NASA Technical Memorandum 81874

Overview of Integrated Programs for Aerospace-Vehicle Design (IPAD)

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SEPTEMBER 1980

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National Aeronautics
and Space Administration

**Scientific and Technical
Information Branch**

1980

SUMMARY

To respond to national needs for improved productivity in engineering design and manufacturing, a NASA supported joint industry/government project is underway denoted Integrated Programs for Aerospace-Vehicle Design (IPAD). The objective is to improve engineering productivity through better use of computer technology. It focuses on development of technology and associated software for integrated company-wide management of engineering information. The project has been underway since 1976 under the guidance of an Industry Technical Advisory Board (ITAB) composed of representatives of major engineering and computer companies and in close collaboration with the Air Force Integrated Computer-Aided Manufacturing (ICAM) program. Results to date on the IPAD project include an in-depth documentation of a representative design process for a large engineering project, the definition and design of computer-aided design software needed to support that process, and the release of prototype software to integrate selected design functions. Ongoing work concentrates on development of prototype software to manage engineering information, and initial software is nearing release. This paper provides an overview of the IPAD project and summarizes goals, plans, and progress to date.

INTRODUCTION

The national need for improved productivity has become increasingly apparent with recent statistics of zero or negative growth in gross national product. Significant improvements in aerospace productivity are believed possible through effective utilization of current and future CAD/CAM technology (figs. 1 and 2). A joint NASA/industry $15M project, Integrated Programs for Aerospace-Vehicle Design (IPAD), has been underway for several years and is making significant progress in advancing integrated CAD/CAM technology. The project goal is to increase U.S. aerospace industry productivity through application of computers for integrated company-wide management of engineering data.

In the early 1970's, NASA-funded feasibility studies (refs. 1 and 2) showed that dramatic increases in engineering productivity were feasible through the automation of routine information handling tasks. These results, which were extensively reviewed by the aerospace and computer industry (refs. 3 and 4), showed that such automation would directly decrease cost and flow time in the product design process and would improve the competitive position of the U.S. aerospace industry. Based on these and other results, NASA began the IPAD project in 1976 to develop the appropriate technology and associated computer software. Work under the IPAD project is being done principally through a NASA prime contract to The Boeing Commercial Airplane Company supported by appropriate subcontracts and under the guidance of an Industry Technical Advisory Board (ITAB) composed of members of aerospace and computer companies (fig. 3). The ITAB concept provides an innovative and effective management approach for a joint industry/government high technology R&D effort (ref. 5). (See Appendix A for a summary of industry involvement in IPAD).

IPAD software development is closely coordinated with the U.S. Air Force Integrated Computer-Aided Manufacturing (ICAM) program, and several IPAD/ICAM cooperative activities are underway or planned. (See, for example, refs. 6 and 7). NASA management of software development is supported by continuing independent evaluation of software performance carried out through a contract to Information Research Associates (ref. 8). While IPAD software is being developed primarily for use by the aerospace industry, it should be useful in support of other complex processes such as large civil engineering projects, shipbuilding, automotive design, electronics, and engineering education (refs. 9, 10-13). Representatives from several non-aerospace organizations serve as observers to ITAB and regularly participate in the review and critique of ongoing work (fig. 3).

DEVELOPMENT PLAN

A fully operational IPAD capability of the future (fig. 4) would be composed of system software including executive, data management, and geometry/graphics software, together with disciplinary technical programs installed in IPAD to implement its integrated design features and project data. The IPAD project focuses on developing prototype system software and would use available technical programs and data for software evaluation and demonstration. It would also take advantage of the capabilities of the host computer interactive operating system.

Major IPAD project tasks during FY 1976-82 (see figs. 4 and 5) include (1) definition of a computer-aided design system of the future denoted Full IPAD; and (2) development of First-Level IPAD software principally composed of a prototype engineering data management software system operational on CDC and IBM computers supported by geometry and graphics software operational on a DEC VAX minicomputer. IPAD software development is being carried out through a careful step-by-step process encompassing aerospace design process definition, system requirements definition, software design, and software development (fig. 6). The schedule in figure 5 indicates that the Full IPAD design has been completed; work is well into the CDC development with geometry/graphics software released; data management software is nearing release; and planning for IBM implementation is underway. The following sections provide further details on the description of a future Full IPAD, as well as on progress and plans toward developing a First-Level IPAD software capability.

DESCRIPTION OF A FUTURE FULL IPAD SYSTEM

IPAD project results to date (see refs. 14-24) indicate that a Full IPAD system of the future should be basically a general-purpose interactive computer-aided design system developed to support engineering design processes. Its primary function would be to handle engineering data associated with the design process. IPAD software would be installed by each company on its computers and used in a manner similar to vendor-supplied operating system software. The IPAD software would augment, rather than replace, existing operating system software. It would support the continuous design activities of a typical company mix of multiple development projects. The IPAD system would serve management and engineering staffs at all levels of design (conceptual, preliminary, and final) and aid in the assembly and organization of design data for manufacturing processes.

The IPAD system would support generation, storage, and management of large quantities of data. Its capacity would only be limited by the computer hardware configurations selected by each company. The system would be used in a distributed computing environment having one or more central host computing systems and many remote computing systems. One such arrangement of Full IPAD components is given in figure 7. The number of terminals might be several hundred or more and may be distributed across the host and remote systems. The IPAD software would function on the computer complexes in use today by aerospace corporations, but would achieve its full potential on the computers in the next decade.

The functions of the three major IPAD software components illustrated in figures 4 and 7 are (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 and to provide communications between computer hardware within and outside the IPAD distributed computing system; (2) 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 (3) geometry and graphics utility software to provide a wide range of capabilities for information and geometry creation, manipulation and display functions including design/drafting and interactive and display graphics.

Libraries within the data bases might include analysis/design computer programs utilized by various disciplinary specialists and extensive quantities of data. The analysis/design computer programs would not be part of IPAD, but would be provided by each company to form the complete design-software system; selected publically available technical programs might be included in IPAD releases to demonstrate capabilities. The data in the data base would 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 would thus be possible. Temporary storage for design information being actively used by individuals or teams would also be provided.

A Full IPAD system would not be a hands-off "automated design" system and would not constrain company design methods. The quality of future aerospace designs generated in an IPAD environment would depend on the same primary factors as in today's design environment: creativity of designers, quality of technical staff, quality of analysis tools and design data, and coordination of design and manufacturing information. IPAD should also be a tool to improve manufacturing direct access to engineering data. While support for the manufacturing process is not a specific requirement for the Full IPAD system, it is believed that many manufacturing needs are met by the resulting system design. Continuing collaboration between the Air Force and NASA should insure compatibility between future IPAD and ICAM capabilities so that manufacturing users can more readily take advantage of the design and data management features of IPAD and can have better access to design information.

In summary, the key results to date in defining a future full IPAD system include:

1. Comprehensive description of a future representative aerospace-vehicle design process and its interface to manufacturing (fig. 8, refs. 14-20).

2. Requirements and preliminary design of a future IPAD software system denoted "Full IPAD" to integrate engineering activities of an aerospace company having several products under simultaneous development (fig. 7, refs. 21-24).

FIRST-LEVEL IPAD SOFTWARE DEVELOPMENT

An initial set of IPAD software denoted First-Level IPAD is now under development. This software is a meaningful subset of the Full IPAD system and, in accordance with ITAB guidance, is focusing on critical technology issues associated with managing engineering data. It provides a significant step toward development of a future integrated computer-aided design capability operational on a network of computers of different manufacture. Key requirements driving software development include numerous interactive terminals, voluminous quantities of data (fig. 9), and extensive consideration of geometry (fig. 10).

In progress to date, major technology issues have been addressed, design of a prototype engineering data management system completed, software development progressed substantially, some initial software released, and a major capability nearing release. The result has been identification and implementation of appropriate geometry/graphical software (fig. 11, ref. 25), and the design and substantial progress toward development of an innovative approach to integrated company-wide management of engineering data for a future distributed computer complex (fig. 12, refs. 26-30).

All IPAD technology, software, and supporting documentation is being supplied to industry as it is developed. (See, for example, refs. 30-35). The software development plan provides for release of incremental capabilities implemented for the CDC/DEC and IBM computing systems. These incremental releases will permit each company to incrementally install and evaluate the software and associated technology and, as appropriate, undertake a gradual transition from the current computing environment to a future IPAD integrated environment at a pace appropriate for the company.

During the balance of 1980, work is focusing on coding the engineering data management software and developing demonstrations of integrated design/manufacturing activities to validate the software and its fundamental concepts. An initial engineering data management capability will be operational in late 1980 and future development, together with demonstrations, will continue into mid-1981. Plans for 1981 and beyond are to implement the engineering data management software on a second computer of different manufacture (IBM), to enhance performance of software, to expand software to respond to manufacturing data management requirements, and to examine the technology challenges of computer-aided design/manufacturing on networks of computers (fig. 13). Close collaboration will be maintained with the Air Force ICAM program to insure that the joint IPAD/ICAM programs best respond to the combined technology needs of design and manufacturing.

In summary, First-Level IPAD software produced to date or planned into 1982 include:

1. Release in October 1979 of IPAD Integration Prototype Software operational on a CDC/DEC computer complex which integrates through an experimental relational data management system the functions of design, drafting, geometry, graphical display, structural and thermal analysis/design, and N/C path generation (fig. 11, ref. 25).

2. Release in July 1981 of a prototype instrumented engineering data management system based on a multi-schema concept which is operational on a CDC computer and provides the capability to integrate company-wide design data (fig. 12, refs. 26-30).

3. Release in July 1982 of the prototype engineering data management system operational on an IBM computer complex.

4. Continued documentation of scenarios of representative engineering design activities which serve to control software development, insure requirements are met, and serve as a basis for software demonstration.

APPENDIX A

INDUSTRY INVOLVEMENT IN IPAD DEVELOPMENT

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 feasibility and possible forms of an IPAD system were carried out by The Boeing Company and General Dynamics/Convair (see ref. 1,2). 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 Company; Lockheed-Georgia Company; Grumman Aerospace Corporation; Rockwell International, Los Angeles Aircraft Division; Control Data Corporation; IBM Corporation; 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 (ref. 3) reveal a wide spectrum of views, but strong consensus that IPAD development should proceed, should not include technical modules 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 Company of its benefit potential for missile design (ref. 4) and a small NASA-funded study by Battelle Columbus Laboratories of its potential for non-aerospace application (ref. 9). 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. NASA prepared an IPAD "Prospectus" in February 1975 which set forth the plan for development, initial maintenance, and release of IPAD; for an Industry Technical Advisory Board (ITAB) to advise the IPAD contractor; and for a user-controlled organization to accept maintenance responsibility for IPAD software. NASA then conducted a survey of 41 aerospace companies seeking their commitment to become a member of ITAB during IPAD development; to evaluate IPAD software before it is generally released; and to financially support, in the context of a user-controlled organization, maintenance and improvement of IPAD software after its value to their company had been demonstrated. Two messages of a general nature were apparent in the company responses. First, support for the IPAD concept and willingness to provide advice and counsel through the ITAB was very good from the large and medium airframe companies for whom IPAD would be primarily tailored. Second, most companies prudently preferred to defer hard commitments beyond ITAB participation until they had a chance to assess results. A few companies specifically declined commitments to participate in the IPAD project, and these fell in two categories - either IPAD did not appear to meet the needs of their particular design process, or they saw IPAD aimed at design problems larger than their company activity. Several such companies wished to remain informed on IPAD progress with an opportunity to re-evaluate their position later.

Based on industry willingness to support the IPAD project, an Industry Technical Advisory Board (ITAB) was formed by the development contractor soon after contract initiation to afford industry the maximum opportunity for influencing the course of IPAD development. ITAB consists of members and observers representing major U.S. aerospace and computer companies and meets periodically. ITAB activities include review of planning and technical documents, critique of key development decisions, ranking of IPAD requirements, identification of demonstration programs, and evaluation of software. As the IPAD software is released, ITAB member companies and other potential IPAD users will be aided in its evaluation and use. More details on ITAB ongoing operation and activities are given in reference 35.

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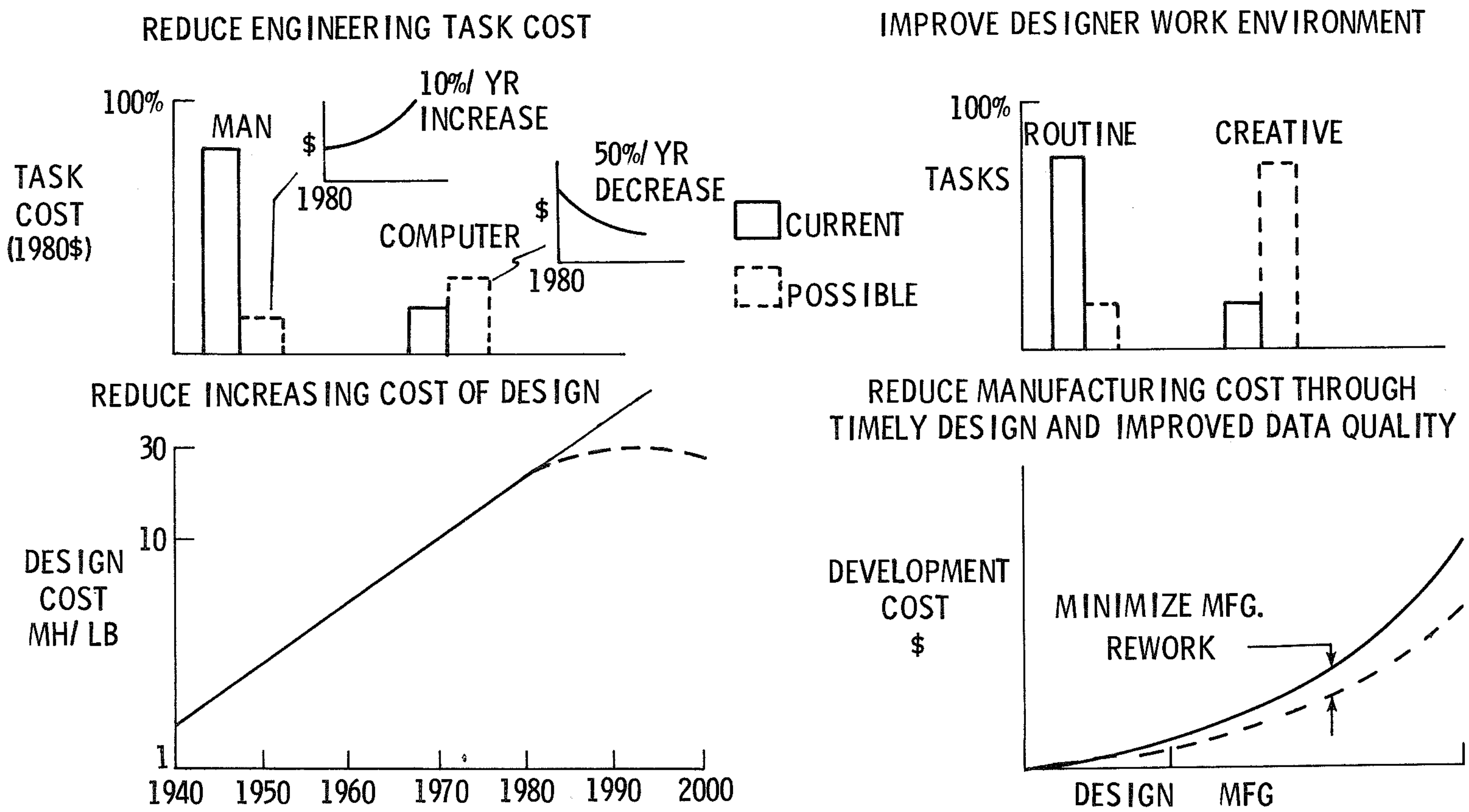

Figure 1.- Benefits from CAD/CAM technology.

GOVERNMENT INVOLVEMENT NEEDED TO ACCELERATE DEVELOPMENT OF NEEDED CAD/CAM TECHNOLOGY

- HIGH RISK LONG-TERM DEVELOPMENT OUTSIDE NORMAL AEROSPACE COMPANY PRODUCT LINE
- HIGH RISK DEVELOPMENT FOR A SMALL COMPUTER COMPANY MARKET
- REQUIRES UNNATURAL COOPERATION AMONG COMPUTER VENDORS
- UTILIZES SCARCE RESOURCES MORE EFFECTIVELY

PROVIDES BASIC TECHNOLOGY NEEDED FOR DOD CAD/CAM PROGRAMS

BENEFIT NASA MISSIONS AND PRODUCTS

Figure 2.- Reasons for NASA development of CAD/CAM technology.

W.E.SWANSON
CHAIRMAN

EXECUTIVE OFFICER/INTERFACE MANAGER
H.R.HARRIS (BOEING)

- MEMBERS

AEROSPACE INDUSTRY
- BOEING
- CESSNA
- FAIRCHILD
- GENERAL DYNAMICS
- GRUMMAN
- LOCKHEED
- MARTIN-MARIETTA
- MCDONNELL-DOUGLAS
- NORTHROP
- ROCKWELL INTL
- VOUGHT

ENGINE MANUFACTURERS
- GENERAL ELECTRIC
- PRATT AND WHITNEY

COMPUTER MANUFACTURERS
- IBM
- CDC
- DEC
- UNIVAC

- OBSERVERS

ADVANCE MARINE ENTERPRISES
AVCO - LYCOMING
BATTELLE
BELL HELICOPTER
COMPUTERVISION
DENELCOR
FORD
GTE
GENERAL MOTORS
GERBER SCIENTIFIC INSTRUMENT
GULFSTREAM AMERICAN
HIGHER ORDER SOFTWARE
HUGHES AIRCRAFT
MACNEAL SCHWENDLER
MANUFACTURING AND CONSULTING SERVICES
NATIONAL BUREAU OF STANDARDS
NAVAL AIR SYSTEMS COMMAND
NASA
NETWORK SYSTEMS
PIPER AIRCRAFT
PRIME COMPUTER
RENSSELAER POLYTECHNIC INSTITUTE
RESEARCH TRIANGLE INSTITUTE
ROYAL GRAPHICS
SOFTECH
STRUCTURAL DYNAMICS RESEARCH
TEKTRONIX
TEXAS A&M
TRW
UNIVERSITY OF MISSOURI-ROLLA
VIRGINIA POLY. INST. AND STATE U.
WESTINGHOUSE
AIR FORCE - ICAM
JOHN DEERE
NSRDC
AIR FORCE - FLIGHT DYNAMICS LAB

Figure 3.- Industry technical advisory board (ITAB).

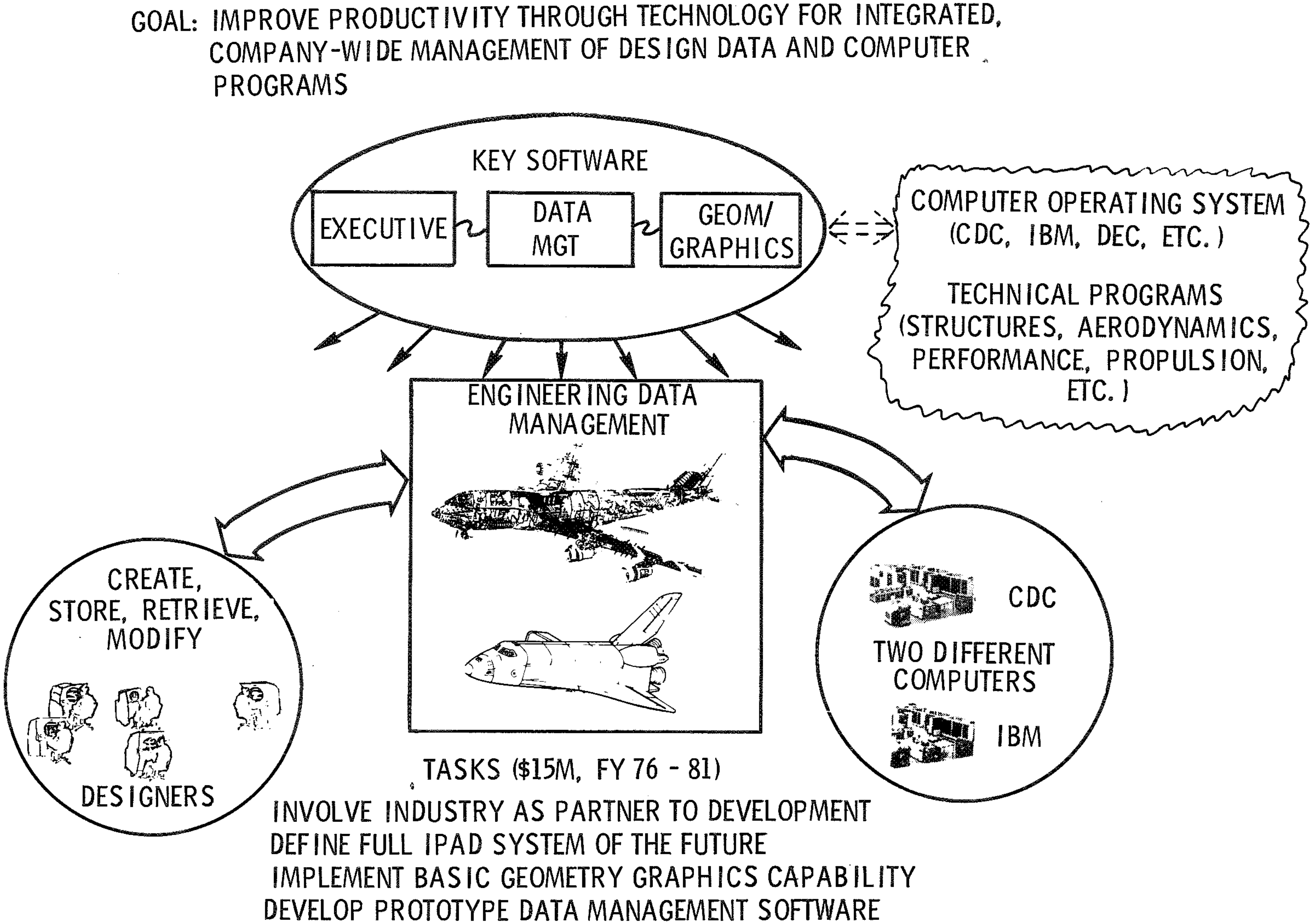

Figure 4.- IPAD: Integrated Programs for Aerospace-Vehicle Design.

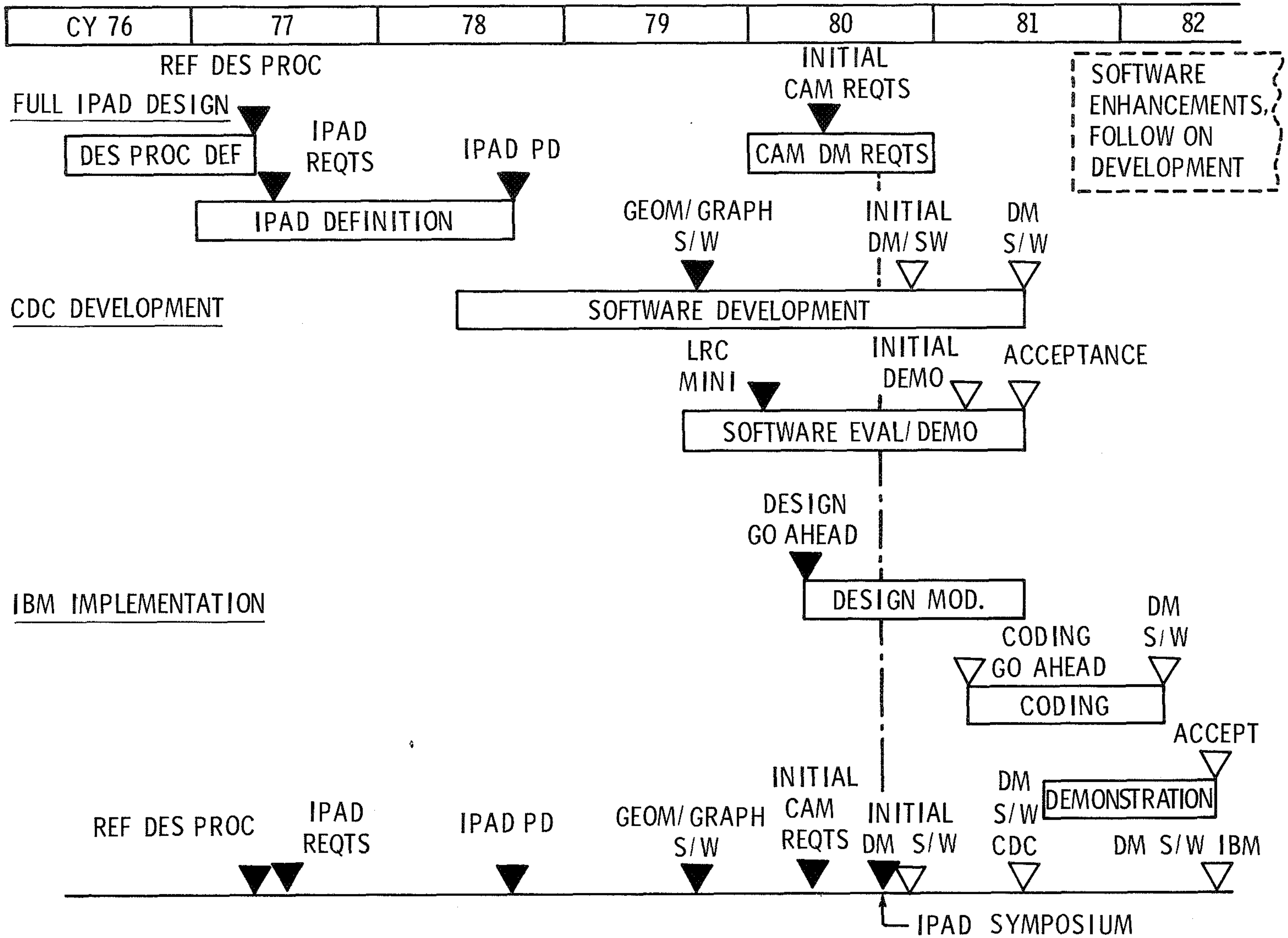

Figure 5.- IPAD development plan (1976-82).

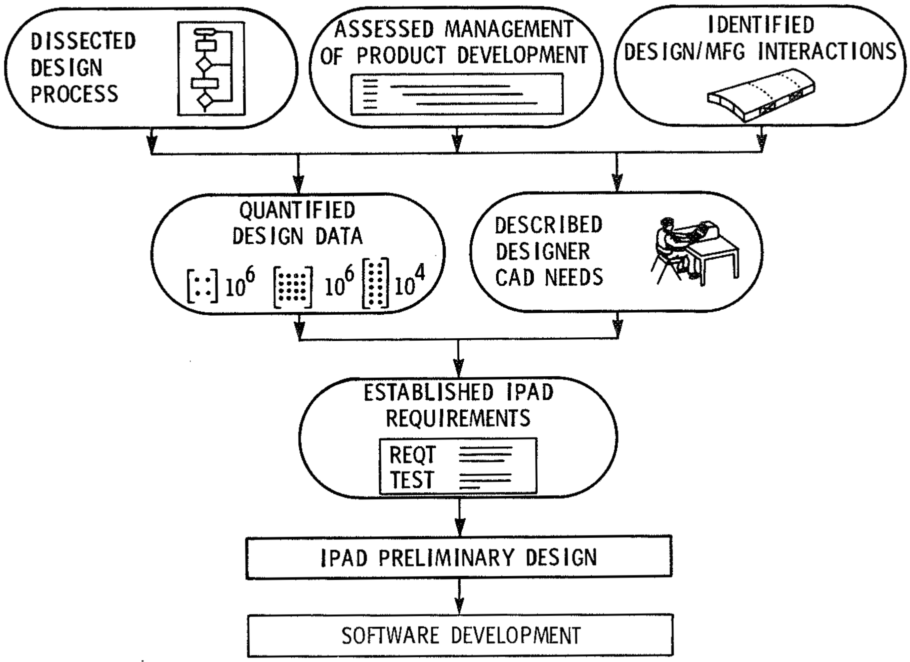

Figure 6.- Approach to IPAD software development.

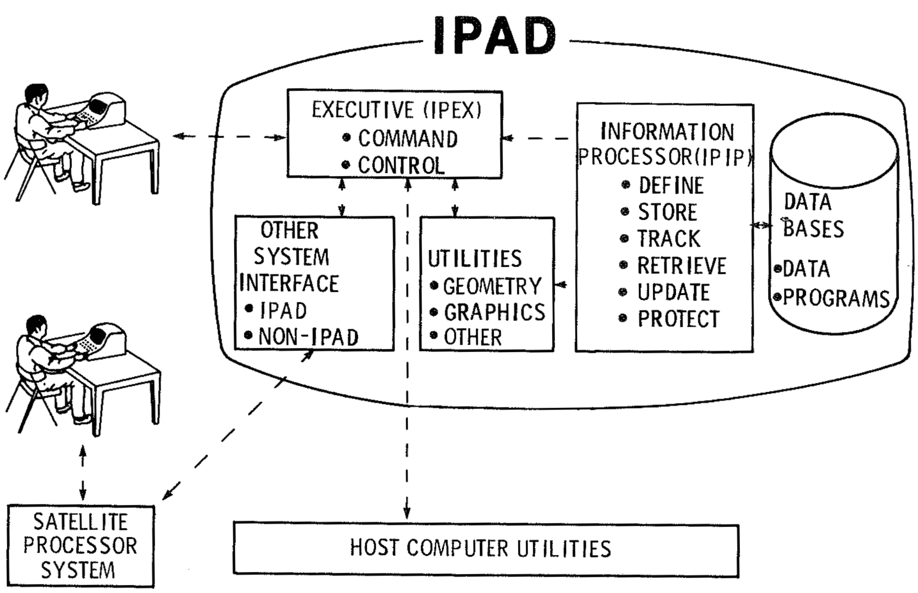

Figure 7.- Arrangement of full IPAD system components.

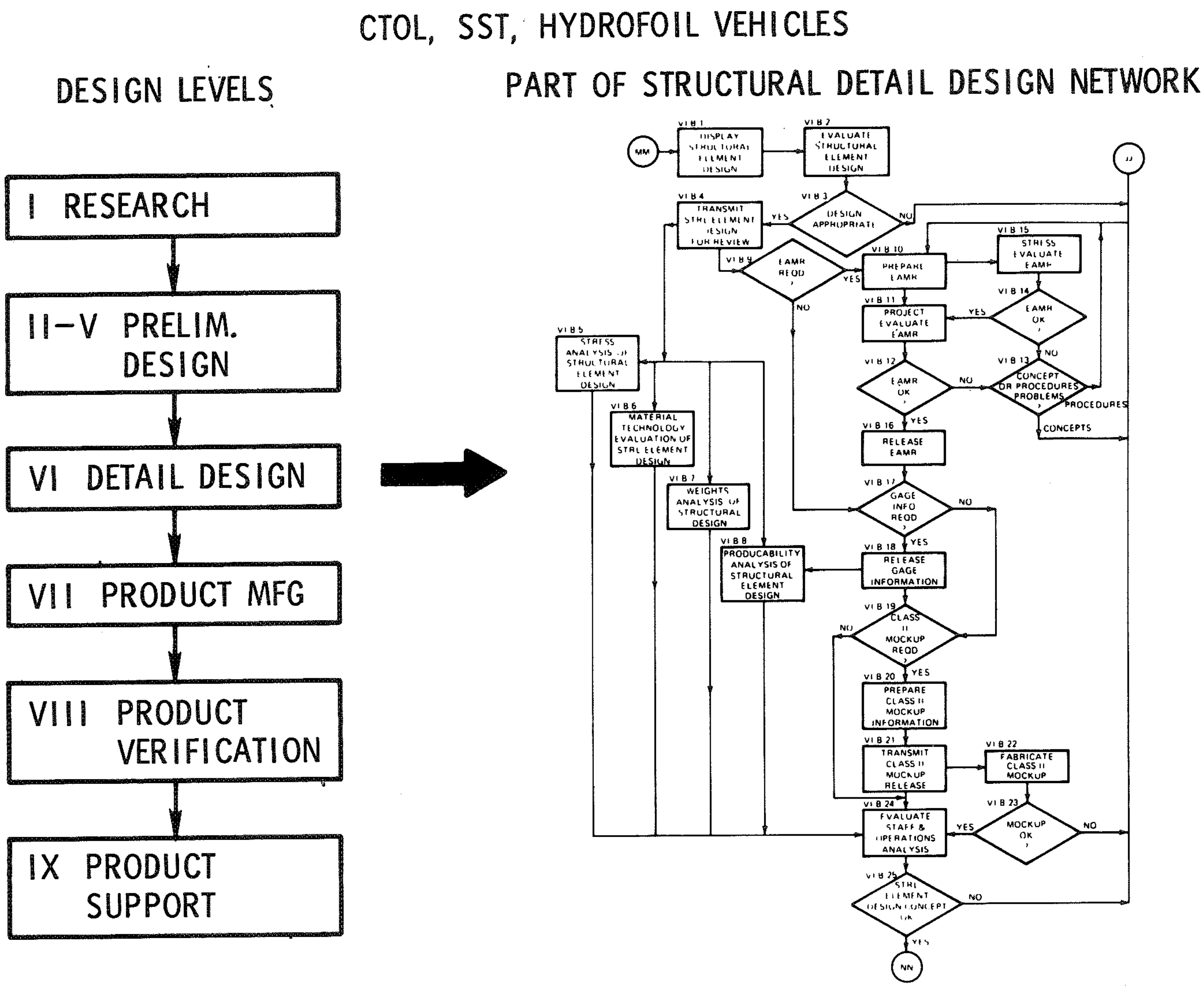

Figure 8.- Detail dissection of design process for representative vehicles.

500 - 1000 SIMULTANEOUS USER TERMINALS

LARGE, RAPID ACCESS DATA VOLUMES TO SUPPORT VEHICLE DESIGN

	ON LINE DATA 10^9 WORDS	10 MINUTE AVAILABILITY 10^9 WORDS
10 PRELIMINARY DESIGNS	1.7	-
10 SUSTAINING DESIGNS	7.8	15.7
2 DETAIL DESIGNS	2.5	3.2
	12.0	18.9

Figure 9.- Key IPAD performance requirements driving software design.

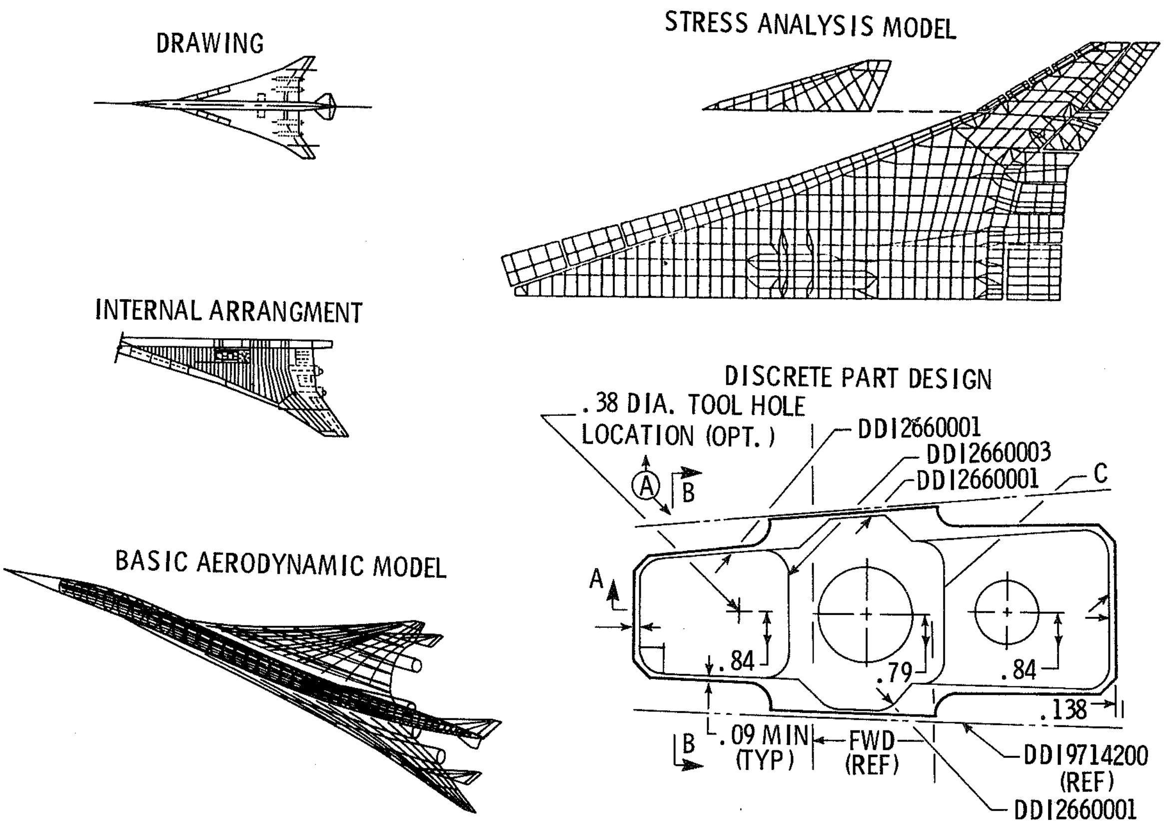

Figure 10.- Geometry permeates the design process.

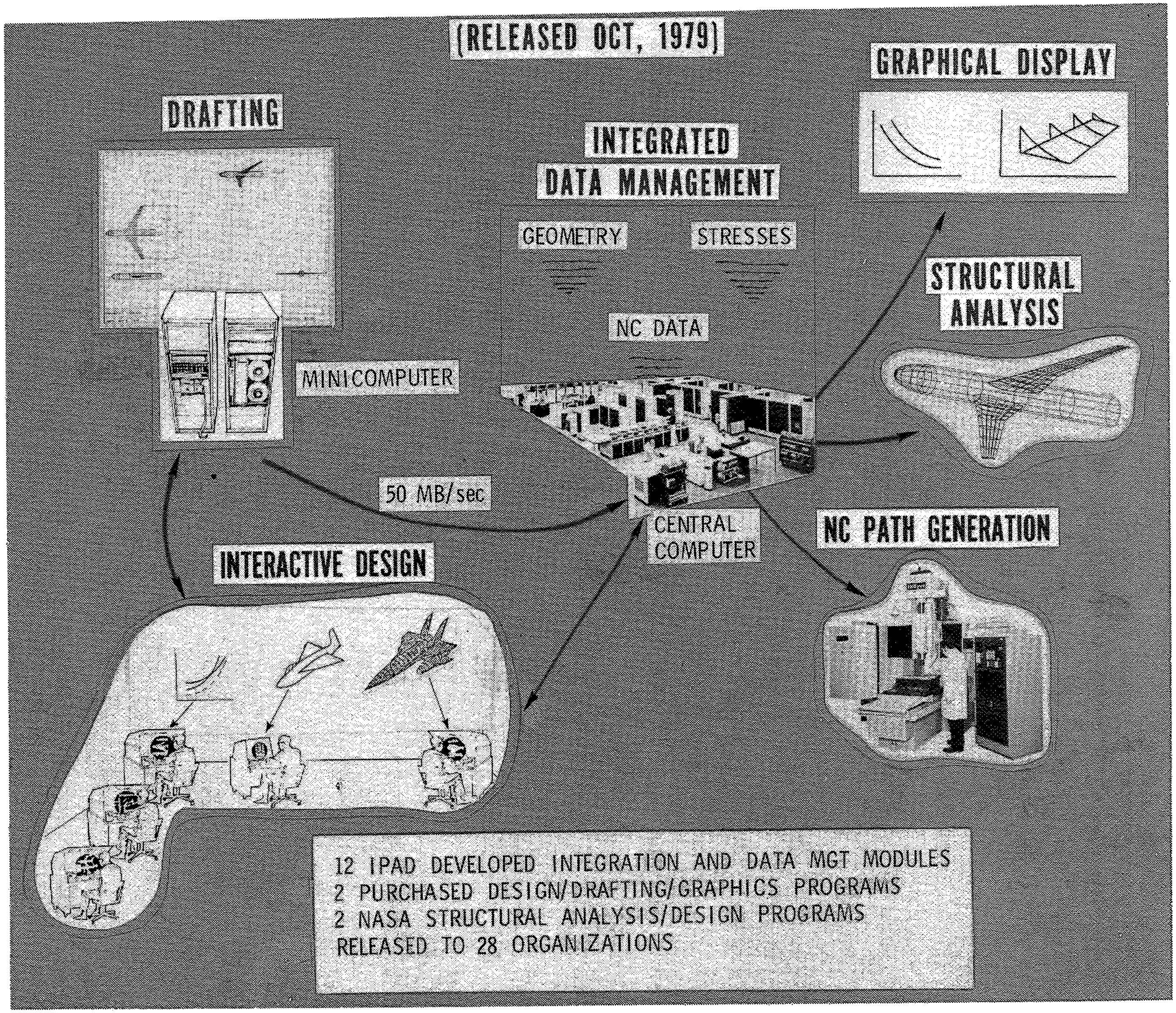

Figure 11.- IPAD design/drafting subsystem.

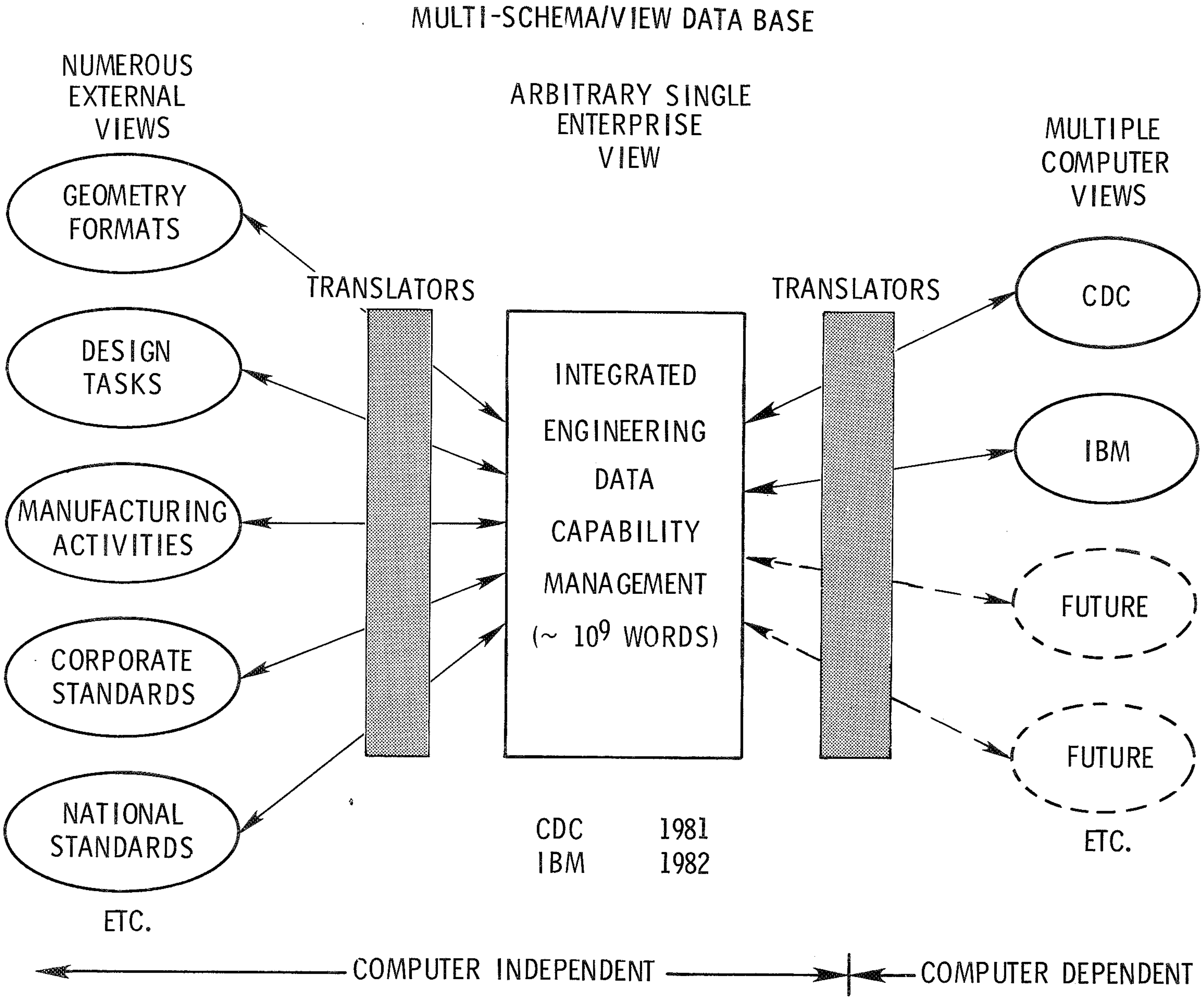

Figure 12.- IPAD engineering data management approach.

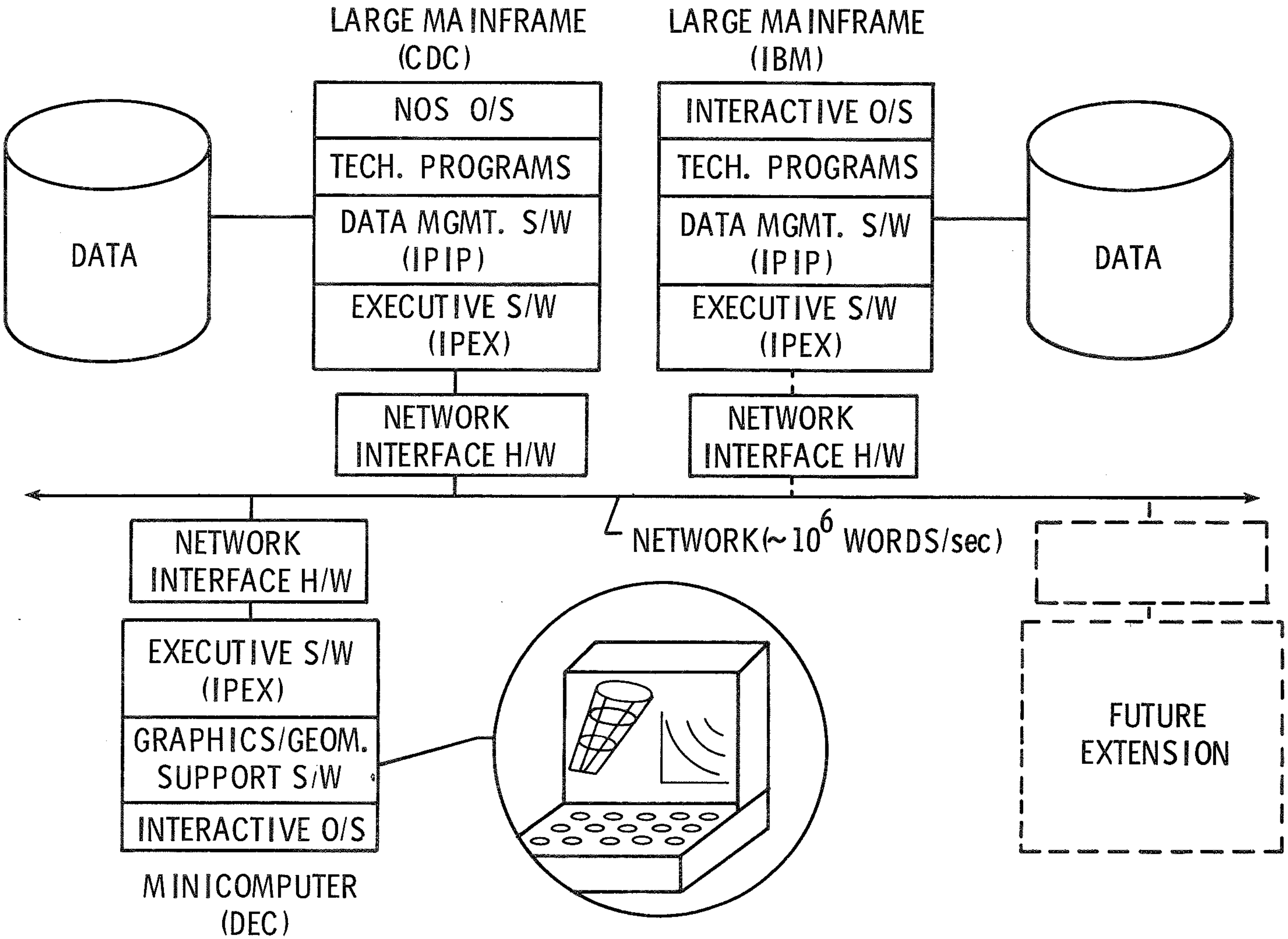

Figure 13.- IPAD hardware/software configuration.

1. Report No. NASA TM-81874	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle OVERVIEW OF INTEGRATED PROGRAMS FOR AEROSPACE-VEHICLE DESIGN (IPAD)		5. Report Date September 1980
		6. Performing Organization Code
7. Author(s) Robert E. Fulton		8. Performing Organization Report No. L-14022
		10. Work Unit No. 510-54-13-01
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		14. Sponsoring Agency Code

15. Supplementary Notes
This paper was presented at the IPAD National Symposium held in Denver, Colorado, September 17-19, 1980, and is published in NASA CP-2143.

16. Abstract

To respond to national needs for improved productivity in engineering design and manufacturing, a NASA supported joint industry/government project is underway denoted Integrated Programs for Aerospace-Vehicle Design (IPAD). The objective is to improve engineering productivity through better use of computer technology. It focuses on development of technology and associated software for integrated company-wide management of engineering information. The project has been underway since 1976 under the guidance of an Industry Technical Advisory Board (ITAB) composed of representatives of major engineering and computer companies and in close collaboration with the Air Force Integrated Computer-Aided Manufacturing (ICAM) program. Results to date on the IPAD project include an in-depth documentation of a representative design process for a large engineering project, the definition and design of computer-aided design software needed to support that process, and the release of prototype software to integrate selected design functions. Ongoing work concentrates on development of prototype software to manage engineering information, and initial software is nearing release. This paper provides an overview of the IPAD project and summarizes goals, plans, and progress to date.

17. Key Words (Suggested by Author(s)) Computer-aided design (CAD) Computer-aided manufacturing (CAM)		18. Distribution Statement Unclassified - Unlimited Subject Category 62	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 20	22. Price* A02

For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA-Langley, 1980