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PROGRAM FOR AEROSPACE VEHICLE DESIGN (IPAD)

Volume IA. Summary

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September 21, 1973

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16 Abstract
IPAD is a total system oriented to the product design process. This new total system has been designed to recognize three major requirements:

- The product design process,
- Individuals and their design process tasks,
- The computer-based IPAD System to aid product design.

This computer-based IPAD System has three principal elements:

- Host computer and its interactive system software,
- New executive and data management software,
- An open-ended IPAD library of technical programs to match the intended product design process.

The basic goal of the IPAD total system is to increase the productivity of the product design organization. This study showed increases in individual productivity were feasible through automation and computer support of routine information handling. Such automation can directly decrease cost and flowtime in the product design process.

An IPAD System is the next logical step in the evolution of design process productivity.

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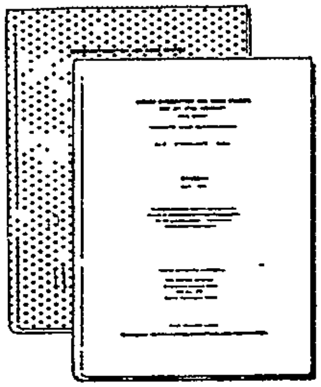

Volume IA
Summary of IPAD Feasibility Study
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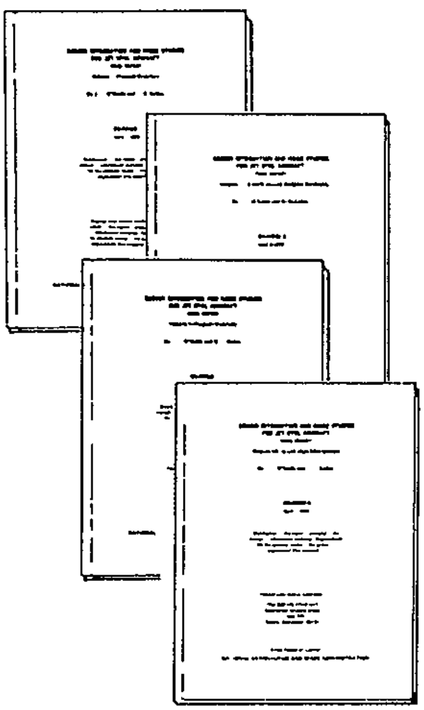
Volume IB
Concise Review of IPAD Feasibility Study
D6-60181-1B

Part I—Final Report, Tasks 1 and 2



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Catalog of IPAD Technical Program Elements
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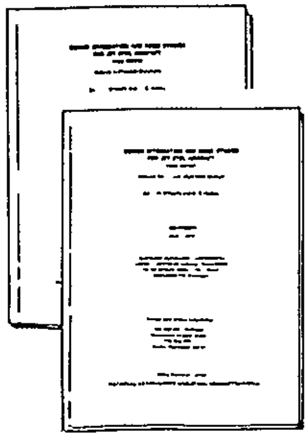

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FOREWORD

The IPAD (Integrated Program for Aerospace-Vehicle Design) Feasibility Study was initiated by NASA Langley Research Center in April 1972. The intent of this study was to analyze and describe the product design process and seek feasible ways to improve the productivity of men and computers in support of this process.

The study ended in September 1973 and is reported in detail in the following reports: Volume IA - Summary of IPAD Feasibility Study; Volume IB - Concise Review of the IPAD Feasibility Study; Volume II - The Design Process; Volume III - Support of the Design Requirements; Volume IV - IPAD System Design; Volume V - Catalog of IPAD Technical Program Elements; Volume VI - IPAD System Development and Operation; and Volume VII - IPAD Benefits and Impact.

ACKNOWLEDGMENT

IPAD has been a real team accomplishment. Men, from the required broad range of specialties, stretched their minds, escaped from their usual narrow compartments; and examined the total air vehicle design process.

Many of us saw for the first time, our role in the total process; a refreshing challenging view. A total product has emerged; shaped first by the requirements of men and their tasks in the design process, then supported by a computer system design that sets the stage for a new man/computer productivity plateau.

The vision of NASA in sponsoring this initial step has helped propel United States Industry into a potentially more productive, cost-effective design environment.

Ralph E. Miller, Jr.
Ralph E. Miller, Jr.
IPAD Program Manager

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1.0 INTRODUCTION

The basic goal of the IPAD system is to increase the productivity of the product design organization. This IPAD study showed increases in individual productivity are feasible through automation and computer support of routine information handling. Such automation can directly decrease cost and flowtime in the product design process.

IPAD is a total system oriented to the product design process. This new total system has been designed to recognize three major requirements:

- o The product design process,
- o Individuals and their design process tasks,
- o The computer-based IPAD system to aid product design.

This computer-based IPAD system has three principle elements:

- o Host computer and its interactive system software,
- o New executive and data management software,
- o An open-ended IPAD library of technical programs to match the intended product design process.

The design process was found to be a complex hierarchy of tasks by which vast amounts of data are produced, evaluated and communicated. Although computers are used extensively to produce data, the routine management, evaluation and communication functions remain largely manual. These functions are becoming unmanageable and consume large amounts of human resources, facilities and flowtime.

A design organization will optimize cost, flowtime and design goals (fig. 1.1). Cost or flowtime allocations will limit the search for optimum design. Unless these limits can be relaxed, resources will not be available to further optimize product design.

An effective way to reduce cost and flowtime requirements is to develop more productive methods. New manpower and flowtime are then available for reinvestment in improved product design or increased profit.

Experience with computer-based systems show it is feasible for an IPAD system to reduce manpower and flowtime by 50%. Such reductions have been evolving as our understanding of automation and the design process have evolved. It appears an IPAD System is the next logical and feasible step in the evolution of design process productivity.

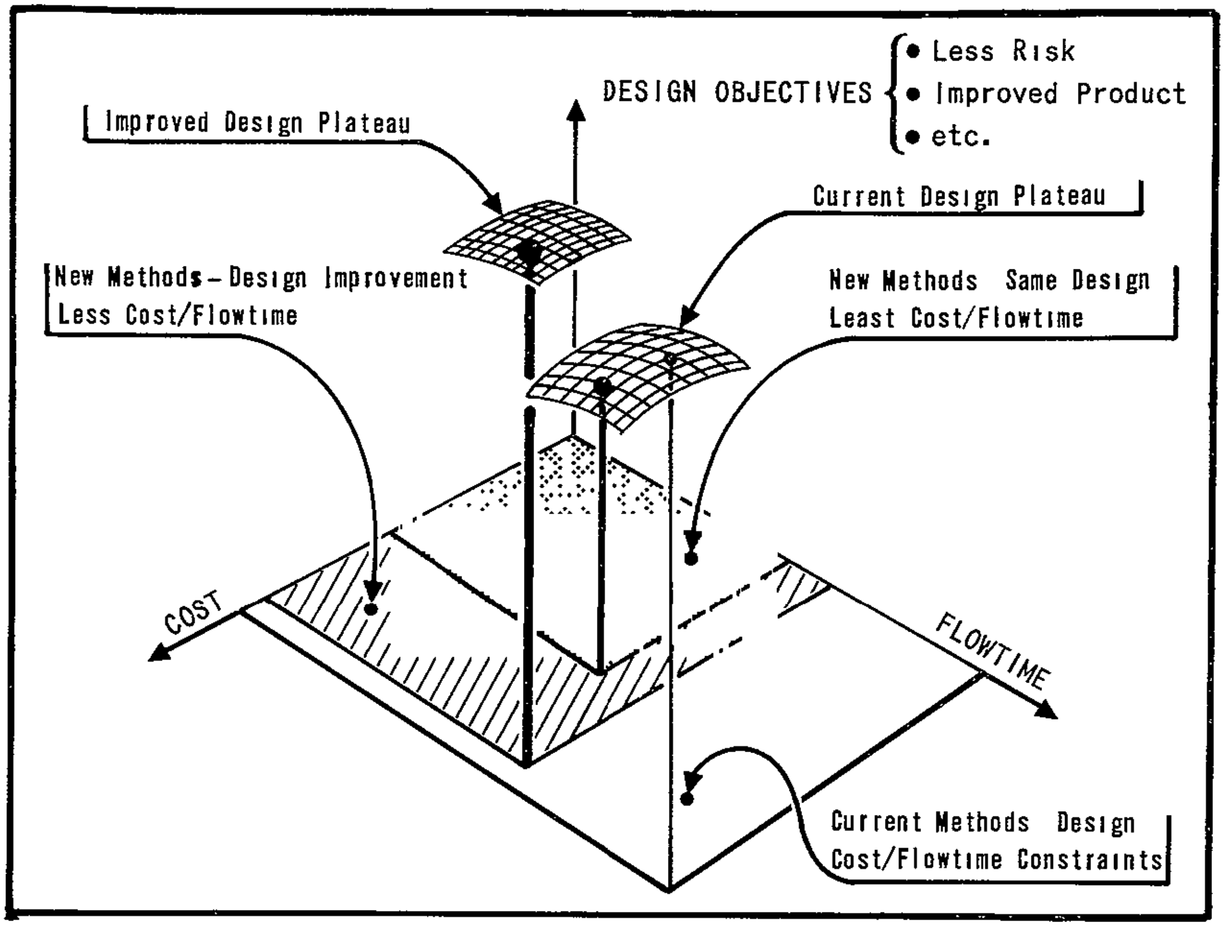


Figure 1.1 Problem Solving Productivity In Design

2.0 HISTORICAL IMPACT OF COMPUTERS ON PRODUCTIVITY IN DESIGN

Large design problems require a division of tasks. Individual designers are assigned a part of a task under the direction of a task leader. The designer performs his subtask by dividing it into several manageable jobs. Tasks are organized and reported by the task leader as part of a project group responsible for the design of a product.

The result of the design process is a single product entity in which all components must function harmoniously. Hence, extensive data communication, evaluation and iteration are required to optimize the design. Orderly methods for introducing changes in the design are necessary to ensure convergence. These methods establish a data (information) handling environment.

This environment characteristically:

- o Requires extensive record keeping for data and configuration management;
- o Requires accurate and timely production and communication of data;
- o Has complex informal and formal communication paths;
- o Is continuous with respect to time, activities and people.

These information functional characteristics are invariant; that is, they remain unchanged even though the methods and computerized tools used may change significantly.

Significant changes have evolved in computational and data handling tools and methods used by design organizations. A review of this evolution of computer usage will establish a context for describing the function and benefits of IPAD.

2.1 BEFORE COMPUTERS

Prior to the use of computers, all calculations were performed by hand or by using slide rules and other mechanical aids. This process required the designer to record a set of values, input these values into a mechanical device, record results and generally manage each detail of the computation by hand. The size and complexity of the calculations were limited by the manual abilities of the designer.

2.2 AUTOMATION OF CALCULATIONS

When computers were first introduced, they were used to relieve the manual constraint on calculations. Typically, the computer was programmed to perform the arithmetic, record intermediate values, and generally manage the compuation process; hence, effectively automating the routine manual activities in performing calculations.

The computer was so effective that the designer was able to extend his computational ability by many orders of magnitude, often utilizing theories and methods previously unavailable because of their extensive arithmetic. Improvements in computing hardware, operating system software and coding languages resulted in further extensions of this computation capability.

The continued automation of calculations, however, produced new constraints. While individual designers were able to produce, with the computer, thousands and even millions of numerical results in very short periods of time, the volume of data to be handled by people became the constraining factor. People began to be faced with unmanageable data volumes associated with data preparation, evaluation of output and communication of results. Computing hardware and software were oriented to batch processing at the physical site of the computer and gave no support to the transmission of data between individuals or between coding modules to be executed together as one job. Hence, while large volumes of calculations could now be performed, information handling was still a manual process. This environment is generalized in figure 2.1.

2.3 AUTOMATION AND COMPUTER-AIDING OF INTERFACES

Early automation of calculations on simple tasks soon gave rise to other problems that were part of the task but manual in nature. The general question of problem solving efficiency began to emerge. Instead of seeking efficiency improvements on one isolated task element such as calculations, all task elements come into question. The studies of references 1 and 2 examined this broader efficiency question of how to lower task total cost by considering both the human aspects and the computer aspects of a task. These studies are described in detail in Appendix A. In summary, the significant findings were:

- o The computing cost is approximately one-tenth of the total cost;

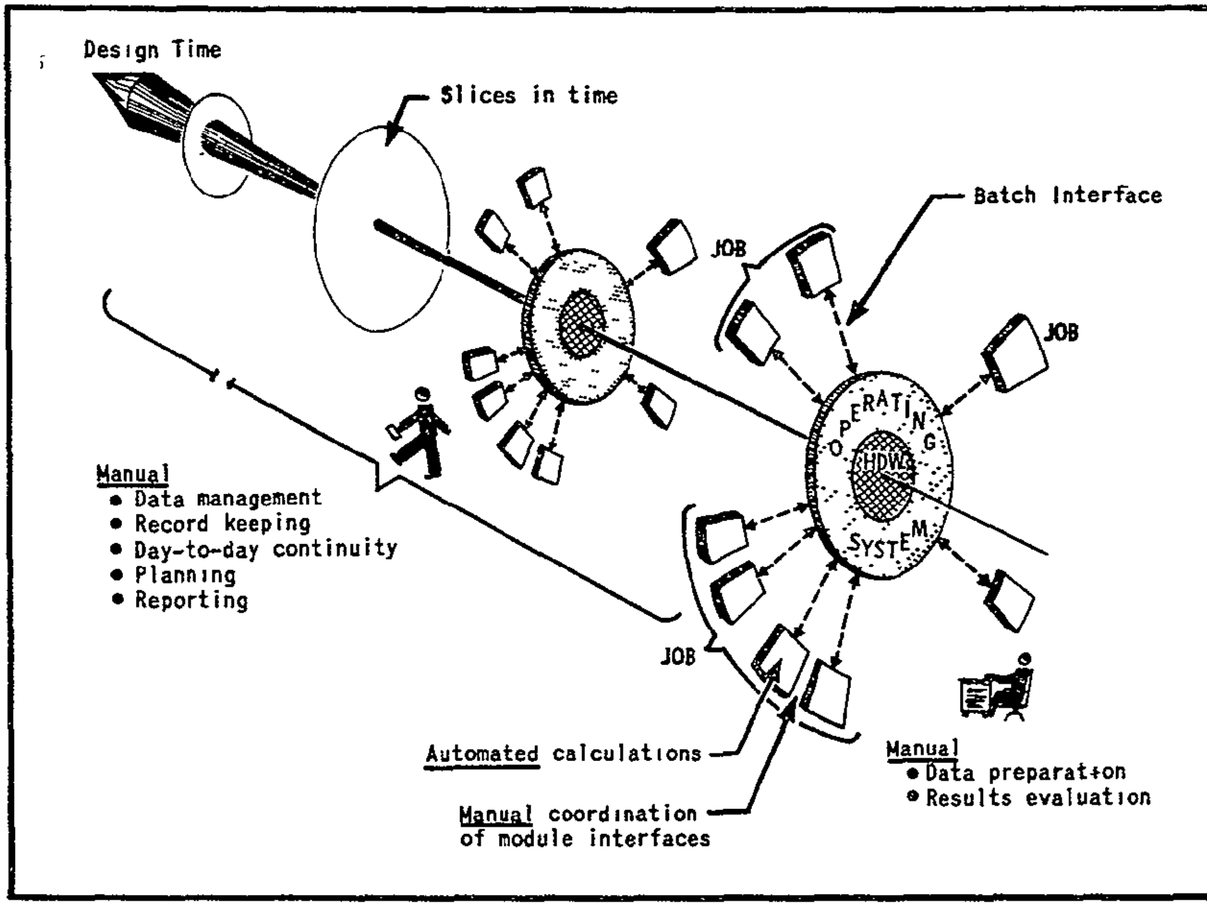


Figure 2.1 Early Computer Problem Solving Environment

- o The time people spend on the task is the most important cost element;

- o A proper selection of computing devices and services can reduce task total cost by 25% through reducing time people spend waiting for computations.

The early successes with calculation automation on simple tasks naturally led to putting more complex tasks on the computer. These more complex tasks inevitably resulted in data handling problems, especially at technical module interfaces.

Integrated systems such as ATLAS (ref. 3) and CPDS (ref. 4) were developed to relieve the constraint of communicating large volumes of data across coding module interfaces. These systems typically included several modules, each identified with a set of calculations. Data was transferred across module interfaces by developing compatible data formats and passing the data through the computer system directly. As a result, modules were able to communicate technical data reliably, precisely and instantaneously.

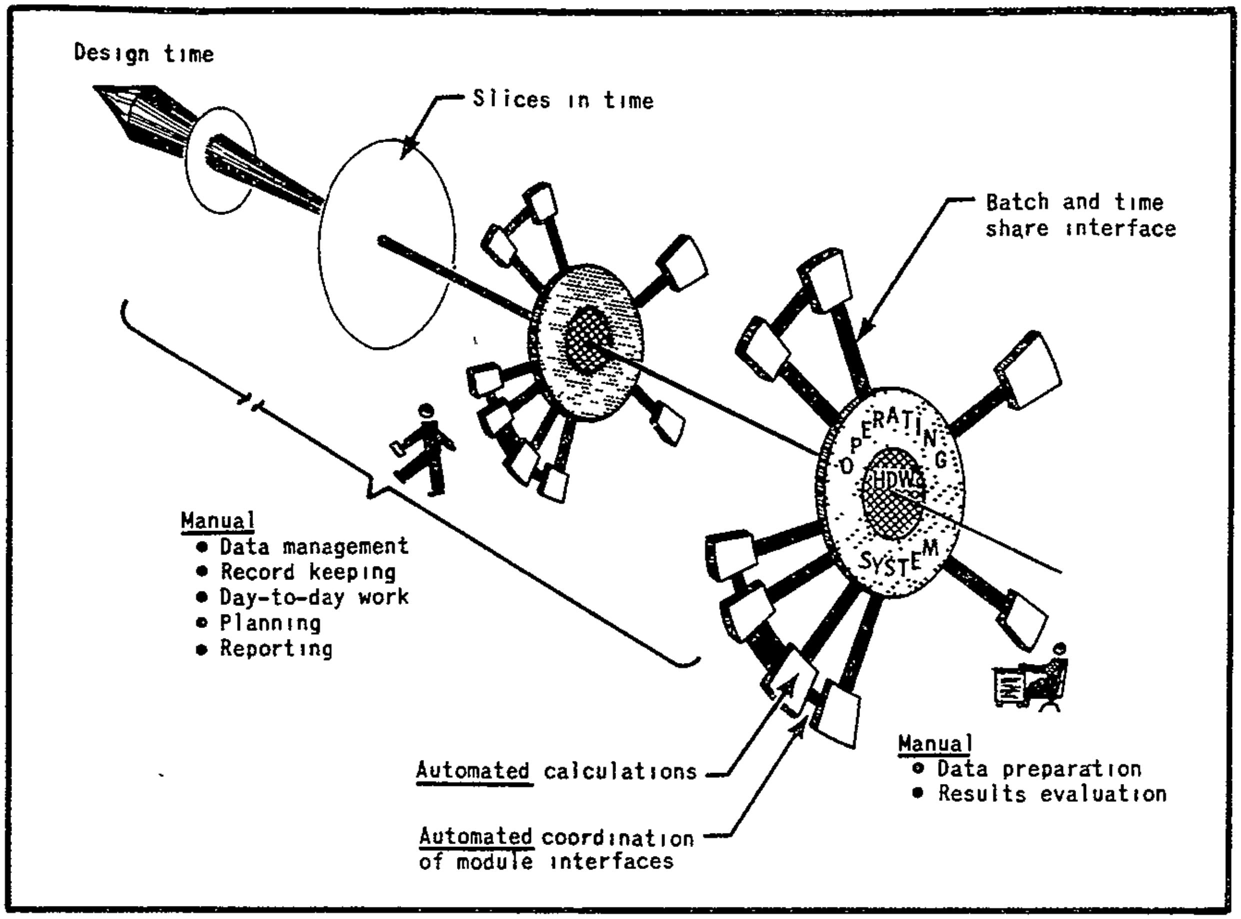


Figure 2.2 Integrated System Problem Solving Environment

Executive control systems were developed, giving the user control of the operation of the integrated system with language syntax familiar to him. Data management systems were also developed for automatic retrieval and storage of data by command of the individual coding modules.

Computing hardware and software were developed to support a direct real-time interface between the user and the computer. This interface, combined with executive and data management software, gave the user control of the computer with respect to his own processing. It allowed the user, within limits, to make real-time adjustments to data and execution sequences and to interrogate output through direct access to large capacity data storage devices.

The details of these developments are sketched in Appendix A. In general, ATLAS and CPDS type systems provided further efficiencies in these more complex task environments. Reductions of 50% in manpower and flowtime were achieved through the automation and computer aiding of the routine information handling. A generalization of this environment is given in figure 2.2.

This environment introduced several advantages. Integrated systems were effectively configured to include several related disciplines, thus providing a medium for exchange of data and a common reference system for problem solution and theory development. In parallel, later generation computing systems provided arithmetic and data transfer rates sufficient to support the data volumes to analyze total aircraft responses such as the aeroelastic cycle, the total flight control system, or the engine to airframe interface.

By coupling integrated systems with interactive graphics devices, computer-aided drafting systems were developed. These systems have been interfaced with numerical control software, thus providing a direct tie between product design and manufacturing.

2.4 IPAD PROBLEM SOLVING ENVIRONMENT

Early in the IPAD study, the problem solving environment typified by ATLAS and CPDS (integrated systems) were re-examined. This examination identified some very different characteristics associated with the design process which had not been identified. These characteristics evolve from the long duration of problem solving which is characteristic of all but the simplest work and is particularly present in product design processes which span months and even years. It was found that design is a hierarchy of processes: individuals and their subtasks, tasks composed of many subtasks, and product studies composed of many tasks.

In examining the details of this process with respect to time duration, it was observed that:

- Different subtasks or different sequences are utilized as the study progresses and as new insight is gained into technology trades;
- Most subtasks are not completed in one work period; therefore, the designer must reorient himself, the data and the subtask in order to continue at his next work period.

Thus, to support the problem solving environment, the IPAD computer-based system must significantly automate routine functions required to:

- Transmit information at the subtask interfaces;
- Maintain information continuity in the work on a day-to-day basis;

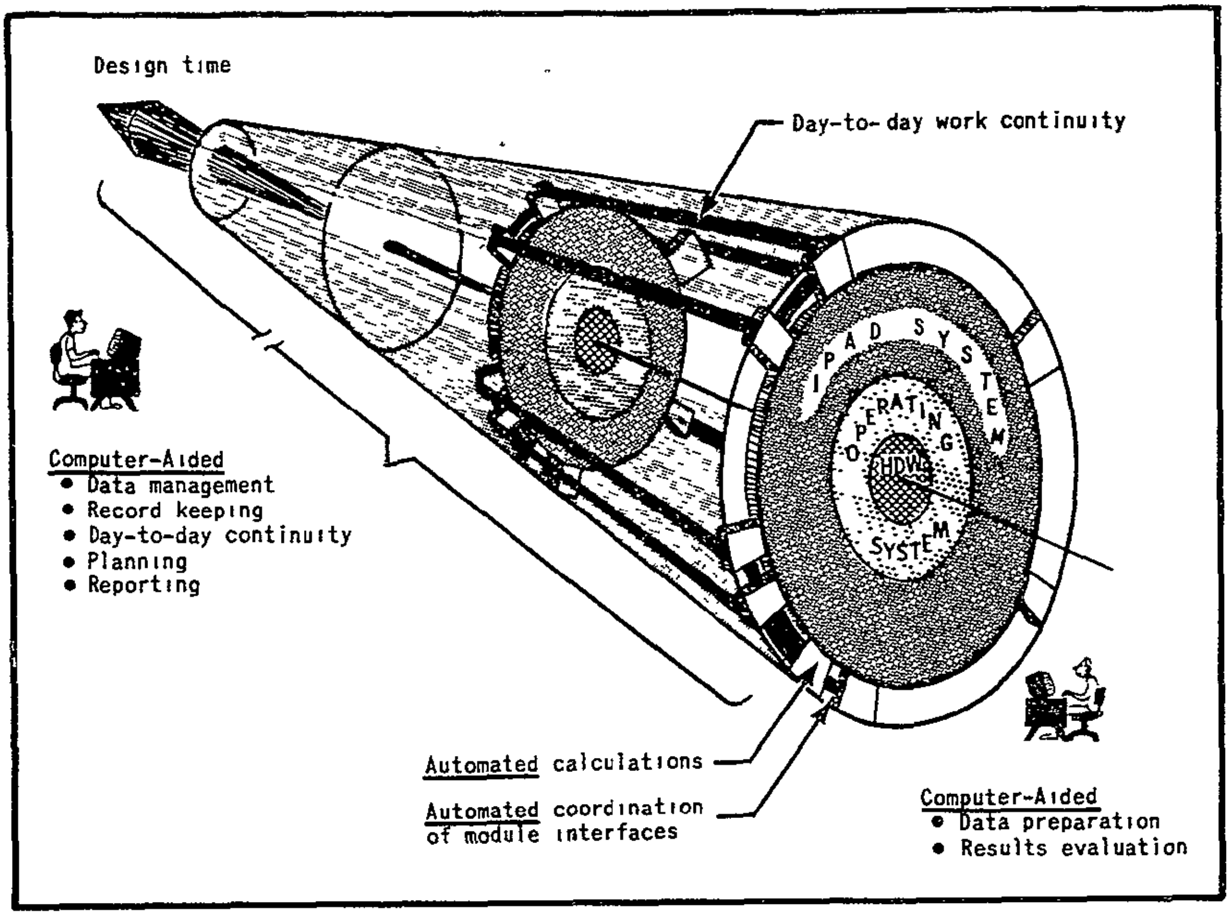


Figure 2.3 IPAD Problem Solving Environment

- o Prepare a plan and log of all input data required for each subtask in each particular study;
- o Prepare and maintain a record of the output, major results obtained and conclusions reached for each definitive study conducted with a corresponding record of what input conditions distinguish one study from another;
- o Prepare and maintain a log of when and what information was transmitted to various other persons or organizations.

A generalization of such an IPAD computer-based system is illustrated in figure 2.3. A review of figures 2.1, 2.2 and 2.3 show that an IPAD System is in fact, the next logical, evolutionary step toward improved productivity in the product design process.

3.0 IPAD STUDY

The general background and motivation for the IPAD feasibility study have been examined. The study required the following:

- An examination and description of the product design process to determine the requirements to be supported by computing software and hardware.
- The design of a computer-based system responsive to these requirements.
- An assessment of the IPAD total system for potential benefits, tangible and intangible, and for potential impact upon organizations and people.
- Estimates of the computer-based IPAD system development costs, implementation strategies, and schedules.

To ensure generality in the study, the following groundrules were established:

- The product design process would be examined from a general environmental point of view, including men, tasks and computation capability as shown in figure 3.1.
- The examination of the product design process would be broad in scope, including all stages of design and all involved functions as shown in figure 3.2.
- The computer-based IPAD system design would be developed considering the broad design objectives shown in figure 3.3.
- The design of the IPAD System would not be constrained to extensions of current applications software nor to current computer hardware and operating system software.
- In the design of the IPAD System, the product design process would be supported by generalized capability. For example, the problem solving environment of the user would be idealized at the general level shown in figure 3.4.

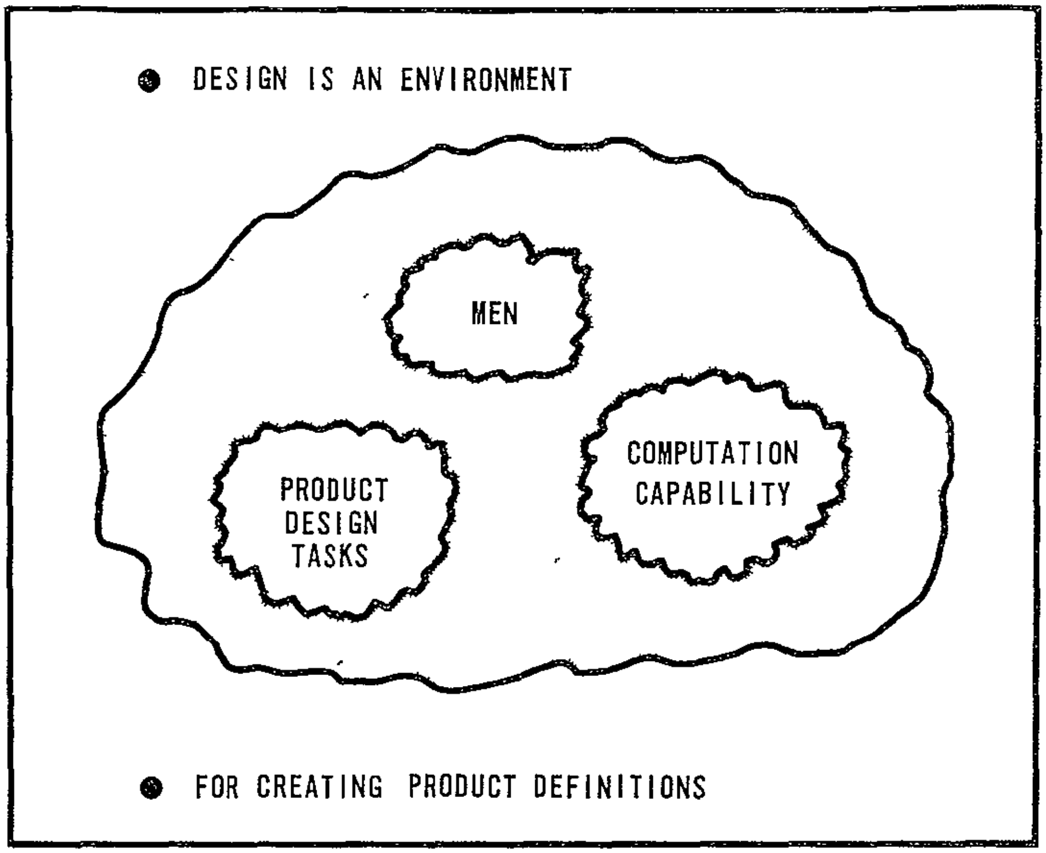


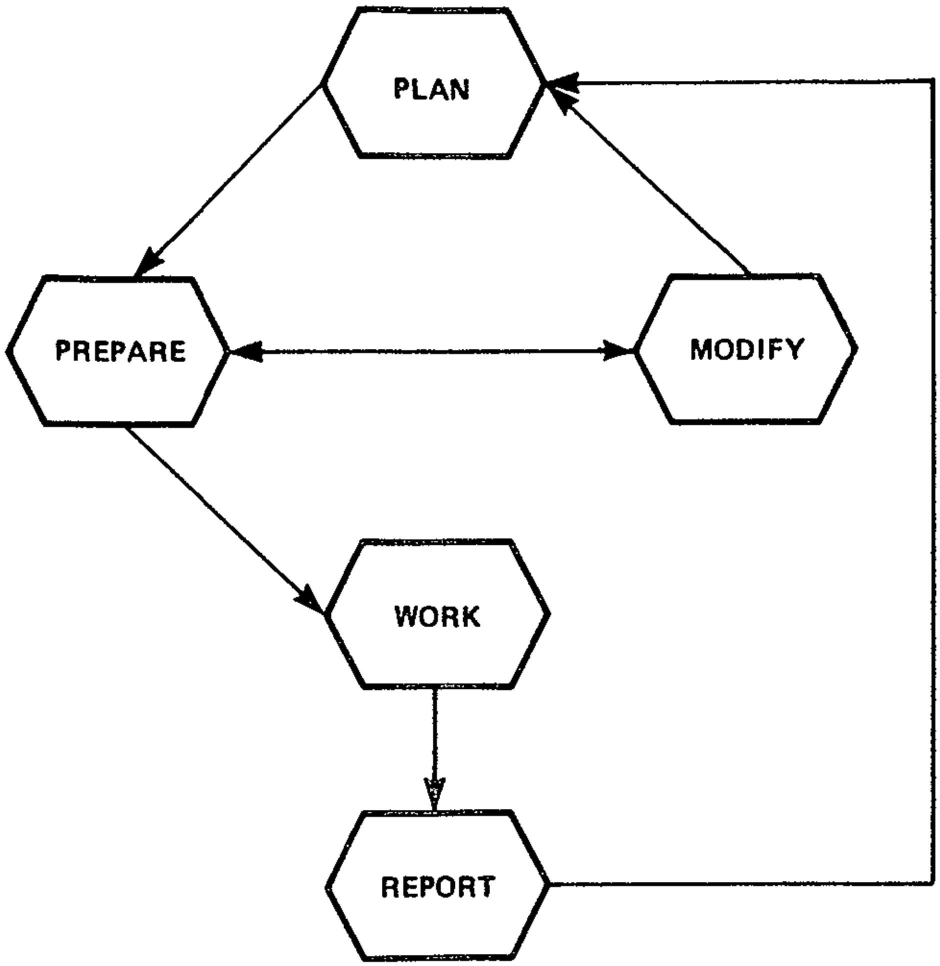
Figure 3.1 IPAD Study Basic Groundrule

		Design Stages			
	Function	State-of-the- Art Development & Definition	Match the Market Need with Product Potential	Product Design	Produce & Deliver Product
Management	Technical/ Engineering	Research	Preliminary Product Design	Convert Design to Released Engineering & Sales Support Data	Production & Sales Support Data
Management	Marketing	Market Studies	Customer Contacts	Sales	Sales
Management	Finance/Cost	Customer & Producers Resource Determination	Cost Data & Financial Viability	Cost Data	Cost Data
Management	Manufacturing	Manufacturing Research	Preliminary Manufacturing Capability & Cost Inputs	Tooling & Production Planning	Procurement, Fabrication, Assembly & Delivery
Management		Operational Data Base Collection	Servicability Input	Field Support Preparations	Supporting Delivered Products

Figure 3.2 Typical Functional Relationships to Design

		ATTRIBUTES		
OBJECTIVES	Design Quality	Accuracy (1) Consistent with product design stage.	Discipline Scope (1) Engineering analysis/design (2) Non-engineering	Product Development Stage (1) Span from research to product delivery
	Flexibility	Change (1) Ease of accommodation of new OM (2) Ease of OM adaptation/modification (3) Pre-existing code (4) Hardware and operating system software	Use (1) Input flexibility (2) Minimum constraints on problem formulation (3) Analysis/design process definition flexibility (4) Output flexibility	
	User Acceptance	User Community (1) Multiple user acceptance (2) Philosophy for transition to IPAD	Man-Machine Interface (1) Security and privacy of data and code (2) Dialogue mode	Reliability (1) Certified code (2) Documented
	Economy	Time (1) Reduce design cycle time (2) Reduce design convergence time (3) Reduce number of cycles (4) Reduce time for interdisciplinary interaction	Cost (1) Low cost interfaces to downstream systems (2) Low development cost (3) Low operating cost	Effort (1) Ease of access for processing a task (2) Automated design strategy assistance

Figure 3.3 IPAD System Design Objectives



PLAN The determination of objectives and constraints which define a desirable product and the development of a plan of activities to achieve these objectives within the constraints.

PREPARE Setting up to do work.

MODIFY Altering preparations to do work when it can be done without changing the plan. Generally, this is due to contingencies which are minor relative to the overall plan.

WORK The activity which aims directly towards completion of a meaningful step in the plan.

REPORT Recording and/or making visible the results of WORK and determining if the planned work is done.

Figure 3.4 General Work Flow Model

3.1 DESIGN PROCESS

The study of the design process is presented in Volume II. The philosophy of this study was to identify relationships between the activities in the development of a new product design. Broadly speaking, a product design evolves from corporate, technical and production activities.

The relationship between these activities and the phases required to develop a product are shown in figure 3.5. All of these activities have, in common, the requirement to control the development and communication of information. Design information, developed through a design process, is an end product of the technical activity. Thus, as shown in figure 3.5, the IPAD study focused on the technical activity.

The design process for the IPAD study was identified by studying the activities and information required in the design of both a subsonic and a supersonic commercial transport. For these case studies a generalized design process was identified. The major characteristics of this process are discussed in the following paragraphs.

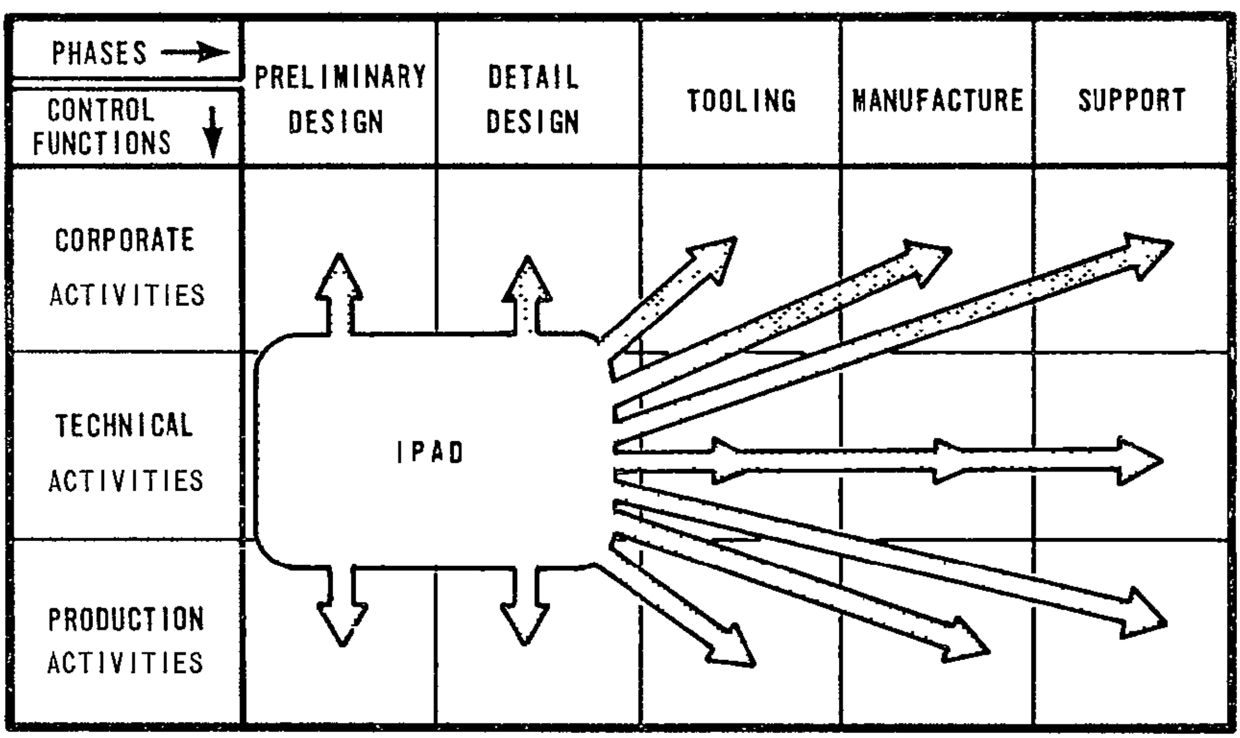


Figure 3.5 Product Development Activities

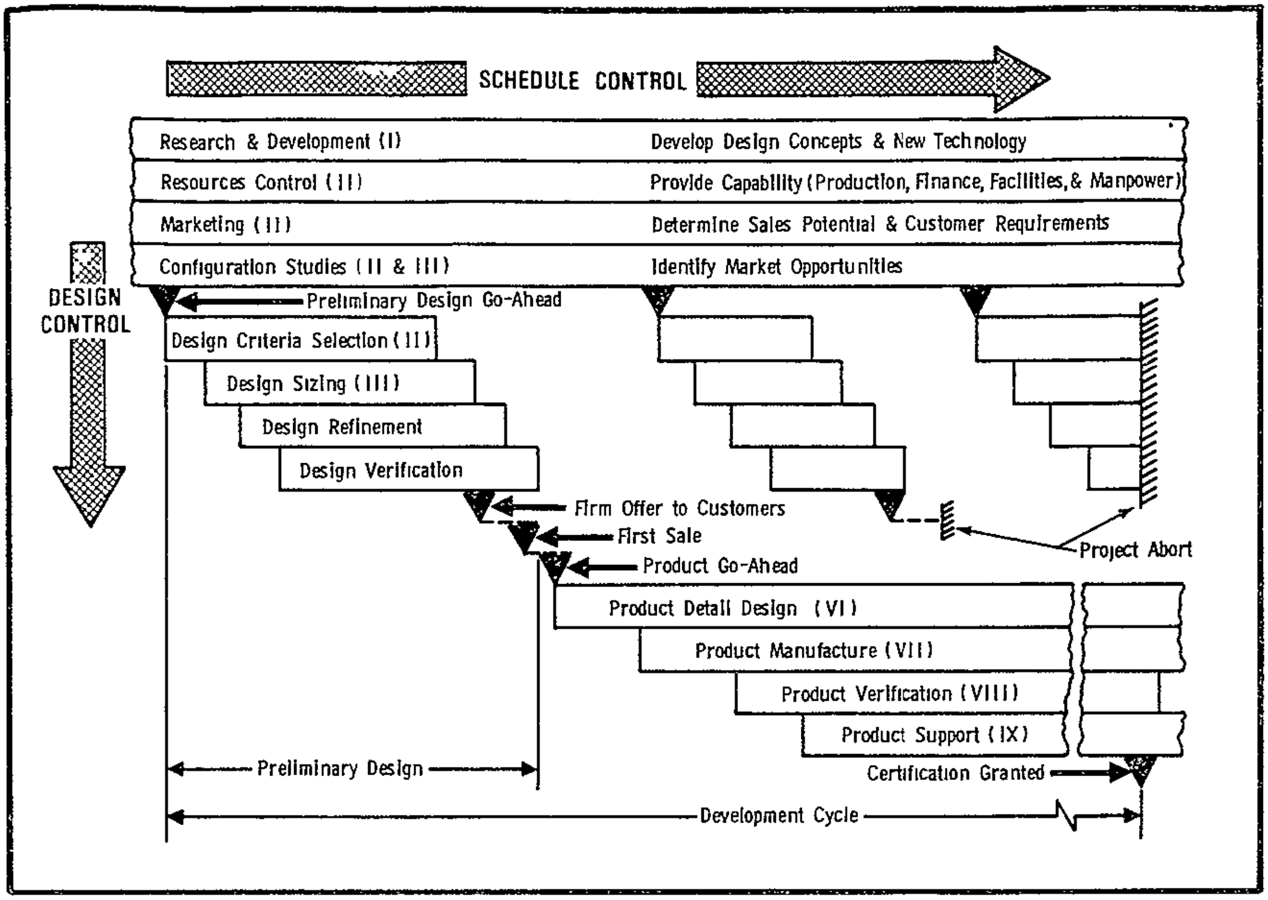


Figure 3.6 Development Cycle - Aerospace Product

3.1.1 Product Development Cycle

Figure 3.6 shows the major development activities of the product development cycle. The four continuous activities at the top are the continuous environment from which the product development originates. Research and development provide new design concepts and technology. Resource control provides manpower, facilities and finances. Marketing, finance and preliminary design make continuing studies of new products. Management will authorize a preliminary design effort when marketing studies identify a product with adequate sales potential to warrant further study. The process then enters several successive stages of design which lead to firm offers for the sale of the product. If sufficient sales response is generated, management will authorize detail design, manufacture, verification and support. A potential product may fail to survive the preliminary design process because of technical inadequacies or because of a poor assessment of the market potential.

The development cycle for a typical subsonic transport aircraft will require several years from preliminary design go-ahead through certification. The preliminary design phase will require 25% to 30% of the total development cycle time. More complex products, such as a supersonic transport or a space shuttle, may require a greater percentage of time for the preliminary design effort. To support these time related, highly flexible development processes, several levels of detail were identified.

3.1.2 Product Design Levels

Product design levels are to be interpreted only as a basis for study of the design process. They do not imply a rigid design process, either in current existence or proposed for IPAD. Some such process is always used to logically guide the work.

The basis for development of design levels was to relate the design process to the product development cycle. Thus, a group of time and information related activities were identified as shown in figure 3.6 and 3.7. Design levels were developed to include <u>phasing</u> which provides the required schedule (time) relationships; and increasing <u>depth</u> of design and analysis information which provides the required computing and engineering cost control relationships.

The characterization of the design process by levels provides a subdivision of the design environment. It was found that this division by levels is not product dependent for the aerospace class of product. The levels serve as a guide for planning man and computer involvement during the design. Hence, it was considered essential to include all design activities which could use computer support and to establish a relationship with all other activities which influence a product design such as marketing, finance, and manufacturing. The IPAD feasibility study, produced the generalized levels of figure 3.7. As shown, there are nine product levels divided into three sections.

The first section is comprised only of Level I, Continuing Research. This is research of a long-term nature that is done independent of IPAD. In the IPAD environment, this research activity will be continually monitored to provide new design procedures, technical analysis capabilities and to improve the technology data base.

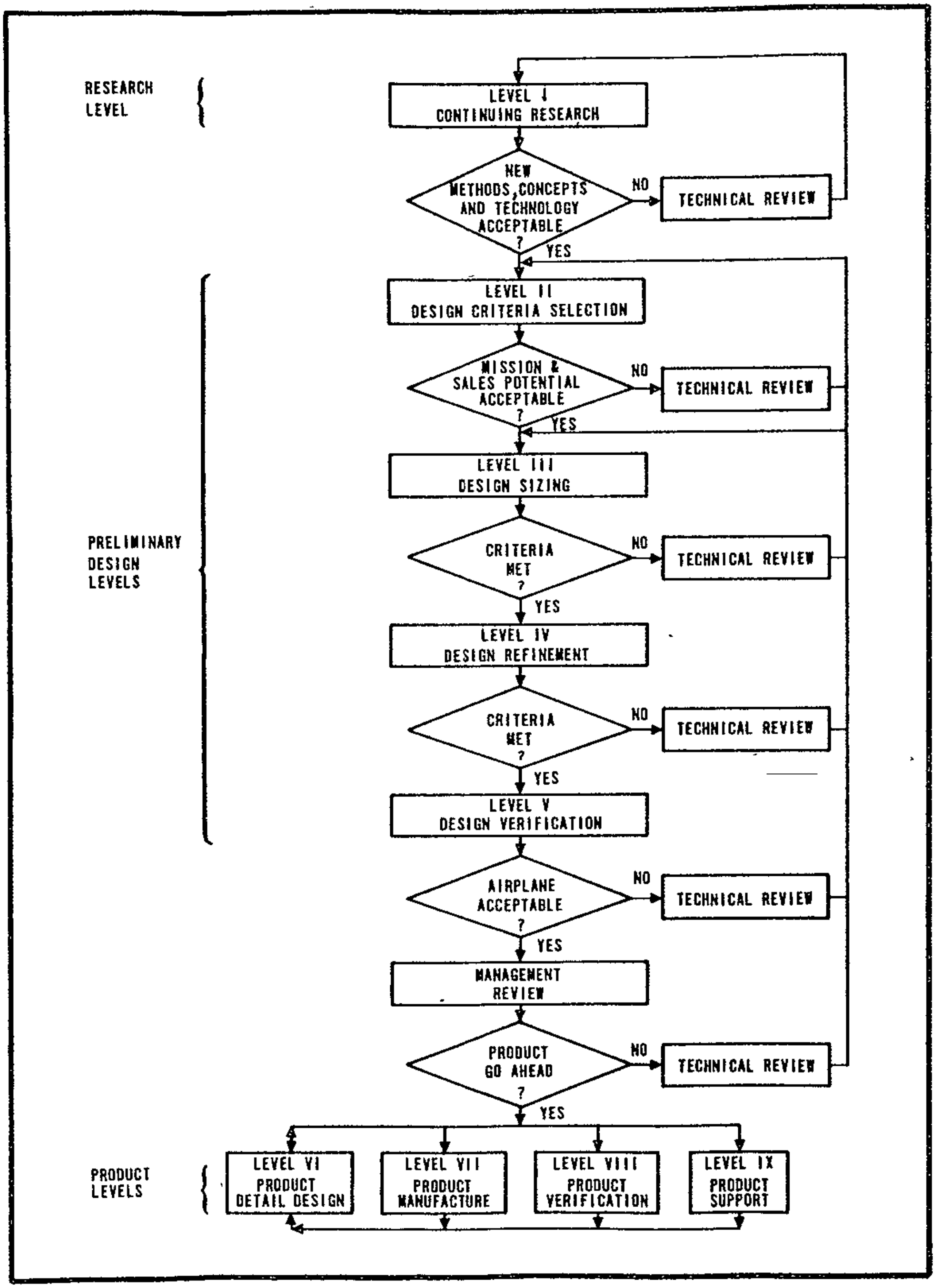


Figure 3.7 IPAD Product Design Levels

The preliminary design levels included in the second section are:

II Design Criteria Selection

III Design Sizing

V Design Verification

Control of the required engineering resources is the principal criterion for the establishment of these levels. Accordingly, the activities relating to preliminary design will be collected by types of activities and hierarchies of analysis capabilities to achieve the objective of meaningful design results in a usable time period. Thus a product design and consistent definition in a data base will be developed in a time sequence which is responsive to management technical and resource control. To further emphasize the time relationship, activities which require long flow times such as wind tunnel testing were placed in Level V. Using this concept a manager may develop very complete technical data on several configurations before selecting the specific configurations to be tested in the wind tunnel.

The four product levels are:

VI Detail Design

VII Manufacture

VIII Verification

IX In-Service Product Support

These levels are parallel activities that continue as required for the life of the product. Within each product level, sequential activities will occur and the control will be similar to the preliminary design levels.

3.1.3 Design Networks

The design networks developed for the case studies are presented in Volume II. They represent a formal effort to organize the entire design process into an identified set of tasks. For a subsonic and a supersonic commercial transport, the tasks were identified in detail for the preliminary design levels and the product levels.

For the preliminary design levels, the following generalized goals were considered for each case study:

- Determine market and design requirements;
- Size the product and determine its economics;

- Refine the design to increase the accuracy of the performance, weight and economic predictions;
- Verify the design with specific test data to increase confidence.

The tasks required to achieve these goals were identified for each of the four levels of preliminary design and a logical sequence of the tasks was developed within each level. An example of the detail of Level IV is shown in figure 3.8. In practice, the design tasks will be arbitrarily ordered and, in fact, interaction between levels is anticipated as may be logically required. Provisions were identified to loop on the sequence of tasks to achieve a converged design solution.

Technical and management reviews are identified in the networks to provide management control and review of design information which supports corporate evaluation activities and provides the interface with production activities.

For the product level studies, the design procedure was less formal and only a generalized description was developed.

For the subsonic and supersonic transport case studies, the capability to support the preliminary design level networks with computer programs was identified and a catalog of computer programs was prepared. Also, in a few sample cases, computer programs were identified for the product levels. The catalog of programs is presented in Volume V.

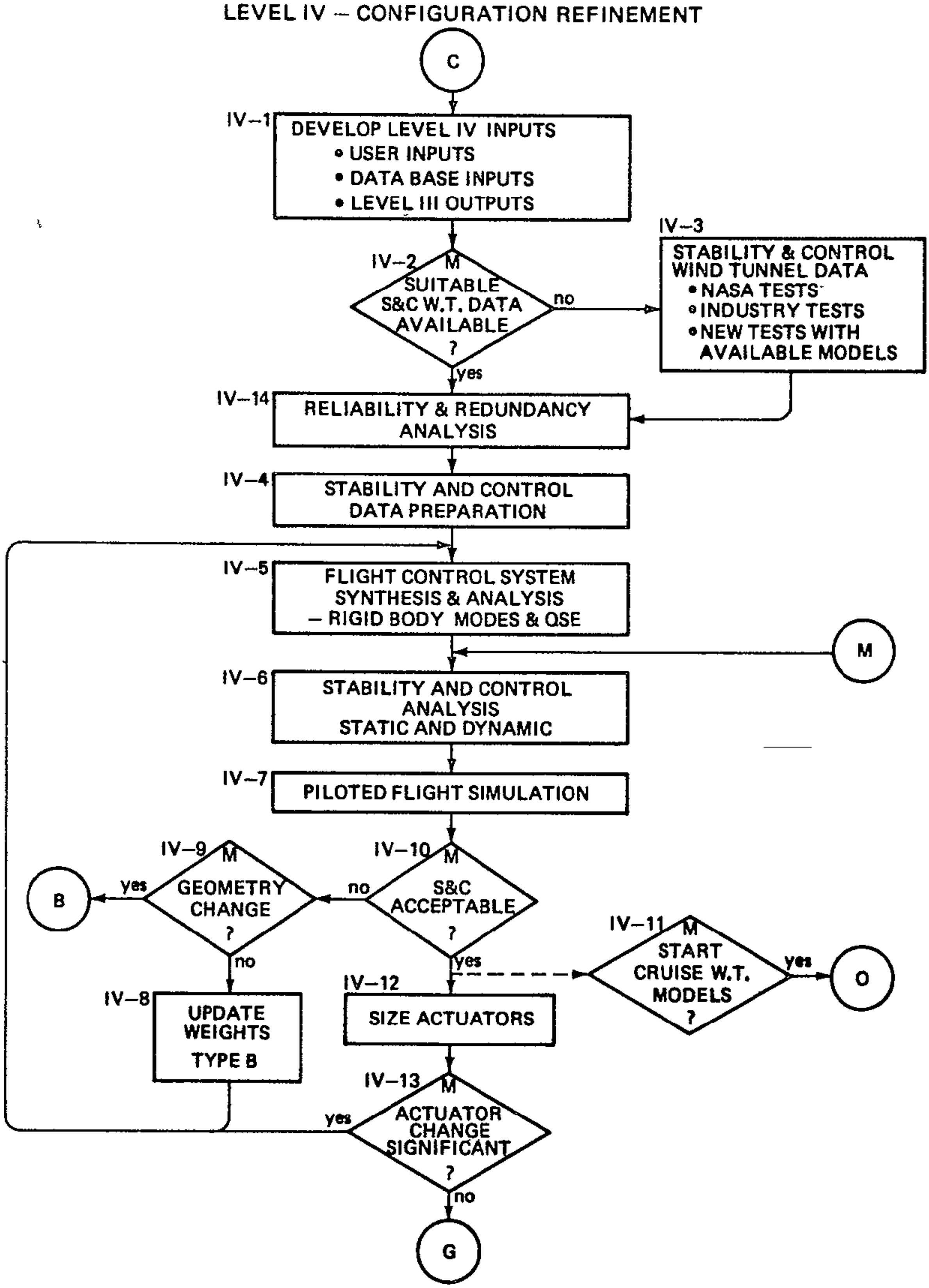


Figure 3.8 Design Networks – Supersonic Commercial Transport Case Study

3.2 IPAD SYSTEM DESIGN

The computer-based IPAD System design is presented in Volume IV. During the design of a product, information flows between people with varying interests, including those managing the work, those performing design work, and those providing tools for work. As illustrated in figure 3.9, the objective of work, at the level of the individual user, is to derive and display his information for decisions about the product design. In the IPAD System, the user works on subtasks. This individual subtask activity is the focal point of the IPAD System design.

The major elements of the IPAD System design in support of the subtask concept are:

- o Data Base
- o System Software

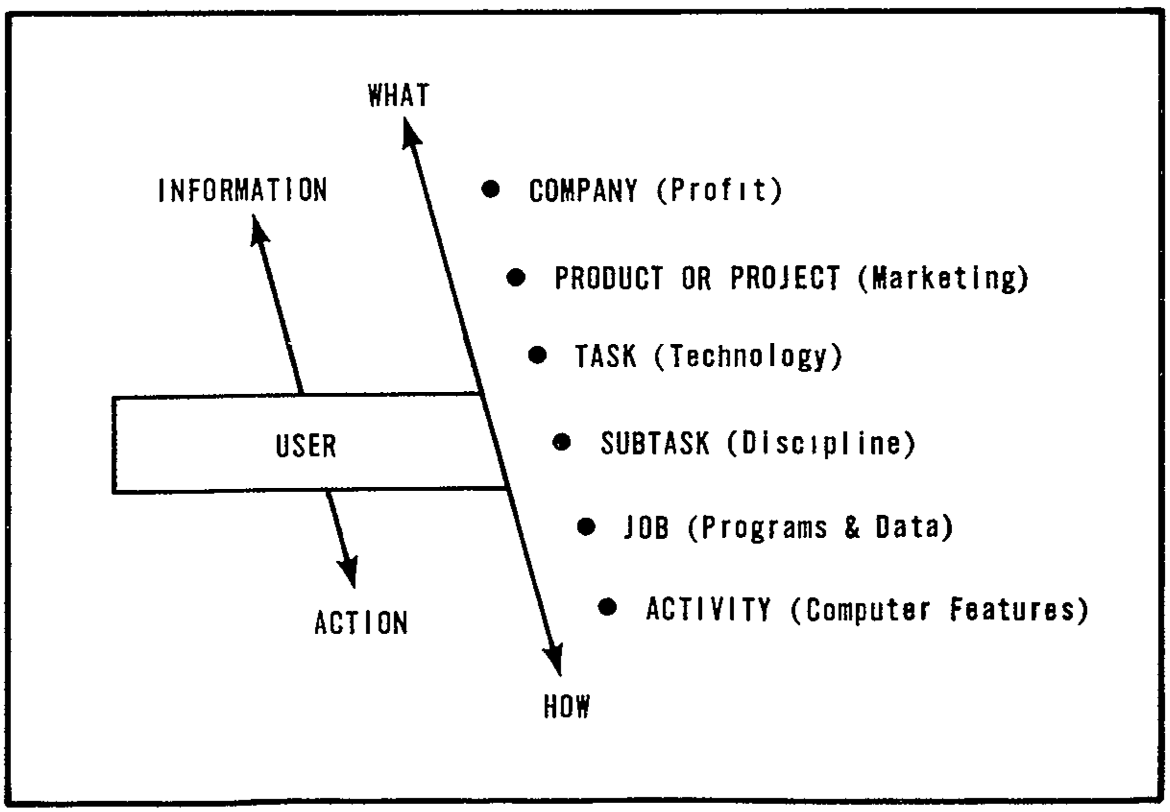


Figure 3.9 Hierarchy of Product Design

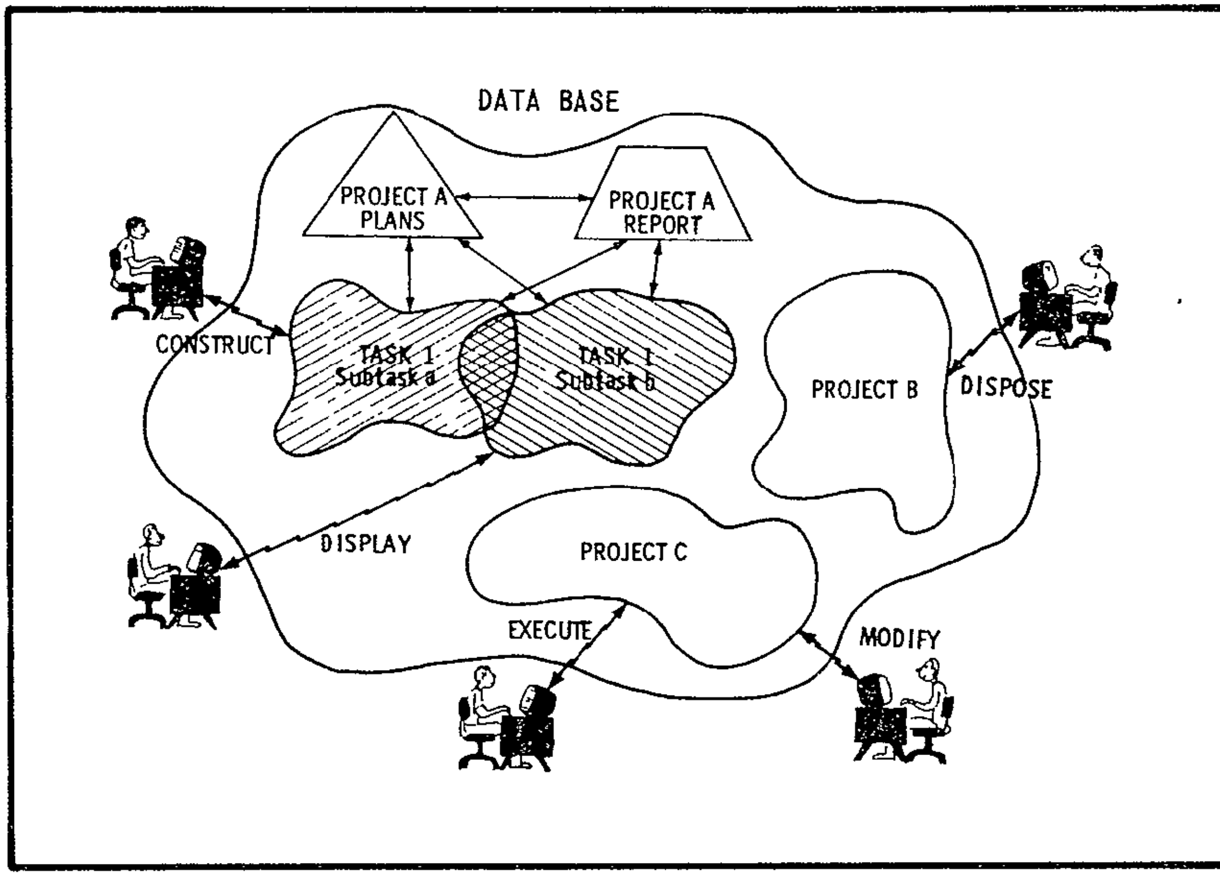


Figure 3.10 Data Base and Work Relationship in IPAD System Design

3.2.1 Data Base - Work Relationships

The data base supports the product design work relationships. These work relationships are illustrated in figure 3.10. The data base design recognizes that all work is initiated by individuals from a terminal-like device. These work functions include:

- o Construction of jobs, thru the assembly of code into executable sequences;
- o Planning subtask definitions;
- o Modification of technical code and data.

The data base design provides for multiple projects; multiple user access to a project; and overlap of data regions within and across projects.

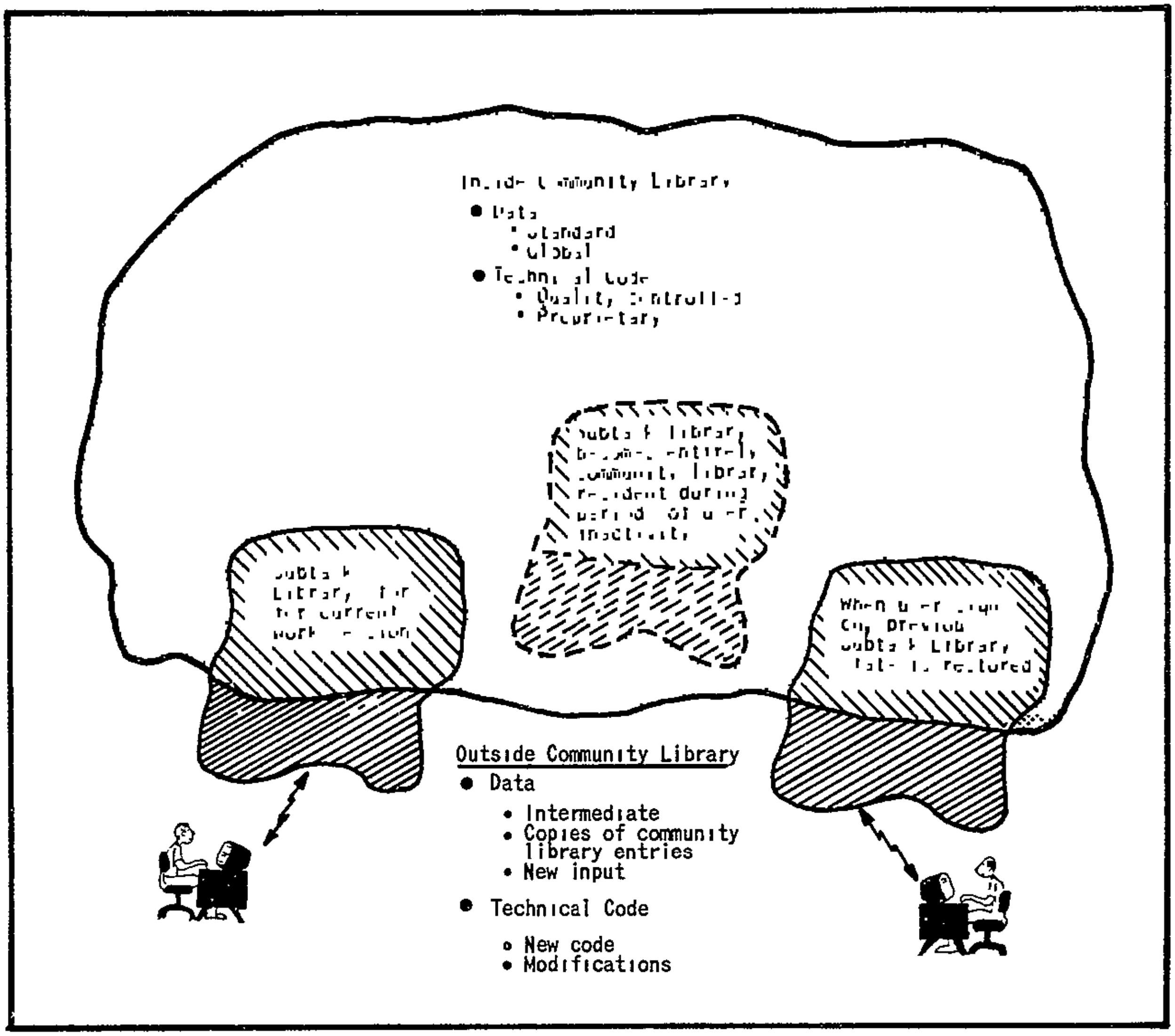


Figure 3.11 Data Base - Community and Subtask Libraries

3.2.2 Data Base - Library Concepts

The data base design supports, as shown in figure 3.11, both a community of users and individual users with a community library and a subtask library, respectively.

The community library contains all data and computer programs (technical code) and provides for communication between subtasks. The community library also contains inactive subtask libraries, in total, as well as portions of active subtask libraries.

The subtask library represents a user's current state of usage of data and programs. This library may have two regions:

1) A region private to the user subtask and not visible to other users;

2) A region of the community library associated with a user and his subtask library, which may also be shared with other users and their subtask library.

Provisions exist in the data base design to enable control of access to and usage of the data and code by the community library users.

IPAD recognizes that the engineering activity has a basic characteristic of continuity over task and time. Computer systems historically have been oriented to running single jobs which are unrelated to other jobs. Any association between various jobs over a period of time, or when being run simultaneously, was strictly the concern of the users. The records of the relationships were kept manually outside the domain of the computational work itself. This continuity requirement is specifically provided for by the community and subtask library concepts. As shown in figure 3.11, when a user temporarily interrupts his activity, his entire subtask library is copied into the community library, and is restored exactly when the user resumes work.

3.2.3 System Software - User Interface

The basic user interface device is assumed to be similar to today's interactive terminals. Figure 3.12 illustrates how the system design supports user terminal access to the IPAD System and its capabilities. The five modes in figure 3.12 represent different states of user activity.

Terminal Interface Mode--The user initiates a work session in this mode with passwords and log-on sequence.

Operating System Mode--The user initiates his IPAD work through IPAD log-on commands. In this case, his state moves to IPAD Executive Control. A user also initiates non-IPAD work in this state, such as host computer batch or time-shared work.

IPAD Executive Control Mode--In this mode, a user initiates IPAD work through subtask utility commands and controls work in progress.

IPAD Subtask Utilities Mode--Most subtask activity, such as executing code and working with the data base, are done in this mode. User interruptions to utility work with a pause command will move the user's state to the Interrupted IPAD Utilities Mode.

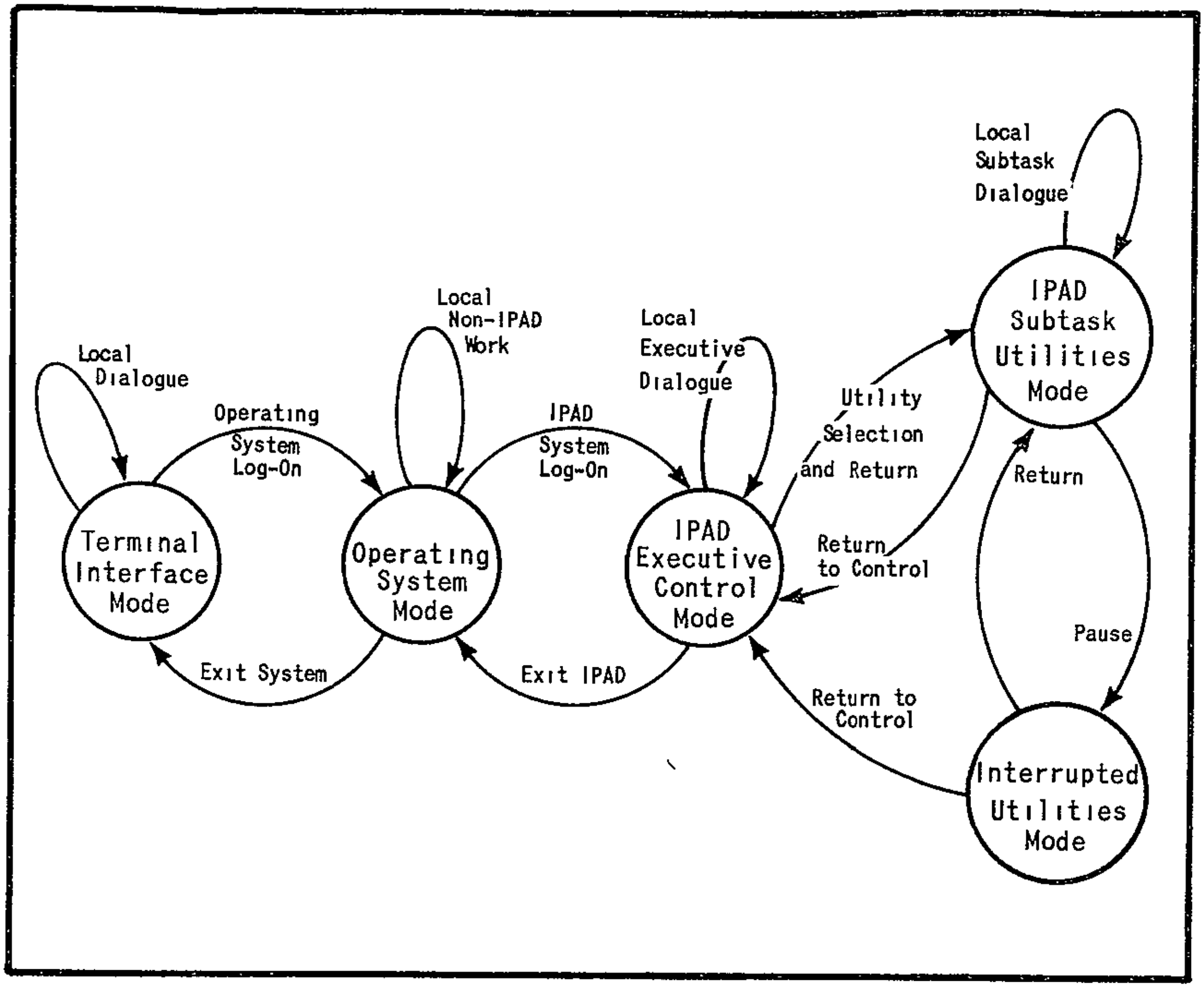


Figure 3.12 IPAD System Design - User Interface Functions

Interrupted IPAD Utilities Mode--This state supports a user's need to interrupt his work to perform other tasks such as correcting code and data, obtaining tutorial help, temporary log-off, etc.

Transitions from this state are either a return to the interrupted utility or to IPAD Executive Control. From IPAD Executive Control the user can continue his IPAD work or set up a sequence of commands that eventually terminates his work by signing off at the Terminal Interface.

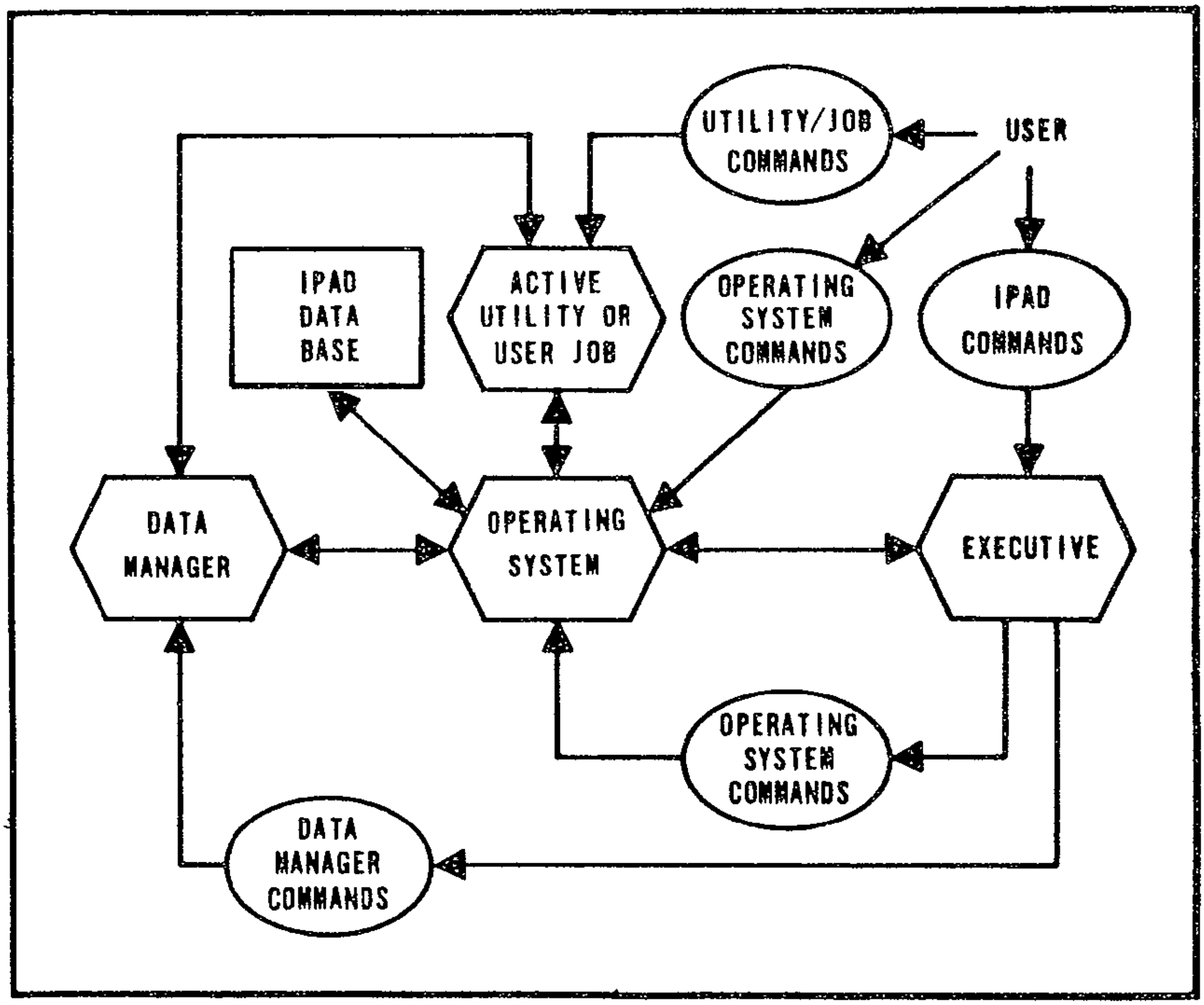


Figure 3.13 IPAD System Design - Command Flow

3.2.4 System Software - Organization

The organization of the software members and command flow in the IPAD system design are shown in figure 3.13. The major software members are:

- Executive
- Active Utility or Jobs
- Operating System
- Data Manager

The user's contact points with the IPAD System are the Executive, one of the IPAD Utilities or an Active Job.

Executive--The Executive software supports such user commands for subtask activities as setup, command mode, interruption, termination and abort.

Active Utility or Jobs--The Utility software enables the user to enter code/data, construct jobs composed of sequences of code, display results, edit code and data, etc. The user's Jobs are also software; the actual code which has been assembled to be passed to the Operating System.

Operating System--The host computer Operating System is the principal software element in finally carrying out commands. The Operating System will be relied upon to provide such basic needs as:

- o Terminal communications
- o Time sharing job handling
- o General job scheduling
- o Execution of object code
- o I/O device handling
- o Permanent file support

Data Manager--The Data Manager responds to commands from the Executive and Active Jobs by issuing appropriate commands to the Operating System. The Data Manager design supports:

- o Many simultaneous users;
- o Each user will have access to his copy of the Data Manager so as to avoid simultaneous user conflicts and to separate the Data Manager software from the Operating System;
- o Hierarchy of storage devices which provide for a spectrum of storage from real time to archive;
- o Acceptance of user defined data structures.

Data has a particular format or structure. User defined data structures are a consequence of the absolute need to transfer such data between technical code modules that were not originally constructed to accept and transfer information from each other. Not all data structures will be known in advance.

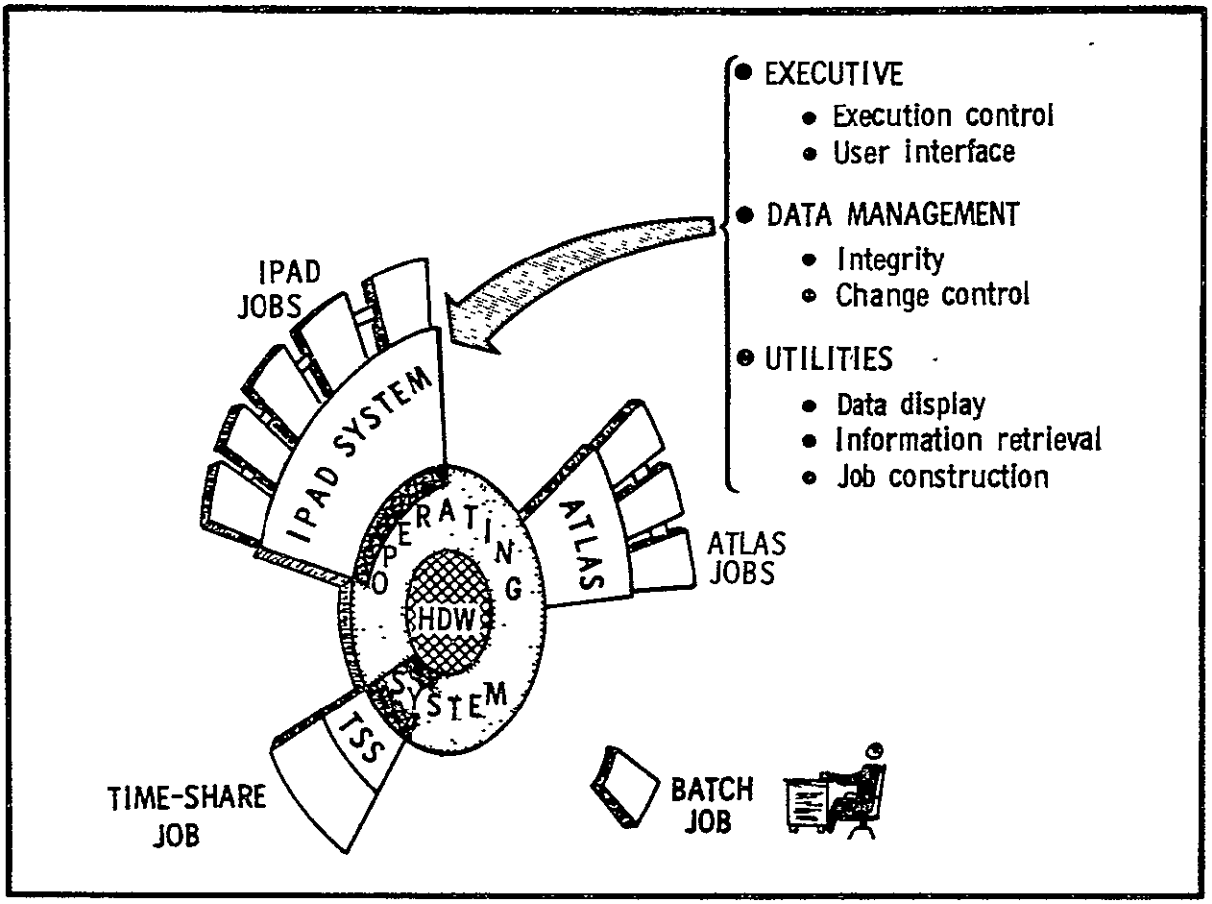


Figure 3.14 IPAD System/Operating System Interface

There are a large body of users, with rapidly changing system and engineering technology which precludes designing the Data Manager to rigid data structures. Therefore the IPAD Data Manager design utilizes the concept of a stored data definition. Using a stored data definition, each data structure (format) in the libraries will be formally described by the user so that reformatting of data sets may be handled automatically in the ideal case, semi-automatically in some cases, and manually in others.

IPAD System Software - Relationships to Others--The IPAD System software is designed to be functionally just one of many softwares that interact with the host operating system.

Figure 3.14 illustrates that there are many concurrent ways (or modes) that the user on the periphery utilizes the host computer.

- o Batch Jobs - the user submits work (jobs) which must be directly acceptable by the Operating System.

- o Time-Shared Jobs - the user is assisted beyond the batch job mode by time share software elements of the operating system. These elements provide for some general user interface requirements like computer interactive responsiveness for editing and entering work, decentralized system interface using low grade telephone communication and low cost terminal devices.

- o ATLAS-type Jobs - the user is assisted beyond the batch and time-shared mode by specialized software that provides automated module interface and by problem oriented languages.

- o IPAD System and Jobs - the host computer operating system must be modified to support the day-to-day work continuity requirements of the IPAD System. The IPAD System design minimizes the impact on the operating system to allow maximum portability.

As discussed previously, the IPAD System is designed to continue the evolutionary trend of enriching the engineering problem solving environment. However, the IPAD System is designed to co-exist with other software and in no way affects the non-IPAD user.

3.3 IPAD BENEFITS, IMPACTS AND SPINOFF

The benefits, impact and spinoff which may result from development of an IPAD System are presented in Volume VII. They have been identified from the IPAD study and from research in related fields.

3.3.1 Benefits

The primary benefit of IPAD will be increased productivity of the designer. This increase will result from the utilization of system software and design methods that require less flowtime and labor cost, extend the technical scope of current methods, or improve the opportunity for creativity. An evaluation of the potential benefits of IPAD was made through an analysis of time and labor utilization; an evaluation of flowtime and cost savings; the affect upon company effectiveness; and a projection of IPAD as a national resource.

Time and Labor Utilization--All design activity can be placed in one of the following categories:

- o Routine information exchange, data preparation, and calculations,
- o Judgmental procedure development and results evaluation.

A flowtime and labor analysis of Level III of the design process was made for the current system of batch standalone computer programs and noncomputer-aided information exchange. A comparison was then made with an integrated system. The results, as shown in figure 3.15, are:

- o Man-weeks are reduced to 20%,
- o Significant redistribution of time spent in the routine and judgmental activities,
- o Significant redistribution of activity between analysis and design, principally resulting from the increased computational power given to the designer.

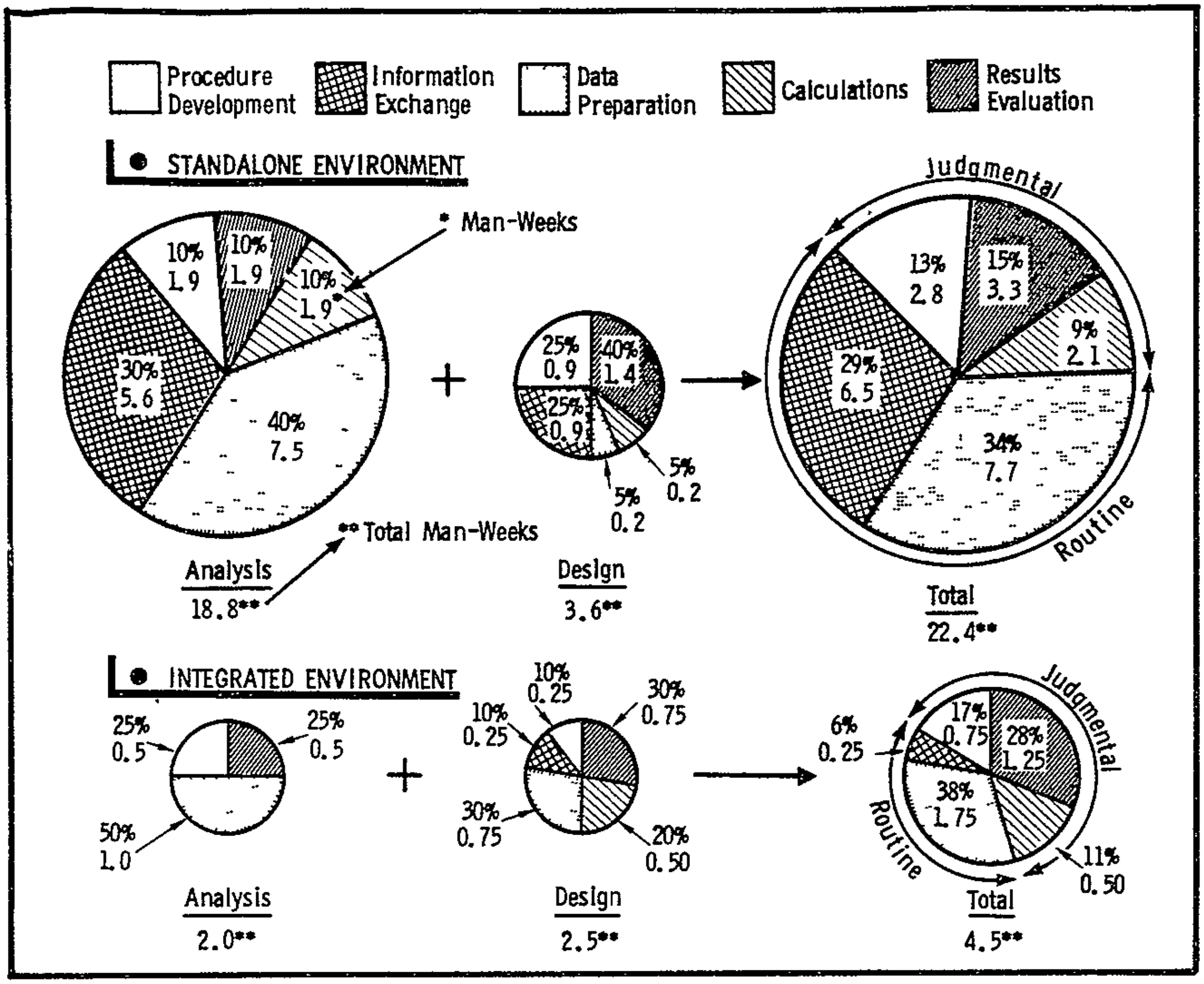


Figure 3.15 IPAD Level III, Subsonic Transport, Division of Effort

Flowtime and Cost Savings--The flowtime and labor cost savings being experienced in the usage of current systems on widely different problems was investigated. The results are summarized below:

System	Cost Saving	Flowtime Saving
NSRDC ISDC		90%
Lockheed CADAM (electrical)	78%	80%
Boeing CPDS	80%	67%
Boeing ATLAS	50%	50%
Lockheed CADAM (floor beams)	62%	46%
Lockheed CADAM (bulkheads)	33%	25%
Adequate Computational Devices	20%	

Existing systems have gained their effectiveness by automating or computer-aiding information handling at the interfaces between computer programs. IPAD will increase effectiveness by providing an information handling environment especially compatible with the day-to-day continuity required in the design organization. Hence, the cost and flowtime savings being experienced with existing systems on small tasks can be feasibly obtained, for the company as a whole, using a suitable IPAD System.

Company Effectiveness--Company benefits from the potential flowtime and cost savings from IPAD depend on how management elects to reinvest them. The following are some of the options:

- o Direct flowtime and labor cost savings. Management may elect to reduce labor costs and shorten product development schedules. An estimation of the magnitude of savings is given in figure 3.16 where flowtime and cost savings being experienced with current systems are extrapolated to a larger design organization.
- o Reduction of risk. Management may elect to reinvest savings into improved product design in order to reduce their risk.
- o On-time design. Potential cost savings downstream from product design may be realized as shown in figure 3.17. Typical cost reductions in this area are reduced tooling changes and reduced retrofitting of manufactured aircraft by elimination of late or inadequate engineering design.

SYSTEM	MANAGEMENT ABOVE FIRST LINE	TECHNICAL JUDGEMENT	TECHNICAL ROUTINE	TOTAL DOLLARS	FLOWTIME
Standalone Batch	6%	34%	60%	100%	100%
	$1,800,000	$10,200,000	$18,000,000	$30,000,000	
Multiple Devices	7%	34%	59%	81%	
	$1,800,000	$8,160,000	$14,400,000	$24,360,000	
CPDS	14%	65%	21%	42%	33%
	$1,800,000	$8,160,000	$3,600,000	$12,480,000	
ISDS					10%
ATLAS	9%	43%	48%	63%	50%
	$1,800,000	$8,160,000	$9,000,000	$18,960,000	
CADAM (Bulkheads)	8%	34%	58%	79%	75%
	$1,800,000	$8,160,000	$13,900,000	$23,860,000	
CADAM (Floor beams)	10%	49%	41%	56%	54%
	$1,800,000	$8,160,000	$6,830,000	$16,810,000	
CADAM (Electrical)	13%	59%	28%	46%	20%
	$1,800,000	$8,160,000	$3,960,000	$13,920,000	

* All dollar values figured on basis of 2000 men, $15,000 per manyear

Figure 3.16 Potential Annual Relative Labor Cost and Flowtime Using IPAD Technology

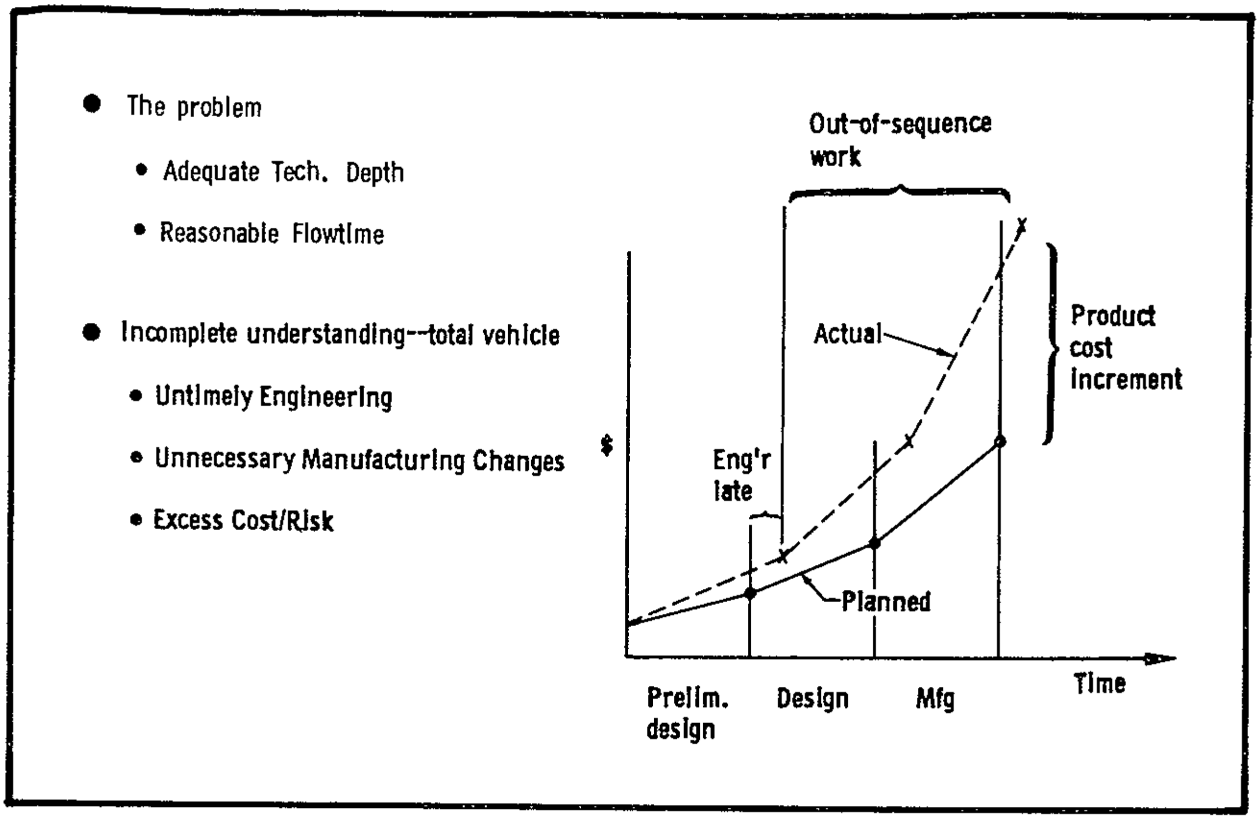


Figure 3.17 Downstream Effects of Late Engineering Design

<u>IPAD as a National Resource</u>--The benefits of IPAD will accumulate at the national level as:

- o Increased competitiveness of United States industry in the international market place;
- o Stimulation of information technology development;
- o Utilization of IPAD to increase the effectiveness of government procurement procedures.

3.3.2 Impact

The developing concept of the computer as an information converter, processor, and library is resulting in an information technology. IPAD is essentially information technology. The primary impact will be:

- o Acceptance of computerized information handling as opposed to manual handling;

- o A trend towards centralization in task and organizational structure with its corresponding impact on people.

Acceptance--The principal factors motivating the acceptance of IPAD are competition, contract requirements and directives. Internal inertia such as lack of skill, current method success and current resources, work against acceptance.

Impact on People--Changes in task structure will require different forms and levels of individual initiative. New standards of work performance will emerge consistent with the change in task structure and the requirements of information technology.

Individuals will make new identifications with the product and with the changed objectives of their immediate organization. These identifications will be of two forms:

1) Where activities are automated and centralized, individuals will have reduced identification with the company product. The demand for professional people in these organizations will diminish.

2) Where activities are broadened in scope, individuals will have an improved identification with the company product. Professional people will tend to seek out these organizations.

The introduction of centralized information in data banks will increase the span of control for those managing this information. It will also increase the opportunity for communication, creativity and innovation by those accessing the information.

The eventual impact of information technology upon people will depend largely upon how it is managed within individual organizations. Like all fundamental developments, its effect can be either motivating or oppressive.

3.3.3 Spinoff

The spinoff from IPAD aerospace technology will impact two areas.

1) Direct use of IPAD system and technical elements. Many of the system features such as data management, executive, some utilities, and many technical elements will have direct application outside the aerospace industry.

2) Motivate similar technical advances. The presence of IPAD will generally motivate advances in industrial design environment, computing technology applications and engineering design methodology.

3.4 IPAD SYSTEM IMPLEMENTATION

3.4.1 Strategy

The IPAD system design implementation is build around a strategy which recognizes three principal factors: (fig. 3.18)

- o Development Environment
- o NASA (langley) Usage
- o Industry Usage

The development environment provides for a phased effort which produces an initial IPAD System in about four years with two plans for implementing the complete IPAD system design as described in Volume VI.

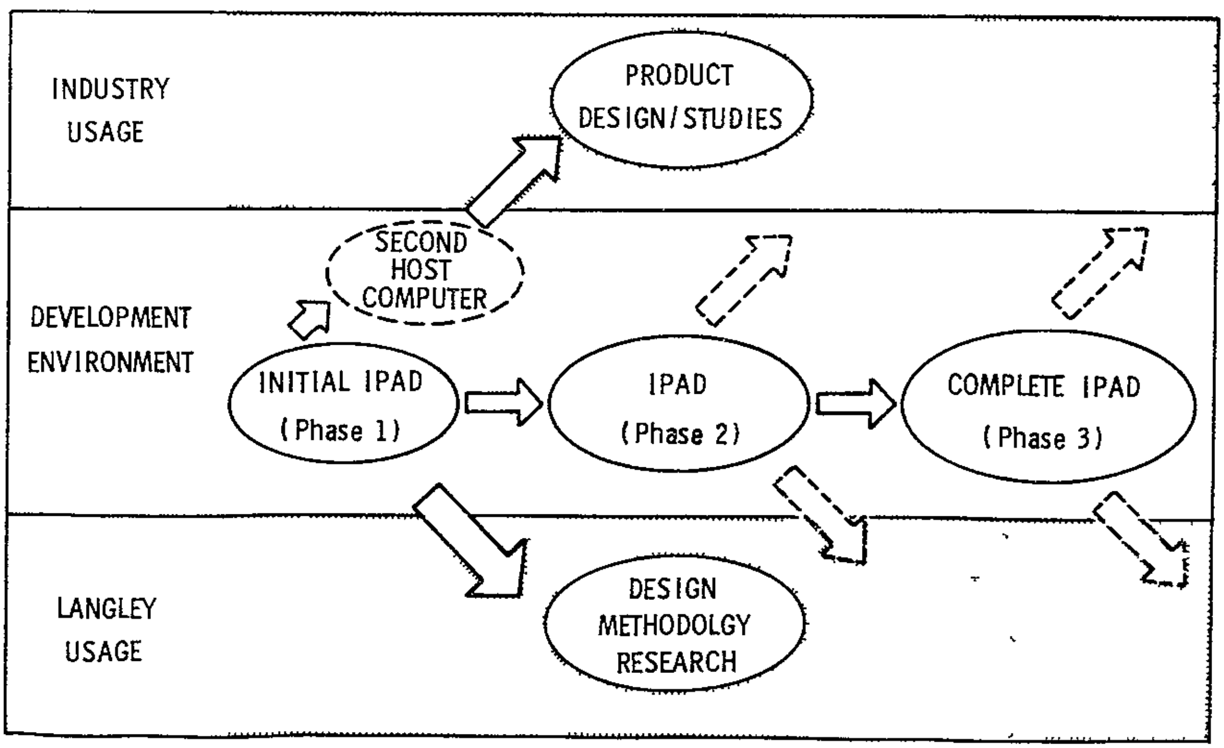


Figure 3.18 IPAD Implementation Strategy

The initial system capability provided in phase 1 includes software for continuity of day-to-day activities, entering programs and data into data base, constructing jobs, executing jobs, modifying programs and data, and displaying data base contents.

Enrichments to the IPAD system software in phases 2 and 3 will be in the areas of project management aided by computer stored plans, privacy/security protection in data base, interactive graphics, specialized interactive commands, expanded utility functions.

The product design capability that is proposed will provide for preliminary design sizing of subsonic transport Levels II and III and supersonic transport Level II and part of Level III. In addition an initial capability will be provided to do interactive detail part design including a data interface between IPAD and the automated functions in manufacturing (CAM).

The IPAD System development environment will provide, at Langley Research Center, the baseline from which both usage by NASA, and usage by industry can begin at the end of Phase 1.

This strategy recognizes that even though the initial IPAD is expected to be implemented for NASA at the Langley Research Center, implementation on a second host may be desirable near the end of Phase 1 to accommodate particular industry interests.

3.4.2 Development

The IPAD capability offers a significant improvement in engineering computing. Consequently, its implementation will require a significant development period. Therefore the proposed development plan is in three phases. The delivery of some useful initial capability early in the total plan permits the major innovative concepts to be available for early evaluation and can provide feedback for the later development stages.

Two plans for development of the IPAD System design are proposed.

Plan 1 (fig. 3.19) indicates an approximate nine year development period to produce the complete IPAD System design described in Volume IV. This alternate provides:

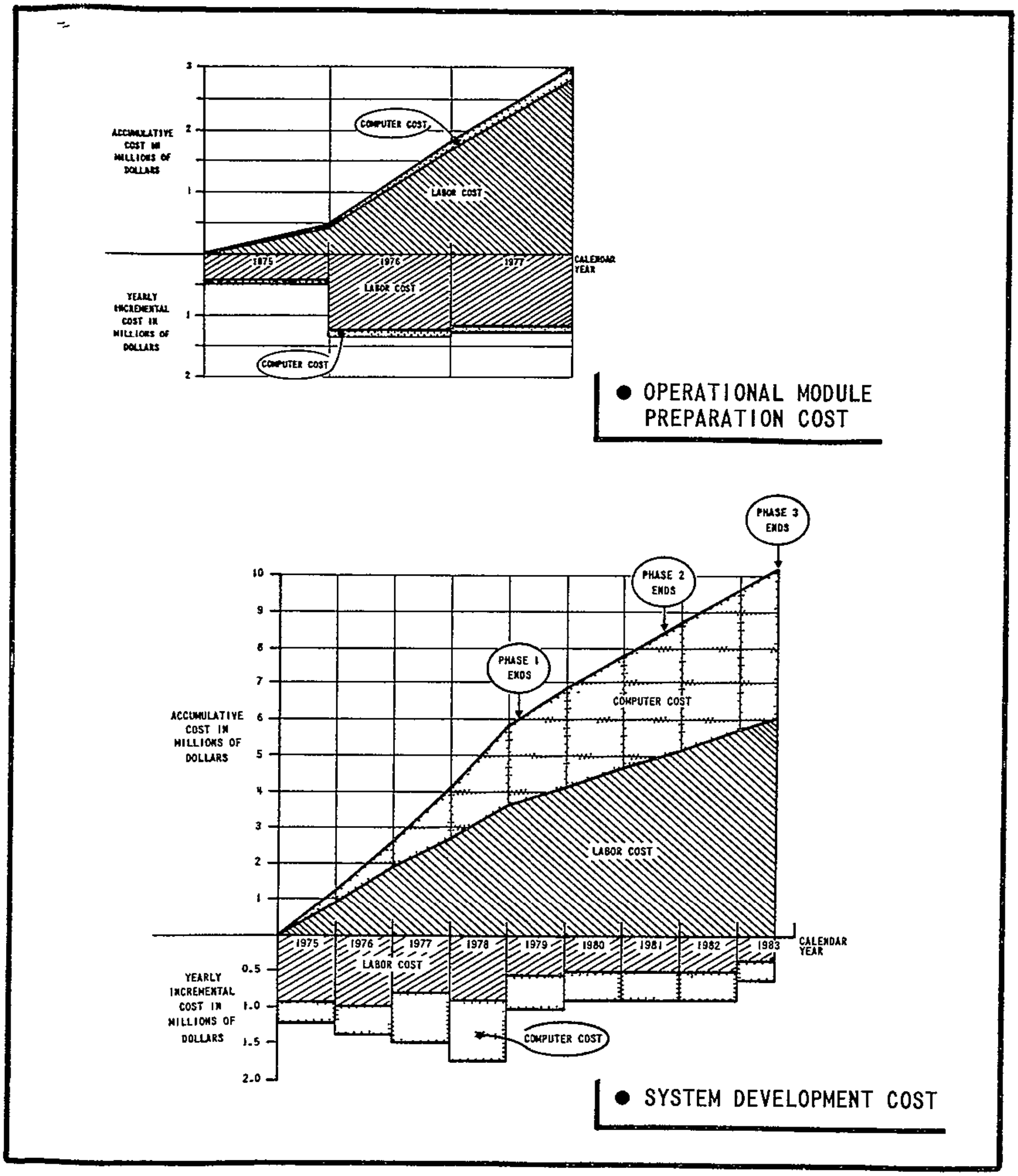


Figure 3.19 IPAD Development Costs and Schedules Summary - Plan I

- No overlap of the development phases,
- Maximum opportunity for feedback to Phases 2 and 3 from NASA or industry usage,
- A significantly lower yearly cash flow.

The major development events, together with estimated costs and schedules for plan 1 are given in figure 3.19. The OM costs are separated from the system costs since the degree of OM development is still arbitrary. The OM costs assume certain existing modules available from the government and new modules to be contracted.

During Phase 1 development, the complete IPAD System design is produced and the Phase 1 subset of the system design is coded. This Phase 1 system subset is the minimum IPAD System capability required to support the air vehicle product design process through the automation of the major portions of the routine information handling functions. The executive and data management function, as discussed in section 3.2, form the backbone of this Phase 1 development. In Phases 2 and 3 additional system capability will be added. The OM capability at Phase 1 will be limited to Levels II and III. In later phases this will be increased to more levels and broader product support.

The major system development events, estimated costs and schedule for plan 2 are given in figure 3.20. In plan 2, some degree of overlap of the phases is proposed to achieve a minimum development time to produce the complete IPAD System design. As a consequence there are:

- Markedly higher yearly cash flows than plan 1,
- Anticipated extra costs due to the potential for re-doing work as the overlapped work produces technical conflicts.

3.4.3 NASA (Langley Research Center) Usage

NASA usage will be initially founded upon the development and implementation of IPAD at the Langley Research Center.

This is expected to provide a focal point installation which can accommodate IPAD exploratory activities by government organizations and provide a nucleus effort in design methodology research.

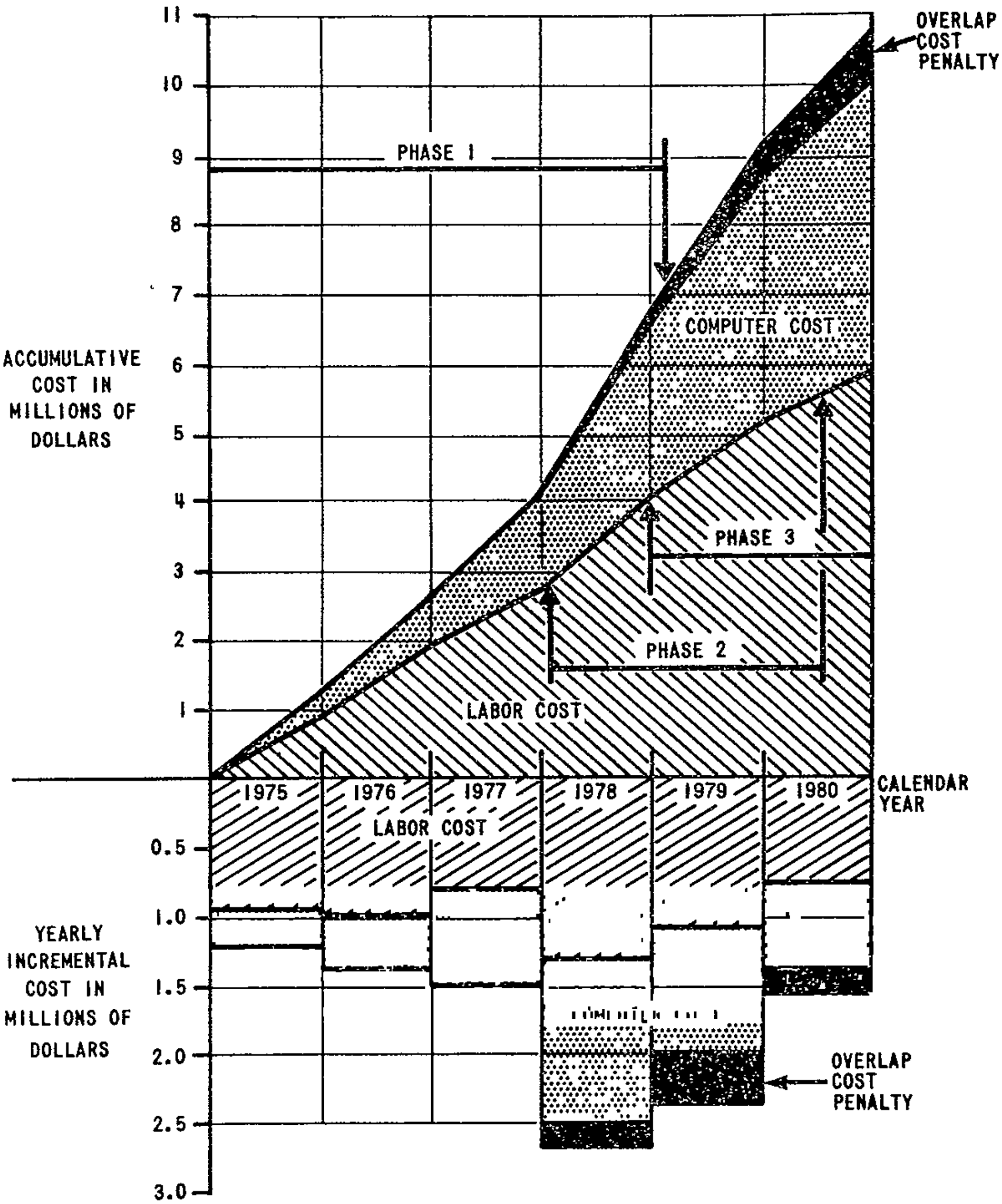


Figure 3.20 IPAD System Development Costs and Schedules - Plan 2

Design methodology research is at a pioneering stage. During the IPAD Feasibility Study, it became painfully clear that if the "Design Process" was to be discussed it would be necessary to:

- o Create a visual representation of the design process (Design Networks - Vol. II);
- o Create a vocabulary for discussing the design process (Design Levels and Activities - Vol. II).

This activity required gathering in one place those technical specialists and managers spanning the vehicle design functions. This activity produced the design process representation and vocabulary. It also created an awareness of what each speciality does and how they do it to achieve a composite design goal.

Such activity as described above is expected to be continued, especially as the IPAD System and design capability evolve. With the completion of Phase 1, both industry and NASA will be equipped to conduct design studies and research.

3.4.4 IPAD Technology Transfer to Industry

Formulation of additional contracted effort will parallel the Phase 1 development. These contracted efforts are aimed at transferring the IPAD technology into industrial organizations. These efforts are expected to be specific government contracted studies which require use and evaluation of IPAD within selected industrial organizations.

To achieve this technology transfer:

- o NASA is expected to issue RFPs for design studies using IPAD and installing the IPAD System software at the sites of successful contractors.
- o Contractors are expected to use IPAD with their technical modules, propose design studies and deliver evaluation reports.
- o The results expected are the establishment of IPAD industry technical/economic value, positive transfer to industry, and early contractor experience with IPAD.

The Phase 1 development has been planned to accommodate both primary implementation at Langley Research Center as well as implementation on a second type host computer. Implementation on a second host could begin approximately halfway into Phase 1 and be completed prior to the end of Phase 1. The added costs for a second type host implementation are shown in figure 3.21.

These additional costs assume the same system and OMs as implemented in the Phase 1 baseline implementation at Langley Research Center. The principal effort is related to OM conversion to second host, system implementation of host dependent software, (i.e., operating system modifications, etc.) and finally, OM system checkout and integration.

	Code and Certify System	OM Conversion	System/OM Integration	Total
Computing	$940,800	$30,000	$925,600	$1,896,400
Labor	$983,000	$500,000	$983,700	$2,466,700
Total	$1,923,800	$530,000	$1,909,300	$4,363,100

Figure 3.21 Additional Implementation Costs - Phase I
Second Type Host Computer

4.0 SUMMARY OF FINDINGS

The preceding sections have presented the IPAD study as it was conducted. In the following a summary of the principal findings is presented.

4.1 DESIGN PROCESS

Most product design tasks which require calculated data should be part of IPAD. A balance between computing time (cost), schedules and required depth in technical design can be obtained by dividing the total technical problem into levels or task hierarchies.

The product design case studies have provided information for the specification of generalized IPAD System requirements. These begin with the requirement that the user be able to easily build, execute and control during execution the particular code sequence chosen to perform his task. The system must also support a large number of users, each working on a part of a design project. The code used in the job sequence and the data used as input must have integrity. This integrity will be established by tracking the history of both code and data and protecting them against unrecorded change and unauthorized destruction. The system must provide for continuity of the data base growth over the tasks involved in the product design, and over the time required to do the design. The principal operating mode will be the personal user terminal, however, the batch job process will still be allowed and will have available all the features of the IPAD System capabilities.

Data display capabilities in IPAD are of primary importance for the user and the managers. Provisions to collect and display information for the management evaluation process are required. This information includes such items as design plans, design status and cost performance reports.

4.2 IPAD SYSTEM DESIGN

The IPAD system design necessary to support the product design process is primarily an augmentation to current computer operating systems. Information continuity over task and time is the basic missing capability which the IPAD system design must supply. Without this added dimension of support to the engineering community, the computing system cannot in any full sense provide the capability for integration of design tasks.

The system design will provide a framework in which the engineering project management may more efficiently plan, control and communicate the design information. In a similar manner the system will support the technical user's needs to more efficiently and reliably:

- o Insert new data,
- o Construct and execute his required program sequences,
- o Interrogate and display results during the life of the project.

The system design is purposely not biased to a particular product design process or management procedures, although it recognizes that specific methods for both activities must be supported with computerized tools.

4.3 BENEFITS, IMPACT, SPINOFF

The primary benefit of IPAD technology will be reduction in task flowtime and labor costs resulting from the automation of routine information handling which is currently performed by analysts/designers/managers. The availability of new cost/time resources and flowtime will give management the option of (1) retaining the savings, (2) investing the savings selectively in more thorough design, reducing risk and increasing competitiveness, or (3) investing the savings in design innovations thus providing additional marketing opportunities. The potential savings available are in the order of millions of dollars per year for a 2000 man design organization, trained in and actively using IPAD concepts.

The impact trend will be towards skill and function changes and task and organizational structures that improve the ability of individuals to contribute to the overall objectives of the organization. Some dislocations of personnel will occur as the evolutionary changes take place, however, the overall acceptance of IPAD technology will be enthusiastic as the benefits become visible.

IPAD System technology deals basically with the routine information handling characteristics of an organization. Hence, the system technology of IPAD will be useful to organizations outside aerospace either through direct use of the software developed or as a guideline for their own development. Since IPAD is basically an extension of the operating system of a computer, it is forseeable that it will be made available on commercial computing networks.

4.4 IPAD SYSTEM DEVELOPMENT PLAN

The IPAD development plan focuses primarily on producing a baseline capability to be further developed and exploited in other areas of government and industry. The baseline capability will include the complete system software and a specific set of operational modules. This capability is to be developed in three distinct phases, with the first phase delivered in 50 months at a cost of about 6 million dollars. Concurrent with this development, a contracted effort is proposed to facilitate the transfer of the IPAD technology to additional user communities.

5.0 CONCLUSIONS

It is concluded from the study that:

1. It is feasible to significantly reduce cost and flowtime in the product design process. If new plateaus of productivity are to be attained, then a computer-based system is required which recognizes the central role of the individual designer and his tasks.

2. It is feasible to design a computer-based IPAD System. Such a system should be time-shared, interactive, and terminal oriented. Significant advances in executive and data manager software are required and feasible to provide. The current third generation large computers are suitable hosts for an IPAD System, however, fourth generation computers will eventually be required to provide the large volumes of rapid access storage and the support of hundreds of terminals.

3. The current technical analysis programs (OM) are a feasible base upon which to build an air vehicle design capability. However, additional significant development is required to augment the analysis programs with new design programs.

4. The six million dollar, four years time required to implement an initial IPAD System are consistent with the scope of the task and the benefits expected. The benefit to cost ratio is expected to exceed 10 to 1.

6.0 RECOMMENDATIONS - TECHNICAL

IPAD System and technical capability should be implemented in a 3 phase plan. The goals of each phase should be:

Phase 1

- o Demonstrate the utility of the IPAD concepts on total vehicle design studies,
- o Demonstrate the task/time continuity capabilities of the IPAD System design,
- o Develop a strategy for transferring Phase 1 IPAD technology from the development environment to an industrial environment.

Phase 2

- o Extend the Phase 1 system capability,
- o Expand IPAD usage to industry,
- o Demonstrate effective man/machine methodology on aerospace vehicle problems at Langely Research Center,
- o Determine the impact of 4th generation computers on the development during Phase 3.

Phase 3

- o Demonstrate the full capability of the IPAD System design.

6.1 PRODUCT APPLICABILITY

Phase 1 - Implementation

Figure 6.1 illustrates the technical areas of the design process recommended as the minimum technical capability for Phase I IPAD implementation.

Preliminary Design Capability

The initial implementation of the Project 1 subsonic class of airplanes should include Levels II and III of the design networks. This technical capability should be adequate to support the development and check out of the IPAD system. It

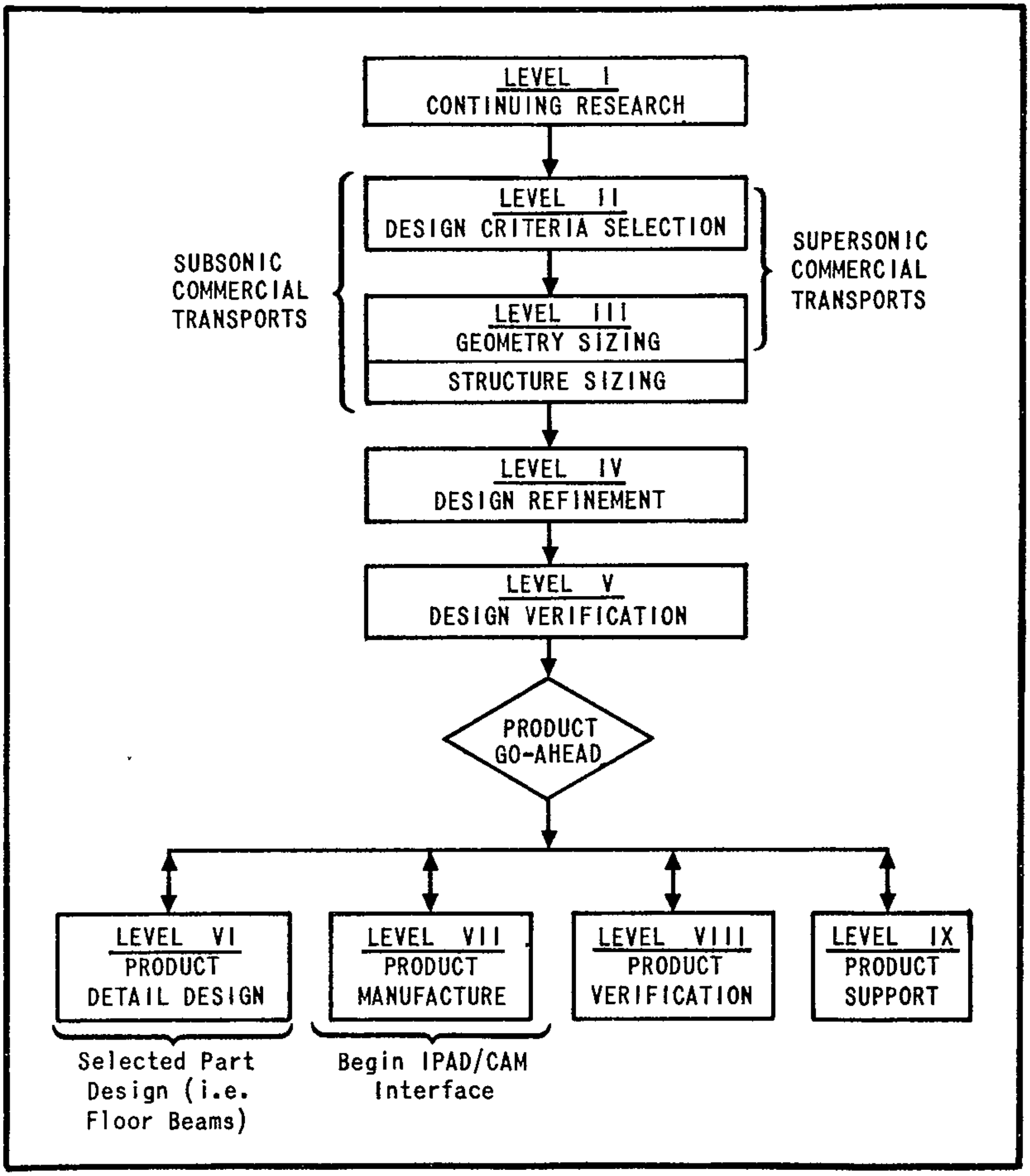


Figure 6.1 Initial Technical Capability—IPAD Product Levels

will also provide a basis for calibration since it will be possible to relate the subsonic class of airplane to both existing in-service airplanes and to studies which are continually in progress for this class of airplane. The initial implementation of the Project 2 supersonic class of airplanes should include Level II and the geometry sizing part of Level III of the design networks. This technical capability would orient IPAD to future vehicles. This should help demonstrate the value of the IPAD System for evaluation of complex design studies for which past experience is limited.

Detail Design Capability

The detail design process utilizing interactive graphics concepts should be done for several representative parts. Typical parts could include floor beams, body frames and wing ribs. These will be useful in understanding the nature of the development of a preliminary design concept into a manufacturable part. These representative parts will also establish the cost savings potential of the enhanced design environment provided by IPAD.

IPAD/CAM Interface

It is recommended that the interface with manufacturing at Level VII be initiated during the Phase I implementation. This interface will be similar for both Project 1 and Project 2 and should make IPAD complement the development of Computer Aided Manufacturing (CAM) Systems. Many present manufacturing facilities are highly computerized and for these, CAM Systems are in various stages of study, implementation, or are presently in use. The IPAD System should provide technical information at the interface between design and manufacturing which can be transferred directly to computing facilities that support manufacturing.

Phase 2 and 3 Implementation

The product technical capability for Phase 2 and 3 are expected to primarily reflect the experiences of NASA and industry with the Phase 1 capability. No specific technical module developments are recommended at this time.

6.2 SYSTEM SOFTWARE AND HOST COMPUTER

The 3 phase implementation of the system software follows the goals for product technical capability (section 4.1). An overall implementation strategy is recommended which:

- Provides an initial baseline system software capability at NASA-Langley Research Center,
- Extends the initial baseline capability in response to NASA and industry experience and needs,
- Responds to the pace at which 4th generation computers become viable in the indústry.

Phase 1 Implementation

System capability is recommended in the areas of Executive, Data Management and Host Computer.

Executive Software

The development of the executive capability to support the continuity of the users activities using the subtask concept and to support construction and execution of jobs.

Data Management System

The development of the data management capability to support the subtask and community libraries including data transfer capability between OM's.

Host Computer

A dedicated CDC 6600 computer system located at NASA-Langley Research Center is recommended for Phase 1 implementation of IPAD. The operating system should be modified to support the continuity requirements of the system design.

Phase 2 Implementation

Phase 2 baseline implementation extends the Phase 1 baseline capability at NASA. During this phase it is recommended that the Executive and Data Base Management capability be extended to include information control via portions of the project plans and report functions.

It is anticipated that the Technology transfer efforts may require a Phase 1 capability installed on host computers other than NASA-Langley Research Center.

Phase 3 - Implementation

Phase 3 baseline implementation will complete the project plans, report functions of the system design, and initiate an interactive graphics capability.

6.3 TECHNOLOGY TRANSFER TO INDUSTRY

It is recommended that contracted efforts be the basic means of transferring IPAD technology from the development environment to the industrial environment.

These contracts should provide innovative firms the opportunity to place themselves in the forefront with IPAD technology. The contracts should require:

- Competitive bidding to select those firms who will have the first opportunity,
- NASA to provide the IPAD system software operational on the successful bidders host computer system,
- The successful bidder to utilize the IPAD System with their technical modules on product design problems proposed by them,
- NASA to receive reports which evaluate the technical and economical aspects of the contractors experience with the IPAD System.

It is recommended that these evaluation reports become the basic guidance for the future development of the baseline system capability.

7.0 RECOMMENDED LEADERSHIP ACTION

The era of IPAD technology will be significant in the environment of problem solving. Naturally, as this new era evolves, significant executive leadership action is essential from the aerospace and computing industries and the government. This leadership action is suggested in the following questions:

Industry - Aerospace--If information technology is critical to your product design organization's future, then are your executives prepared:

- To understand information technology as opposed to task technology?
- To guide broad, computer-based system development and usage?
- To evaluate the compatibility of current human task structures with information systems?
- To evaluate the compatibility of human resource management practices with information management?

Industry - Computing--If information technology is critical to your market in product design organizations then:

- How can your technical staffs, not marketing staffs, obtain insight into the product design processes?
- How can your hardware/software reliability reach the state where product designers, who are cost/schedule motivated, need not worry or plan for computing unreliability?

Government--If the government continues in their technology catalyst role:

- Can they help create a prototype IPAD capability that industry can exploit in their national and international business?
- How will creative competition be maintained to build better future IPAD Systems?

8.0 REFERENCES

1. Miller, R. E., Jr., and McCaslin, J., "Cost-Effective Matching of Tasks and Computing Devices", ASCE 5th Conference on Electronic Computation - Purdue University, August 21-Sept. 2, 1970.

2. Streeter, D. N., "Cost-Benefit Evaluation of Scientific Computing Services" IBM System Journal - No. 3, 1972.

3. Miller, R. E., Jr., Hansen, S. D.; Large-Scale Structural Analysis of Current Aircraft", presented at Winter Meeting of ASME in New York City, December 1970..

4. Wallace, R. E., "Parametric and Optimization Techniques for Airplane Design Synthesis", AGARD Lecture, Boeing Document D6-40090, March 15, 1972.

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APPENDIX A

PRODUCTIVITY OF EXISTING SYSTEMS

Computers have increased productivity through the automation and computer-aiding of routine data handling tasks. Some substantial productivity gains reported in the literature are presented below.

The studies in references 1 and 2 demonstrated that significant decreases in both cost and flowtime can be achieved by attacking the time element of problem solving. It was shown in reference 1 that, by minimizing the manual functions identified in the task model in figure A.1, through optimization of the use of the computing devices and services shown in figure A.2, total task cost can be reduced. The components of the total task cost are:

- o Computer cost
- o Men waiting cost
- o Men doing cost

The effect of optimizing devices and services upon each of these cost elements is shown in figure A.3. As shown, the cost of computer services increases from 50% to 100%; however, the cost of "waiting" and "doing" is substantially decreased. For this case study, it was assumed that 50% ($\alpha = 0.5$) of the waiting time for a response from a device was used productively on other tasks.

The total effect is summarized in figure A.4 based on a total task cost, using the "current" system, of $300,000 per month. As shown, use of the current system resulted in the greatest cost. In contrast, use of either the 5, 6, or 7 device system would reduce total task cost by approximately $75,000 per month while increasing the cost of computer services by approximately $8,000 to $12,000 per month.

Figure A.4 also shows that costs associated with facilities, computers and processing are approximately one-tenth of the total task cost. Most of the mantime costs are spent waiting for data preparation, method selection, computer processing turn-around and information dissemination.

The increase in productivity is achieved by reducing or eliminating the mantime waiting in the simple, one person tasks associated with the devices studied.

In reference 3, it was shown that similar cost and flowtime reductions can be obtained for more complex tasks. Figure A.5 illustrates the Boeing ATLAS system which involves several technologies within the structures discipline. Each technology is represented by one or more computer program modules.

This is a more complex problem than discussed in reference 1 and introduces additional functions in the task model as shown in figure A.6. These additional functions include:

- o Evaluating the results of the previous subtask,
- o Preparing data and programs for the next subtask,
- o Evaluating total task results.

As shown in figure A.7, for this more complex task environment, the ATLAS system produced a 50% reduction in flowtime and manpower costs. These savings were achieved by automating the routine mantime functions at the data interfaces of the technical modules.

The Boeing Computerized Preliminary Design System (CPDS, ref. 4), was developed to solve problems at the multi-discipline level as shown in figure A.8. CPDS automated the routine functions at the interface between design and analysis. As a consequence, a 65% reduction in problem flowtime was achieved as shown in figure A.9.

In summary, the productivity increases in these studies resulted from:

- o Better optimization of men, functions and devices to reduce waiting,
- o Automation or computer-aiding of the routine information handling chores at technology and discipline interfaces.

REFERENCES

1. Miller, R. E., Jr., and McCaslin, J., "Cost-Effective Matching of Tasks and Computing Devices," ASCE 5th Conference on Electronic Computation - Purdue University, August 21-Sept. 2, 1970.

2. Streeter, D. N., "Cost-Benefit Evaluation of Scientific Computing Services," IBM System Journal - No. 3, 1972.

3. Miller, R. E., Jr., Hansen, S. D., "Large-Scale Structural Analysis of Current Aircraft," presented at Winter Meeting of ASME in New York City, December 1970.

4. Wallace, R. E., "Parametric and Optimization Techniques for Airplane Design Synthesis," AGARD Lecture, Boeing Document D6-40090, March 15, 1972.

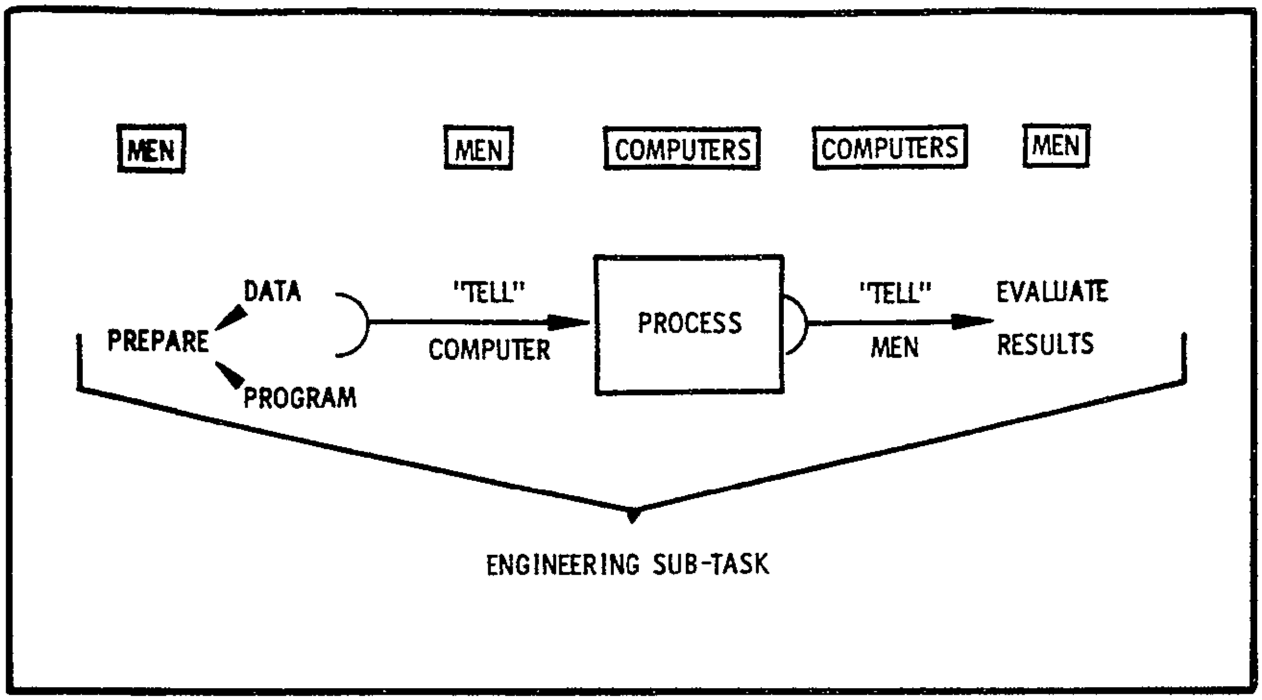

Figure A.1 Computational Device Task Model

	CURRENT SYSTEM	7 DEVICE SYSTEM	6 DEVICE SYSTEM	5 DEVICE SYSTEM
SLIDE RULE	●	●	●	●
MECHANICAL DESK CALCULATOR	●	●	●	●
PROGRAMMABLE DESK CALCULATOR		●	●	●
SMALL TIME-SHARE SYSTEM		●	●	
LARGE TIME-SHARE SYSTEM		●	●	●
SMALL BATCH COMPUTER		●		
LARGE BATCH COMPUTER	●	●	●	●

Figure A.2 Computational Device System Definition

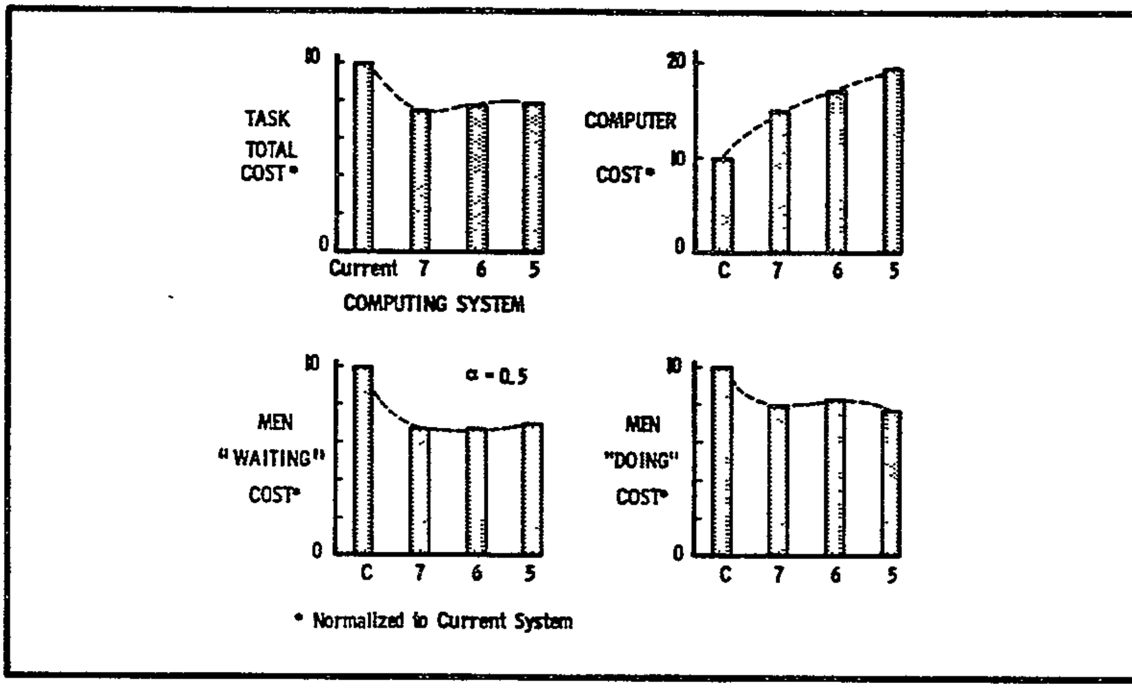

Figure A.3 Device Impact on Task Cost

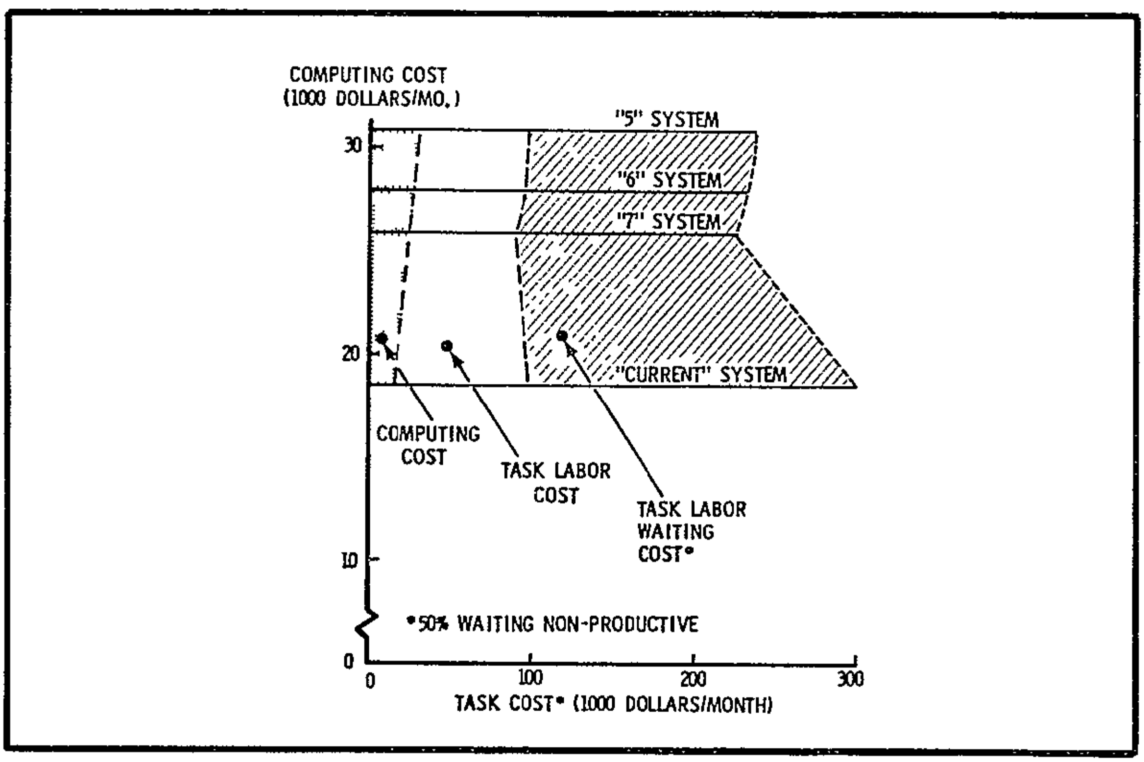

Figure A.4 Subtask Cost vs Device System

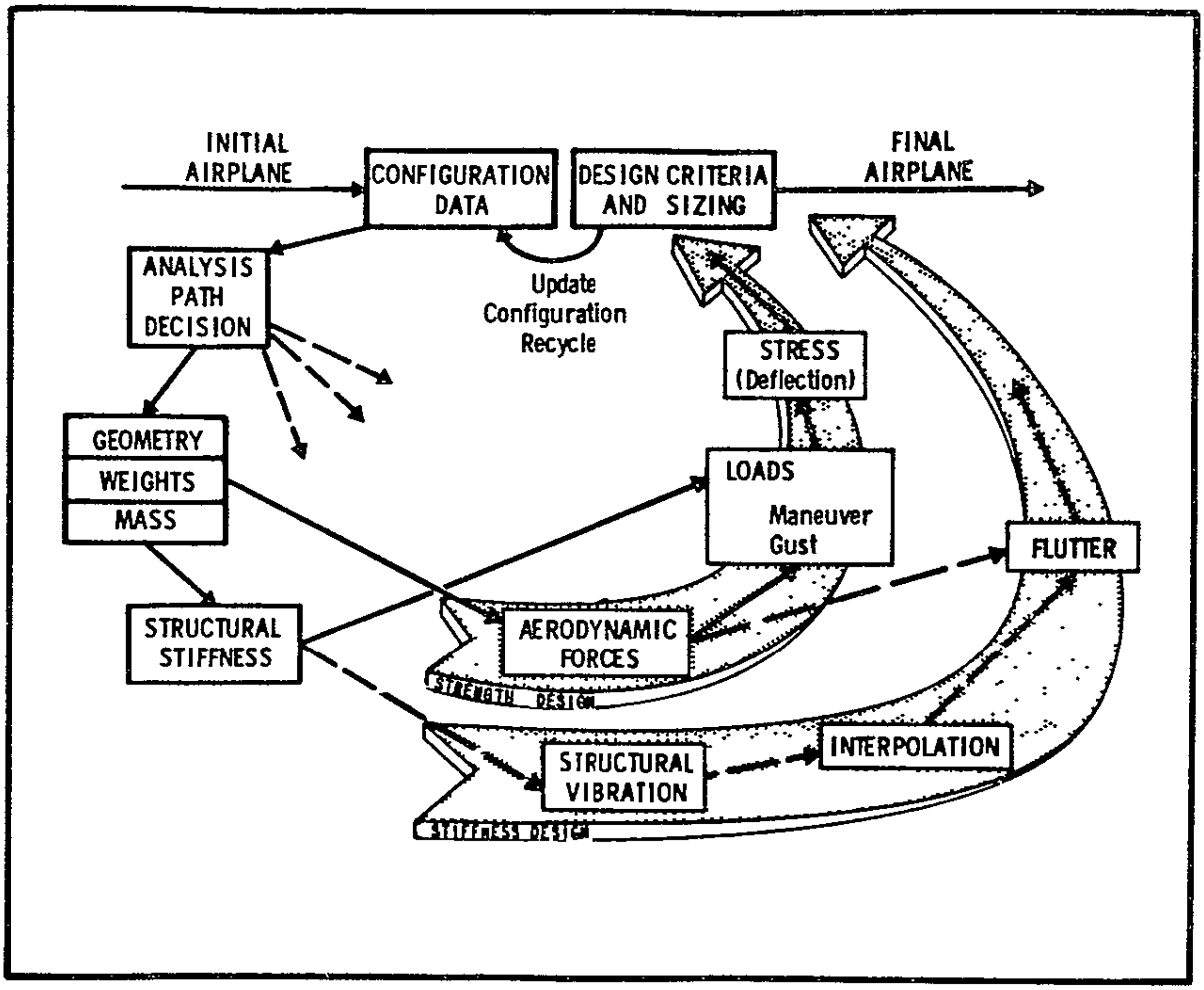

Figure A.5 ATLAS Task—Basic Airframe Structural Analysis and Design Cycle

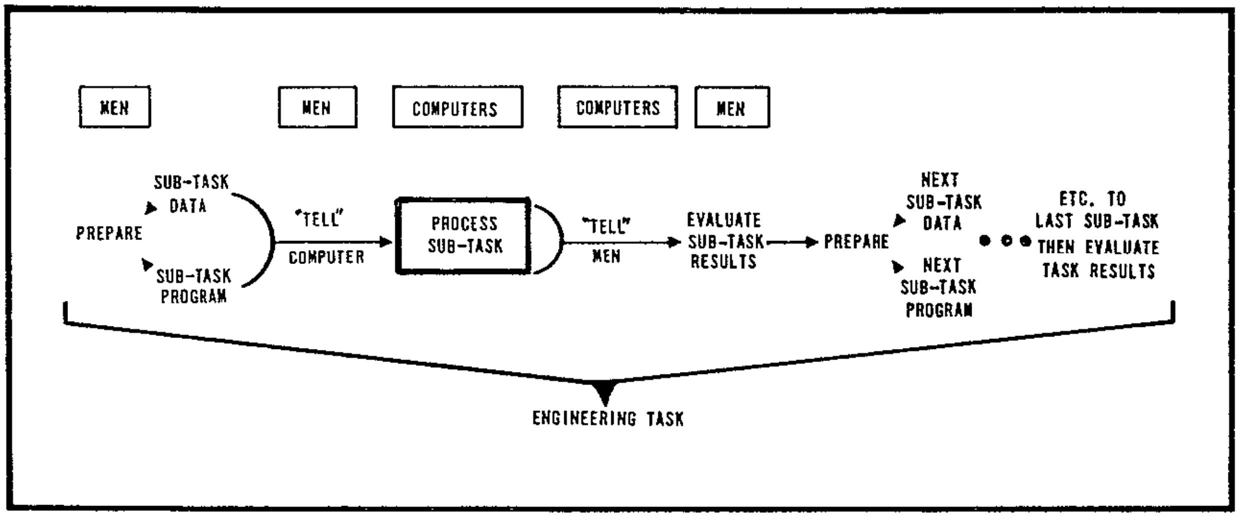

Figure A.6 Task Elements

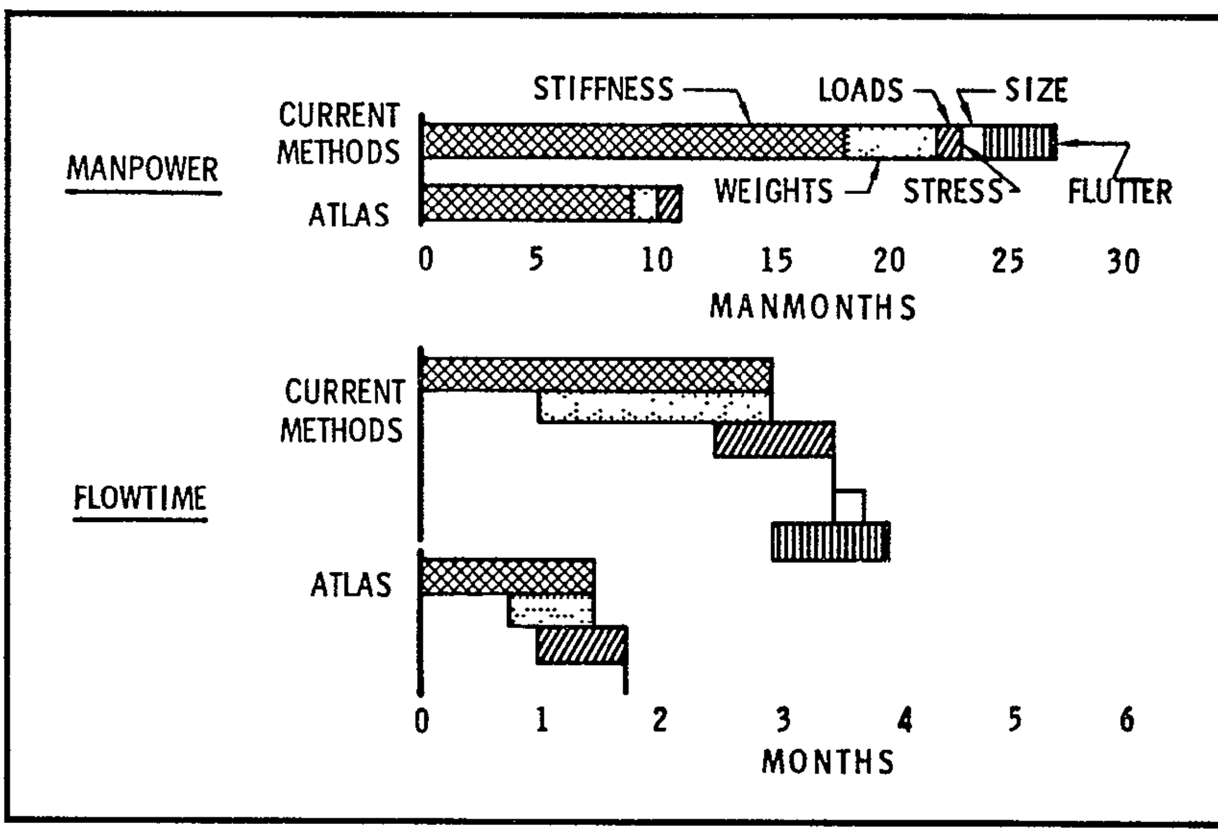

Figure A.7 ATLAS Task—Resources and Time Summary

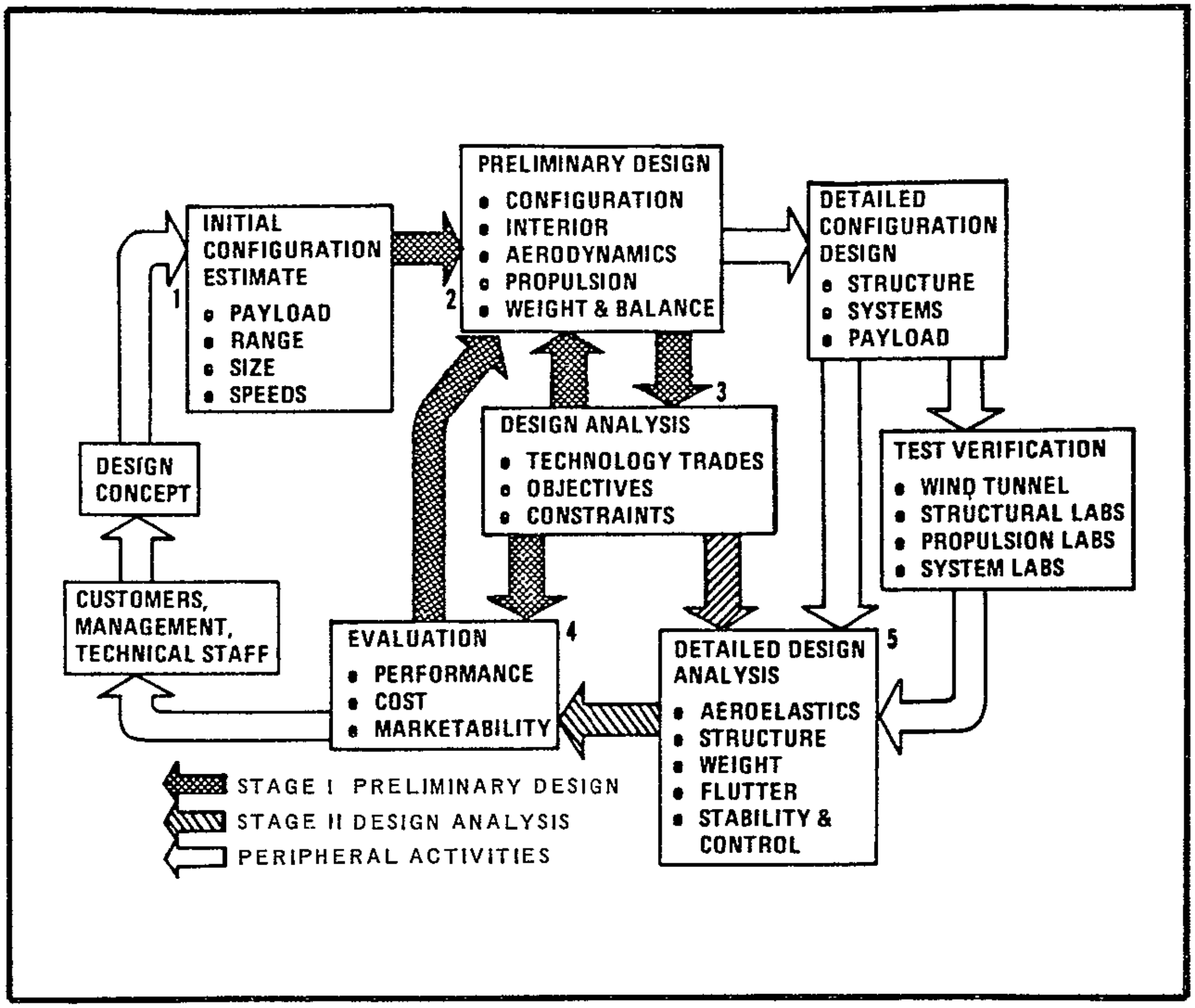

Figure A.8 CPDS Multi-Tasks—Preliminary Design Flow Chart

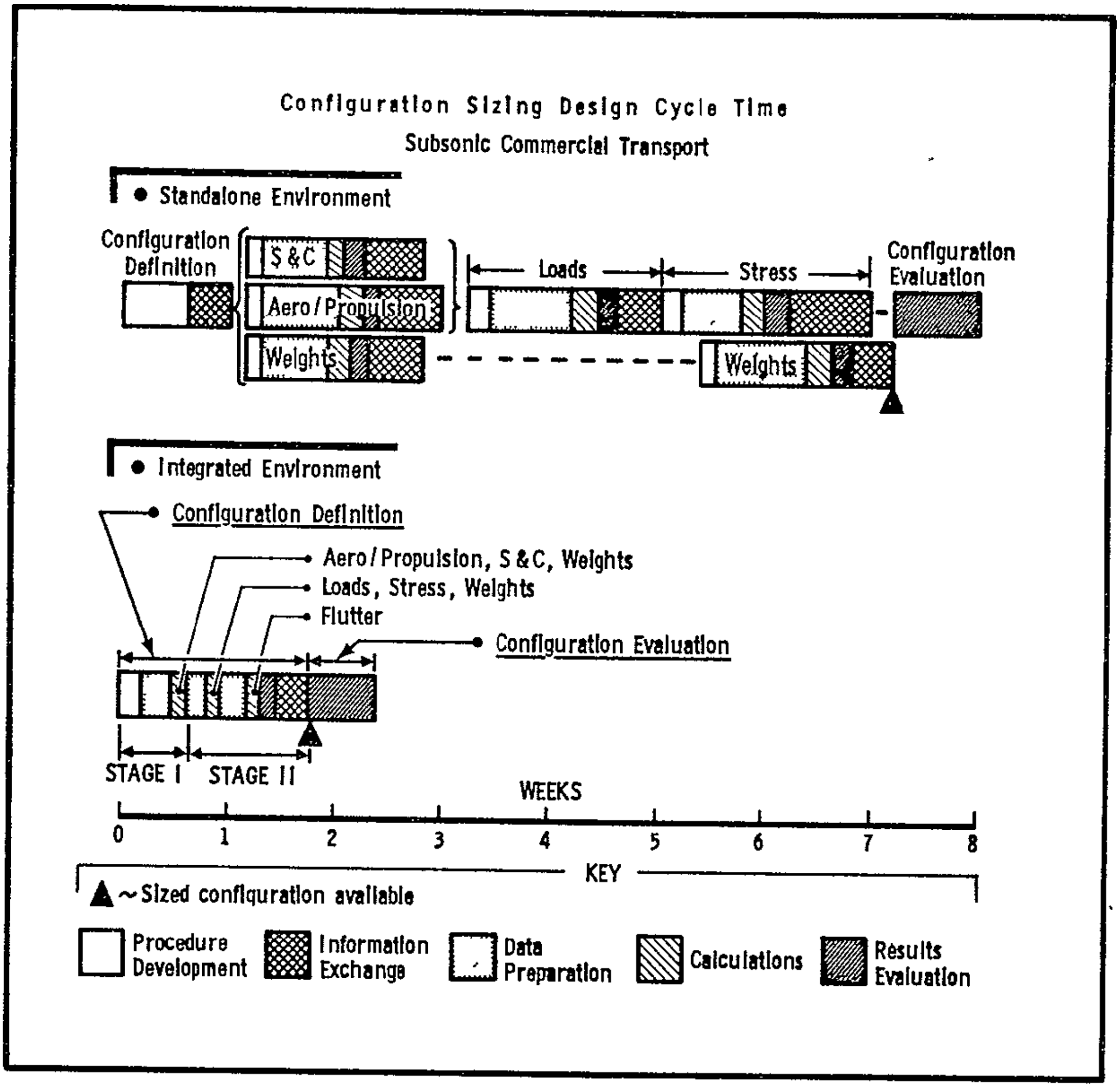

Figure A.9 CPDS Multi-Tasks Flowtime Comparison