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MANAGEMENT OF CAD/CAM INFORMATION - KEY TO IMPROVED MANUFACTURING PRODUCTIVITY

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Space Administration

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SUMMARY

A key element to improved industry productivity is effective management of CAD/CAM information. To stimulate advancements in this area, a joint NASA/Navy/Industry project designated Integrated Programs for Aerospace-Vehicle Design (IPAD) is underway with the goal of raising aerospace industry productivity through advancement of technology to integrate and manage information involved in the design and manufacturing process. The project complements traditional NASA/DOD research to develop aerospace design technology and the Air Force's Integrated Computer-Aided Manufacturing (ICAM) program to advance CAM technology. IPAD research is guided by an Industry Technical Advisory Board (ITAB) composed of over 100 representatives from aerospace and computer companies. This paper summarizes IPAD accomplishments to date in development of requirements and prototype software for various levels of company-wide CAD/CAM data management and discusses (1) plans for development of technology for management of distributed CAD/CAM data and (2) information required to control future knowledge-based CAD/CAM systems.

INTRODUCTION

For the United States to remain competitive in the world market, improvements in industrial productivity are essential. A key element to improved productivity is the advancement and effective use of computer-aided design/manufacturing (CAD/CAM) technology. To stimulate advancements in CAD/CAM technology, a joint NASA/Navy/Industry project, denoted Integrated Programs for Aerospace-Vehicle Design (IPAD), is underway and is making significant progress (fig. 1). The project goal: raise aerospace industry productivity through advancement of technology to integrate and manage information involved in the design and manufacturing process. The program complements traditional NASA/DOD research to develop aerospace design technology and the Air Force Integrated Computer-Aided Manufacturing (ICAM) program to advance CAM technology. Work under the IPAD project is being done principally through a prime contract to the Boeing Commercial Airplane Company under the guidance of an Industry Technical Advisory Board (ITAB) composed of members of aerospace and Navy contractors and computer companies (fig. 2). ITAB reviews provide a regular forum for over 100 engineering and computer organizations to hold indepth discussions of critical CAD/CAM issues which direct IPAD research and spur internal company efforts. This paper summarizes the background of the IPAD program, NASA and Navy needs for data management technology, an approach to developing CAD/CAM data management software, and priorities for future development.

BACKGROUND

In the late 1970's, NASA-sponsored work on the project showed that significant improvement in engineering productivity was possible through effective automation of information management tasks. The studies included indepth investigation of representative design processes, quantification of the flow of information through such processes, and determination of how automation could significantly aid that flow (fig. 3). Requirements and system design of a future integrated engineering information management system was developed and the concepts were subjected to extensive review by ITAB. It was concluded that available commercial computer software would not meet these requirements and that leadership was needed to stimulate development in critical areas (refs. 1-4).

While the Navy has been associated with IPAD since its inception, in 1982 the Manufacturing Technology Program of the Naval Material Command formally joined NASA to extend IPAD data management research to address the added requirements of manufacturing. Requirements for manufacturing data management have been developed from (1) earlier IPAD requirements studies (ref. 1); (2) ICAM-funded tasks on Product Definition Data Interface by McDonnell Aircraft Company (ref. 5) and Integrated Information Support System by General Electric Company (ref. 6); and (3) an IPAD-funded study of manufacturing information flow for a naval aircraft by Grumman Aerospace Corporation (ref. 7). An initial report on manufacturing data management requirements has been prepared for ITAB to guide future CAD/CAM research. References 1 and 8 provide comprehensive summaries of results from the IPAD program, as well as how organizations are using IPAD and related approaches to address CAD/CAM data management needs.

NASA/NAVY NEED FOR CAD/CAM DATA MANAGEMENT TECHNOLOGY

Advancement of technology to manage CAD/CAM information is an important activity for NASA/Navy leadership and has the potential for significant NASA/DOD benefit. For example, NASA responsibilities include development of key high-risk technologies to support both DOD and civilian aerospace industry needs, and many studies show improved CAD/CAM data management capability is critical to improve industry productivity (ref. 9). NASA also needs engineering data management capabilities to support internal research activities such as scientific computations, development of wind-tunnel models, development and operation of experimental facilities, and project troubleshooting (ref. 10). Furthermore, NASA and its contractors need extensive CAD/CAM data management capabilities to support cost-effective development of high-technology projects such as a future space station and/or other spacecraft (ref. 11).

Navy needs for CAD/CAM data management technology are many and typical of DOD (ref. 12). For example, technology addressed in the IPAD project has the potential to significantly reduce cost and improve productivity in design and manufacture of Navy airplanes, weapons, and ships. The IPAD development strategy, which is based on aerospace industry requirements, appears applicable to many engineering systems and should be useful to the entire spectrum of Navy design and construction. The importance of data management to Navy ship development is illustrated in the following paragraphs.

The Navy ship acquisition process is divided into two stages bound together by the need for common data transfer. Early stage design, performed by the Naval Sea Systems Command, consists of feasibility studies, preliminary design, and contract design. This work includes cost and performance trade-offs, platform sizing and definition, and specification generation. The end product is a contract bidder's package which includes the development specifications for the ship's detail design. The second stage, performed by private shipbuilders, deals with the ship detail design and construction process. This second stage accomplishes selection, procurement, and arrangement of ship components; final detailing of distributive systems; and production of working drawings, lists, and miscellaneous information needed for construction and testing (fig. 4). Detail design and construction includes functional systems for hull/structures, propulsion machinery, combat systems, and distributive systems. Detail design development strategy must accommodate naval shipbuilders who use a variety of computer hardware for technical tasks. Portability is a key need for all engineering data bases, and maintenance of data integrity and consistency among different applications and different subcontractors greatly magnifies the complexity of the management of engineering data.

Ship design data base management requirements are similar to many other engineering requirements, but differ markedly from transaction-oriented business applications. Some significant differences are related to volume of data, volatility and complexity, variety of applications that use the data, and iterative nature of the design process. A complete ship design data base, for example, contains a digital description of ship components and their interrelationships. Data volume for detail design and construction is estimated at 2 billion data items; figure 5, for example, shows the evolution of design data for an aircraft carrier. Data base management systems to support this work must include flexible data modeling and multiple data structures. Convenient features are needed to update and retrieve data by name or through queries based on data values and conditions, to cross reference data in different files, and to obtain information on various data base attributes. Data items in the data base must be separated from the engineering design and analyses programs to negate the cumulative effect of continual changes to data items during design. Each design discipline must also have the capability of accessing the data from its own perspective. The data base must be capable of being accessed by multiple users concurrently, each using the data in different ways and for different purposes. At the same time, procedures must be provided to protect data from being accessed or modified by unauthorized persons. Thus, the CAD/CAM data base will continually change and grow throughout the design cycle due to the iterative nature of the ship design process, and effective computer software is needed to support that process.

The critical need for data management in a NASA or Navy engineering/manufacturing organization stems from the complexity and volume of data and the large number of activities requiring the data. The lack of a unified approach to data base management can result in inefficient storage, control, and use of data. Data redundancy can become widespread and can result in significant potential for errors due to lack of data integrity or to attendant complexity in configuration management procedures.

CAD/CAM DATA MANAGEMENT DEVELOPMENT APPROACH

Under the guidance of ITAB, the IPAD project has developed prototype computer software to meet many CAD/CAM information management requirements (refs. 3 and 4). Some of the basic requirements driving CAD/CAM systems development (refs. 13-21) include (fig. 6): (1) accommodate many different views of data from a variety of users and computing storage devices; (2) allow many levels of data descriptions to support a wide variety of engineering organizations and tasks; (3) permit easy changes in data definition as work progresses; (4) allow data to be distributed over networks of computers of various manufacture; (5) permit data definitions to be readily extended as needs arise; (6) store and manipulate geometry information; (7) embody adequate configuration management features; and (8) provide extensive capability to management information describing stored data. The IPAD approach taken is to conduct appropriate research and develop prototype software for a future network of computers (refs. 22-24). To provide the required CAD/CAM functionality, and yet meet software performance requirements, data base management is staged at two or more levels with different software capabilities needed for both the local (user) level and global (project) level (fig. 7). With such a tiered data base management approach, today's inconvenient file-oriented procedures (fig. 8) can be replaced by future procedures (fig. 9) where convenient user languages efficiently create, store, manipulate, access, and control information in accordance with CAD/CAM requirements.

Prototype software has now been developed under the IPAD project at both the local and global levels. A system denoted Relational Information Management (RIM) was developed for local level data management. RIM is based on the highly flexible relational models which organize and manage engineering and scientific information according to tables and relationships among tables. Its features include interactive queries, report writer, and FORTRAN interface. RIM was first operational in 1979 and is now a mature system. In 1981, it served as a critical information management capability to support NASA investigations (ref. 25) of the integrity of 30,000 tiles on the space shuttle (fig. 10). The success of RIM in such evaluations has led to its continued development and enhancement by government and industry. A public Version 5.0 is available from COSMIC* for CDC, IBM, DEC, UNIVAC, PRIME, and Harris computers. Commercial organizations have continued to enhance RIM and now provide compatible RIM derivative software (e.g., BCS/RIM and MicroRIM) and associated maintenance and support for such software operational on a wide range of computers (from personal computers to super computers). Commercial versions of RIM are being used extensively by industry (refs. 26-29), and one version has been adopted by the Naval Sea Systems Command for use in its early stage ship design integration process.

IPAD research has continued on development of a global data base management system denoted IPAD Information Processor (IPIP). The approach taken in IPIP is to provide the capability within one system to manage information composed of a wide variety of information structures including hierarchical, network, relational, and geometric. The IPIP approach uses multiple levels of information formats (schemata) to permit unlimited reorganization of information as work progresses (fig. 11).

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Each schema is connected to other schemata via a general-purpose mapping capability (language). IPIP is a new concept, still in test and evaluation phases, and is currently operational on a CDC computer. Its approach to management of geometric data is a unique and important concept which could be very important to future integration of design and manufacturing. A critical technical challenge to IPIP development has been to provide the high degree of engineering user flexibility and yet achieve acceptable response times. In late 1983, a test system which has user responses for test problems of less than 0.5 seconds was provided to selected ITAB organizations to support evaluations such as that illustrated in figure 12. IPIP has also been established by one computer vendor as an "as is" product and limited support is provided by the vendor for its installation and evaluation. IPAD results to date in defining CAD/CAM data management requirements and in developing prototype software have helped stimulate development of commercial CAD/CAM data management software (refs. 30-33), and several computer vendors plan release in 1984 of relational-type data management systems which address many of the CAD/CAM requirements identified in IPAD research. IPAD results have also helped stimulate infusion of data base management technology into university engineering research (refs. 34-36).

A critical CAD/CAM requirement not yet contained within any available or planned commercial data management system is the ability to efficiently manage geometry information in concert with other engineering data (fig. 13). Through use of the multischema capability, IPIP provides the first approach to management of geometry information within a data management system (refs. 13 and 14). The IPIP approach provides software capability to create on top of the basic geometric data an information structure having an unlimited number of geometric descriptions (schemata). One geometry schema includes the evolving geometry/graphics standard, Initial Graphics Exchange Specifications (IGES). This IPIP information structure concept opens the door for convenient integration of geometric information with other types of information associated with a CAD/CAM development process (fig. 14). An evaluation of the IPIP geometry concept is now underway, and comparisons are being made with other approaches in which management of the geometric data takes place oustide the basic data base manager.

PRIORITIES FOR FUTURE CAD/CAM DEVELOPMENT

A key data management requirement for CAD/CAM integration is the ability to manage unified information distributed across computers of different manufacture with the user flexibility provided by software such as RIM and IPIP. A typical company may have several different computers to support its combined engineering manufacturing activity; the addition of subcontractors introduces even more heterogeneity in computers. Examples of recent high-technology developments include the space shuttle (fig. 15) and the Navy advanced aircraft (e.g., fig. 16), wherein major components were developed by many widely dispersed companies, each having different computer complexes. IPAD research has begun development of technology for distributed data management. The basic IPIP design was planned for a distributed complex, and prototype software was developed in 1980 to provide high-speed (greater than 10^6 bits/sec) information transfer between CDC CYBER 730 and a DEC VAX 11/780. This transfer concept is a critical element to distributed data management and has already been expanded by vendors into commercial products (e.g., NETEX). IPAD research underway in 1984 is to investigate distributed data management across a test-bed system composed of a CDC CYBER 835, an IBM 4341, and a DEC VAX 11/780, with each computer utilizing different data base management software (fig. 17). Critical needs identified by ITAB, NASA, and the Navy for CAD/CAM related data management research over the next few years include:

1. Refinement of manufacturing data management requirements
2. Development of executive software to control information management over a network of heterogeneous computers
3. Development of distributed data management software capabilities
4. Extension of geometry data management concepts to include solid modeling data
5. Development of multidisciplinary analysis/design data management approaches for sequential and concurrent processing computers (fig. 18)
6. Development of data management approaches for expert engineering systems (fig. 19)

A National Research Council report states (ref. 9): The use of computers in design and manufacturing offers the potential of an integrated information system that encompasses product planning, designing, manufactural engineering, purchasing, materials requirements planning, manufacturing, quality assurance, and customer acceptance. A single product definition data base containing an electronic description of the designed products that are being constructed or manufactured is a keystone to the successful utilization of CAD/CAM technology. The NASA/Navy IPAD project under the guidance of ITAB has helped focus unified government/industry technology development on this important national productivity need.

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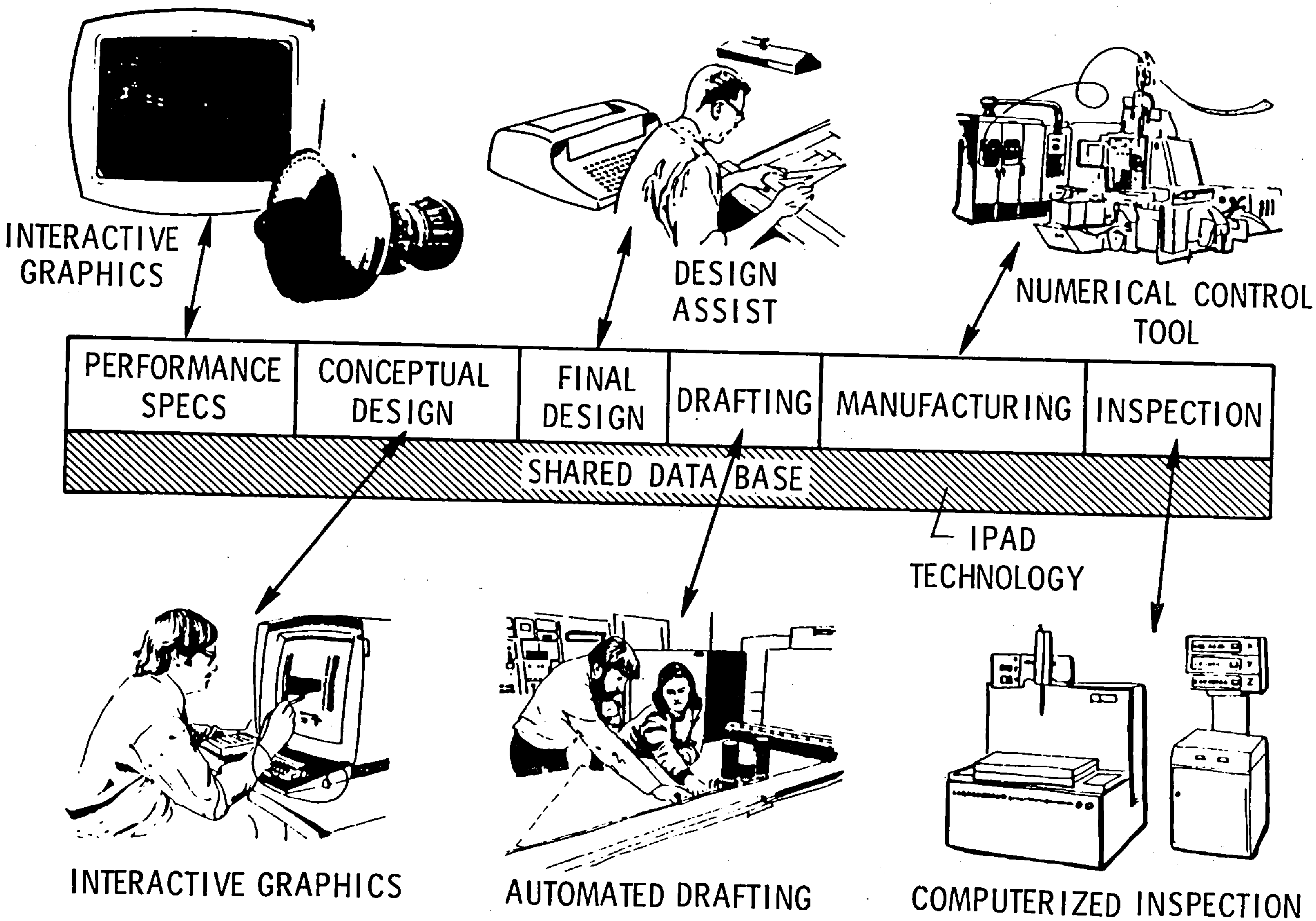

Figure 1.- Joint NASA/Navy research program to develop technology to manage CAD/CAM information.

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AEROSPACE INDUSTRY
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ENGINE MANUFACTURERS
- GENERAL ELECTRIC
- PRATT AND WHITNEY

COMPUTER MANUFACTURERS
- IBM
- CDC
- DEC
- UNIVAC

• OBSERVERS (100 +)

- • 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
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- AIR FORCE - MATERIALS LAB
- ⋮

• ADDED SINCE 1979

ITAB ACTIVITIES

GUIDE DEVELOPMENT TO MEET INDUSTRY NEEDS

REVIEW/CRITIQUE ONGOING WORK

EVALUATE PROTOTYPE SOFTWARE

USE IPAD TECHNOLOGY AND PRODUCTS TO SPUR IN-HOUSE PLANNING AND DEVELOPMENT

Figure 2.- IPAD Industry Technical Advisory Board (ITAB).

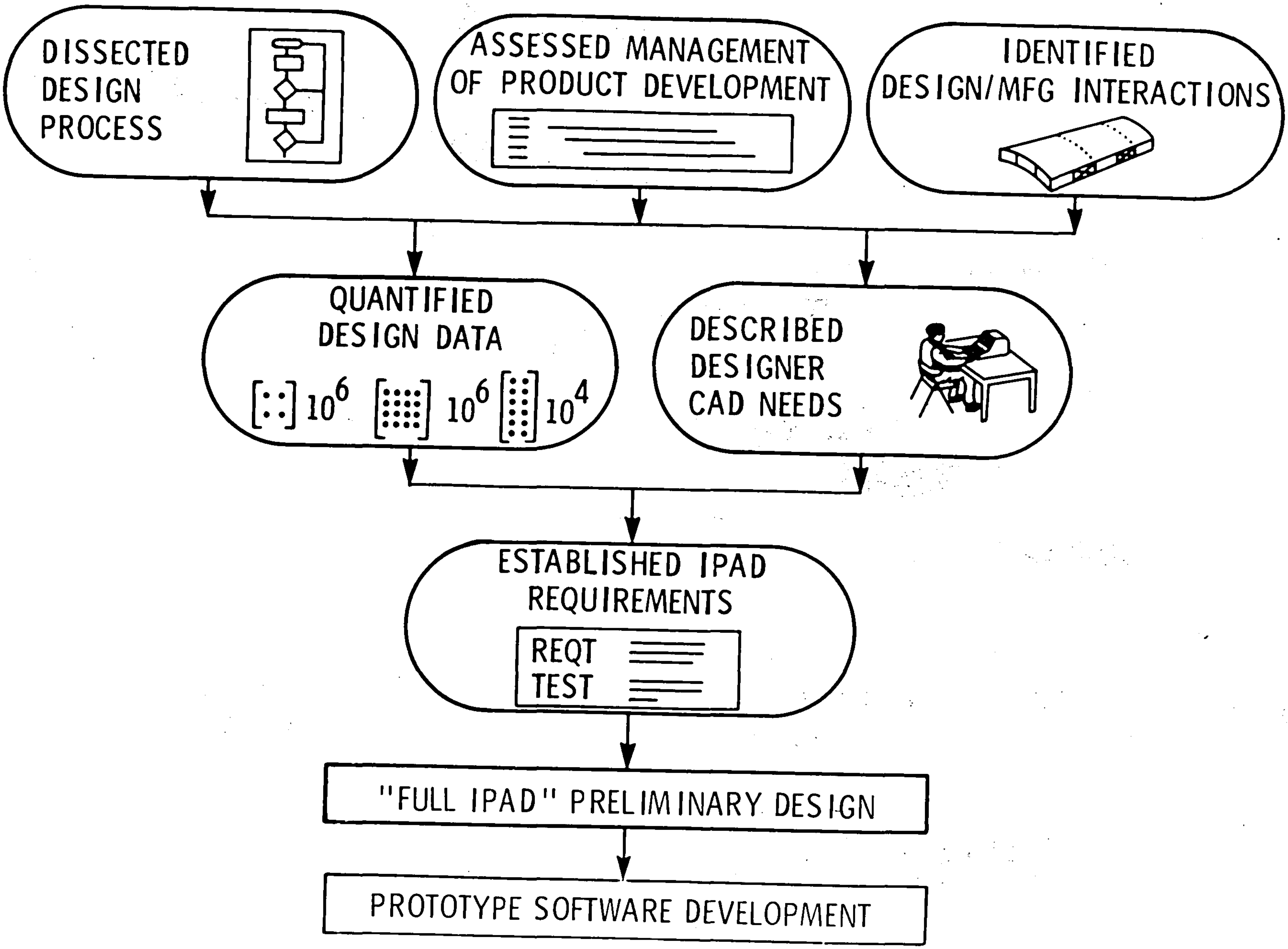

Figure 3.- IPAD approach to developing prototype software.

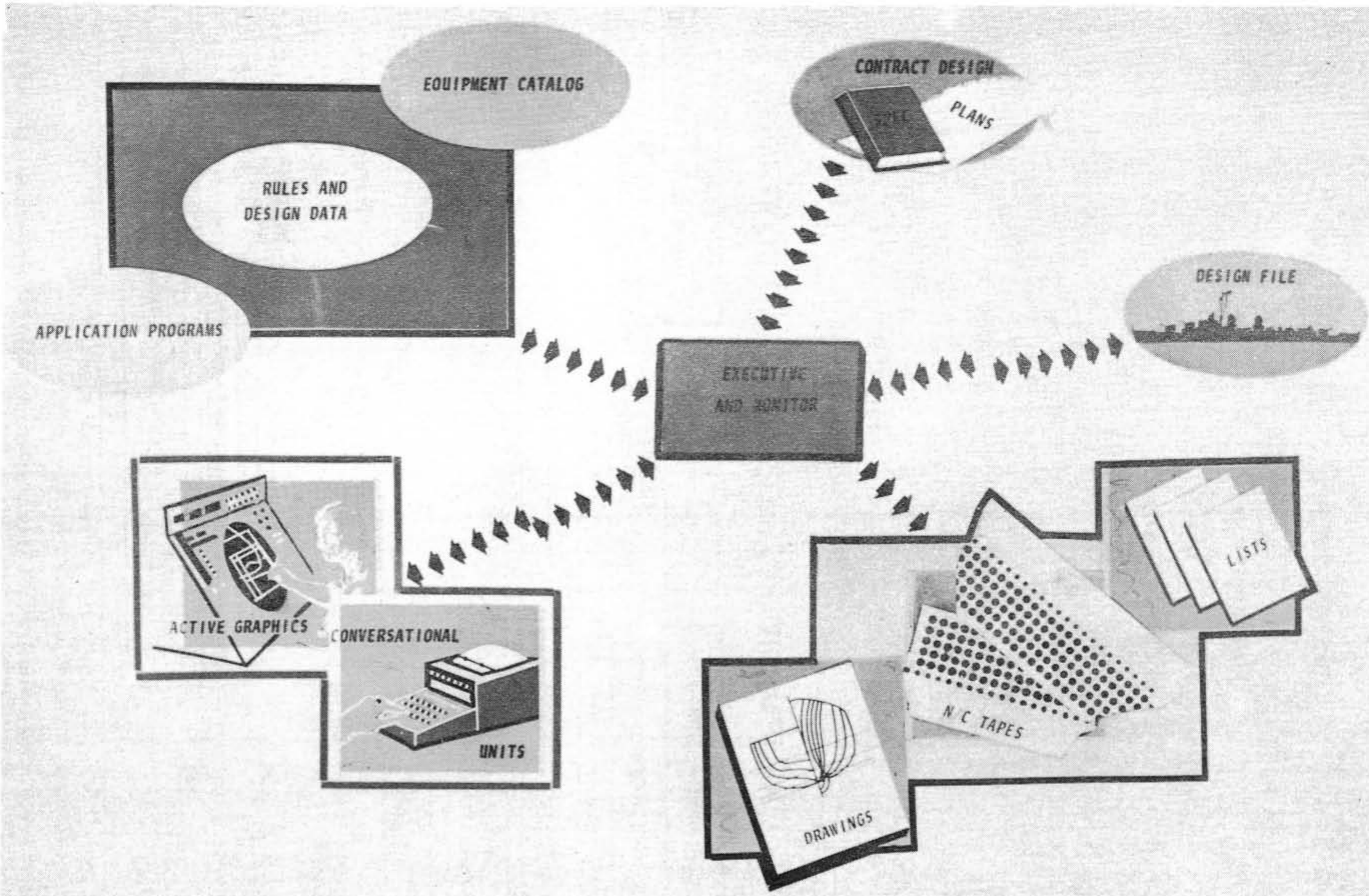

Figure 4.- Navy ship detail design system.

MISSION REQUIREMENTS -
18 PAGES

PRELIMINARY DESIGN -
12 PLANS AND 70 PAGE BOOKLET

CONTRACT DESIGN -
150 PLANS AND 800 PAGE SPEC.

DETAIL DESIGN -
7,000 PLANS AND 70 TECH. MANUAL

Figure 5.- Growth of information during ship design process. Data for aircraft carrier.

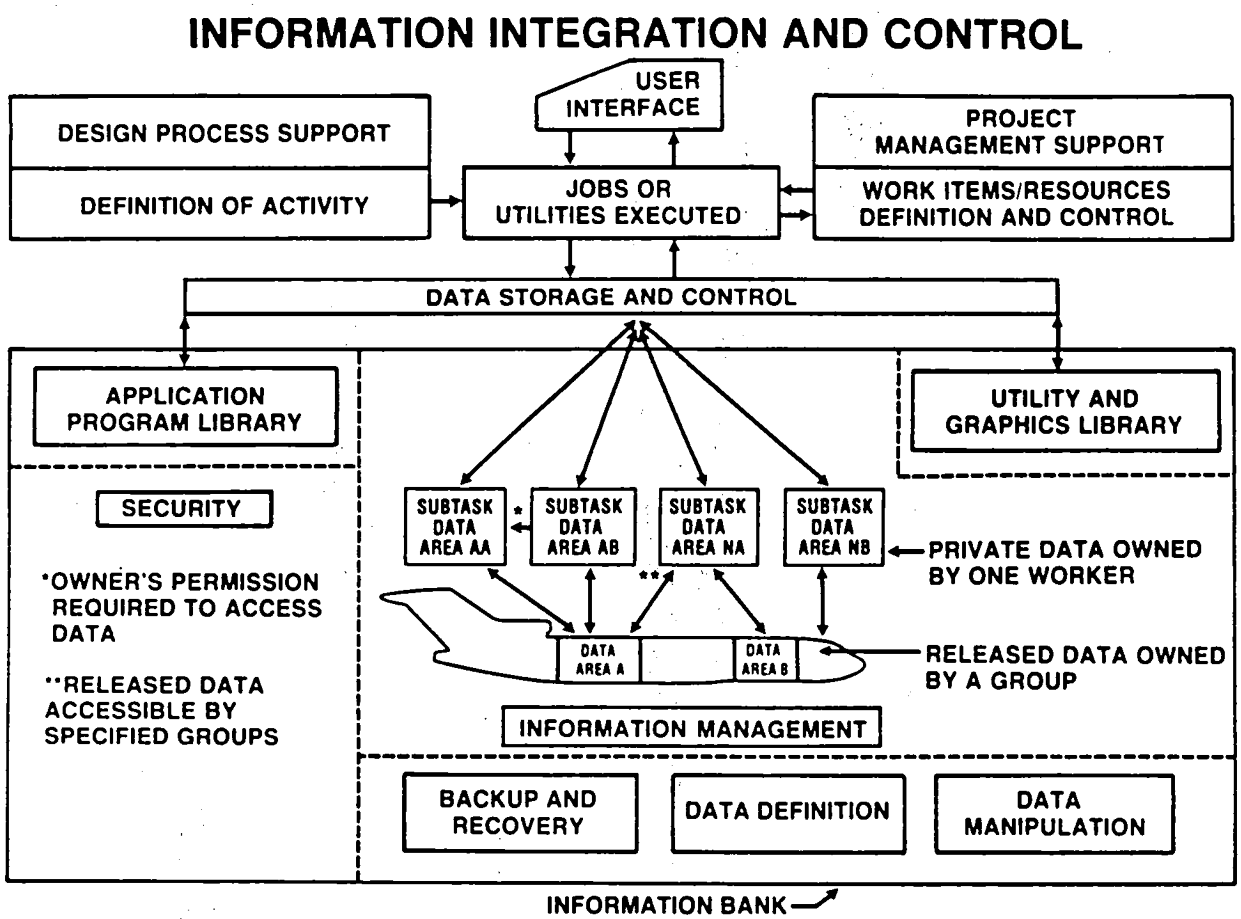

Figure 6.- Engineering use of integrated CAD/CAM data management system.

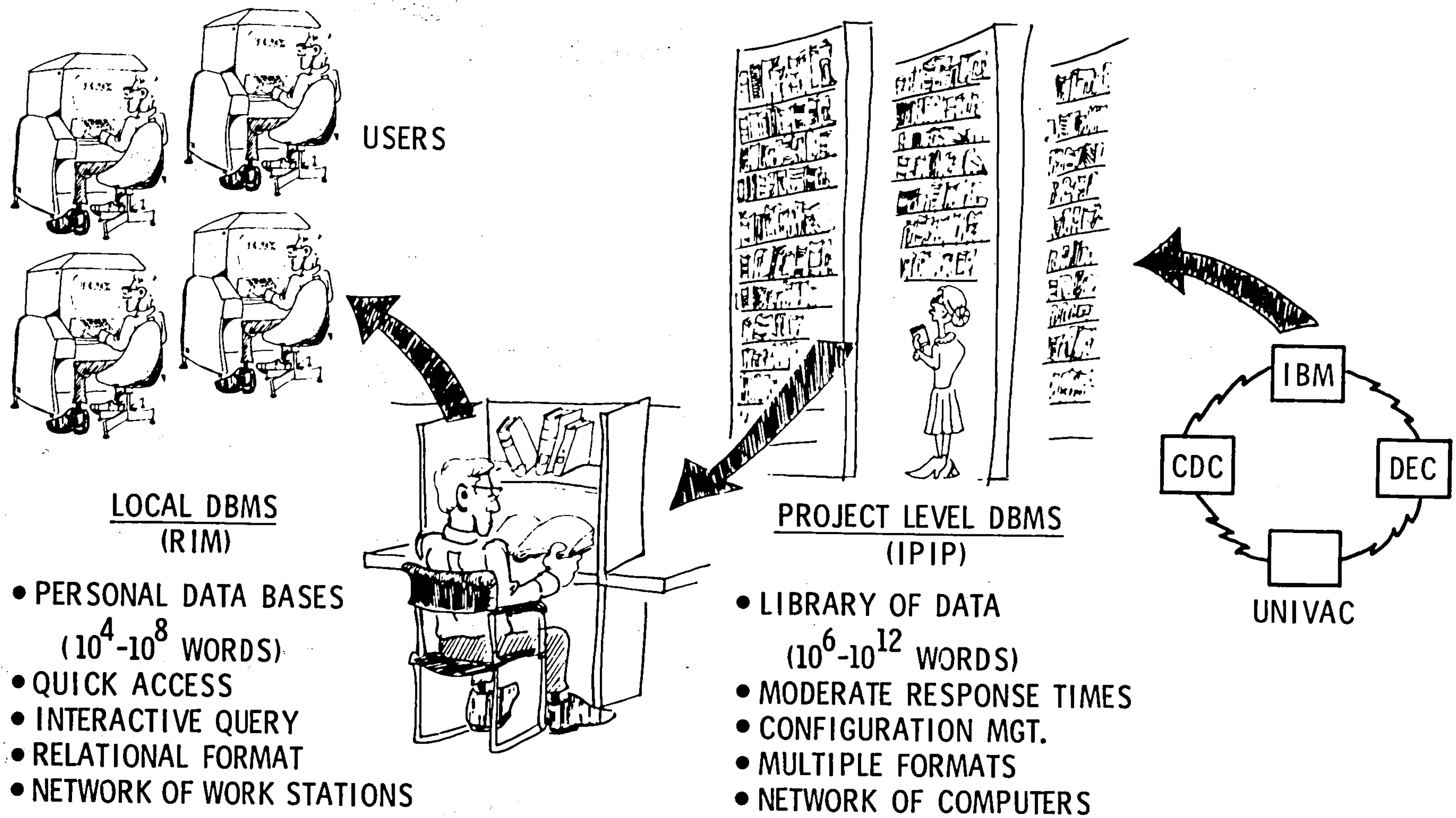

Figure 7.- IPAD multilevel approach to engineering data base management.

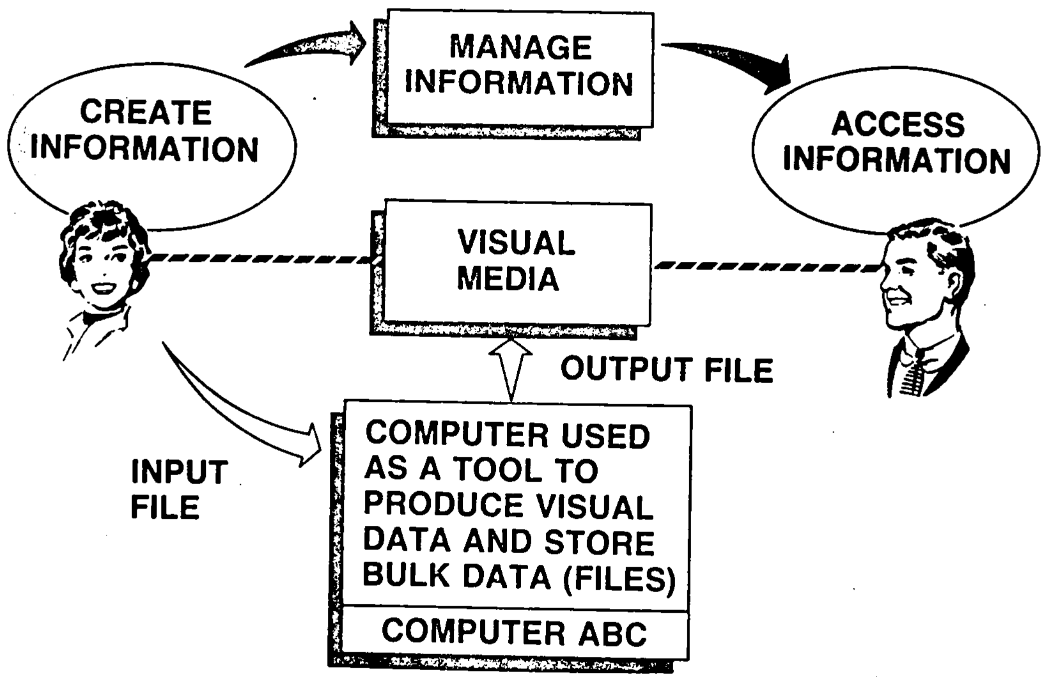

Figure 8.- Current file-oriented approach for CAD/CAM information.

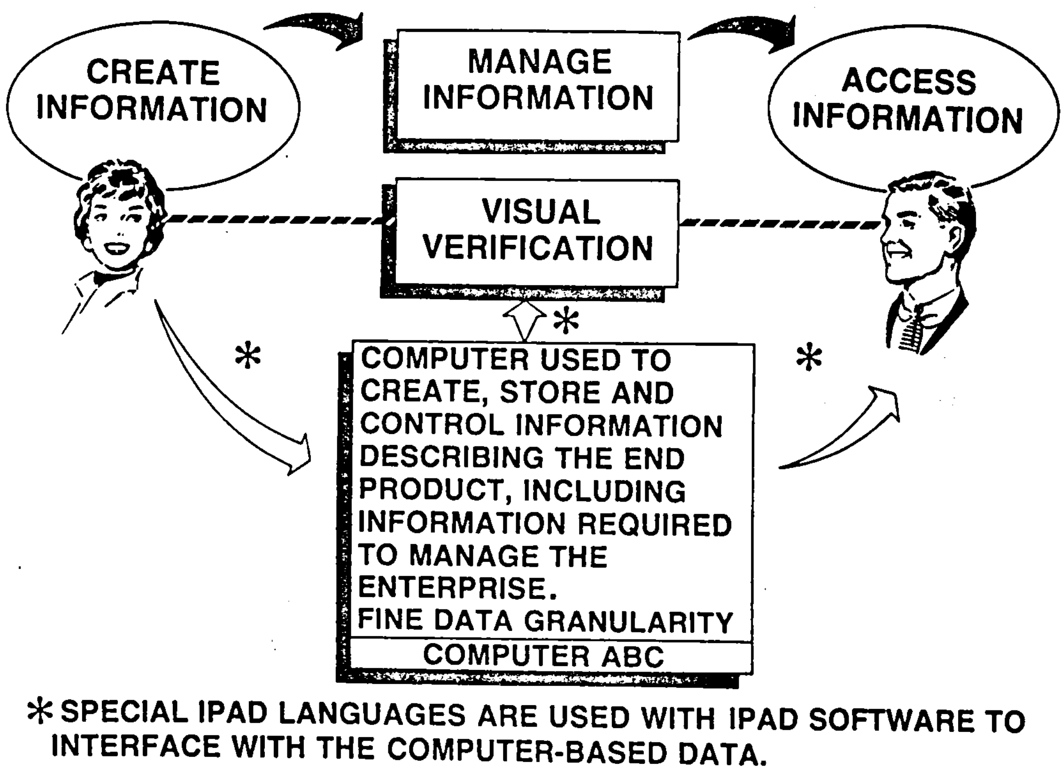

Figure 9.- Future data base management approach for CAD/CAM information.

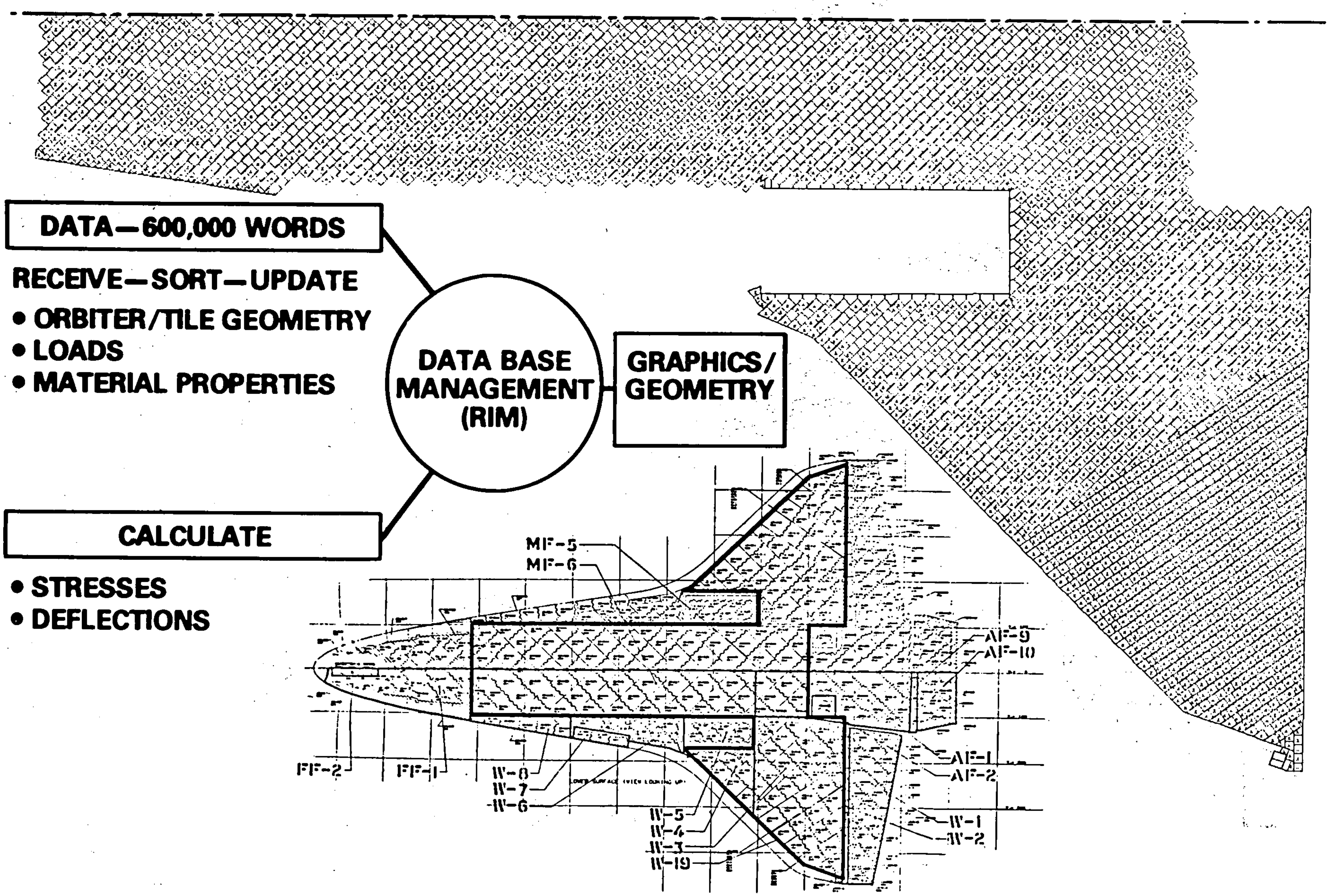

Figure 10.- Use of IPAD/RIM data manager to support investigation of space shuttle tile analyses.

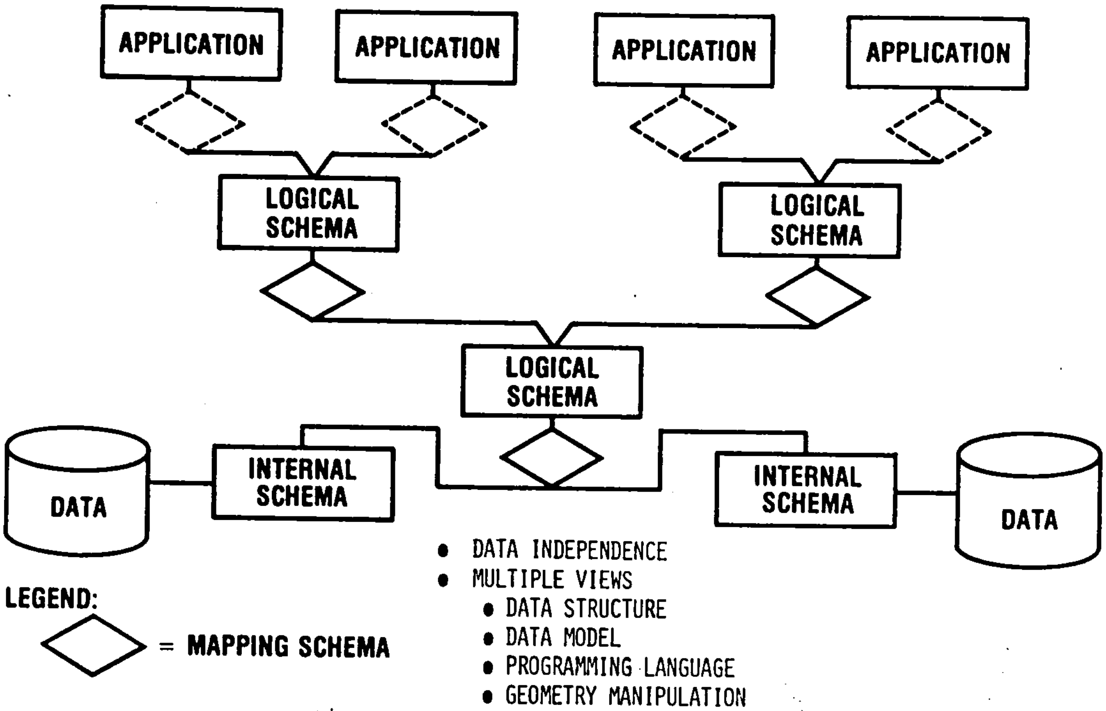

Figure 11.- Typical arrangement of IPIP data schemata (formats) to connect application schemata to storage schemata.

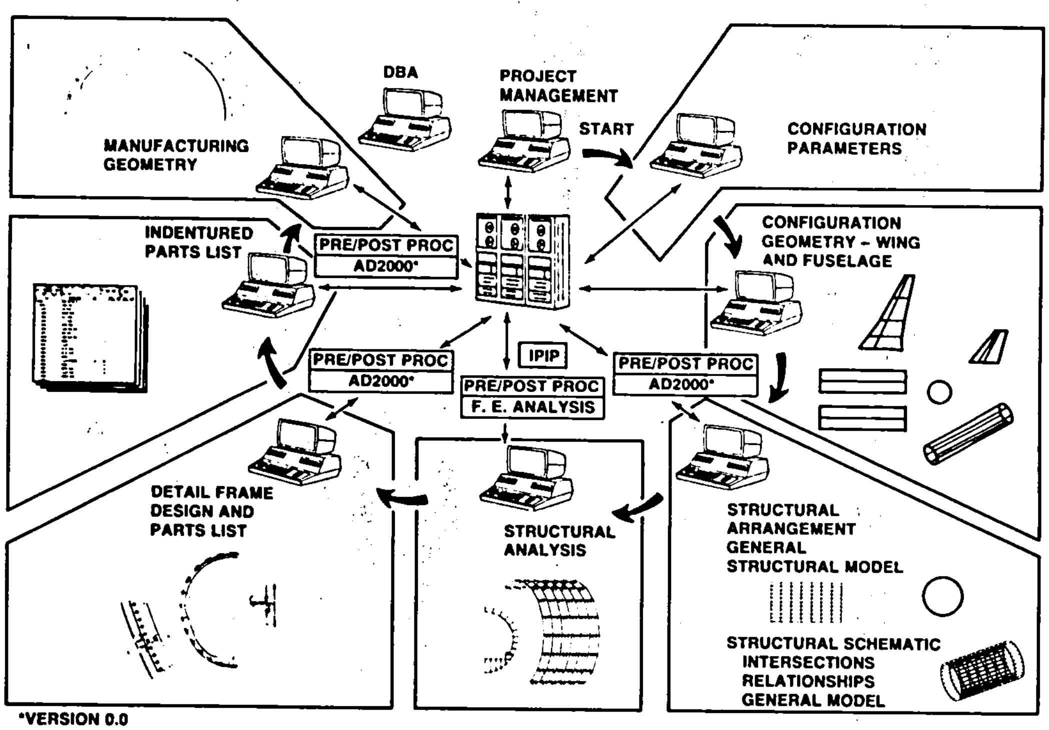

Figure 12.- Planned test demonstrations to evaluate IPAD/IPIP for CAD/CAM use.

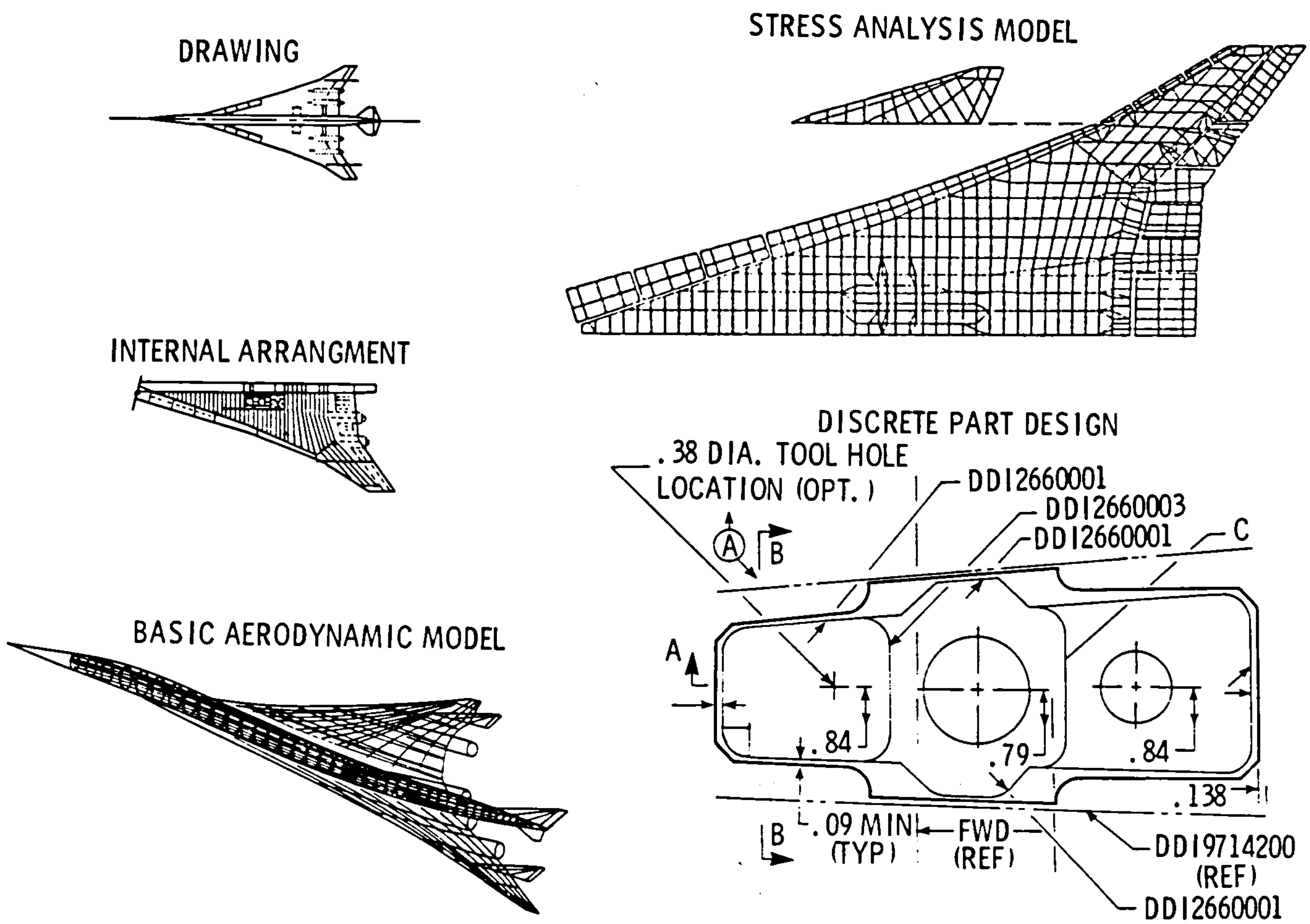

Figure 13.- Critical role of geometry information to CAD/CAM.

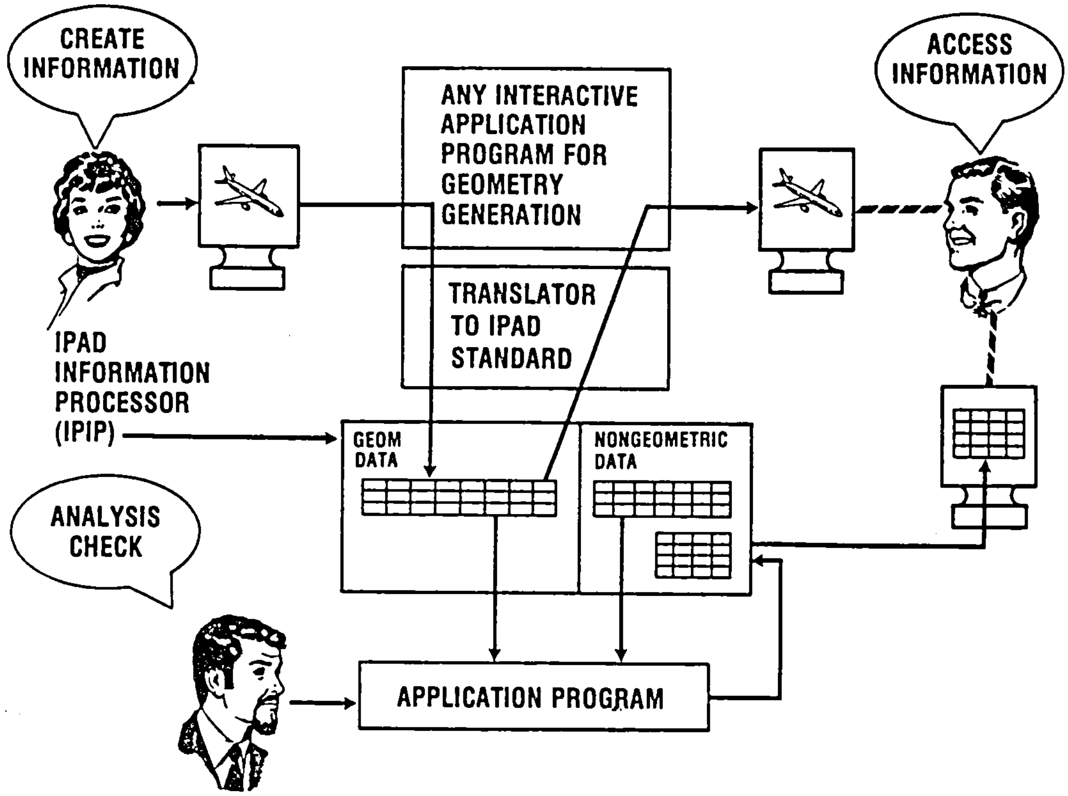

Figure 14.- IPAD approach to unified management of combined geometry and nongeometric CAD/CAM data.

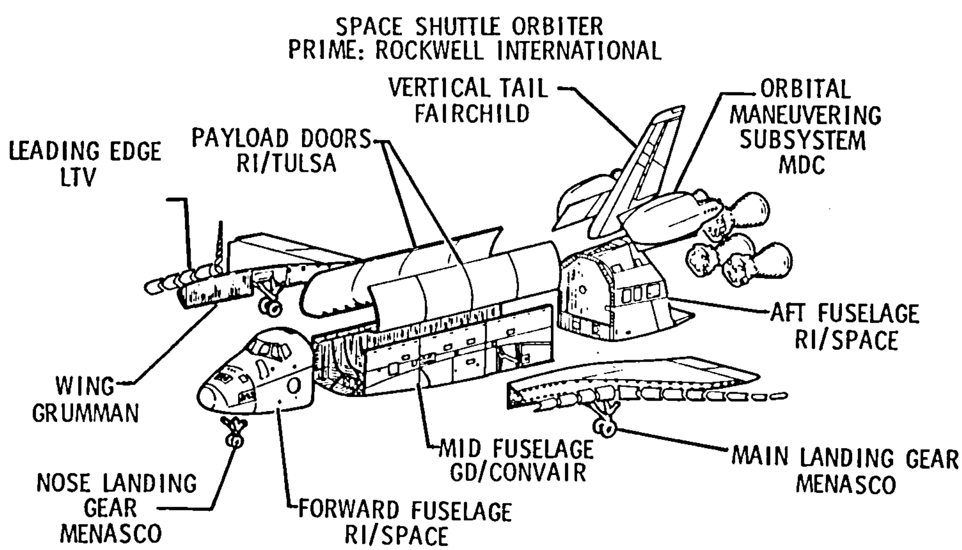

Figure 15.- Typical multicompany development approach for aerospace products.

MAJOR SUPPLIERS

RADAR	GENERAL ELECTRIC
PASSIVE DETECTION SYS.	LITTON AMECOM
COMPUTER PROGRAMMER	LITTON DSD
ROTODOME	RANDTRON
CONTROL INDICATOR GROUP	HAZELTINE
COMMUNICATION	COLLINS
IFF DETECTOR PROCESSOR	HAZELTINE
EQUIPMENT COOLING	GARRETT

EQUIPMENT LOCATIONS

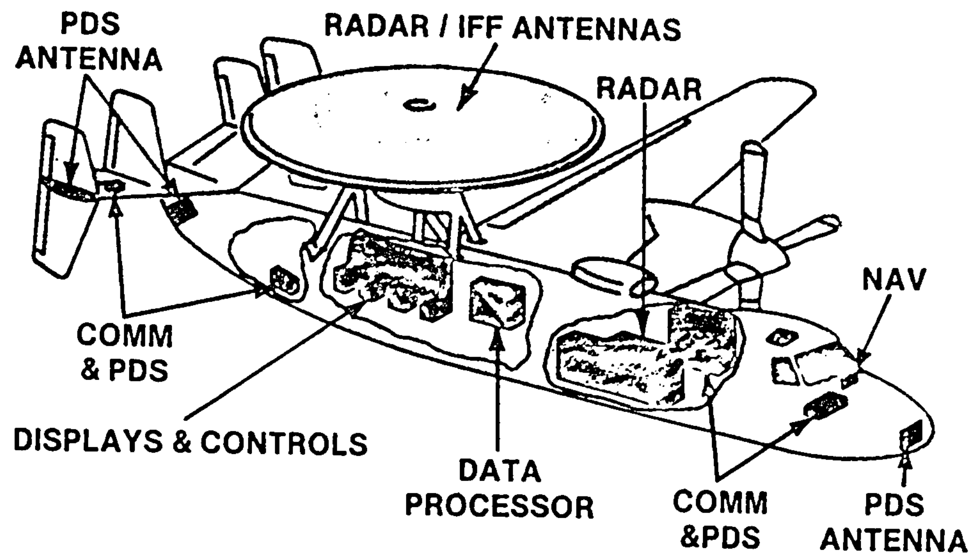

Figure 16.- Major avionics suppliers for advanced Navy aircraft E2C (courtesy Grumman Aerospace Co.).

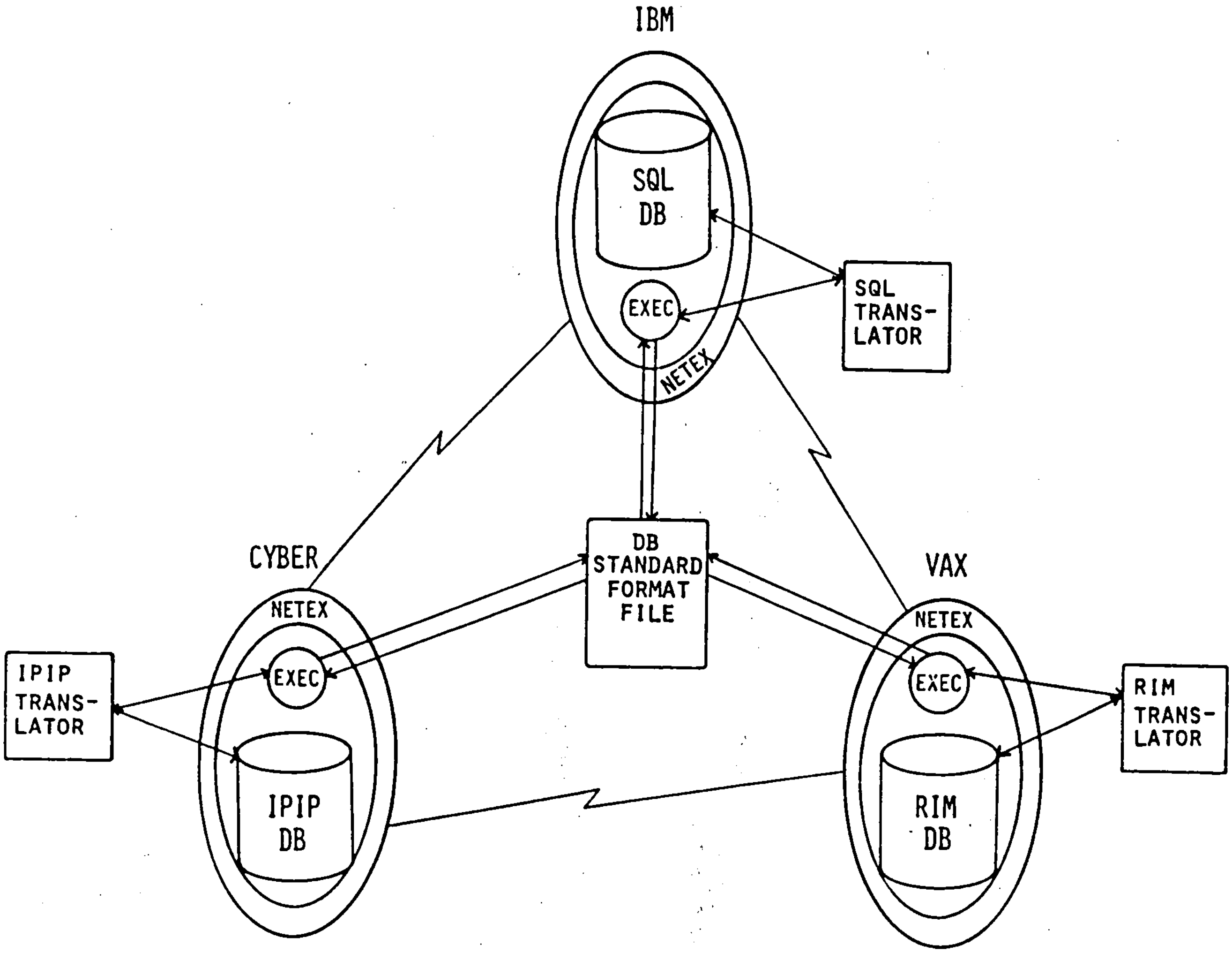

Figure 17.- Initial CAD/CAM distributed data management approach.

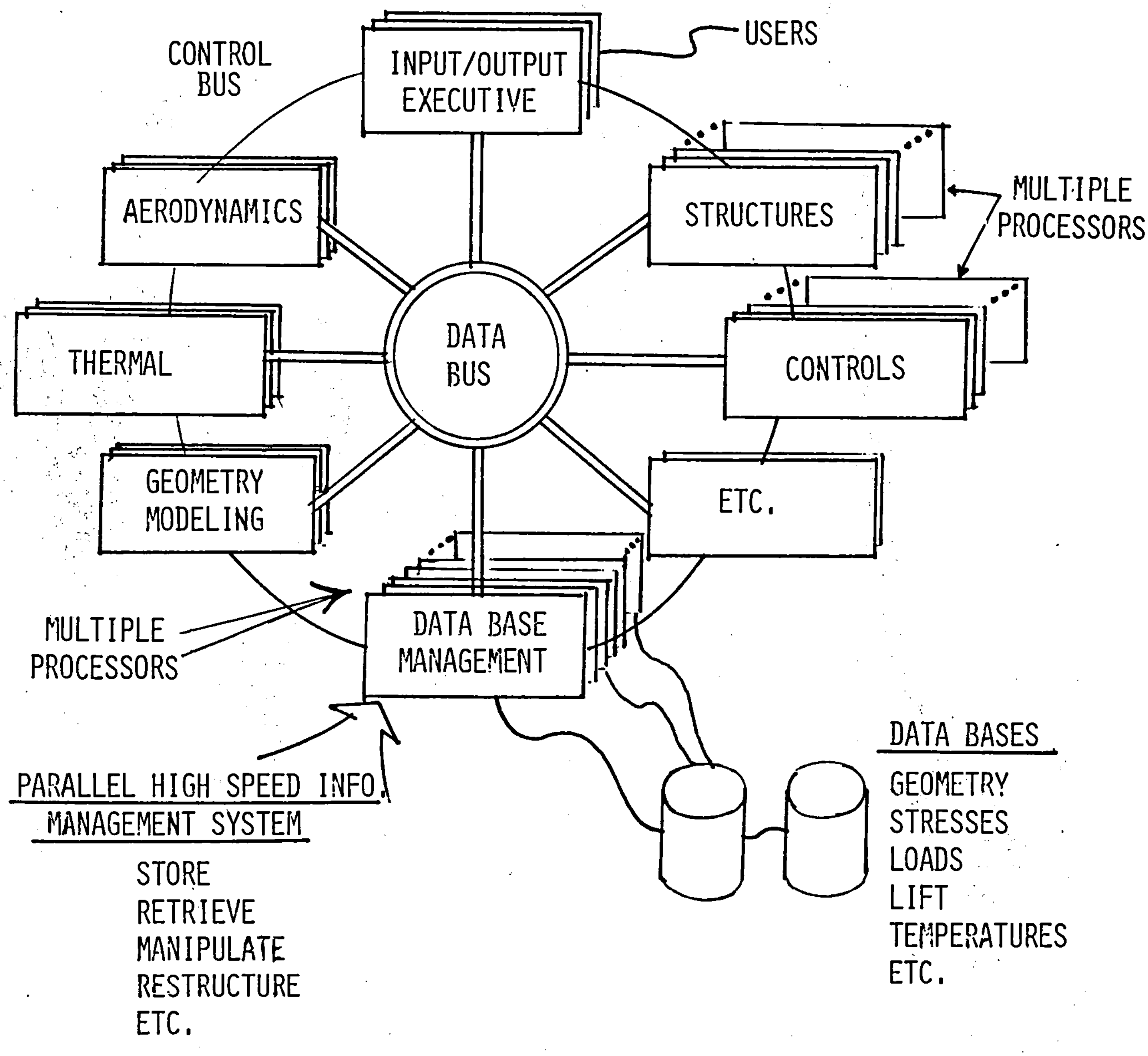

Figure 18.- Data base management in a concurrent processing multidisciplinary environment.

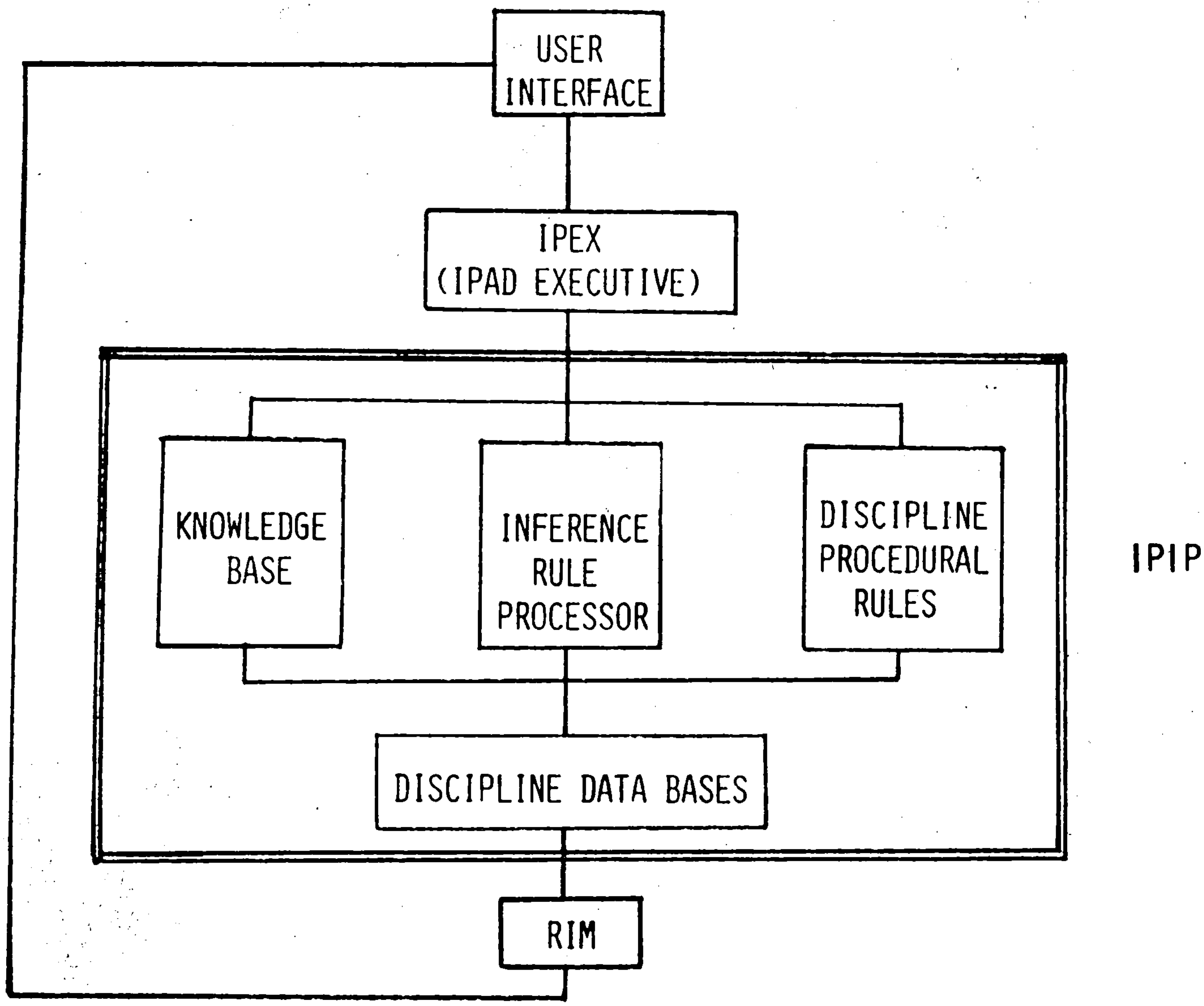

Figure 19.- Data base management approach for engineering-based expert systems.

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15. Supplementary Notes

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16. Abstract

A key element to improved industry productivity is effective management of CAD/CAM information. To stimulate advancements in this area, a joint NASA/Navy/industry project designated Integrated Programs for Aerospace-Vehicle Design (IPAD) is underway with the goal of raising aerospace industry productivity through advancement of technology to integrate and manage information involved in the design and manufacturing process. The project complements traditional NASA/DOD research to develop aerospace design technology and the Air Force's Integrated Computer-Aided Manufacturing (ICAM) program to advance CAM technology. IPAD research is guided by an Industry Technical Advisory Board (ITAB) composed of over 100 representatives from aerospace and computer companies.

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