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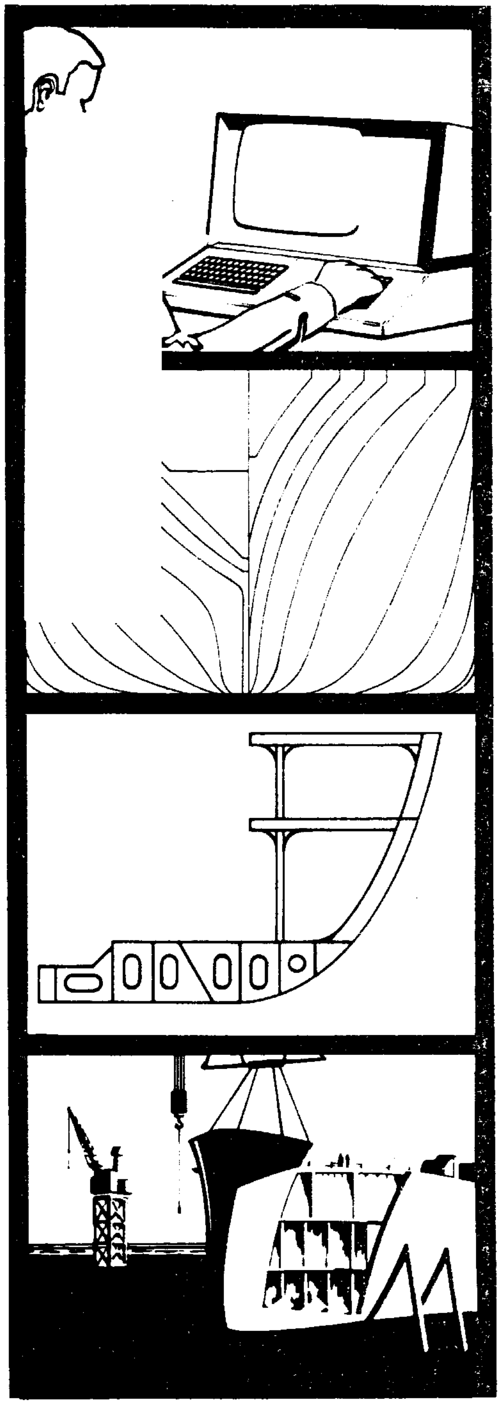

R ESEARCH
AND
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IN
S HIPBUILDING

Proceedings of the
REAPS Technical Symposium
June 21-22, 1977
New Orleans, Louisiana

COMPUTER AIDED SHIP DESIGN AND CONSTRUCTION IN THE NAVY

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Currently, Mr. Corin is Manager of the Computer Aided Design and Construction (CASDAC) system at DTNSRDC. He has over 40 years' **experi-**ence in the shipbuilding industry in England and in the United States as apprentice shipbuilder, naval architect and special engineer with Bethlehem Steel Central Technical Department.

Mr. Corin received his training at the University of Durham in England and at the Technical University of Norway.

1. Introduction

The paper discusses a number of facets of Computer-Aided Ship Design and Construction (CASDAC) in which the writer has been involved. A brief history of computers in the Navy is given, some notes on the CASDAC project, the flavor of two recent programs, Navy planning and philosophy in detail design. and construction, some notes on the Computer-Aided Piping Design and Construction (CAPDAC) project, and finally some notes on the increasingly important role of computer science.

The U. S. Navy has a long history in the use of computers in shipbuilding. In May 1944 the first computer came into operation at Harvard, the Automatic Sequence Controlled Calculator -- the Harvard Mark I. This was designed and constructed by Professor Howard Aiken -- at that time a Commander in the United States Navy. It was the Bureau of Ships which first sponsored the operation of this calculator and some of the first problems attacked originated from the Bureau.

In 1952, the Applied Mathematics Laboratory was established at the now David W. Taylor Naval Ship Research and Development Center (DTNSRDC) to initiate computer service to the Navy. For this installation the Univac's 6th computer was installed in 1953. Early work included shaft vibrations, shell stiffening, propeller design, underwater sound intensities, pipe stress analysis, and nuclear reactor design. Within a year, this computer was operating around the clock. By 1958, clients included personnel from the naval shipyards processing programs associated with their ship construction program. By 1960 naval shipyards possessed their own computers and programs were in operation for tank capacity tables, hull deflection, voltage drop, shock mounts, sound isolation, mast calculations, weights and moments, propulsion shaft bearing reactions, pipe bend calculations and pipe stress analysis.

In 1964, the Computer Aided Ship Design and Construction (CASDAC) project was initiated and is now under the sponsorship of the Naval Sea Systems Command (NAVSEA), with *technical* management in the Naval Ship Engineering Center (NAVSEC) and

2. Computer-Aided Ship Design and Construction (CASDAC)

The broad objectives of CASDAC are to employ computers:

(a) to provide improved ships and ship systems at reduced cost, and

(b) to reduce ship acquisition time.

In 1965, a comprehensive program *was* proposed covering the principal areas of ship design and construction. However, Navy priorities of the late 60's and early 70's were such that funding for this program was severely restricted. Work accomplished has been mostly in the area of preliminary design, except for two large detail design programs, Computer-Aided Structural Detailing of Ships (CASDOS) and Cabling and Wiring (WIRES). In preliminary and contract design there are currently about one hundred Navy programs listed in the new edition of CASDAC Computer Abstracts. To give the flavor of some of the work being accomplished, two topics are discussed below -- Integrated Design and Interactive Graphics.

3. Integrated Ship Design System (ISDS)

Attempts to link programs together are well known to result in dilemmas relating to input/output incompatibilities. Of equal importance, when programs are linked across the boundaries of more than one discipline, the resultant suite of programs seems to become an orphan -- people want only to maintain their own portion of the whole. These problems are resolved when, in lieu of linking together, programs are made to operate against a maintained data base. ISDS was conceived as a mechanism whereby time spent on preliminary ship designs could be substantially reduced. The system is under development at DTNSRDC for the Naval Ship Engineering Center (NAVSEC). Figure 1 shows the collection of ship design programs which currently reside in ISDS. Figure 2 outlines the operation of the ISDS.

The principal components of the system are:

- Ship Design File, which provides a residence for design data pertaining to a specific ship.

- Catalog data files -- storage for particulars of equipment common to many ships, e.g., electronic components, deck machinery, etc.

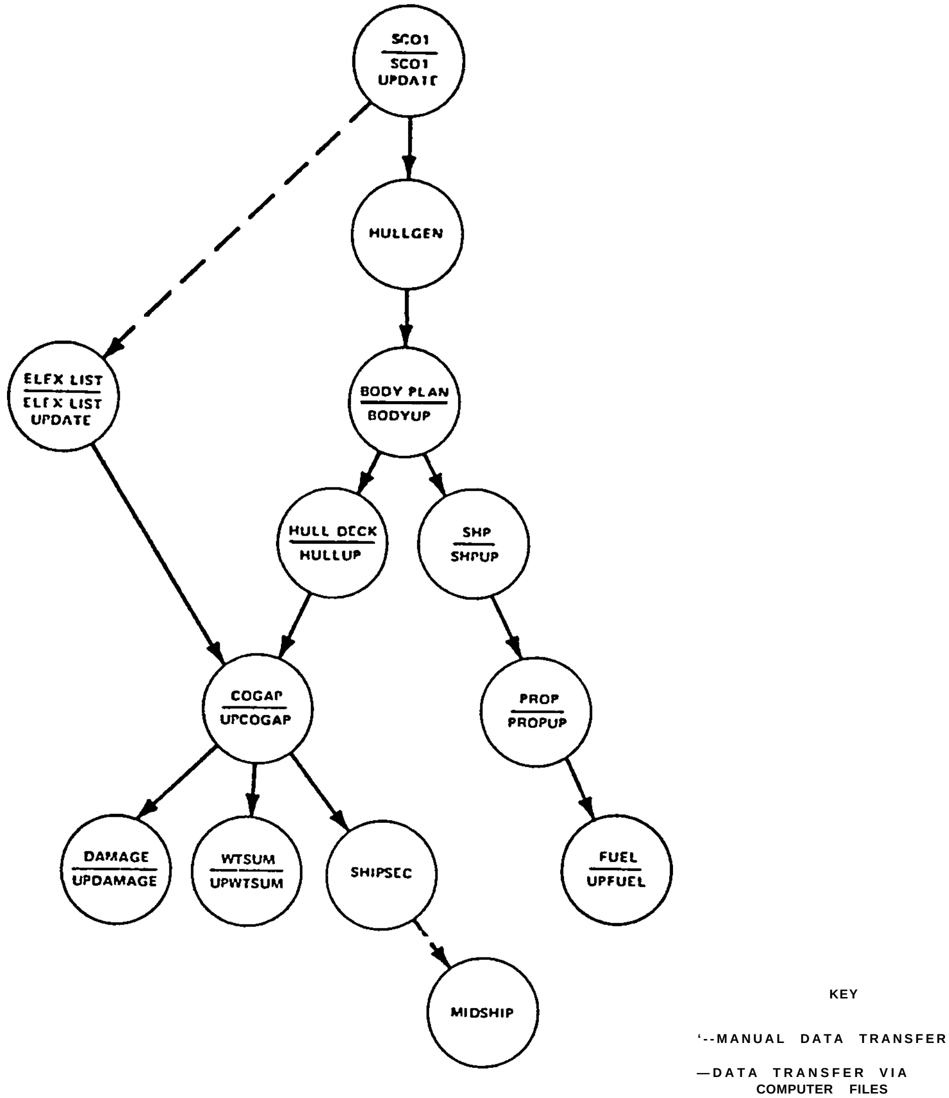


Figure 1 - ISDS DESIGN PROCEDURES

INTEGRATED SHIP DESIGN

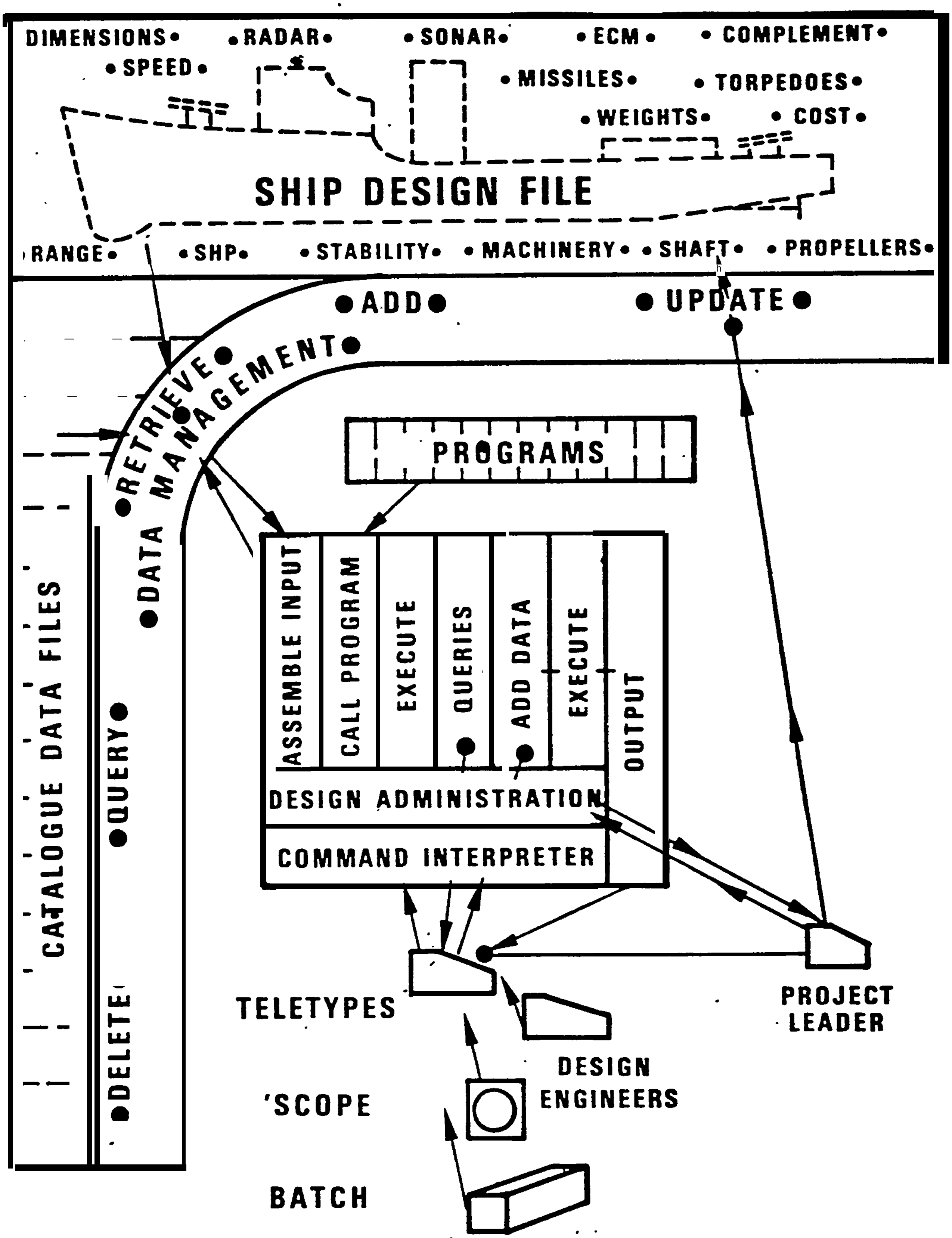


FIGURE 2 - ISDS OPERATIONS

- Ship design programs as shown in Figure 1.
- Central software system, the Computer Aided Design Environment (COMRADE), consisting of an Executive, some Design Administration Procedures, and a Data Management System which can delete, query, retrieve, add, and update data.

The system can operate in the batch mode and interactively from teletypes or a graphics scope. operations are conducted by design engineers under control of a project leader.

For a new design the first program used is a synthesis program, SCO1, which accepts input giving the payload, speed, range, etc. Output comprises particulars for a range of ships, usually of varying lengths. These particulars include beam, draft, depth, coefficients, weights, crew required, etc., all derived from statistical information stored in the program: A ship from this range is selected for detail study and output from SCO1 is used to pollinate the ship design file.

Other programs are called using English language commands, commands are interpreted, and design administration verifies the access rights of the design engineer. Thereafter, the executive assembles input via the data management system from the design file. This may be scrutinized by the design engineer and modified prior to execution. The design engineer may run the program a number of times with varying inputs and the outputs may be saved on a working file. After consultation with the project leader, an acceptable set of results is updated into the ship design file.

The execution of a number of ISDS programs results in the completion of the design file which initially contained only a sparse amount of data from the initial program SCO1.

Most programs are interactive and the user is assisted with two levels of tutorials -- either complete tutorials for the novice or abbreviated tutorials for the expert.

ISDS is currently in a skeletal form with 12 operational programs. The system is now undergoing test and evaluation at NAVSEC. A complete ISDS would include some 30 - 35 programs. While the ISDS represents a substantial advance over a collection of independent programs, ISDS operations do require engineers with more than minimal computer expertise.

4. Interactive Graphics

Work in this area has been maintained at various levels since 1966, first at the CDC Digigraphics Laboratory, later with Navy IBM 1130-2250 equipment, and, currently, with a time-shared CDC 6000 and four CDC 274 scopes with 1700 drivers. Production graphics tasks are marginally satisfactory due to delays at the time-shared mainframe. Local graphics using a minicomputer has been under procurement for the past three years and eventually this will replace the current equipment. Nevertheless, graphics is establishing its place. and two programs may be noted.

A. Hull Generation (HULLGEN)

This program runs within ISDS and also stand-alone. Inputs are ship dimensions, coefficients, an area curve, LCB, load waterline curve and LCF and a *curve* of the flat of bottom. These can be displayed, Figure 3, and may be interactively modified to suit the user. A light pen pick will produce *a* display of transverse station shapes, Figure 4, compatible with the input data. The transverse station shapes may be modified by adding slope specifications at the flat of bottom, the load waterline and at the deck-at-edge. This program enables the designer to review a large number of hull form alternatives during early design.

B. Graphics Arrangements

Segments of this program run within ISDS and other segments currently run stand-alone. Some inputs may be derived from ISDS and others are entered by the user at the scope. The hull and superstructure geometry is stored and may be displayed in the form of plan views and longitudinal and transverse sections. Bulkheads and partitions may be interactively added, thus defining compartments, Figure 5. A substantial capability is being built up to deal with equipment arrangements. Equipment outlines are stored in catalogs as crude or primitive outline approximations. These primitives may be displayed readily and manipulated until an acceptable arrangement is achieved. Upon requesting hard copy, the program accesses detail equipment outlines in lieu of primitives, and the former are plotted for the finished arrangement such as Figure 6. Some 1000 pieces of equipment are incorporated in the catalogs.

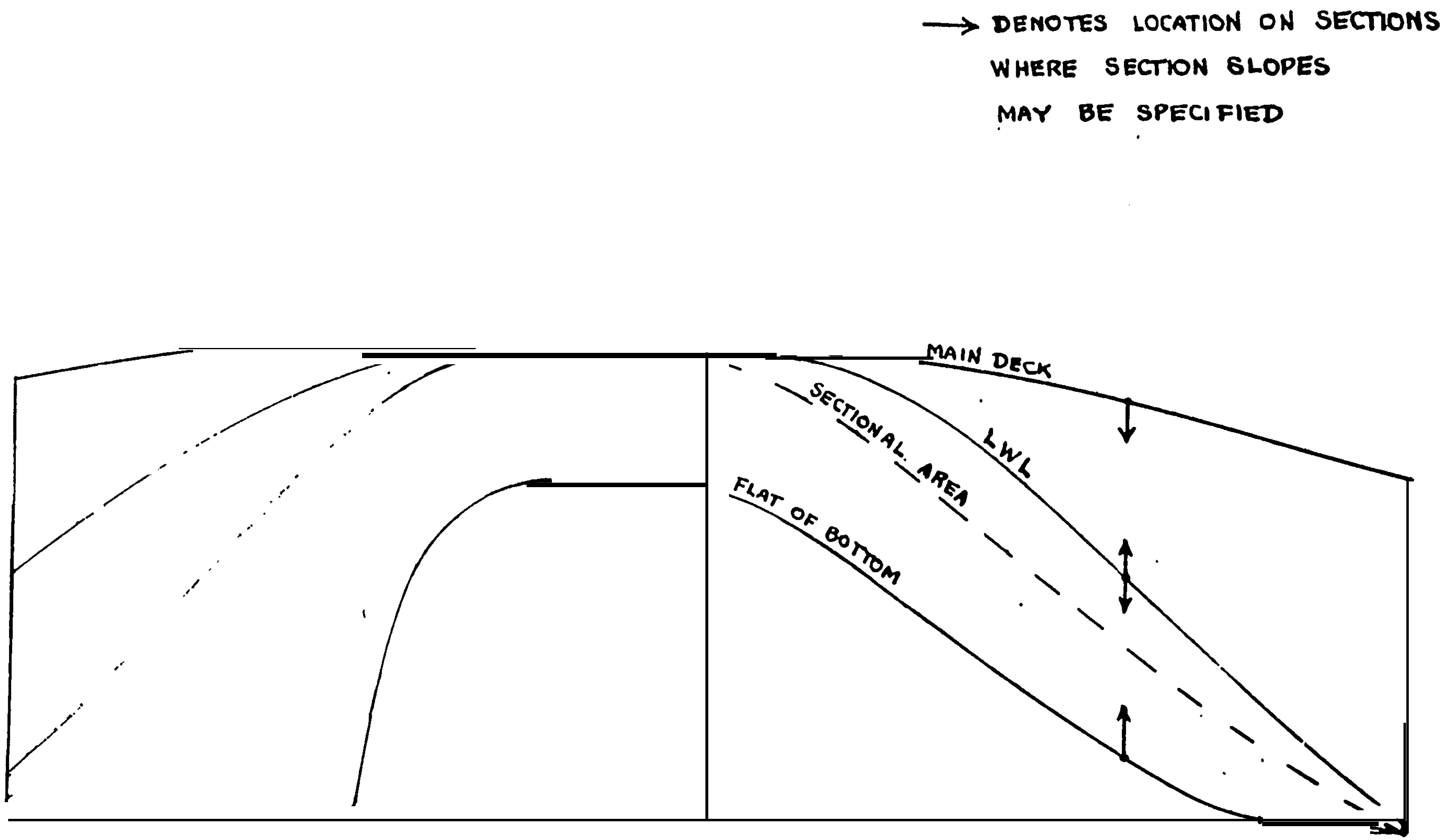


FIGURE 3 - HULLGEN INPUT DISPLAYS

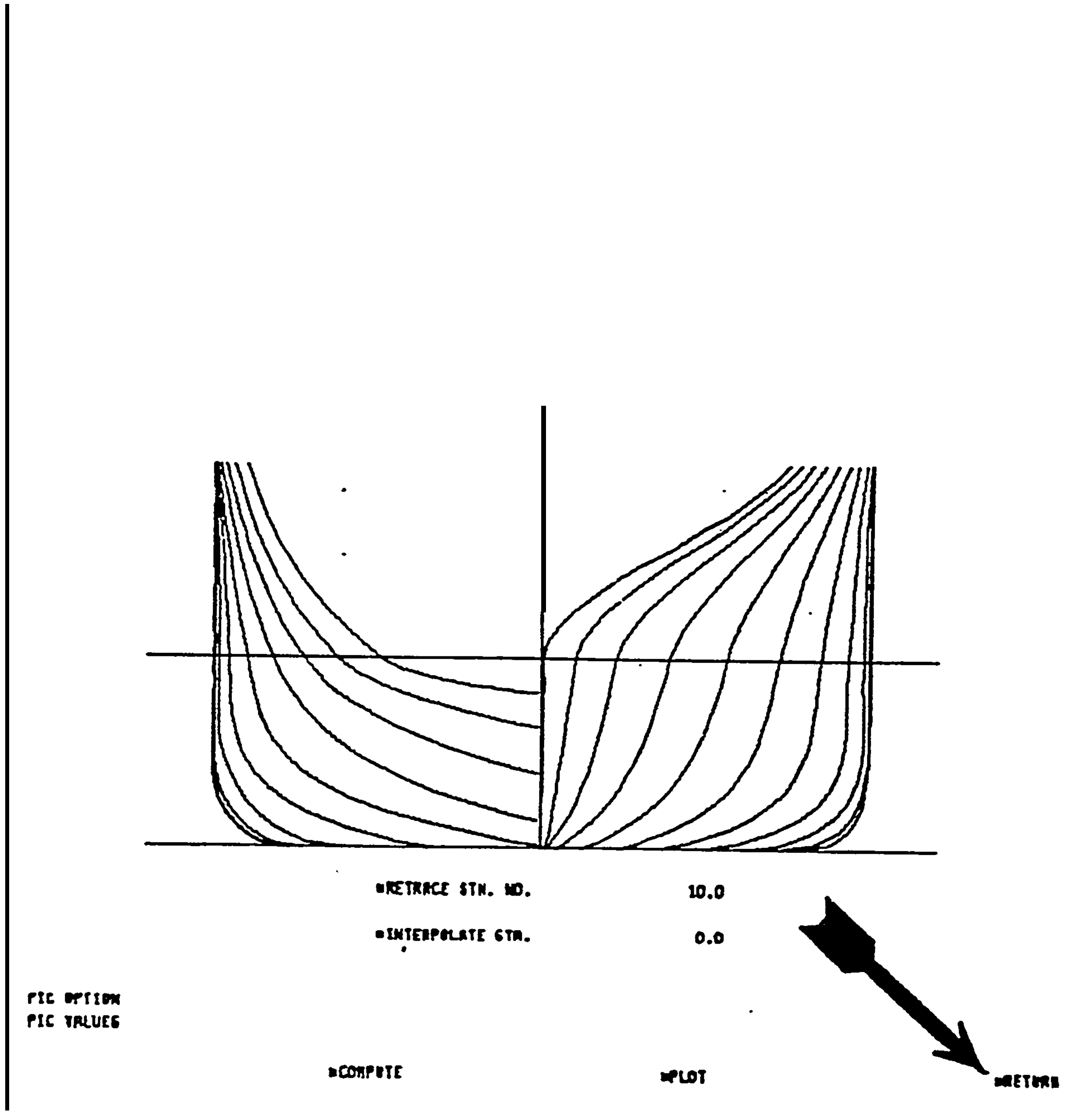


FIGURE.4 - HULLGEN BODY PLAN DISPLAY

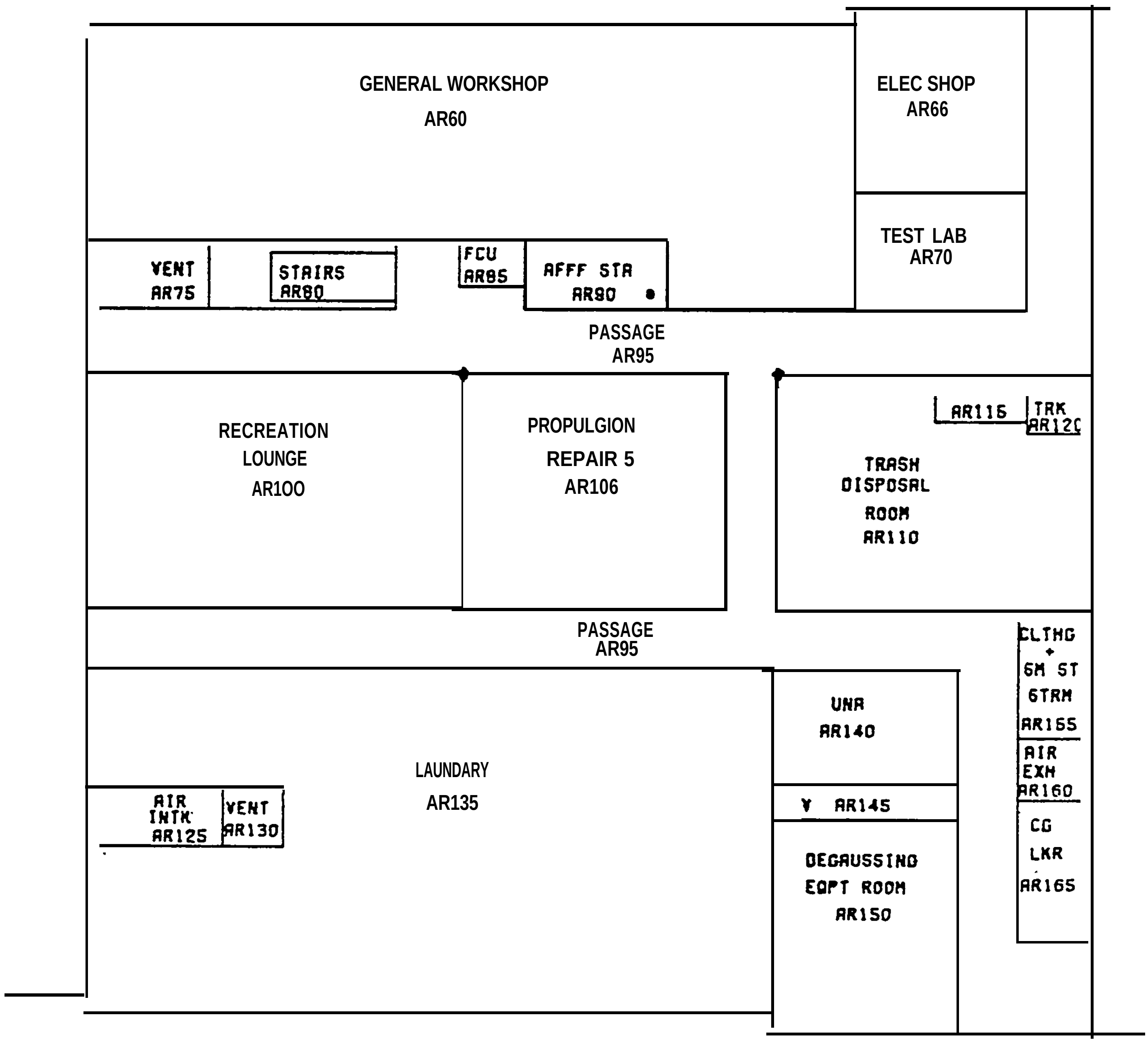


FIGURE 5 - GRAPHICS ARRANGEMENTS - COMPARTMENTS

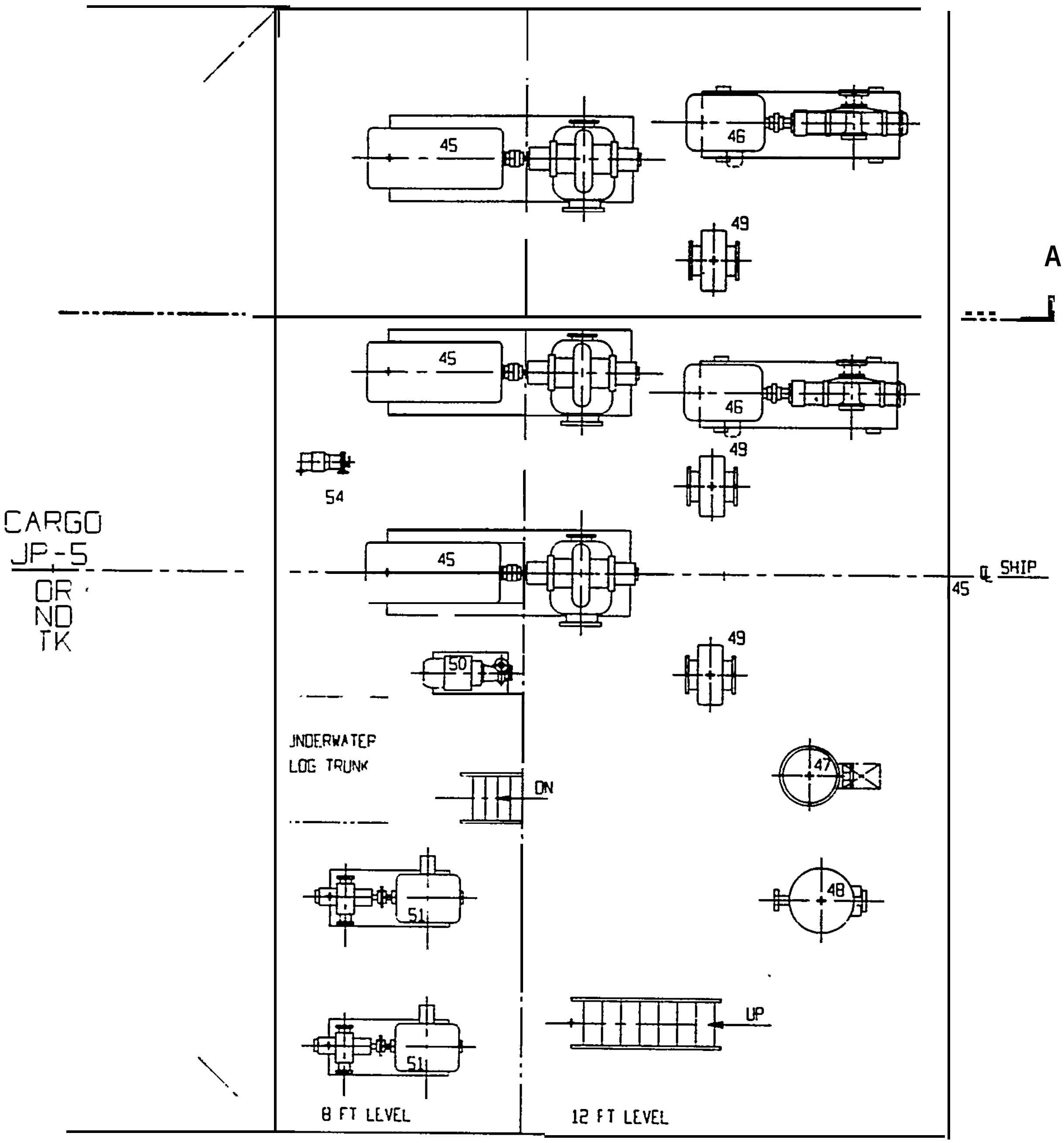


FIGURE 6- GRAPHICS ARRANGEMENTS - EQUIPMENT

5. Detail Design and Construction Plans

The introduction of a Manufacturing Technology program by the Department of Defense in the mid-70's saw improved prospects of fiscal support for work in detail design and construction. Development philosophy was initiated and a number of guidelines was developed:

(a) User involvement was essential to planning programs, establishing their development priorities and execution of test and evaluation.

(b) While integrated system could be a long-range goal, programs should be developed for initial stand-alone operation and integration potential built in, if possible. When feasible, new programs should be compatible with and complement software currently in production use by shipyards.

(c) The earliest implementation was to be given to those programs which could produce highest dollar and/or time savings.

(d) Useful existing programs should be recognized, and acquired when suitable and adaptable.

(e) Inasmuch as the majority of Industry uses IBM computers, IBM program versions would always be developed and maintained. CDC, Honeywell and Univac versions would be implemented depending on the extent of the demand.

(f) To facilitate program portability between computers of various manufacture, programs would be constructed in modular form and have complete documentation.

(g) Application program development would generally be under prime contract with shipbuilders or shipbuilding design agents. Contractors would be asked to report program performances in the construction environment.

(h) Particular attention was to be accorded the interface between programs used in Contract Design (Level III) and programs developed for Detail Design (Level IV) and Construction (Level V).

(i) Development would generally address technical programs and data and exclude management information systems - although technical input to the latter might be developed.

Again, for convenience in planning, detail design and construction was subdivided into a hierarchy with the following components:

Functional Systems:
- Hull
- Handling (boats, mooring, stores, ammunition, etc.)
- Machinery
- Piping
- Heating, Ventilation and Air Conditioning (HVAC)
- Electrical/Electronics

Subsystems:
Each functional system would contain a number of subsystems.

Programs:
Each subsystem would contain a number of programs.

Modules:
Each program would contain one or more modules.

Algorithms:
Each module would perform a single function and would consist of one or more algorithms. Each algorithm consists of one or more source code statements.

The hierarchy described above admits systematization and, while this is a long-term goal, nothing prohibits the development of stand-alone programs of high savings potential.

Again, programs are not necessarily unique to particular subsystems. It can be anticipated that arrangements, drawing, document generating and other programs might well serve a number of subsystems.

The orderly development of programs for CASDAC has been the subject of considerable discussion. It is planned that Documentation will follow the Department of Defense Manual 4120.17M as implemented for the Department of the Navy by SECNAVINST 5233.1A - Automated Data System Documentation Standards. Briefly, for programs, the following documents will be required:

Program Functional Description
Program Specification
Test and Implementation Plan
Test Report
Users' Manual
Computer Operations Manual
Program Maintenance Manual

The first three documents will be required before coding is begun and in this way it is expected to plan effective programs with a minimum of coding revisions.

Again, programs will be expected to conform with CASDAC Software Specifications recently developed at DTNSRDC. These are listed below:

I. Introduction, Executable Program Specification and Glossary

II. Use and Control Specification

III. Coding Language Specification

IV. Module Organization and Design Specification

V. Programming Style Specification

VI. Program Internal Documentation Specification

VII. Requirements on Programming

VIII. Form of Deliverables Specification

IX. Processor Environments Specification

It will be appreciated that program development is planned as a more orderly process than that which has existed in the past. But the skyrocketing cost of software development demands that more formal controls be introduced into software development.

6. Computer-Aided Piping Design and Construction (CAPDAC)

It was noted in Section 5 that the mid-70's gave greater promise of development in the area of Detail Design and Construction. In the autumn of 1976, DTNSRDC was given management of a modest program in this area. While planning studies have been initiated in the areas of hull and electrical/electronics, the greatest impact has been on the CAPDAC System, for which initial planning had been completed in 1975.

This planning comprised an Engineering Analysis of shipboard piping design, planning and fabrication. It was conducted in-house but with substantial inputs from a CAPDAC Industry Advisory Committee with members from the principal shipyards and design agents. Again, two one-week in-depth sessions were held with industry consultants covering Detail Design and Planning and Construction. These sessions resulted in a definition of the Piping Functional System consisting of 14 subsystems, 51 programs, 8 component catalogs and 14 catalogs of technical information. During these deliberations the Commerce Business Daily was used to solicit information respecting developed software. A number of replies was received and investigated. However, about the same time CAPDAC project personnel were invited to the Electric Boat (E.B.) Division of General Dynamics for a presentation on their piping design and material system software. This paralleled a number of facets of the CAPDAC system and Electric Boat was approached respecting the terms and conditions under which the software could be made available to CAPDAC. Electric Boat generously agreed to release the software for the cost of reproduction.

At a CAPDAC Advisory Committee Meeting and Workshop held in December 1976, the Engineering Analysis was approved as the vehicle for CAPDAC development. At the Workshop the E.B. software was demonstrated and participants processed a number of pipe problems deriving piping arrangement drawings and pipe fabrication sketches. With the use of scale models E. B. personnel demonstrated how piping was fabricated and assembled using their unique “Match Mark” system. Fabrication and assembly instructions are produced by computer. Implementation of their system has substantially reduced fabrication costs and has minimized the training period required by unskilled personnel entering production status.

Figure 7 gives an overview of the software. The software has many capabilities and implementation by the Navy to date provides computer-generated pipe arrangement drawings, Figure 8, and computer-generated pipe details, Figure 9. Test problems have been run for Avondale Shipyards, Puget Sound Naval Shipyard, and for Mare Island Naval Shipyard. Other shipyards are planning to submit test problems. The software is operational on the Univac Computer at the National Bureau of Standards and is currently being used by Puget Sound, which possesses the necessary Remote Job Entry hardware. It is planned to arrange for complete documentation of the software and, in addition, the acquisition of an IBM version.

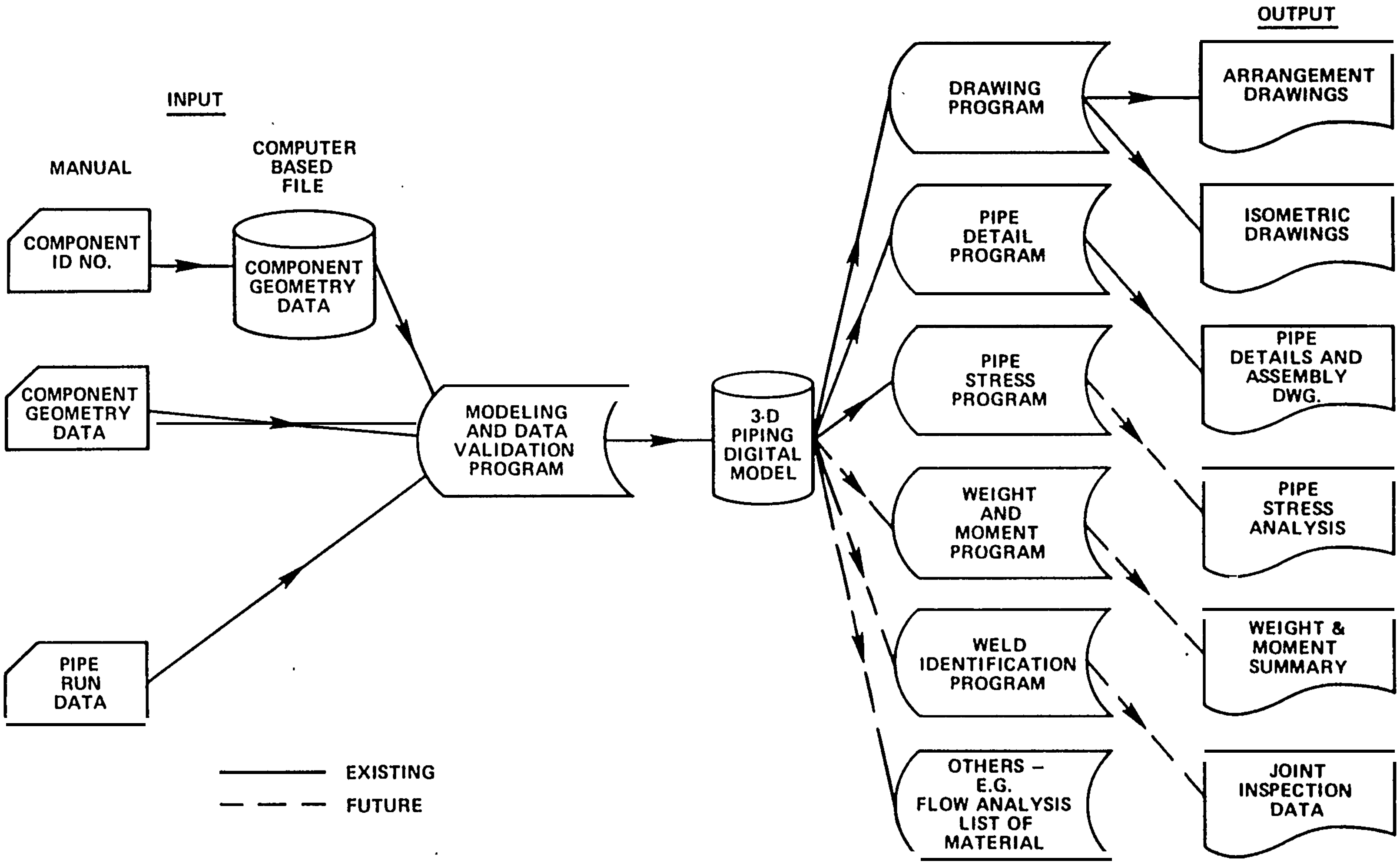
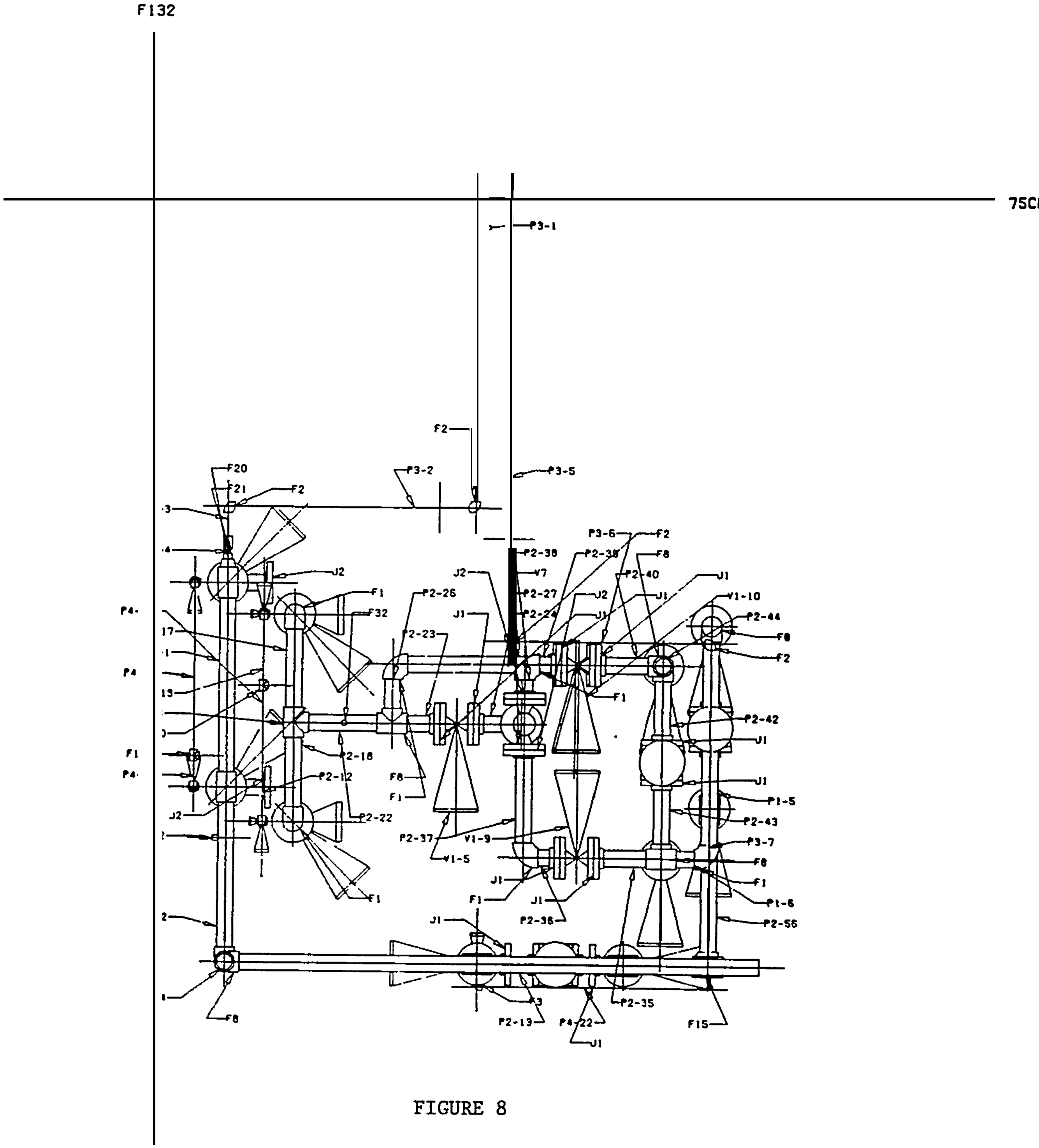


FIGURE 7 — OVERVIEW OF E. B. SOFTWARE



F132
75CL
P3-1
F2
P3-2
P3-5
F20
F21
F2
J2
F1
F32
P2-26
P2-23
J1
J2
V7
P2-38
P2-27
P2-24
P3-6
F2
F8
P2-40
J1
V1-10
P2-44
F8
F2
F1
P2-42
J1
J1
P1-5
P2-43
P3-7
F8
F1
P1-6
P2-56
P2-16
P2-12
P2-22
F8
F1
P2-37
V1-9
V1-5
J1
F1
J1
P2-36
J1
F8
F3
P2-13
P4-22
J1
P2-35
F15

FIGURE 8

ADMINISTRATIVE DATA

DWG. NO. | **PIPE** | **HEIGHT OF**
PIPE DIM. | I.D. NO. | BEND HEAD ABOVE FLOOR

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

OFFSETS OF BEND POINTS &TYPE OF JOINT

X **BENDING INSTRUCTIONS AND "MATCH MARK''DATA** X

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

TOP VIEW | **SIDE VIEW** | **END VIEW**

LIST OF MATERIALS
FABRICATION AND ATTACHMENT INSTRUCTIONS

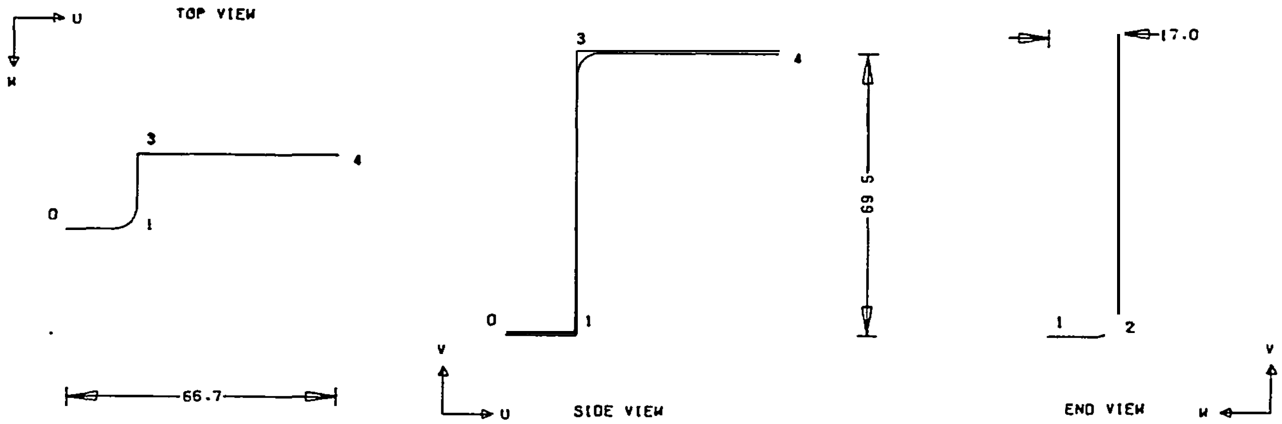
* MAR 301976 NOT APPL ENGINE RM INNERBOTTOM PIPING PLAN P/O
DATE ________ BOAT NO. ___ S.O. ________
PIPEFITTER & BADGE NO. ________
SUPERVISOR ________

PLAN C3-700-48-00-172 | PIPE P09-2 | DET 9 | REV APPLICABILITY | SHEET 12
2.375 X .218 STL | WBR 2.5 FLOOR 44

PT NO	U	DELTAS V	W	END JOINT
0-1	18.0	.0	.0	BW
1-2	.0	.0	-17.0	
2-3	.0	69.5	.0	
3-4	48.7	.0	.0	BW

LENGTH END TO END = 97.9 INCHES

BEND	ROLL ANGLE	BEND ANGLE	DIST WIRE	PBR	DIST PIPE	STRAIGHT PIPE	CLAMPING OR FITUP
1	270	90	15.5	20 4.0	14.0	14.0	.0
2	0	90	31.4	20 4.0	29.3	9.0	
3	90	90	99.9	20 4.0	97.1	61.5	
	270		150.0		148.1	44.7	.0



LIST OF MATERIALS

PC. MK.	QTY	SIZE	TYPE	MATERIAL	SPECIFICATION	REMARKS	LEVEL CLASS
P09	12-S	2.375X.218	PIPE	STL			

FABRICATION
P09-2 (AT POINT 4) ATTACHED TO P09-1 OF DETAIL 8

FIGURE 9 – COMPUTER GENERATED PIPE DETAILS

The development of the CAPDAC system will be by both in-house **effort at DTNSRDC and by contract with industry. The current in-house effort involves the development of a skeletal , CAPDAC. Subsystem for Composite Drawings. Figure 10 depicts the systerm in simple-terms. ,Development is such as to permit the preparation of the input data from a centerline run of piping either by a digitizer (Alt 1) or by card input (Alt 2). The " system will create a 3-dimensional digital model of the piping system. There will also be a generalized 2-dimensional drafting capability to permit the preparation of systems other than piping. The skeletal system will have a limited data base of piping and machinery components and will not include the interface of engineering application programs. The complete development of this system will be by contract with the Industry. Other areas of CAPDAC are currently under development and the processing of a number of contracts has been initiated.**

7. Related Endeavors

Naval architects, engineers and managers are generally concerned with' application programs which process their work. The success-of these programs depends not only on the.engineering algorithms used but equally on the computer science base, 'i.e., the computer operating system, library routines high-level language compilers, data storage media, data manipulation techniques, etc. As application programs become more sophisticated the computer science base demands increased sophistica- ,tion and extension.

Considerable attention is now being directed toward the computer science side of computer-aided design. The Office " of Naval Research (ONR) is initiating work in this area and the Navy is also following with interest two other large developments, one by the National Aeronautics and Space Administration and the other by the Air Force.

(a) Office"of Naval Research - Computer Science Project

ONR is initiating a program directed toward identifying the computer science techniques required to enhance and extend computer usage in shipbuilding. The first meeting is to be held on 29 June in Washington and attendees have been invited from shipbuilders and design agents, universities and other institutions, and Navy and other government agencies. Computer-aided ship design and construction requirements in computer science will be discussed under the general topical areas:

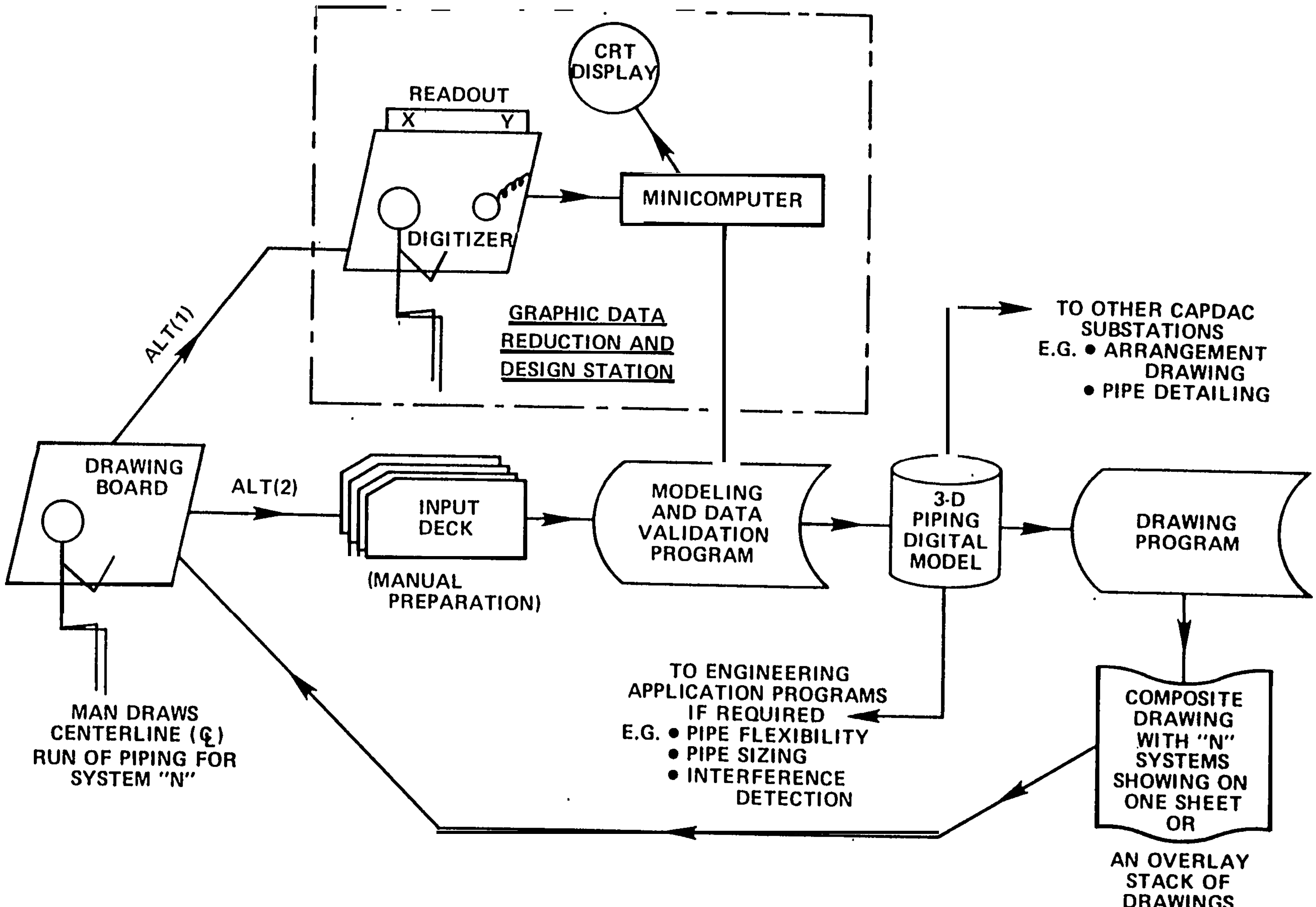


FIGURE 10 — CAPDAC COMPOSITE SUBSYSTEM

- Computer systems requirements analysis
- Computer systems (hardware and software) design and implementation
- Information management
- Interactive systems and graphics
- Networking and distributed computing
- Automation technology

It is expected this meeting will review the.problem areas, identify and attempt to prioritize needs, suggest potential solutions and develop a program to address the needs identified.

(b) National Aeronautics and Space Administration - Integrated Programs for Aerospace-Vehicle Design (IPAD)

This is approximately a five-year $10 million effort for the National Aeronautics and Space Administration (NASA). The principal contractor is Boeing. IPAD has been briefly defined as software to computerize, inso far as possible, company-wide design information processing. Its intended scope is such that it will simultaneously support design activities of a typical company mix of multiple development projects. It will serve management and *very* large engineering staffs at all levels of design (conceptual, preliminary, and final) and will aid in the assembly and organization of design data for support of manufacturing processes.

IPAD software will function on "third generation" computer complexes typical of those in use today by large aerospace corporations and will augment, rather than replace, existing "system software." It is currently visualized as composed of (1) executive software that will control user-directed processes through "interactive" interfaces with a large number of terminals in simultaneous use by engineering and management personnel; (2) a large number of utility software packages for routine information manipulation and display functions; and (3) data management software to provide a comprehensive, versatile capability for efficiently storing, tracking, protecting, and retrieving exceptionally large quantities of data maintained on multiple storage devices.

The data base includes the technical analysis and design computer programs utilized by various disciplinary specialists. Such programs are not regarded as part of IPAD, but must be provided by the user to form the complete design-software system; they can include existing and future company-proprietary programs, as well as those in the public domain. The data base will also include all official project information defining the characteristics of current baseline and alternative designs and their performance, as well as archival "handbook" information forming the technology base for company designs. Simultaneous access to the same baseline design information by all disciplinary groups Will thus be possible. Temporary libraries, for design information being actively utilized by individuals or teams, will also be provided.

A substantial effort was mounted in 1975 to determine the feasibility of IPAD and some 83 industry representatives attended the final feasibility briefings. IPAD has now been under development for approximately a year and project guidance stems from an Industry Technical Advisory Board consisting of 18 aircraft industry members representing 14 aircraft companies together with three computer industry representatives.

(c) Air Force - Integrated Computer Aided Manufacturing (ICAM)

This is a five-year $75 million effort by the Air Force under the Manufacturing Technology program to develop a system that will replace the existing patchwork of computers with one that is integrated from the outset. To date three tasks have been awarded:

Task I - to Softech - to develop an architectural model that blueprints such manufacturing complexities as machines, materials, processes, designs, information, -procedures, people, and organizations.

Task II - to Softech - concerns group technology in which parts and processes are grouped according to common features.

Task III - to Boeing - the assessment of sheet metal formability and assembly technology.

Other tasks will be awarded as the project progresses. In addition, considerable work has been done by the National Bureau of Standards to analyze those existing standards which are relevant to the ICAM Program and to outline a policy to achieve Air Force programmatic objectives through the use of standards.

Again, some eight major aircraft companies are involved in the project as well as consultants from various universities and institutions. A joint Air Force - NASA agreement pledges cooperation in areas of mutual interest.

8. Concluding Remarks

The paper presents some aspects of Computer-Aided Ship Design and Construction in the Navy and attempts to set down some current philosophies. These are that software production is becoming more formal, that computer science limitations increasingly constrain the degree of sophistication that application programs can include, and finally, a reiteration of the absolute necessity of user participation in program planning and development.

Probably the most difficult technical problem at present is the approach and determination of a data structure and a data base management system which could permit data to be shared readily among all the various disciplines involved in shipbuilding. If we further suggest this software be portable to different computers, including minicomputers, the difficulties appear insurmountable at this time. It is of interest to note the IPAD approach to this problem, which is probably to adapt an existing data management system. Portability is planned to be achieved by successive conversion and implementation on a range of computers. The proposed ICAM solution is to develop comprehensive data mangement requirements and specifications and solicit proposals from the software industry.

The current Navy philosophy is to develop stand-alone programs and possibly stand-alone subsystems on the computer most used by industry and to recognize that an integrated detail design and construction system is a longer-term goal. As a practical matter, of course, this will mean that the near-term emphasis will not be on computer science but rather on application programs with good potential for dollar and time savings. And the development, implementation and acceptance by industry of such programs is essential if Navy support for the CASDAC project is to be maintained and augmented.

Respecting user involvement, the brief discussion of IPAD and ICAM in Section 7 emphasized the substantial aircraft industry support in those developments. Navy work in CAPDAC has been handsomely supported by our shipbuilding industry, and"Navy developments in hull, machinery, electrical, etc. would be greatly encouraged if closer ties with industry in those areas can be forged. Such support is desirable not only at the technical level but also at the executive level.

In conclusion, I would like to extend my hearty thanks to REAPS for the use of this forum to present some current philosophies of CASDAC.

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