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EXECUTIVE SUMMARY

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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ABSTRACT

This document summarizes a computer software system denoted Integrated Programs for Aerospace-Vehicle Design (IPAD). A description of IPAD; its capabilities; perspective views by the engineering executive, manager, user and application programmer; and the IPAD development plan are presented.

The goal of IPAD is to increase U.S. aerospace industry productivity through the application of computers to manage engineering data in the 1980's. IPAD supports the definition and control of enginering design processes and definition and management of large quantities of data and computer programs. IPAD is an interactive system which will operate on several computing systems in common use. The number of terminals supported may range up to 100 when using a single computer, or several hundred in a distributed computer environment.

The IPAD system development is coordinated with the U.S. Air Force Integrated Computer-Aided Manufacturing (ICAM) and makes provision for interfacing design data with manufacturing organization within a company, as well as with other companies. This summary reflects IPAD as perceived at the software preliminary design stage and will be updated as IPAD development proceeds.

LIST OF ACTIVE PAGES

SECTION	PAGE NUMBER	REV SYM	ADDED PAGES						SECTION	PAGE NUMBER	REV SYM	ADDED PAGES					
			PAGE NUMBER	REV SYM	PAGE NUMBER	REV SYM	PAGE NUMBER	REV SYM				PAGE NUMBER	REV SYM	PAGE NUMBER	REV SYM	PAGE NUMBER	REV SYM
	i																
	ii																
	iii																
	iv																
	v																
	vi																
	vii																
	viii																
	ix																
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	A.2																
	A.3																
	B.1																
	B.2																
	C.1																
	C.2																
	C.3																
	C.4																
	D.1																

REVISIONS

REV SYM	DESCRIPTION	DATE	APPROVAL

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TABLE OF CONTENTS

LIST OF FIGURES

TBD LIST

ITEM	PARAGRAPH REFERENCE	RESPONSIBLE	DUE DATE
1. Description of increment-al releases	App. D	J. W Southall	April 1978

1.0 INTRODUCTION

The goal of IPAD is to increase U.S. aerospace industry productivity through the application of computers to manage engineering data in the 1980's. The system is being developed by The Boeing Company under contract to NASA. The system development is coordinated with the U.S. Air Force Integrated Computer-Aided Manufacturing (ICAM) and makes provision for interfacing design data with manufacturing organizations within a company, as well as with other companies. This document presents the purposes of IPAD, an overview of its capabilities, and how the system should be viewed by executives, managers, engineers, and programmers. It reflects IPAD as perceived at the software preliminary design stage and will be updated as IPAD development proceeds.

The purposes of the IPAD development are to implement: a method for computerized definition and control of an integrated engineering design process; computerized data base for definition and control of large quantities of engineering scientific data; and enhanced facilities for control and use of a large library of engineering application computer programs. Functional capabilities are provided and include: implementation of enhanced user interface features which support several levels of user skill; implementation of communication features which support distributed processng on several computing systems in wide use and implementation of state-of-the-art standard utilities for CAD and CAM in an integrated environment.

During the late 1960's the use of computers as integrators of design data evolved as a basic concept. In the early 1970's a NASA-funded feasibility study (ref. 1 and 2) showed that increases in individual productivity are feasible through automation and computer support of routine information handling. Such automation will directly decrease cost and flowtime in the product design process and will improve the competitive position of the U.S. aerospace industry. The industry was deeply involved during the IPAD feasibility studies and continues to be involved in the current IPAD development. A description of this involvement is given in Appendix A.

The IPAD development plan, which is open-ended and evolutionary, stems from requirements based on needed improvements in scientific data processing and from known potential improvements in engineering productivity. The development plan recognizes that IPAD is part of an environment composed of the IPAD system, users, technical application computer programs, and data bases. Thus the IPAD system is developed to be an intimate part of the total design environment.

2.0 IPAD DESCRIPTION

The IPAD system is a general purpose interactive computing system developed to support the design processes. Its primary function is to handle the engineering scientific data and the management data associated with the design process. It is intended to support continuous design activities of a typical company mix of multiple development projects. IPAD serves management and engineering staffs at all levels of design (conceptual, preliminary, and final) and aids in the assembly and organization of design data for manufacturing processes.

The IPAD system design will support generation, storage and management of large quantities of data. Its capacity will only be limited by the hardware configurations selected by each company. The system is intended for use in a distributed computing environment having one or more central host computing systems and many remote computing systems. The number of terminals supported may range to several hundred and may be distributed across the host and remote systems. The IPAD software will function on the "third generation" computer complexes in use today by large aerospace corporations.

Figure 2.0-1 illustrates the relationship of the major software elements of IPAD. It is currently visualized as composed of four major software elements: 1) executive software to control user-directed processes through "interactive" interfaces with a large number of terminals in simultaneous use by engineering and management personnel; 2) a large number of utility software packages for routine information manipulation and display functions; 3) data management software to provide a comprehensive, versatile capability for efficiently storing, tracking, protecting, and retrieving exceptionally large quantities of data maintained on multiple storage devices and 4) other systems interface software to provide communications to computing systems outside of IPAD and communications between computer hardware within IPAD.

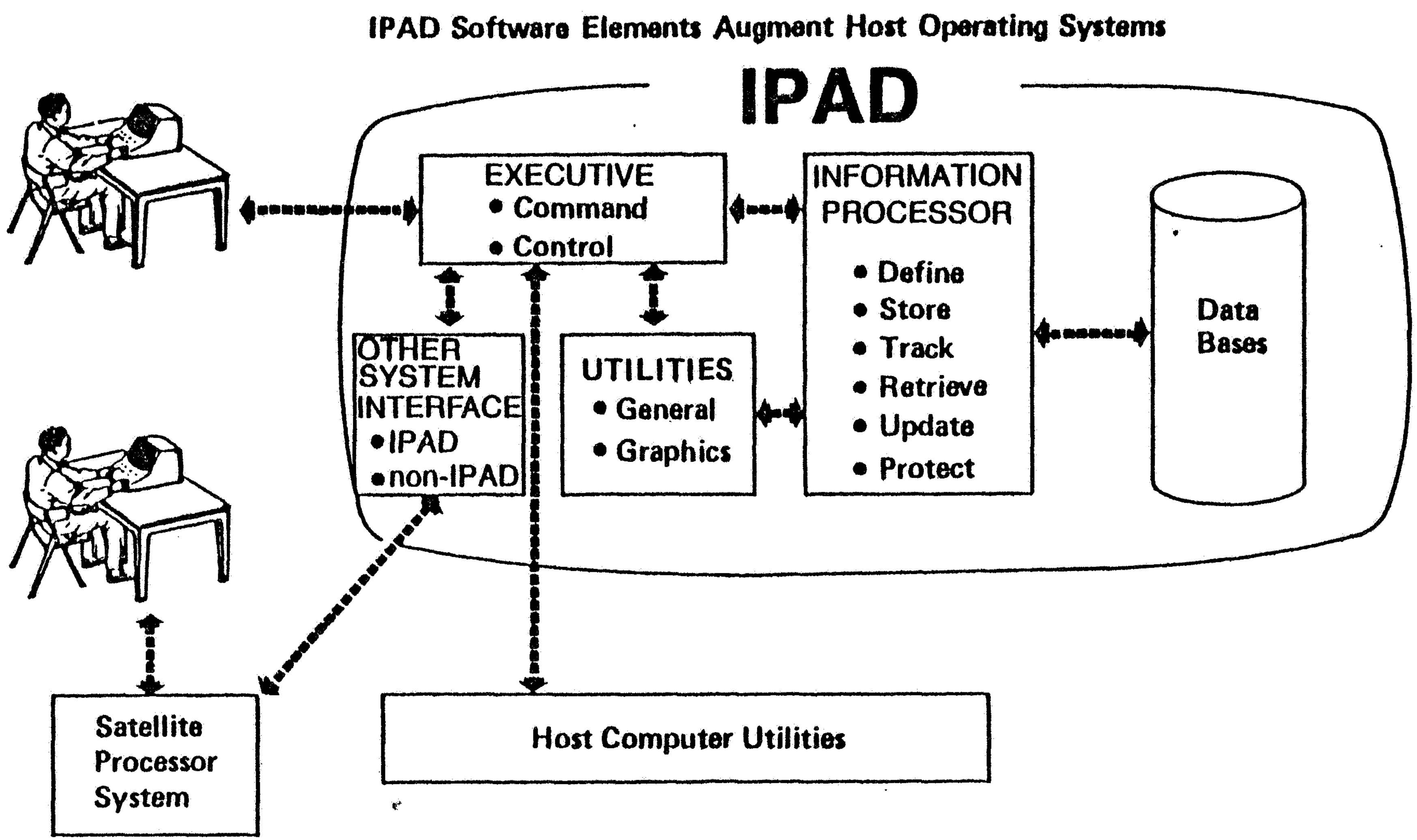


Figure 2.0-1 Primary IPAD Software Elements

Libraries within the data bases include the technical analysis and design computer programs utilized by various disciplinary specialists. Such programs are not part of IPAD, but must be provided by each company to form the complete design-software system. Some public technical programs will be included with the IPAD system to demonstrate its capabilities. The data base will include all official project information defining the characteristics of current baselines and alternative designs and their performance, as well as archival "handbook" information forming the technology base for company designs. Simultaneous access to the same baseline design information by all disciplinary groups will thus be possible. Temporary storage, for design information being actively used by individuals or teams, will also be provided.

IPAD is not a hands off "automated design" system and will not constrain company design methods. The characteristics and quality of aerospace designs in the future, as now, will depend on such elements as creativity of designers, quality of technical staffs and their analysis tools and design data, and coordination of design and manufacturing information. IPAD is a tool to improve the efficiency and effectiveness of these elements and to provide manufacturing direct access to engineering data. The manufacturing process is not encompassed by the IPAD system. However, manufacturing may find features of the IPAD system useful.

The IPAD system and its supporting documentation will be supplied to aerospace companies. IPAD may be installed by each company on its computers and used in a manner similar to the operating systems supplied with each computer. It will augment rather than replace the existing operating system. The IPAD system development plan provides for release of incremental capabilities implemented on CDC and IBM computing systems and allows a gradual transition from the current computing techniques to IPAD integrated techniques at a pace selected by each company for its own implementation schedule.

While IPAD is developed for use by the aerospace industry, it should support other complex processes such as large civil enginering projects, ship building, automotive design and the development of other computing systems. (See the ref. 13 for examples of potential non-aerospace applications of IPAD.)

3.0 IPAD CAPABILITIES AND DOCUMENTATION

This section contains a brief description of the capabilities of the IPAD system and the documentation to be provided along with the IPAD system.

The IPAD system capabilities are:

a) Support the definition of the design process by a modeling method that breaks the design process into groups of related activities, which may be time-phased as required to develop the technical definition of a product.

b) Support computer aided design project management with the capability for defining design projects; assigning manpower, resources and schedule for tasks and subtasks; and for monitoring progress of design projects relative to resources and schedule.

c) Manage data by means of a single-source, bank of current and historic information accessible to all users. Such a bank enables management to control and use data as a company resource and thus improve all of its operations by ensuring that all organizations have common access to a uniform information source which is continuously updated and purged of obsolete, redundant, or conflicting data.

d) Support an open-ended computer program library of user-installed application programs in source and executable forms. One or more of these programs may be executed as an IPAD job. Each IPAD job will have sufficient library information installed with it to adequately describe the job's purpose and capabilities (abstract, key words, etc.). This information is available to anyone performing a function associated with the job and is used to plan and define process activities based on available IPAD jobs. This program library should minimize program redundancies.

e) Enable users to interface effectively with the IPAD system by providing:

   Fast, convenient access to the system and identification of individual users for security and control purposes

   User-oriented, functional command language which guides the users control of the IPAD system

Help capabilities prompting users (three skill levels are accommodated, expert, intermediate, and novice)

Computer-aided instruction in the use of IPAD functions (this instructional system can also be used to train engineers in design procedures, use of computing tools, etc.)

Aid in locating input data, executing jobs, monitoring jobs in execution, and storing output data

Job status reports showing progress of the job and resources used

Aid users in suspending jobs in execution and resuming execution under user control with minimum effort at a later time

Aid to make jobs from application programs in the program library

Aid to define data

f) Provide essential functional utilities including:

State-of-the-art graphics and interactive graphical capabilities for design drafting and finite element modeling

State-of-the-art programming aids for on-line programming, program maintenance, and installation of existing programs into the program library

Miscellaneous aids such as tutorial, text editing, menu building, report generation, and message processing

Documentation provided with the IPAD software include:

A reference design process (ref. 16) the interaction with manufacturing (ref. 17) and program management (ref. 20). These serve as aids for each company's use in producing its unique version of the design process, information bank, and application program library

An enginering standards handbook to serve as a means for communications during the development and use of IPAD.

A software standards handbook to ensure consistent techniques for the IPAD system development

IPAD user manuals to provide reference material on IPAD functional capabilities

IPAD system manuals to provide instructions on installation and maintenance of IPAD software

4.0 ENGINEERING EXECUTIVE'S (INDUSTRY) VIEW OF IPAD

IPAD should be viewed by industry as an advanced computing system for processing engineering data. The following are major considerations of the engineering executives perception of IPAD.

4.1 EFFICIENCY

IPAD will provide the capability to increase productivity of a product design organization by providing tools for handling information. Examples of the reductions possible in one area of preliminary design (see Ref. 1, Vol. 7 for more detail) are illustrated by figures 4.1-1 and 4.1-2. These figures show flowtime and manhours required for one airplane configuration sizing design cycle in a stand alone environment and an integrated environment with data interfaces defined. The estimated reduction for the integrated environment are summarized as follows:

Flowtime is reduced to 30%;

Man-weeks are reduced to 20%;

Significant reduction in routine activities

4.2 COMMUNICATIONS

The IPAD interfaces with other systems will support communication between the computing systems within engineering and the computing systems of other functional organizations.

The IPAD data management capabilities will handle both business and scientific data types. These capabilities will support communications within engineering and between engineering and other organizations.

Figure 4.2-1 illustrates the range of engineering data types that may be stored and communicated with IPAD. Many organizations currently use data base management systems (DBMS) to store and communicate business data such as release of engineering parts. Examples of business data are: part names, part numbers, part quantities, etc. Data of this type have characteristics and relationships that are easily communicated to people. In contrast engineering scientific data are more complex and include elements such as coefficients of a polynomial expression and the coordinate values of points on the surface of an aircraft. These numbers, in general, have no specific relationship other than the mathematical context in which they are to be used and are handled by IPAD through an enhancement of data base technology.

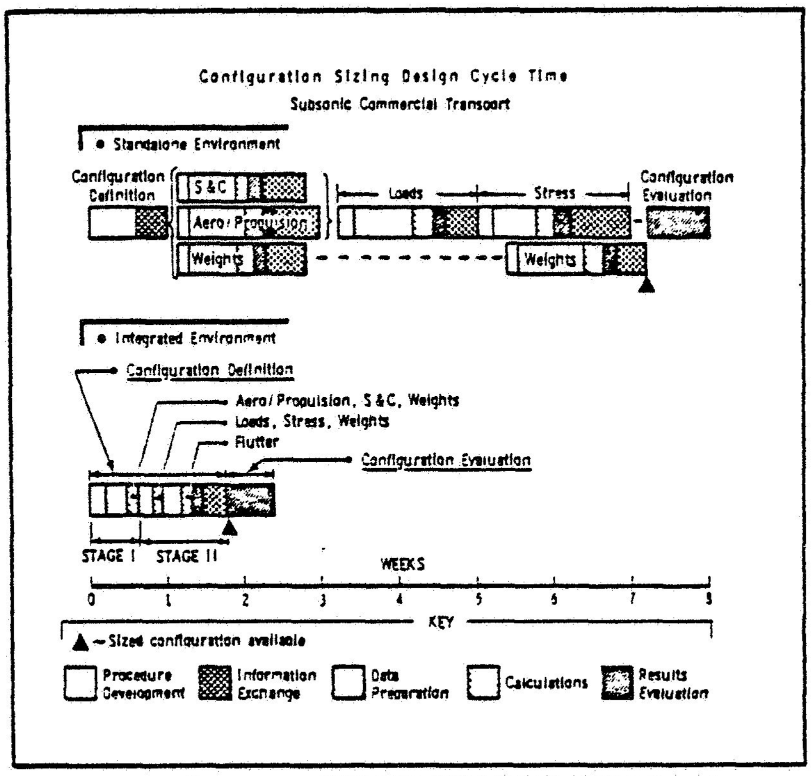


Figure 4.1-1. — Subsonic Transport, Relative Flowtime, Standalone/Integrated Environment

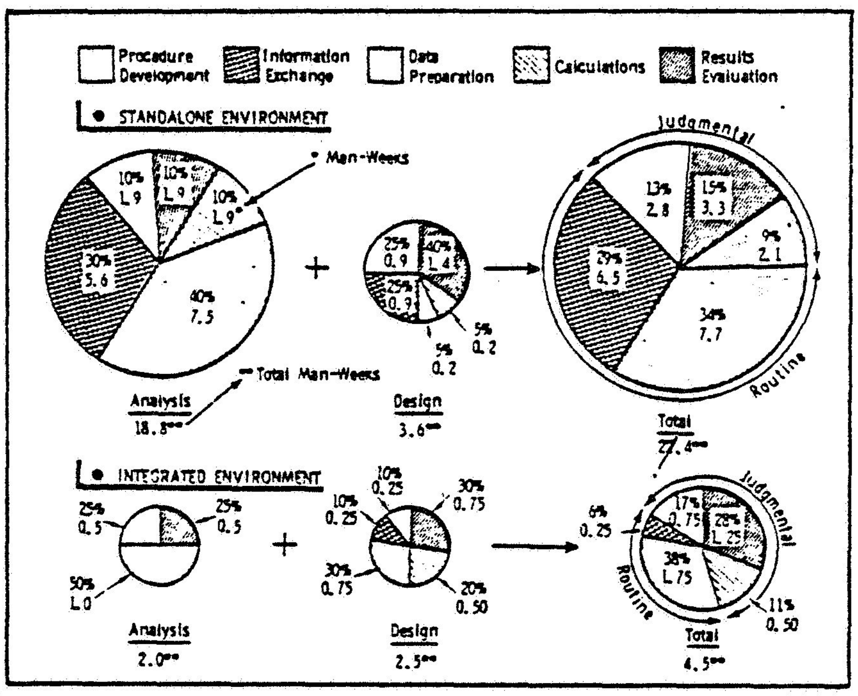


Figure 4.1-2. — Subsonic Transport, Division of Effort Standalone/Integrated Environment

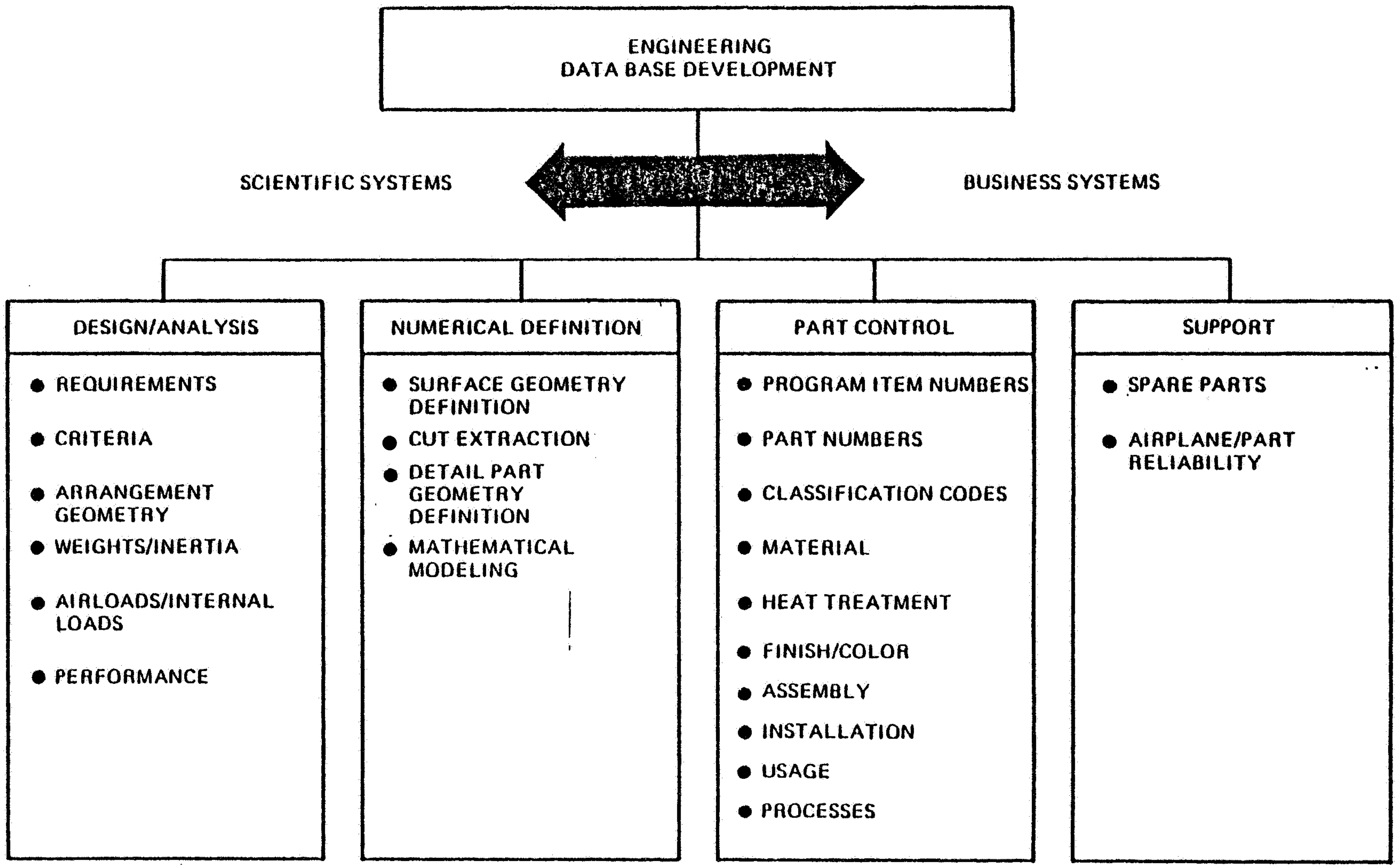


Figure 4.2-1. — Engineering Data Types

Data interfaces within engineering are developed with the IPAD capability to define integrated design processes which are related to one another in a way that will cover the development cycle of a product from conceptual design through product certification and support. The integration of a process or a series of processes within and between engineering disciplines can be accomplished using IPAD through a coordinated effort on the part of engineering managers, group supervisors, and methods research.

The IPAD capability to support definition of data interfaces can also be applied to the interfaces among engineering and other functional departments of a company, such as finance, marketing, and manufacturing. This can be accomplished through a coordinated effort initiated by department executives to utilize the capabilities of IPAD to plan and implement desired data communication among their respective organizations.

4.3 COSTS TO IMPLEMENT IPAD

The IPAD system is developed in the public domain and is available to the U.S. Industry. Incorporation of IPAD by a company may be planned as a transition, beginning with a small initial implementation for specific portions of the design process. This initial implementation can be built upon and expanded until all elements of the design process and its interfaces have been integrated. In this manner a company may implement IPAD at its own pace consistent with the benefits desired.

The cost of involvement in IPAD activities will be a function of how deeply each company elects to become involved and will remain under company control. A comprehensive approach for initial implementing IPAD (approximately five to ten man-years required) might be:

Identify a team of specialists in each engineering discipline from ongoing design and analysis projects, methods research and the computing staff

Review the reference design process (D6-IPAD-70010-D), manufacturing interactions with the design proess (D6-IPAD-70011-D), and product program management systems (D6-IPAD-70035-D)

Assess the applicability of the reference material to comparable functions within the company

Select portions of the design process to be implemented and make changes required to tailor the process to the organization

Utilize the IPAD incremental release definition to develop a transitional implementation of IPAD

Send representatives to the training provided by the IPAD development team

Initiate computer program conversion and installation into IPAD

Initiate implementation of the IPAD information bank

Utilize the computer aided instruction within IPAD to train engineering users

Consider participating with other IPAD users to guide and shape continued development of IPAD

The costs for initial IPAD implementation should be sufficient for a trial period to gain experience with IPAD. The conversion and installation of applicable computer programs and data into IPAD will be an on-going process based on cost benefits. Companies planning to use IPAD should consider implementation in parallel with the development of the IPAD system. This would be beneficial for computer programs presently in development and the planning for program conversion may influence the development of the IPAD system.

5.0 ENGINEERING MANAGER'S VIEW OF IPAD

An engineeering manager should view IPAD as 1) a means to develop design processes which incorporate engineering computing tools and interface those tools based on data relationships, and 2) a means to plan and monitor the progress of design projects including schedules, resources and manpower assignments. Sample capabilities are described in this section.

5.1 DESIGN PROCESS SUPPORT

Design process networks are constructed with IPAD to integrate enginering activities and interface engineering data within engineering disciplines and between engineering disciplines. The basic building blocks for process definition are computer programs in the computer program library. These programs are the computing tools used by engineering and are executed as jobs. Jobs may be grouped and groups of jobs grouped to any level required to stage or phase the design process and to support forward and feedback communications.

Figure 5.1-1 illustrates an overview of the design levels which were used in reference 16 to describe the technical activities of the IPAD reference aerospace design process. Each level is further defined by one or more design networks of the type shown for IPAD level II. This network establishes the interfaces between engineering, marketing and finance and can be used to develop the design criteria for potential products.

IPAD will support displays of these process definitions and assist the engineer in the preparation for execution of the jobs required to accomplish activities identified in the process description. Engineers are assigned to accomplish these activities in accordance with the project plans described in 5.2.

5.2 DESIGN PROJECT MANAGEMENT

Computer aided design project management is provided by IPAD. Design projects are defined to control the execution of a complete process or any segmented portion of a process. The primary elements supported by IPAD are project planning and project records.

Tasks and subtasks are identified in a project plan. Each task is scheduled and resources allocated in the plan. Each subtask is scheduled and resources allocated in a task plan. A critical path may be constructed by defining dependencies of both tasks and subtasks. Tasks identify the work to be accomplished by engineering groups and subtasks describe the work activities to be accomplished by individual engineers. Each subtask may require execution of one or more jobs or IPAD utilities.

Project records are used as the primary means to identify the source and quality of all data generated and used by a project. These records are appended by IPAD to the data stored in the information bank.

IPAD will support interactive displays and automated pre-formatted displays of project records from the information bank. This will provide management with the capability to review plans, and schedules, make planned versus actual comparisons and track costs, such as development, production estimates, product support and product operation.

The engineering manager's decisions are based on known confidence in the data produced by a project. The known confidence stems from the process tools used and the planned quality of the input data used. These factors support risk evaluation by engineering managers of the technical definition of the product. The reduced time and resources for a design cycle permit the manager, based on known risk, to iterate these cycles until the confidence in the quality and consistency of data is adequately established.

5.3 PERFORMANCE

Reduction of costs and schedules for design cycles were discussed in section 4.1. Managers can apply these improvements in costs and schedules to all applicable areas of their operation using a transitional implementation of the integrated information processing technology supported by IPAD. The reduction of routine data preparation by interfacing jobs with data stored in the IPAD information bank will shift the level of effort from routine to judgmental activities thus improving the quality of the solution. In addition, the number of job failures caused by errors in input data will be reduced. These factors will contribute to improved performance of each engineering unit.

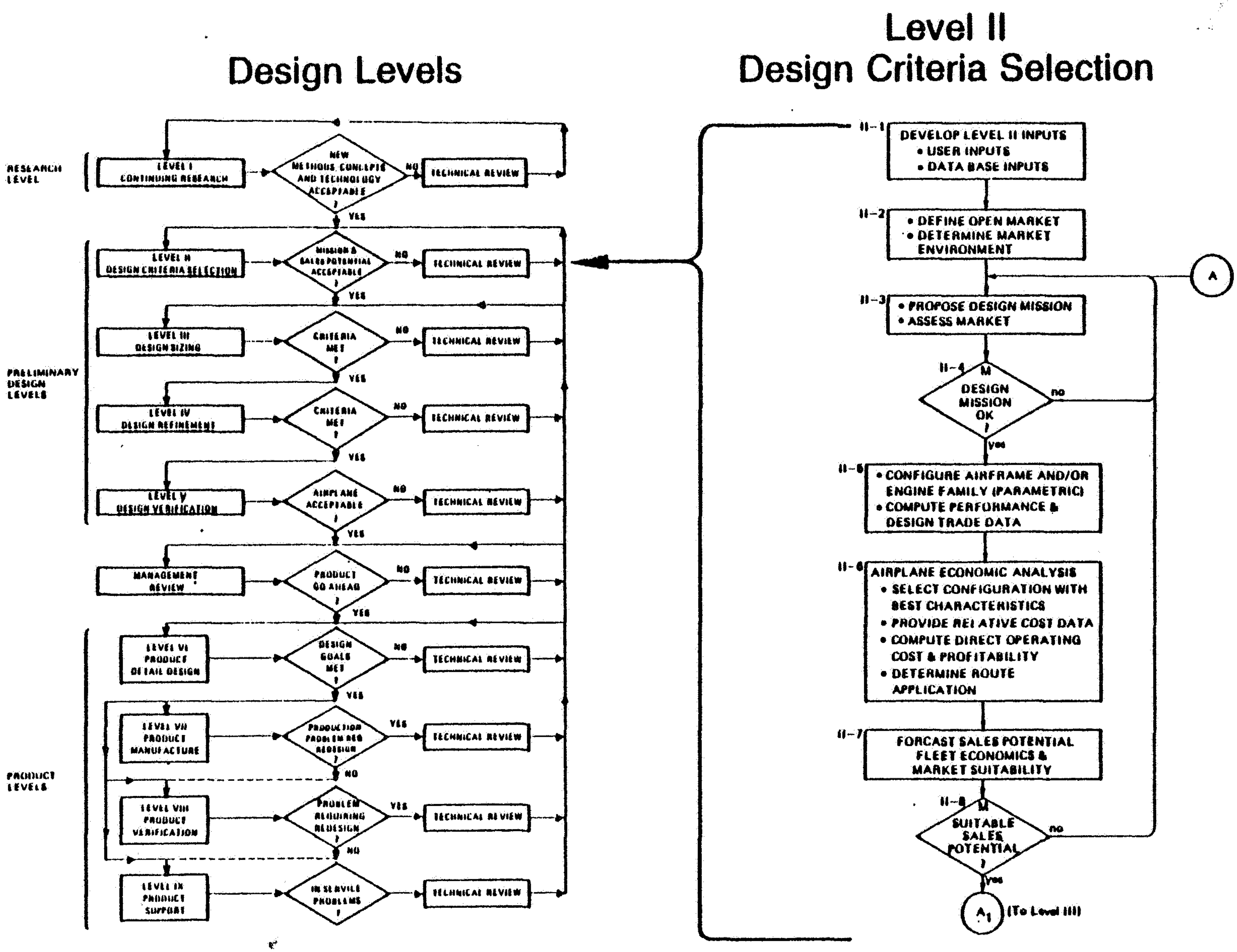


Figure 5.1—1. Reference Design Networks

6.0 ENGINEER'S VIEW OF IPAD

The engineer should view IPAD is an advanced interactive computing system tailored to the enginering users needs. These needs range from the random gathering of information to control of the execution of complex programs in the application program library and IPAD system standard utility library.

6.1 DATA BASE SUPPORT

IPAD provides capabilities to store, retrieve and maintain engineering data. The IPAD information bank is a repository for historic data and data on current products and future products under development. Data maintenance provisions include version identification and the capability to track the differences between versions.

IPAD assists engineers in identifing and retrieving information. The engineer can request data by name or browse through the contents of the information bank by specific disciplines such as configuration design, wing design, loads, stress, hydraulic system, etc., or by key words such as wing aspect ratio, engine bypass ratio, cruise mach number, part number, etc. Ready access to engineering information is an important advantage for engineers, especially detail designers, and reduces the time to gather the information required to get ready for design work.

6.2 APPLICATION PROGRAM LIBRARY

IPAD provides the engineering user with access to a company-wide application program library. These application programs are readily available for execution as jobs which are the state-of-the-art tools developed by each company to apply technology to its product lines. The engineer can request jobs by name or browse through the library by specific technology and by key words. This ready access to tools should enhance the engineer's technical capability and reduce duplicate development of programs.

6.3 IPAD SYSTEM STANDARD UTILITY LIBRARY

IPAD provides the engineering designer with a set of standard utility programs which are state-of-the-art capabilities in such areas as graphics, design drafting, and finite element modeling. These utilities are supported by the IPAD system in a manner that provides a unified CAD/CAM capability in which a design may be created, analyzed, and released to the applicable manufacturing process within an integrated design environment. The geometry is stored in an IPAD standard geometry format and easily communicated among CAD/CAM application and to manufacturing system.

6.4 WORK ENVIRONMENT

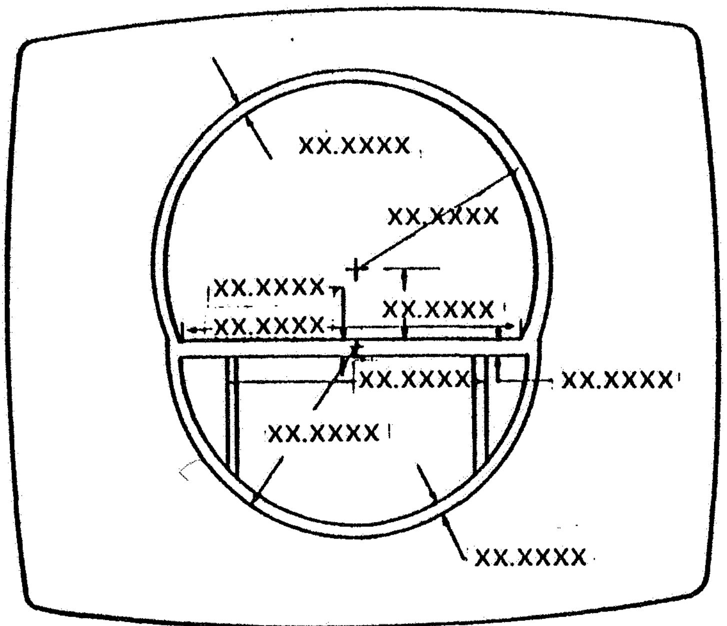
The engineer will work in an environment in which computing tools are readily available and structured to accommodate various user skills. Help is available on line and the engineer may easily terminate a session and resume at a later time. Most data bookkeeping is done automatically by the system, which can trace the origin of any data set.

In the areas of creative design for which integrated processes may not be defined, the design drafting capability of the standard CAD/CAM utility will enable the user to construct, modify, display, and manipulate geometric definitions. These geometry definitions are used by manufacturing to support functions, such as tool path definitions. Figure 6.4-1 illustrates typical hardware supported by IPAD at a computed aided design work station. Menus may be displayed on the graphics terminal or on a slave text terminal as illustrated. Menu selection may be implemented with function buttons, with light pens or using a data tablet with a menu overlay. The system can access the product loft definition for both cut and surface extractions needed for detail parts. Retrieval may be accomplished rapidly in an interactive mode using a language comfortable to the user, such as:

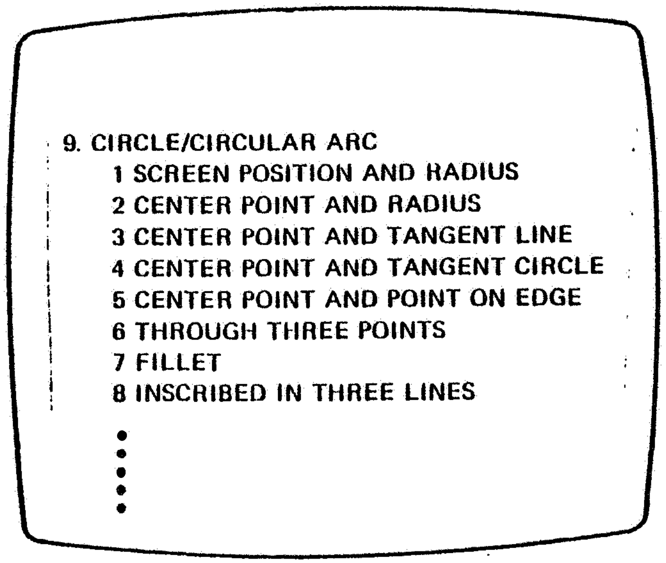
"DISPLAY REAR VIEW WHERE BODY STATION = 960"

Computer program execution within IPAD is based on job control and many data interfaces with the information bank can be pre-defined. The user identifies the job to be executed and the project and subtask names. IPAD links the job to applicable existing input data sets based on the project name and the process definition. The user inputs the required additional data and initiates interactive execution or submits the job for batch processing. In either case, IPAD will automatically store the user-supplied input and the output produced in a temporary private data storage area identified by the user's subtask name. The user may access the data by the subtask name and data set name. Computer-aided features for data validation such as set comparison and range checks will assist the user in evaluating the results. This improved data communication will reduce the time enginers spend on routine data preparation and result in increased time spent on judgmental activities.

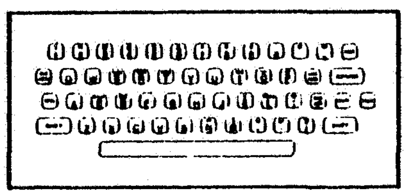
The system will provide the capability for a user to manage use of computing resources such as central processor time. If resource limits are exceeded, the system will automatically suspend execution and package the completed results in a manner



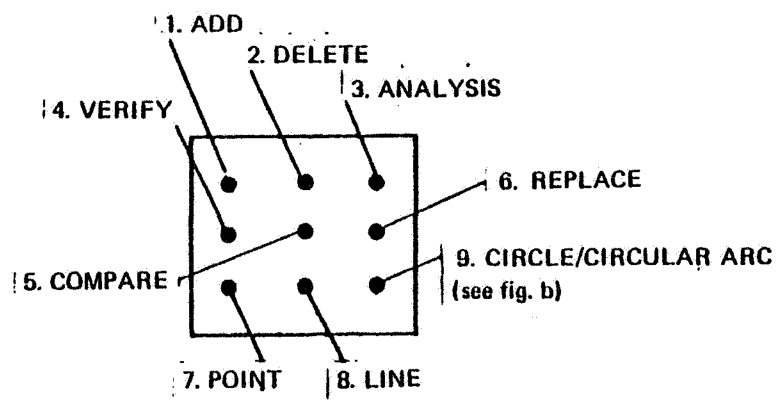
a. Primary Graphics Terminal



b. Text/Menu Terminal (Optional)



c. Keyboard



d. Function Keys (Optional)

Figure 6.4-1. – Typical Equipment – CAD work station suitable for restart with minimum loss. The user may examine the results completed and resume execution. Status reports are available to each user for all subtasks in work. The status reports include such items as:

Subtask schedules

Computer resources budget/used/remaining by subtask

Jobs completed by subtask

Resources for each job

Jobs suspended and probable cause of suspension

Resources used for results completed prior to job suspension

Data sets created

Data sets due

IPAD provides a data release procedure equivalent to signing a drawing and may include the categories such as prepared, checked, and approved. When the user is satisfied with the output, an appropriate entry is made by the user. After persons designated have checked and approved the data and made appropriate entries, the data is transferred logically by IPAD from temporary storage to permanent storage area and is accessible as released information. This relieves the engineering user from the burden of tracking data.

6.5 COMMUNICATIONS

Many features of the IPAD system will support both on-line and off-line communication between engineers. The terminal conference data viewing mode supports multiple terminals with common text and graphical displays. It will be possible to send messages on the screen and edit screen content from any of the terminals. Other online support includes review of process description and data interfaces. Offline output includes check print quality hard copies of complete drawings or screen content for coordination purposes prior to completion or release.

7.0 ENGINEERING APPLICATION PROGRAMMERS VIEW OF IPAD

The engineering application programmer should view IPAD as a means to handle scientific data using a data base management system and to control application programs in a library environment similar to operating system and run time libraries thus simplifing use by the engineers.

7.1 PROGRAM DEVELOPMENT AND INSTALLATION

IPAD will support a large library of application programs and will provide the application programmer with a set of programming aids and standards.

Programs developed within IPAD or suitable existing programs may be installed in the IPAD program library which will support management of modules. Application programs must conform to an IPAD installation standard and will be installed as one or more operational modules. A job is use of a selected set of Operational Modules and/or other jobs executed by the user as part of a subtask. Any set of source code used several times will be entered once as a source language module and made available to the user community. The same applies to operational modules and jobs. Naming conventions result in unique names for all modules and jobs in the program library and are used as primary keys for program management. The construction of jobs from modules and the administration information supported by IPAD is illustrated by figure 7.1-1.

Programming aids are provided to support creation and maintenance of application programs and include on-line utilities for program text editing, debugging and update. In addition, host operating system programming aids may be accessed and used in conjunction with IPAD.

7.2 PROGRAM INTEGRATION

Program integration into IPAD involves linking programs as IPAD jobs to the data within the information bank and to other IPAD jobs as determined by its use within the design process.

Data formats must be defined for each input and output data set associated with a job. Two types of formats are provided. The first is for undefined data sets where IPAD manages data at the level of sets and does not know the contents of the set. The second is for defined data sets where data elements within a set and relationships betwen elements (i.e., structure of the data set) are defined and IPAD manages data at the level of elements.

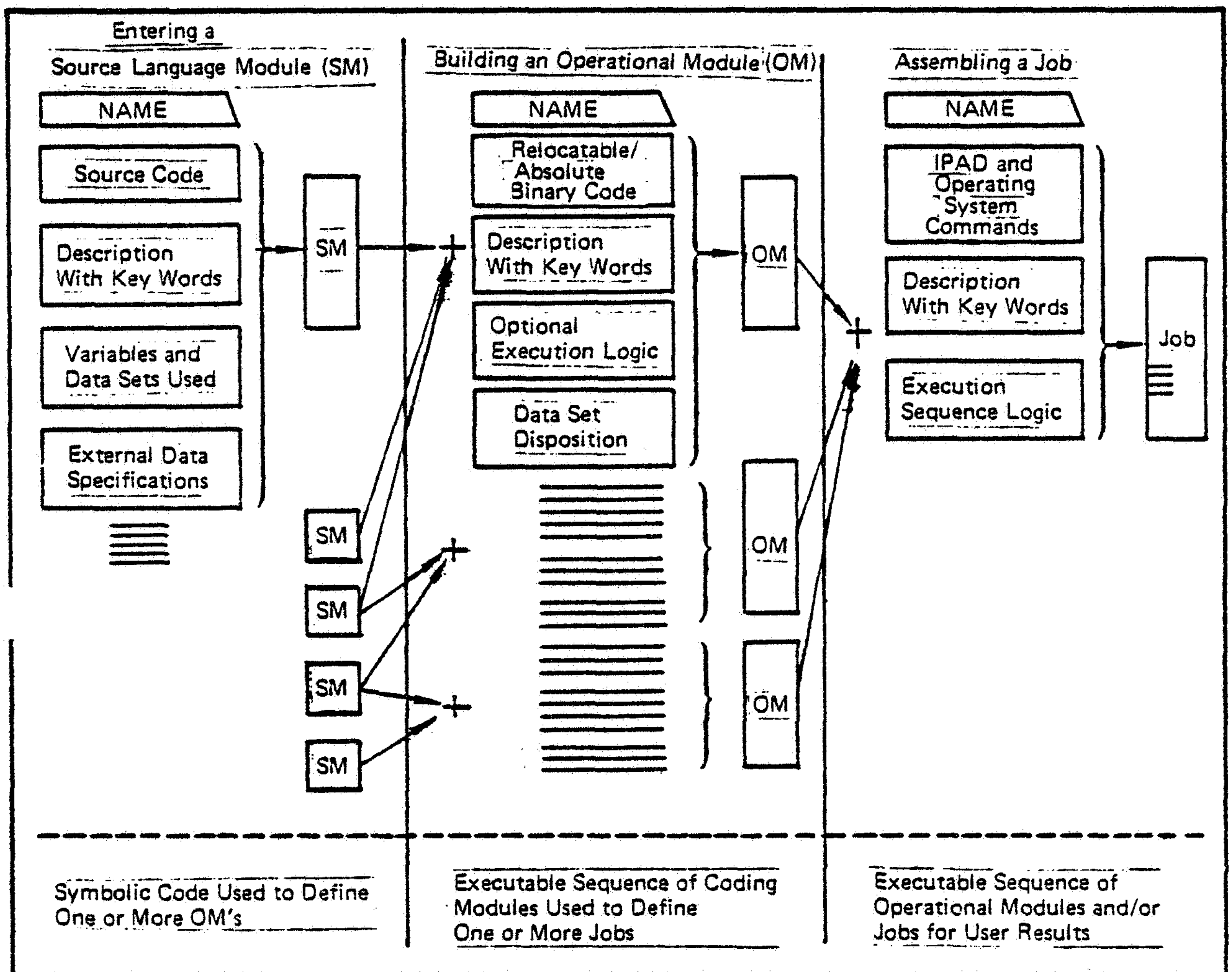


Figure 7.1-1 — Steps in Job Construction

A data modeling capability is used to establish definition of data flow within the design process. This definition identifies the source and destination of all input/output and makes provisions for job to job communication. Any required data reformating on translation is identified by this data flow definition. Both forward and feedback data flow paths are supported. The source and destination definition are used to map storage and retrieval data flow between the process and the information bank and between related activities defined in the process.

7.3 PROGRAM MAINTENANCE

In addition to the programming aids mentioned in 7.1, the IPAD program library makes provision for version identification of modules and jobs and to track the difference between versions. The IPAD system itself is written in a high level system implementation language and has extensive system documentation. Sufficient information is provided to allow modification and enhancements to the IPAD system by individual companies choosing to tailor their IPAD installation.

8.0 IPAD DEVELOPMENT PLAN

The IPAD development is composed of two major steps.

1. Preparation of specifications and preliminary design of an IPAD system which will meet aerospace company design needs of the 1980's.

2. Design, code, document, test, and release a "First-Level" IPAD system, a truncated working version of IPAD, which encompasses the critical features and is extendable to a full IPAD system.

These steps are covered by the current development contract. A third step, for subsequent maintenance and improvement has a tentative duration of three years and gradual diminishment of government financial support, is identified by the IPAD Prospectus (ref. 15).

The first step developed specifications and preliminary design of the IPAD system based on functional and software requirements provided by NASA, as refined and expanded by the development contractor. Use has been made, where appropriate, of references 1 and 2. The IPAD functional requirements include support of the design process at all levels for long periods of time; information processing; technical computer program assembly, integration, and execution; sequencing of design tasks; and display of graphical and alphanumeric information. The interactive computer terminal is the primary interface between IPAD users and the system. The design of IPAD software builds on existing computer-aided design technology and uses new concepts in computer science where the need is critical. It will support today's design processes and permit development of new design methods for the future.

The second step develops First-Level IPAD from the IPAD preliminary design and meets minimum requirements specified by NASA. High levels of system reliability, maintainability, and portability are key characteristics of First-Level IPAD. First-Level IPAD includes incremental releases of selected software for testing by industry beginning approximately 2-1/2 years after the IPAD development contract commences and continuing at regular intervals. The precise nature of software releases is determined during the development process. All First-Level IPAD software is developed for two time-shared computer complexes (CDC CYBER 172, and IBM 370) to demonstrate portability requirements which minimize machine dependency. A subcontract will be issued to substantiate the portability of the IPAD system and to demonstrate its usefulness to the aerospace industry. Appendix D to be prepared in the first part of 1978 will contain a brief description of the capabilities of each incremental release.

The IPAD system will be maintained by Boeing during the development contract. The major milestones for development of IPAD are shown on figure 8.0-1. These milestones are the primary events which industry may use to plan the transitional implementation of IPAD.

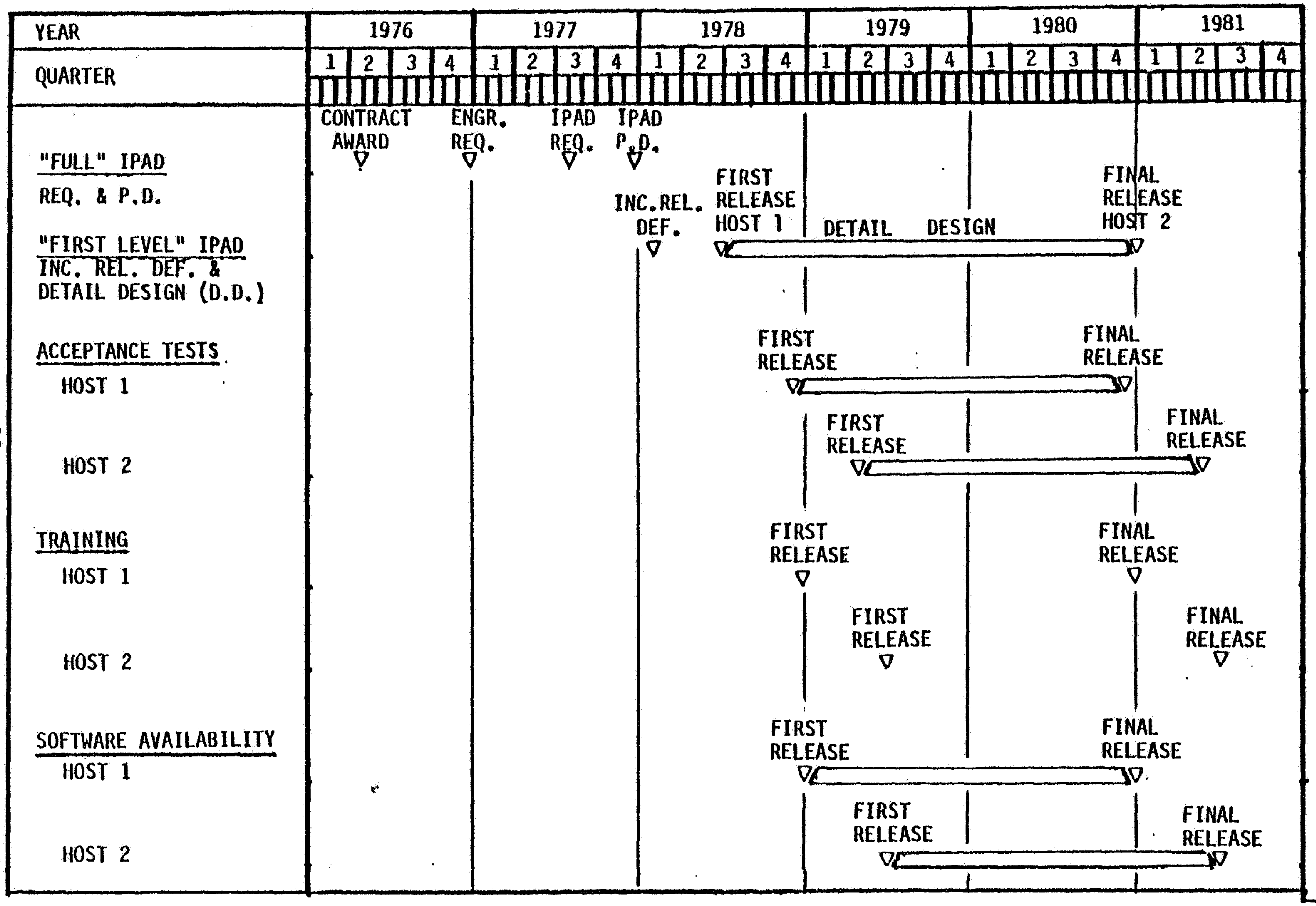


FIGURE 8.0-1 IPAD MILESTONE SCHEDULE

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13. A Preliminary Investigation of the Potential Application of the IPAD System to NonAerospace-Industry, NASA CR-2603, Battelle Columbus Laboratories, Contract NAS1-12802, 1975.

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15. IPAD Prospectus, NASA Langley Research Center, Hampton, Virginia, February 10, 1975.

IPAD DEVELOPMENT DOCUMENTS

16. IPAD Document D6-IPAD-70010-D, "Reference Design Process."

17. IPAD Document D6-IPAD-70011-D, "Product Manufacture Interaction with the Design Process."

18. IPAD Document D6-IPAD-70012-D, "Integrated Information Processing Requirements."

19. IPAD Document D6-IPAD-70013-D, "User Requirements."

20. IPAD Document D6-IPAD-70035-D, "Product Program Management Systems."

21. IPAD Document D6-IPAD-70036-D,"IPAD Preliminary Design."

22. IPAD Document D6-IPAD-70040-D, "IPAD Requirements."

APPENDIX A

INDUSTRY INVOLVEMENT IN IPAD SYSTEM DEVELOPMENT

BACKGROUND

The definition of IPAD has evolved over many years from a study and critique process that included extensive aerospace industry involvement. Two in-depth studies of the feasibilty and possible forms of an IPAD system were carried out by the Boeing Company and General Dynamics/Convair (see refs. 1 and 2). The total cost of these studies over a 17-month period was $611,000. Each study contractor undertook a careful dissection of the vehicle design process to delineate those functions and tasks that can be beneficially supported by computer hardware and software and then defined the format and elements of a software system that could substantially improve the design process. They also assessed the impact of this IPAD system on company computer hardware requirements and on the performance of company staffs and evaluated its cost and benefit potential.

One company examined these questions in the context of design of three kinds of vehicles--a large subsonic transport, a supersonic transport, and a hydrofoil--and developed a comprehensive, detailed picture of the design process as a multilayered network of functions. The other examined intensively the tasks and interfaces of individual designers and groups and analyzed carefully the information flow in design. They considered the effects of the detailed constituent parts of the design process and extrapolated their experience with existing software systems to arrive at computer requirements, costs, and benefits of IPAD software. Both concluded that IPAD is feasible and will fit on existing computers. They arrived at software systems that differed in detail, but exhibited the same general characteristics and order-of-magnitude costs. Projected benefits included 25-90 percent time and 20-60 percent cost savings in design, better management visibility, and reduced risk and cost resulting from greater depth in early trade-offs, on-time designs, and fewer design changes during production.

Results of these studies were presented in four oral reports that were well attended by representatives of industry; for example, 83 industry representatives attended the final oral presentations. Following completion of the studies, the results were critiqued by teams from McDonnell Aircraft Co.; Lockheed-Georgia Co.; Grumman Aerospace Corp.; Rockwell International Corp., Los Angeles Aircraft Div.; Control Data Corp.; IBM Corp.; and Sperry Univac. These firms examined such questions as completeness of the studies, credibility of the proposed systems and projected development parameters, user acceptance, and government and industry roles. They expended significant effort over four months, employing 31 team members and about 100 part-time consultants. The critique reports (refs. 3-10) reveal a wide spectrum of views, but strong consensus that IPAD development should proceed, should not include technical module development which should remain largely the prerogative of industry, and should provide early delivery of software and user involvement. Because of the inevitable budget limitations, it was recommended that NASA limit its specific objective to production of a truncated, but "working", system.

Other evaluations of IPAD include an Army-funded study by McDonnell Douglas Astronautics Co. of its benefit potential for missile design (ref. 11) and a small NASA-funded study by Battelle Columbus Laboratories of its potential for non-aerospace application (Ref. 13). In addition, the NASA Research and Technology Advisory Committee (RTAC) on Materials and Structures sponsored a colloquium of high-level aerospace managers at MIT on January 30-31, 1974, at which IPAD was examined and discussed (ref. 12). As a result of the industry critiques and RTAC recommendations, IPAD development was initiated.

CURRENT INVOLVEMENT

An Industry Technical Advisory Board (ITAB) consisting of members and observers representing major U.S. aerospace and computer companies meets periodically. The ITAB structure is illustrated by figure A-1. ITAB activities include review of planning and technical documents, critique of key development decisions, ranking of IPAD requirements, identification of demonstration programs and consideration of the formation of an IPAD user group.

As the IPAD software is released, ITAB member companies and other potential IPAD users will be trained in its use. This training will be conducted by members of the IPAD staff.

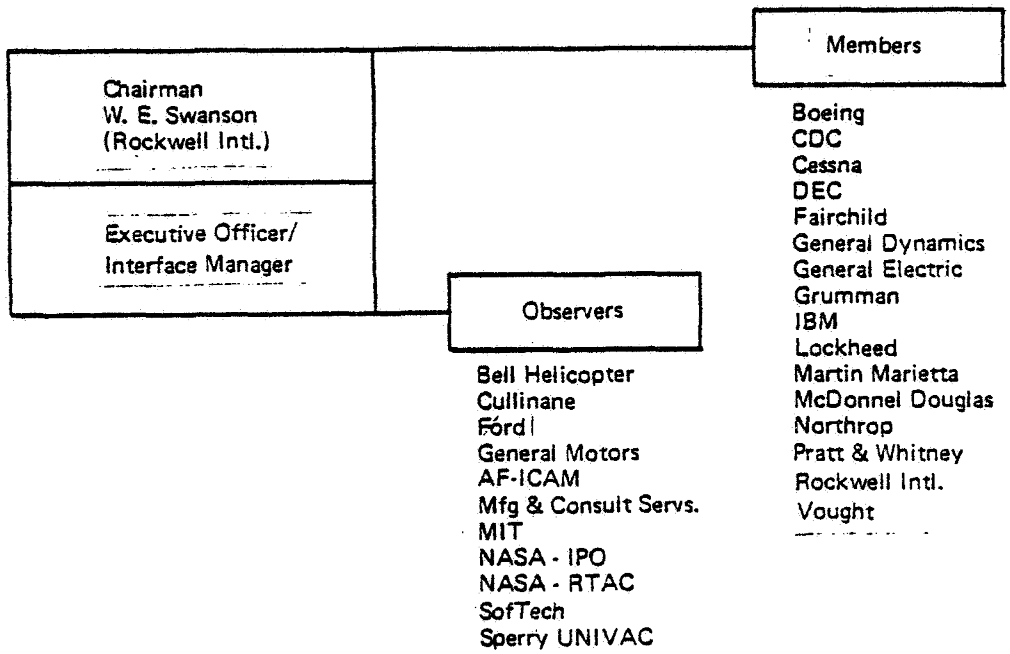

Figure A—1. Industry Technical Advisory Board (ITAB)

APPENDIX B

IPAD DEVELOPMENT PHILOSOPHY

The IPAD development philosophy is to produce a user oriented interactive system with portability as a design objective. The system design makes provisions for extending its capabilty as an open-ended evolutionary process having minimum impact on users of the system. The following are major considerations supporting this development philosophy.

A systematic software development process is used consisting of the following principal steps:

User specification of requirements

Analysis of user requirements

System preliminary design

System detail design

System coding

System development tests

System acceptance tests

System installation/maintenance

User training

Each step is documented completely to provide continuity of system development. The requirements have been developed to encompass the entire engineering design process, its interface with other organizations and user needs. These requirements are being used to produce the preliminary design of a "Full" IPAD system. The cost and time to develop individual IPAD system modules, a priority ranking of the requirements, and a definition of the basic IPAD software components will be used to identify the "First Level" IPAD system within the constraints of the contracted funds available. The "First Level" IPAD is a subset of "Full" IPAD and will support extension to "Full" IPAD.

Since the IPAD development is long term, incremental releases have been planned. Preliminary design will be completed for "Full" IPAD and the remaining steps--detail design through user training--will be done for "First Level" IPAD for each incremental release on two host computing systems.

The preliminary design task began with models of the user interface and the interface to other systems. At the top level, the system is described in gross terms to identify input and output requirements and functional relationships. Each succeeding lower level describes the processes or functions in greater detail. The lowest level contains the individual elements applied to meet the requirements of higher levels. This "top down" approach assures that all required processes are clearly identified and accounted for in a cost effective manner.

The IPAD development is driven by the requirements to produce an effective interactive user oriented system. This is addressed by developing models of the user interface and other systems interface as the first step of IPAD preliminary design. These models are used to test the user input/system response for each function to be performed by IPAD. Scenarios posed by the engineering team assigned to IPAD development are used to guide this testing. The scenarios are developed to test the primary functional requirements of the IPAD system. The tests further substantiate the computing staff understanding of the requirements and help formulate the language syntax that IPAD will display during terminal operations.

Modular development will be used throughout IPAD to improve visibility of functional elements of the IPAD system and to facilitate module testing and implementation. Other advantages of developing a modular system include: improved ability to deactivate optional functions, ease in isolating changes to the system, and ease of installation of new functional modules.

To be an effective system for the aerospace industry, IPAD must be transferable to many computing systems. This will be achieved by minimizing machine dependencies and isolating machine dependencies within interface modules wherever practical.

IPAD will be implemented in a high level system implementation language for two major computing systems to make its initial use available to many companies and to test the capability to transfer the system from one host to a second host.

The acceptance testing conducted by the IPAD engineering development team will include execution of typical application programs based on scenarios developed to demonstrate the usefulness of IPAD. These application programs are obtained from or released to the public domain and will be delivered with IPAD to provide an initial technical capability which demonstrates functional capabilities of IPAD.

APPENDIX C

KEY SPECIFICATIONS

This appendix contains a summary of key IPAD specifications relative to performance of the Full IPAD system.

HARDWARE CONFIGURATIONS

The IPAD system shall support processing on computer hardware complexes supplied and maintained by each company incorporating the IPAD system. IPAD shall be capable of distribution over multiple processors or of operating on a single processor. In addition, other computing systems can be interfaced to IPAD as satellite computing systems. The following ranges of hardware configurations shall be possible:

1-4 large scale computer systems

0-100 remote satellite computer systems

100-800 interactive terminals (approximately 25% will be used in graphical mode and 75% in text mode).

As a minimum, the IPAD system shall be compatable with the following computing systems:

CDC CYBER 170 Series

IBM 370 Series

DEC PDP 11/70

SIZE OF DATA BASE

The data volumes and data processing activities that IPAD supports vary from company to company. The following guidelines establish the upper bound of data volumes.

Two product development processes through detail design are in progress at any given time. The data storage required is:

Immediate access - 15 billion bits

Archive (10 min. access) - 55 billion bits

Archive (24 hr. access) - 45 billion bits

Sustaining design of 10 products--this activity requires data availability in less than 10 minutes, except for data currently being worked on. The volume in direct work is to be 20% of the total volume, while 80% of the information is unused but available with 10 minutes notice. The data storage required is:

Immediate access - 50 billion bits

Archive (10 min. access) - 190 billion bits

Archive (24 hr. access) - 120 billion bits

Preliminary design, of exploratory nature of 10 products per year. Data storage required:

Immediate access - 10 billion bits

Archive (24 hr. access) - 60 billion bits

For archival purposes, it is assumed that there is a continued increase of data volume that corresponds to one product description (detailed design) every two years and 10% of the information developed during exploratory preliminary design. The annual increase in data storage is:

Archive (10 min. access) - 30 billion bits

Archive (24 hr. access) - 25 billion bits

The bounds of data storage required are as follows (the lower bound is assumed to be 10% of the upper bound):

	Minimum	Maximum	Annual Growth
Immediate access (billion bits)	8	75	8
Archive - 10 min. access (billion bits)	25	245	30
Archive - 24 hr. access (billion bits)	25	225	25

RESPONSE

The IPAD system monitors response time and controls access to the system when response time is above a parameter set by each company using IPAD. Response time is defined as the time elapsed between the last input by the user and the first character displayed by the computer. The response times given are those for which the user will be comfortable and continue to utilize the terminal for his purposes. The following are design goals:

(15 to 60 seconds)

Access functions where the user is familiar with the delay.

Single enquiries where the user is familiar with the delay, cued by a message from the computer within two seconds acknowledging the command.

System failures and recoveries, cued, where possible, by a message from the computer within two seconds warning of the delay.

Loading of programs and data for execution and processing, cued by a message within two seconds acknowledging the command.

Restart from a prior session.

(4 to 15 seconds)

Low key enquiry dialogue possible but awkward.

Intense creative dialogue not possible.

(2 to 4 seconds)

Complex enquiries where continuity of thought is necessary.

Initial acknowledgment by the system that it is "listening."

Error messages.

(Less than 2 seconds)

Intense creative dialog.

Acknowledgment by the system that a command has been received.

Response to a paging request through a keyboard.

(Less than 1 second)

Response to a paging request using a light pen.

Development of geometric entities.

(Less than 0.1 seconds)

Brightening of characters from a light pen selection.

Appearance of a line when using the light pen as a drawing stylus.

Appearance of a character on a CRT keyboard.

The critical threshold for effective creative dialogue is two seconds. Beyond two seconds mental efficiency degrades rapidly and delays beyond fifteen seconds are structured to relieve the user of both mental and physical captivity (see ref. 1, vol. 4).

ACCURACY

The system accuracy will be to store numerical data with at least 10 significant digits and to perform arithmetic operations with no additional loss of accuracy other than that imposed by purely mathematical considerations and the characteristics of arithmetic operations of the host computing system.

EFFICIENCY

At all times the active system configuration will be structured on a minimum system functional support consistent with the user needs. The responsibility for efficient operation is a system design requirement and the user is not required to guide the system into its most cost effective support.

RELIABILITY

During any consecutive four week period, the minimum average user availability for the IPAD system is not less than 97.5% of the total available host computing time allocated to IPAD. The IPAD system is considered available when a user is able to productively perform his desired objectives.

APPENDIX D

DESCRIPTION OF INCREMENTAL RELEASES

(To be added.)