = $\frac{\text{3600 SEC./HR.}}{\text{135 SEC.}}$ = 27 PCS./HR.

OUTPUT PER WORKER = 27 PCS./HR.

HUMAN PRODUCTIVITY INCREASE: $\frac{27 - 20}{20}$ = 35%

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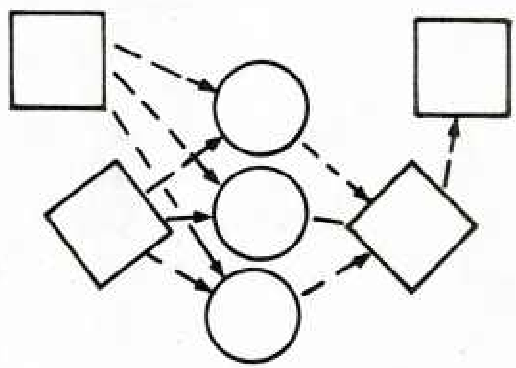
Figure 4-7. Multimachine Processing

JUST IN TIME (JIT) LAYOUTS

- AVOID STRAIGHT-LINE LAYOUTS UNLESS VERY SHORT.
- USE GROUP TECHNOLOGY (G.T.)--A CELL OF WORK STATIONS THAT PROCESS A LARGE OR SMALL NUMBER OF PARTS THAT USE THE SAME TECHNOLOGY (SAME PROCESS FLOW).
- USE U-SHAPED LAYOUTS. EXAMPLES:

*LONG LINES FED BY SHORT FABRICATION AND SUBASSEMBLY LINES

*G.T. CELL WITH VARIETY OF FLOW PATHS



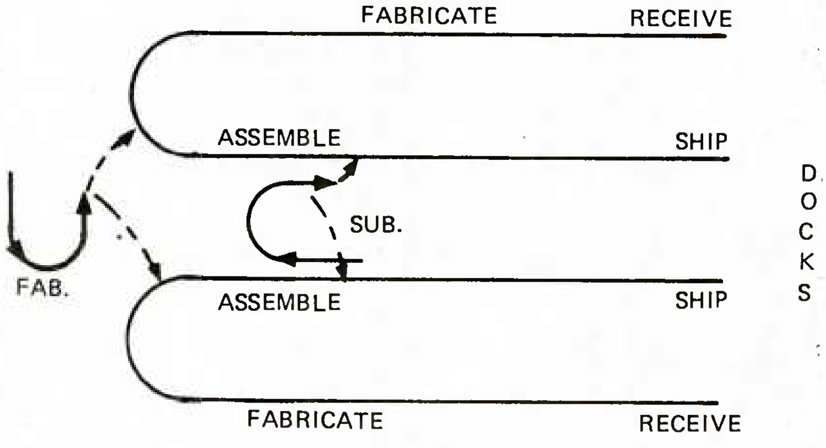


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Figure 4-8. JIT Layout Philosophy

Figure 4-9 shows how the U-shaped cell has been adapted in the United States. This example shows eight stations which are currently manned by eight people. These people have been cross-trained so that they can perform any of the assembly and test operations needed to produce a flexible disc drive. An advantage of this approach is that if only one person reports to work, the line will still operate. The Kanban squares represent the only inventory on the line; therefore, if a quality problem arises, only a small number of units will have to be reworked. Typically, the process time of any one unit is less than one hour. The yellow lights are used to signal when an operator is out of work and the red lights are used to stop the line. All operators have access to both lights.

The ultimate GT cell is called a Flexible Manufacturing System (FMS). The basic purpose of an FMS is to establish a totally integrated, computer-controlled, automated production system through the union of computers, material handling systems, and production equipment. FMS applications have thus far been limited to a few select sections of a plant; however, the FMS concept can easily be expanded to include the total factory. The most logical expansion method is to develop many small flexible systems for each group of families. The Japanese have been very successful in using this concept in just-in-time production systems. Figure 4-10 illustrates the differences in tendencies for flexibility between the U.S. and Japan.

4.3.7 Material Handling Systems

One of the most important planning considerations for the development of a facility is the material handling system. The flexibility of the manufacturing system is directly related to the capabilities of the material handling system.

The material handling system can be divided into two major components; the intercell systems and the intracell systems. Material handling equipment that can be used in an intercell handling system includes conveyors, towlines, monorails and the automated guided vehicle (AGV).

Variable-path, automated guided vehicles can be designed to provide much more flexibility than the fixed-path conveyors. An AGV can be easily programmed to follow any of numerous routings during its travel paths. In addition, the travel paths can be quickly and inexpensively modified.

The future of material handling is the smart AGV. This implies an AGV with an on-board computer to determine the optimal vehicle path using current schedules and traffic on the guide paths. Rough-cut traffic paths will be determined by the host computer controller and communicated to the AGV via radio or

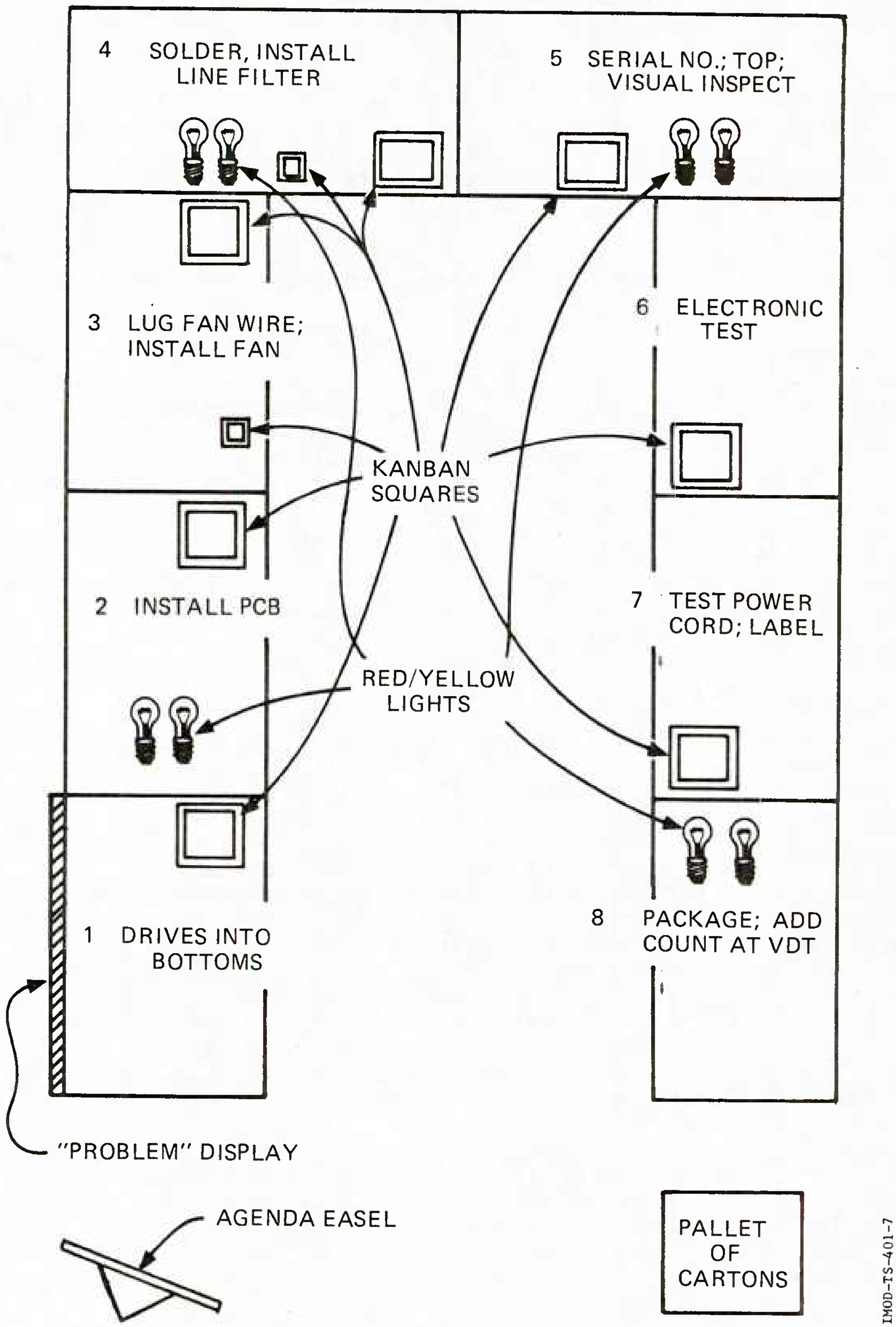

Figure 4-9. Flexible Disc Drive Line

CONVENTIONAL WESTERN TENDENCIES			JAPANESE TENDENCIES
FACTORS OF PRODUCTION	REPETITIVE PRODUCTION OR	FLEXIBLE RESPONSE	BOTH REPETITIVE AND FLEXIBLE RESPONSE
PRODUCTION EQUIPMENT/ TOOLING	SPECIAL-PURPOSE WITH PREFERENCE FOR LARGE-CAPACITY MACHINES.	MULTIPURPOSE WITH PREFERENCE FOR LARGE-CAPACITY MACHINES.	SPECIAL-PURPOSE BUT SMALL AND CHEAP MACHINES.
EOUIPMENT DESIGN AND TOOL-MAKING SUPPORT	EQUIPMENT BOUGHT FROM OUTSIDE MAKERS WHO HAVE LONG LEAD TIMES.	STANDARD, GENERAL-PURPOSE EQUIPMENT BOUGHT FROM OUTSIDE MAKERS.	SELF-DEVELOPED MACHINES.
LAYOUT AND WORKER	FLOW SHOP, WITH DEDICATED LINES.	JOB SHOP, WITH RELATIVELY FIXED ASSIGNMENTS OF SKILLED TRADESMEN.	FLOW SHOP, WITH DEDICATED LINES. G.T. AND MULTI-FUNCTIONAL WORKERS.
MATERIAL HANDLING EQUIPMENT	COMPLEX, FIXED AND AUTOMATED. G T AND MULTI-FUNCTIONAL WORKERS.	STANDARD, GENERAL-PURPOSE, AND DIVERSE.	FULLY AUTOMATED FOR HIGH VOLUME. SIMPLE AND MANUAL OTHERWISE.
PRODUCT DESIGN	RIGID, INFLEXIBLE, WITH DESIGNERS ISOLATED.	MODULAR, PARTLY STANDARDIZED, WITH DESIGNERS ISOLATED.	MINIMAL SPECIFICATIONS BUT GREAT STANDARDIZATION; DESIGNERS ON SHOP FLOOR.
PLANNING AND CONTROL SYSTEM	REDUNDANCY AND EXCESS AS COPING DEVICE.	OFTEN COMPUTER-BASED.	PROBLEMS SOLVED AT THEIR SOURCES PERMIT SIMPLE PLANNING AND CONTROL.
ADMINIS-TRATIVE TIME TO CHANGE PRODUCTS AND CAPACITY	FAST DECISIONS, BUT RIGIDITY OF PRODUCTIVE CAPACITY MAKES IMPLEMENTATION SLOW AND ERROR-PRONE.		DECISIONS MAY BE MADE AND IMPLEMENTED OUICKLY BECAUSE FLEXIBLE PRODUCTIVE CAPACITY PAVES THE WAY.

Figure 4-10. Flexibility: Western versus Japanese Tendencies

microwave or the guidelines. The AGV would then query the host to establish current traffic paths being used and determine its optimal path and schedule to the delivery station. Each AGV would transmit each change of its path to the host, thereby keeping all vehicles updated as to the traffic patterns.

Conveyors do not have the same capability as they are inflexible and inherently dumb. One other major drawback of conveyors for medium and long distant material movement is that there can be a lot of in-process inventory stored on them. In Japanese factories, conveyors are only used for short movement such as within cells.

Towlines and monorails are expensive to reroute. They will eventually have little role to play in the factory of 1995. There will still be a need for overhead cranes to move heavy assemblies, and this may become the prime application of monorails.

A significant trend in material storage will be the abandoning of large automatic storage and retrieval systems (AS/RS) and stacker cranes. As the factory reduces lead times, inventories and lot sizes, the need to store material will be reduced. This trend can already be seen in high volume U.S. plants using Japanese JIT techniques. It will eventually become standard even for custom-made products.

New facility concepts that provide flexibility and modularity for computer-integrated plants are the spine concept for site development, the Group Technology cell concept for facility layouts, and the FMS concept for production systems. Integration of all of these concepts is required to develop computer-integrated manufacturing facilities that are more effective and economical than conventional systems. It will be very difficult to adapt current aerospace plants to these concepts. For the most part, such adaptation probably should not be attempted. Therefore, building new facilities to replace older facilities should be considered first.

4.3.8 Energy Management

Since 1972, industry's energy costs have risen eight to ten fold. The rate of increase will probably lessen, but is expected to remain higher than the overall rate of inflation. Companies that recognized the potential of energy management and launched programs early have achieved energy cost savings of 15 to 25 percent with very little effort and expenditure.

Energy management is the judicious use of energy to reduce costs and enhance the company's competitive position. Thus, energy management includes any energy-related activity that directly affects cost.

Several case studies have shown that when energy management is considered in a factory's design phase, normal energy use can be significantly reduced.

Examples of these opportunities are:

- Most automatic fabrications, process or material handling systems usually have low personnel densities. With fewer people working in the immediate area, less lighting, ventilation and space conditioning levels can result in immediate large savings.

- The planning required for large factory systems allows designers to carry out energy management strategies prior to system installation to avoid later costly construction charges.

Energy sources in the future will most likely be a combination of current energy sources (hydroelectric, coal, gas, nuclear) and new technology sources (geothermal, photovoltaic, wind, solar, electrochemical). The cost of current sources will rise as these fuels are depleted, but the new sources however, promise the possibility of cheap energy in abundant supply in the future. It is not possible to predict the future of energy sources because of the sporadic research that has been and is being done.

4.3.9 Lighting

Lighting for factory operations is also a high-cost item in the Factory of the Future. Table 4-1 lists recommended light levels for various types of spaces. Lighting needs occur, for example, when maintenance is required or when there is a quality problem. This intermittent need offers the potential for selective light switching.

Table 4-2 presents the characteristics of the most common light sources. The basic procedure in lighting systems design is to identify two or more alternative sources to provide the required light levels, research the various fixtures and wattages available, and design the system to provide the necessary lumens at minimum cost.

Heating, ventilating and space conditioning requirements in the Factory of the Future will be predicated on the available BTUs. Each BTU will be used to heat, cool or ventilate at its maximum efficiency. The source of the BTUs will be a combination of wind, sun, thermal and fossil fuels.

Table 4-1. Recommended Illumination Levels for a Variety of Space Types

Building/Space Type	Guideline Illumination Range (footcandles)
Commercial Interiors	
Art galleries	30–100
Banks	50–150
Hotels (rooms and lobbies)	10–50
Offices	30–100
Restaurants (dining areas)	20–50
Stores (general)	20–50
Merchandise	100–200
Institutional Interiors	
Auditoriums/assembly places	15–30
Hospitals (general areas)	10–50
Labs/treatment areas	50–100
Libraries	30–100
Schools	30–150
Industrial Interiors	
Manufacturing areas	50–1,000
Ordinary tasks	50
Difficult tasks	100
Highly difficult tasks	200
Very difficult tasks	300–500
Most difficult tasks	500–1,000
Exterior	
Building security	1–5
Floodlighting (low/high brightness of surroundings)	5–30
Parking	1–5

Source Energy Management Handbook, *ed, W.C. Turner (New York: Wiley Interscience, 1982).*

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Table 4-2. Comparison of Light Source Characteristics

			High-Intensity Discharge			
Characteristics	**Incandescent, including Tungstan Halogen**	**Fluorescent**	**Mercury Vapor (Selt-Ballaated)**	**Matal Hallda**	**High-Pressure Sodium (improved Color)**	**Low-Pressure Sodium**
Wattages (lamp only)	15–1,500	15–219	40–1,000	175–1,000	70–1,000	35–180
Bulb life (hr)*	750–12,000	7,500–24,000	16,000–15,000	1,500–15,000	24,000 (10,000)	18,000
Efficiency (lumens/W) lamp only*	15–25	55–100	50–60 (20–25)	80–100	75–140 (67–112)	Up to 180
Lumen maintenance	Fair to excellent	Fair to excellent	Very good (good)	Good	Excellent	Excellent
Color rendition	Excellent	Good to excellent	Poor to excellent	Very good	Fair (very good)	Poor
Light direction control	Very good to excellent	Fair	Very good	Very good	Very good	Fair
Source size	Compact	Extended	Compact	Compect	Compact	Extended
Relight time	Immediate	Immediete	3–10 min	10–20 min	Less than 1 min	Immediate
Comparative fixture cost	Low, simple fixtures	Moderate	Higher than incandescent and fluorescent	Generally higher than mercury	High	High
Comparative operating cost	High, short life and low efficiency	Lower than incandescent	Lower than incandescent	Lower than mercury	Lowest of high-intensity discharge types	Low
Auxiliary equipment needed	Not needed	Needed, medium cost	Needed, high cost	Needed; high cost	Needed, high cost	Needed, high cost

Note:
*Life and efficiency ratings subject to revision.

Source Energy Management Handbook, *ed, W.C Turner (New York: Wiley Interscience, 1982).*

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4.3.10 Maintenance and Housekeeping

There are two main reasons for keeping a plant clean: quality and safety. Inasmuch as good housekeeping is considered a contributor to good quality, housekeeping responsibility must reside with those who have quality responsibility. As discussed earlier, the Factory of the Future will require workers to be flexible; therefore, it will become common for the workers to do their own cleaning and facility repairs. If the U.S. aerospace industry is to match the Japanese in quality control, the good housekeeping concept must be a prerequisite.

To produce the best quality products, daily machine maintenance is a must. For example, a pilot of an airplane would never fly the aircraft until he is satisfied that all gauges, instruments and structures work properly. The machine operators of the Factory of the Future will have to take the same careful precautions before starting production each day. The Japanese have already learned this. The first thing each morning, the machine operators go through a checklist, assuring that the machine functions correctly. Oiling, adjusting, tightening and sharpening preceeds the start of work. Daily machine checking is routine for those workers whose first priority is quality.

4.3.11 Summary and Prediction

The conclusions to be drawn are that companies that thrive on change will survive; those companies that resist change will die. These conclusions come from many sources and many disciplines. The interpolation to this prediction is that companies must do more than allow change. They must find new ways to make changes faster. The following predictions are taken from a presentation given by William H. Slautterback at the annual 1983 membership meeting of CAM-I titled "Manufacturing Environment in the Year 2000."

"Utilization of facilities will become increasingly important as emphasis on manpower is decreased. The investment in the unmanned work cell of the Factory of the Future will demand utilization 24 hours a day, 365 days per year. This will be brought about by the high investment necessary to automate a cell with robotics and FMS.

Plants will become smaller and strategically placed to be close to their markets. The plants will be multi-product operations due to the increased flexibility of the equipment. Due to the reduced lot sizes and reduced lead times, inventories will decrease drastically. All of this means that warehouse and distribution companies or centers will decrease substantially."

As we (the Task B Coalition) look into the future for aerospace facilities, we see one emerging theme: a comprehensive corporate plan is essential to achieve the needed benefits of computer-integrated manufacturing.

As was once said, "If you don't know where you are going, any road will take you there."

4.4 Information Processing and Communications Network

4.4.1 Identification

The Information Processing and Communications Network (IPCN) in the FoF is an integrated mechanism to receive, store, communicate, process, and display information of all types and forms. An IPCN is used to house all enterprise information and provides tools to automate the factory operating procedures. It is physically linked to every information source or user both human and non-human, in the FoF. Physical resources are logically integrated by the IPCN through the sharing of common information and procedures. Although the IPCN is used to physically implement the enterprise information structure and operating procedures it must be viewed separate from these logical components. Paragraph 4.4.3 discusses how balance is maintained between the IPCN and the logical components of the FoF. The IPCN will continually evolve to take advantage of new computer technology, digital communication technology, and communication media to improve efficiency; on the other hand, the configuring of the enterprise information structure and operating procedures will be driven by the business needs of the FoF.

Despite the major advancements in computer technology, the flow of most of the information in a typical factory of today is non-automated. Information flow within a particular application may be automated, but humans are relied on to integrate and communicate information between a variety of application systems. See Figure 4-11. The boundaries of application systems are defined by the automation of specific activities performed by a specific group of users. The application system typically uses its own independent IPCN and automates a relatively small portion of the enterprise information structure and company operating procedures. Many companies have built automated interfaces to dump information from one application system into other application systems. Although this is better than totally independent applications, it does not satisfy the need for total integration. Some companies have begun replacing groups of applications with a single application of much broader scope. For example, engineering design analysis programs have been incorporated into CAD systems which are, in turn, being incorporated into integrated CAD/CAM systems which are significantly more automated and integrated.

Ultimately, the boundaries of application systems, as we know them today, will disappear through the total sharing of common information and operating procedures. Recognizing this goal, the FoF IPCN will consist of data storage, data processing, and user access nodes tied together on a factory-wide basis via common communications channels. See Figure 4-12. Although data may be

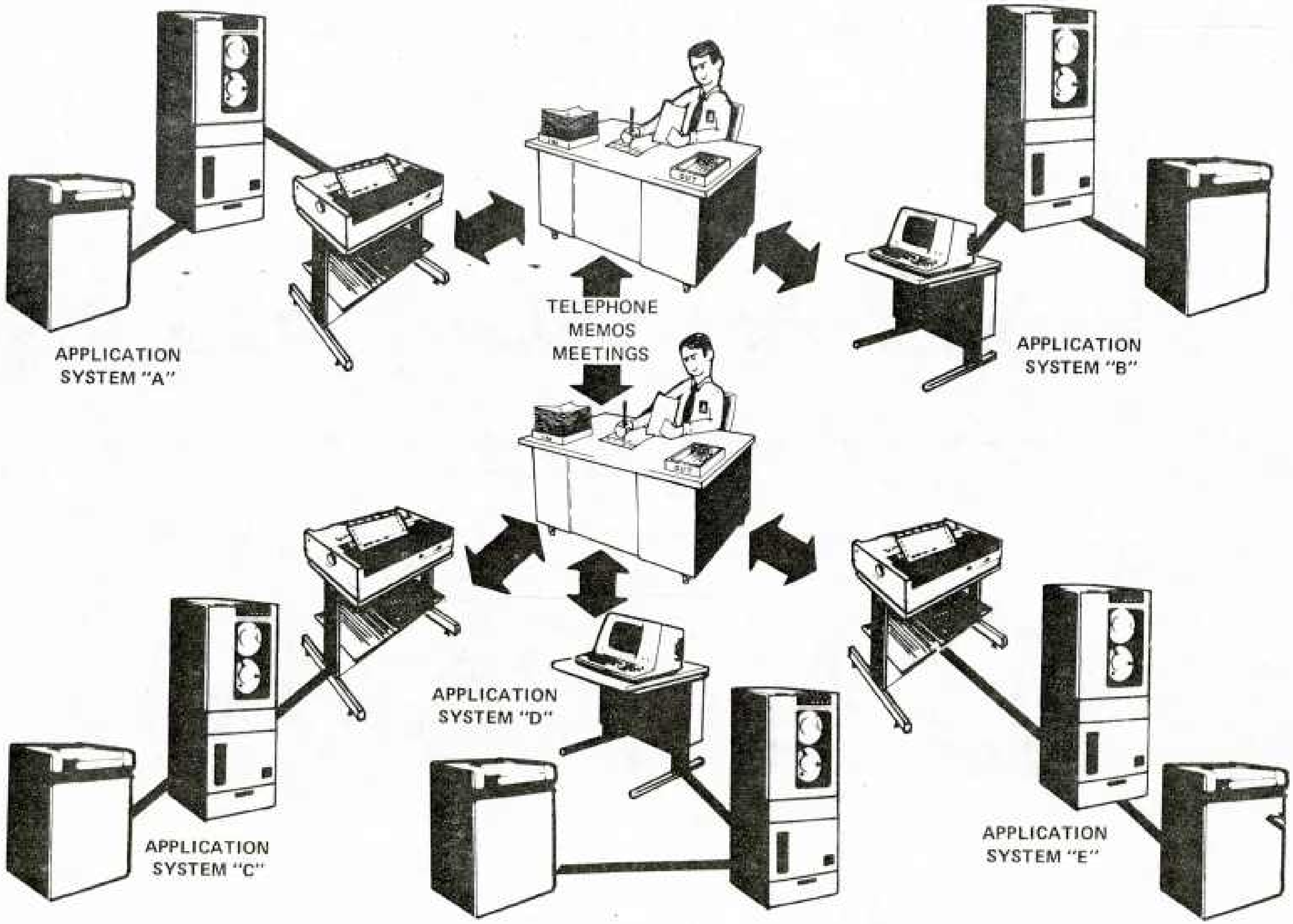

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Figure 4-11 FOT INFORMATION & COMMUNICATION NETWORK

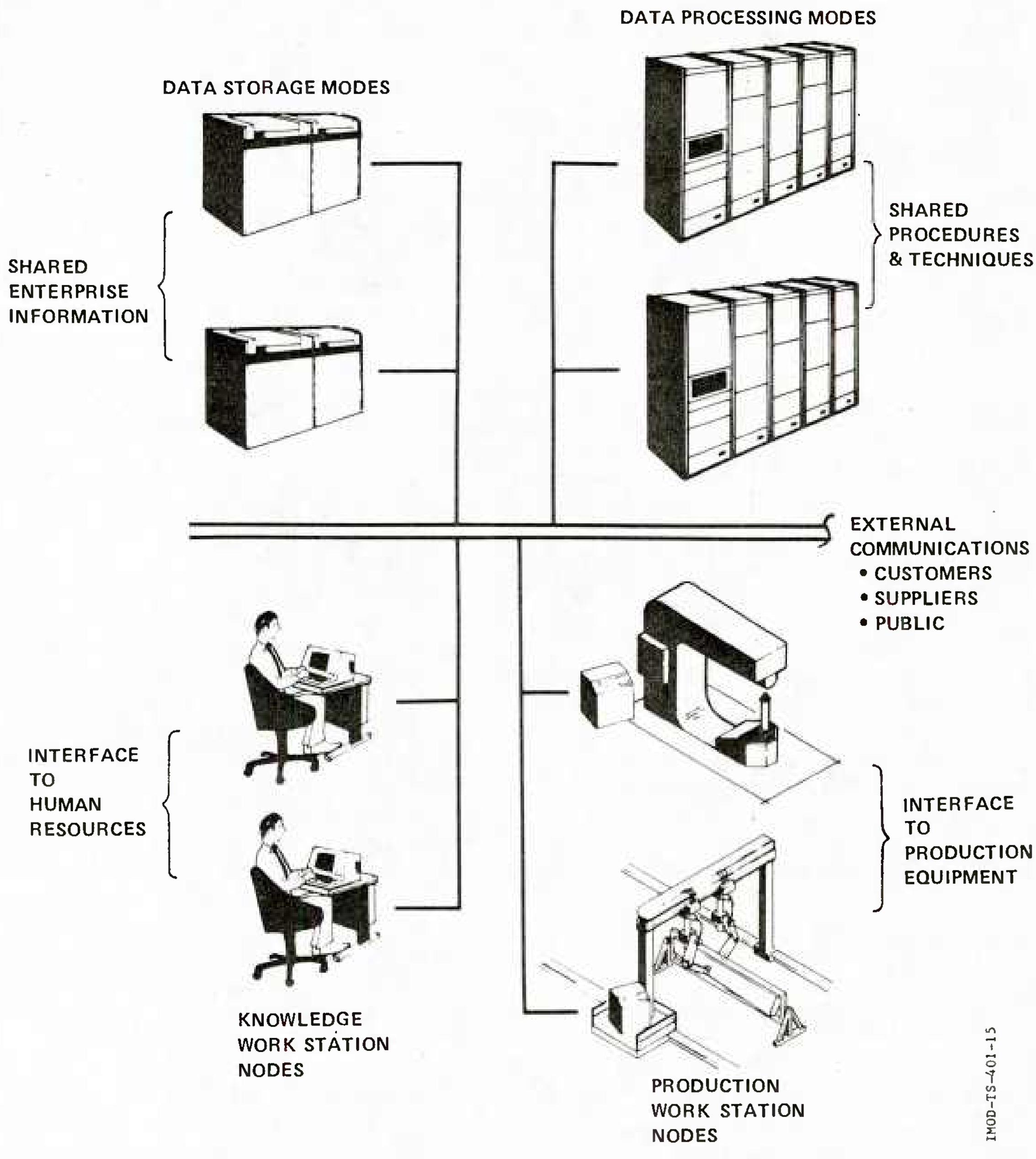


Figure 4-12 FoF Information Processing & Communications Network

physically stored in a variety of locations, all update and access to common data is controlled by an Integrated Data Manager which provides factory-wide coordination of local data base management systems resident at individual nodes. This Integrated Data Manager consists of a common data model and data base transform engine which are described later. Data processing nodes consist of shared computer processors for executing automated procedures. The automated procedures are logically separated from the information they process and common procedures may be resident in multiple processing nodes. An Integrated Process Manager coordinates the library of procedures on a factory-wide basis. User access nodes may be either knowledge workstations for human users or production work stations for material processing equipment. This single integrated IPCN for the FoF then becomes the mechanism to support all information applications throughout the factory. In addition, to providing the means to integrate today's independent computer application systems, the FoF IPCN will also integrate all electronic-based communication including telephone systems and video broadcasts.

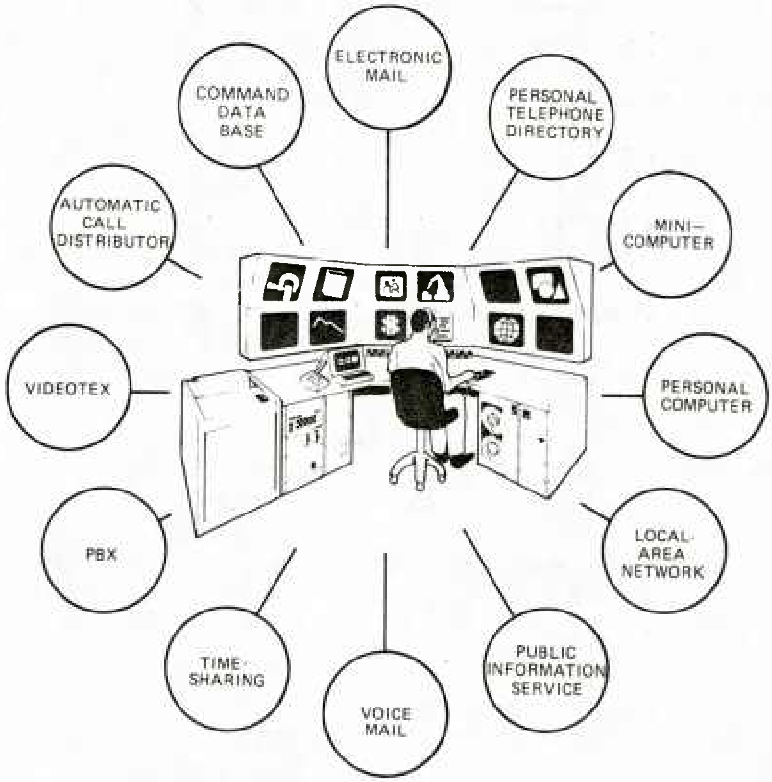
The goal for the FoF IPCN is to have a totally paperless environment including totally electronic-based communication with customers, suppliers, and external information sources, e.g. library data bases and public communication systems. However, printed materials will probably coexist in the new electronic environment for many years to come. Regardless of the particular storage medium and communication mechanism used, an integrated approach to the IPCN must be established for the FoF.

4.4.2 Functional Description

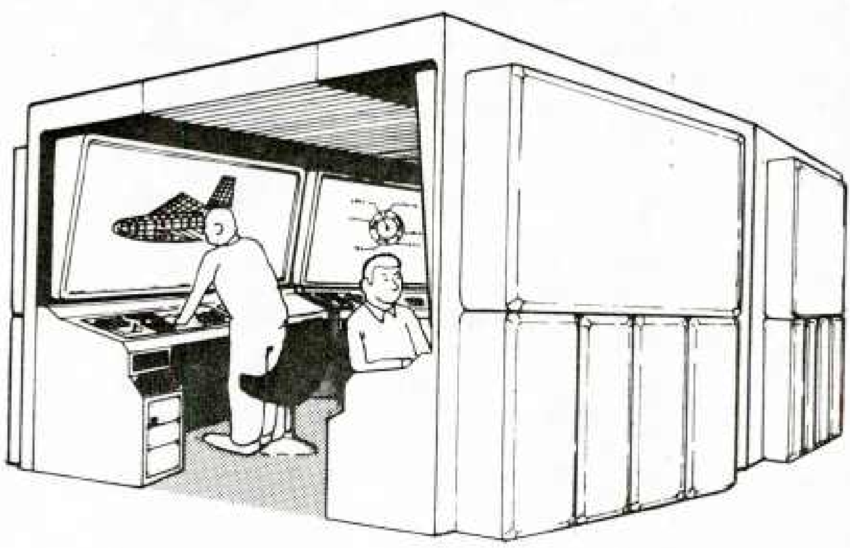
The FoF IPCN must provide a communications and information processing tool which can be used to satisfy the requirements for each needs category as defined by the System Specification document. Basic functions of the IPCN include interaction with information sources/users, communication of information, information storage, and information processing. These functions are described below.

4.4.2.1 Interaction with Humans

Humans will interact with the FoF IPCN via workstations which will support a variety of information based activities, referred to as knowledge workstations. See Figure 4-13. Each knowledge workstation will have some local data processing and storage capability to support private or temporary information. These workstations are discussed further in later paragraphs. All humans will have access to the IPCN via these knowledge workstations to perform the following types of functions:



IDEAL EXECUTIVE WORKSTATION



IDEAL ENGINEERING WORKSTATION

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Figure 4-13 Knowledge Workstations

- o Electronic mail for both internal and external communications
- o Voice communications replacing current internal telephone systems and eventually expanded to video communications
- o Teleconferencing combining video and graphics communication for multi-user interactions
- o On-line access to both internal and external video program libraries
- o On-line access to both internal and external library data bases
- o Access to public communications networks
- o Definition and invoking of structured decision making procedures that access both common and private information (equivalent to current application programs written with procedural languages)
- o Definition and invoking of semistructured decision-making procedures which interact with a human decision-maker or use artificial intelligence software with stored reasoning logic
- o Definition and invoking of ad hoc data base queries and information analysis using a non-procedural language to support unstructured human decision making
- o Expansion and refinement of the defined enterprise information structure and operating procedures
- o Custom formatting of information input and output.

4.4.2.2 Interaction With Production Equipment

Production tools and equipment may also interact directly with the IPCN via production workstations. The production workstations may range in sophistication from one or more monitors or sensors, which basically provide one-way communication, to a computer-based controller which, through artificial intelligence, may actually generate ad hoc queries. Production workstations will be used to perform the following types of functions:

- o Serve as a knowledge workstation for humans supervising the processing of the equipment

- o Downloading of part definition and work instructions to drive material processing activities, including test and inspection, material handling, and material storage processes as well as fabrication and assembly processes
- o Provide automatic feedback on material location and status
- o Provide automatic feedback on the maintenance and usage status of tools and equipment
- o Generate requests for other resources, either human or automated equipment, when needed
- o Invoke structured decision-making procedures
- o Invoke artificial intelligence logic for semi-structured decisions
- o Invoke ad hoc data base queries to support local artificial intelligence capability.

4.4.2.3 Communications Functions

An essential capability for achieving an integrated environment is the ability to move data or information quickly and efficiently between various nodes of the IPCN. The old methods of moving data by word-of-mouth and the physical flow of paper will be replaced by electronic communications in the FoF. Electronic communication may be transmitted in a variety of ways using various forms of data and protocols. The IPCN must provide common communication channels throughout the manufacturing enterprise which will perform the following functions:

- o Provide internal communication linkage to all:
  - Knowledge workstations
  - Production workstations
  - Data storage nodes
  - Data processing nodes
- o Provide external communication linkage to:
  - Customer IPCNs
  - Vendor and supplier IPCNs
  - Public IPCNs and broadcast stations
  - Public library data bases
- o Guarantee and verify message delivery
- o Accept data in a variety of logical and physical protocols

- o Translate senders protocol to receiving protocol automatically
- o Communicate over both short and long distances
- o Automatically convert between various forms of transmission (e.g. wire to microwave and back to wire again)
- o Carry audio, video, and digital communication signals.

4.4.2.4 Data Storage Functions

The ability to store data must exist throughout the IPCN. Each workstation node must have some local data storage capability to buffer messages and to support local data processing. The communication channel itself serves as a data storage mechanism when the data is in transit. Similarly, the data processing nodes store data as an integral part of the processing function. However, the primary data storage functions will be performed at the data storage nodes. Data storage nodes may range in sophistication from a magnetic tape library to a special-purpose data base machine with associative memory. The data storage functions of the IPCN include the following:

- o Flexible update and retrieval of stored data
- o Automatic translation of logical data views to physical data storage structures including decomposition and aggregation of queries against geographically dispersed data bases
- o Automatic transaction recovery and restoration of lost data
- o Data security enforcement
- o Data integrity checking
- o Data management and control including data versioning and archiving
- o Uninterrupted addition of data types and logical relationships
- o Storage and retrieval of audio, video, and digital information
- o Execution of both ad hoc and structured queries.

4.4.2.5 Data Processing Functions

Similar to the data storage function, the ability to process data must exist throughout the IPCN. For example, each workstation node will have some local data processing capability to support user interaction and personal computing. Data processing capability is also required to manage each data storage node. However, the primary data processing for common automated procedures will be provided by data processing nodes. These automated procedures are defined independent of the data they process. The data processing nodes may possess a broad range of capabilities and be accessed by only a few users or the entire enterprise. The data processing functions which must be supported by the IPCN are:

- Execution of automated structured decision-making logic.
- Execution of interactive semistructured decision-making logic
- Execution of artificial intelligence based semistructured decision-making logic
- Execution of general purpose analysis tools for unstructured decision-making.

4.4.3 Information Resource Management in the FoF

Previous paragraphs have described new computer and communications capabilities which will be needed for the FoF. The desired capabilities center around improving both the effectiveness and efficiency of managing information. Efficient management of information resources will result in reduced time and cost to perform various factory functions (Figure 4-14). The quality of the results will be improved as will the communication between functions. This will in turn allow the FoF to attain its goals of:

- Reduced product cost
- Improved product quality
- Effective use of human resources
- Reduced time to respond to customer needs
- improved manufacturing flexibility.

Efficient management of information will increase the return on investment in IPCN resources and improve the responsiveness of these resources to meet the dynamic needs of users within the factory. The following paragraphs will discuss how these capabilities will be achieved in the FoF.

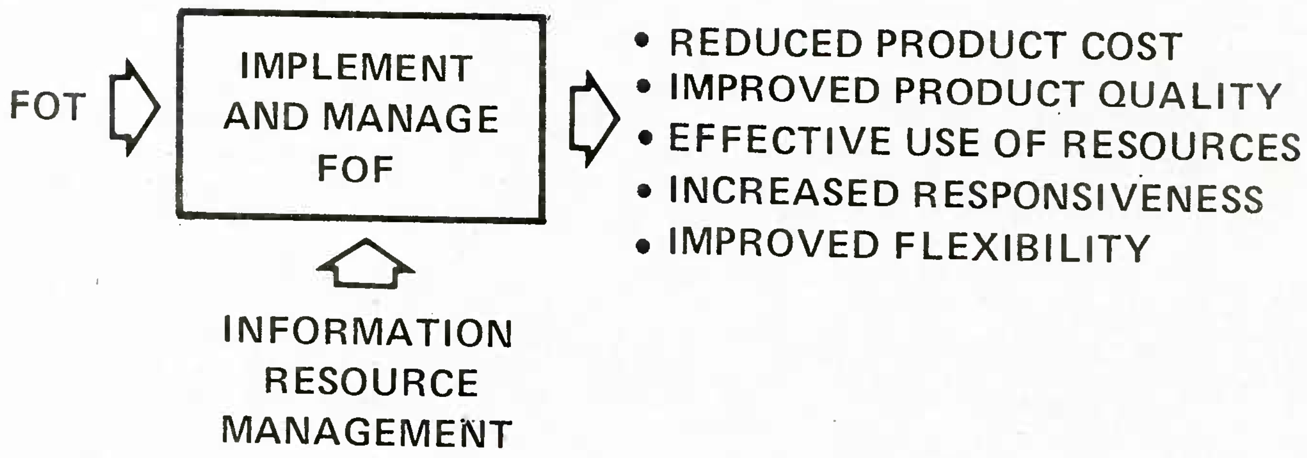

Figure 4-14 Information Resource Management FoF System

4.4.3.1 Architectures for IRM

Information resources in the FoF must be managed from three different architectural perspectives. The user's view of the information he needs to carry out his functions is defined by the Information Architecture (IA). This is a logical view. The computer hardware, storage devices, communications facilities, and software, i.e., the Information Processing and Communication Network (IPCN), is defined by the Computer Systems Architecture (CSA). This is a physical view. The neutral view of information resources, which is independent of any single user view and independent of how the information is physically stored or processed, is defined by the Control Architecture (CA). The Control Architecture reflects the total enterprise view of its information resources, both logical and physical. The development and use of the Control Architecture will be the key to the success of IRM in the FoF. Together, these three architectures compose the "technology environment" for Information Resource Management in the FoF.

The information architecture and the computer systems architecture are highly interrelated. This high degree of interrelation should not, however, obscure the fact that each of these architectures must respond to different forces for change in the FoF environment. The information architecture must respond to changes which come from dynamic user needs, while the computer systems architecture must respond not only to changes in user needs but also to changes in the technological foundation of computer and information management technology.

To understand information resource management in the Factory of the Future, we must define the information architecture perspective and the computer systems architecture perspective. Only after defining these two perspectives, can we understand how integration can be achieved through the "control architecture."

The concept of the three architectures of the IRM technology environment for the Factory of the Future is shown in Figure 4-15. The information architecture is the user's view of information. It is defined in terms appropriate to him. It is a logical perspective, which is dynamic and responsive to changing user needs. There are a wide variety of users in the Factory of the Future, including shop personnel, engineers, buyers, planners, marketeers, salesmen, accountants, administrative support personnel, supervisors, managers, and executives. Users can customize the information architecture and may think in terms of applications, transactions, reports, screens, systems, ad hoc queries, or all of the above. There is no requirement that the information architecture be completely automated.

The computer systems architecture represents the physical structure of the information resources which constitute the IPCN. The physical structure contains many different types and levels of hardware and software technology, which must be tuned and retuned for efficiency purposes. The CSA is described in terms of records, files, access methods, programming languages, disks, processors, communications facilities, data base management systems, operating systems, and so on. These resources may be distributed or centralized.

The control architecture contains the standards, procedures, organizational responsibilities and plans needed to maintain alignment between the information and computer systems architectures, and to control changes in both environments. The control architecture is "process-driven" in most factories of today. The control architecture for the FoF must be "data driven." A "data driven" control architecture contains a neutral model of the data structure of the business and manages changes to that model as a means of accomplishing integration in the technology environment.

This three-architecture perspective is a critical concept for the Factory of the Future. Factories of today have not defined information resources in this way. Typically, they have defined IRM in terms of application systems, with each system supporting some aspect of the information architecture (e.g., bills of

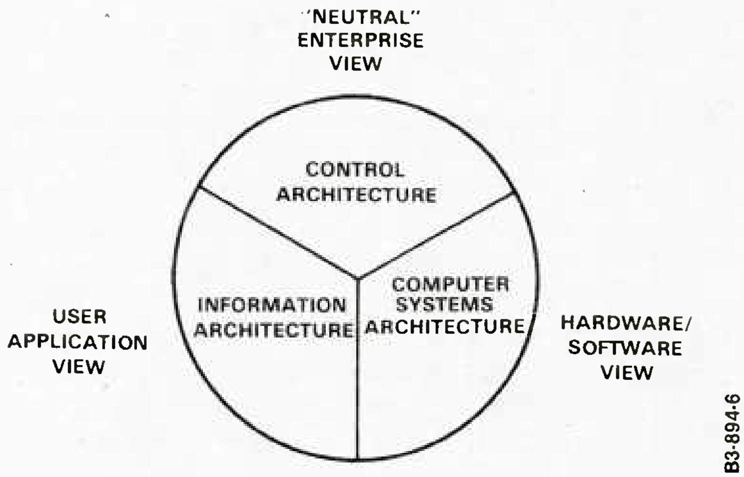

Figure 4-15 Factory of the Future Information Resource Management (IRM) Technology Environment

material or MRP) implemented on its own subset of the computer system architecture (e.g., a mini-computer, with programs written in COBOL, using the index sequential data storage and access techniques). With this approach, the information architecture is bound to the computer system architecture (Figure 4-16). The lack of flexibility in this binding is illustrated by users who want to improve the information architecture (which affects their productivity), but cannot do so because it is too costly and too time consuming to make the required changes in the appropriate segments of the computer system architecture.

IRM technology, introduced in this way, is difficult to integrate, much less change. It is also subject to a high degree of inconsistency (from the information perspective) as each system maintains its own data, even though the data maintained may be common to several systems. It also requires considerable technical skill to augment and maintain. The segmentation of information resources, forced by the application systems, may actually cause suboptimization of the total factory's information requirements.

The three-architecture strategy for the Factory of the Future proposes to integrate the user's information needs through the information architecture and to integrate the various hardware

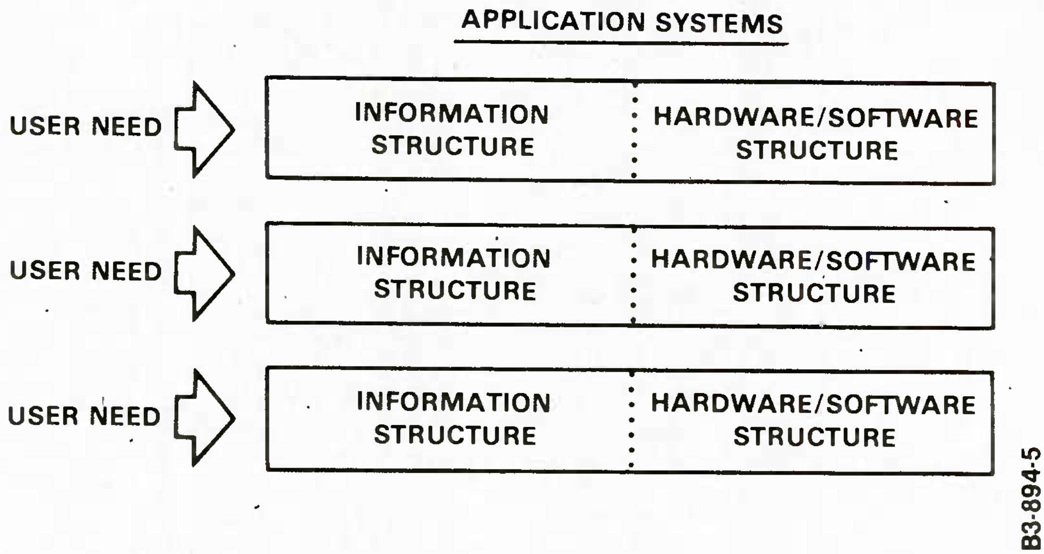

Figure 4-16 "Old" Approach to Information Resource Management (IRM)

and software components, i.e., the IPCN, through the computer system architecture, and finally, through the control architecture, to integrate the information and computer systems-architectures dynamically, through time. (Figure 4-17).

4.4.3.2 The Information Architecture

Productivity in the Factory of the Future is directly related to the degree of sophistication, consistency, and responsiveness of the factory's overall information architecture. This architecture is defined by users based on their needs at a given point in time. Users should be free to define this architecture in terms of "applications" (such as shop floor control, MRP, accounts payable, etc.), or in terms of reports or screens or data bases, or in terms of operational control systems and decision support systems. The long-term objective is for the information architecture to be whatever the user needs it to be at any given point in time. This architecture must be extremely dynamic, allowing the user to reorganize his information needs, to change his organizational structure, or to change his managerial processes based upon the imperatives of the business, its markets, financial structure, products, and physical assets.

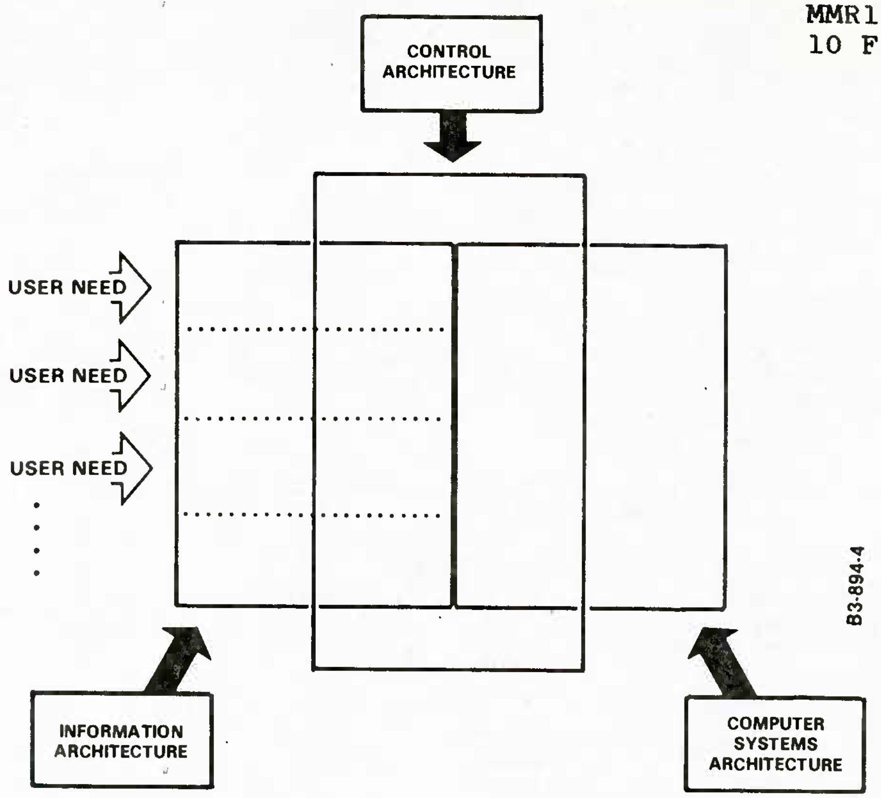

Figure 4-17 "New" Approach to Information Resource Management (IRM)

The FoF activity model, shown in Appendix A, defines the functions which must be supported by the Information Architecture in an aerospace company. User-defined applications of information resources may be oriented toward supporting the activities of a particular type of function or the application may address a need which affects several functional areas. Figure 4-18 illustrates how the information architecture supports the FoF generic needs categories which in turn support the FoF functions through "applications" or user views.

The nature of the Information Architecture will vary from company to company depending upon the position of their products in the product life-cycle and the manufacturing strategy of the company. Figure 4-19 illustrates the match up between the product structure and process structure. Maintaining proper balance between the two is critical to a company's success. However, the Information Architecture to support a job shop is significantly different from the Information Architecture required to support a high volume, continuous flow factory. The major portion of aerospace manufacturing is associated with processes designed for low volume production, although some components may well be manufactured in high volume. Increased application of programmable shop floor automation will eventually cause batch manufacturing to become more flow oriented. This change must be reflected in the Information Architecture.

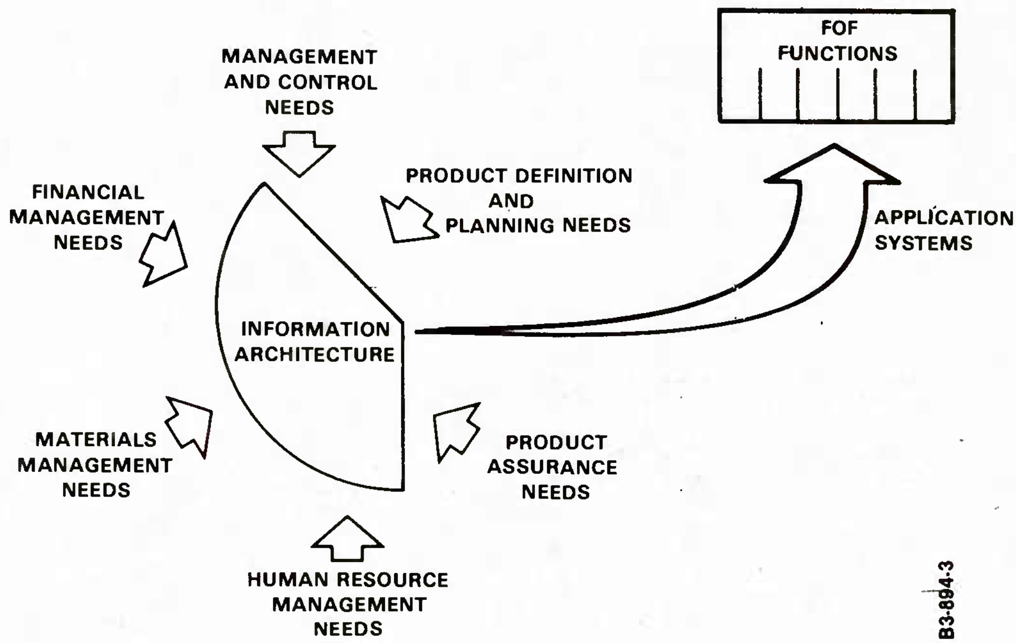

Figure 4-18 Information Architecture Support of FoF Functions

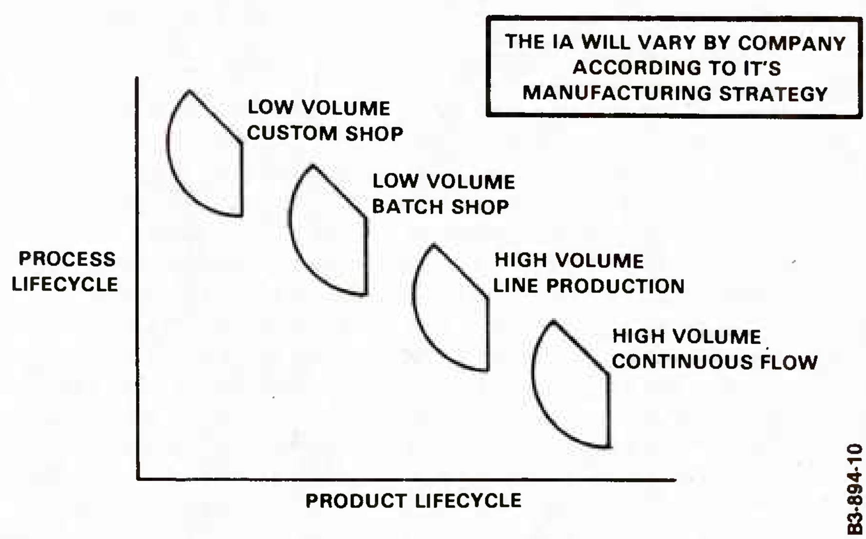

Figure 4-19 Information Architecture Variables

Recently, new techniques for data base design have been introduced. These techniques define the data structure from a logical view, rather than the physical view of how the data will actually be structured in the computer. This logical view is defined by relational structures which can be thought of as a group of interrelated entities about which data is kept. The definition of these entities and relationship between them can be logically refined through the process of normalization. Once normalized, the entities may be manipulated to create any desired data structure. The logical data base structure defined by these new data base design techniques in a normalized form is completely independent of physical data storage constraints.

A logical data base design which has been normalized can be mapped into a hierarchical or network oriented data base management system. Relational data base management systems are now emerging which allow the normalized data structure to be implemented directly. We can even say that a normalized data base doesn't have "shape." What it does have is intrinsic relatability defined in the form of individual relations (two-dimensional tables). These relations can be projected, joined, selected, intersected, "differenced," and "unioned" to create new relations. All of this can be done based purely on data content.

4.4.3.3 The Control Architecture

The role of the control architecture is to manage changes within and maintain alignment between the information and computer systems architectures, i.e., the logical application view and the physical IPCN. It contains standards and procedures in the following areas:

- Planning
- Organizing
- Enabling technologies
- Software management
- Operational control.

There are basically two approaches to the control architecture: 1) process-driven and 2) data-driven. Process-driven control architectures design, build, and implement standalone systems. Each of these "islands of automation" contain a piece of the information architecture and a piece of the computer systems architecture. The focus of a process-driven control architecture is on systems development. It does not treat the information architecture as a totality, nor does it deal with the computer system architecture as a totality.

Figure 4-20 provides a framework for the data-driven approach to manage the information process in the FoF.

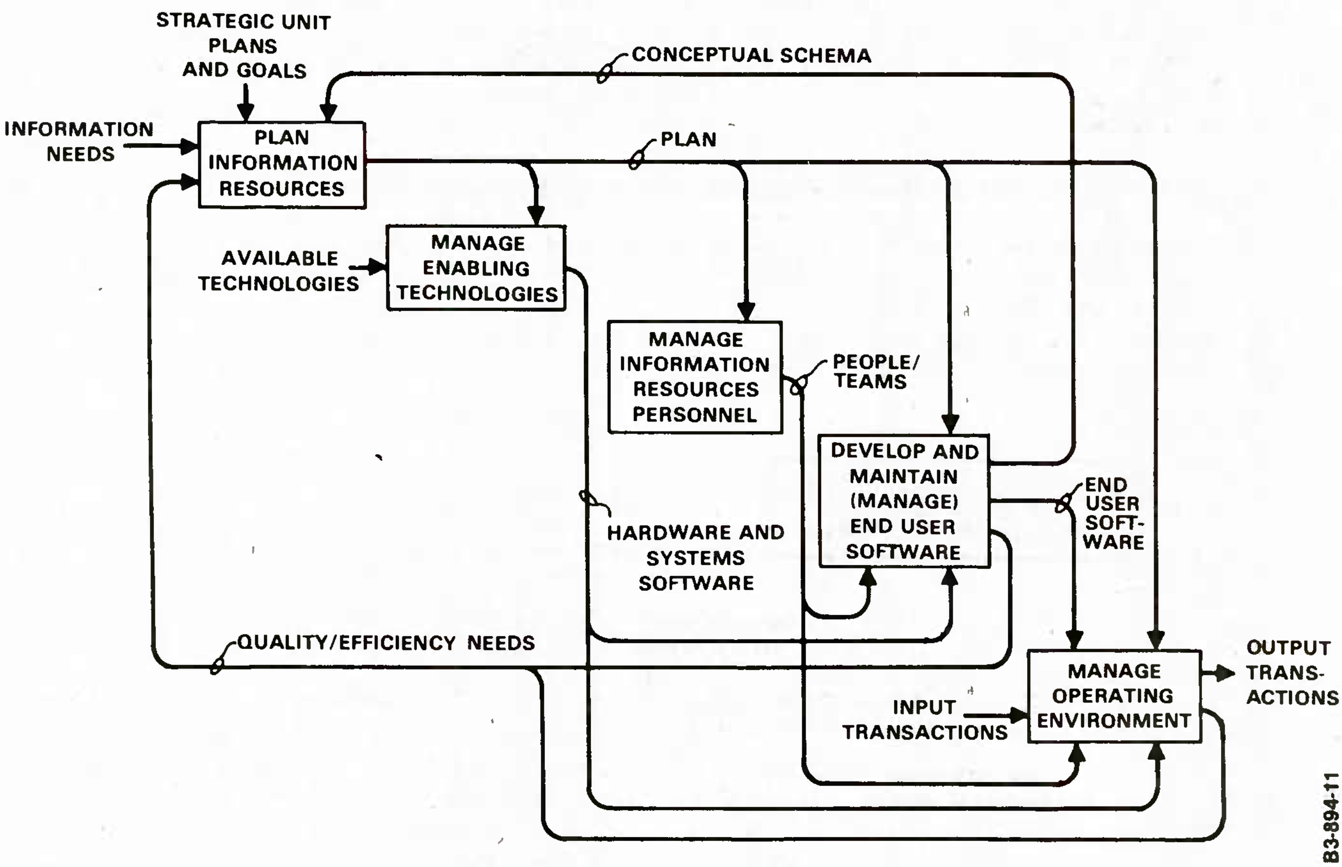

Figure 4-20 Manage Factory of the Future (FoF) Information Resources

A data-driven control architecture focuses on data standards as the primary tool for integrating and managing the whole technology environment. Data transcends systems and is not subject to the capricious life cycles of a systems development philosophy. The data-driven control architecture manages implementation and integration of information capability within the technology environment. It is responsible for managing its overall efficiency, through time.

The role of a data-driven control architecture in the technology environment is described in Figure 4-21. In this figure, the control architecture is responsible for managing the information resources needed to support seven organizational perspectives. Each organizational perspective manages its own processes (though some processes may cross-perspectives); each process defines its own data needs. In a process-driven control architecture, there is no entity structure, so the data and fields categories shown in Figure 4-21 would be mapped one-to-one, as within a standalone system. However, in a data-driven control architecture, entity structures are maintained and these neutral, non-redundant, application independent, processor independent data standards provide the bridge between the logical and physical aspects of the IRM technology environment.

4.4.3.3.1 The Three-Schema Concept

The foundation for this data-driven philosophy in the control architecture was established in 1971 by the American National Standards Institute (ANSI). The Standard Planning and Requirements Committee (SPARC) of ANSI defined what it called a "three-schema architecture" for data management. A "schema" is a description of data. It is a disciplined and formal way to define what data items are included, what they are named, and how they are organized. The three-schema approach calls for the description of data from three distinct perspectives:

- The internal schema - which is an extremely technical description of data, principally concerned with computer dependent factors and data storage, e.g. what device will store the data and what encoding method will be used?

- The external schema - which reflects only that portion of the data which is of interest to a particular user or application (e.g., the design engineer's view of the data). Since there are many users, there are many external schemas.

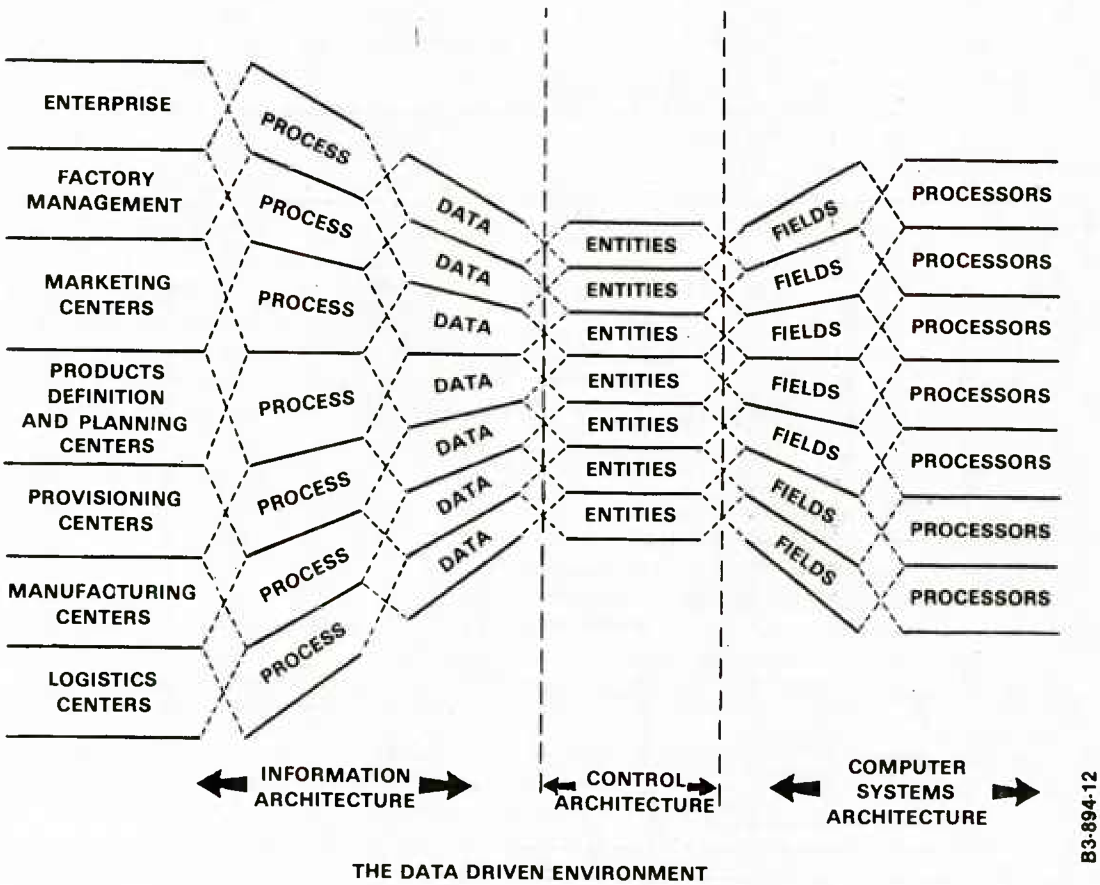

Figure 4-21 The Data-Driven Environment

3. The conceptual schema - which contains a description of all the data (possibly even data not yet automated) which is independent of how individual users see the data or how it is physically stored.

4.4.3.3.2 FoF Common Data Model

In the FoF, the Control Architecture will contain a complete definition of the conceptual schema for all information needed by the enterprise and the relationship between the conceptual schema and both internal and external schemas. This definition is referred to as the Common Data Model (CDM). Information which is only used by a single person or for a single application is considered private and will not be defined by the CDM.

The CDM must define the neutral enterprise view of all information, which transcends applications systems, organization structures, and functional activities (Figure 4-22). The enterprise view will define all the information which reflects the company's:

- o Business knowledge
- o Marketing and sales knowledge
- o Product design knowledge
- o Manufacturing knowledge
- o Quality Assurance/Quality Control knowledge.

Figure 4-23 shows a high-level view of the relationship between information subject areas and FoF functions. This diagram illustrates the high degree of shared information within the manufacturing enterprise. The contents of the common data model are described later as a logical component of the FoF.

4.4.3.3.3 Data Base Transform Engine

In addition to a well-balanced architectural framework, successful integration of information resources will require a data base transform engine. It is the data base transform engine that allows a user or application system to access data stored in multiple data bases and files. The data base transform engine implements the ANSI/X3/SPARC three-schema approach to data base management. A major thrust of the current ICAM Integrated Information Support System (I^{22}) is the development of an experimental transform engine which can access a heterogenous mixture of local DBMSs. The work of this project along with private developments, indicates that a data base transform engine will be available for the FoF.

The data base transform engine is the focal point of the information resource architectures and the key to implementing an integrated IPCN without completely, replacing computer systems

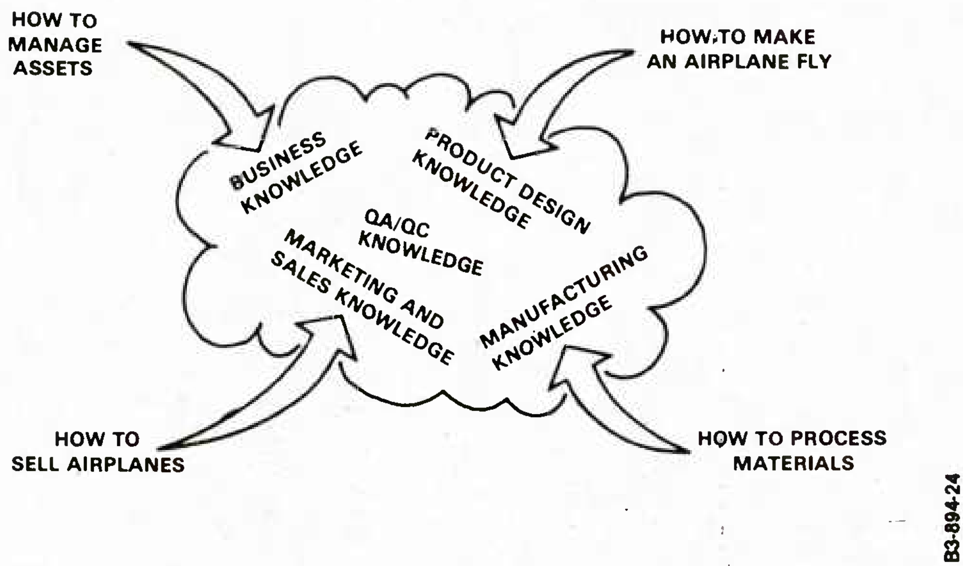

Figure 4-22 Factory of the Future (FoF) Common Data Model

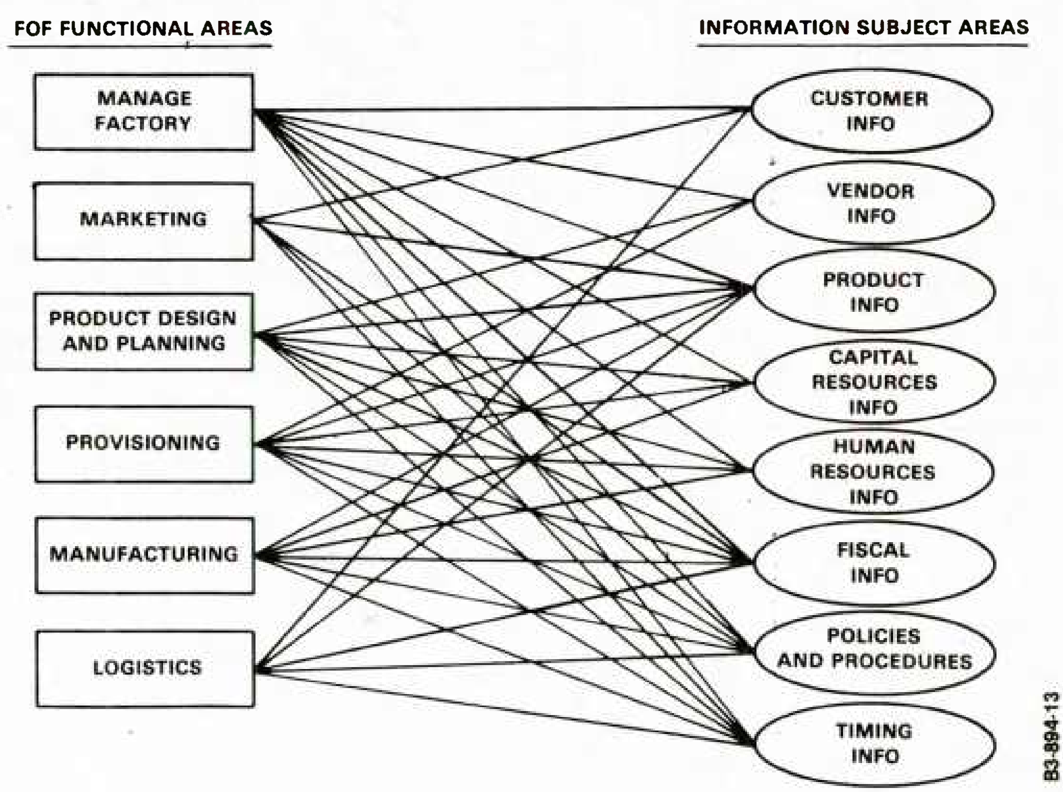

Figure 4-23 Relationship Between Function and Information

already in place. Its relationship to each of those architectures is shown in Figure 4-24. External schemas support the man-machine interfaces of the information architecture. Internal schemas describe the physical implementation of data bases on the IPCN. The conceptual schema describes the enterprise logical data structure i.e., the enterprise information infrastructure, that enables the control architecture to maintain balance between the other two architectures.

As shown in Figure 4-25, the data base transform engine has knowledge of not only the three types of schemas, but also includes the transforms that are necessary to support multiple user views (external schemas) of an integrated data structure, that is perhaps distributed over multiple physical data bases (internal schemas). The user is provided with a consistent view of the shareable data available in existing data base structures. The transforms implement both integration of the data resource and the logical-physical independence that is necessary to provide flexibility for adapting to change. External schemas can change to adapt to the dynamic manufacturing environment; internal schemas can change to take advantage of improvements in processing technology.

Consider a single example of the use of the schema transforms. Assume that there are three data bases: a CODASYL IDMS-II data base of production resource planning data, a hierarchical IMS data base of bill-of-materials data, and an inverted/network ADABAS data base of personnel/payroll data. If these data bases were integrated, then a user would be able to pose a single request; for example "what are the names and salaries of managers in departments where machines of type X are used to apply zinc-oxide coating to parts that are used in making wings? Such a question would cause data to be accessed in all three data base. The locations of these data bases and which data come from which data bases would be transparent to the user. The user's external schema would include information about managers, departments, machines, coatings, parts, and their interrelationships. The user's request would be phrased in terms that would be independent of the data manipulation languages of the particular data base management systems (DBMSs) involved. This request language ideally might be a natural language like English or a nonprocedural language. The data base transform engine would apply its knowledge of schemas, data locations, and DBMS requirements to decompose the user's request into subrequests (each of which would retrieve data from one data base). This would transform each subrequest to the equivalent commands of its target DBMS, to aggregate the data retrieved from the multiple data bases, and convert the result to the appropriate form for presentation to the requestor. (See Figure 4-26).

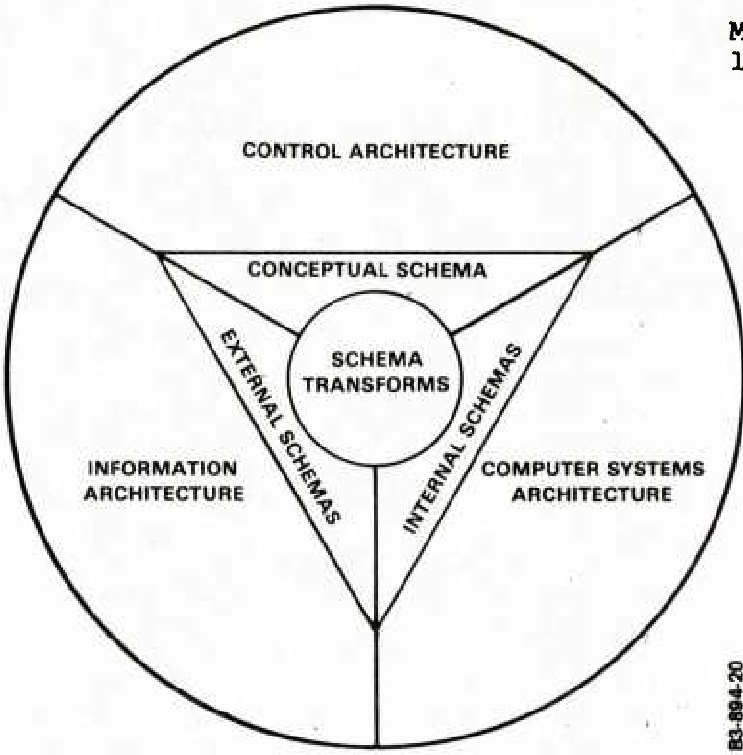

Figure 4-24 Data Base Transform Engine as the Local Point Of the Information Resource Architecture

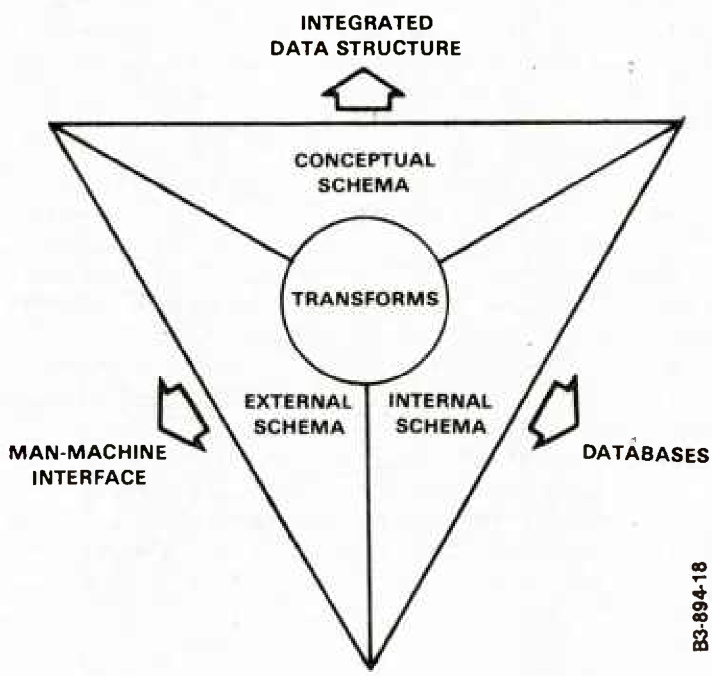

Figure 4-25 Data Base Transform Engine

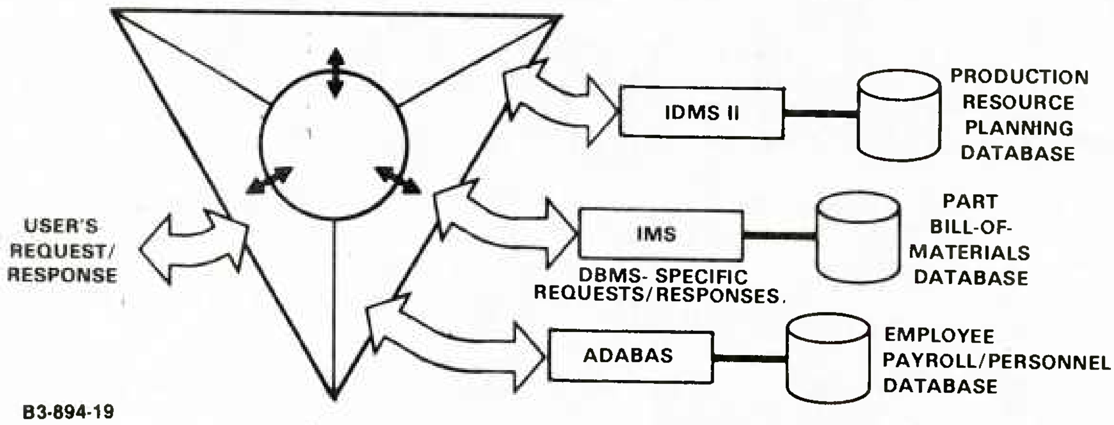

Figure 4-26 Example of Integrated System Response to User Request

When a new user view is added to the system, the data base transform engine first tries to construct it from the existing conceptual schema, which provides an integrated view of the enterprise data base, independent of physical implementation details. That is, new user applications build upon the existing integrated data resource. If the user application requires extraction of new data, the conceptual schema is evolved to include those entities, attributes, and/or relationships while maintaining the consistency of the enterprise view. In order to support this graceful evolution of the conceptual schema and the ability to augment the range of user views, it is necessary that the systems engineering methodology used be data-driven, as opposed to process-driven or application-driven.

The data base transform engine provides the facility to integrate an organization's existing data bases. With the proper transforms (e.g., CODASYL-to-relational, inverted-to-relational, hierarchical-to-relational) the schemas of existing heterogeneous data bases can be integrated via a conceptual schema, and neutral transactions can be processed against the multiple heterogeneous data bases. The transform engine also provides the facility to integrate new data bases and users in the IRM environment.

4.4.3.3.4 System Development Methodology

The traditional approach to building systems has focused on building standalone applications which share computer resources. The data-driven approach which must be employed in the FoF will seek to build integrated systems which share data resources. Although data base management systems (DBMSs) have been around since the early 1970's, DBMSs alone are not enough to ensure sharing of common data resources. The FoF must:

- o Build and maintain a data-driven IRM plan which views data as a resource "pool" not a resource "flow"
- o Obtain data management tools which will assist in data development and administration
- o Assign responsibilities for data base administration, input administration, and output administration
- o Employ a data-driven system development methodology (SDM) to design, develop, implement, and maintain end-user software.

The first objective of the data-driven SDM is to define sets of information entities. An information modeling technique is used to do this.

The neutral data structure represented by the information model is used to define and manage an entity-based conceptual schema. The Data Base Administrator (DBA) stores the conceptual schema in a data dictionary. The DBA uses the conceptual schema to keep track of all data regardless of its physical (DBMS) or logical (user view) form. Because the conceptual schema is neutral is represents the most stable view of information available. It remains stable even while user views change and while DBMSs technologies change. The conceptual schema is consistent and complete regardless of its physical or user projections, until the evolving knowledge requirements of the business cause it to be further augmented.

The second objective of the data-driven SDM is to articulate entity sets in terms of their attributes and relationships. This objective is partially accomplished by the data design methodology, through a process usually called "user view synthesis"; however, that procedure is not, by itself, effective enough. It must be augmented by heuristic analysis techniques, such as prototyping. Prototyping provides a data validation procedure. These heuristic techniques focus on stabilizing data definitions, based on user experience. They provide the capability for exercising ad hoc queries against prototype data base definitions, with live data in the data base. Heuristic analysis also flushes out critical information needed to optimize the structure of the physical data base, because it exposes "real" access keys and parameters, volumes and frequencies, based on empirical evidence.

Once the logical data base has been validated, it must be transformed into its physical form on the DBMS. This is the third SDM objective. The data-driven SDM may require this transformation from the neutral view to the DBMS view to be made several times, especially if the SDM employs prototyping and heuristic analysis. The transform logic is most difficult if the DBMS architecture is hierarchic, a little easier if it is CODASYL and easier still if it is a relational structure. The data-driven SDM must provide for recording the physical transforms in the data dictionary, along with the neutral form of the conceptual schema.

Having constructed the logical and physical data base forms, the data driven SDM must next address the data acquisition problem, the fourth objective. This is a very tricky problem because update transactions have the unique quality of being able to change data base states. They do so through adding, changing, and deleting data stored in the physical data bases. Data base update transactions are responsible for maintaining integrity in the physical data bases; for managing redundancy; for enforcing triggers and assertions; for providing for data base checkpointing, backup and recovery; for managing commitment logic; for editing and auditing data base contents; for enforcing update security; and for logging transactions.

The end product of the preceding steps can be characterized as "a pool of accurate and timely data which can, given appropriate security constraints, be easily and economically drawn upon - on demand - to satisfy the decision-making requirements of an information-dependent work." (Figure 4-27). The first three data driven SDM objectives are targeted at creating such an information pool. The fourth objective is focused on the issue of accessibility. Conventional applications, and their data bases, are designed based on requirements which constrain accessibility in terms of how much data can be accessed, and how many parameters can be used to control the access. Severe limitations on both have rendered most applications, in users' minds, inflexible. In the FoF the most flexible aspect must be the retrieval transactions. They must allow many parameters against a large number of data elements to maximize user flexibility. Thus, these transactions must be designed last, and they should be built using non-procedural, user-friendly programming languages.

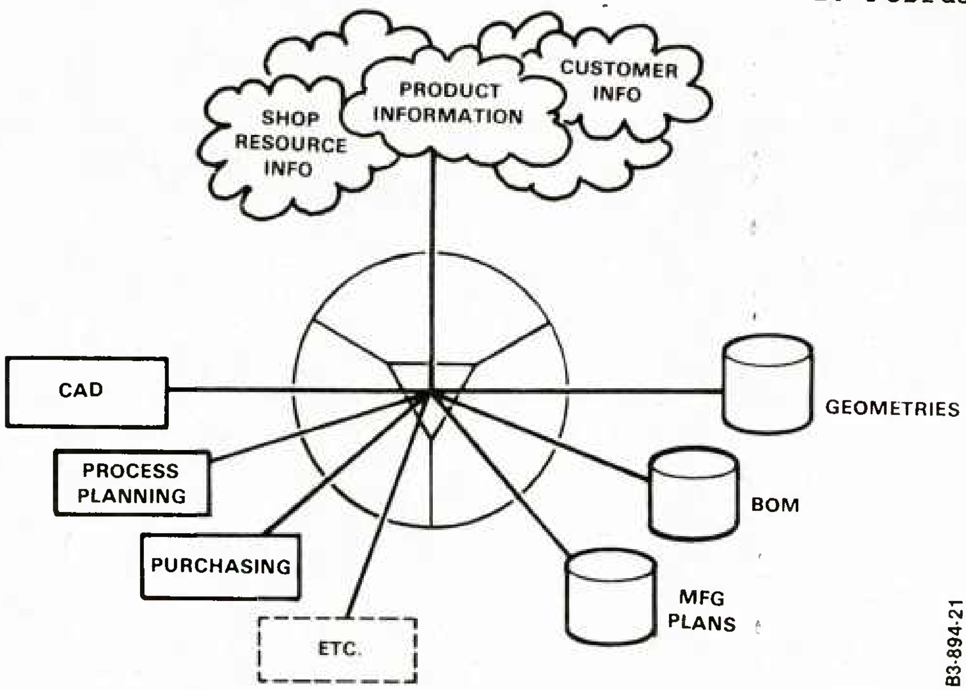

Figure 4-27 Factory of the Future Information Resource Management

The final issue facing a data-driven SDM is the efficiency issue. The SDM must provide the ability to not only monitor efficiency, but to affect it. This means that data and transaction performance parameters must be understood and monitored by the SDM. Efficiency can be a tricky issue in a DBMS environment. Data bases are sensitive to small things such as the order in which parameters are stated in a query, and to big things such as the way DMBS files are distributed on disc or the number and frequency of data base reorganizations. However, the data-driven SDM focuses on effectiveness first - especially in terms of how useful the data base is to its users. Hardware efficiency is considered second, recognizing that the proper balance must be maintained, but that any tilting of the balance must be in favor of effectiveness.

Efficiency is monitored by performance measurement tools, at the operating system level, the communications level, and the DBMS level. Physical data base structures may be changed, updated or retrieval transactions may be modified, or facilities such as multi-thread and multi-user may be invoked. All of this must be controlled by the environmental tuning features of the data-driven SDM.

4.4.4 Conclusion

It is evident that the implementation of Information Resource Management concepts on an enterprise-wide basis will not occur overnight. In the factory of today, there is a substantial investment in computers, systems software, communications equipment, etc. There is an even larger investment in data base management systems and applications programming. As new technology becomes available, we must try to fit the pieces together in such a manner so as not to unduly disrupt the technology already in place. The only means by which we can effectively control the implementation of these new technologies is to develop a long-range implementation plan. This plan must reflect an evolutionary implementation, not revolutionary, and consider the logical as well as physical development of Information Resources. Only through this evolutionary implementation approach can we hope to achieve the promised benefits of computer technology. Once implemented, Information Resource Management will continue to evolve in concert with the growth and evolution of the enterprises information requirements and demands.

SECTION 5.0

LOGICAL COMPONENTS

5.1 INFORMATION AS A LOGICAL COMPONENT OF THE FOF

5.1.1 Introduction

Information is an indispensable resource that must be managed and controlled in the FoF. Indeed, a company's ability to acquire, manipulate, and strategically leverage information may well mean the difference between its success and failure. From a logical point of view, information can be defined as one component of the FoF system. Information serves to logically connect the physical components of the FoF to integrate factory activities. Generally, information exists as symbolically coded data and may reside: in a computer's memory banks, on magnetic tape, in paper files, as physical models and templates, or stored in people's brains. Like energy, information can be converted from one form to another for transmission or application.

Information is not consumed in the sense that traditional resources are consumed; consequently, the management challenge is to acquire the right information at the right time and in a form which can be readily utilized. Therefore, an understanding of the information and its infrastructure is essential in managing and applying it effectively. Information which is required by more than one user is referred to as the Logical Common Database. The following paragraphs provide a conceptual framework for the Logical Common Database and its infrastructure. The intent of this discussion is to give a top-down view of the total information infrastructure independent of individual applications and the physical mechanisms used to store, process, and communicate the information.

5.1.2 Approach

Even prior to the development of computer technology, considerable time and effort was spent in developing systems to store, process, and communicate manufacturing information. These early systems generally employed paper forms and files, many of which have been directly converted to computer-based forms and files. As a result, the information infrastructure for the company was, in effect, defined within the context of these specific application systems. As more and more applications were developed, data redundancy and inconsistency became rampant and led directly to the information management problems currently being experienced by many companies.

The need to define the information infrastructure independent of individual information applications was recognized by the ICAM Program. This led to the development of an information modeling technique called IDEF1 which was used to construct a generic model of the aerospace manufacturing information referred to as MFG-1. IDEF1 has proven to be a valuable tool for those companies who recognize the importance of an application independent definition of information structures. However, IDEF1 structures are too detailed to provide a high-level view of the total FoF information infrastructure. The MFG-1 model, for example, contains over five hundred entity classes and several thousand relationships. Yet it does not cover all the Enterprise information.

Various attempts have been made to establish a structured approach to top-down definition of the enterprise information infrastructure, including definition of data classes, business rules, and subject data bases. Many of these techniques are still under development and will evolve as more knowledge is gained on how to manage information as a resource. The efforts of the coalition in defining the FoF information infrastructure are based on the Business Systems Planning (BSP) technique developed by IBM and the work of the D. Appleton Company.

5.1.3 Business Entities

The FoF information infrastructure can be derived from an understanding of the things about which information is needed to run the Enterprise. These "things" may be either physical or conceptual and information may exist about their past, present, or future. In order to establish a top-down view, high-level aggregations of types of "things" will be defined as Business Entities. Individual "things" are referred to as an "instance" of a Business Entity. By defining the Business Entities and decomposing the information about them, the information infrastructure is developed.

Business Entities can be divided into two basic categories. The first category deals with Business Entities which are external to the Enterprise and corresponds to the Factory System interfaces. The types of external Business Entities for an aerospace manufacturing enterprise include:

- Customers
- Competitors
- Suppliers
- The Parent Corporation
- Government Organizations
- Labor Unions.

A second category of Business Entities are internal to the Enterprise and correspond to resources. The types of internal

Business Entities for an aerospace manufacturing enterprise include:

- o Product/Part Designs
- o Materials
- o Facilities
- o Equipment/Tools
- o Personnel
- o Money.

Each type of Business Entity listed above may have information associated with groups of entities. For example, customers may be grouped into markets; personnel may be grouped into departments; tools and equipment may be grouped into production cells, etc. Table 5-1 lists potential parameters for groups of Business Entities about which information may be kept.

Some of the types of Business Entities listed above represent organizations or structures which can be further decomposed in Business Sub-Entities. For example, customers may be decomposed into Systems Program Office (SPO), Test Pilots, Logistic Depots, etc. Table 5-2 list potential Sub-Entities.

The results of grouping and/or splitting basic Business Entities will be referred to as Business Subject Entities.

To further categorize and define the information associated with Business Subject Entities, it should be recognized that the information structure of a specific Business Subject Entity depends on its life cycle stage. The basic life cycle stages are:

- o <u>Pre-Existence Stage</u> - which deals with future instances of Business Subject Entities. Prospects, for example, represent Customers in the pre-existence stage.

- o <u>Initiation Stage</u> - which deals with the creation or acquisition of an "instance" of a Business Subject Entity. Contract negotiations and sales, for example, are associated with customers in the initiation stage.

- o <u>Stewardship Stage</u> - which deals with the active life of the Business Subject Entity Instance. Contract Management is associated with customers in the stewardship stage.

- o <u>Post-Existence Stage</u> - which deals with the Business Subject Entity Instance after it is no longer an active entity. Historical sales data, for example, are associated with customers in the post-existence stage.

Examples of the Business Entity life cycle stages are shown in Table 5-3.

TABLE 5-1: POTENTIAL PARAMETERS FOR GROUPING BUSINESS ENTITIES

Business Entity	Example Business Entity Groups	Grouping Parameters/Variables
Customers	Markets Sales Regions	- Type of customer (military/commercial) - Location of customer (domestic/intl.)
Competitors	Industries	- Type of product/services
Suppliers	Subcontractors Material Vendors Equipment Vendors Information Sources Service Organizations Lending Institutions	- Type of products/services provided o hard goods o people o services o information - Contracting/Proposal Procedure
Government Organizations	Federal Laws State Laws Local Laws EPA EEOC IRS	- Scope of authority (Federal/State/Local - Type of regulations (environmental,employment,etc)
Products	Product Lines Models Versions Spares	- Type of product (aircraft,missiles, spares) - Design configuration
Materials	Finished Goods Work-in-Process Raw Stock Component Parts Purchased Items Supplies Production Lots	- Type of material - Source of material - Use of material - Inventory management technique
Facilities	Plants/Complexes Production Facilities Office Facilities Warehouse Facilities Training Facilities Computer Facilities	- Location - Type of usage - Environment control requirements

TABLE 5-1: POTENTIAL PARAMETERS FOR GROUPING BUSINESS ENTITIES (Concluded)

Business Entity	Example Business Entity Groups	Grouping Parameters/Variables
Equipment/ Tools	Work Stations Cost Centers Cells Production Centers Factories Perishable Tools Jigs & Fixtures Hand Tools NC Machine Tools Robots Material Handling Equipment Process Equipment Inspection Equipment Computer Equipment Office Equipment Laboratory Equipment GFE (Government Furnished Equipment) Communications Equipment	- Location - Type of Usage - Source of equipment/tool - Management/control requirement
Personnel	Groups Departments Functional Organizations Machinist Inspectors Buyers Executives	- Location - Reporting requirements - Type of function performed - Type of authorization - Skill Classification
Money	Accounts Funds Investments Cash	- Source of money - Use of money - Financial management technique

TABLE 5-2: POTENTIAL BUSINESS SUB-ENTITIES

BUSINESS ENTITY	EXAMPLE BUSINESS SUB-ENTITY
Customer	- SPO/PMO - Test Pilots - Air Force Bases - Depots
Suppliers	- Supplier Reps - Warehouses
Corporation	- Controller - Board of Directors - Stock Holders
Government Organizations	- Agencies - Government Reps
Labor Union	- Union Management - Stewards - Members
Products	- Final Assembly - Major Components - Subassemblies - Detail Parts
Facilities	- Buildings - Rooms - Locations - Systems
Equipment/Tools	- Components - Parts

TABLE 5-3: BUSINESS ENTITY LIFE CYCLE STAGES

Business Entity	Pre-Existance Stage	Initiation Stage	Stewardship Stage	Post-Existance Stage
Customers	Prospects (RFP's)	New Customer (Proposal/Sales Negotiation)	Activity Customer (Program Mgmt)	Past Customers
Competitors	Potential Competitors (Technology/Market)	Bid Competitors	Product Competitors	Past Competitors
Suppliers	Potential Suppliers	Approved Suppliers	Activity Suppliers	Past Suppliers
Products	Planned Products	New Products	Current/Active Products	Past Products
Materials	Required Material	Ordered Material	Inventoried Material	Used Material
Facilities	Planned Facilities	New Facilities (under construction)	Current Facilities (Usable)	Past Facilities (Sale of Property)
Equipment	Planned Equipment	New Equipment (installation)	Current Equipment (Usable)	Past Equipment
Personnel	Planned Personnel (Openings)	New Personnel (Recruitments)	Active Personnel	Past Personnel (Retired/Layoff)
Money	Planned Income	Income	Cash On-Hand & Financial Assets	Payments

5.1.4 Business Transactions

Many relationships which exist between Business Entities must be defined in the Logical Common Database. For example, products, materials, facilities, equipment, and personnel must all be brought together to perform a manufacturing process. In some cases, the relationship between two or more Business Entities are formally defined and documented. These "formal" relationships are sometimes referred to as an "order" or "agreement", e.g., sales orders, purchase orders, and shop orders. If a relationship between Business Entities is formally recognized by the company, it may be considered as a Business Subject Entity in its own right. These formal relationships are referred to as Business Transactions. Although the specific relationships defined as formal Business Transactions may vary from company to company, major Business Transactions which are typical for an aerospace Enterprise include:

- Production Contracts (sales orders)
- Work Authorizations (work orders)
- Strategic Business Plans (policies and procedures)
- Purchase Agreements (purchase orders)
- Laws and Regulations
- Labor Agreements (union contracts)
- Shop Orders (production orders)
- Budgets

The relationships defined by these Business Transactions are shown in Figure 5-1. Many other transactions may also be defined between Business Entities. These include:

- Facility Layouts
- Payroll
- Investments
- Loans
- Payments (accounts payable)
- Income (accounts receivable)

However, many of these transactions do not need to be managed independent of the Business Entities they involve. For example, a layout is always associated with a specific facility.

Major Business Transactions have life cycle stages like Business Entities. Table 5-4 lists examples of life cycle stages for Business Transactions.

Business Transactions which are formally recognized by the enterprise are identified as Business Subject Entities as are the Business Subject Entities which resulted from the grouping and splitting of the basic Business Entities.

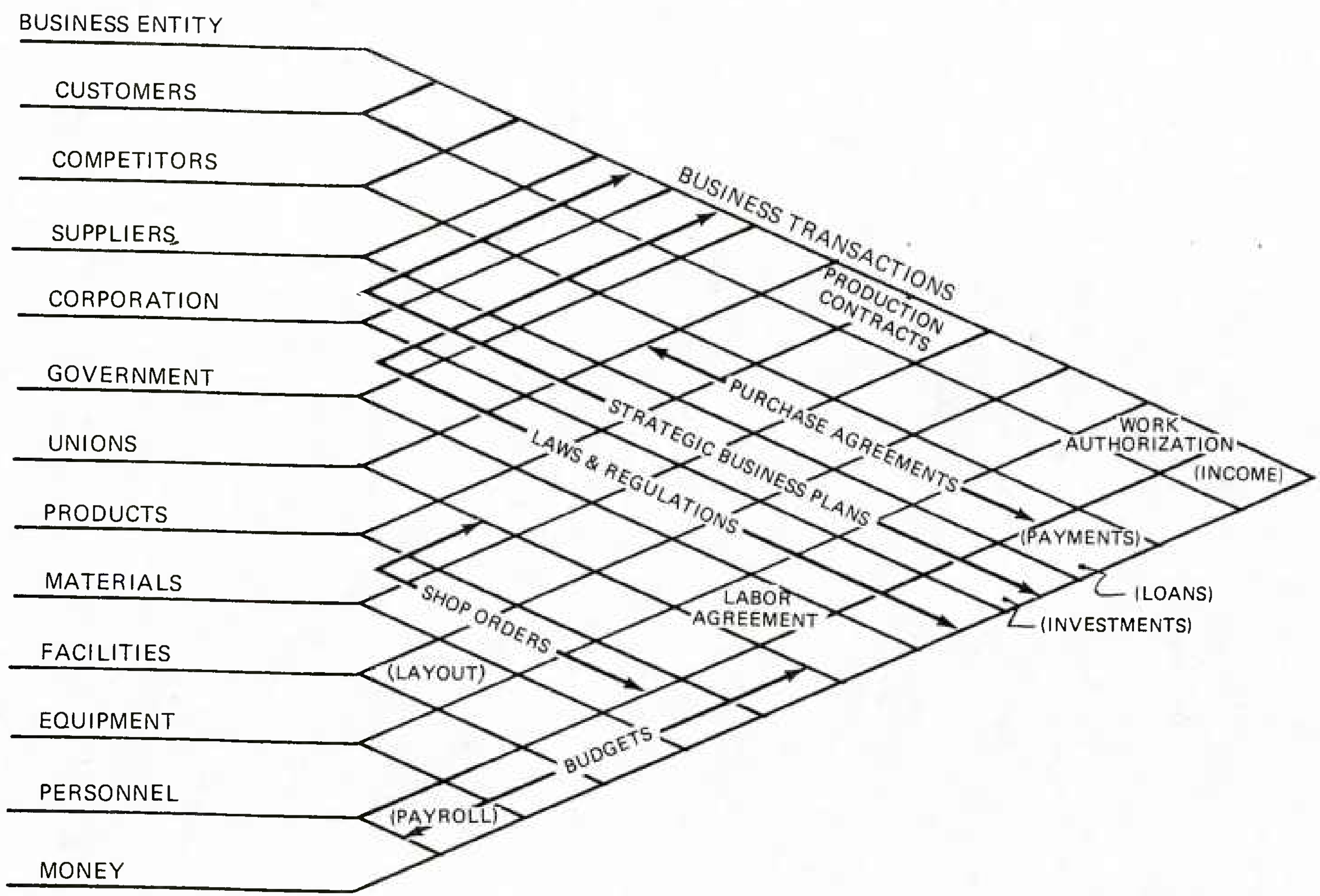

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Figure 5-1. Business Transactions

TABLE 5-4 BUSINESS TRANSACTION LIFE CYCLE STAGES

BUSINESS TRANSACTION	PRE-EXISTANCE STAGE	INITIATION STAGE	STEWARDSHIP STAGE	POST-EXISTANCE STAGE
Production Contracts	Sales Forecasts	Proposals/ New Contracts	Active Contracts (Work Authorization)	Past Contracts
Strategic Business Plans	Business Proposals	Approved Business Plans	Management Directives	Past Business Plans
Purchase Agreements	Purchase Requests	RFP/Vendor Proposals/ New Contracts	Active Purchase Contracts/Orders	Past Purchase Contracts/ Orders
Laws & Regulations	Proposed Regulations	Newly Inacted Regulations	Active Regulations	Past Regulations
Labor Agreements	Proposed Labor Agreements	New Labor Agreements	Current Labor Agreements	Past Labor Agreements
Shop Orders	TO-BE Released Shop Orders	Released Shop Orders	Shop Orders In Work	Completed Shop Orders
Budgets	Planned Budgets	Approved Budgets	Current Budgets	Past Budgets

5.1.5 Types of Information

The information requirements associated with each life cycle stage of the Business Subject Entities may be further defined by the types of the information which may exist about the life cycle stage. The types of information needed can be defined by four broad categories:

- o Descriptive Information
- o Value Information
- o Event Information
- o Relationship Information.

Descriptive information identifies specific instances of a particular Business Subject Entity and its physical properties. For Business Subject Entities which relate directly to objects in the real world, such as parts, tools, and material, this information may include geometric descriptions, electrical properties, mechanical properties, structural characteristics, weight, dimensions and color. Physical functioning and use of the item may also be included as part of the descriptive information.

Value information describes the qualitative aspects of a Business Subject Entity. Most financial information falls into this category since dollar equivalency is used to measure the relative value of items. Estimated and actual manhours or machine hours associated with the creation of an item may also be used to measure value. Value information may also reflect conformance/nonconformance of an item to established standards or policies, e.g., approvals of Business Transactions or rejection of manufactured parts.

Event information deals with the dimension of time and location. Schedules are a prime example of event information. Status of an item in terms of its state and location is also considered event information. Where descriptive information deals with the first three dimensions, this type of information deals with the fourth dimension, time.

Relationship information defines the logical links between various Business Subject Entities. These relationships are the key to the "intelligence" of the information infrastructure and reflect the strategic, tactical, and operational procedures of the company. These relationships can be defined only through the development of a normalized information model.

5.1.6 FOF Information Infrastructure

Application of the above concepts leads to the identification of Information Classes which are high-level groupings of information describing the information infrastructure of the enterprise. A summary of the development of these Information classes is shown in Figure 5-2. The Information Classes can be further defined by a normalized information model which becomes the conceptual schema for the logical common database. However, for purpoes of defining a conceptual FoF framework, a list of Information Classes has been defined as shown in Table 5-5. Each Information Class may represent multiple life cycle stages and types of information about the associated Business Subject Entity.

The list of Information Classes and the implied information model constitutes the information infrastructure for the FoF. This infrastructure can be related to the activities of the FoF. Each Information Class must have an activity which generates the required information. In addition to creating information, activities can also be viewed as users of information. The relationship between FoF activities and the defined Information Classes in shown in Figure 5-3. Since the mechanisms for the FoF activities are directly related to the physical components of the total factory system as discussed in Section 4.0, the Information Classes are also relatable to the physical components of the FoF.

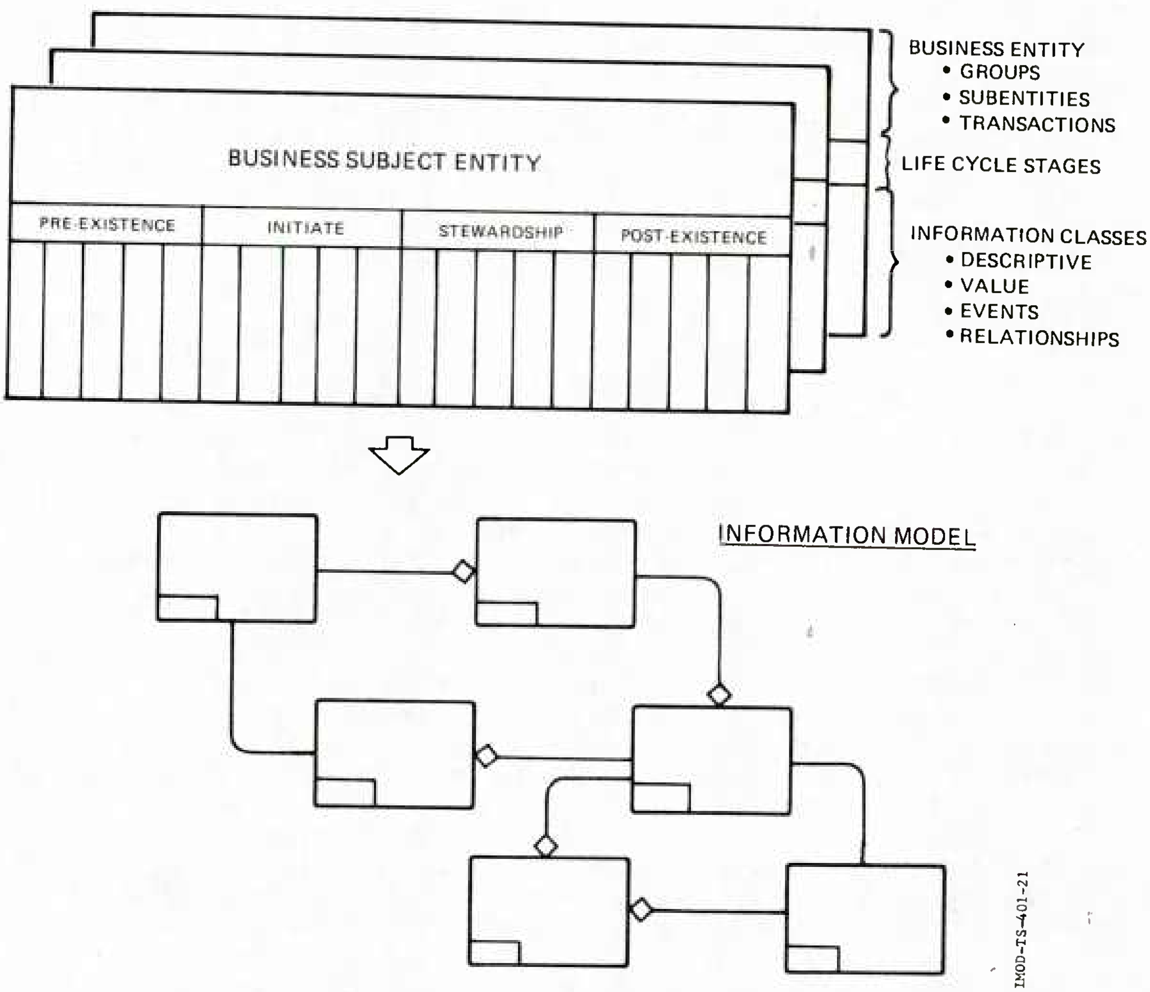


Figure 5-2 Information Definition Structure

TABLE 5-5: FOF INFORMATION CLASSES

CUSTOMER INFORMATION CLASSES

D11	Market Description History
D12	Custmer Identification & History
D13	Sales Forecasts
D14	Customer RFP Info
D15	Proposal Info
D16	Contract Info
D17	Work Authorizations

COMPETITOR INFORMATION CLASSES

D21	Competitor Description & History

SUPPLIER INFORMATION CLASSES

D31	Production Material Supplier Info
D32	Material Purchase Agreements
D33	Office Equip & Supply Vendor Info
D34	Office Equip & Supply Purchase Agreem'ts
D35	Facilities Supplier Info
D36	Facilities Purchase/Service Agreements
D37	Production Equip & Tool Supplier Info
D38	Production Equip & Tool Purchase Agreem'ts
D39	Human Resource Supplier Info
D3A	Human Resource Service Agreements
D3B	Info Processing Equip Supplier Info
D3C	Info Processing Purchase/Service Agreem'ts
D3D	Info & Software Supplier Info
D3E	Info & Software Purchase/Service Agreem'ts
D3F	Money Supplier Info
D3G	Money Acquisition Info

CORPORATE INFORMATION CLASSES

D41	Strategic Business Plans
D42	Policy & Procedures
D43	Mangement Directives

GOVERNMENT INFORMATION CLASSES

D51	Legal Info
D52	Regulations
D53	Compliance Info

UNION INFORMATION CLASSES

D61	Labor Agreement Info

PRODUCT INFORMATION CLASSES

D71	Program Requirements
D72	Program Plan
D73	Program Management
D74	Program History
D75	Product Definition & Effectivity
D76	Component Definition & Effectivity
D77	Detail Part Definition & Effectivity
D78	Field Support Description
D79	Process Planning & Control Info
D7A	Mfg Technology Development Info
D7B	Product Technology Development Info

MATERIALS INFORMATION CLASSES

D81	Finished Goods Reqm'ts & Inventory Info
D82	Spares Reqm'ts & Inventory Info
D83	Parts & Component
D84	Supply Reqm'ts & Inventory Info
D85	Raw Stock Reqm'ts & Inventory Info
D86	Shop Order Info
D87	Field Operations Info

FACILITIES INFORMATION CLASSES

D91	Property Info (Acquisition & Mgmt)
D92	Building Info (Acquisition & Mgmt)

TABLE 5-5: FOF INFORMATION CLASSES (CONCLUDED)

FACILITIES INFORMATION CLASSES CONT.

D93	Energy/Resource Control Info
D94	Facility Design Info
D95	Facility Allocation Info

EQUIPMENT & TOOL INFORMATION CLASSES

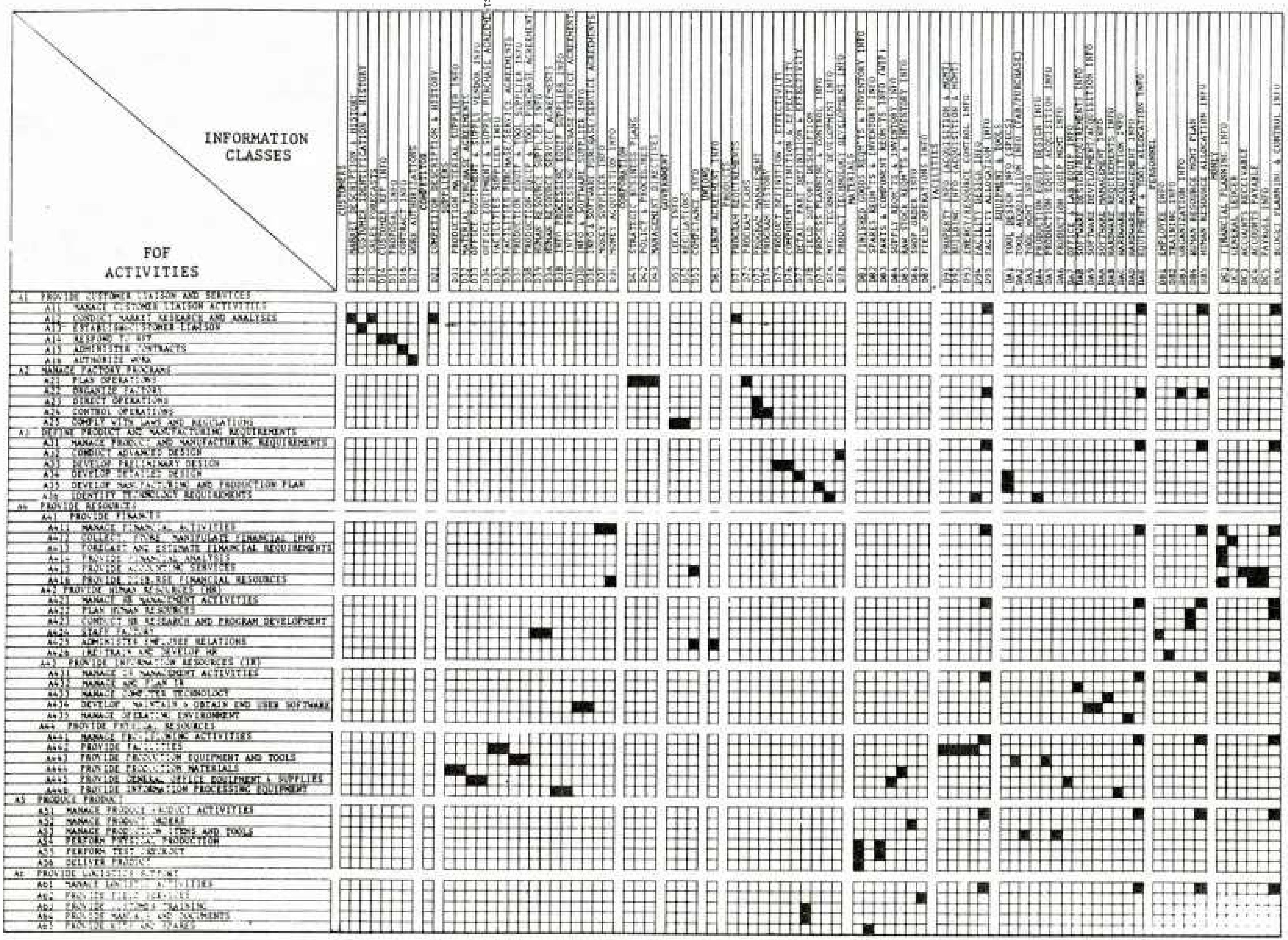
DA1	Tool Design Info (Specs)
DA2	Tool Acquisition Info (Fab/Purchase)
DA3	Tool Mgmt Info
DA4	Production Equip Design Info
DA5	Production Equip Acquisition Info
DA6	Production Equip Mgmt Info
DA7	Office & Lab Euip Info
DA8	Software Design/Requirements Info
DA9	Software Development/Acquisition Info
DAA	Software Management Info
DAB	Hardware Requirements Info
DAC	Hardware Acquisition Info
DAD	Hardware Management Info
DAE	Equipment & Tool Allocation Info

PERSONNEL INFORMATION CLASSES

DB1	Employee Info
DB2	Training Info
DB3	Organization Info
DB4	Human Resource Mgmt Plan
DB5	Human Resource Allocation Info

MONEY INFORMATION CLASSES

DC1	Financial Planning Info
DC2	General Ledger
DC3	Accounts Receivable
DC4	Accounts Payable
DC5	Payroll Info
DC6	Budget Planning & Control Info



■ FOF ACTIVITY CREATES INFORMATION

Figure 5-3 Activity versus Information Class Summary Matrix

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5.1.7 Analysis of the Information Infrastructure

The achievement of a computer-integrated manufacturing Enterprise demands that all activities (and the physical mechanisms which perform the activity) be logically integrated through the sharing of common information. Examination of the relationship between Information Classes and activities reveals that a high level of common information exists, even among the relatively high level of activities shown in the IDEF0 model of the FoF. Therefore, an approach to creating and managing common information which will facilitate its sharing must be developed.

The traditional approach to implementing the factory Information Infrastructure has been through the developmemt of application systems. In fact, the formal BSP methodology results in an application systems portfolio for the Enterprise. The typical design objective for this approach is to build applications quickly and cheaply as far as hardware, software, and people are concerned. As a result, data are treated as a secondary issue. The development methodology in this environment has the following steps:

- o Identify the function (or information output) requirements
- o Design the systems functions (or information output)
- o Figure out what data are required and identify the quickest, cheapest source of the data
- o. Extract the data from an existing file and reproduce it for the new system, recreate it at the source, or use a secondary source.

The repetitive use of this approach results in multiple sourcing and serial distribution of the data as shown in Figure 5-4. As applications are added to the application portfolio, the following problem evolves: data begins to reside in multiple applications; consequently, it becomes inconsistent, unreconcilable, and unavailable. As a result, control of data is lost and management loses visibility.

If, in contrast, the systems design objective is to optimize the management of the data, the steps in the development methodology would be:

- o Identify a single source for every kind of data
- o Establish a reference control for managing the data
- o Design the functions required to acquire the data at its source and control its integrity
- o Design the information output systems on demand using the reference control facility.

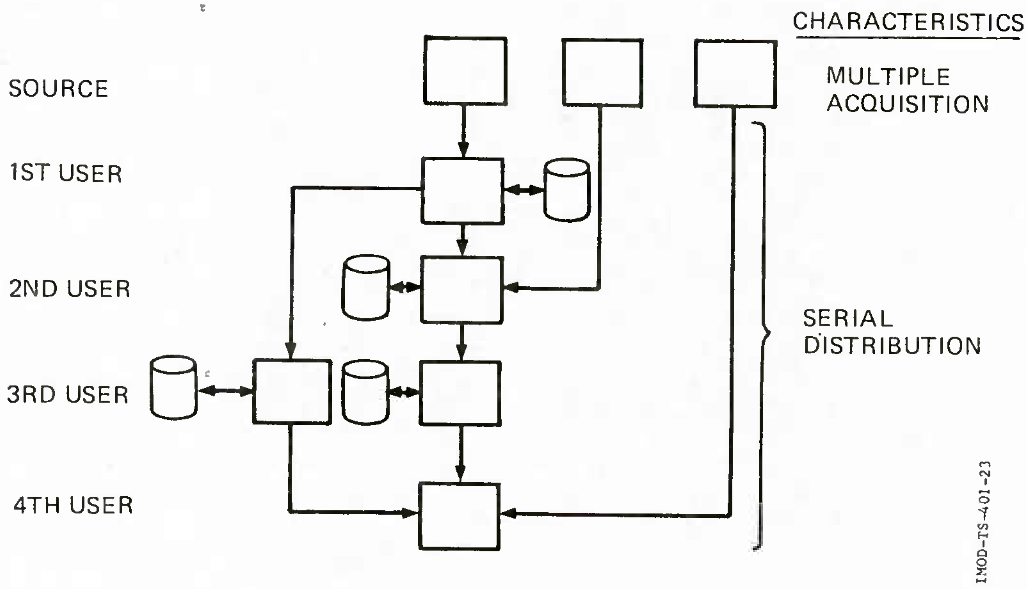

Figure 5-4 Treatment of Information Under "Application-Oriented" Systems Design

This approach results in singe-source, parallel distribution of the data as represented in Figure 5-5. The potential problem is the extravagant use of computer technology, designing and managing data for which there is no requirement. However, this is the only approach which will result in an integrated Information Infrastructure which is flexible enough to meet the needs of the rapidly changing environment of the FoF.

Although the activity versus Information Class matrix (see Figure 5-3) does not show a single source for each information class, a single source relationship between activities and information classes can be established through further decomposition. Some of the information required to run the Enterprise is obtained directly from observation or from external sources, such as customers and suppliers. Much of the information, however, is derived through the processing of other information which acts as an input to an activity. The information processing capabilities required to derive this information are discussed in Section 5.2.

5.1.8 Extensions: Data versus Information versus Knowledge

Before discussing the capabilities required to maintain the common data associated with the FoF Information Infrastructure,

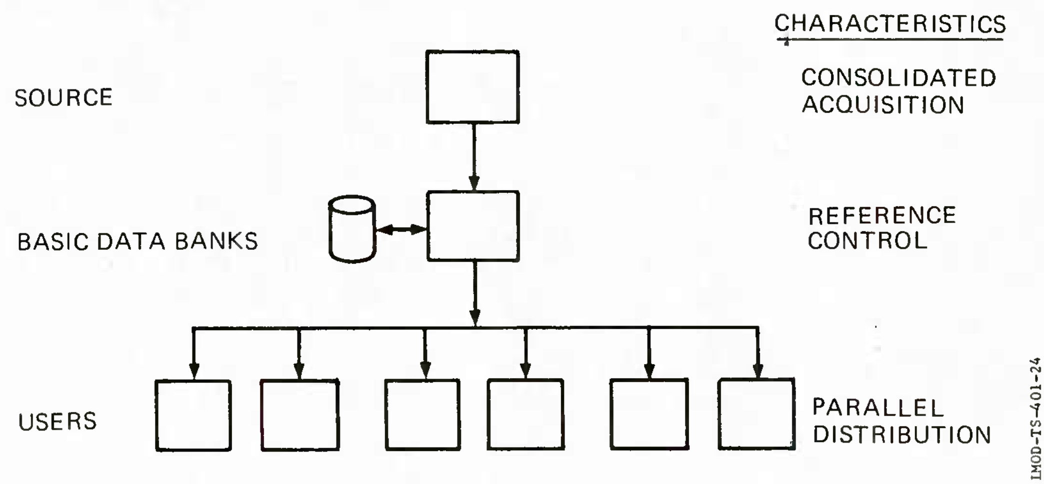

Figure 5-5 Treatment of Information Under "Data-Managed" Systems Design

its exact nature should be understood. Both a formal and informal Information Infrastructure exist. The informal infrastructure is maintained in the minds of the people who carry out the functions of the enterprise. Although not well understood, this has been the key means in logically integrating the manufacturing Enterprise in the past. Over the last several decades, individual companies have been building formal Information Infrastructures which can be shared by many individuals within the Enterprise. The formal Information Infrastructure is derived from the informal infrastructure and is conducive to mechanization.

Prior to the development of computer technology, the formal infrastructure was mechanized through manual paper-based systems. Computer technology has rapidly increased our ability to mechanize information and, thus, the need to further define a formal Information Infrastructure has become critical.

In the aerospace Factory of Today, the use of the computer-based formal Information Infrastructure has grown to the point that most aerospace companies can no longer operate on the informal infrastructure alone. However, the formal infrastructure in today's aerospace Enterprise is also not sufficient without the use of informal, human-based information. The typical aerospace Enterprise is currently at "the point of no return." Therefore, a strategy must be developed to continue the evolvement of the formal Information Infrastructure

The evolution of the formal infrastructure began with the definition of data. Data can be thought of as facts about the real world. Initially, the meaning of these facts was almost totally left to human interpretation. The computer proved to be a very handy tool for storing and manipulating facts. As the discipline of data processing evolved, system development techniques were put in place which emphasized the optimal use of the computer (as opposed to the optimal use of information).

As more and more data processing systems were developed, redundancy and inconsistency between computer-stored facts became apparent. This led to the current stage of development of formal Information Infrastructures which attempts to attach "meanings" to the facts. These "meanings" can be defined in terms of data relationships. They require the use of data base management technology in order to be automated. Many companies are now in the process of adopting systems development techniques which emphasize the optimizatizon of data relationships rather than optimal use of the computer.

The evolution of the formal Information Infrastructure cannot stop with current efforts to define facts and meanings. It must continue to drive towards the formal definition and automation of knowledge. Knowledge, in a technical sense, is currently not well defined. However, research in the field of artificial intelligence has combined concepts for reasoning with facts and meanings in defining "knowledge-based" systems. The feasibility and power of expanding a formal Information Infrastructure into a formal Knowledge Infrastructure has already been demonstrated in both the laboratory and industry. The strategy for achieving a computer-integrated manufacturing Enterprise of the future must address development of a formal Information Infrastructure which will evolve from data to information to knowledge.

As the evolutionary Information Infrastructure evolves, the detailed structure of the computer-stored data will change. A prime example is in the evolution of the formal infrastructure for descriptive information about parts:

"A principle objective of integrated CAD/CAM in the industrial process is to replace abstract information, which requires human interpretation for precise meaning, with concrete information which much more closely represents physical reality and which is informationally rich enough to sustain algorithmic evaluation. This transition in information structure is one of change from two-dimensional representation of product geometry to three-dimensional forms thereof or, more to the point, geometrically complete representations instead of incomplete ones. The most obvious example of two-dimensional representation, and by far the most pervasive medium of product description, is the orthographically projected engineering drawing. This information medium, if complete and unambiguously rendered, when accompanied by any required reference or discrete digital data, and when contextually treated with regard to spatial orientation, permits precise human interpretation and serves as an adequate form of product definition when so interpreted. The engineering drawing, however, even in computerized digital form, is virtually worthless as a mathematical model of physical objects in the context of using such models to automate engineering and manufacturing functions. The 3-D edge-vertex ("wire frame") models common in today's generation of interactive graphics CAD systems, though more useful than 2-D drawing models, also impose definite technological limits in attempting to move to more sophisticated integrated CAD/CAM applications. A geometrically complete three-dimensional description is required for such purposes; to the end that a designed product's spatial, topological, volumetric and mass properties are intrinsic to its computer-sensible representation and can be evaluated directly. Examples of such methods include "solid geometric modeling" wherein volumetric building block primitives are combined through Boolean operations to represent homogeneous "solid" objects of arbitrary shape, or, physically complete 3-D objects are represented by manifolds of contiguous analytic surfaces which form their shape and enclose their volume."[2]

5.2 LOGICAL PROCESSES AS A COMPONENT OF THE FOF INTRODUCTION

5.2.1 Introduction

To obtain an integrated view of the factory system, a definitive list of all the activities in the factory is needed. An example of this list for the manufacturing of an aerospace product is the MFG_0 architecture. At the bottom nodes of this architecture are the activities performed in the factory. Each of these activities has an input, an output, a control and a mechanism. From the logical view (see Figure 5-6) the inputs are the information required by the activity. The outputs are the transformed information. The controls on the activity are the goals, policies, laws and regulations of the system. The mechanisms are the capabilities required to perform the activity.

From the physical view (see Figure 5-7), the inputs are the raw materials. The outputs are the products. The controls are the physical procedures. The mechanisms are the people, machines, equipment and facilities required to perform the activity.

2 Barnes, Robert D., "Technology for Integrated CAD/CAM," Autofact 5 Conference Proceeding, SME, Dearborn, Michigan, 1983, pp. 1-4, 1-5.

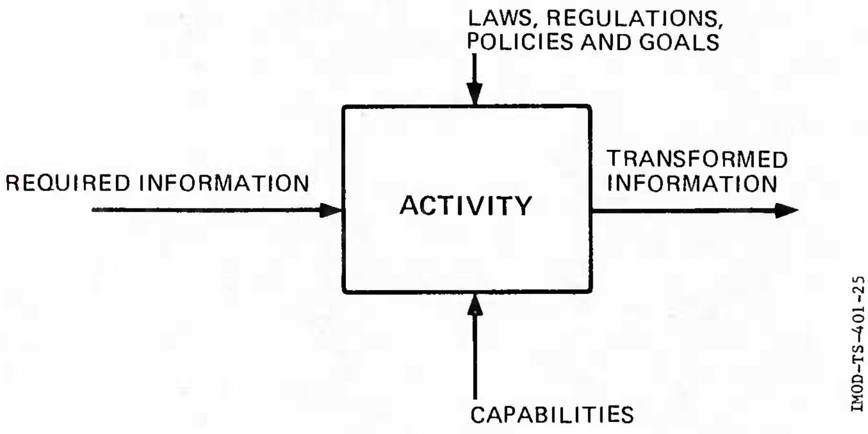

Figure 5-6. Logical View

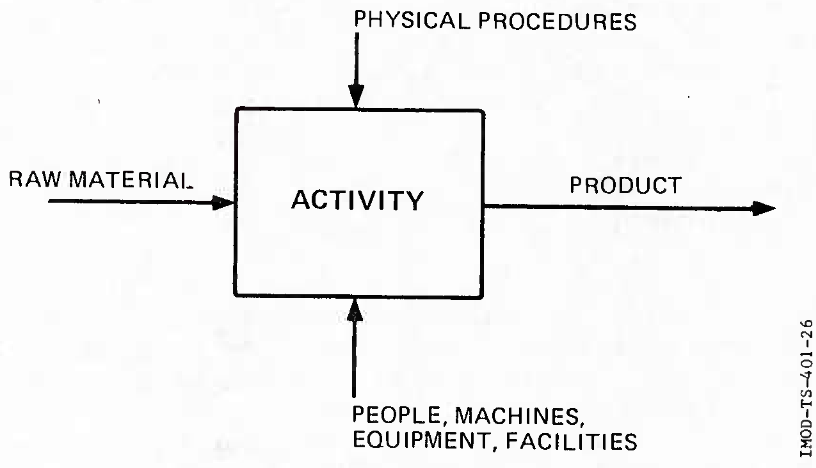

Figure 5-7 Physical View

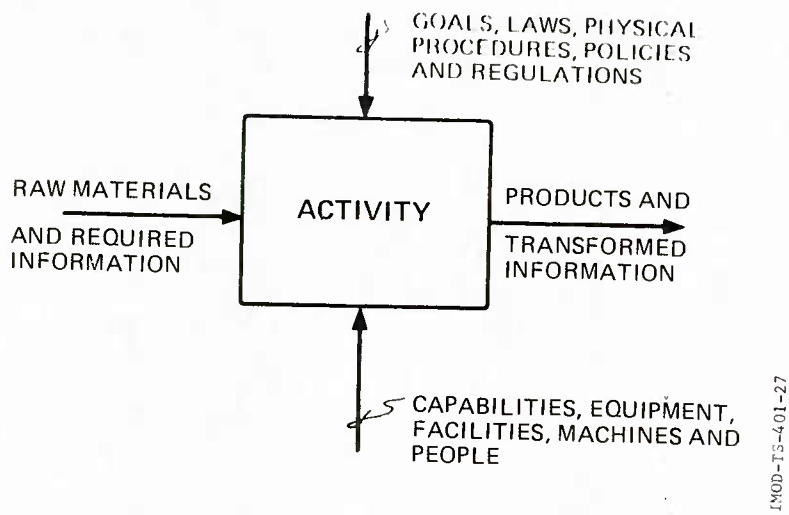

Figure 5-8. Composite View

Therefore, the composite activity view (see Figure 5-8) would include: inputs of raw materials, outputs of products, controls and the mechanisms.

5.2.2 Approach to Development of Logical Processing Capabilities

To establish a logical framework for the computer-integrated FoF, the capabilities required to create and use the Information Infrastructure must be defined. Each data item within an Information Class must have a source of update. See Figure 5-9. The update of a data item may result from:

- o Direct entry
- o Communications
- o Transformation of other data.

Both human and non-human information users may be responsible for direct entry of data. This data may be simply recording observations about the real world, e.g., machine failure reporting, attendance reporting, etc. Monitors and sensors can be used to enter observation data without human intervention. Direct entry of data may also result from inferences or decision-making which is external to the shared company information processing resources. This would include data

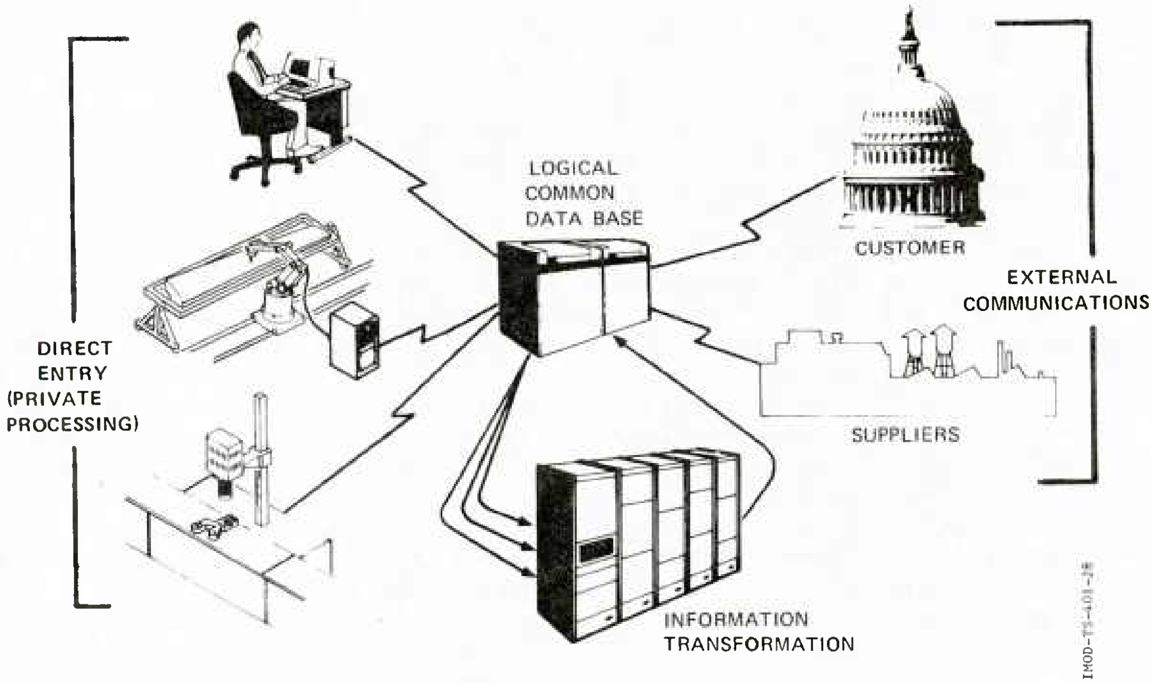

Figure 5-9. Logical Common Database Update Sources

resulting from individual human creativity and private computation such as through the use of a personal computer or a dedicated equipment controller. The integrated information processing and communications networks treats private computers as users whether they are used interactively with humans or fully automated.

Common information for the Enterprise may also be updated by external information sources through the use of communications. This is the same concept as direct entry except that the user is external to the enterprise. The basic capability needed is that of receiving incoming information. This information may be a result of a specific request of the Enterprise or it may be totally initiated by the sender.

A large percentage of the information required to run the aerospace FoF will be derived through a series of transformations. Each data item may be generated by a variety of data transformation techniques depending on the established operating procedures for the company and the specific technology employed in the transformation process. IDEF0 activities models of factory operations implicity define types of transformations required to run various portions of the Enterprise. An "activity" represents a basic transformation capability applied to specific groups of data. Section 5.1 identified the Information Infrastructure independent of the related activities. This section will identify the transformation capabilities required to run a manufacturing enterprise independent of the related activities.

Thus far we have discussed the information transformation as a way of generating updates to the common information needed to run the Enterprise. However, transformations may also be used to produce information for private or individual use. For example, the transformation of a computer-stored geometric model into a two-dimension graphical display would generally result in private information for the user initiating the inquiry. The results of transformations need only be stored in the logical common data base when they are going to be used by more than one user, and when the transformation is not fully computerized or the computational expense is too great to regenerate the output each time it is needed, i.e., a trade-off between computing cost versus storage cost.

5.2.3 Integrated FoF Transformation Capabilities

An analysis of various IDEF0 activity models of manufacturing operations led to the list of transformation capabilities show in Table 5-6. These capabilities have been grouped into six major categories:

- o Data collection
- o Process
- o Analysis
- o Communication
- o Update
- o Decision

Data collection capabilities have the ability to gather raw data from humans and other resources within the Enterprise. Process capabilities generally provide structured decision-making capabilities, where a standard procedure is used to transform a given set of inputs into a specific output. Analysis capabilities relate to semistructured decision-making in which transformations are used to evaluate "what-if" questions. Communications capabilities include transformations for both internal and external communications. Update capabilities deal with the actually changing of stored or previously defined information. Decision capabilities address both semistructured and unstructured decisions.

This list is representative of the capabilities defined by previous ICAM system analysis work and is not intended to be

Table 5-6 Information Transformation Capabilities

DATA COLLECTION CAPABILITIES	
DC1	COLLECT REALTIME PRODUCTION DATA
DC2	COLLECT TEXT DATA
DC3	COLLECT GRAPHIC DATA
DC4	COLLECT VOICE DATA
DC5	COLLECT POLICY/ORGANIZATION DATA
DC6	COLLECT EXTERNAL DATA
DC7	COLLECT GENERAL DATA
PROCESS CAPABILITIES	
PC1	CLASSIFY INFORMATION
PC2	RETRIEVE CLASSIFIED INFORMATION
PC3	PROCESS AND STORE TEXT DATA
PC4	RETRIEVE DOCUMENTS/PROCEDURES/POLICIES
PC5	ESTIMATE COST
PC6	ALLOCATE BUDGETS
PC7	DO STANDARD COST ACCOUNTING
PC8	JUSTIFY EXPENDITURES
PC9	CONTROL ITEM/PRODUCT CHANGES
PC10	CONTROL POLICY/PROCEDURE CHANGES
PC11	CONTROL INVENTORY
PC12	DO CAPACITY PLANNING
PC13	DETERMINE SEQUENCE OF ASSEMBLIES/PROCESS
PC14	PLAN ACTIVITIES
PC15	PRODUCE SCHEDULES
PC16	DEFINE ASSEMBLY STRUCTURE
PC17	DETERMINE MATERIAL REQUIREMENTS
PC18	ALLOCATE RESOURCES
PC19	TRACK INFORMATION/ITEMS/PRODUCTS
PC20	SET PRIORITIES
PC21	VALIDATE AND SECURE DATA
PC22	STORE HISTORY
PC23	RETRIEVE GENERAL INFORMATION
PC24	RETRIEVE HISTORY
ANALYSIS CAPABILITIES	
AC1	ANALYZE DOCUMENTS/TEXT
AC2	ANALYZE VENDORS
AC3	COMPARE ALTERNATIVES
AC4	ANALYZE PRIORITIES
AC5	SIMULATE/ANALYZE SCHEDULES
AC6	ANALYZE GRAPHIC INFORMATION
AC7	SIMULATE/ANALYZE BUDGETS
AC8	APPLY STATISTICAL EVENT SIMULATION
AC9	APPLY GRAPHICAL EVENT SIMULATION
AC10	APPLY MATHEMATICAL MODELS
AC11	FORECAST EVENTS/COST/RESOURCES
AC12	APPLY ECONOMIC MODELS
AC13	ANALYZE ASSEMBLIES
AC14	ANALYZE FINANCIAL RESOURCES
AC15	ANALYZE MANUFACTURING RESOURCES
AC16	ANALYZE DESIGN/PLANNING RESOURCES
AC17	ANALYZE INFORMATION RESOURCES
AC18	ANALYZE MANPOWER RESOURCES
AC19	APPLY MECHANICAL ANALYSIS AND TEST
AC20	APPLY ELECTRONIC ANALYSIS AND TEST
COMMUNICATION CAPABILITIES	
CC1	DISPLAY TEXT/DOCUMENTS
CC2	DISPLAY GRAPHICS
CC3	PREPARE FORMS/PRODUCE REPORTS
CC4	COMMUNICATE TEXT
CC5	COMMUNICATE GRAPHICS
CC6	COMMUNICATE VOICE
CC7	COMMUNICATE INSTRUCTION TO EQUIPMENT
CC8	COMMUNICATE DATA TO HETEROGENEOUS
UPDATE CAPABILITIES	
UC1	CHANGE DOCUMENTS/TEXT INFORMATION
UC2	CHANGE GRAPHICS DATA
UC3	UPDATE DESIGNS/PLANS
UC4	UPDATE ALLOCATIONS/SCHEDULES/PRIORITIES
UC5	UPDATE ACTIVITIES/SEQUENCES/INVENTORY
UC6	RE-CLASSIFY INFORMATION
DECISION CAPABILITIES	
DC1	APPROVE/DISAPPROVE ACTIONS
DC2	MAKE ANALYTICAL DECISION
DC3	IMPLEMENT DECISION

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exhaustive. The relationship between these capabilities and the FoF activity model is shown in Figure 5-10. This matrix shows a high degree of commonality between the basic capabilities needed to carry out the various FoF activities. Capabilities which can be implemented independent of the type of information they transform can offer a great deal of flexibility to the FoF framework. That is, the logical tools, i.e., transformation capabilities and information, needed to carry out an activity can be dynamically combined. This means an almost limitless number of "virtual applications" which can be tailored to specific objectives. This concept takes advantage of the parallel distribution of information described in the previous paragraph.

5.2.4 Extensions, Data Processing versus Decision Support versus Artificial Intelligence

The technique used to perform data transformation consists of a logical process or procedure by which the input data is transformed into the desired output, and the mechanism for carrying out the transformation.

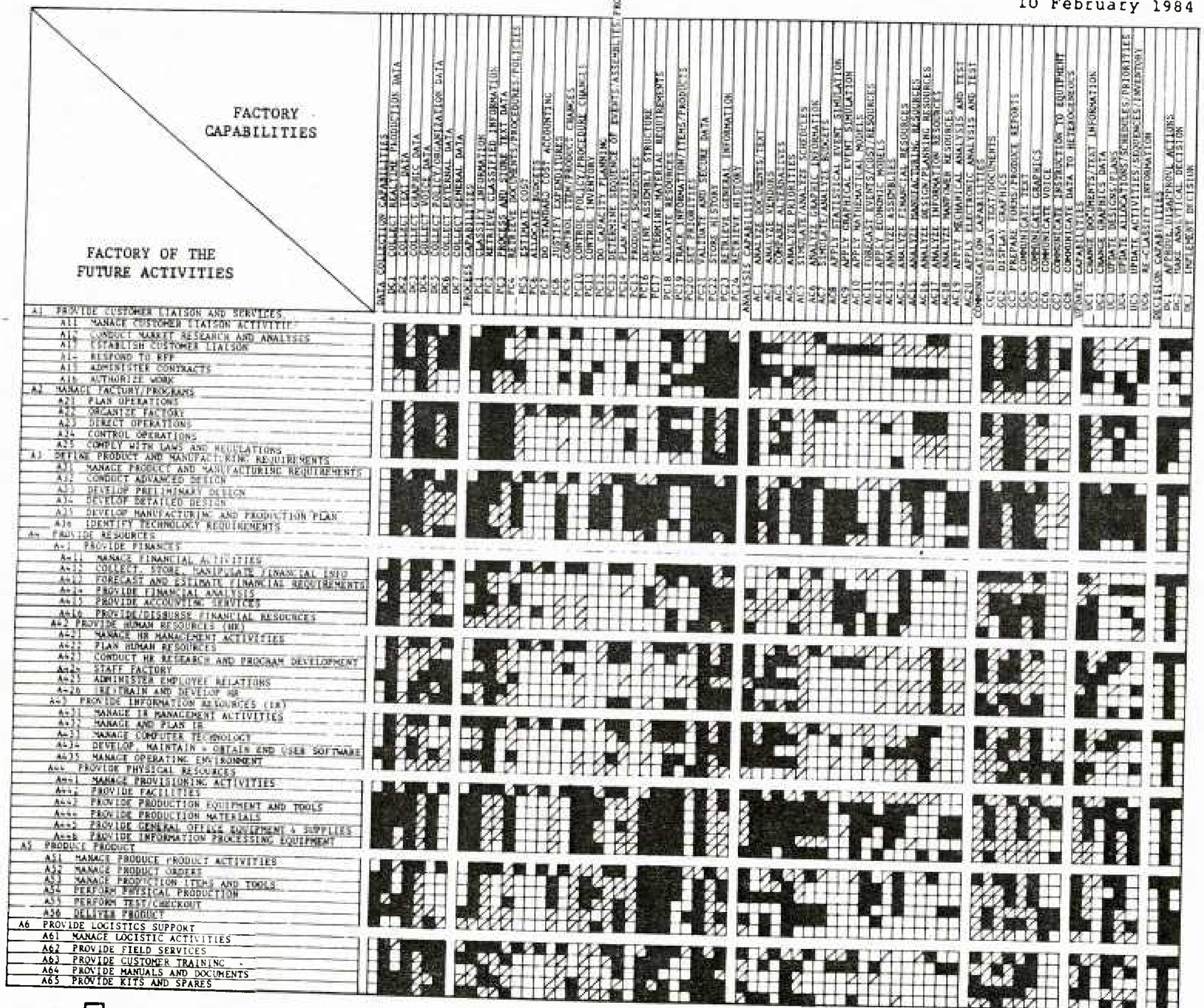
The transformation mechanism may be:

- o A user (either human or non-human),
- o A combination of user and shared computing facilities which are part of the company network, or
- o Fully computerized.

User based transformations differ from direct data entry in that the transformation is formally recognized by the Information Infrastructure and may be controlled by company policy and procedures. In the case of computer-based transformations, the logic for performing the transformation has been totally captured in software. The output is generated from a given set of inputs without user intervention. Computer-aided transformations use both user and common processing capabilities in an interactive fashion. This approach allows the intuitive reasoning capabilities of a human to be combined with the storage capacity and processing speed of the computer. See Figure 5-11.

The logical process or procedure associated with a transformation technique can generally be equated to one or more steps in the decision-making process. The basic steps in decision making are:

- o Observation
- o Inference
- o Evaluation
- o Choice



KEY
- DOES NOT APPLY
- EXPECTED USE
- PROBABLE USE

Figure 5-10. Factory of the Future Activities and Required Transformation Capabilities

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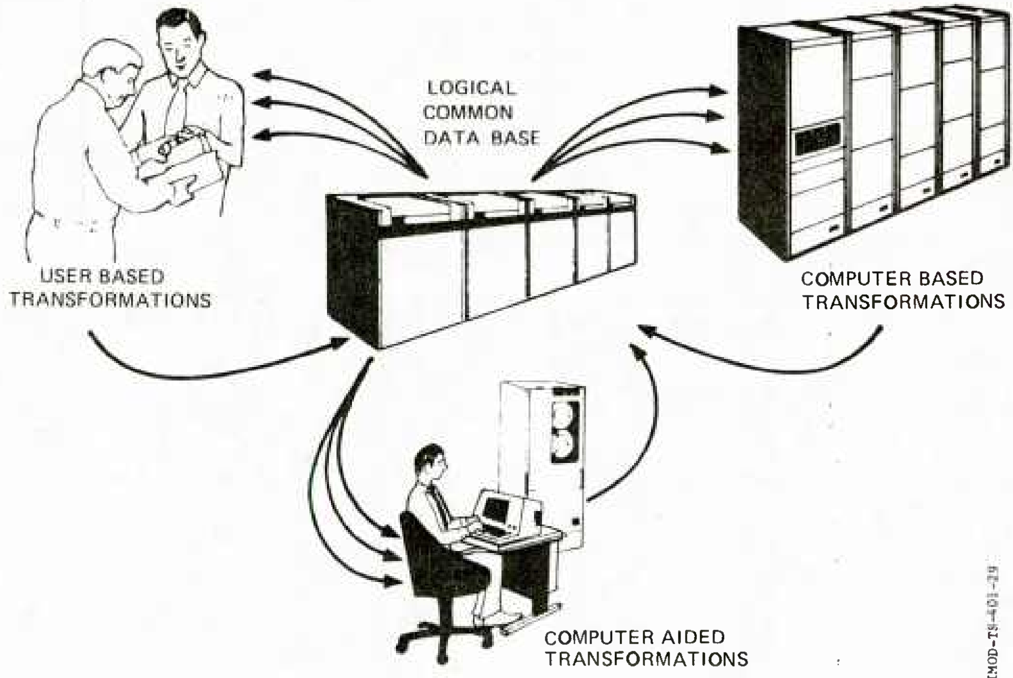


Figure 5-11. Information Transformation Mechanisms

The decision process begins with observing states of the environment; measurements are taken, and data are collected, encoded and stored. The second stage involves analysis of the recorded data as a base for inference and prediction. Stage three is initiated by the need for a decision. Inferences and projections are analyzed to identify action alternatives and these, in turn, are evaluated with respect to goals, constraints and efficiency. Finally, an alternative is selected which is preferred (or "best") under the criterion of choice; the action is communicated, resources are committed, and the decision is implemented. The process actually perpetuates itself through cycling and feedback since, upon implementation the decision becomes a source for new observations.

Computer-based transformations can be characterized by four levels of maturity. In its most elemental form, the computer-based transformation simply maintains a repository of "observation-type" information. Inference, evaluation, and choice are left to human-based transformation. The computer-based transformation organizes and stores raw data in a convenient form for retrieval and reporting. Basic data processing systems are of this elementary form. Simplicity, per
processing systems are of this elementary form. Simplicity, per
se, is not a criticism of such systems; their shortcoming is that they do not discriminate between vital information and trivia.

Thus, managers interacting with an elementary data processing system often become frustrated by the lack of relevancy in large volumes of data.

At the second level of maturity, the role of computer-based transformations has been expanded to include the activities of "inference." In addition to exception reporting, the computer now has the capacity to forecast and to artificially test the consequences of implicit decisions. Here, the human component interrogates the system with "What if ..." questions, and receives an array of answers for him to evaluate. The hidden danger in this dialogue is that the user is usually insulated from factual data in the system by a host of assumptions embedded in the model which provides the inferences. It is surprising how readily individuals are lulled into believing that "realistic-looking" output is fact.

The ability to perform computer-based inference is limited by the completeness and validity of the computer-stored models. Past approaches have made gross assumptions about the real world in order to develop a computationally feasible model. For example, the requirements generation algorithm for an MRP system uses gross assumptions about queue times, scrap rates, machine capacities, etc. to make inferences about material quantities. Inference models have traditionally been entered into the computer through the use of procedural computer languages, such as FORTRAN, COBOL, and PL/1. The role of the systems analyst has been to create the inference models, although his work may not have been recognized as such. In addition to the dangers of misleading inferences, these inference models are difficult and expensive to change to make them more realistic.

More recent efforts have focused on "decision-support systems" which provide the user with the ability to construct his own inference models through the use of "natural language" rather than procedural languages. The object of natural language research is a system that can interact with humans at the WHAT level (Here's what I want you to do) rather than the HOW level. The HOW level requires translating a human's original intention into a procedure such as the code of a high-level programming language. Natural language is the ultimate step in the ongoing attempt to make programming easier and more productive. See Figure 5-12.

The detailed data structure defined by the formal Information Infrastructure must support the inference model being used. Various levels of sophistication may exist for the inference model and its associated data structure. As mentioned previously, a solid geometric model is much better for

Source: "Artificial Intelligence," Mini-Micro Systems, December, 1983, p. 229

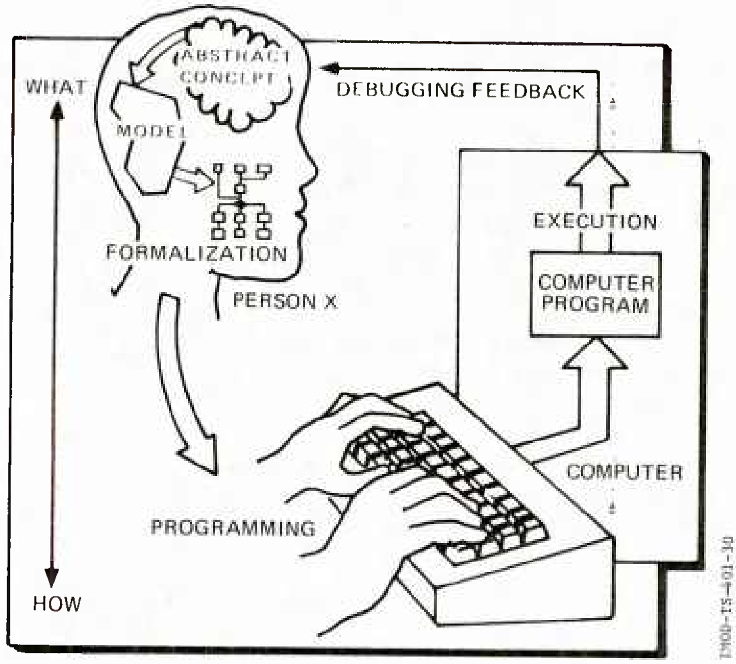


Figure 5-12. The What-How Spectrum

inferencers than a series of two-dimensional models. However, the solid model requires a more complex data structure capable of storing the additional information not found in two-dimensional models. Inference models can be directly related to the four basic types of information discussed in Section 5.1. That is:

- <u>Physical characteristics inference models</u> (e.g., geometric models, structural models, aerodynamics models, circuity models, etc.)
- <u>Value inference models</u> (e.g., cost estimating models, cost allocation models, justification procedures, authorization procedures, etc.)
- <u>Event inference models</u> (e.g., finite scheduling techniques, infinite scheduling techniques, event simulation, etc.)
- <u>Relationship inference models</u> (e.g., resource allocation models, configuration management techniques, etc.)

At the third level of maturity, evaluation activities have been programmed into the selective-inference structures so that the computer-based transformation now encompasses an action recommendation. Here the need for a decision is triggered within the formal system on the basis of monitored observations and predetermined rules of a time-scheduled event. Procedures are programmed to evaluate alternatives against assigned goals. The "best" course of action is chosen and recommendation to the human component. At that point, the user either implements a decision based on the recommendation or he rejects the alternative and asks for further analysis. This concept is analogous to the advisory staff group or committee. In this case, line management delegates authority for a certain area of responsibility to a staff department, but retains final control for decision through review and certification. This capability has appeared in the form of large-scale optimization models, particularly linear programing applications in industrial scheduling. In many of these cases, systems originally designed for "action recommendation" have reverted back to "selective-inference" systems as limitations of the model became apparent.

More recently, new efforts have focused on construction of "expert systems" using artificial intelligence concepts. An expert system is built by transcribing the logic rules of a human expert within a given area into a "knowledge base" which is computer-stored. This is referred to as Knowledge Engineering. Given the facts of a particular problem or decision-making requirement, the knowledge base is used to dynamically construct and evaluate an inference model. See Figure 5-13. The system may repeat the data-gathering step by asking for additional inputs. Eventually the system winds up with a recommended solution which can be accepted or rejected.

In the final stage of maturity, the entire decision process has been automated. All activities from observation to choice and the ability to initiate action, commit resources and monitor results have been programmed. In effect, the human is now outside the structure, having fully delegated his authority, although he retains the power to revoke the delegation at some future time. The simplest form of an automated decision system is the "standard operating procedure" in organizations; a more sophisticated example would be a computerized process control system in a petroleum refinery. Modern factory inventory control systems are another common example. Obviously, automated decision systems require extensive knowledge of the decision process for the given application and, consequently, their development has been limited to well-defined environments.

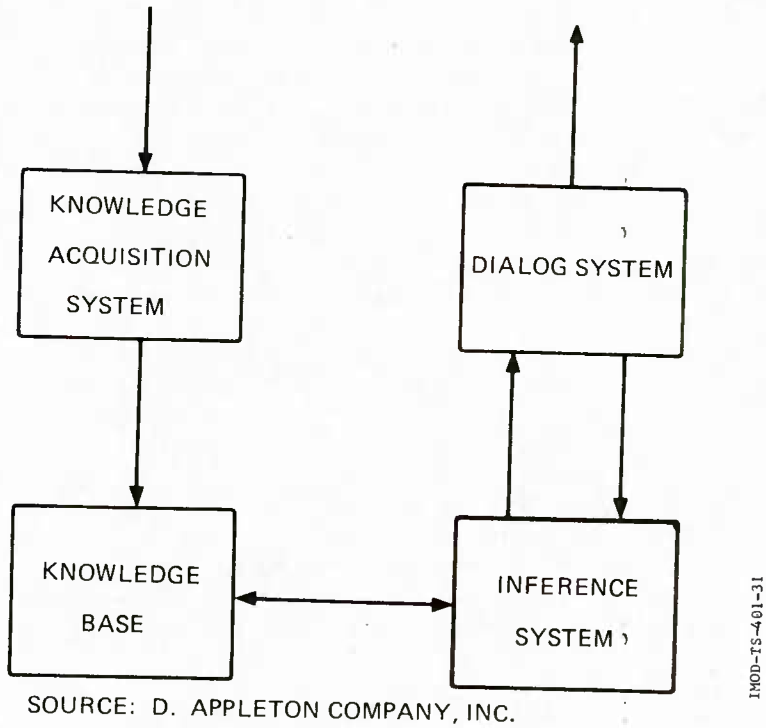


Figure 5-13. Components of an Expert System

The decision-making process depends upon the method of reasoning. See Figure 5-14. Decisions which are based on intuitive reasoning are considered unstructured decisions and require human-based transformations. Decisions can also be made on the basis of deductive and inductive inferences. Deductive reasoning involves the application of general concepts to a specific situation. This is the form of reasoning implemented in most automated decision-making programs today. Simple concepts can easily be programmed into a computer for repeated application to variable inputs. These are considered structured decisions. More complicated concepts require the use of artificial intelligence to establish a knowledge base to guide the reasoning process. In AI systems, the actual decision process changes are based on the inputs and the inferences made about the inputs. These are referred to as semistructured decisions.

Inductive reasoning is much more difficult. It involves creating general concepts from a set of specific situations. This is the basis of learning, in which one or more "experiences" are generalized for use in deductive reasoning in future situations. Computer-based inductive reasoning is still primarily in the research stage, but it offers great promise for future industrial applications.

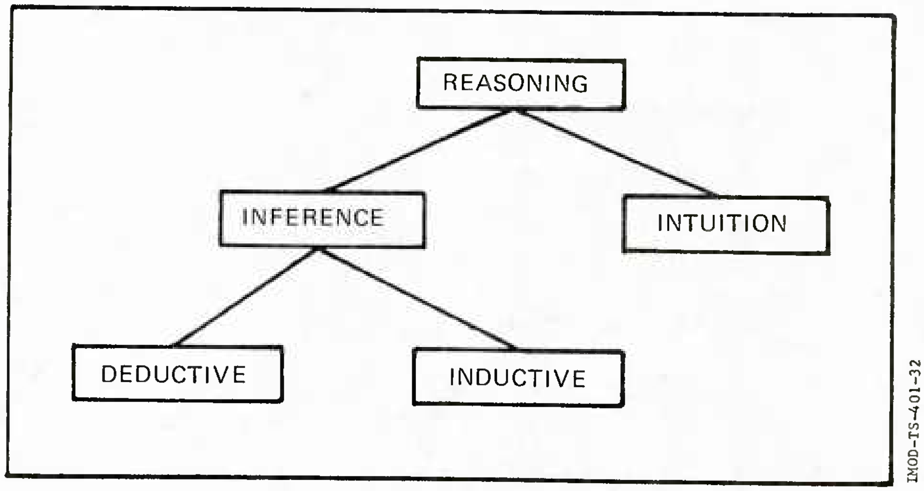


Figure 5-14 Methods of Reasoning

In summary, the conceptual framework for the FoF must recognize the "knowledge-base" of the Enterprise in terms of information and logical processes. A strategy for evolution and a method of control must be put in place to facilitate an orderly migration from an informal Information Infrastructure to a computer-based formal Information Infrastructure and from human-based logical processes to computer-based logical processes. A summary of the required computer-based capabilities is shown in Table 5-7.

Table 5-7 Categories of Computer-Based Capabilities

- <u>Observation</u>
  - Human input
  - Event monitoring
  - Internal communication
  - External communication
  - Database retrieval
  - Information display(for human-decision processing)
- <u>Inference (Model Building)</u>
  - Identification
  - Physical characteristics definition
  - Value definition
  - Event definition
  - Relationship definition
- <u>Evaluation and Decision Making</u>
  - Optimization
  - Decision support
  - Reasoning(Artificial Intelligence)
- <u>Decision Implementation</u>
  - Database update
  - Internal communications
  - External communications
  - Resource control

SECTION 6.0

1995 COMPUTER-INTEGRATED AEROSPACE ENTERPRISE

6.1 INTRODUCTION

This section provides a description of an aerospace Enterprise in 1995. It is based upon the concepts developed both in the ICAM Life Cycle Documents and in this document. This document represents the Task B coalition's view of an aerospace Enterprise. Others using this methodology could develop different views of the activities of specific enterprises as opposed to the generic enterprise activities used by the coalition.

For successful factory operations, certain areas of responsibility must be assigned to functional groups. These groups are called centers. Each center has the responsibility to create, use, maintain and secure distinct information classes within the logical common data base. For integration to work, each type of information can only have one center as its source. Each center will also have tools for collecting, processing, analyzing, updating, displaying, communicating and making decisions on the information used or created.

These tools (consisting of human and computer-based knowledge) are defined by the capabilities they possess. Therefore, the capabilities of one center may show up in many other centers. Also, by defining a different set of capabilities a new tool can be created. This leads to the possibility of dynamically creating tools to perform a non-repetitive task.

The six centers follow the functional FoF architecture as described in paragraph 3.6. The relationship between the identified FoF centers and the FoF activity model is as follows:

CENTERS	ARCHITECTURE
Executive Management	Manage Factory/Programs
Business Development	Provide Customer Liaison & Services
Technology Development	Define Product & Mfg Requirements
Resource Management	Provide Resources
Manufacturing	Produce Product
Product Support	Provide Logistics Support

There is almost an infinite number of ways the components and capabilities of a FoF could be organized and implemented. Figure 6-1 shows a logical grouping of information and capabilities for computer-based systems in the FoF. It should be noted that this systems architecture is a departure from the serial information flow concept which has been used for the development of individual "application systems" in the past. Therefore, modules or systems such as MRP, CAD, CAM, Group Technology, etc. do not appear directly on the architecture. The information associated with these applications, however, is covered by the shared logical data bases and the capabilities they provide are included in the various knowledge systems associated with the major functions of the business. All common information is made available throughout the Enterprise and is defined and managed through an intelligent common data model/directory. Likewise, logical processes which represent the formal knowledge base of the Enterprise are maintained by a library of logical processes. Each major business function is supported by a knowledge system which provides the tools to support or automate the various levels of decision-making within each business function. Individual workstations house private information and logical processes. These workstations support decision-makers at all levels which, in the case of manufacturing, may represent intelligent equipment as well as humans. The following paragraphs will describe the characteristics of the various types of FoF centers and the capabilities associated with the supporting knowledge system.

6.2 EXECUTIVE MANAGEMENT CENTER

This center represents the executive level management group that has ultimate responsibility for the factory and is answerable to the owners of the Enterprise. This center will plan, control, organize and direct factory operations to reach the goals of the Enterprise. This function will also be responsible for complying with the laws, regulations and needs of the local, state and federal governments. The relationship of the FoF A2 node to other ICAM architectures is displayed in Figures 6-2, 6-3, 6-4 and 6-5.

The Plan Factory operations activity sets the goals and objectives for each center; each center then refines these controls to plan the operations of its own center. Each center develops strategies, establishes priorities, allocates resources, and establishes policies and procedures for its own environment.

The Organize Factory activity sets the organizational structure for each of the management functions for each center. Each center then creates an organization structure to meet the

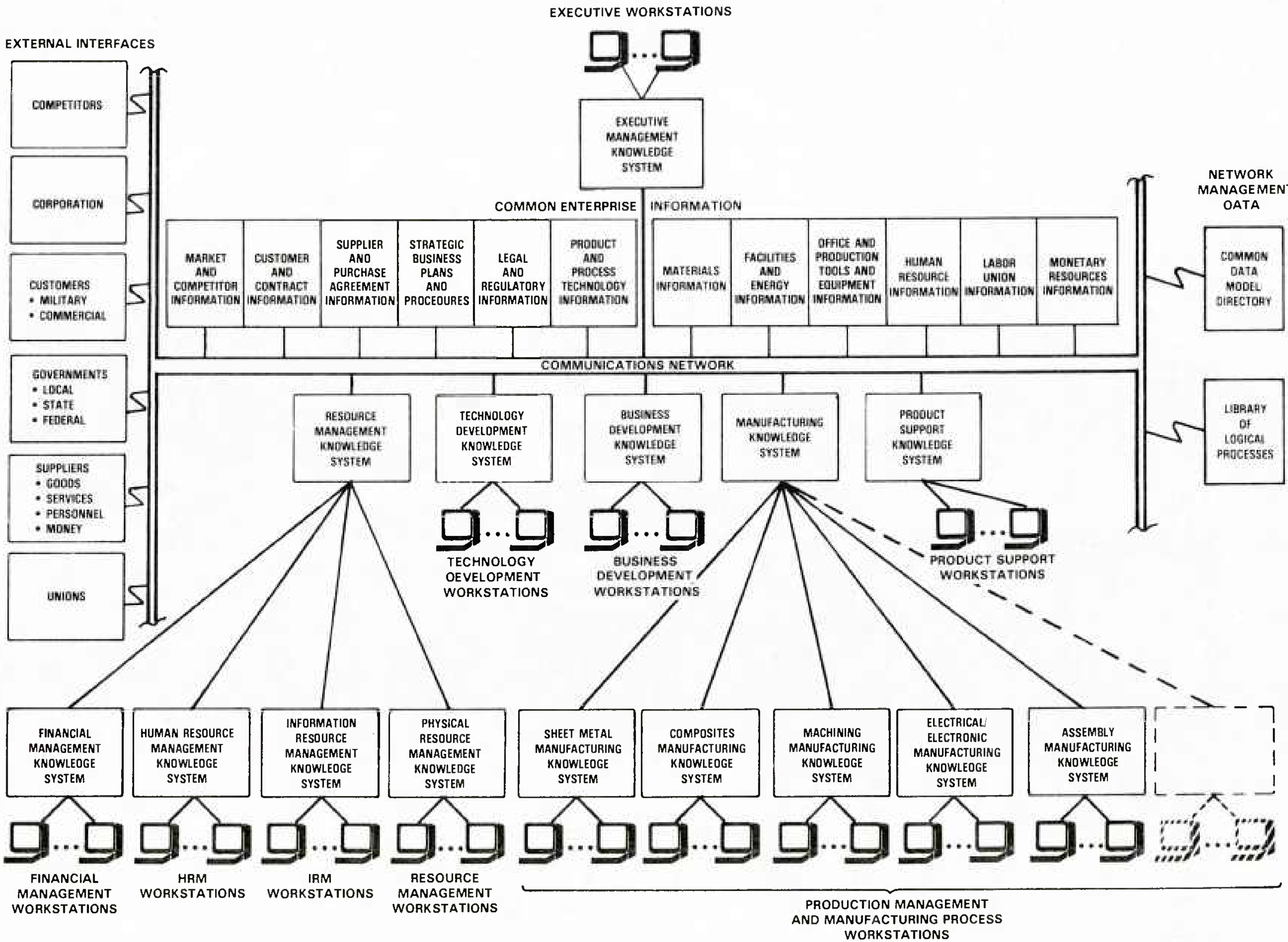


Figure 6-1 FoF Computer Based Systems Architecture

FOF-0 / DES-0, MFG-0, QA-0	A1 PROVIDE CUSTOMER LIAISON AND SERVICES	A11 MANAGE CUSTOMER LIAISON ACTIVITIES	A12 CONDUCT MARKET RESEARCH AND ANALYSES	A13 ESTABLISH CUSTOMER LIAISON	A14 RESPOND TO RFP	A15 ADMINISTER CONTRACTS	A16 AUTHORIZE WORK	A2 MANAGE FACTORY/PROGRAMS	A21 PLAN OPERATIONS	A22 ORGANIZE FACTORY	A23 DIRECT OPERATIONS	A24 CONTROL OPERATIONS	A25 COMPLY WITH LAWS AND REGULATIONS	A3 DEFINE PRODUCT & MANUFACTURING REQUIREMENTS	A31 MANAGE PRODUCT & MANUFACTURING REQUIREMENTS	A32 CONDUCT ADVANCED DESIGN	A33 DEVELOP PRELIMINARY DESIGN	A34 DEVELOP DETAILED DESIGN	A35 DEVELOP MANUFACTURING AND PRODUCTION PLAN	A36 IDENTIFY TECHNOLOGY REQUIREMENTS	A4 PROVIDE RESOURCES	A41 PROVIDE FINANCES	A42 PROVIDE HUMAN RESOURCES	A43 PROVIDE INFORMATION RESOURCES	A44 PROVIDE PHYSICAL RESOURCES	A5 PRODUCE PRODUCT	A51 MANAGE PRODUCE PRODUCT ACTIVITIES	A52 MANAGE PRODUCTION ORDERS	A53 MANAGE PRODUCTION ITEMS AND TOOLS	A54 PERFORM PHYSICAL PRODUCTION	A55 PERFORM TEST/CHECKOUT	A56 DELIVER PRODUCT	A6 PROVIDE LOGISTICS SUPPORT	A61 MANAGE LOGISTICS ACTIVITIES	A62 PROVIDE FIELD SERVICES	A63 PROVIDE CUSTOMER TRAINING	A64 PROVIDE MANUALS AND DOCUMENTS	A65 PROVIDE KITS AND SPARES
DES-0 A1 DEVELOP CONCEPTUAL DESIGN																■																						
DES-0 A2 DEVELOP PRELIMINARY DESIGN																	■																					
DES-0 A3 DEVELOP DETAIL DESIGN																		■																				
MFG-0 A1 PLAN FOR MANUFACTURE																			■																			
MFG-0 A2 MAKE AND ADMINISTER SCHEDULES AND BUDGETS																					/					/												
MFG-0 A3 PLAN PRODUCTION														■																								
MFG-0 A4 PROVIDE PRODUCTION RESOURCES																					■																	
MFG-0 A5 OBTAIN MANUFACTURING MATERIALS																									■													
MFG-0 A6 PRODUCE PRODUCT																										■												
QA-0 A1 PREPARE FOR FUTURE QA/QC AEROSPACE DEMANDS																				■																		
QA-0 A2 DEVELOP QA/QC RFP RESPONSE			■																																			
QA-0 A3 PREPARE QA/AC PROGRAM PLAN											/								/																			
QA-0 A4 IMPLEMENT QA/QC PROGRAM PLAN														/							/																	
QA-0 A5 PERFORM TO QA/QC PROGRAM PLAN														/							/					/							/					
QA-0 A6 EVALUATE QA/QC EFFECTIVENESS														/																			/					

Key:

■ ICAM ARCHITECTURE INCLUDED IN FOF ARCHITECTURE

/ ICAM ARCHITECTURE PARTIALLY INCLUDED IN FOF ARCHITECTURE

☐ ICAM ARCHITECTURE DOES NOT APPLY TO FOF ARCHITECTURE

Figure 6-2 Relationship of Existing ICAM Architectures (MFGØ, DESØ, QAØ) with the FoF Ø Architecture

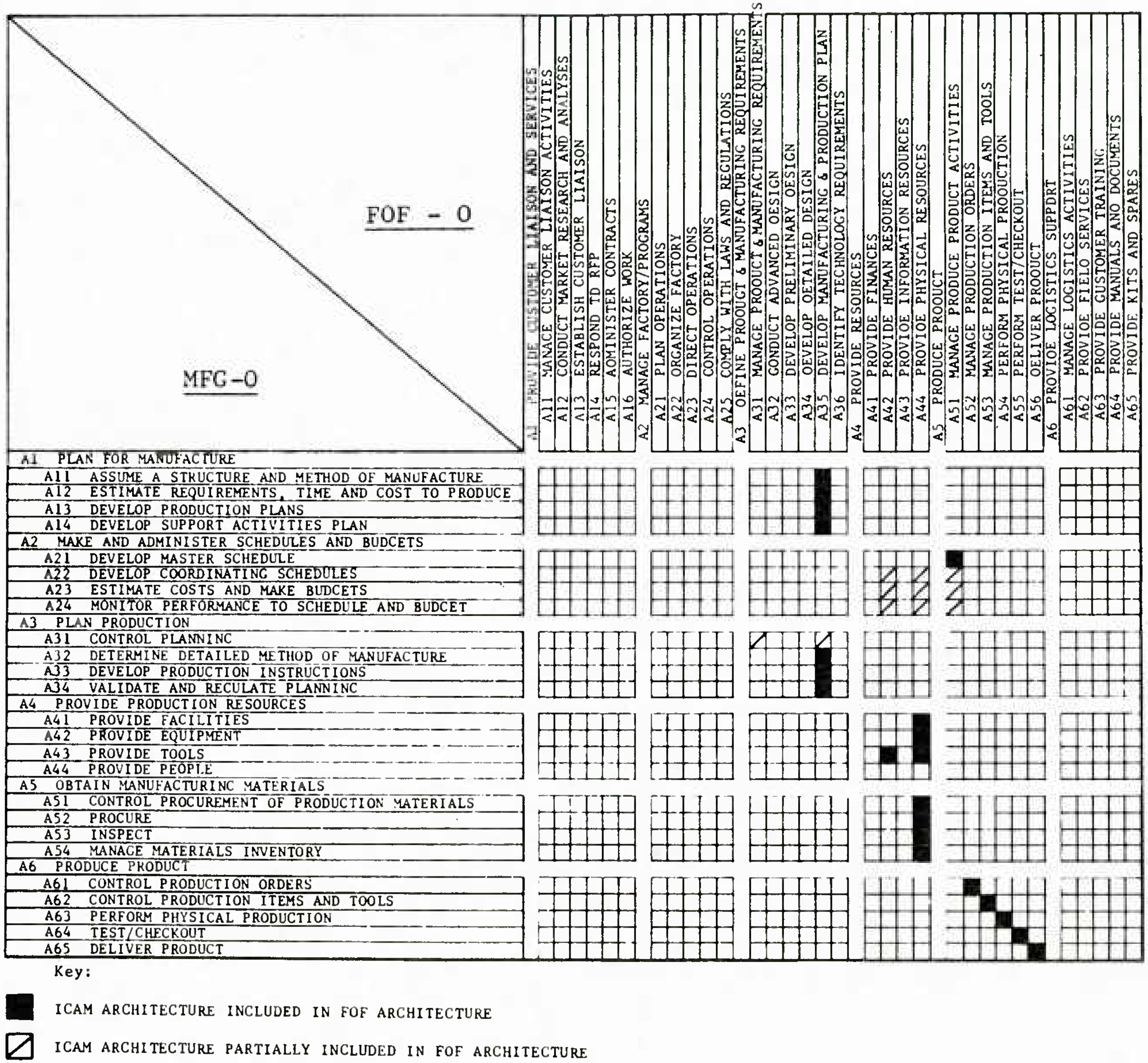
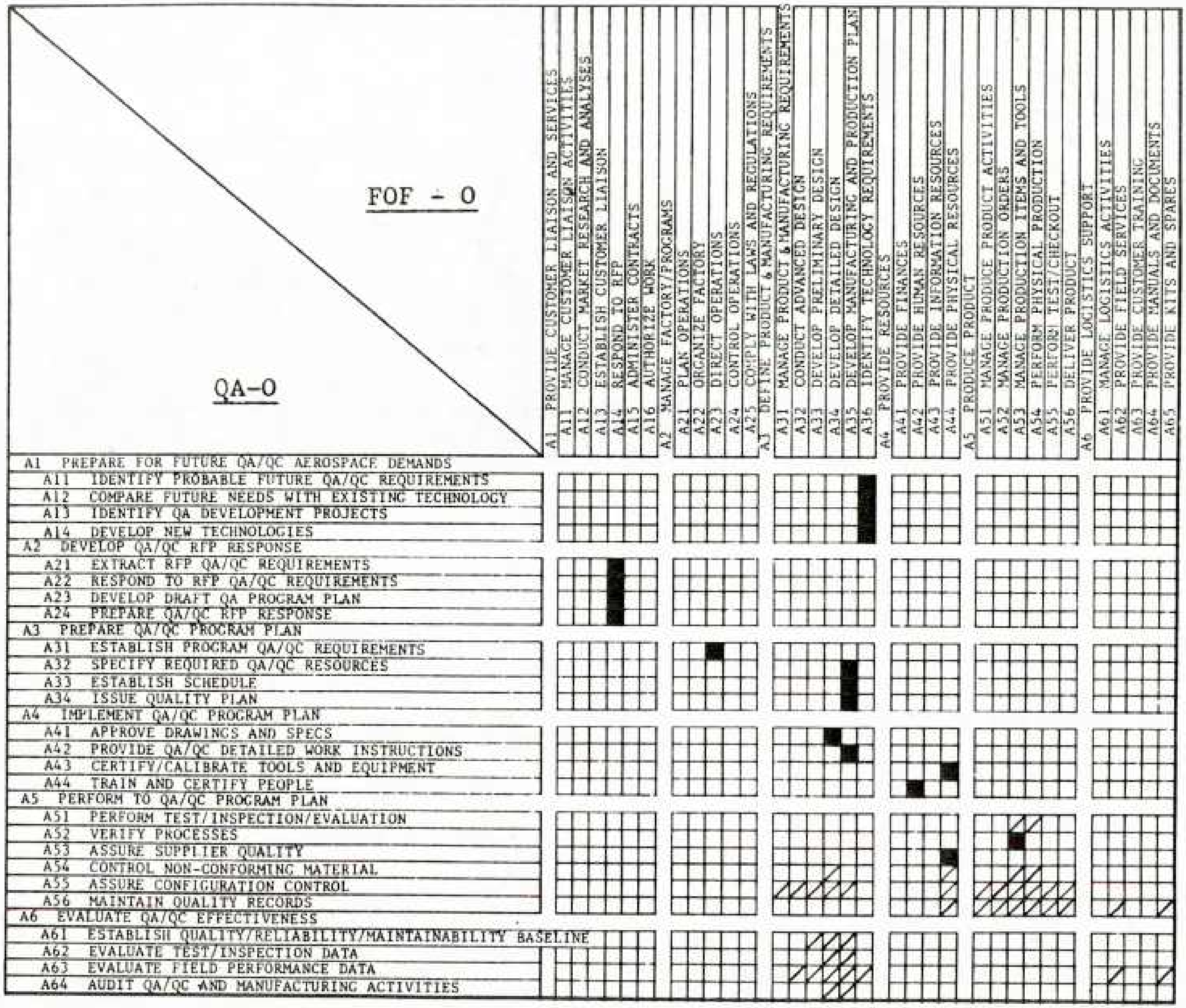


Figure 6-3 Relationship ICAM Manufacturing Architecture (MFGØ)versus FoF Architecture



Key:

■ ICAM ARCHITECTURE INCLUDED IN FOF ARCHITECTURE

▨ ICAM ARCHITECTURE PARTIALLY INCLUDED IN FOF ARCHITECTURE

Figure 6-4 Relationship ICAM QA (QAØ) Architecture versus FoF Architecture

DES - 0 \ FOF - 0	A1 PROVIDE CUSTOMER LIAISON AND SERVICES	A11 MANAGE CUSTOMER LIAISON ACTIVITIES	A12 CONDUCT MARKET RESEARCH AND ANALYSES	A13 ESTABLISH CUSTOMER LIAISON	A14 RESPOND TO RFP	A15 ADMINISTER CONTRACTS	A16 AUTHORIZE WORK	A2 MANAGE FACTORY/PROGRAMS	A21 PLAN OPERATIONS	A22 ORGANIZE FACTORY	A23 DIRECT OPERATIONS	A24 CONTROL OPERATIONS	A25 COMPLY WITH LAWS AND REGULATIONS	A3 DEFINE PRODUCT AND MANUFACTURING REQNTS	A31 MANAGE PRODUCT AND MANUFACTURING REQNTS	A32 CONDUCT ADVANCED DESIGN	A33 DEVELOP PRELIMINARY DESIGN	A34 DEVELOP DETAILED DESIGN	A35 DEVELOP MANUFACTURING AND PRODUCTION PLAN	A36 IDENTIFY TECHNOLOGY REQUIREMENTS	A4 PROVIDE RESOURCES	A41 PROVIDE FINANCES	A42 PROVIDE HUMAN RESOURCES	A43 PROVIDE INFORMATION RESOURCES	A44 PROVIDE PHYSICAL RESOURCES	A5 PRODUCE PRODUCT	A51 MANAGE PRODUCE PRODUCT ACTIVITIES	A52 MANAGE PRODUCTION ORDERS	A53 MANAGE PRODUCTION ITEMS AND TOOLS	A54 PERFORM PHYSICAL PRODUCTION	A55 PERFORM TEST/CHECKOUT	A56 DELIVER PRODUCT	A6 PROVIDE LOGISTICS SUPPORT	A61 MANAGE LOGISTICS ACTIVITIES	A62 PROVIDE FIELD SERVICES	A63 PROVIDE CUSTOMER TRAINING	A64 PROVIDE MANUALS AND DOCUMENTS	A65 PROVIDE KITS AND SPARES
A1 DEVELOP CONCEPTUAL DESIGN																■																						
A11 CONDUCT RESEARCH																■																						
A12 ANALYZE CUSTOMER REQUIREMENTS																■																						
A13 FORMULATE CONCEPTS																■																						
A14 SELECT CANDIDATE CONFIGURATION																■																						
A2 DEVELOP PRELIMINARY DESIGN																	■																					
A21 REFINE CANDIDATE CONFIGURATIONS																	■																					
A22 SELECT OPTIMUM CONFIGURATIONS																	■																					
A23 CONDUCT MANAGEMENT REVIEW AND APPROVAL																	■																					
A3 DEVELOP DETAIL DESIGN																		■																				
A31 DEVELOP DESIGN LAYOUTS																		■																				
A32 PREPARE DETAIL DESIGN																		■																				
A33 RELEASE DETAIL DESIGN																		■																				

Key:

■ ICAM ARCHITECTURE INCLUDED IN FOF ARCHITECTURE

Figure 6-5 Relationship ICAM Design Architecture (DESØ) versus FoF Architecture objectives of its individual center. The same is true for the direct factory operations activity. Here, the responsibility of directing each center is delegated to each center's management activity.

Control Factory Operations creates a feedback loop with corrective action as an output. The Executive Management Center monitors the activities of the management functions of each of the centers and takes appropriate corrective action, if necessary. Therefore, each of the centers controls its own activities.

The Comply with Laws and Regulations activity represents a single authoritative source for all activities. It is reflected in all the outputs of the Executive Management Center.

6.2.1 Physical Attributes

The physical attributes of the centers correspond to the physical components of the factory system. They are the components that can be seen or touched.

Controls for the other centers are produced here; therefore, people of this center must be able to visualize the future and set goals and objectives that reflect the company's strategic plans. Characteristics of the Executive Management Center personnel include:

- Strategic planners and goal setters - with the ability to turn these plans into operational plans that the factory can follow

- Social leaders - who are able to negotiate a good working relationship with the community

- Civic Leaders - who are able to interact with government bodies and influence changes favorable to the Enterprise.

The primary tools used by the Executive Management Center involve communications - voice, video and text. They are the focal point of the executive workstation, of the information processing, and communications network. These tools will provide communications to external and internal sources. The following is a list of required executive workstation capabilities:

- Provide integrated voice communications to all workstations in the system

- Provide text communications to all workstations in the factory system

- o Provide external voice, text and video communications
- o Provide the logical tools and information necessary for the executive to perform his duties.

Communications are the heart of the Executive Management Center. Current developments in network communications are making the "paperless" factory achievable and will permit communication via video display terminals to corporate offices and government agencies. This center will also incorporate integrated telephone and voice/text conversion software to support the "paperless" environment and closed circuit systems to support video conferencing.

The Executive Management Center will require the following capabilities:

- o Offices with integrated communication outlets for workstations
- o Conference rooms to provide meeting space for human interface
- o Lighting, heating and ventilation for human environment.

6.2.2 Logical Attributes

The logical attributes of this center correspond to the logical components of the Factory of the Future. There is one component added for clarity; that is the organization of the center. This does not imply a physical organization but only a logical explanation of the purpose of the organization.

The factory is moving from an industrial-based environment to an information-based environment. Figure 6-6 compares how today's factory is run by off-line techniques and how the future factory will be operated in a real-time management environment. Figure 6-7 describes how the management structure is changing to become more flexible in the information era.

The factory of today is in the organizational transition stage. It is becoming more flexible as robotics, CNC, and automated material handling systems become more prevalent and reduce direct labor numbers. At the same time, there is an ever-increasing reliance on our professionals in marketing, engineering, services, etc. to plan and operate the factory. As a result, there is a mid-level bulge in the hierarchy as the

Source: Preparing for the Factory of the Future, Modern Machine Shop, October 1983

PRESENT INDUSTRIAL ERA ORGANIZATION	FUTURE INFORMATION ERA ORGANIZATION
MANUAL	COMPUTER AIDED SYSTEMS
OUTDATED POLICIES, SYSTEMS AND PROCEDURES SUPPLEMENTED BY INFORMAL ORGANIZATION	CAD, CAM, FMS, MRP, TEXT PROCESSING, ELECTRONIC MAIL, ETC., SUPPORTED BY FLEXIBLE POLICIES, SYSTEMS AND PROCEDURES
DIVISIVE	INTEGRATIVE
OVERLY DIVIDED IN WORK TASKS AND BETWEEN FUNCTIONS AND LAYERS	INTEGRATING INFORMATION NETWORK, RELYING ON SOME FUNCTIONAL EXPERTISE, BUT IN A MORE OPEN AND COOPERATIVE CONTEXT
DISENGAGING	INTERACTIVE
HIERARCHICAL APPROACH WHICH NARROWS AND RESTRICTS EFFECTIVE PROBLEM SOLVING, CAUSING PEOPLE TO RETREAT INTO THEIR OWN WORLDS	ACTIVE INTERACTION BOTH INTERNALLY AND EXTERNALLY WITH VENDOR BASE AND CLIENT SYSTEM
DECLARATIVE	INTERROGATIVE
TOP/DOWN COMMANDS WITH LITTLE LISTENING OR FEEDBACK	ACTIVE USE OF "WHAT IF" SCENARIOS, WITH HEAVY GRAPHIC SUPPORT
OFF-LINE MANAGEMENT	REAL-TIME MANAGEMENT

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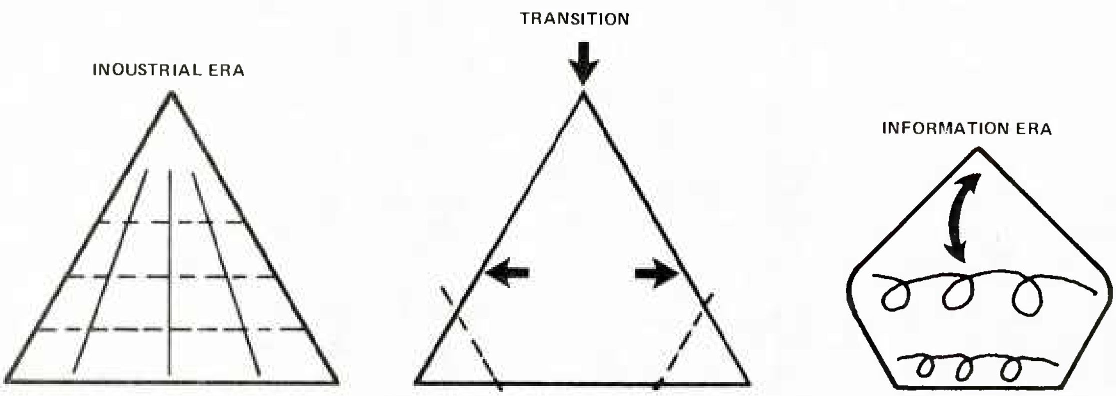
Figure 6-6. Contrast of Industrial vs Information Environment

Source: Preparing for the Factory of the Future, Modern Machine Shop, October 1983



- DIVIDED BY FUNCTIONS AND LEVELS
- AIM: MAXIMIZE INVESTMENTS IN PLANT AND EQUIPMENT
- COMMUNICATIONS: FRAGMENTED, OFTEN IN FIRE-FIGHTING MODE
- MANAGEMENT STYLE: TOP-DOWN, DECLARATIVE

- LESS HIERARCHICAL
- MID-LEVEL BULGE DUE TO INCREASED RELIANCE ON PROFESSIONALS IN MARKETING, ENGINEERING, SERVICE, ETC.
- DECREASED DIRECT LABOR BASE DUE TO WP, NETWORKING, ROBOTICS, ETC.

- INTEGRATIVE ACROSS FUNCTIONS AND WITH CLIENTS AND VENDORS
- AIM: MAXIMIZE VALUE OF KNOWLEDGE SYSTEMS
- COMMUNICATIONS: INTERACTIVE AIDED BY ELECTRONIC INFORMATION INFRASTRUCTURE
- MANAGEMENT STYLE: INTERROGATIVE ("WHAT IF") TO KEEP FOCUS AND EVOKE COMMITMENT OF PROFESSIONALS

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Figure 6-7. Organization Change

management of information assumes more importance. The ultimate realization of this transition is depicted in the changing organization shape for the information era, Figure 6-7.

In order for this organization change to occur, management must be measured both by the way they internally administer their departments and how they interact with other departments. The key to this new organization is the Information Infrastructure which allows products and functions to be managed equally. Figure 6-8 depicts the "spade" management organization with the Information Infrastructure.

Source: Preparing for the Factory of the Future, Modern Machine Shop, October 1983

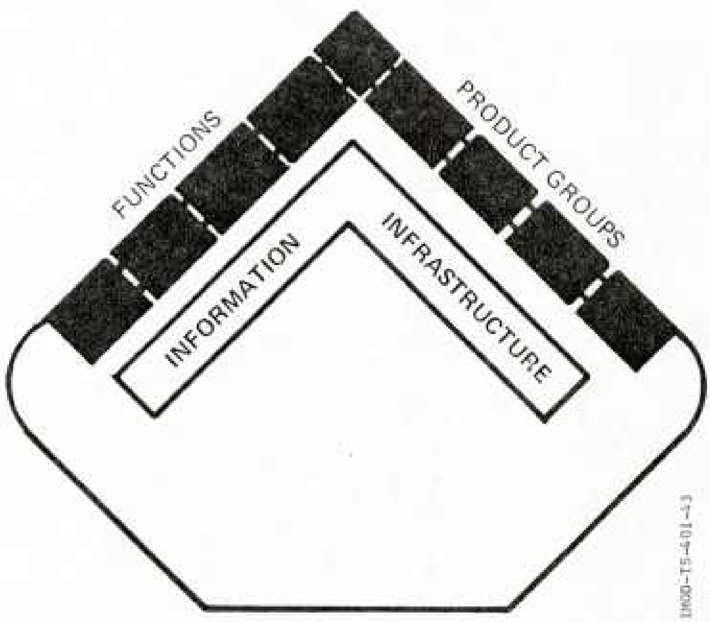
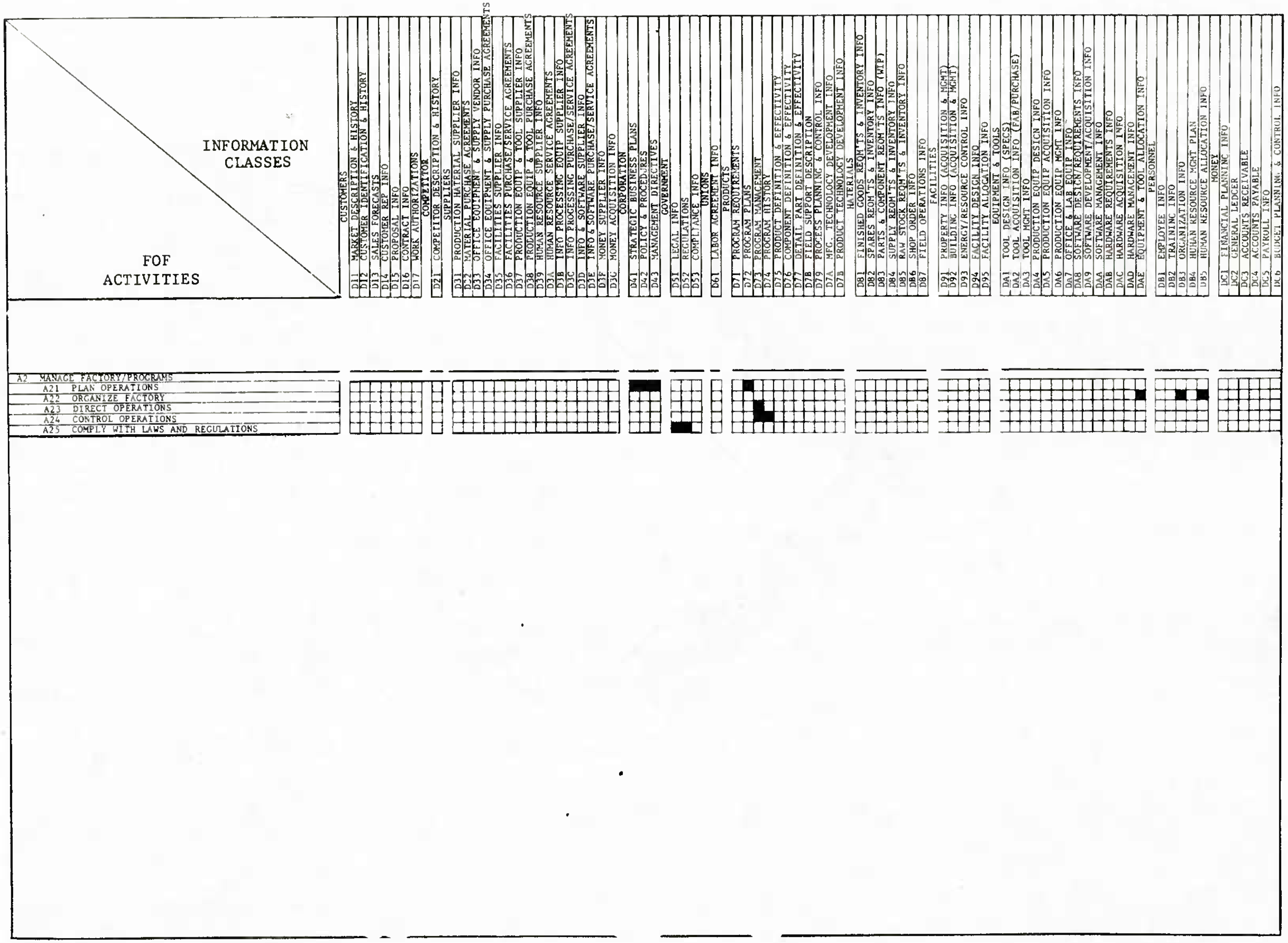


Figure 6-8. "Spade" Organization

The information classes created by the Executive Management Center are from the corporate and government groups. These groups represent the controls of the factory system. They pervade all other centers. This center also accesses most all other information classes to keep controls and feedback for all other activities. The detail of information classes can be seen in Figure 6-9. The activities of this center are node A2 of the FoF architecture.

The capabilities of the Executive Management Center can be found in Figure 6-10. These capabilities describe the technology needed to accomplish the activities of the A2 node of the FoF architecture. The relationship of the capabilities to



FOF ACTIVITY CREATES INFORMATION

Figure 6-9 FoF/A2 Creates Information

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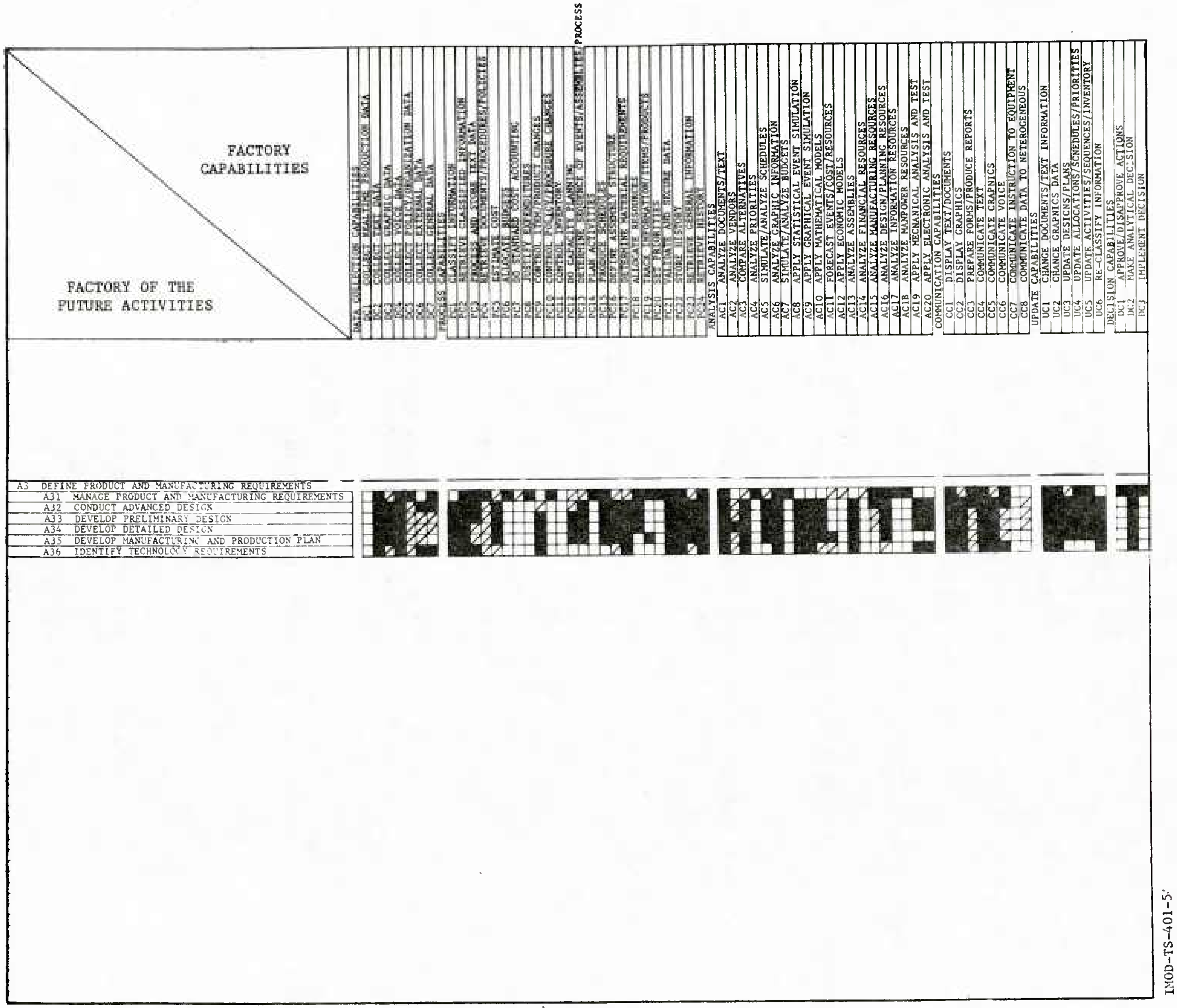


KEY
- DOES NOT APPLY
- EXPECTED USE
- PROBABLE USE

Figure 6-10 FoF/A2 versus Factory Capabilities

application systems already in operation are shown in Figure 6-11. These tools only address a small set of the capabilities needed to perform all the activities.

6.3 BUSINESS DEVELOPMENT CENTER

The purpose of the Business Development Center is to acquire and develop business opportunities for the factory. The responsibilities of the Business Development Center are to manage the center activities, conduct market research and analysis, establish customer liaison, respond to RFPs, administer contracts and authorize work. The relationship of the FoF A1 node to other ICAM architectures is displayed in Figures 6-2 through 6-5.

The Manage Customer Liaison activities function receives its direction from the Executive Management Center. It then plans the activities for other functions, assigns responsibilities, monitors and controls the functions, allocates budgets for the functions, requests capital expenditures, justifies expenditures and generally manages the Business Development Center.

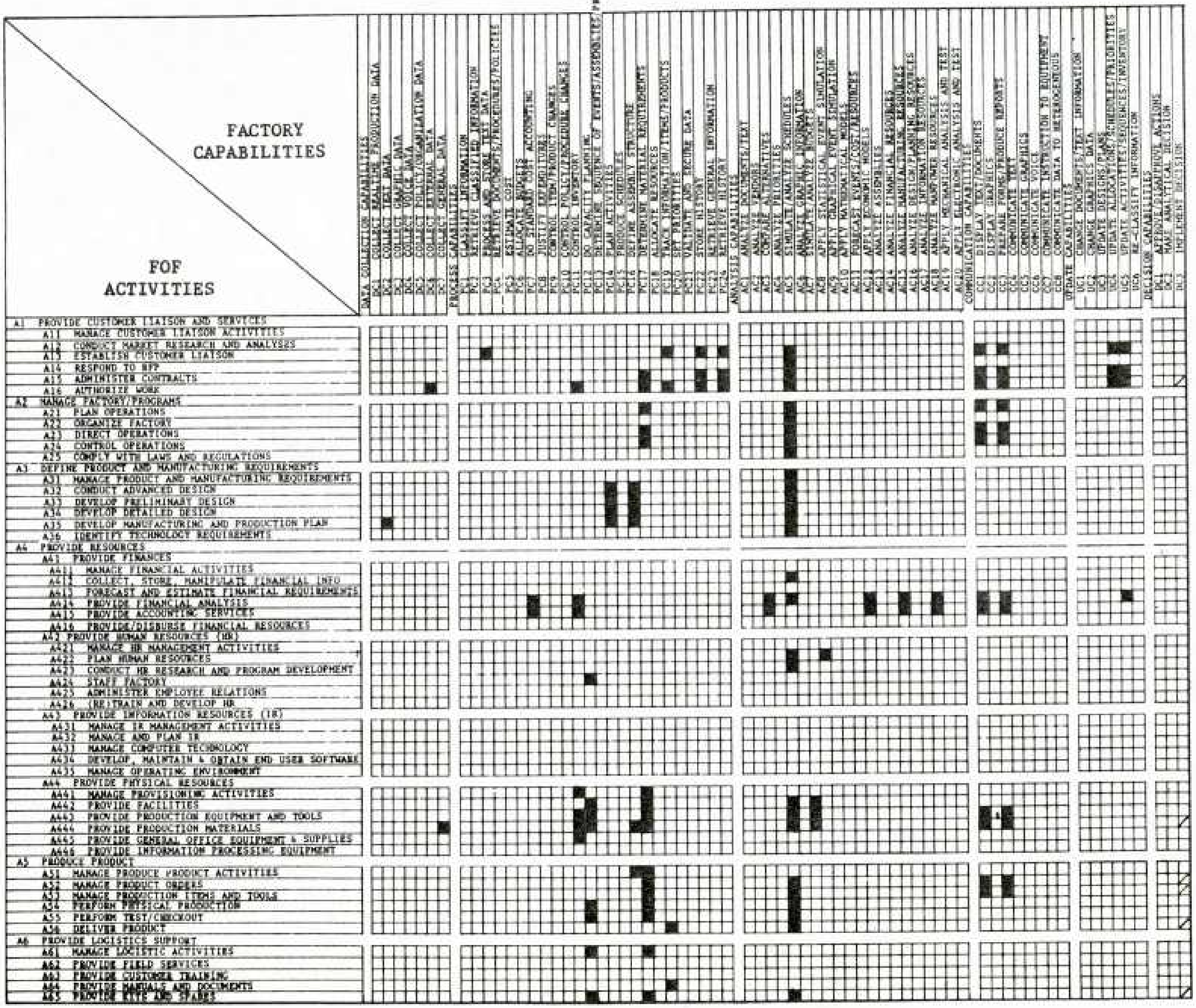
Conduct Market Research and Analysis function identifies market trends, forecasts sales, analyzes demographics, and determines which markets fit within the current company goals and technology profile.

Establish Customer Liaison activities include meeting with customers and keeping all customer contacts open. All interface with customers' requests are handled by this function, including accepting RFPs and contracts. This function represents the Enterprise's sales effort. Information gathered by this function is used to improve the market position of the Enterprise and is a source for unsolicited proposals.

The response to the RFP creates a proposal plan. This plan and the RFP are dispensed to centers concerned with the technical response. The Establish Customer Liaison function also coordinates the proposal writing and delivers the completed proposal to the customer. Negotiations with the customer and the technical centers are coordinated through this function.

Administer Contracts includes monitoring the contract work for compliance and communicating changes both from the customer and the factory. This function also coordinates the changes in contract budgets.

The Authorize Work function coordinates the delivery dates with the factory master schedule as specified by the contract. Each individual center produces its own schedules for production based on work authorized and customer delivery dates.



KEY

- DOES NOT APPLY
- EXPECTED USE
- PROBABLE USE

Figure 6-11 Mapping of PIOS MRP

6.3.1 Physical Attributes

The personnel of the Business Development Center includes business professionals for market analysis, sales, advertising, managing center activities, and engineers for building the data bases. The most visible people in the center will be the professionals that make customer contacts and they must:

- o Be informed on all company capabilities and customer background
- o Present a professional image for the Enterprise
- o Be able to correlate customer wants to Enterprise products.

Behind the customer liaison people are the technical people that operate the Business Development Center. They will engineer the data bases necessary for market analysis and other business development tasks. Their primary responsibilities include:

- o Assembling necessary data bases on vendors, products and customers
- o Encoding marketing know-how into expert knowledge systems
- o Conducting research to identify markets and improve products.

The computer will be the main tool for analysis and research. It will maintain customer data bases and marketing analysis information and make it available to all centers. The workstation will include both text and audio communications capabilities as well as graphics.

The integrated processing and communications network (IPCN) will provide a common communication channel through which the Business Development Center will perform the following functions.

- o Internal communication linkage to all workstations, data storage and data processing nodes
- o External communication linkage to customer IPCNs, public IPCNs and public library data bases.

The Business Development Center will require office space for managers and technical people and an area for internal and external communications of voice and text. There will be requirements for distributed facilities for sales and advertising which are close to the location of the customer. These distributed facilities will require direct telecommunications with the factory system.

6.3.2 Logical Attributes

The Executive Management Center will set the control of the organization for the Business Development Center. Developing a cohesive team effort will be the basic philosophy for forming the Business Development Center. Each team will be responsible for a product line or group of products. The team will be an entity that operates similarly to a Group Technology cell. The makeup of the team will include all the people and tools necessary to perform the activities of the Business Development Center for a family of products or particular market segment. Eventually, each worker in the team will be able to perform any function. This cross-training provides the company with a valuable employee and gives the employee a broader experience base.

The Business Development Center creates information about the customer and competitor business entities. To better respond to requests for proposals and customer inquiries, the Business Development Center needs to access information about the following entities:

- o Products/parts/designs
- o Facilities
- o Equipment/tools
- o Personnel.

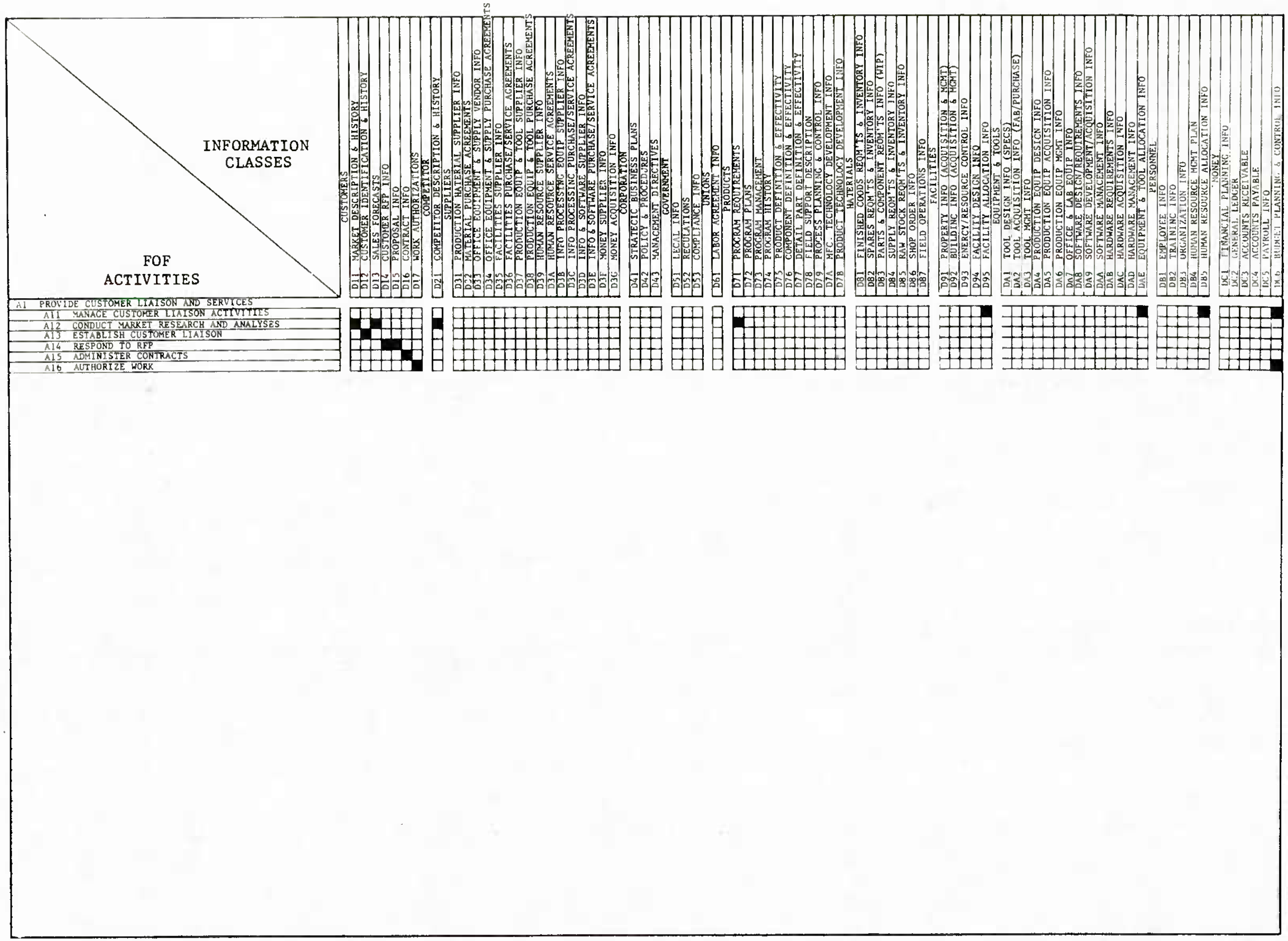
Information about each of these business entities is defined by multiple information classes. A more detailed relationship can be seen in Figure 6-12, which represents the entire Information Infrastructure.

The capabilities of the Business Development Center can be found in Figure 6-13 which defines the relationships of the activities and capabilities of the Factory of the Future. The marked intersections represent the coalitions' view of the capabilities required for an activity. A decomposition will give a more understandable list of these capabilities and activities.

6.4 TECHNOLOGY DEVELOPMENT CENTER

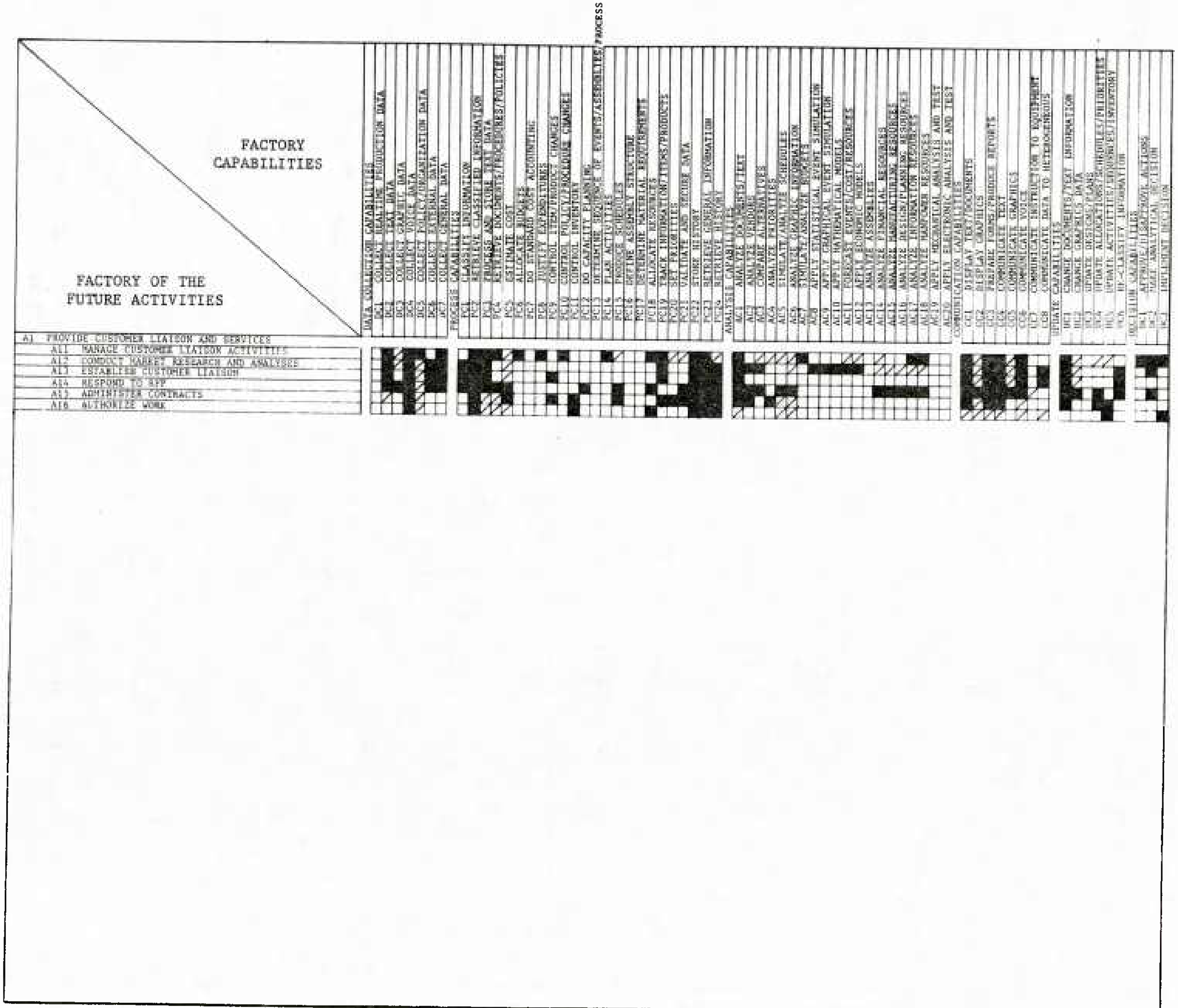
This center has the responsibility for acquiring or creating the product and process technology required by the factory. This technology includes:

- o The design of physical and logical technologies
- o Generation of:
  - Product designs



FOF ACTIVITY CREATES INFORMATION

Figure 6-12 FoF/A1 Creates Information



KEY
- DOES NOT APPLY
- EXPECTED USE
- PROBABLE USE

Figure 6-13 FoF/A1 versus Factory Capabilities

- Detail designs
- Product specifications
- Process specifications
- Program plans
- Process plans
- Manufacturing plans
- Quality assurance plan.

The physical technology can be broken down into the disciplines of mechanical, electrical and chemical. These disciplines represent the product and process technologies of the factory. The logical technologies are the necessary knowledge to design the logical data bases and logical processes needed to operate the factory.

This center ascertains customer needs, determines technical feasibility for the implementation of concepts and identification of constraints, and focuses on the financial possibilities and practicalities of the purchaser's requirements. If there are possibilities for further applications of the product design, additional research would be required.

Customer requirements and management decisions, reconfiguration requests, and information from prototypes, models, preliminary design, test results, and manufacturing are transformed into geometry. The geometry and associated analytical data are used to formulate and define alternate concepts and individual configuration development data which are sent to technical disciplines for each concept.

The best configurations for possible preliminary design are chosen. This selection process entails the assigning of relative merits to the candidate configuration, performing tradeoff studies based on life-cycle costs, comparing performance predictions with the requirements, ranking like parameters of each design, and documenting information covering all of the available considerations. The end product includes the program requirements' baseline. Product design may be prompted by contracts, proposals, or corporate requests for research into new market areas.

During Preliminary Design, the advanced (or conceptual) product design is refined. Prototypes may be constructed. Producibility studies are performed. Analysis is done on trade studies and improvements, the information from prototypes, models, Conceptual Designs, and recommendations from Detail Design such that a baseline capable of being subjected to detail investigations is built. Moreover, the activity involves applying more advanced analytical methods to the design problem in order to build confidence in the final selected design.

By use of the conceptual design information, candidate configurations are studied in relation to engineering, manufacturing, logistics, and economic considerations subject to design analysis data. As a result, a concept is recommended.

The recommended configuration and manufacturing cost and schedules, along with analysis reports, are studied to confirm that all necessary analyses and studies have been completed and that the results satisfy the requirement to commit to the Detail Design phase. If the Preliminary Design is not approved, new requests for a selection change are made.

The Develop Detail Design activity occurs when the Preliminary Designs have explored representative design areas to a depth where there are no significant problems, mysteries, or voids remaining: in other words, every detail part, assembly, and subassembly is designed in its entirety. When the risk of design changes is small, and the market prospects are high, management decides on the "go ahead" and the product Detail Design commences.

The information from prototypes, models, preliminary design, testing and manufacturing is used to investigate, design, and document, with layouts, all of the task areas to eliminate all unknowns. The layouts are then complete enough for a guide or pattern to produce detail data to completely describe the part to be fabricated.

The recommended design layouts and other information are used to produce formal detail designs and data that will ultimately be used to direct Manufacturing in fabricating and inspecting the article and to show the customer what is being produced.

The detail geometric descriptions are used in addition to other information to obtain design approval, releasing the layout and detail design information, and making periodic reports of the release status.

In addition to product design, the center must perform the overall task of converting engineering designs into detailed manufacturing methods. For each engineering item, a detailed manufacturing method is devised. This involves identifying the manufacturing parts to the extent that they are planned to exist temporarily in different structures or in different forms from the engineering versions (for example, groups of parts may be put together into subassemblies not identified by engineering or holes may be omitted in detail parts and drilled after assembly to assure alignment), and identifying the tools to be used. Production plans and resource characteristics are necessary considerations in this task.

Detailed instructions for making each part are an elaboration of the detailed manufacturing method. In the process of making them, specifications for tools and for procured items are produced. All of these must be validated to be sure that the items produced or acquired will conform to the engineering design.

The Identify Technology Requirements activity serves as an aid to the other activities in researching technological areas applicable to such activities. Existing technology is used to create technological advancements which can be applied to future products and manufacturing processes.

6.4.1 Physical Attributes

The human element of the Technology Development Center will be planned, organized, directed and controlled by the management function of the center. These are the same type of people which exist in other management functions.

The technologists accomplish the work of the Technology Development Center. The following is a list of the types of disciplines necessary for this center to function efficiently:

- Scientists
  - Physical
  - Mathematical
  - Management
  - Computer

- Engineers
  - Mechanical
  - Electrical
  - Chemical
  - Aerospace
  - Industrial
  - Civil
  - Systems

In the research and design area, there will be a need for many private data files and programs. This is caused by the nature of design and research. Usually, more than one approach will be attempted before a solution is found. This information is not needed by any other center and should be kept private. Therefore, the research workstations of the Technology Development Center will be unique from the other workstations.

These workstations must be able to store data and programs off-line and communicate, when necessary, with a computer with more computing power, (such as today's mainframe) to test the prototype, and transfer the technology to the center that requires it.

The Technology Development Center also produces the design, specifications and plans used by the other centers to analyze and produce products. This function will require a graphic design workstation, (such as todays CAD systems) which can communicate these designs, specifications and plans to other center workstations.

Humans will interact with the FoF IPCN via workstations which will support a variety of information-based activities. These are referred to as "knowledge workstations." All humans will have access to the IPCN via these "knowledge workstations" which will be able to perform the following functions:

- o Electronic mail
- o Voice communications
- o Teleconferencing
- o On-line access to both internal and external video program libraries
- o On-line access to both internal and external library data bases.

The Technology Development Center will need facilities for research as well as for specific production tasks. The research facility could be located near other independent research facilities, such as universities, to take advantage of university resources for research and development. Or, the facility could be located close to the other factory centers to take advantage of their talent. The following is a list of characteristics needed for Technology Development Center facilities:

- o Office space for management
- o Work space for technical people
- o Laboratories for research.

6.4.2 Logical Attributes

The Technology Development Center creates information about the following business entities:

- o Product and part design (including process specifications)
- o Materials
- o Facilities
- o Equipment/tools.

This list is broken down further and its relationship to other activities is presented in Figure 6-14.

The capabilities of the Technology Development Center can be found in Figure 6-15. These capabilities describe the technology needed to accomplish the activities of the A3 node of the FoF architecture. A decomposition of the activities will give a more understandable list of its capabilities and activities.

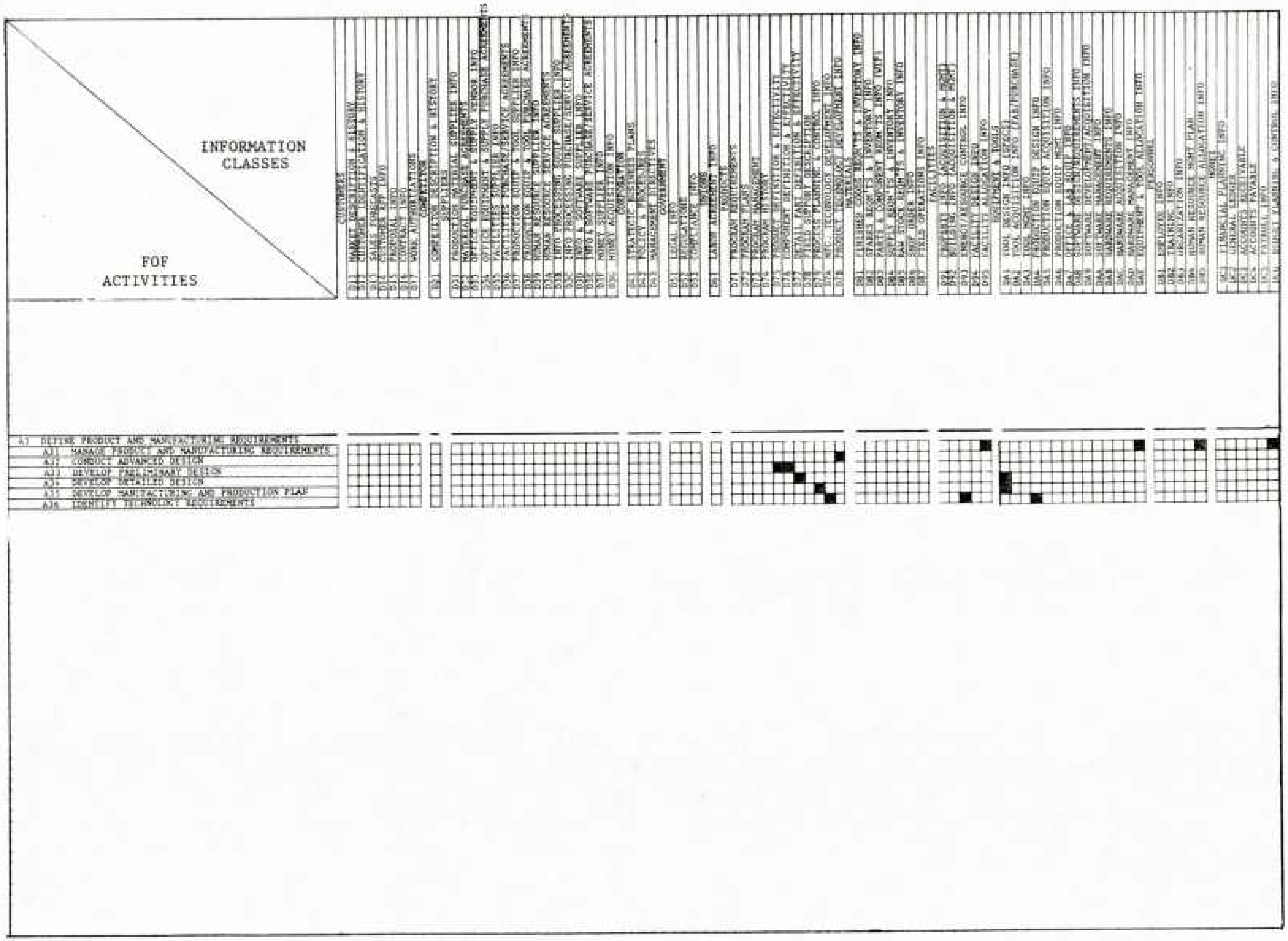
6.5 RESOURCE MANAGEMENT CENTERS

The Resource Management Center includes: financial resource management; human resource management; physical resource management; and information resource management. Controls are set by the Executive Management Center and the management function of the resource center. The purpose of the Resource Management Center is to provide all the resources used by the Enterprise.

The Resource Management Center is organized by functions because of its service nature. The center will have a management function to plan, direct, organize and control the allocation of resources according to the requests from other centers. When conflicts occur for the same resources, priorities will be set by the Executive Management Center until additional resources can be procured.

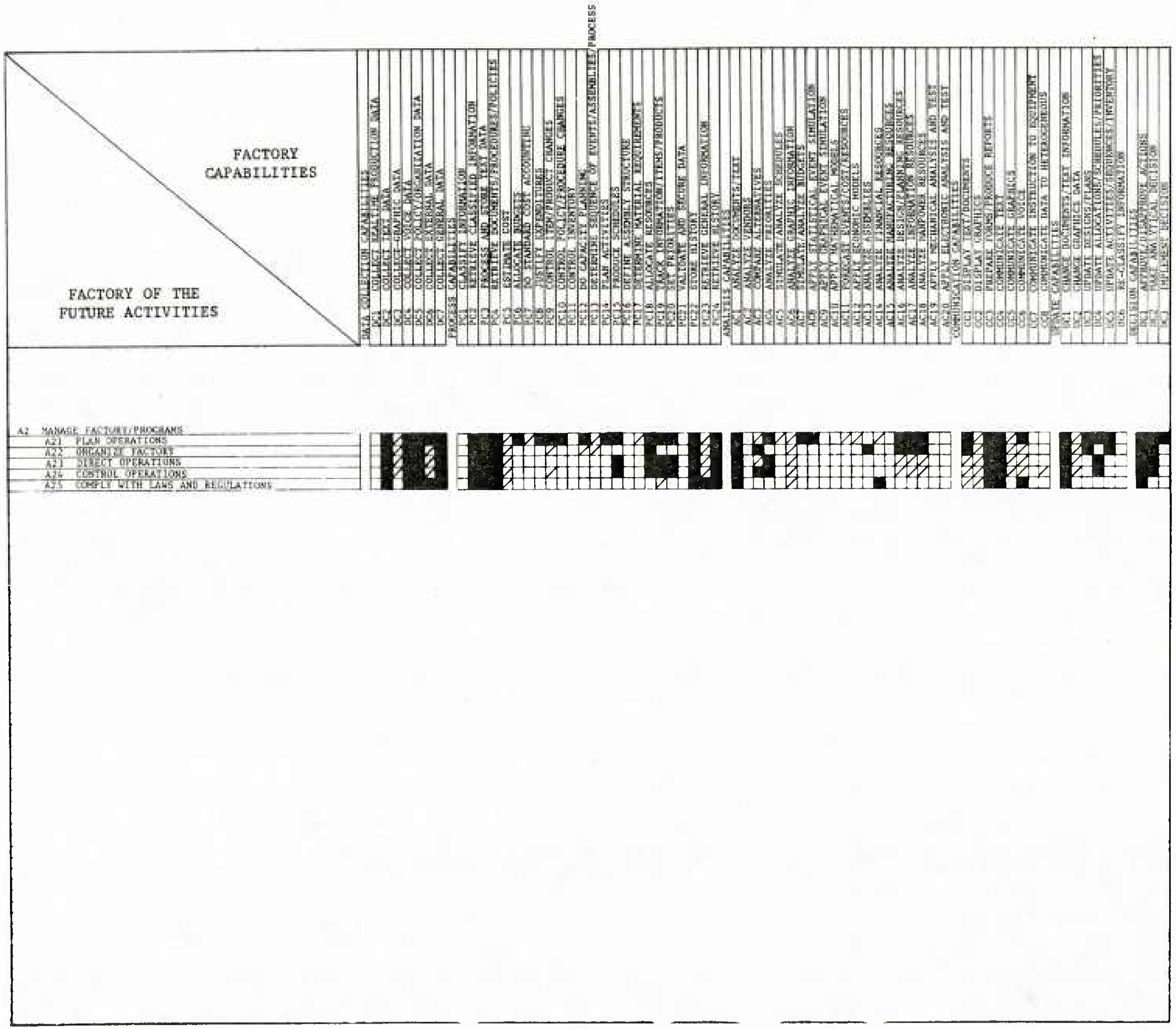
The Resource Management Center has the responsibility for allocating resources to provide the following financial services:

- Administer the financial resource function
- Allocate cash assets
- Acquire capital
- Track company assets
- Collect and store financial data
- Retrieve historical and current financial information
- Validate all financial data
- Secure selected financial information
- Display financial information
- Distribute overhead costs
- Produce customer financial profiles
- Forecast financial requirements
- Estimate costs
- Analyze cost of production changes
- Calculate ROI/ROA/IRR/Network
- Analyze production improvements
- Provide accounting services.



FOF ACTIVITY CREATES INFORMATION

Figure 6-14 FoF/A3 Creates Information



KEY
- DOES NOT APPLY (blank box)
- EXPECTED USE (filled box)
- PROBABLE USE (box with diagonal line)

Figure 6-15 FoF/A3 versus Factory Capabilities

The Resource Management Center has the responsibility for allocating resources to provide:

- o Management of the human resource management/function
- o Forecasting and planning human resource needs
- o Development of new human resource programs
- o Staffing for the factory
- o Administration of employee relations
- o Training human resources.

The Resource Management Center has the responsibility to provide the following information services:

- o Manage information resource activities
- o Plan information resources
- o Develop and maintain end-user software
- o Manage computer operating environment.

The Resource Management Center also has the responsibility to:

- o Manage physical resource management activities
- o Provide facilities
- o Provide production equipment and tools
- o Provide production materials
- o Provide general office equipment
- o Provide information processing equipment.

6.5.1 Physical Attributes

The Resource Management Center will include the following disciplines and people:

Managerial

- Resource managers

Technologists

- Engineers
- Statisticians

Business Professionals

- Financial accountants
- Financial economists
- Financial analysts
- Buyers
- Recruiters
- Trainers
- Psychologists
- Behavioral scientists
- System analysts
- Data base administrators

Computers will be used to acquire and allocate resources to the factory system centers. The computer workstation will have internal/external communications, graphics, voice and text capabilities.

The workstations of the Resource Management Center will have the communications capabilities to interact with the logical common data base and with the data bases of suppliers, vendors and subcontractors. The characteristics of the communication portion of the workstations follow:

- o Electronic mail for both internal and external communications
- o Voice communications
- o Graphic and text communications for sending and receiving specifications of equipment, tools, parts and supplies
- o Interaction with material handling equipment.

The responsibility for providing all resources requires that this center has material handling and procurement ability to procure and deliver resources to the different centers.

The Resource Management Center will also be responsible for acquiring and training people; but each center will be responsible for on-the-job training after the basics have been taught by the Resource Management Center.

6.5.2 Logical Attributes

The organization of the Resource Management Center is divided by resource responsibilities. The center will plan, organize, direct and control the acquisition and distribution of resources.

This center is organized by function rather than product family, because it supports other centers and not products. The center manages inventories of all resources and has the responsibility for maintaining these resources.

The Resource Center is mainly responsible for providing information dealing with inventory control, work-in-process and procurement. In financial resources, services such as accounting, financial analysis, budget forecasting and pricing are provided. Instead of physical items, financial resources provide financial services and maintain system integrity. These financial services will probably be automated.

The Resource Management Center also provides information services to other centers which include:

- o Data processing storage
- o Software development
- o User training and support.

The relationship of resource management activities to information classes is found in Figure 6-16. The activity nodes A41 through A44 represent the resource management function.

Figure 6-17 shows the relationship of capabilities to the activities of the Provide Resources, A4 node, which correlates to the Resource Management Center.

6.6 MANUFACTURING CENTERS

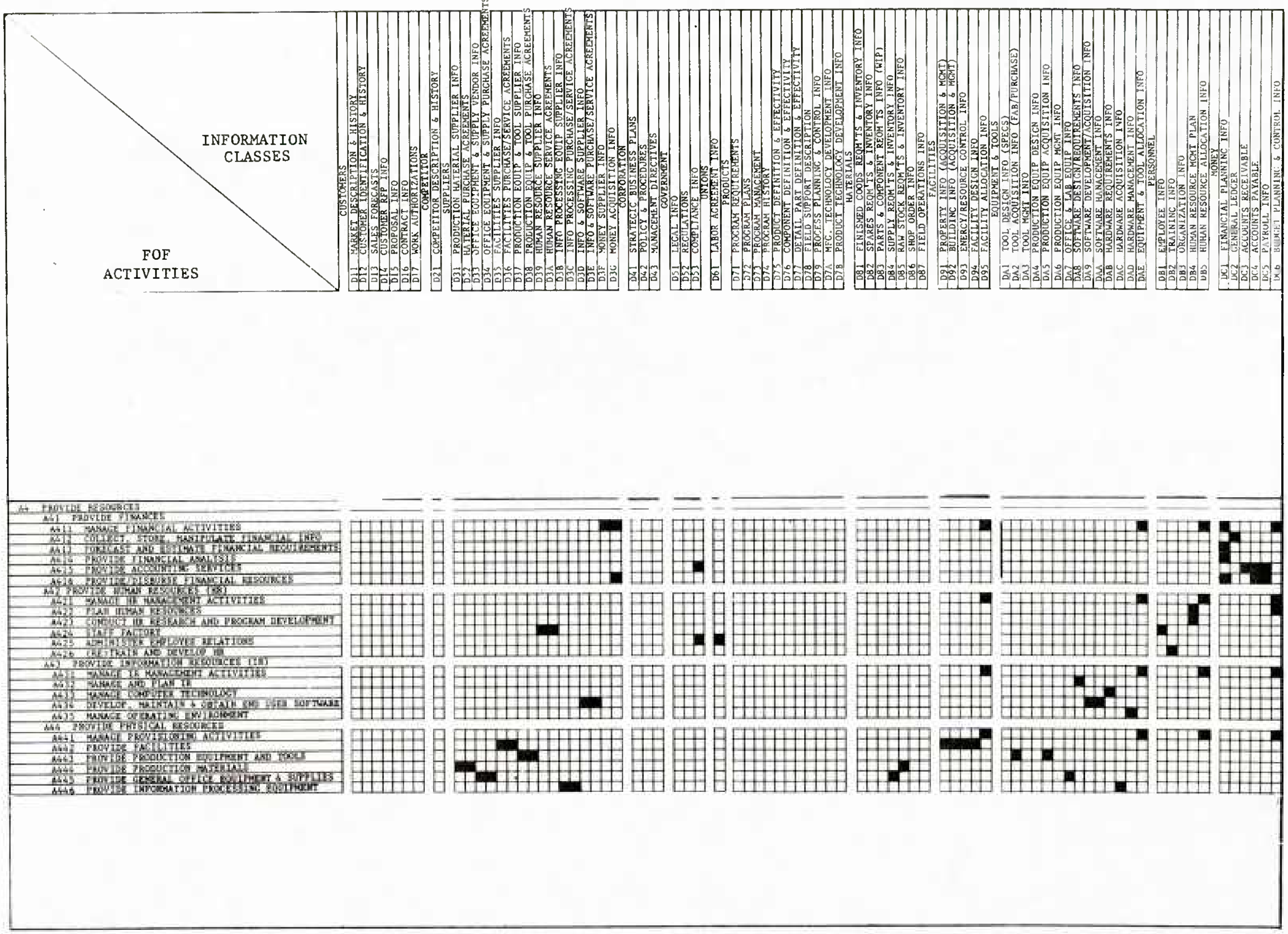
The purpose of the manufacturing centers is to produce all parts, subassemblies, assemblies and products of the factory. The manufacturing centers include processing of: machined, sheet metal, composite, electrical, electronic and assembled parts as well as other processing and support functions.

The management function of the Manufacturing Center sets the controls for the other activities of the center. These controls include budgets, contract requirements, organization and business controls.

In the Manage Production Orders activity, the detail master schedule is developed using customer delivery dates and manufacturing capacity as a baseline. The schedules for the production centers will be planned for less than full capacity. This will allow time for solving production problems, training and daily maintenance. Under-capacity planning allows for an increase in production without any additional resources. This provides the needed flexibility required by changing customer demands.

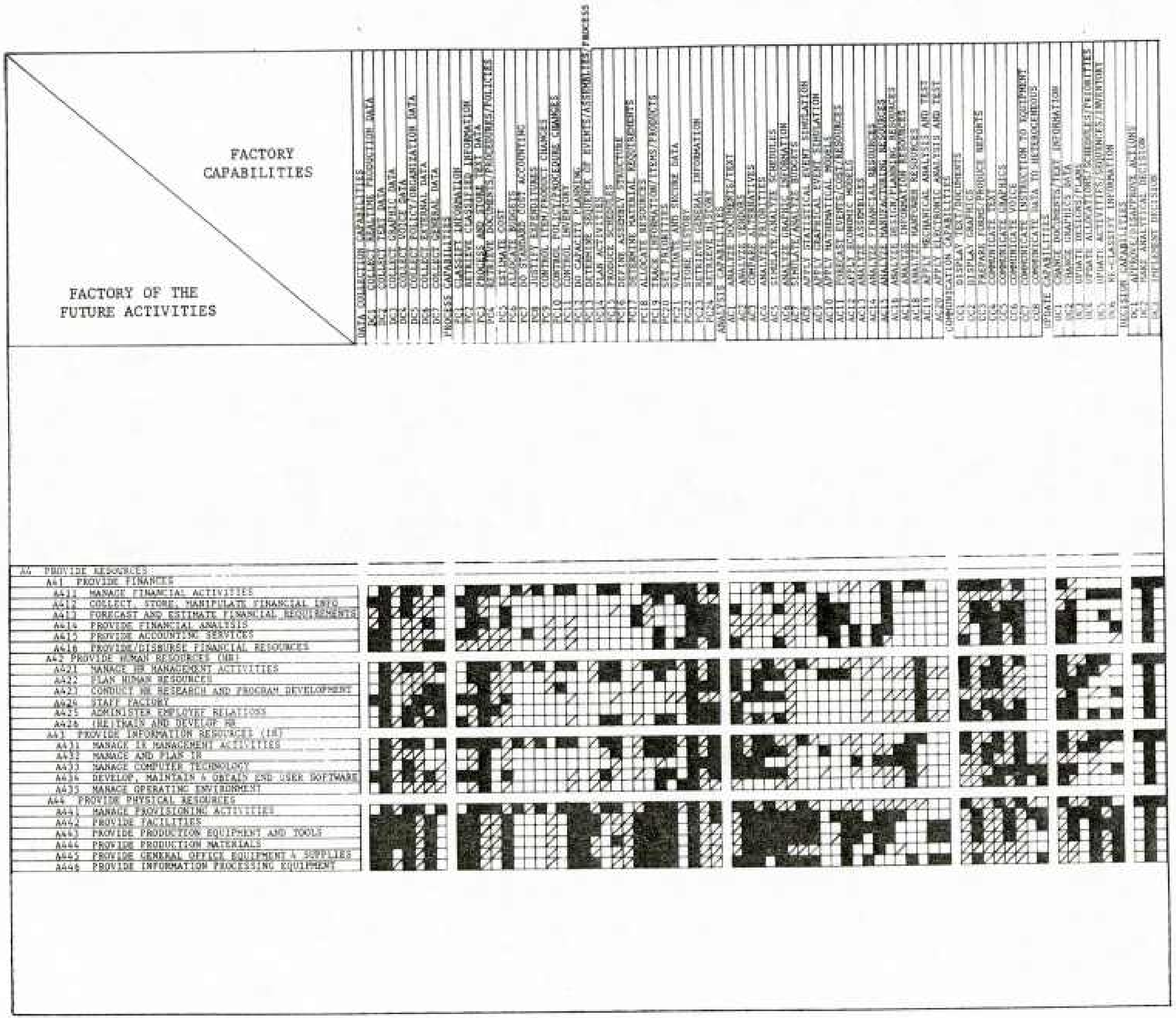
Manage Production items and tools will receive the materials from the Resource Center and create kits for production. Tools that will be used, and then reused later, will be kept in the inventory controlled by this function.

The Physical Production function represents the transformation of raw materials, parts and assemblies into finished goods. These centers will adjust the production schedules and set priorities of work to be accomplished. If problems arise within the Production Center, the center has the responsibility of correcting its own problem using any or all of the resources of the factory.



FOF ACTIVITY CREATES INFORMATION

Figure 6-16 FoF/A4 Creates Information



KEY
- DOES NOT APPLY
- EXPECTED USE
- PROBABLE USE

Figure 6-17 FoF/A4 versus Factory Capabilities

Perform Test and Checkout is the function that has customer acceptance, flight test or any other type of quality action that cannot be performed by production personnel.

The final step of the production process is the delivery of the product to the customer. This function must coordinate the products and documents or any other material that must be delivered to the customer as part of the contract.

6.6.1 Physical Attributes

In addition to managerial people similar to those identified in previous sections, this center will be made up of shop floor personnel. Because of the underlying philosophy of the factory system to make decisions on the lowest level possible, these people are the most important link in the system. They will be required to analyze and act upon information made available by the factory system.

Production center workers of the future will be required to make decisions as to the quality of the process, parts, schedules, equipment and tools of the work cells. An implication of these increased responsibilities is that key people must be better trained and educated.

Labor grades based on specialized skills will be replaced by a system of rewards based on proficiency and the number of tasks a person can accomplish and his decision-making ability. A high level of technical skill and education will be required of the Manufacturing Center worker in the FoF. In addition, he must understand and monitor significantly larger portions of the production process plus have a more integrated perspective of his job and the relationship of his job to the entire production process.

The physical attributes of the Manufacturing Center consists of the tools and equipment that act upon material and support the decision-making process of the center. The following is a list of the attributes of this equipment:

- o Monitor and provide adjustments to correct deviations during the material alteration process
- o Collect processing and machine status information during operations
- o Communicate processing and machine status back to a higher level controller
- o Perform processing of sensing information for adaptive control.

There will also be support equipment used in the manufacturing centers for waste removal, test equipment, computer terminals and material handling equipment. Manufacturing tests will also have to be integrated into the production process.

The facilities of the Manufacturing Center must be planned for integration, modularity and flexibility. The integration of the facility will require a system to communicate between centers and machines as well as between vendors and subcontractors. External transportation will also need to be coordinated. Paragraph 4.3 explains in more detail the requirements for integration, modularity and flexibility for facilities.

The workstations of the Manufacturing Center will have the communications capability to interact with the logical common data base. The characteristics of the communications portion of the workstation follow:

- o Electronic mail for internal communications
- o Voice communications
- o Graphic and text communications
- o Interactive communications.

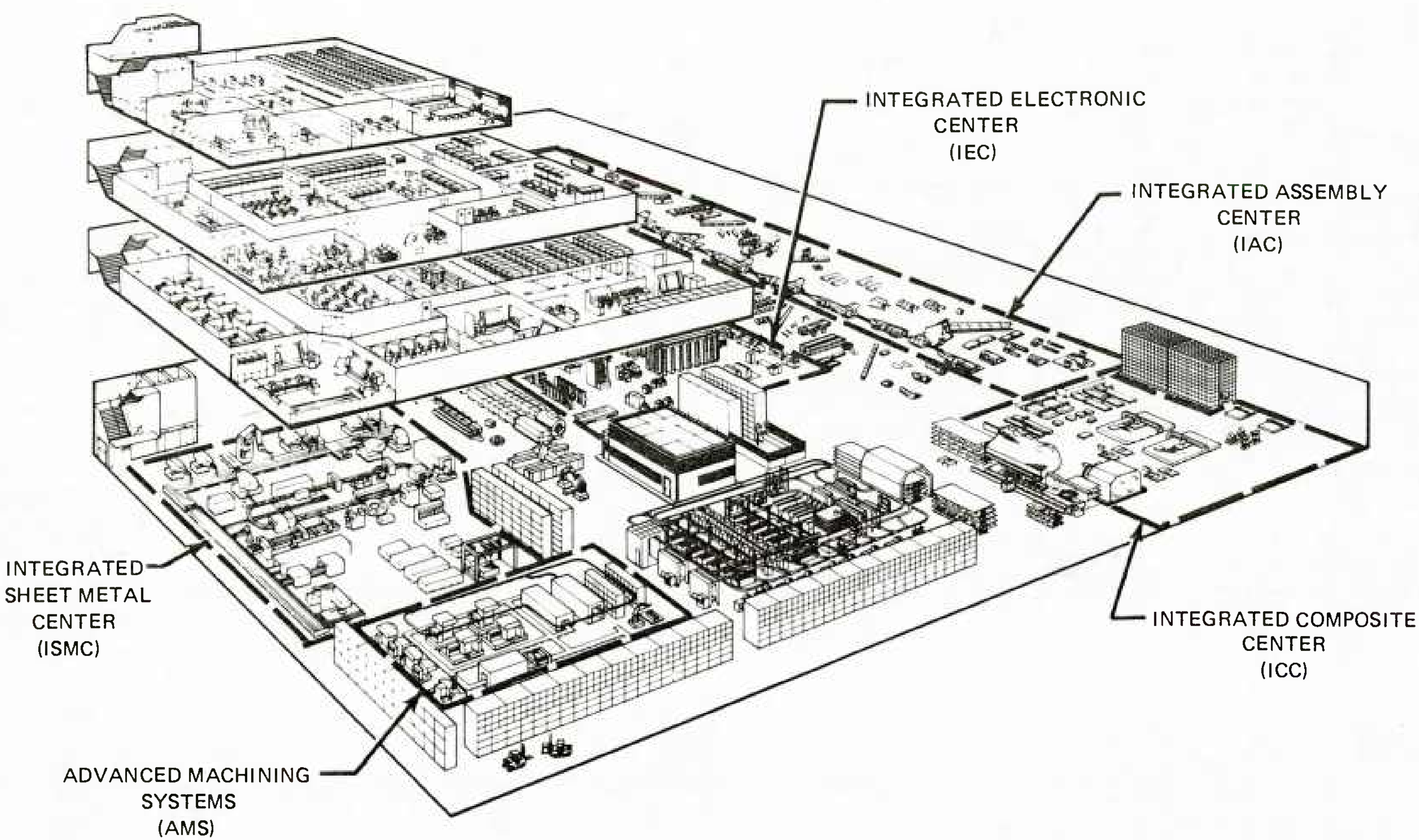
6.6.2 Logical Attributes

The organization for the Manufacturing Center is built around families of parts, products and assemblies. These families are used to create cells for manufacturing. The cell is planned, organized, directed and controlled by the management function of the Manufacturing Center.

One possible scenario for organizing the manufacturing center is the Air Force's Integrated Manufacturing Centers approach. The Air Force has identified centers for the following:

- o Advance Machining System (AMS)
- o Integrated Composites Center (ICC)
- o Integrated Sheet Metal Center (ISMC)
- o Integrated Assembly Center (IAC)
- o Integrated Electronics Center (IEC).

These centers represent the physical production centers of an aerospace factory. An aerospace company may have multiples of each of the centers depending on the products and the size of the facility. The integration of these centers into the factory will be through a sharing of common information and common physical resources such as material handling equipment. Figure 6-18 shows the integrated centers in the factory.



IMOD-TS-401-33

Figure 6-18 Air Force Integrated Centers

Each cell will have the responsibility for production, quality, training, maintenance and configuration of every part and assembly that passes through the cell. This implies that the improvement environment of these functions is also the responsibility of each cell. Once the raw material is delivered to the cell, the cell has total authority over the production of that part until it is delivered to another cell or to the customer. The cell also has the authority to request support from any of the other centers in the course of solving any production problem. This organization is fundamental in the framework for the factory system. Even though there is a great burden placed on the Manufacturing Center, the advantage of a central point of authority for production far outweighs the burden.

The Manufacturing Center is the end user of planning and technology information in an aerospace factory. Each center that creates information, creates information so that the factory may produce quality products, on time, at the lowest possible cost. The Manufacturing Center, in turn, creates the "as-built" information which describes the actual physical products which are produced and the actual usage of various Enterprise resources. Even though there are some planning information classes that are not used directly by the Manufacturing Center, this information is included when other classes are created, and then it is used by the Manufacturing Center. An example of this is the market description and history which is used to identify markets for products and will eventually end up in customer contracts.

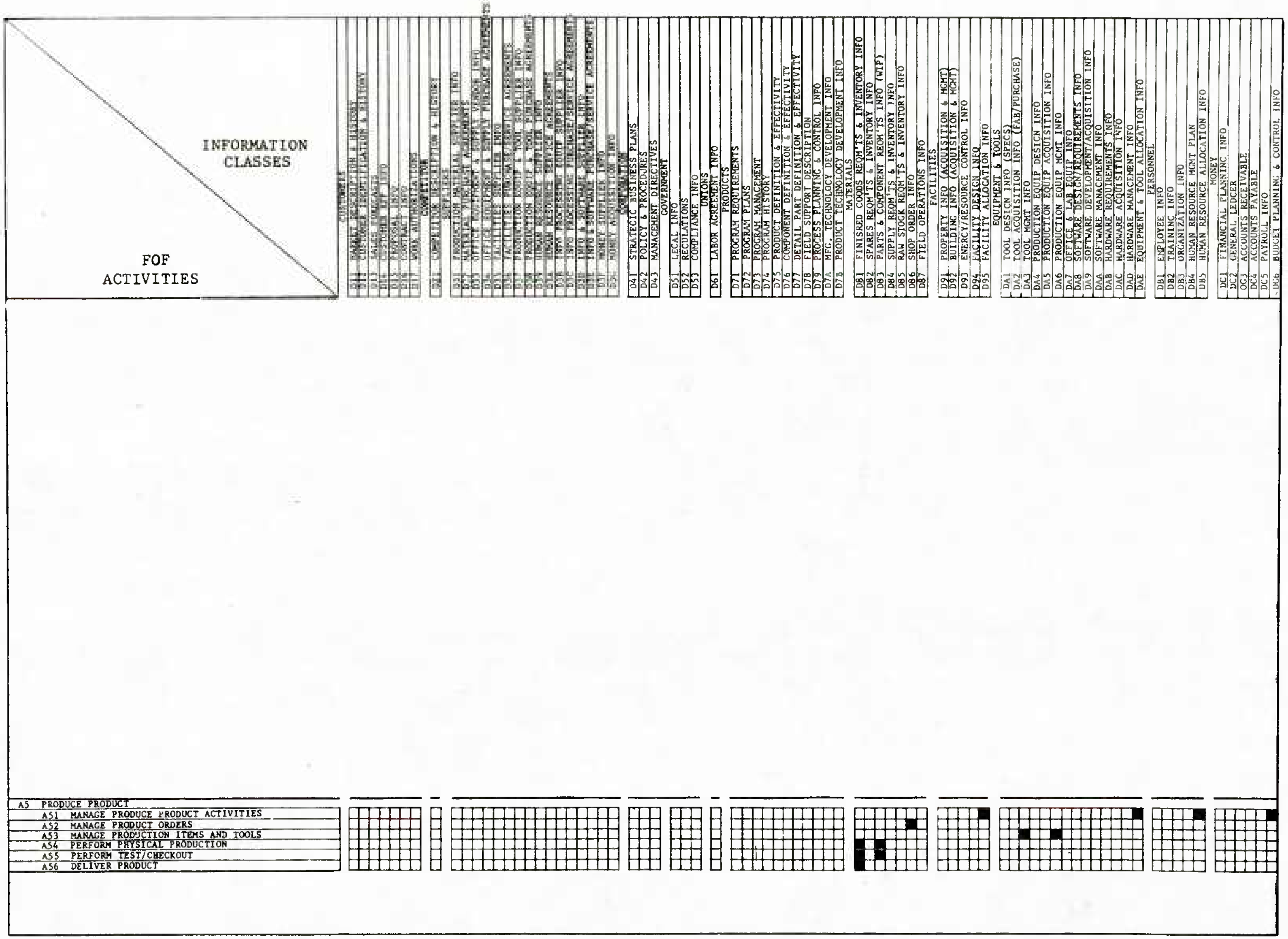
The relationships of the Manufacturing Center, represented by node A5, and information classes is contained in Figure 6-19.

The relationship of the Manufacturing Center, node A5, and its capabilities is contained in Figure 6-20. Some of the more important capabilities are internal communications and interactive communications with the machines.

6.7 PRODUCT SUPPORT CENTER

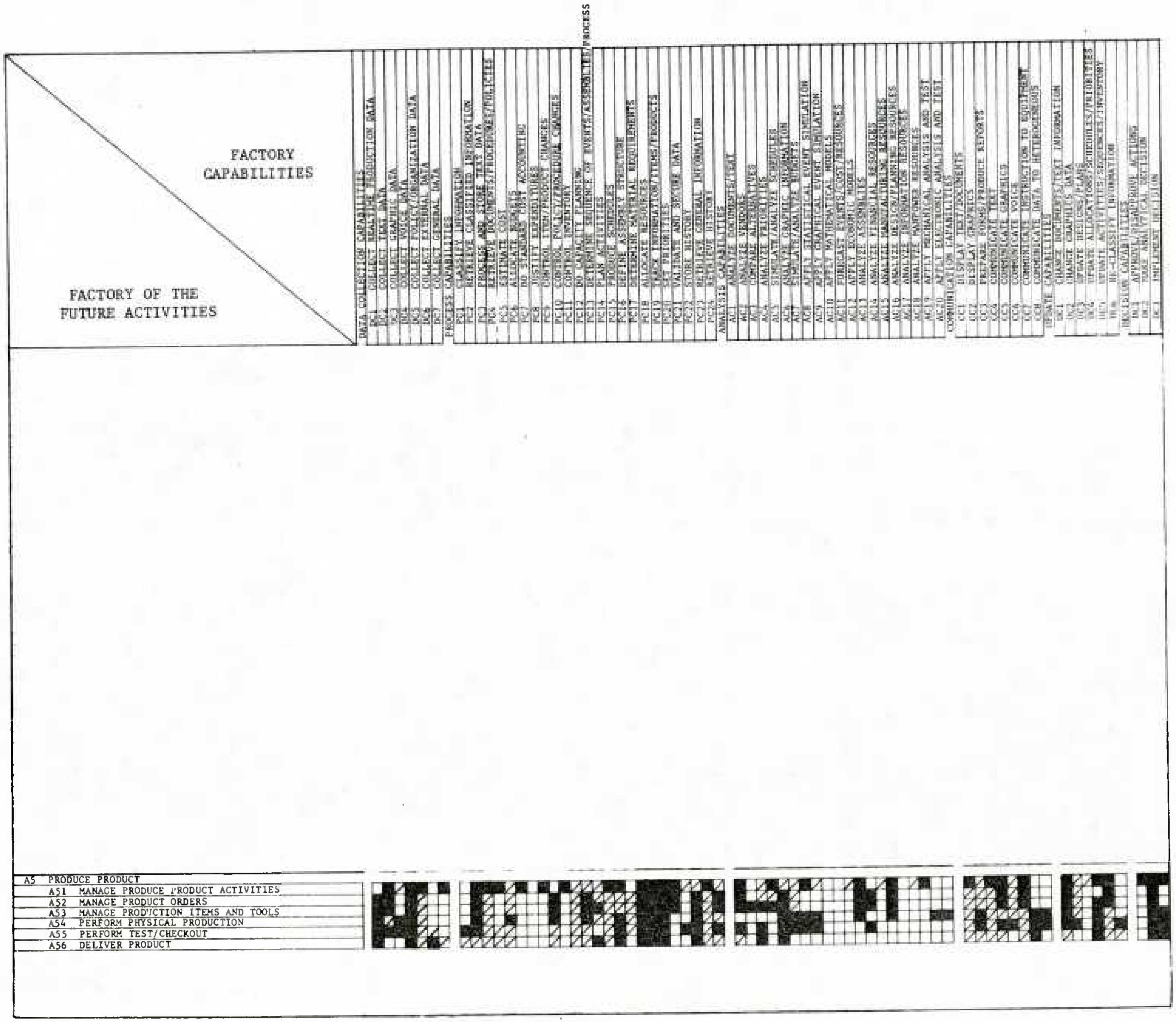
The purpose of the Product Support Center is to provide support for company products after delivery. This includes warranty work, customer training and any upgrades to the products in the field.

The IDEFØ of Appendix A relate the major functions of the A6 node of the FoF architecture. The management function of the A6 node sets the controls for the other functions of the center.



FOF ACTIVITY CREATES INFORMATION

Figure 6-19 FoF/A5 Creates Information



KEY
- DOES NOT APPLY
- EXPECTED USE
- PROBABLE USE

Figure 6-20 FoF/A5 versus Factory Capabilities

The field services and customer training functions are determined by contracts with the customers and requests after product delivery.

The manuals and documents are the required materials for each product shipped. This function must also provide user changes and maintenance guides for products in the field.

The providing of kits and spares requires that product configuration be known and detail part design checked for possible changes needed to correct the reason for failure of the part.

6.7.1 Physical Attributes

Most of the people of the Product Support Center will be engineers and technicians who will be doing the field support and writing user documents. The remainder will be managers, customer liaison personnel and trainers.

Providing spares is a big part of the Product Support Center's effort; therefore, computer terminals that can access the detail part drawings and configuration specifications will be needed. The creation of user documents such as repair manuals is another area in which the Product Support Center has a large part. As a result, the need for a rapid method of preparing documents and changing them is a must. In preparing documents, there is a need to incorporate drawings into the text of the manuals so the workstation will also need a graphics capability.

The communications required by the Product Support Center will need to link all offsite/onsite groups to the logical common data base. Direct link to customer sites will also be required. All groups will have access to the communications network which will have the following characteristics:

- o Electronic mail
- o Teleconferencing
- o Text and graphics communications
- o Access to public communication networks
- o Voice communications.

Some of the product support groups will need to be located close to the customer for user training and maintenance work. These facilities will have a life that is approximately equal to the warranty period. These offsite facilities will need two-way communications capabilities with the parent company for transferring engineering data.

6.7.2 Logical Attributes

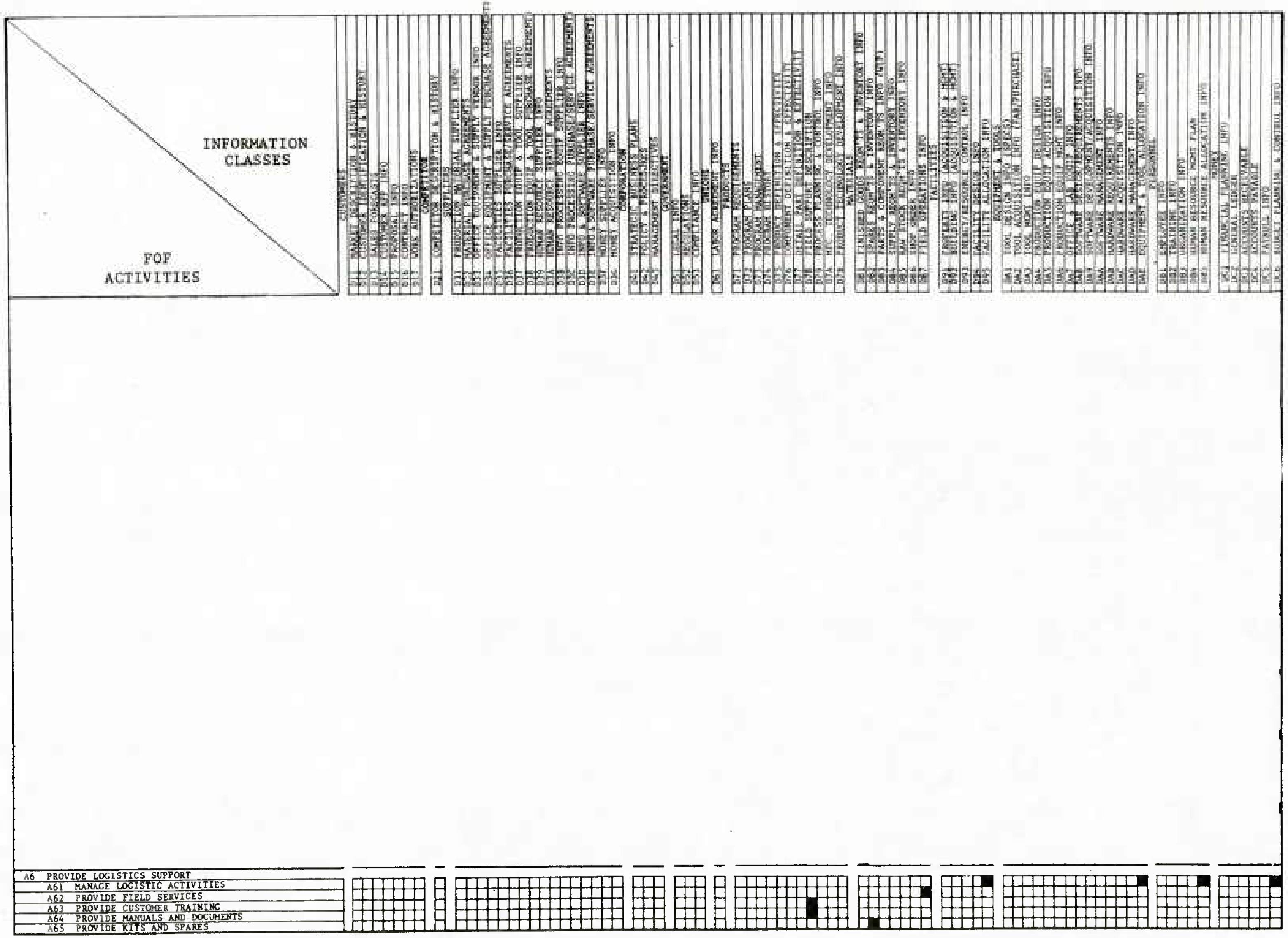
The organization for the Product Support Center is divided into responsibility for product lines and customer types. The organization is geared for quick response to customer requests. These requests will come from users of the products. The product support requirements will differ for commercial and military customers.

Although information is not consumed in the sense that traditional resources are consumed, the management challenge is to acquire the right information, at the right time, in a form which can be readily utilized. The basic business entities related to the Product Support Center are:

- o Customers
- o Product and part designs
- o Materials.

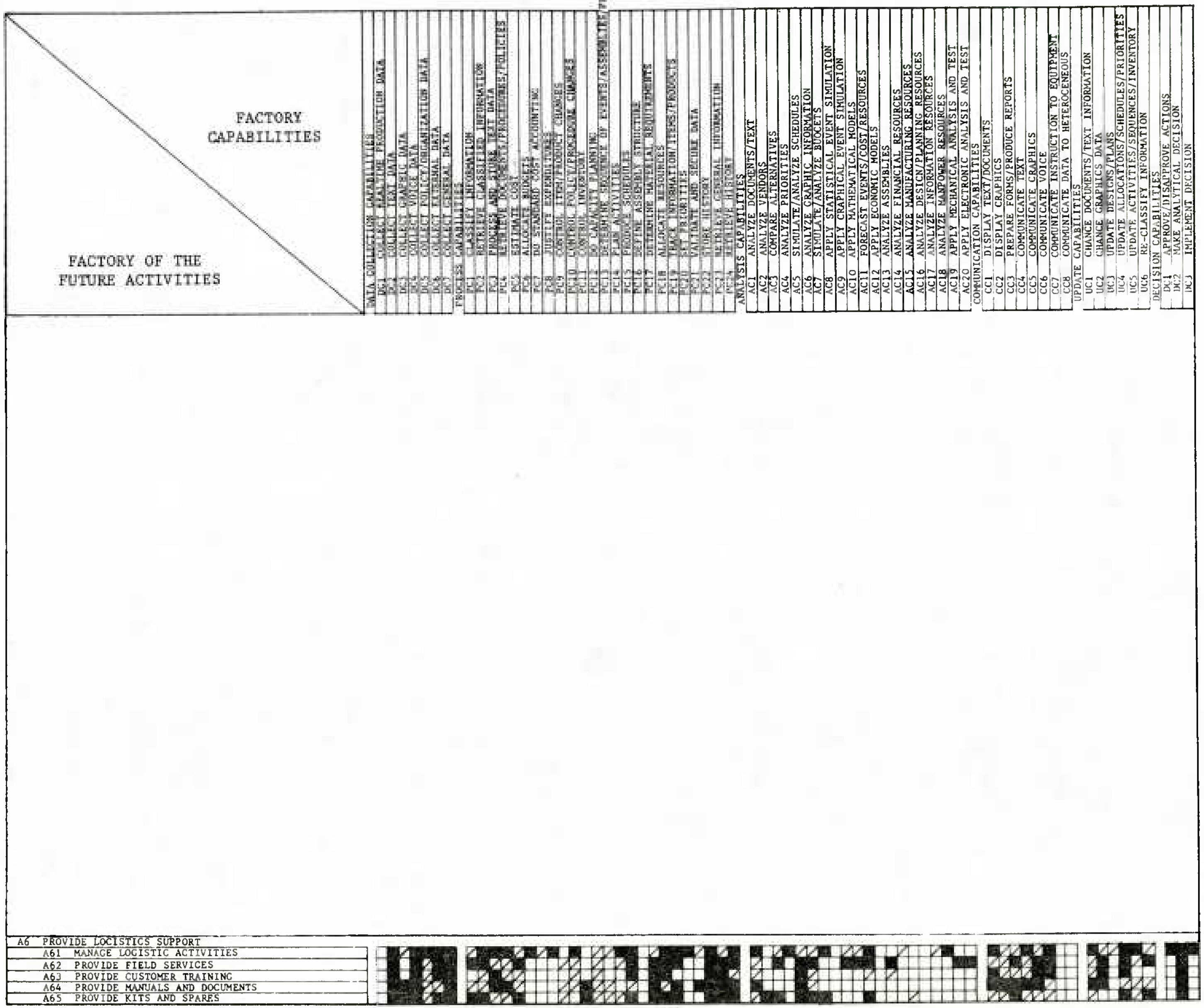
The basic business entities relate to many information classes as presented in Figure 6-21. The center will also have access to all information in the logical data base. The information classes that this center will create are in the product and materials categories.

The Product Support Center must be able to react quickly to customer demands for service and spare parts. The matrix of Figure 6-22 reflect these capabilities as applied to node A6.



FOF ACTIVITY CREATES INFORMATION

Figure 6-21 FoF/A6 Creates Information



KEY
- ☐ DOES NOT APPLY
- ■ EXPECTED USE
- ⧄ PROBABLE USE

Figure 6-22 FoF/A6 versus Factory Capabilities

APPENDIX A

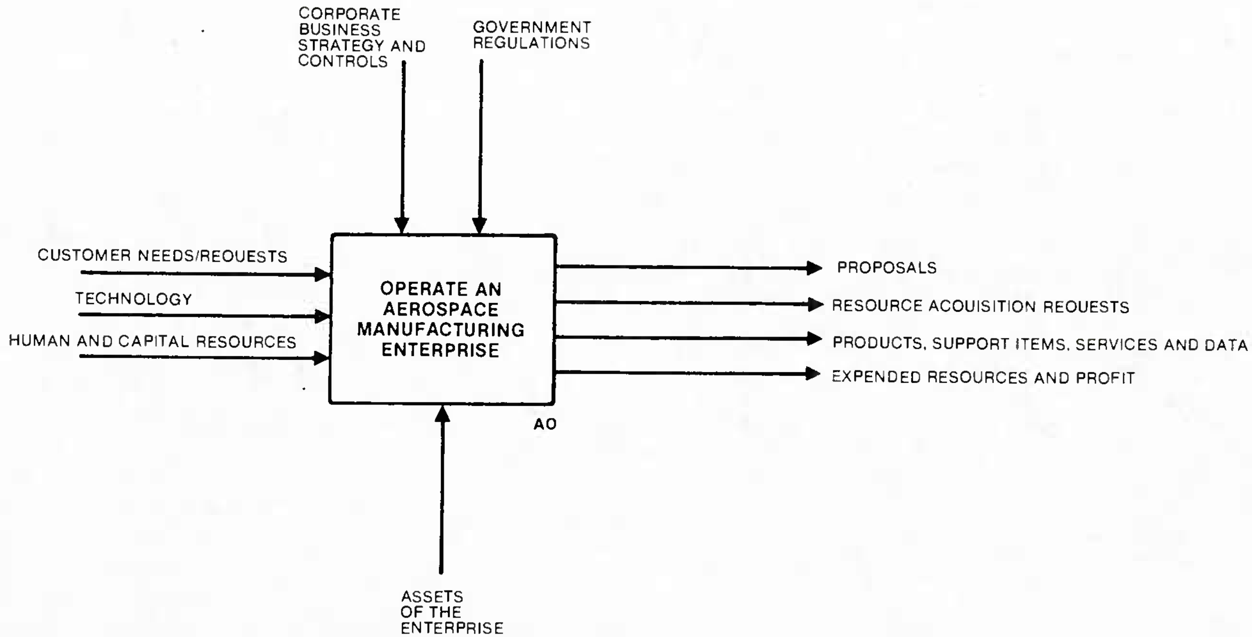
IDEFØ DIAGRAMS

A-0 OPERATE AN AEROSPACE MANUFACTURING ENTERPRISE

Diagram A-0 emphasizes the pervasive scope of Task B, Project 1105, "Establish Factory of the Future Conceptual Framework." This scope led to establishing a viewpoint of the total manufacturing system for the Factory of the Future (FoF) conceptual framework. Without this viewpoint (in the coalition's opinion), it would be impossible to establish a conceptual framework for integrated aerospace operations in the FoF (circa 1995).

The primary inputs to our Enterprise are: 1) customer needs, i.e., what is perceived necessary to accomplish an objective or mission, and the request or order for that item; 2) the current technology available which affects the capabilities of the product and the processes, material, etc. to build the product/item; and 3) the human and capital resources required to produce the product or item. Controls on the manufacturing Enterprise consist of the policies and goals of corporate management and government regulations. The primary outputs of the aerospace manufacturing Enterprise consist of: proposals to obtain business, request to purchase, hire, lease or otherwise obtain the necessary resources; the expended resources and profit obtained from the products; support items; services, and data provided. Finally, the diagram indicates that all assets of the Enterprise are needed to produce the above mentioned output.

PUBLICATION



VIEWPOINT: TOTAL MANUFACTURING SYSTEM

PURPOSE: TO ESTABLISH A CONCEPTUAL FRAMEWORK FOR THE FACTORY OF THE FUTURE (FOF)

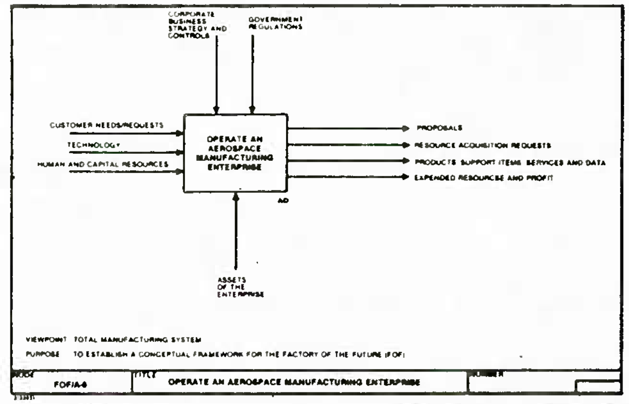
NODE:	TITLE:	NUMBER:
FOF/A-0	OPERATE AN AEROSPACE MANUFACTURING ENTERPRISE	

2-22031

A0 OPERATE AN AEROSPACE MANUFACTURING ENTERPRISE

A0 is the source diagram from which all subsequent diagrams in the FoF Conceptual Framework Architecture emanate. It has the same inputs, controls, outputs and mechanisms as does the one block diagram A-0.

The six boxes on the diagram correlate to the generic functions of the FoF that were described in the Scoping Document, SD110512000 dated March 1982. The emphasis on the A0 diagram has changed since it was originally established in March 1982. This shift has been necessitated because the coalition's investigation led to the conclusion that our thrust was really the operation of an aerospace Enterprise in the 1995 time frame as opposed to emphasis on the development and production of an aerospace product. This conclusion appeared during the needs analysis effort and crystalized during the identification of system requirements and the establishment of the system specification.



Box 1, Provide Customer Liaison and Services depicts all those actions required to interact with the customer and analyze the outside environment to determine future courses of action for the business Enterprise. Outputs of this activity include proposals for new products on contractual requirements levied by the customer. NOTE: This activity was not included in MFGØ.

Box 2 depicts the Manage Factory activity. It involves all the necessary actions to plan, organize, direct and control factory operations. The major output of this activity is business controls. NOTE: There was no corresponding activity in MFGØ to which this function can be specifically correlated, although it includes all the activities in A2.

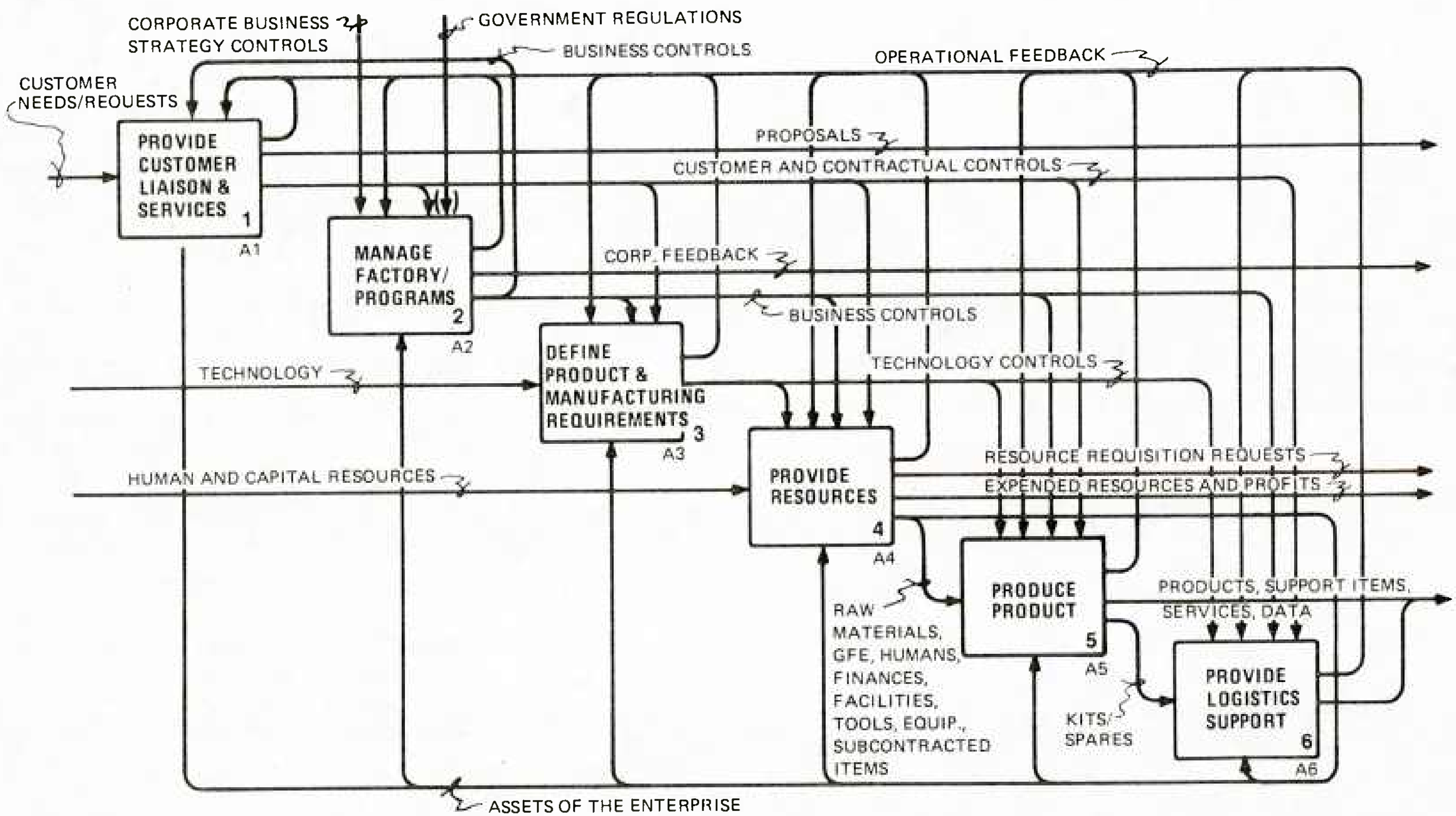
Define Production and Manufacturing Requirements, Box 3, includes the activities of design, engineering, and manufacturing planning. The output of this activity includes all the technical considerations/controls that impact: the selection of raw materials, vendors, subcontractors and personnel, the production approach selected, and the providing of logistics support. NOTE: This activity correlates directly to DESØ and boxes A1 and A3 of MFGØ; in short, it describes the potential for integration of these current "AS IS" functions.

Box 4, Provide Resources, includes the acquisition of capital, materials, tools, facilities, equipment, and people necessary for the operation of an aerospace manufacturing activity. As such, it provides the life's blood of the Enterprise. The efficiency of this function is essential for successful operation of the Enterprise. NOTE: This activity partially correlates to MFGØ in that it includes the A4 and A5 boxes; however, its scope has been significantly expanded.

Box 5, Produce Product, is the activity of: fabricating parts, making subassemblies, and performing final assembly. This is the physical activity and includes all the integrated centers, e.g., assembly, composites, electronics, machining and sheet metal. NOTE: This function directly correlates with box A6 of MFGØ.

Provide Logistics Support, Box 6, is the product support function. It is the key interface with the customer in all matters dealing with product performance and support from the factory. NOTE: There is no corresponding MFGØ activity.

PUBLICATION



NODE: FOF/A0	TITLE: OPERATE AN AEROSPACE MANUFACTURING ENTERPRISE	NUMBER:

2-22031

MMR11051200
10 February 1984

A11 MANAGE CUSTOMER LIAISON ACTIVITIES

Planning, organizing, directing and controlling the other functions of A1 are performed here. Budgets, activity planning, resource allocation and business controls are performed by this function.

A12 CONDUCT MARKET RESEARCH AND ANALYSIS

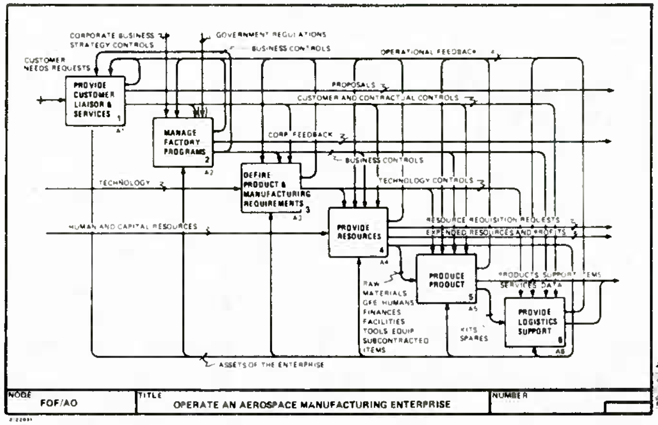
Current customer contracts and agreements, market information, and technology information are analyzed to determine potential customers and modifications and/or extensions to current customer agreements.

A13 ESTABLISH CUSTOMER LIAISON

Expressed and/or implied requests from customers and recommendations from A12 are acted upon by establishing new, or strengthening old, customer contacts, for the purpose of developing new and/or extended business possibilities as expressed in an RFP.

A14 RESPONSE TO RFP

A response to an RFP generated by A13 is developed based on current business agreements, technology information which may include product concepts, and further discussions with the customer. The RFP response appears as a proposal. Negotiation for a contract then occurs, with the customer needs as the driving inputs controlled by the business policies of the factory. The final document is a contract.



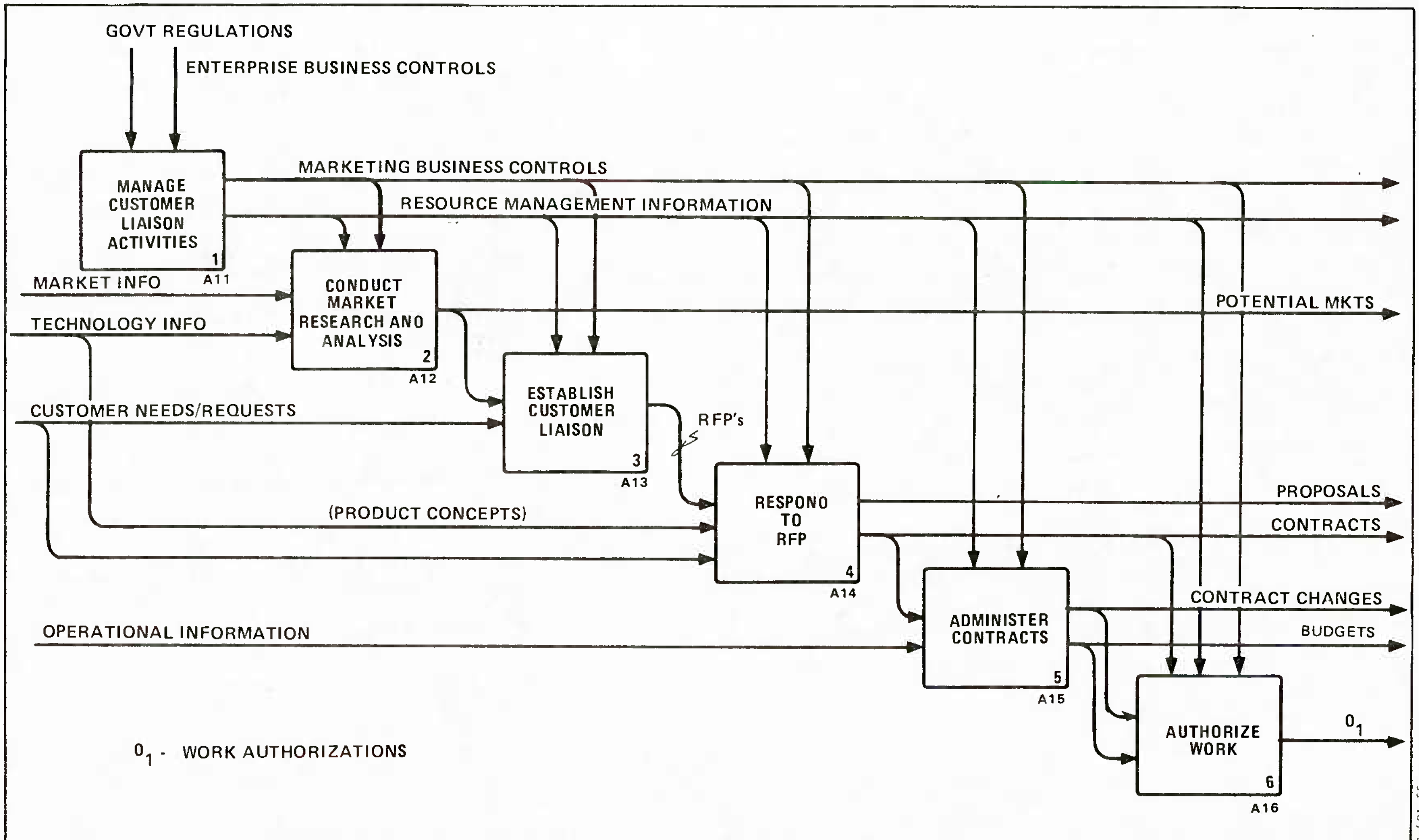
A15 ADMINISTER CONTRACTS

The contract, as delivered from A14, is used to develop budgets and as a benchmark against which operational information is checked for the life of the contract. Contract changes, as requested by the customer or by the factory, are negotiated to the point of acceptance or rejection.

A16 AUTHORIZE WORK

Budgets prepared by A15 are used to develop specific work authorizations, controlled by the delivery schedules specified in the contract as altered by approved contract modifications.

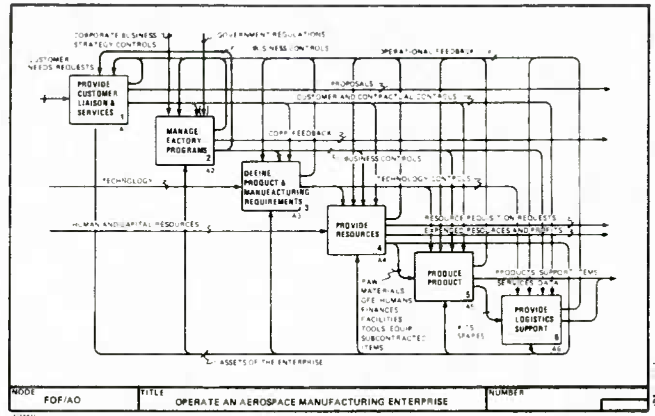
PUBLICATION



NODE:	TITLE:	NUMBER:
FOF/A1	PROVIDE CUSTOMER LIAISON AND SERVICES	

2-22031

MMR110512000
10 February 1984



A21 PLAN OPERATIONS

The output of this function is a set of controls for planning for the other management boxes of A1, A3, A4, A5 and A6.

A22 ORGANIZE FACTORY

Directives for factory creation and/or modifications are developed, based on contracts and the strategic business plan as represented by policy statements and directives. A statement of the required factory environment is created.

A23 DIRECT OPERATIONS

Daily operations and tactical goals of the factory are analyzed. Directives are prepared to implement requirements established by the A22 activity and as represented in the business controls.

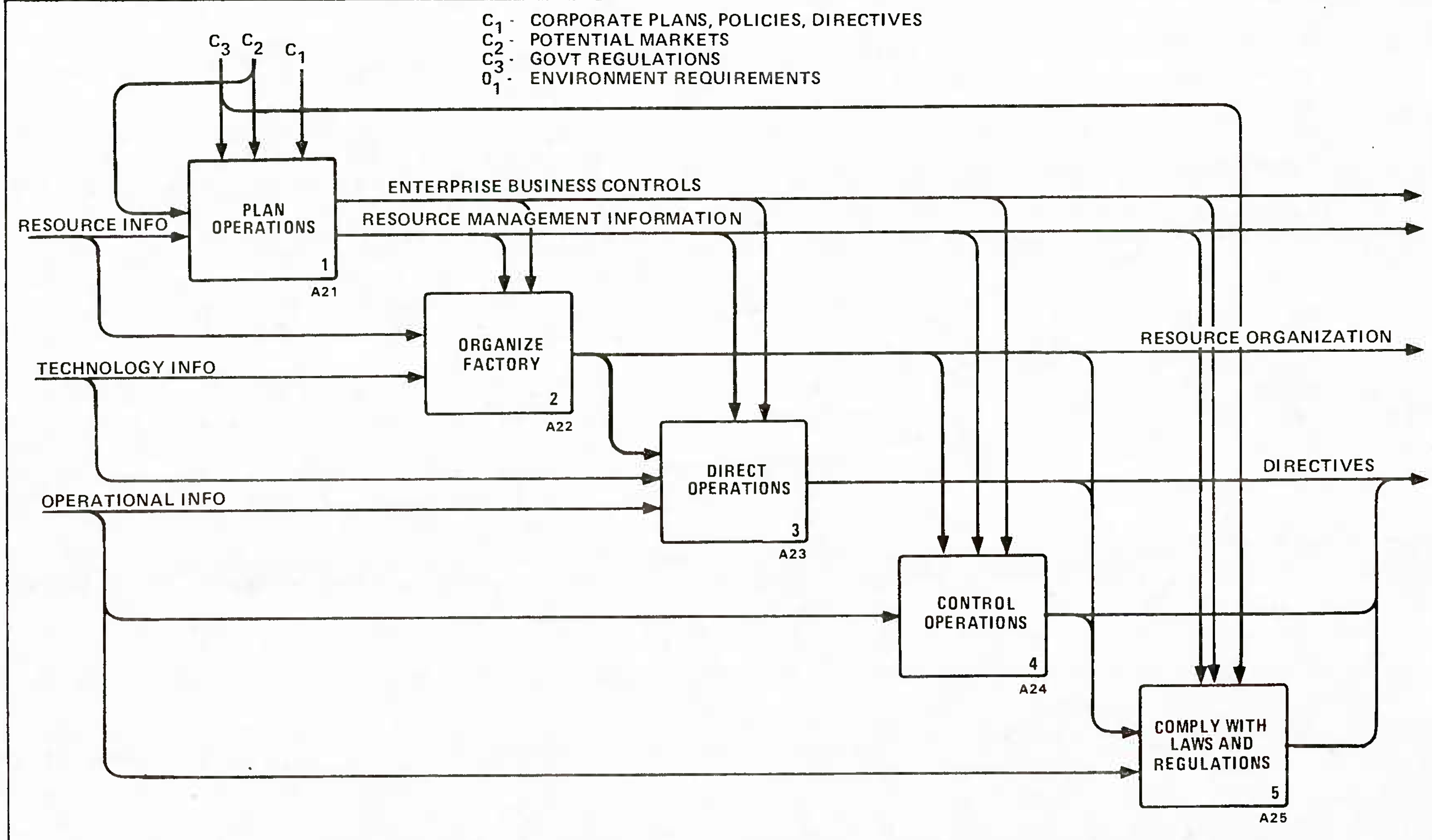
A24 CONTROL OPERATIONS

Operations are checked against requirements as presented in business controls to ensure that such operations are meeting tactical and strategic goals. Directives are prepared so that operations not meeting such goals are brought into line.

A25 COMPLY WITH LAWS AND REGULATIONS

Corporate business controls and government regulations are compared against directives issued and environmental requirements for organization, operation and control of the factory. Directives are issued to comply with such requirements and directives.

PUBLICATION



NODE: FOF/A2	TITLE: MANAGE FACTORY/PROGRAMS	NUMBER:

2-22031

IMOD-TS-4101-56

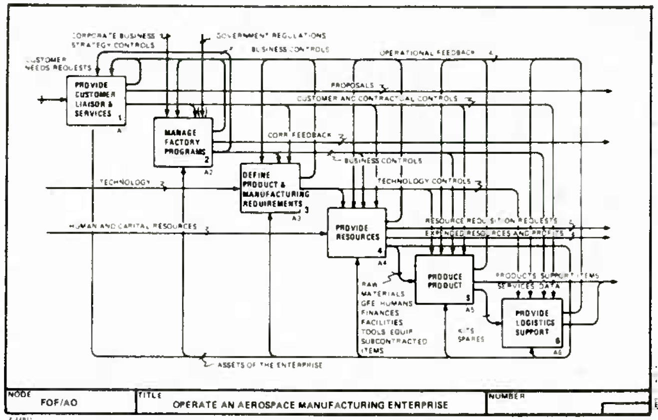
A31 MANAGE PRODUCT AND MANUFACTURING REQUIREMENTS

Planning, organizing, directing and controlling the other functions of A3 are performed here. Budgets, activity planning, resource allocation and business controls are performed by this function.

A32 CONDUCT ADVANCED DESIGN

This activity ascertains customer needs, determines technical feasibility for the implementation of concepts and identification of constraints, and focuses on the financial possibilities and practicalities of the purchaser's requirements. If there are possibilities for further applications of the product design, additional research would be required.

Customer requirements and management decisions, reconfiguration requests, and information from prototypes, models, preliminary design, test results, and manufacturing are transformed into geometry. The geometry and associated analytical data are used to formulate and define alternate concepts and individual configuration development data which are sent to technical disciplines for each concept.



The best configurations for possible preliminary design are chosen. This selection process entails assigning relative merits to the candidate configuration, performing tradeoff studies based on life-cycle costs, comparing performance predictions with the requirements ranking (like parameters of each design), and documenting information covering all available considerations. The end product includes the program requirements' baseline.

Activity may be prompted by contracts, proposals, or corporate requests for research into new market areas.

A33 DEVELOP PRELIMINARY DESIGN

The advanced (or conceptual) product design is refined. Prototypes may be constructed. Producibility studies are performed.

Analysis is done on trade studies and improvements, the information from prototypes, models, conceptual designs, and recommendations from detail design so that a baseline capable of being subjected to detail investigations is built. Moreover, the activity involves applying more advanced analytical methods to the design problem to build confidence in the final selected design.

By using the conceptual design information, candidate configurations are studied in relation to engineering, manufacturing, logistics, and economic considerations subject to design analysis data. As a result, a concept is recommended.

The recommended configuration and manufacturing costs and schedules along with analysis reports are studied to confirm that all necessary analyses and studies have been completed and that the results satisfy the requirement to commit to the detail design phase. If the preliminary design is not approved, new requests for a selection change are made.

A34 DEVELOP DETAILED DESIGN

The Develop Detail Design activity occurs when the preliminary designs have explored representative design areas to where there are no significant problems, mysteries, or voids remaining: in other words, every detail part, assembly, and subassembly is designed in its entirety. When the risk of design changes is small, and the market prospects are high, management decides on the "go ahead" and the detail design commences.

The information from prototypes, models, preliminary design, testing and manufacturing is used to investigate, design, and document, with layouts, all of the task areas so that there are no unknowns. The layouts are then used as a guide or pattern to produce detail data to completely describe the part to be fabricated.

The recommended design layouts and other information are used to produce formal detail designs and data that will ultimately be used to direct manufacturing in fabricating and inspecting the article and to show the customer what is being produced.

The detail geometric descriptions are used in addition to other information to obtain design approval, release the layout and detail design information, and make periodic reports of the release status.

A35 DEVELOP MANUFACTURING AND PRODUCTION PLAN

This activity has the overall task of converting engineering designs into detailed manufacturing methods.

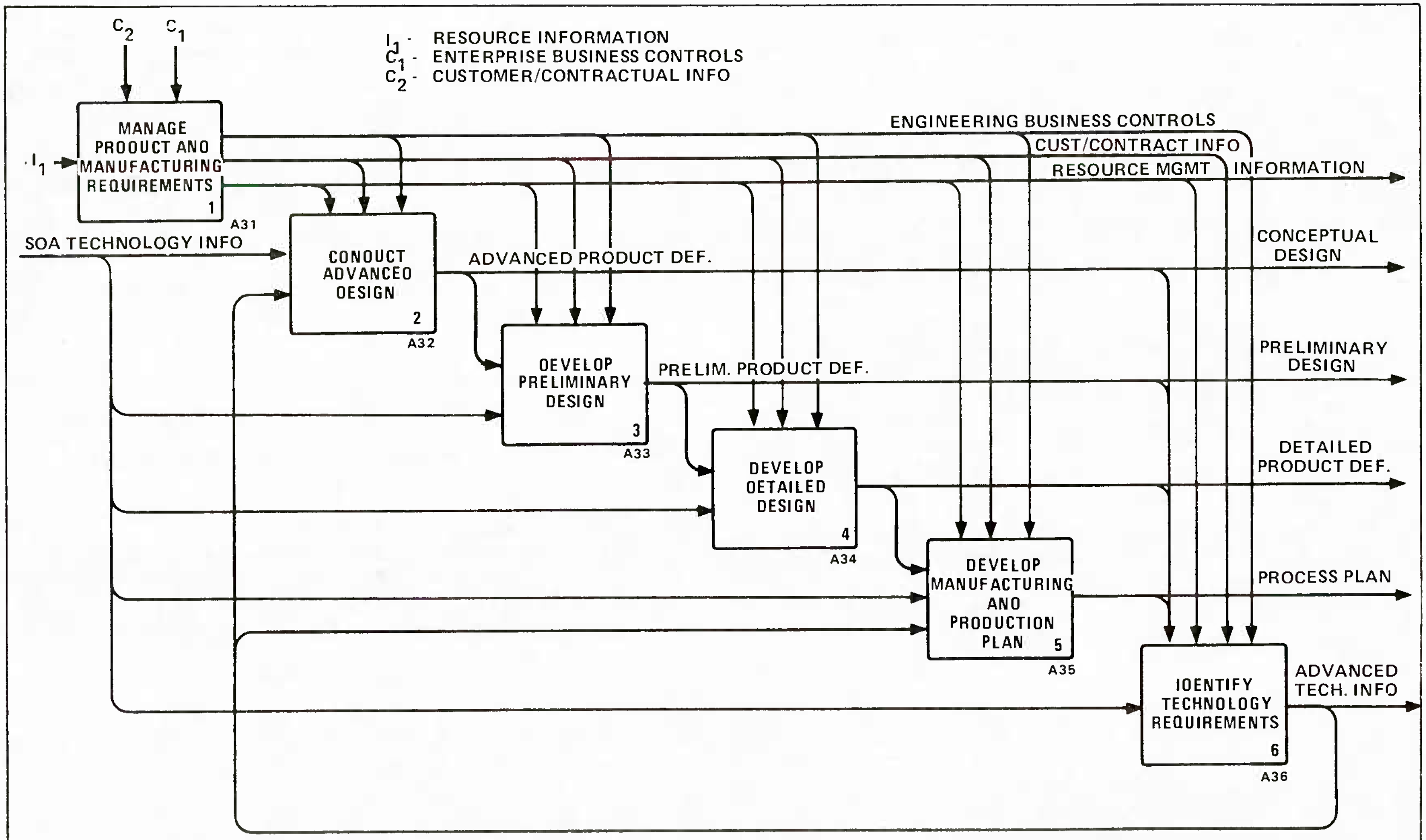
For each engineering item, a detailed manufacturing method is devised. This involves identifying the manufacturing parts to the extent that they are planned to exist temporarily in different structures or in different forms from the engineering versions (for example, groups of parts may be put together into subassemblies not identified by engineering or holes may be omitted in detail parts and drilled after assembly to assure alignment), and identifying the tools to be used. Production plans and resource characteristics are necessary considerations in this task.

Detailed instructions for making each part are an elaboration of the detailed manufacturing method. In the process of making them, specifications for tools and for procured items are produced. All these must be validated to be sure that the items produced or acquired will conform to the engineering design.

A36 IDENTIFY TECHNOLOGY REQUIREMENTS

This activity aids other activities in researching technological areas applicable to its functions by using existing technology to create advancements which can be applied to future products and manufacturing processes.

PUBLICATION



NODE: FOF/A3	TITLE: DEFINE PRODUCT AND MANUFACTURING REQUIREMENTS	NUMBER

2-22031

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A41 PROVIDE FINANCES

All financial resources for the company are located here. Requests for financial services are recevied and processed for all other functions.

A42 PROVIDE HUMAN RESOURCES

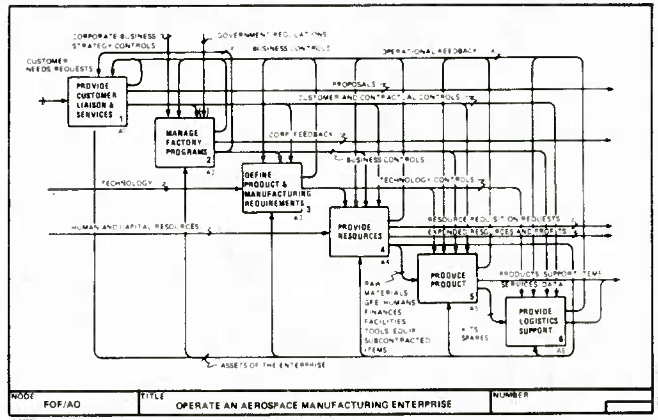
Personnel for all activities in the factory are supplied, trained and administered from this function.

A43 PROVIDE INFORMATION RESOURCES

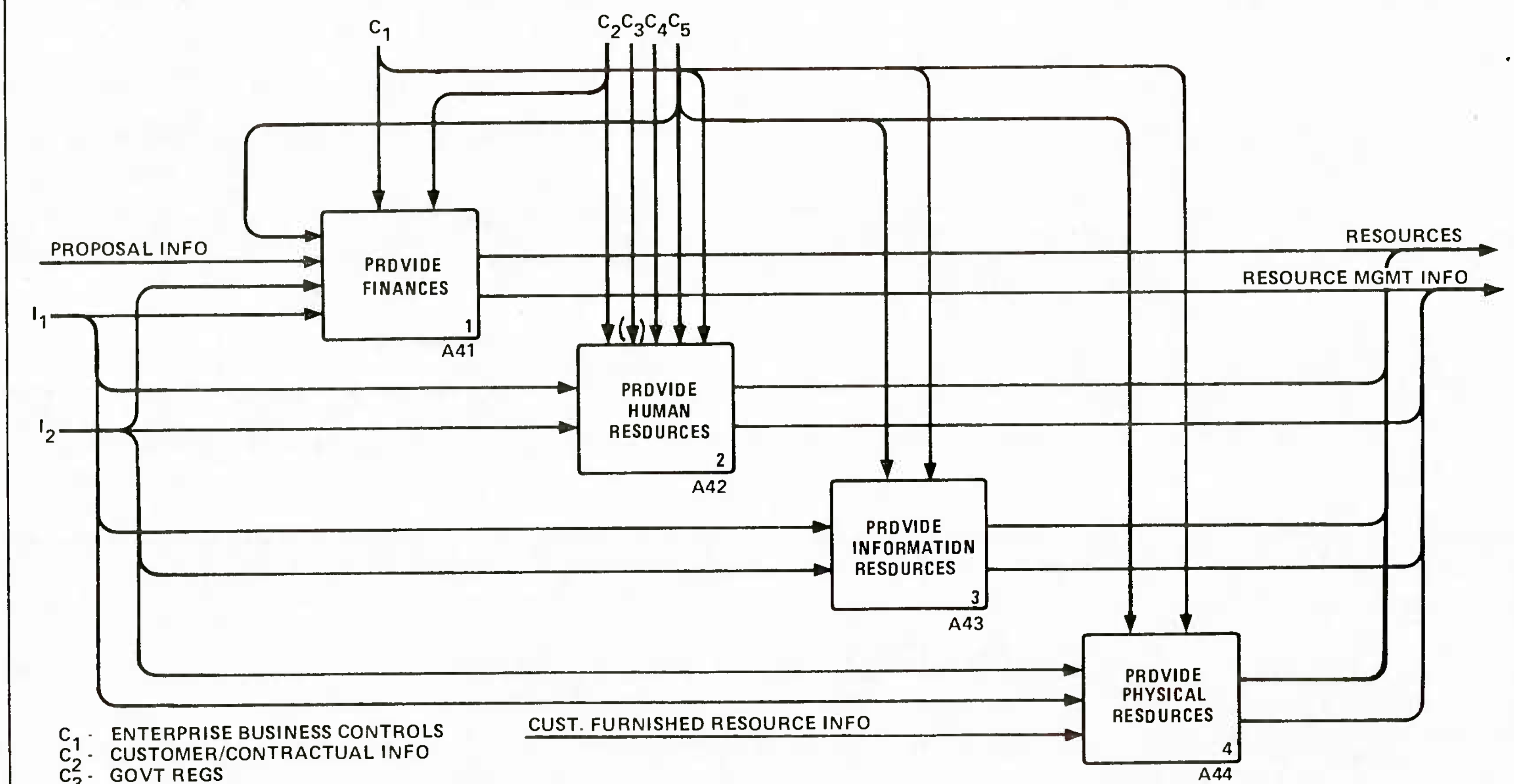
Requests for computer hardware and software are received and processed by this function. Procurement of information equipment is also accomplished by this activity.

A44 PROVIDE PHYSICAL RESOURCES

Procurement, inventory and repair of all physical equipment, except information processing equipment, is accomplished by this function.



PUBLICATION



C_1 - ENTERPRISE BUSINESS CONTROLS
C_2 - CUSTOMER/CONTRACTUAL INFO
C_3 - GOVT REGS
C_4 - LABOR AGREEMENT
C_5 - BUDGET INFO

I_1 - AVAILABLE RESOURCES
I_2 - RESOURCE REQUESTS

NODE: FOF/A4	TITLE: PROVIDE RESOURCES	NUMBER:

2-22031

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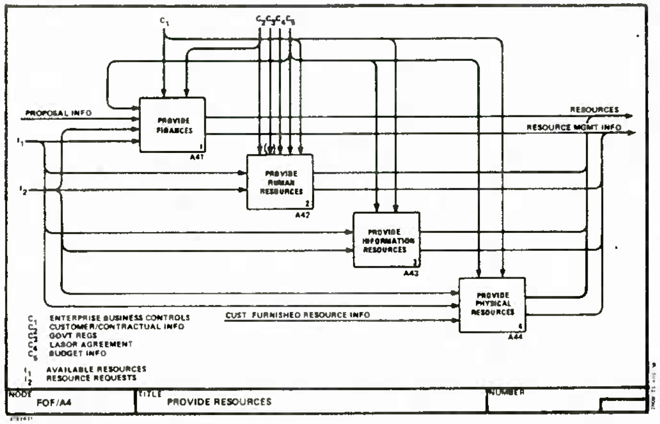


A411 MANAGE FINANCIAL RESOURCES

Planning, organizing, directing and controlling the other functions of A41 are performed here. Tracking company assets, budget allocations, activity planning and resource allocations are performed by this function.

A412 COLLECT, STORE, MANIPULATE FINANCIAL INFORMATION

This activity provides what is traditionally termed the financial transactions to the remainder of the factory. Operational and budgetary information are stored, retrieved and manipulatedb ased on requests and controls from other activities.

A413 FORECAST AND ESTIMATE FINANCIAL REQUIREMENTS

Past, present and projected financial needs of the factory are used to develop firm estimates of both short- and long-term capital requirements. Internal and external money supplies are inventoried and used to determine if requests to obtain outside financing are necessary. In situations where further analysis is required, requests for such activities are prepared and passed to A414, PROVIDE FINANCIAL ANALYSIS. Authorizations to disburse funds are prepared by this activity.

A414 PROVIDE FINANCIAL ANALYSIS

Analysis of various financial information occurs here prompted by requests from other factory activities. Such analysis may include projections of actuals as opposed to budgets, statistical analysis, graphical representations and extrapolations of various costs.

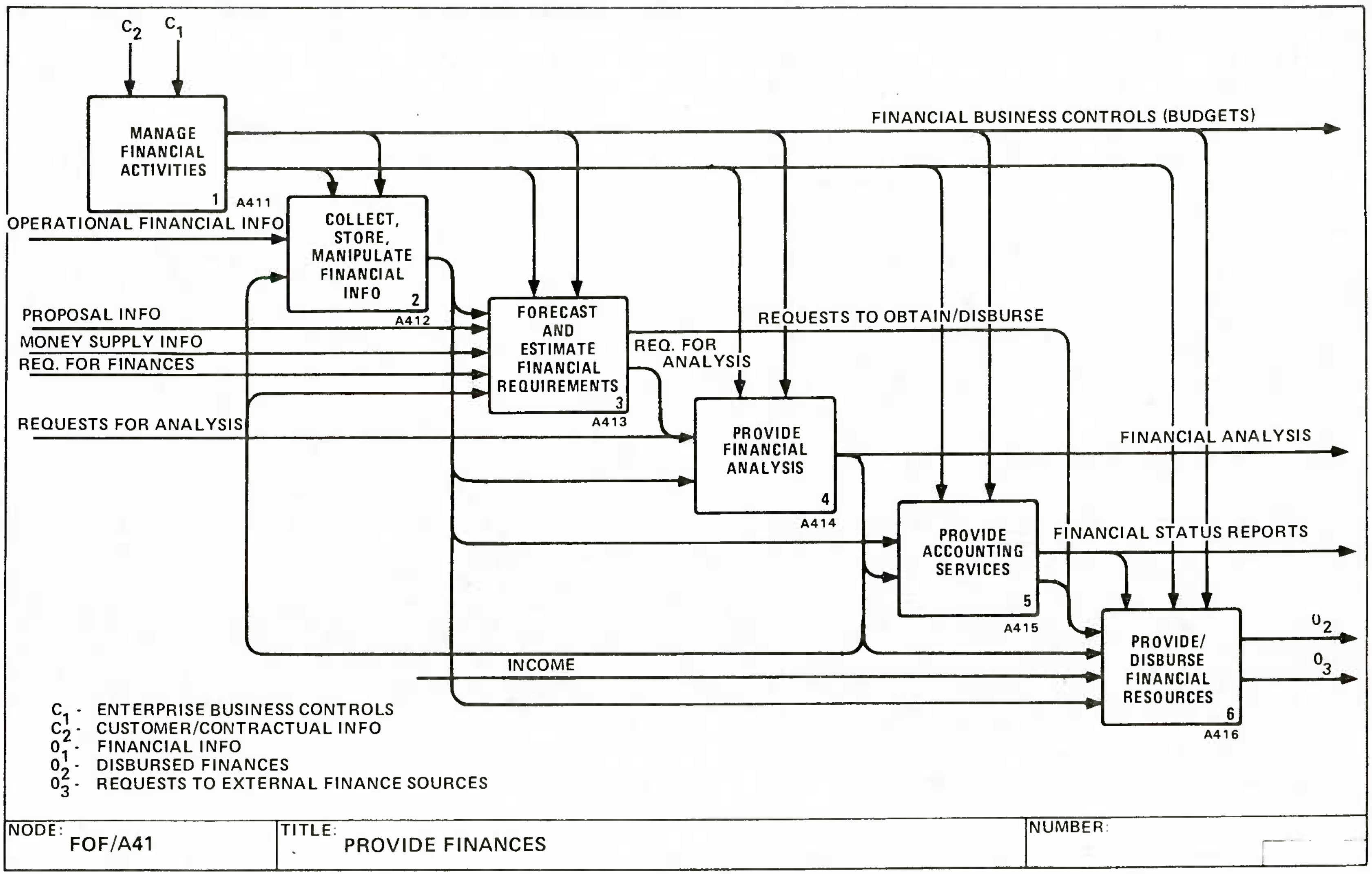
A415 PROVIDE ACCOUNTING SERVICES

The traditional accounting services, such as general ledger, chart of accounts, payroll processing and time-keeping are performed here. Many functions are done on behalf of other factory activities, such as payroll processing done on behalf of HRM. This activity also provides the organizational mechanisms for storage and retrieval of financial analysis created by A414, PROVIDE FINANCIAL ANALYSIS. Requests for collection of accounts receivable and payments of accounts payable are prepared here.

A416 PROVIDE/DISBURSE FINANCIAL RESOURCES

This activity serves as the clearing-house for the flow of capital within the factory and between the factory and customers and suppliers. The means by which the capital flow is to occur (e.g., funds transfer, letter of credit, exchange/barter, cash) are usually specified in the request for capital flow, as are account numbers, contact personnel names, etc. This activity has responsibility for ensuring that the capital flow is occurring as specified. Disbursements such as payroll, retirement, and benefits are handled through this activity as requested by A415, PROVIDE ACCOUNTING SERVICES, as are billings to customers and payments to suppliers.

PUBLICATION



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A421 MANAGE HUMAN RESOURCE MANAGEMENT ACTIVITIES

Planning, organizing, directing and controlling the other functions of A42 are performed here. Budgets, activity planning, resource allocation and business controls are performed by this function.

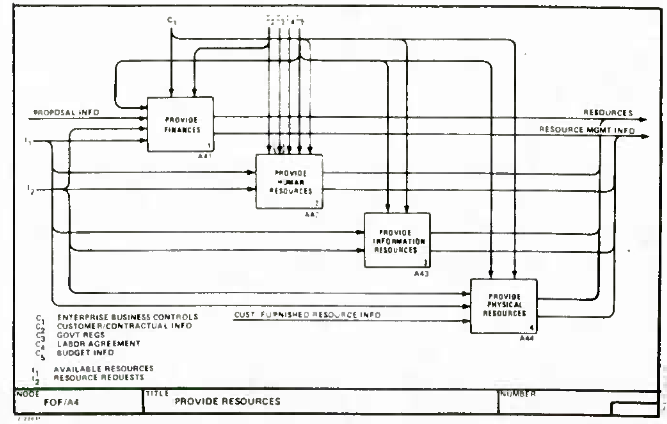
A422 PLAN HUMAN RESOURCE NEEDS

Requests for human resources, labor availability (both in-factory and outside), budgets and business controls are utilized to determine the short- and long-term requirements for human resources. Shortcomings in current HR capabilities are identified and translated into requests for research, which are passed to A423, CONDUCT HR RESEARCH AND NEW PROGRAM DEVELOPMENT.

Overall plans for staffing the factory are developed here.

A423 CONDUCT HR RESEARCH AND NEW PROGRAM DEVELOPMENT

Effectiveness of current HR programs is analyzed. Developments in the HR



field are studied for applicability to the local factory environment. HR requirements, as prepared by A422, PLAN HUMAN RESOURCE NEEDS, are studied for effectiveness and applicability. New HR programs are developed for implementation by other A42 activities.

A424 STAFF FACTORY

Requirements stated in the overall staffing plans as developed by A422, PLAN HUMAN RESOURCE NEEDS, and in plans for new HR programs developed by A423, CONDUCT HR RESEARCH AND NEW PROGRAM DEVELOPMENT, are used to create detailed plans for human resources. Current staffing levels and labor availabilities are used with these plans to generate requests for changes in staffing levels and for (re)training people. Hire and fire activities occur here as does negotiation of union agreements.

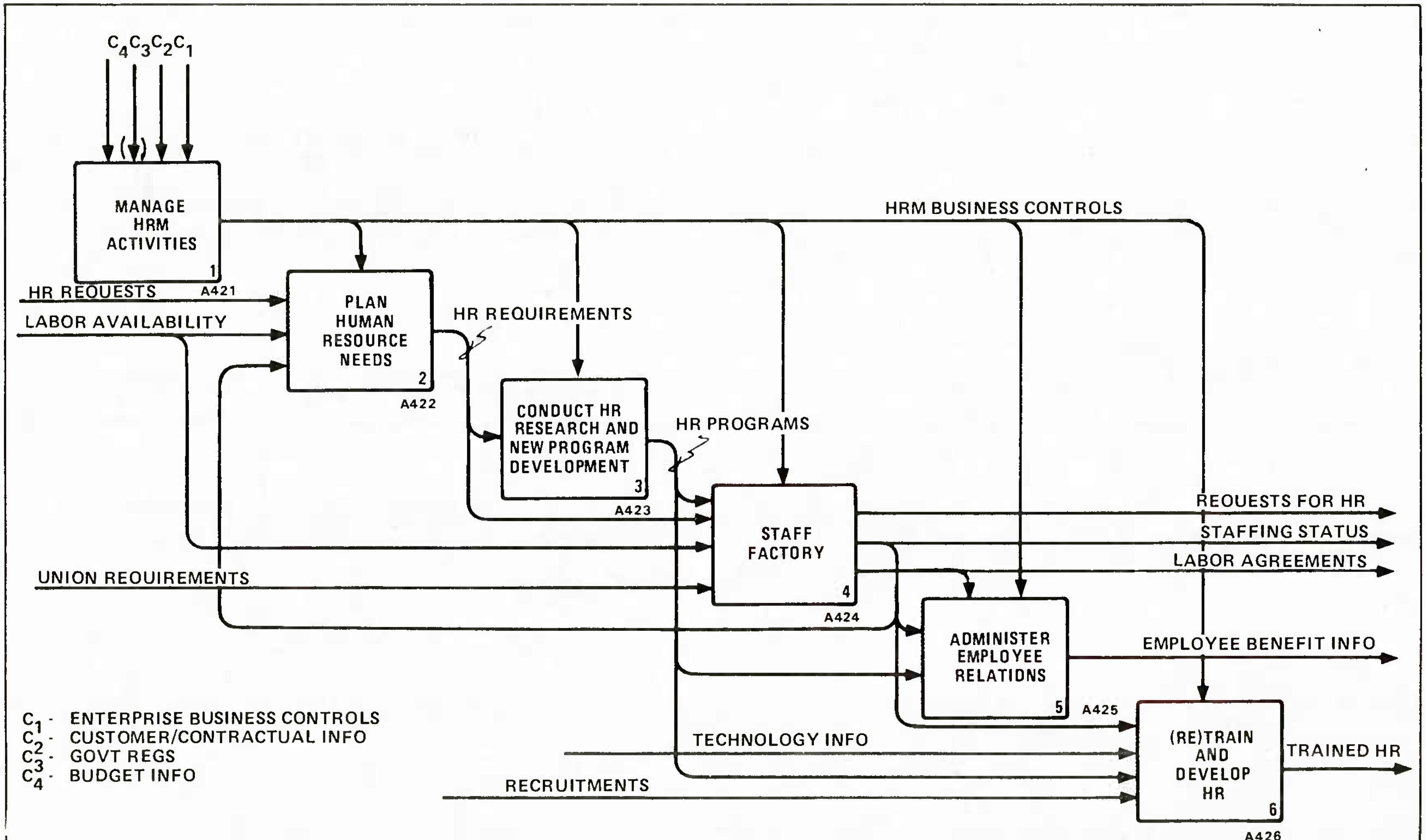
A425 ADMINISTER EMPLOYEE RELATIONS

Employee benefit plans, grievance procedures, promotion procedures, salary review procedures and cost/performance improvement incentive programs are administered here. Existing labor agreements are an important control of this activity.

A426 (RE)TRAIN AND DEVELOP HR

Employee educational and training programs are developed and performed here. Such programs include job-related activities, such as soldering schools, overall programs, such as management training, and career-oriented programs, such as tuition assistance and factory on-site higher educational classes in association with post-secondary institutions. Personnel suffering job displacement due to technological changes or changes in production line are counseled and retrained, as necessary. Organizations such as quality circles are usually administered through this activity. The functions performed are, in many cases, closely controlled by an existing labor agreement, as reflected in business controls.

PUBLICATION



NODE: FOF/A42	TITLE: PROVIDE HUMAN RESOURCES	NUMBER:

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A431 MANAGE INFORMATION RESOURCE MANAGEMENT ACTIVITIES

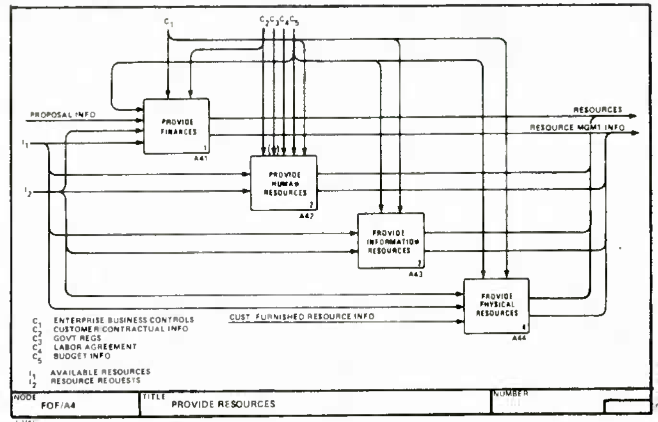
Planning, organizing, directing and controlling the other functions of A43 are performed here. Budgets, activity planning, resource allocation and business controls are performed by this function.

A432 MANAGE AND PLAN IR

The overall plan for meeting short- and long-term IR needs of the factory is developed here. The incoming requests for IR are usually rather general and are translated into overall plans for the remaining A43 activities. The data administrative staff operates within this activity and coordinates the operation of the remaining A43 activities in such areas as data definition, usage and population.

A433 MANAGE/PROVIDE COMPUTER TECHNOLOGY

The overall IRM plan prepared by A432, MANAGE AND PLAN IR, is translated by this activity into specific plans for operating system, application development



and test/production system management facilities. The personnel in this area include applications programmers, analysts, coders, operating system staff, program librarians, data base administration and supporting technical staff. Requests for hardware (including communications hardware) and requests for provisioning of telecommunications vendor supplied facilities (such as telephone lines) are created by this activity.

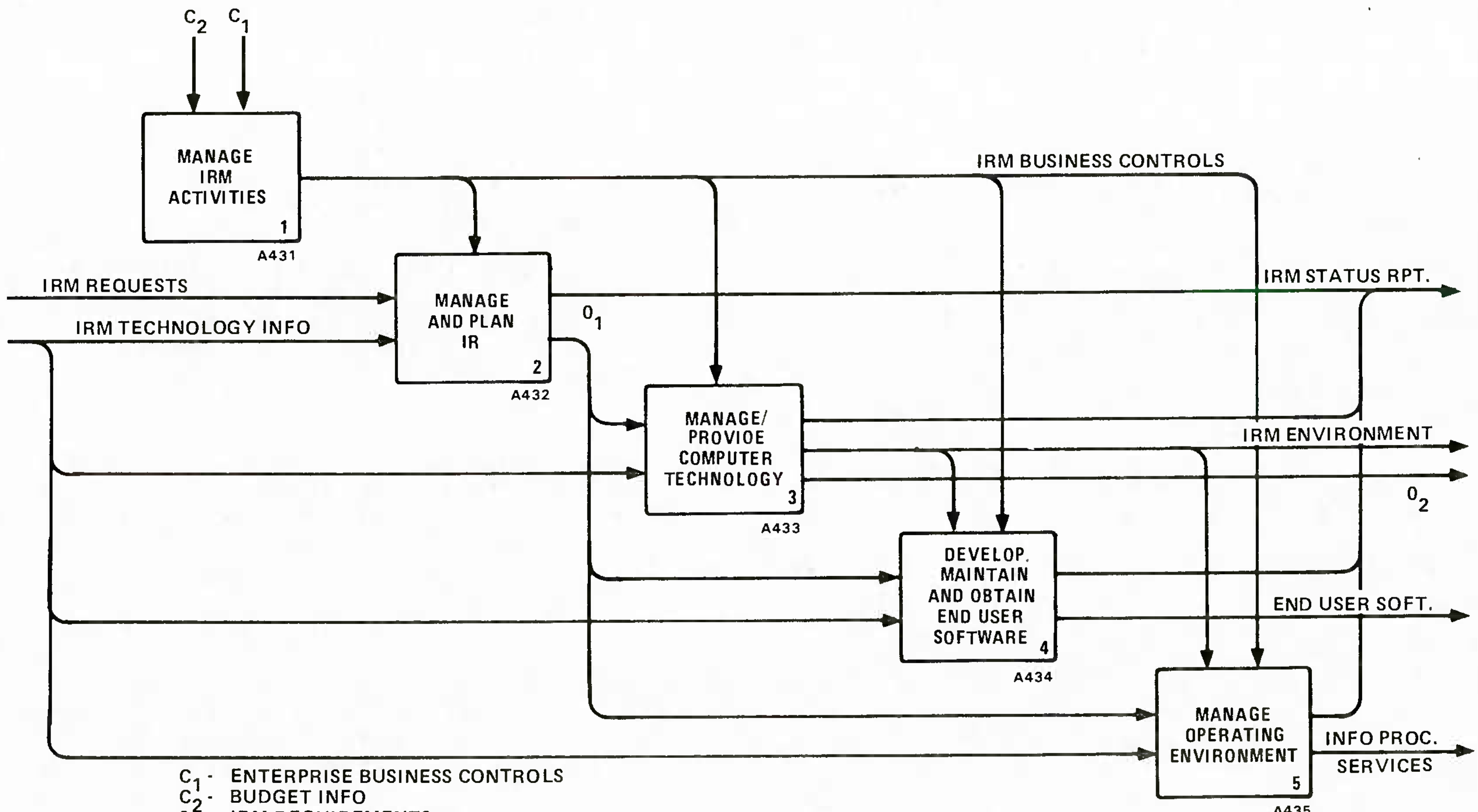
A434 DEVELOP, MAINTAIN AND OBTAIN END-USER SOFTWARE

Access to factory information by the non-IR factory staff is provided by this activity. Fourth-generation languages, natural-language query facilities, statistical and graphics packages and other capabilities as deemed necessary are obtained, installed and maintained. Training programs are developed and performed in conjunction with the Human Resources Management staff. Situations in which the requirements of the user conflict with IR production (e.g., batch payroll runs) are negotiated and resolved. Access by users to production and/or secure (company private or classified) data is controlled. The major interface between the traditional IR facility and the end-user for those situations in which the end-user wishes to directly utilize end-user software rather than have IR do the job are provided here.

A435 MANAGE OPERATING ENVIRONMENT

This activity manages the hardware and peripheral areas of the IR environment, including areas such as data entry, control desk, magnetic media librarians (e.g., tape librarian), unit record staff and operating staff. This activity utilizes the IRM requirements prepared by A432, MANAGE AND PLAN IR, to prepare the operational IR area to meet both short- and long-term IRM goals.

PUBLICATION



C_1 - ENTERPRISE BUSINESS CONTROLS
C_2 - BUDGET INFO
0_1 - IRM REQUIREMENTS
0_2 - REQUESTS FOR FACILITIES, HARDWARE, TELECOM

NODE:	TITLE:	NUMBER:
FOF/A43	PROVIDE INFORMATION RESOURCES	

2-22031

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A441 MANAGE PROVISIONING ACTIVITIES

Planning, organizing, directing and controlling the other functions of A44 are performed here. Budgets, activity planning, resource allocation and business controls are the activities performed by this function.

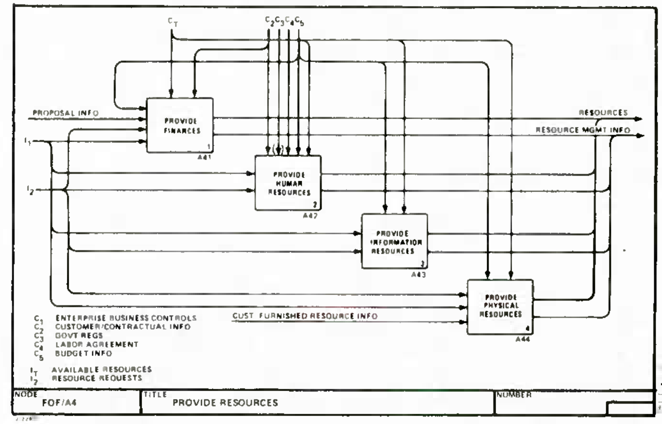
A442 PROVIDE FACILITIES

Provide Facilities encompasses planning, building, modifying, operating and maintaining facilities within the prescribed budgets to house the work identified. Three major activities occur here:

- o Activity 1 is the analysis, coordination, and engineering design of the facility to accomplish the assigned work.

- o Activity 2 includes purchase, fabrication, and modification of facilities in accordance with requirements developed in Activity 1.

- o Activity 3 provides the facilities maintenance and support. Plant maintenance includes painting, gardening, plumbing upkeep, and heating, ventilation and air conditioning operation. Monitoring of utilities includes water, power, and telephone service. Janitor services are the responsibility of this function. Waste handling includes the responsibility for complying with OSHA and EPA directives for personnel and safety and disposal of liquid and solid wastes that are by products of the manufacturing process.



A443 PROVIDE PRODUCTION EQUIPMENT AND TOOLS

Provisioning of equipment and tools produce of the end-items occurs here.

Equipment:

There are five major activities here:

- o <u>Activity 1</u> establishes equipment requirements from an analysis of the planned production loading. It reviews the inventory of current equipment for useability and availability. If required, it does make/buy trade-offs and estimates costs. It then justifies the costs and obtains the proper approvals.

- o Activity 2 involves issuance of purchase requisitions in compliance with the detailed equipment specifications. For those equipment orders dealing with items to be made, design specifications are developed. These specifications are used, together with the procured items and the available equipment, to perform the actual building or modification of the desired items. These items are then installed and checked out.

- o Activity 3 is responsible for control, movements, and accounting of facilities equipment. It moves equipment when required and is responsible for equipment control (property accounting).

- o Activity 4 includes the activities associated with the maintenance of the equipment.This includes repair and inspection.

- o Activity 5 includes equipment certification for compliance with the QA/QC plan.

Tools:

The design and manufacture of unique product tooling occurs here. The five major activities are:

- o In Activity 1, it is determined whether or not there exists any tooling that will perform the required function, or if any tooling does exist which is similar to the tooling required.

- o In Activity 2, the design of new tooling or the modification of existing designs is accomplished. Group technology will be a key control of this function.

- In Activity 3, the planning and instructions required for the actual production of the tooling are accomplished, including information necessary for the procurement of tooling raw material.

- In Activity 4, production/ maintenance of the tooling takes place.

- In Activity 5, represents all the functions necessary to verify, record, and control the tools produced in Activity 4. The tools are verified to design requirements and functional tests, if required. Recording and controlling (managing) tool supplies is done via manual and/or computer methods. If, during the process of tool verification defects are found, the tools, will be sent back to the make tools function for rework and/or touch-up.

A444 PROVIDE PRODUCTION MATERIALS

Raw and finished material necessary for the production process is obtained by this activity. Four major functions necessary for support are:

- Establish Requirements – the requirements stated in the detailed product definition and process plan are used in conjunction with current technology, resource availability, waste estimates, and business controls to establish requirements.
- Procure Materials – the established requirements are used to negotiate with approved suppliers for delivery, within contractual commitments of the needed materials. Computer interfaces may be used to directly connect suppliers and the factory to accelerate the procurement activity. However, a high level of human interaction between supplier and buyer will probably continue to exist due to the personal nature of negotiations.
- Receive and Store Material – inspection and storage of incoming material will be greatly decreased as companies move to receipt of materials only as they are needed for production.

Graphic and pictorial capabilities will be used to identify incoming material, with pattern recognition equipment carrying more of theworkload.

- <u>Issue Materials</u> - automatic generation of "pull lists" will occur, based on operational information and work release authorization created by other factory activities. Such "pull lists" will be fed directly to automated material handling and retrieval equipment so that, in many cases, human interaction will not be required. Inventory information will be continually and automatically updated as material is removed from storage.

A445 PROVIDE GENERAL OFFICE EQUIPMENT AND SUPPLIES

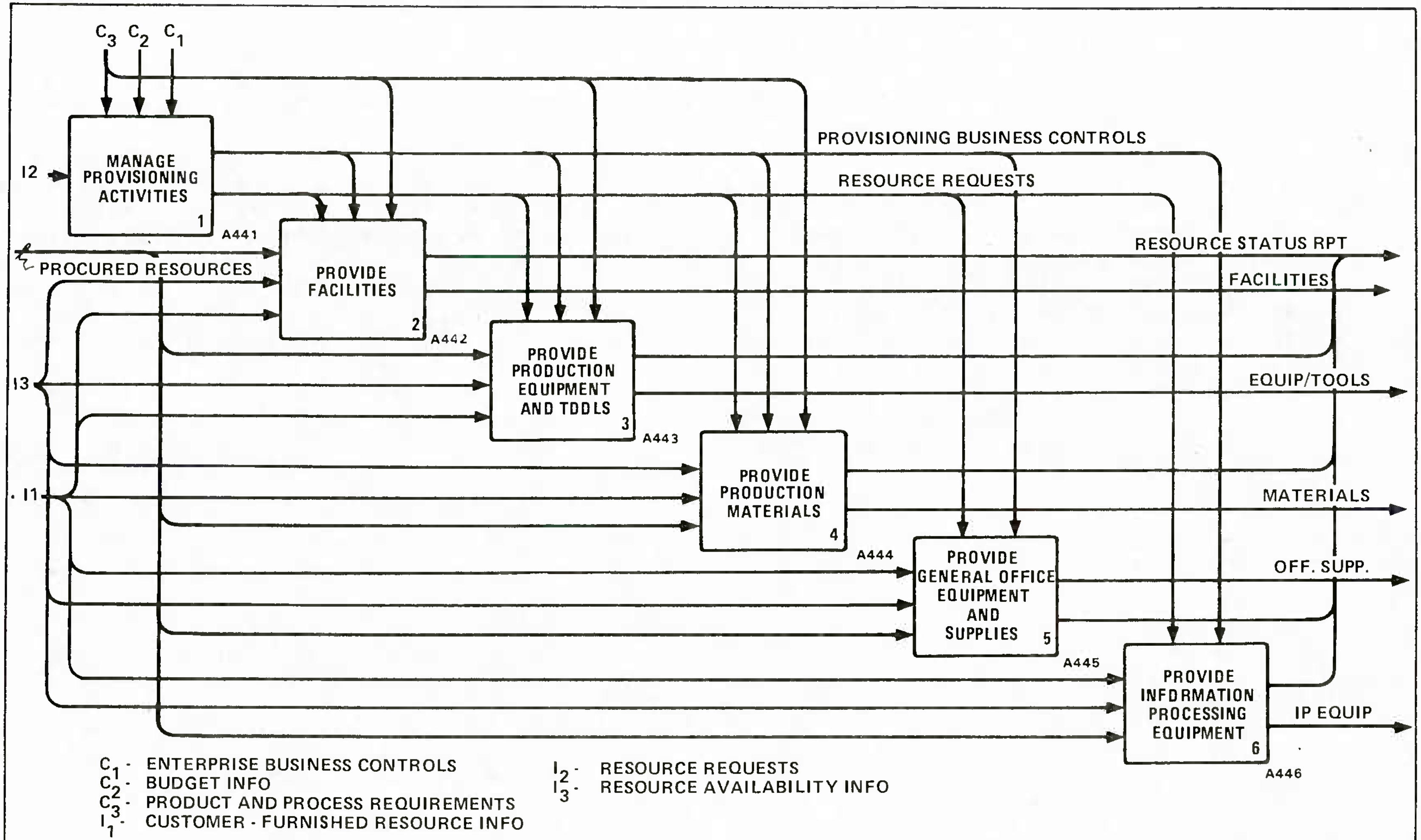
Office supplies and equipment such as chairs, desks and pencils that are not procured as part of any other factory activity are obtained, stored and issued

In most cases, business policies will dictate the specifications for such items and company-wide contracts will exist. Where a contract does not exist, this activity, in conjunction with the requestor, will develop specifications. The negotiations with approved suppliers, the purchase, rent, or lease agreement and the delivery schedule will all be handled by.

A446 PROVIDE INFORMATION PROCESSING EQUIPMENT

Hardware associated with the information processing environment will be obtained by this activity. Since the expertise for specification development of such specialized equipment exists in the A43 node, the activities within this node are usually confirmed to contract negotiations and establishment of delivery schedules. Equipment, such as modems, and certain types of terminals that are of relatively low cost, are stored and issued by this activity. More expensive equipment is usually shipped directly from the manufacturer to the site of use. Inventories of all IR equipment are maintained here. Telecommunications equipment, including locally-installed communications links and links provided by a telecommunications company are also inventoried here.

PUBLICATION



NODE:	TITLE:	NUMBER:
FOF/A44	PROVIDE PHYSICAL RESOURCES	

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A51 MANAGE PRODUCE PRODUCT ACTIVITIES

Planning, organizing, directing and controlling the other functions of A5 are performed here. Budgets, activity planning, resource allocation and business controls are performed by this function.

A52 MANAGE PRODUCTION ORDERS

Using the contractual requirements, business controls, stock records and tracking information, this activity develops the detailed production requirements and spares, repair and retrofit shop orders.

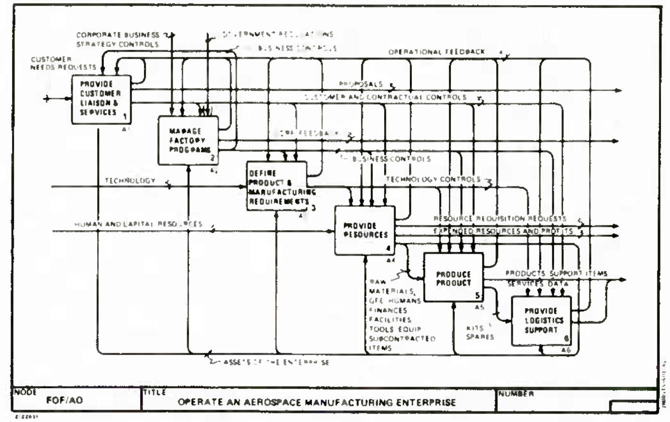
The production requirements incorporated in a work schedule are adjusted for changes due to Engineering Changes, procurement status and shortage items.

Work Packages released to the shop are subject to additional adjustments at the work center level where priorities are set.

Once released, these orders are followed up for status reporting and cost reporting.

A53 MANAGE PRODUCTION ITEMS AND TOOLS

From the work packages, this activity provides tool and material requisitions



and a "pull list" to be used against items in the current inventory. Meanwhile, procured items, new and used tools, and production items are stored to provide the inventory. Using the "pull list" and the work packages, kits, spare parts, and repair and retrofit kits required for the physical production are provided. Status of the inventory transactions are prepared to maintain the stock records.

A54 PERFORM PHYSICAL PRODUCTION

The functions performed by this activity are those which convert purchased items into the end product. The subactivities convert raw material into details; details and subassemblies into further subassemblies and assemblies, and finally subassemblies, details and assemblies are built into major assemblies and installations.

In addition to the materials required to be converted into the final product, tools required during these processes are also shown as inputs.

These tools may accompany the materials, or may be obtained at a later time. On completion of the production activity (or if tools are worn during production), they will be returned to storage for refurbishment or replacement.

Problems regarding the method of manufacturing stated in the planning instruction, or problems regarding producibility found in the design that have been overlooked in "Develop Manufacturing and Production Plan" (A35), will be solved by A35 on the shop floor.

Finished items may not all be passed to a storage are a but may be forwarded for inspection and/or testing, and put through a checkout phase prior to delivery.

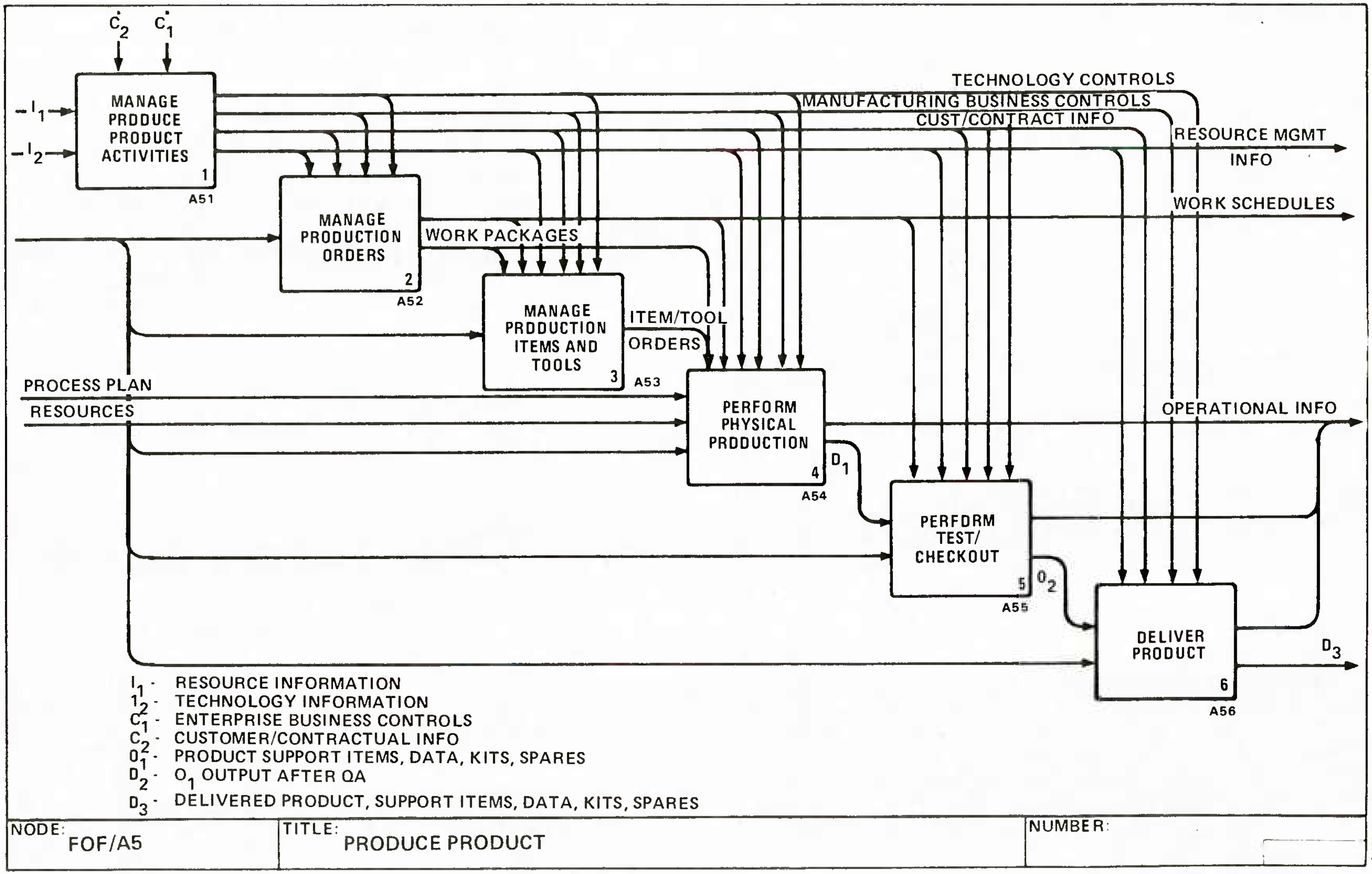
A55 PERFORM TEST/CHECKOUT

Test and checkout activities are an integral part of design and manufacturing even though they are shown here as separate. Components, parts and materials are checked for form, fit and function. Non-conforming items are returned for rework or scrap. Controls include contractual specifications (which may include MIL SPEC), business controls and technology information. Test and checkout data are collected, processed and stored for delivery to the customer and future test and checkout operations.

A56 DELIVER PRODUCT

The final product is delivered to the customer. This might include documentation, spares, kits, test equipment and other support items as well as the product itself. "Delivered" could mean to a customer-provided storage area at the factory site, to the point of use, or to store at the customer's facility, or to the field.

PUBLICATION



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A61 MANAGE LOGISTICS ACTIVITIES

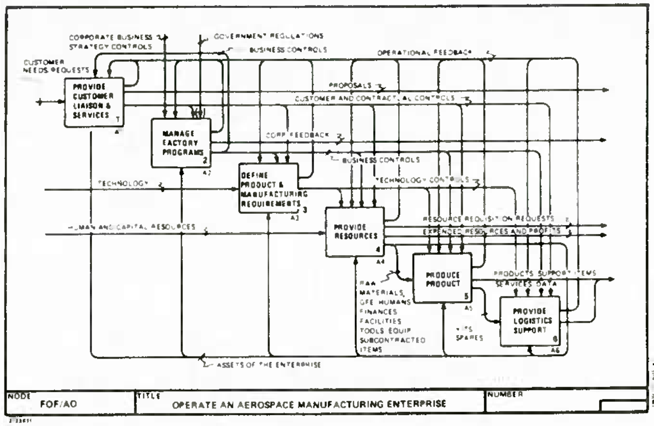
Planning, organizing, directing and controlling the other functions of A6 are performed here. Budgets, activity planning, resource allocation and business controls are performed by this functions.

A62 PROVIDE FIELD SERVICES

The management, support, and performance of field operations occurs in this activity. Controls established by A61 are translated into detailed plans of action and budgets. The primary customer interface (other than training) occurs here.

A63 PROVIDE CUSTOMER TRAINING

The product definition and various controlling inputs are used to establish the customer training programs necessary to support the delivered product. Arrangements for training are made with the customer. Training can be done at the factory, at the customer's or in field training."Train the trainees" programs are established and executed. Continual updating of training programs occurs as the product changes, training technology changes and/or contractual changes occur.



A64 PROVIDE MANUALS AND DOCUMENTS

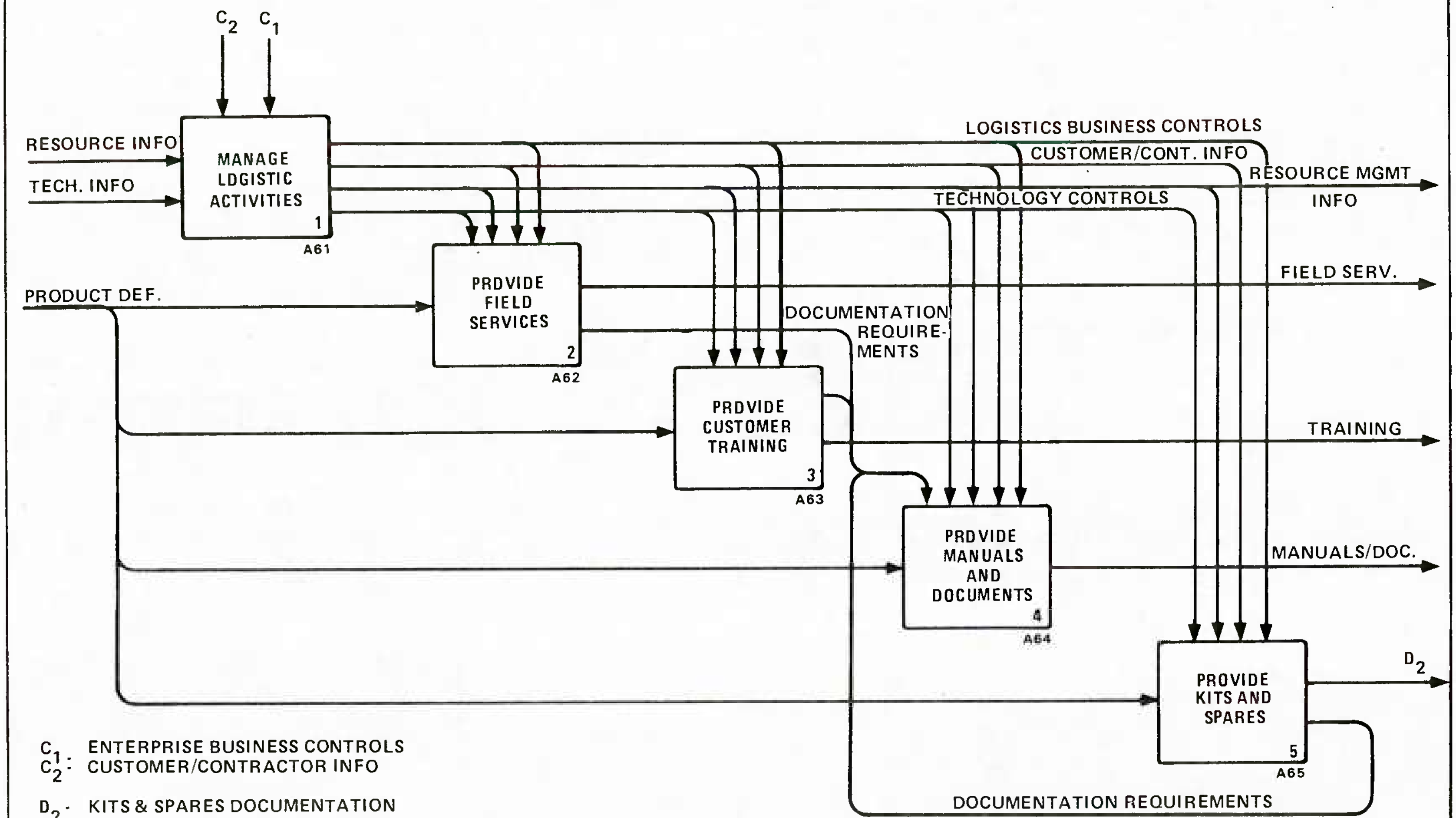
Manuals and documents required for support of the product are prepared. Training of customer personnel is provided. Training materials may take the form of paper manuals, drawings, microform, magnetic media, or other forms of computer storage.

A65 PROVIDE KITS AND SPARES

The definition of required kits and spares is developed in cooperation with activity A3. The manufactured product from A54/A55 is then tracked through A56 to ensure successful delivery to the customer. In some instances, this activity may actually deliver the kits and spares.

Any customer-supplied field support equipment is administered through this activity.

PUBLICATION



C_1: ENTERPRISE BUSINESS CONTROLS
C_2: CUSTOMER/CONTRACTOR INFO
D_2: KITS & SPARES DOCUMENTATION

NODE: FOF/A6	TITLE: PROVIDE LOGISTICS SUPPORT	NUMBER:

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APPENDIX B

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APPENDIX C

TERMS AND ABBREVIATIONS

Additional Facility Requirements

Additional facility requirements impose constraints during the selection of candidate products and their method of manufacture. This information serves as a primary control on design by advising at an early stage what products are feasible to manufacture. It includes the availability of facilities, equipment, computers, people, and machinery.

Ad Hoc Query

This is a non-standard query into a data base. It may be predefined and parameterized or totally unplanned.

Alternative Work Pattern

A pattern that allows the employee to work other than a standard per-hour rate or traditional work pattern.

Alternative Work Schedule

A schedule that allows the employee to work other than a traditional 8-hour day, 40-hour workweek.

Analysis Reports/Change Requests

These are conceptual and theoretical reports documenting the results of aerodynamics, thermodynamics, dynamics, structural and subsystem analyses and tests. These reports reflect a coordinated and integrated evaluation of the product design. Changes are fed back to reflect detrimental results in performance analysis.

Analysis Reports

Includes reports of mass property, structural, subsystems, aero-performance, dynamics, thermodynamics, producibility, reliability, and maintainability as well as reports on component and structure testing. These reports are used for reviews and disclose why various design solutions were chosen.

Application

An application is a set of computer programs written in any programming language with the intent of supporting end user activities and providing all the services necessary to define files of data, input and update that information, and report that information to a user. An application is self-contained in terms of its data storage, processing and input and output facilities. It is usually "owned" and controlled by a user organization. Examples of application systems are: Accounts Payable, CAPP, shop floor control systems, Purchasing, etc.

Approved Design Drawings, Data, and Release Schedule

These documents are approved documentation released by engineering design, engineering staff, and manufacturing departments. They also include a schedule for the release group of the priority of manufacturing or procurement needs.

Architecture

An architecture is a framework of principles, guidelines, rules, procedures, functions, standards, physical entities, and the interrelationships between them. The purpose of an architecture is to guide conscious actions and decisions toward achieving well-defined objectives.

Artificial Intelligence

Consists of computer systems that exhibit characteristics associated with intelligence in human behavior, including understanding language, learning, reasoning and solving problems.

Assembly Methods

A logical assembly flow arrangement for each assembly.

Assembly Time Plan

A plan based on master schedule requirements specifying time frames allowed for details, subassemblies, major assemblies, installations, and testing of a product to meet contract delivery dates.

Authorized Requisition

An approved request authorizing budget for an open position and notifying Employment to search for a candidate.

Automation

An automatically controlled operation of an apparatus, process or system by mechanical or electronic devices that takes the place of the human functions of observation, effort and decision.

Available In-House Resources

Plant capacity, workforce, skills mix, technological know-how, etc., available within the firm.

Available Methods

Available techniques, such as GANTT charts, crew load charts, drawing release curves, etc., used to identify and evaluate cost and schedule variances.

Available Resources Information

Includes information on characteristics of resources needed to manufacture the product which might influence the evaluation of resources requirements. This could include material formability, lead time for procurement, required maintenance/support, etc.

Batch Assembly Plan

This plan is the general manufacturing concept which combines manufacturing resources to produce those assemblies (generally small) which can be produced in discrete lots.

BLS (Bureau of Labor Statistics)

Government agency which monitors and forecasts labor statistics.

Blue-Collar Workers

Those persons generally employed in a factory environment, especially unskilled or semi-skilled workers; non-desk jobs, non-professional jobs.

Budgeted Capacity

The total available in-house facility and resources available for production

Budgets

The allocations of funds for each of the major subactivities.

Build-Up Rates

The most economical or efficient production delivery curve that will support customer delivery requirements.

C/SCS Requirements

Cost and Schedule Control System performance measurement and reporting requirements contractually imposed upon major government procurement programs.

Candidate Designs and Data

A complete definition of all possible designs under consideration and the data to support subsequent evaluations.

Change Requests

These may include unsolicited proposals for major changes to the product as well as requests to make minor changes in the specification of the product; those requests from manufacturing or logistics which require alterations to the design of the product. The reason for the change request from manufacturing is to enhance producibility or to make possible producibility. The reason for the change request from logistics is to enhance or make possible the maintenance of the product. "Enhance" means to make faster, cheaper, or better.

Classes of Technology:

Leading Edge

Demonstrated technology with no consideration given to cost impact or implementation time, e.g., 3-D solid geometric modeling, generative process planning.

State-of-the-Art (SOA)

The most current, up-to-date technology developed by the most respected and capable sources in the market (from Design Ø Architecture).

Coalition expansion of definition: SOA technology has the demonstrated potential of being cost effective.

Enabling

The technology required to implement SOA technology into an existing environment.

Emerging

The technology to be developed in the near future or under development now.

Common Data Model

The description of the structure, allowable operations, and integrity constraints for common data and meta-data.

Compensation Inequities as Perceived by Employees

How the employee feels about the appropriateness of his salary in relation to his peers; this includes whether the employee feels he is under or overpaid.

Complete Manufacturing Indentured Parts List

The complete structure of the product as seen by manufacturing -- what the parts are that are assembled to make the product, and for each of these parts assembled to make it, etc., down to the lowest level detail or the lowest level purchased part.

Completed Master Schedule

This schedule requires program and/or corporate approval. Any conflicts are resolved by negotiation or by program mandates.

Computer Integrated Manufacturing (CIM)

The concept of integrating the entire manufacturing enterprise through the use of computers to link tasks such as design, planning, and finance.

Computer Systems Architecture

That aspect of an Information Resources Management (IRM) system that includes computer hardware, firmware, operating systems, communication facilities, data management facilities, programming languages and system software

Concepts and Test Results

Concepts represent alternate configurations, e.g., individual loft and development data for each configuration. Test results include test model analytical data and related test results which support the concepts, such as new materials, processes, etc.

Conceptual Design Data

This consists of configuration data provided to manufacturing in order to test: hardware, new materials, models, etc.

Conceptual Design Information

This consists of conceptual data provided to manufacturing to test hardware, new materials, models, etc., as well as to plan manufacturing.

Configurations

This represents alternate concepts which define the critical components and their physical location. An example of an aircraft configuration would include such critical components as radar, crew station, engines, landing gear, etc.

Contracts

That information which directs an organization or corporation to perform certain specified acts.

Control Architecture

That aspect of IRM in the FoF that includes the plans, organizational structure, standards, software engineering methods, procedures, logical data models, cost-tracking mechanisms, etc. necessary for integrating the Information Architecture and the Computer Systems Architecture and for managing their balanced evolution.

Coordinating Schedules

Schedules which show required completion dates for items which pass between engineering, planning, materials, resources and production (e.g., engineering releases, production plans, tool specifications, tools, equipment, procured material specs, procured materials, etc.). These items are identified to the level necessary for coordination of the efforts (often identified by group -- e.g., all tools for indenture 3 details to the XYZ assembly). NOTE: There are lower level "departmental schedules" in A3, A4, A5, A6 of MFGØ which detail these schedules to control internal (to those boxes) activities.

Coordination Data

Packages the design data, updates production memos, advance material orders and puts all previously released data in agreement.

Corporate Directives, Regulations and Budgets

These are the output of the activity "Manage Product" (CV/A-1). They include information on Statement of Work, budgets, program control system requirements, product requirements, and design directives. Design directives represent Corporate guidelines and criteria in the design and selection of product lines. The regulations include federal, commercial, military, local government and Corporate roles. Budgets indicate allocations of manpower, schedules, etc.

Corporate Policy and Directives

These are guidelines, procedures and directions for achieving the goals and objectives of the corporate business.

Cost Drivers

Cost drivers are major factors influencing the corporate business. They consist of expense items, revenue, profit, and capital.

Customer Needs

RFPs and RFQs coupled with intelligence information on customer desires. (Expanded to include formal RFP and RFQ input - definition in Design Ø Architecture excluded).

Customer Requirements and Management Decisions

The customer's requirements define the customer's need for the product, its use and maintenance. Management decisions are based on both the technical and economic feasibility of the product, resulting in a response to the customer.

Data

A specific time-variant value stored in a file or data base.

Data Base (DB)

A structurally interrelated collection of data whose interrelationships are identified to a Data Base Management System (DBMS) for efficient and effective user access.

Data Base Administration

The management and documentation control of data bases, including their physical structures.

Data Base Engine

A processor that is specialized via firmware and/or software to provide complete data base management and integration support.

Data Base Management System (DBMS)

Software/hardware for creating, maintaining, and protecting an organized, structured collection of data and providing means for supporting various types of access including interrogation of the data base. Today's DBMSs are implemented primarily in software; tomorrow's DBMSs will be increasingly implemented in firmware.

DESØ

An abbreviation for the ICAM Architecture of Design. This is an architectural model of the functions necessary to carry out the aerospace design process as documented in IDEFØ. This model is published in Volume VIII of the ICAM Architecture, Part II, Final Report. (Report #FTR110210000).

Design and Manufacturing Capability/Additional Facility Requirements

This is the information that serves as a primary control on design personnel by advising them at an early stage of what is feasible to design and manufacture. It includes the availability of facilities, equipment, and people, both in-house and subcontracted and the accessibilty of materials, etc.

Design and Manufacturing Capability

This is the intellect and resources which represent the potential of a Corporate entity to develop and produce a product. It includes such things as design/manufacturing knowledge (allowables, standards, methodology, tools, etc.); people; design/manufacturing facilities; laboratories, etc.; computers; and other resources.

Design Data, Test Model Data and Program Requirements

- All information output of the "Conceptual Design" activity which includes weights, loads, vibration and flutter, stress, aerodynamics, thermodynamics, and candidate configuration layouts. Also includes wind tunnel model definition and recommended changes for further tests as well as data on stability and control, drag characteristics, loads, surface hinge moments, and pressure distributions. Analysis results from engineering development testing.

- Design data consists of the basic parameters of the product and its conceptual configuration. An aircraft example would be: thrust to weight ratio, energy and maneuverability, range, payload, etc. Test model data consists of analytical data derived from the testing of models. An aircraft example would be wind tunnel model testing and related data such as lift versus drag, performance, stability and control, surface hinge moments, and pressure distribution.

Design Directives and Schedules

These are design management's philosophies to be applied to design decisions and the detail schedules for the design activity.

Design Directives, Regulations and Schedules

This is information output of "Manage Product" (CV/A-1) which includes guidelines and criteria in the design of a product and federal, commercial, military regulations, as well as local government and corporate rules.

Design Product

This is an activity which occurs basically one time; but, of course, as there are changes to the design, some amount of redesign does occur.

Design Requirements/Change Requests

These are updated product specification and layout drawings in sufficient detail to allow definition of subsystems and structural arrangements. This includesidentification of materials and types of construction for the major components.

Detail Design Problems (Major)

Are those which require considerable design effort to solve and require study layouts for solution.

Detail Design

This consists of Product Design, Documentation, Parts List; Final Design Drawings and Data; Kits, Spares, and Group Support Equipment (GSE) Design, Manufacturing Information and Design Release Status Reports.

Develop and Produce

Methods to manage, design, manufacture, and support the product.

Directives/Reports and Change Requests

These include the following: Contracts; Corporate Directives; Regulations; Schedules/Budgets/Status Reports; Field Inputs and Change Requests; Engineering and Manufacturing Policy and Procedures; and Market and Customer Needs.

Drawing Status

A tabulation of known engineering drawings, showing scheduled and actual in-work and release dates (and intermediate dates, when appropriate).

Dual-Career Marriage

When both spouses have a career.

Employee Request For Assistance

A request from an employee as to the applicable personnel policies or procedures or the explanation behind a policy regarding personnel.

Employment Maintenance

A policy of transferring employees to other jobs or training them for other jobs or in problem-solving skills, instead of laying them off during downturns.

Engineering Change Request

A request that the design of a product be changed in some manner (to improve form-fit, function, producibility, etc.).

Equipment Resource Plan

A general plan for obtaining additional needed machinery and equipment, special test equipment, etc., and the overall utilization of that equipment.

Equipment

The machines which operate on materials to form parts or assemblies. In particular, the items called "machine tools" are equipment. For example, lathes, drills, presses, etc.

Estimate

These are estimated requirements for production facilities; cost to produce; time to produce the product.

Estimated Time for Assembly and Installation of WBS Items

The estimated start and completion dates for assembly, installation and checkout for each major end item.

Evaluation Reports/Change Requests

Documented information covering all considerations available at the time. This report summarizes and compares like parameters of each design and conducts trade studies to document relative merits.

Existing and Prospective Labor Pool

Those persons presently employed by the company, and those persons who are available to be employed by the company.

Experience and Capability Information

The available information on previously used manufacturing resources and methods which is available to support the manufacture of the present product.

Fabrication Plan

The sequence and flow of detail parts necessary to accomplish the fabrication of these parts.

Facilities Plan

A plan for physical manufacturing areas, i.e., buildings, floor space, storage areas, plant layout, etc., to support program requirements.

Factory

The management and marketing, engineering, production, and support functions working in concert to produce a product (i.e., the Northrop Aircraft Division and Vought Corporation are factories). (An expansion of the MFGØ definition which says, "a physical location wherein the manufacturing resources of a company are housed and work is performed.")

Factory of the Future (FoF)

The aerospace factory as projected to exist in the 1995 time frame. There will be automation and integration of all major activities, including: Marketing, Product Definition and Planning, Provisioning, Production Centers, Logistics, and Factory Level Management Systems.

Factory of Today

The aerospace factory as it exists today: integrated by humans with numerous islands of automation and multiple layers of management.

Field Inputs and Change Requests

Suggestions for improvements in the products (or similar products) or documentation arising from their use.

Field Inputs

- o Requests for improvements, spare parts, changes to correct deficiencies, improve operations, and/or improve producibility.
- o Suggestions for improvements in the product or documentation arising from its use or maintenance. Also includes needs for parts or materials for maintenance.

Final Assembly Plan

The general concept of combining manufacturing resources to accomplish assembly and installation of the highest level or indenture of parts to complete the manufacturing of the product.

First Article Schedule

Includes timing of all events to allow the first article to be produced. Includes Engineering Release Schedule, Planning Completion Schedule, Facility and Equipment Schedule, Tooling Schedule, First Item Production and Testing Schedules. It also covers initial materials ordering and startup for staffing and training.

Flexible Manufacturing System

A totally integrated, computer-controlled, automated production system made possible through the union of computers, material handling systems, and production equipment.

Flow Plan

A sequence of product WBS elements such as key parts, sub- and major assemblies and final assembly installations to produce an orderly product build-up.

Flow Plans and Station Charts

A manufacturing sequence for the assembly build-up and the display media such as crew load charts which will portray this build-up. It portrays the sequence of the manufacturing flow of the breakdown of the product through individual work stations to final assembly.

Flow Time

The expected elapsed times for fabrication, assembly, movement, etc. for each item or group of items (e.g., 20 days for fabrication of all indenture 3 details of some assembly).

Firmware

Hardware that includes instructions; reprogrammable.

FoF Conceptual Framework

A structure for understanding activities and information focusing on factory management and functional relationships.

Generative Programs

(Computer) programs which have the capability of generating, originating, producing, or reproducing data.

Goal

A high level objective.

Government Agency Request For Information

A request for information, relative to personnel practices, from the City, County, State or Federal governments.

Human Resources

The available supply of people that can be drawn upon when needed; this includes all those in the existing and prospective labor pool.

Human Resource Management

The management considerations related to the people in the factory at all levels.

Human Resources Plan

The detailed formulation of a program of action intended to utilize the available Human Resources to the fullest.

Implementation Strategy

A roadmap to achieve systematic factory modernization based on the FoF Conceptual Framework.

Improvement Concept

A statement of recommended action which has the potential to satisfy the needs identified in the Needs Analysis phase to attain the goals of the FoF.

Information

Information is knowledge about the physical and conceptual world we live and work in. In the content of the IRM, "information" is the knowledge base of the Factory of the Future. Information is constructed from data to service specific logical needs of human and non-human users.

Information Architecture

The aspect of the technology environment that includes the logical views of the information, reflecting specific user information needs at a particular point in time. The information architecture is highly dynamic, since it reflects users' information requirements concerning operational, management and strategic information needs.

Interface

A mechanism for the transfer or transition of information from one system to another.

Integrate

The process of forming into a whole. In the case of systems, the sharing of common information. [As defined by ICAM Project Priority 3101, Computer Based Information System (CBIS).] For example; to merge two or more systems or subsystems or a combination thereof to form a unified system capable of performing all the operations of the merged systems.

Internal Schema

A description of the physical organization of a data base as viewed by its DBMS.

Instructions

- Documentation for using, maintaining, reworking, rebuilding the product.

- A detailed description of the manufacturing process steps required to assemble or install line assemblies or installations, with a notation of the tools and parts required to accomplish the assembly or installation. Gives detail sequencing of the parts, components and subassemblies with notation of tools required and operations to be performed on the production line.

Knowledge Workers

Those employees with an understanding of a science, art, or technique; highly skilled or trained employees; those employees dealing with data.

Labor Laws

These are Federal, State, County and City laws governing the policies and practices of employers in relation to their personnel.

Layout and Detail Design Information

Advance information used to direct engineering designers in the preparation of detail designs and to inform the manufacturing department of the scope of detail designs to come. The design layouts are of a family of items or a unique item. They are complete enough to direct designers and draftsmen in the preparation of complete detail designs and to give interested manufacturing departments an example of the designs to come.

Maintenance Needs

Those needs based on field experience, of parts for spare and repair of the product.

Major Assembly Breakdown

A functional division of major sections into logical subsections.

Major Assembly Breaks

Structural boundaries comprising each major assembly unit.

Major Assembly Flow Plan, Station Plan

A postulated sequence of manufacturing or major assemblies flowing through individual manufacturing stations to best accomplish the manufacture of the product.

Major Configuration Units

Large manufacturing assemblies which result from the manufacturing breakdown of the product to the first level of detail. (Example: fuselage section, wing).

Major Section Breakdown

A breakdown of major sections of the product based on facilities arrangement, tooling and manufacturing techniques, and final assembly requirements.

Major Tools Identified

Major assembly floor mounted tools are identified.

Make-or-Buy Decisions

Management decisions to procure or manufacture various major configuration units.

Manufacture the Product

The activity in which procurable items are modified and assembled to form a product. It essentially occurs once for each product which is delivered and is, therefore, a continuing operation.

Manufacturing

Manufacturing is the conversion of a design into a finished product. Manufacturing includes the planning, scheduling, and gathering together of whatever is necessary for the actual making of the product.

Manufacturing Bill of Materials

The list of subparts of any single part which is to be made. This pertains only to subassemblies and major assemblies in the product.

Manufacturing Capabilities

Those capabilities that are in place and available within the company for producing the products.

Manufacturing Capability Information

The information that serves as a primary control on design. It advises design at an early stage of those products feasible to manufacture. It includes the availability of facilities, equipment people and the availability or accessibility of materials, etc.

Manufacturing Costs and Schedules

This is information on various manufacturing processes based on conceptual design data to improve the ability to manufacture economically.

Manufacturing Indentured Parts Lists

This list is the completion or extension of the manufacturing parts list as developed by production planning. It is primarily needed for scheduling purposes.

Manufacturing Information

This includes tools and fixture information, assembly and disassembly information, and test result information, which may be useful in determining how to support the product. This represents design, drawings, and data intended specifically to support and test new producibility concepts, new materials and new methods to be performed by manufacturing for revalidation purposes as well as to process and finish specifications.

Manufacturing Plans

These are overview plans which include flow sequence, item and station charts, item indentures, facilities and requirements, material requirements, etc.

Market and Customer Needs

Encompasses intelligence dealing with the customer's desires and the competition's plans and progress.

Marketing and Cost Data

This is private company data dealing with market potential and analyzing the competition for that market. It also defines the resources which must be committed to compete for that market. The data includes political, technological, managerial, and financial.

Master Schedule

- o Establishes major milestones and phasing to accomplish the task.
- o An operating document that bears appropriate approvals. All subsequent schedules emanate from this master schedule.

Material Plan

This is part of a production plan. It specifies how materials will be handled, philosophies, general needs, overview methods of material acquisition, maintenance, supply, etc.

Matrix Management

A management style which encompasses the use of personnel from several different disciplines (such as manufacturing, engineering, finance, etc.) within the company. These people are brought together to work on a specific project or task, each being given an equal voice in the decision-making process.

Method of Manufacturing

The general concept determined to be the best method of combining manufacturing resources to produce the product which requires cost, schedule, and technical evaluation.

MFGØ

An abbreviation for the ICAM Architecture of Manufacturing. This is an architectural model of the functions necessary to carry out the aerospace manufacturing process as documented in IDEFØ. This model is published in Volume VIII of the ICAM Architecture, Part II, Final Report. (Report #FTR110210000).

Minor Assemblies

These are a breakdown of product subsections (major assemblies) into units of manageable and accessible size for optimum use of factory facilities, tooling and personnel.

Minor Reconfiguration Requests

Mandatory change requests of a minor nature that can be accomplished within the purview of Preliminary Design. These changes will not be fed back into the conceptual design activity.

Need

That which is required to develop a FoF from an existing factory, as defined in the Needs Analysis.

Neutral Data Structure (NDS)

A description of the data, its structure, allowable operations and integrity constraints for data with a common interest. The Neutral Data Structure permits different subsystems to share common data; one is necessary for the control of common data and, thus, is the key ingredient to integration.

Non-Obtrusive Measures

Facts obtained from sources which do not require intrusion into a workplace (such as attendance records, number of grievances filed, etc.).

Normal Forms

- Flat-file form, a relation that contains no repeating attributes. An entity class that contains no repeating attribute classes.

- First normal form, plus the restriction that each non-key attribute is functionally dependent upon the entire key.

- Second normal form, plus the restriction that no non-key attribute is functionally dependent upon another non-key attribute that is not also a candidate key.

NSD & HRI (New Systems Development & Human Resource Integration)

New subfunction under the HRM function, which represents the "human factor" present during systems design and implementation.

Part (Subpart) Form

The intermediate level form of a part which is ready to be used in the assembly of another larger part. The intermediate (normally unfinished) form of a part, which is considered to constitute its end form, as it is forwarded to its next use. The complete form will normally be produced on a subsequent assembly.

Performance and Status Reports History

An evaluation of cost and schedule progress. Used for management appraisal of tasks or for archival purposes.

Performance Reports/Change Request

Reports documenting performance achievement and disclosing the degree (deficient, sufficient or excessive) to which performance or contract goals are met. Also includes feedback of changes.

Personnel Resource Plan

A general plan for needed additional employees; including recruiting, training, upgrading, multi-shift approach, overtime usage, etc.

Planning Assignments

Specific planning task assignments derived from those schedules internal to planning which in turn were extensions of overall product schedules. They instruct planners to process each engineering release item at the proper time.

Preliminary Data

This represents preliminary definition of candidate configurations. The intent of preliminary data is to provide early information to manufacturing to support testing and revalidation of design concepts and to generate preliminary planning.

Preliminary Design Interfaces

An element of the general data input "Preliminary Design" Test and Manufacturing Data. This data is limited to the subsystem equipment interface definition with the structures definition.

Preliminary Design, Test and Manufacturing Data

A detail design requirements baseline for the selected configuration. This includes definition of external lines, subsystem equipment layouts, schematics, structural arrangements, and technical discipline analyses. The technical disciplines provide design requirements in thermodynamics, flight dynamics, structural dynamics, acoustics, fatigue, human factors, reliability, maintainability, materials, etc. Producibility requirements are based on marketing data and the preliminary design and define the volume and schedule that will be imposed on manufacturing.

Procured Item Specification

These are detailed specifications of items that are needed (so that they can be ordered from a vendor). The specification also includes inspection procedures.

Procured Item

Any item which is obtained from the outside and used in making facilities, equipment or tools. (It also includes people who are hired for a particular task).

Product Assurance (PA)

The planned, interdisciplinary and systematic establishment and application of all quality assurance, quality control, reliability and maintainability actions necessary to provide adequate confidence on the independent basis that: requirements are properly specified, that the design will achieve these requirements, that the adequate test, inspection and evaluation systems are established to detect nonconformance and that the final product will perform the intended function(s) in the operational environment for the designed life cycle.

Product Design

Product Design includes both preliminary and final engineering design. The preliminary engineering design, as well as the final design, is available to plan for manufacturing. The engineering release itself and change orders are used for Plan Production. The Engineering Design also includes identification of long lead items for which early procurement is required.

Product Functional Requirements

These requirements include functional capabilities, performance specifications, etc.

Product Manufacturing Requirements

Includes the quantity and delivery schedule of production and the constraints on sources of components (such as Government-furnished equipment or subcontracted items).

Product Support Requirements

Specifies the frequency, location, and extent of maintenance required for the product.

Production

Production is a function of manufacturing which is predominantly characterized by physical processes, such as fabrication, assembly, installation, inspection and test, which transform the raw materials and components into the end product. Efficient production mandates management and control of all operations entailed, as well as very close coordination with the manufacturing support functions such as material handling, allocation and provisioning of resources, QA/QC, configuration control, planning, scheduling and budgets, etc.

Production Data

Provides detailed description of each specific serial number of the product, change levels, serial number of the components which it contains, etc. It exactly describes the product. It does not describe how to use it or how to repair it. It may include the bill of materials with the change level of each part for the serial number of the product.

Production Instructions

The detailed description of the operations and processes that must be carried out to produce any given item. These instructions include the sequence in which the operations are to be performed.

Production Schedule

Includes Master Position (Acceleration) Curves for major assembly and installation (start and completion dates for each major item), plus subassembly and detail fabrication schedules (start and completion dates by indenture group). The start date is when all materials, sub-items and tools must be available. The completion date is when the item must be available to go into the next assembly. The time between these dates is "scheduled" by production control (A61).

Proposals

These are documents which convey offers to satisfy customer needs or requests.

Prototypes, Models, Data

Represents quantitative data by which the design requirements can be verified on the prototype vehicle. Models, data, e.g., include wind tunnel model definition and recommended changes for further tests to meet the requirements for stability, control, drag characteristics, aerodynamics loads, surface hinge moments, pressure distributions, etc. This is both an input and a feedback in the design of a product. Other models include static/dynamic test models, operating models (fly before buy), etc.

QA/QC

Quality Assurance/Quality Control.

QA Plan, Material/Management Plan, Tooling Plan

These are supporting manufacturing plans pertaining to quality materials, tooling requirements, methods, and concepts of manufacture.

Quality

The composite of all the attributes or characteristics including performance of an item or product.

Quality Assurance

The planned and systematic establishment of all actions (management/engineering) necessary to provide adequate confidence that non-conformance prevention provisions and reviews are established during the design phase and performed throughout the product manufacturing and life cycles phases.

Quality Circles

Defined as groups of people from the same work area meeting voluntarily to solve work problems (normal size group, 6-12).

Quality Control

The planned and systematic application of all actions (management/technical) necessary to control raw materials or products and detect non-conforming materials or products through the use of test, inspect, evaluate and audit techniques.

Quality Requirements

Quality standards on 1) major components/assemblies and final product characteristics and 2) applicable QA/QC contract requirements no directly related to product application.

Quality-of-Work-Life (QWL)

Refers to the atmosphere present in the work environment; QWL programs attempt to develop a workplace with a quality atmosphere.

Rate: The steady amount of produced parts or deliverables per period of time until final delivery.

Rate Range

An established range of salary with a minimum, a midpoint and a maximum limit. The range reflects the relative value for a particular job within an organization.

Reactive Management

A management practice which involves reacting to a current situation, rather than planning for it.

Recommendations

These recommendations flow from the detail design group to the preliminary design group for reevaluation and/or redesign of critical areas. Recommendations are based on additional data.

RFBD

Request For Bid Decision.

Relational DBMS

- Implement tabular views of data, without user-visible navigation links between the tables

- Support a data manipulation language with at least the minimal relational processing capabilities of project, restrict, and join.

Request for Change in Planning

Includes problems in manufacturing for which it would be best to change the production instructions; problems in designing or obtaining tools; or problems in the specification of a procured item for which a change is desirable.

Requirements

These encompass both mandatory and desirable customer requirements.

Resource Characteristics

The characteristics and capabilities of the resources necessary to produce the product.

ROA

Return On Assets.

ROI

Return On Investment.

Schedules

Establishes phasing of production plans, resources, materials and production. Schedules typically include start and completion dates for major items which depend on subfunctions.

Selected and Tentative Structure and Method of Manufacturing

The breakdown of the components of the product and the general concept of combining resources to best meet the manufacturing requirements.

Selected Structure

The manufacturing breakdown of the product which is determined to best meet the manufacturing requirements.

Setbacks

"Item and Indenture" assignment for each item showing its relation to an "end item." It identifies the major item into which each item goes and defines the indenture level at which it is needed.

Setback Schedule

Shows item flow times applied to setback relationships.

Ship Sets

These are end item quantities broken down into manageable and economic lots.

Startup Time and Production Rate Data

Relates manufacturing experience to the manufacturing schedules and rates which can be attained by various manufacturing methods and resources; also the spans of time necessary to attain those rates with these methods/resources.

Statement of Work (SOW)

This is a refinement of WBS elements as discrete technical tasks.

Status Reports

Represents reports of satisfying (or problems in satisfying) contract requirements; current and expected availability of needed items; comparison reports of the design progress versus the scheduled or anticipated programs.

Strategic Business Plan

This is a long range planning document which establishes corporate business objectives with regard to: marketing, competition, finance, engineering technology, manufacturing technology, human resources, and product assurance policy. This plan is generally updated annually.

Subassembly Breaks

These are further structural breakdowns of major assemblies into units of an optimum size for use in floor-mounted tooling.

System Requirements and Research Data

System requirements are the total requirements for the product, its use, and maintenance. Research data includes analysis, methods and concepts applicable to the product.

Technology

A method or process for resolving a specific technical problem; the response to the technical problem satisfies the needs of the customer (or society in general).

Technology Environment

Encompasses the overall system used to manage information resources. It consists of three cooperating architectures: information architecture, computer system architecture, and control architecture.

Tentative Concept

A preliminary concept of combining manufacturing resources to produce the product; it requires cost, schedule, and technical evaluation.

Three Schema Architecture

A framework for controlling data which incorporates three different levels of data description. These are Internal Schemas, External Schemas and a Conceptual Schema. The model allows one conceptual schema which describes the entire data base. Many External and Internal Schemas may be derived from a single Conceptual Schema. (Developed by the ANSI/X3/SPARC.)

Time and Cost Estimates

The output from the cost and schedule evaluations of a tentative manufacturing concept.

Time Standards

The standard times derived for each work task, through the production line.

Tools

All items used in making the product. Includes expendable tools, cutters and formers, holding tools, jigs and fixtures, measuring tools, gauges, NC tapes, etc.

User-Friendly

Refers to a system that is used easily by people with minimal computer expertise or technical backgrounds.

Work Authority

The go-ahead for the various factory activities to start work on developing and producing the product.

Work Breakdown Structure (WBS)

An identification of the major tasks of the contract.