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FACILITIES AND ENVIRONMENTAL EFFECTS  
SURFACE PREPARATION AND COATINGS  
DESIGN/PRODUCTION INTEGRATION  
HUMAN RESOURCE INNOVATION  
MARINE INDUSTRY STANDARDS  
WELDING  
INDUSTRIAL ENGINEERING  
EDUCATION AND TRAINING

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# **THE NATIONAL SHIPBUILDING RESEARCH PROGRAM**

## **REAPS 2nd Annual Technical Symposium Proceedings**

### **Full Proceedings**

U.S. DEPARTMENT OF THE NAVY  
CARDEROCK DIVISION,  
NAVAL SURFACE WARFARE CENTER

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## PREFACE

The REAPS program aims at increasing U.S. shipyard productivity through automation technology. To do so, however, requires the cooperation of all U.S. yards, for without knowing their needs, problems and priorities, a concerted effort lacks force and direction.

The 1975 REAPS Technical Symposium, the second annual meeting of U.S. shipbuilders and shipbuilding support agencies, sought to stimulate this spirit of cooperation among U.S. yards. It "gave cognizance to the advancements in hardware/software technology and how these advancements are relevant to the shipbuilding industry.

The Proceedings of the 1975 REAPS Technical Symposium contain all the reports presented at the meeting. The Agenda, in Appendix A, lists topics and speakers; while Appendix B is a compendium of the Symposium attendees.

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ACCOMPLISHMENTS AND EXPECTATIONS  
FOR THE REAPS PROGRAM

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Mr. Williams is responsible for the direction and management of projects which involve operations research, computer aided manufacturing development, numerical control applications engineering, industrial and systems engineering, manufacturing planning and technological forecasting. These projects span a wide geographical and technological range.

REAPS is an acronym which stands for Research and Engineering for Automation and Productivity in Shipbuilding. For the benefit of those of you who were not at last year's technical meeting, I would like to recap the history of REAPS and how it came into being. REAPS is a group participation program,, it is sponsored by MarAd and its sponsorship will gradually shift over the years to the participating shipyards.

The primary objective of the REAPS program is to improve or; enhance shipyard productivity. This will take the form of both software and hardware research and development projects'. As I mentioned, it is currently MarAd-sponsored and will:, ultimately become shipyard-sponsored. The heaviest degree 'of financial sponsorship comes from MarAd during the earliest formative years of the REAPS program and in the later years that financial support will come primarily from the shipyards with minor financial support from MarAd.

Several years ago, it was recognized that there was a decided productivity lag between the U.S. and other shipbuilders of the world. For instance, on container ships, the U.S. required 120 man-hours per delivered ton compared to west Germany who required 90 man-hours per delivered ton, For ore carriers the U.S. requtrred 75 man-hours per delivered ton whereas Japan required 59 man-hours per delivered ton. This productivity lag was recognized by MarAd and by a number of shipbuilders who met to attempt to define what the problems were and, if Possible, to correct the deficiency and improve our own productivity.

They identified one significant area of productivity potential. That potential was computer-aided design and computer-aided manufacturing. As a result of that identification and further study by those shipyards, the AUTOKON computer system for ship design and construction was identified as the most widely used computer-aided design and computer-aided manufacturing system in the world. Consequently, the Maritime Administration acquired AUTOKON-71 for sublicensing to U.S. yards.

AUTOKON-71 is a computer software system whose primary purpose is the design and construction of ships-with ..emphasis on the construction portion. .

The shipyards recognized that there is more to implementing an AUTOKON-71-type system than just hanging the tape on a computer. There are problems with system maintenance. When the system fails given a particular problem; someone needs to be in a position to address that failure and correct the problem. There is a need for updating the system to document these failures and to develop and document improvements and enhancements to the system requested by the participating yards. There is also a need for someone to assist the new user to get up and running with a computer package such as AUTOKON-71. And there is a need for realistic, usable documentation that is regularly updated so that the system and its documentation are always in concurrence with each other.

As a result of these identified needs, a contract was let with IITRI to provide this kind of system support. The

contract was primarily for maintenance and development support of AUTOKON-71. However, there was a definite indication that there was a total system needed not just software support, not just software developments. There was a need to improve productivity through related hardware developments, and it is the combination of these two things that provides the greatest opportunity for productivity enhancement. Software development and support and hardware development and support combined together will create the greatest productivity enhancement.

As a result of this recognition, REApS was born. REAPS is a whole new concept in cooperation. It's a concept that suggests a number of competing shipyards can sit down around the same table and in the same discussion identify common problems and then address those problems with common solutions. REAPS is the method that the shipyards have chosen to address those problems and to put the entire approach, both software development and hardware development, all under one umbrella. To make this a truly viable program it was obvious that Long Range Planning had to be included under the same umbrella. To identify the high-cost areas and subsequent target opportunities for new research and development activities, long range planning is a must. And, of course, someone is needed to oversee and manage this total program.

The software support and development portion of this effort is quite significant. Instead of each user employing about three people for this task, they each pay IITRI less than one man-year's cost to perform the function concurrently

and Volume 5 for SHELL, TEMPLATE and NEST.

Our REAPS library is becoming very extensive. Most of you here are receiving our Shipbuilding Technology Update Bulletin regularly published since REAPS first began. If anyone is not getting it, REAPS member or non-REAPS member, please let us know and we'll see that your name is added to the mailing list.

Our training activities have been rather extensive in the past year. We have an overview of REAPS, a management orientation, that requires one day for exposure of top management to what REAPS is all about. We've presented that about six times in the past year. We have a two-week ALKON user's course. That course includes the course books, and we've given it twice. We have a one-week PRELIKON user's course, also with a course book. It's been given one time. And there is a one-week PRELIKON workshop which we give at the user's yard; we've done that one time.

We have ready at this *time* a one-week advanced ALKON course. We have not given that yet; we have just completed the documentation for that course. Next year we will complete the documentation" and course books and will be ready to give LANSKI, SHELL nad TEMPLATE courses. That training we anticipate will require two to three days.

As I mentioned earlier, productivity is a result of both a software and hardware effort. So far, I've talked only about the software effort under REAPS. Let me talk just a few moments about the hardware efforts.

There is, of course, the frame bender which most of you have heard something about; you will receive a major update on that later in this technical meeting from its developer.

Another task we undertook just recently was to conduct an early review of the feasibility of retrofitting a flame burner to NC',. It is our opinion that a retrofit package can be developed at grossly less cost than those which are currently on the marketplace. I don't mean to sound critical of the marketplace; it is very limited. A recent survey indicates that there are only between 60 to 80 total NC flame burning machines in the entire U.S. That's not a very large market for an industrial activity to make research and development investments to bring down costs. Perhaps, if that market were larger, there might be an incentive. The way it is now, there is no incentive. Consequently, we feel it is a primary responsibility of the REAPS program to do that research and development which is not normally expected from the sector that distributes industrial equipment and industrial technology.

As a result, we've done a survey recently that included several shipyards across the U.S. primarily identifying potential flame burners for retrofit. We feel that there is a definite need for a retrofit capability for older NC machines and for optical tracing conventional machines, and a standard retrofit control system can be developed. The iron of the machine (drive system) and the machine interface are going to be custom things; that cannot be avoided because each flame burner is a different machine. Whether the drive system

will have to be replaced is a decision which will have to be made on each individual machine. However, we do feel that there is significant commonality up to the point of machine interface. Currently, we believe that a system of this kind should cost the user about \$35,000 including the software. The software and specifications for the hardware required to make the retrofit would go into the public domain, available for anyone to use at no cost.

Another area we've identified that needs significant effort is the terminals to access a CAD/CAM system from the shipyard user's point of view. Surprisingly, there are a great number of people beginning to recognize this in various facets of the numerical control world. NC metal cutting users are just beginning to recognize the need for a terminal tailored to satisfy their needs in accessing the supporting programming system. We've seen the same thing from a number of other industries that are involved in precision cutting, turning and milling, who feel that they have a specific need for a specialized terminal. What has brought this about is that most commercial graphic terminals available today take a generalized approach to attempt to satisfy everyone's needs in one package. The resultant terminals contain a significant degree of overkill, much of it totally unnecessary to the user, particularly the user who is up and running with a shipbuilding computer system.

Consequently, we've taken a look at the possibility of developing a shipyard terminal system. Some of the current

systems in use today include Calcomp plotters, card readers, line printers, teletypes with varying speeds (10, 15 and 30 cps). We've concluded that there is a definite potential for developing a hybrid shipbuilding computer terminal. After talking to a number of REAPS and non-REAPS shipyards, it is our concluded opinion that a hybrid system composed of off-the-shelf components assembled into a single system is potentially possible. This can all be done at a minimum cost compared to today's current market level for graphic terminals.

Another area we've been involved in is the area of nesting. We've been conducting internal research and development addressing the potential of doing a nest routine on a cathode ray tube here at IITRI.

So far, I've discussed what REAPS has done. Where does REAPS go from here? What are we going to be doing from this point on? The NC retrofit flame burners are a potential project we will definitely follow. We will make every effort to get that project funded and get the final specs and software to the user. We will definitely continue the terminal efforts. That is currently in our plans and within our resources. The specifications for such a terminal would include the following: **a 16-bit minicomputer, a 300 cpm card reader, a 300 lpm printer, a 19-inch CRT, a paper tape reader/punch, some type of mass storage device, an NC drafting machine with intelligent controller, a five-foot by eight-foot NC drafting table, and all of the necessary software to interface the various**

devices. We're looking at a current market price of about \$150,000 for this terminal. That's roughly \$100,000 less than any commercially available graphics terminal on the market today.

We will also continue to do some of the nest work that we've done on the CRT, as time permits.

This is the sum total of what we have done to date and rather a quick glimpse of what we plan to do in the future. But I'd like to stress one very important thing. Our primary objective is to address problems in shipbuilding, problems that when resolved will enhance productivity. We can do that only with your assistance, both the REAPS yard and the non-REAPS yard. Please let us know your problems. We cannot begin to address or resolve those problems until we know what they are.

THE UPDATED REAPS AUTOKON SYSTEM

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Ms. Taska is currently involved in the technical support and maintenance of the AUTOKON-71 System. Her major tasks include processing Analysis Requests, releasing new system versions, and coordinating program modifications.

Some past involvements in data processing include: the design of a reduction program to handle skin burn data; current enhancement of three-dimensional plotting for deformed meshes; improvement of crane boom analysis test data and a post-processing program.

I. BACKGROUND

1. What is the AUTOKON System?

Before surveying the current version of the updated REAPS AUTOKON System, it might be useful to take a look at the general structure of the System and its programs.

Slide 1.

The AUTOKON System is a collection of 11 major computer programs for ship design and construction. Each 'major program, or module, runs independently to perform a specified function. *commu-*nication between modules is accomplished through the use of a common database which serves as both a supplier and storehouse of information. Input to a module may originate from the user or the database; output from a module may be stored in the database or may be punched on cards or papertape for eventual drawing on N/C equipment. The modules which make up the System are:

- MISC - program for initialization of the System database and limited utilities
- FAIR - program to fair offsets. A table of offsets and a set of curves used as reference contours are produced for later reference by other AUTOKON programs.
- DRAW - program to read curves stored by FAIR and produce ESSI output for eventual drawing of the curves.
- TRABO - program to transfer the bodyplan from the FAIR temporary database to the System database.
- LANSKI - program to fit longitudinal curves on the hull surface and store the Tables of Details into the database.
- SHELL - program to produce N/C burning tapes for the cutting of shell plates.
- TEMPLATE - program to produce shell plate templates and frame templates.
- ALKON - parts programming module. ALKON is an interpretive language which lends itself to application in problem solving situations. Its features include capabilities for a vocabulary, stored programs, plane geometry definition, curve fairing, text generation, N/C output production, and many others.

NEST - program to store nesting formats for parts to be cut from steel plates.

PRODA - program for the generation of planning and production data.

PRELIKON - module for preliminary lines design.

DUP - utility program for database manipulation.

Through the interaction of these programs with each other, a ship is taken from the initial design stages through the final production stage.

## 2. The Standard U.S. Base Version

The AUTOKON System was originally developed in Norway and was acquired in 1973 by the Maritime Administration (MARAD) for availability to U.S. Shipyards. In November of that year the Standard u.S. Base Version of the AUTOKON System was delivered to IITRI and installed on a UNIVAC 1108 EXEC 8 computer. At that time, the System consisted of the 11 aforementioned modules at their then current state of improvement.

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In addition to the programs, the System contained a vocabulary and set of standard norms for the ALKON parts programming module (norms are sets of stored ALKON code, much like subroutines); a battery of acceptance tests for almost all of the modules; and users, systems, and installation documentation. Versions of the AUTOKON System exist for several computers, the UNIVAC, IBM, CDC, and Honeywell versions to name a few; however, all maintenance activity on the U.S. version is currently being done on the UNIVAC 1100 Series Version at IITRI. Plans for expanding the maintenance support to include three versions of the System - the UNIVAC, IBM, and Honeywell versions - are underway and expected to be realized in the near future.

## 3. How Modifications Originate

Since the initial implementation of the AUTOKON System, an unending stream of updates to either enhance or correct the capabilities has been generated. Two major sources contribute these updates: the REAPS Analysis Request (AR) Activity and the SRS Maintenance Central Activity.

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AR's are, as the name suggests, requests to the REAPS Technical

Staff from a user participant to analyze a particular situation regarding the AUTOKON System, The requests may address any topic, but in general have fallen into two categories; either System failure reports or suggestions for improvements, A standard form has been prepared by the REAPS Staff for submitting requests,

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It provides space for identifying the submitter the problem, and the installation on which the system is mounted, As soon as the AR is received at IITRI, the REAPS librarian assigns a number to it, logs it in, and acknowledges receipt of the Ar to the submitter. It is then forwarded to the Analysis Coordinator for assignment to a member of the Technical Staff familiar with the module in question. Effort is made to analyze the request as soon as possible and respond within a reasonable time period, depending on the urgency of the request. In general, system failures are resolved more quickly than system enhancements. When an AR finally is resolved, the resolution is sent to the submitter together with *all* necessary program updates or documentation changes. All other REARS participants are notified of the problem if the nature of the AR is such that its immediate attention is necessary.

Slide 5, 6 and 7

To date, a total of 87 AR's have been received by the Staff. Of those, 44 were requests for enhancements and 43 were system failures. Forty-two, of the 87 have been resolved - 28 system failures and 14 enhancements.

SRS Maintenance Central updates are merged with updates resulting from the AR resolution activity to form a set of modifications to the Base Version of AUTOKON. Periodically, the updates

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will be released to the REAPS Participants, thus generating a new Standard Version of the System. Such a release was made about a month ago, May 15th, of a new version of the AUTOKON System, Standard Version "A".

## 11. Standard U.S. Version "A"

### 1. Distribution

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Version "A" was distributed to the yards via two magnetic tapes accompanied by distribution documentation of approximately 130 pages to assist the REAPS liechnical representatives in interpreting and implementing the new System.

Covered in the distribution document were:

- o a description of the differences between the Base Version and Version "A" visible to the user in application and performance,
- o an explanation of the individual updates to each subroutine and the reasons for the change,

Slide 10

- procedures for implementation of the new Version "A" including suggested JCL (Job Control Language)
- changes to user's and system documentation resulting from the update, and
- o a description of the new acceptance tests generated to test the 'AR-generated updates-.

In all, five modules and three service programs were upgraded by the update.

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Standard Version "A" is the most current version of the AUTOKON System available to the REAPS participants, offering considerably increased user capabilities and a marked improvement in performance.

### 1.2 Features of Standard Version "A"

Of the five modules and three service programs affected by the update, the most extensive changes were made to

Slide 12

- o AUTOBASE - optimization of database routines led to improvements of approximately 20% in required CPU time and 50% I/O time. Protection has been given to the database at abnormal run termination.
- o ALKON - optimization of parts programming routines led to 50% improvements in ALKON runs over both required CPU and I/O time. Additional user capabilities were introduced. Three volumes of user documentation were written. Several serious program bugs were eliminated.
- o FAIR - input may be entered in a free format mode for the fairing process. Informative error messages have been added. Minor program bugs have been corrected.

- DUP - new commands are available for the database utility program. A new volume of documentation has been written.
- MISC - anew capability is available in the database initialization routines. A volume of user documentation has been written.

Modules ALKON and AUTOBASE (p'arts programming and database routines) showed the most striking improvements in performance. Re-running the standard acceptance tests for ALKON on Version "A" resulted in the aforementioned observed savings of 50% in CPU time and 50% in I/O time.

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The acceptance tests are healthy exercises of the ALKON code, so the claim can be made that, in general, savings of up to 50% across the board can be expected. To observe the effects of database optimization alone, the acceptance tests for modules NEST (parts nesting) and SHELL (shell plate development) were re-run.

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Savings of 7% - 27% were observed in CPU time and 50 - 80% in I/O time required. Both of these modules are actively used by the database and reflect the program improvements.

Examining the Updated AUTOKON System at close range, the new user capabilities that are available emerge:

#### 1.2.1 Updated AUTOBASE

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A serious problem existed on the Base Version of AUTOKON, that being the inability to close and access the System database should one of the programs accessing it terminate in error due to max time exceeded, system crash, etc. Version "A" database routines have been modified to update the database only at successful run completion. Should an error occur which causes the run to abort, the database will assume the status it had before the aborting run began.

As has already been mentioned, considerable performance improvements have been observed of = 20% CPU time and 50 - 80% in I/O time. Changes to the logic for allocation of memory buffers is the chief contributor. The run times for standard acceptance tests follow.

BASE VERSION

STANDARD VERSION "A"

<u>Module</u>	<u>Data</u>	<u>CPU(sec)</u>	<u>I/O(sec)</u>	<u>CPU(s'ec)</u>	<u>I/O(sec)</u>
		<u>Version 1</u>	<u>Version 1</u>	<u>Version 1</u>	<u>Version 1</u>
NEST	NESTDATA/USA	0:12.3	1:11.7	0:09.0	0:14.2
SHELL	SHELLDATA/USA	0:42,9	2:06.4	0:39.8	1:00.7

### 1.2.2 Updated ALKON

The most radically changed module in Version "A~" is the parts programming module, ALKON. User and system changes have been made to increase the features offered to the parts programmer while decreasing the programming costs involved in generating and storing parts of a ship in the database.

New features available to the user are:

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- 0 Improved logic for the contour intersection command INT  
INT (+U+V+W)  
Define point of intersection at approximate point (u,v) falling within the confines of a square window encompassing the area (u+W, v+w). If the window parameter, w, is omitted, an infinite window is assumed. Because fewer contour elements need be tested for possible intersection, the total processing time will decrease.
  
- 9 14 new functions are available to the user and are resolved by in-line FORTRAN code:
  - LISTVOC - List the ALKON vocabulary
  - TANH(arg) - Get hyperbolic tangent of arg
  - EXP(arg) - Evaluate the exponential of arg
  - LN (arg) - Evaluate the natural logarithm of arg
  - LOG(arg) - Evaluate the common logarithm of arg
  - TRUNC(arg) - Truncate the fractional part of arg
  - MOD(+arg1+arg2 ) - Find the remainder of the division of arg1 by arg2
  - MAX(+arg1+arg2 ) - Find the maximum of arg1 and arg2
  - MIN(+arg1+arg2) - Find the minimum of arg1 and arg2
  - SIGN(+arg1+arg2 ) - Transfer the sign of arg2 to arg1
  - DIM(+arg1+arg2)- Find the positive difference between arg1 and arg2
  - FEET(arg) - Return the whole foot portion of arg (arg given in millimeters).

INCHES (arg) - Return the whole inch portion Of arg  
(arg in millimeters) less the whole foot  
portion,

FRACT(arg) - Return the remaining fractional inch portion  
of arg in millimeters less the whole foot  
and whole inches portions.

An example of the output from command LISTVOC follows:

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0 Two new norms were added to the standard norm set and  
three norms were corrected:

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MAX1(arg1+. ..) - Find the maximum of the given arguments.  
Find the minimum of the given arguments.  
HOLE102 - ~~When~~ manhole is requested and length = width of  
hole, permit norm to default to a circle.  
ROUT3 - Correct erroneous list element from L4 to A4.  
BKT22 - Modify norm to work with left geometry.

The old TRUNC norm is deleted, since truncation can now be accom-  
plished by in-line FORTRAN code.

o Option letter Z has been incorporated for control of the  
stack trace.

%Zval - Control stack trace and dump  
if val < 0. - Trace off  
= 1. - Trace on. For each stack  
operation, the values of the operation type,  
status, arguments, pointer, and stack entry  
at pointer will be printed.  
>1, - Dump stack. The entire stack,  
list pointer and creation number are  
printed.

o NEW or EQU statements are permitted outside of a DO-loop.

o Two features which are included as optional updates in  
Version "A" permit default values of center touch on and  
startpoint at the local origin.

o Twenty-six error messages were changed and four new messages  
were incorporated into Version "A".

- Three volumes of documentation for the ALKON

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Module have been released, Volume 1, the ALKON Handbook, is a reference guide. All elements of the ALKON language are defined

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and references are given to one of the other volumes for additional detailed information. The procedures for accessing the System database are explained in depth. At the end of the Handbook, the ALKON error messages are given with supplementary explanatory information.

Volume 2 is the ALKON Programmers Guide which describes the language and its capabilities supported by many illustrative examples. The

third volume in the set, NORMS Descriptions, contains a complete set of descriptive information for the standard norms library. Together, the three volumes compose a tool for learning, applying, and referencing the parts programming construction language.

Slide 21

For quick and easy reference to the ALKON error messages and related debugging information, an ALKON Reference Card has been published as an aid to the experienced ALKON user who requires a minimum of handy reference material. The card is printed on 8 sides and can be folded to fit conveniently in a pocket.

- Several changes which are not directly visible to the user have caused the performance improvements of 50% in CPU and 50% in I/O times required to process an average ALKON run. These statistics were determined by re-running the ALKON acceptance test runs under Version "A" and comparing the CPU and I/O times to the same runs done under the Base Version. These considerable improvements will enable the user to fully exploit the resources of ALKON with a tremendous reduction in overhead. The actual acceptance test run times follow:

		BASE VERSION		STANDARD VERSION "A"	
		Version 9.1		Version 9.1	
<u>Module</u>	<u>Data</u>	<u>Cpu('s"e"c)0. (s"e"c)</u>		<u>CPU(sec)</u>	<u>~</u>
ALKON	ALKONDATA1/USA	0:56.1	3:04.6	0:31.2	1:35.6
	ALKONDATA2 /USA	0:56,4	2:51.3	0:34.1	1:45.3
	ALKONDATA3 /USA	0:21,1. .	1:28.6	0:11,2	0:31.0

Slide 22

The changes which contributed to the performance improvements are in general: the removal of the Translation pass, PASSO; the re-coding of low level multiply-executed routines from FORTRAN to assembler language; the optimization of norm and record storage in the database; the optimization of stack access routines; and as already mentioned, the improved database accessing routines.

Many bugs were removed from the system. As a result of two corrections, a missing end-of-file mark will produce a warning message but allow execution to continue, and serious error messages will abort a manuscript rather than permitting it to go on in an error mode.

Finally, twelve brief acceptance tests were written to exercise<sup>ise</sup> the new ALKON user functions.

### 1.2.3 FAIR Updates

A free-format input processor has been incorporated into the FAIR module to eliminate the difficulties encountered in correctly encoding input data. In addition, several useful enhancements have been added to simplify the task and help verify the data. The major features of the processor are:

Slide 23

- to allow input to be encoded in an unrestricted format;
- to permit specification of the delimiter separating input data items;
- to permit comments anywhere in the input stream and on individual cards;

- to permit all numbers to be specified in either real or integral format, and literals to contain any number of characters;
- 0 to eliminate specification of the U.S. vocabulary;
- to provide a units specifier to indicate decimal feet or ft, /in. /16th over any range of the input;
- 0 to provide a scanning capability for pre-execution verification of the data; and
- to give concise error messages designating syntax and content errors on data cards.

No card types or input data are altered by the incorporation of this processor, (except for the omission of U.S. vocabulary cards) so that the original FAIR Input Data Forms can still be used as a guide in preparing a deck. The free-format processor relieves the user of the bother of formatting and permits him to arrange his data in a direct and uncluttered-manner.

When fully utilizing this feature, data entry becomes less time-consuming and will actually reduce the number of runs lost due to improper data formats and missing or incorrectly-specified data. The savings realized in omitting bad runs should offset the 10% overhead for using the free format processing.

Slide 24

Two sample input streams are presented using the FFP. In the first example, data is encoded in a compact format with a comma separating each data item. Note the omission of the U.S. vocabulary.

Slide 25

The data in example 2 is spread over eight columns and right-justified. A drum card would produce similar looking data. The blank character delimits data fields. Comments are scattered freely throughout the data. Both decimal feet and millimeter units are specified over various ranges by the 'UNIT' command.

Slide 26

Scanning input data before execution will show up many keypunch and coding errors as evidenced by this sample output from the scanner program.

#### 1.2.4 DUP Updates

Slide 27

Three new commands were added to the DUP, database utility, module for dumping records and catalogs from the database. A fourth command allows the user to specify whether non-active records are to be kept or deleted from the database.

A new users manual for the program has been written which documents all utilities available for database manipulation.

#### 1.2.5 MISC Updates

Minor changes to this module for database initialization involve the incorporation of the save/delete non-active records option.

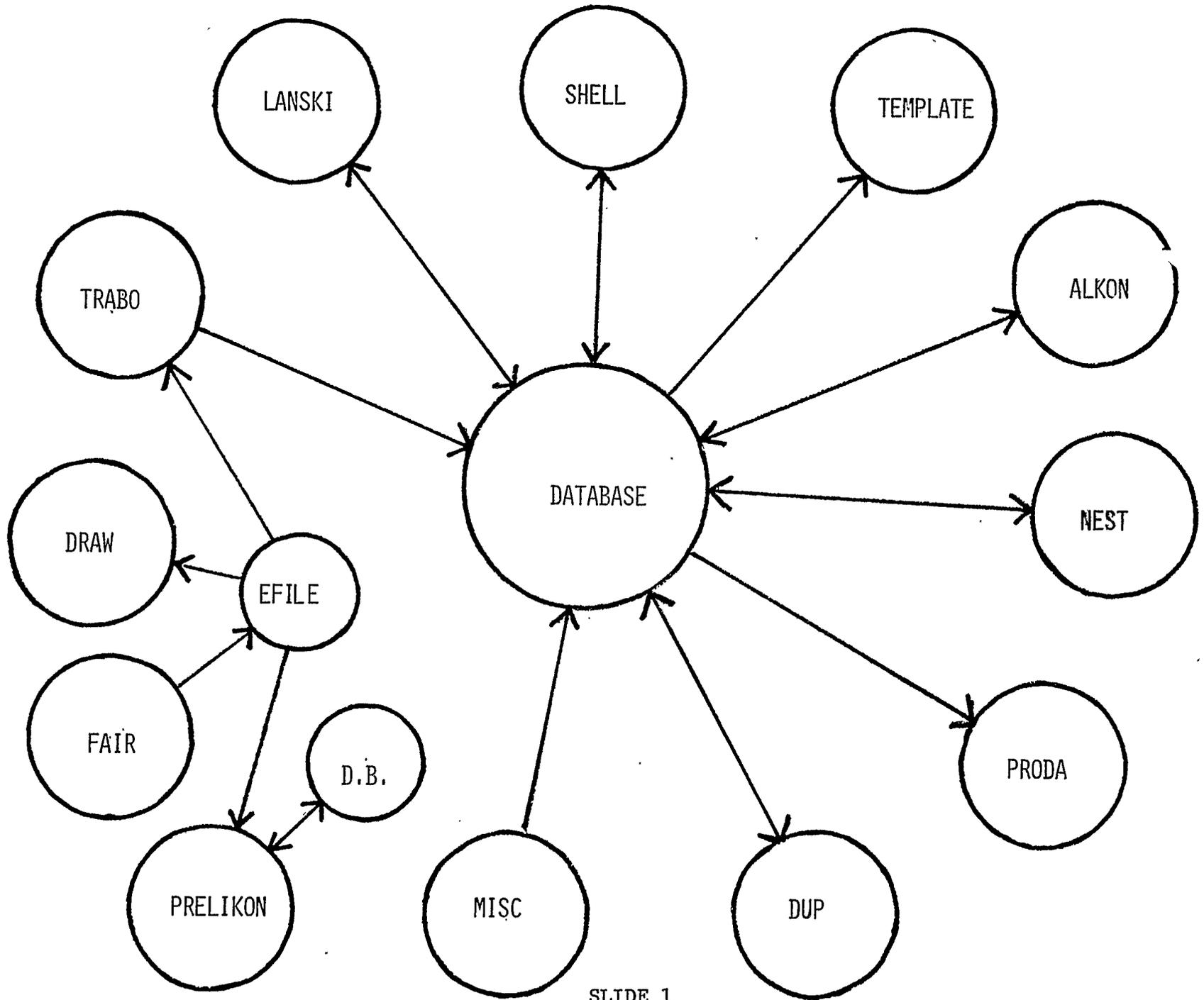
A users documentation manual describing all the procedures for initializing a new database has been written.

Slide 28 and 29

For the purposes of viewing the ESSI output produced by runs performed at IITRI, a graphics package utilizing CALCOMP calls for output to a TEKTRONIX graphics display terminal or to a CALCOMP drum plotter has been developed. Sample plotted output is from the faired-curves drawing module DRAW and the parts nesting module NEST.

In summary, the Updated REAPS AUTOKON System has emerged from the efforts of users and maintenance staffs as a considerably improved tool for the shipbuilding industry both in application and performance. Through its continued use by the REAPS participants, more enhancements will be added in the future tailored to the needs of those involved in the automated processes.

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SLIDE 1

## STANDARD U, S, BASE VERSION

- PROGRAMS

<u>MODULE</u>	<u>BASE LEVEL</u>
AUTOBASE	1
GENPUR	3
FAIR	3
DRAW	3
TRABO	2
MISCELLANEOUS	
DINIT	1
DFREC	1
DFDEC	1
DFDTT	1
DFPPT	1
CHNAME	1
RSI	1
DFCHAR	1
DFOPT	1
GEJOL	1
TRJOL	1
RECUT	1
DUP	1
SHELL	2
TEMPLATE	2
LANSK1	1
PRODA	1
ALKON	3
NEST	1
ALKNES	1

- ALKON VOCABULARY

- ALKON NORMS

- ACCEPTANCE TESTS

- DOCUMENTATION

SLIDE 2

HOW MODIFICATIONS ORIGINATE

REAPS ANALYSIS REQUEST ACTIVITY

. SRS MAINTENANCE CENTRAL ACTIVITY

SLIDE 3



# ANALYSIS REQUEST

FROM: _____ _____ _____ _____ _____ _____	AR # _____ (TO BE ASSIGNED BY IITRI)
	AUTOKON MODULE _____ VERS 10N _____ COMPUTER _____ OPERATING SYSTEM _____

PROBLEM:

USE ADDITIONAL SHEETS IF NECESSARY

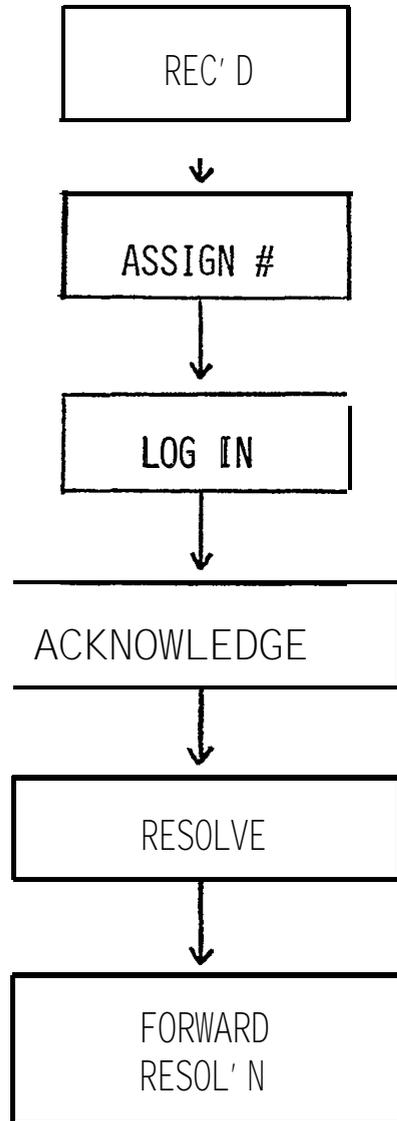
ENCLOSURES:	<input type="checkbox"/> LISTING	<input type="checkbox"/> SOURCE DECK	<input type="checkbox"/> TEST MATERIAL	<input type="checkbox"/> OTHER
DATE	SIGNED: _____			

NOTES :

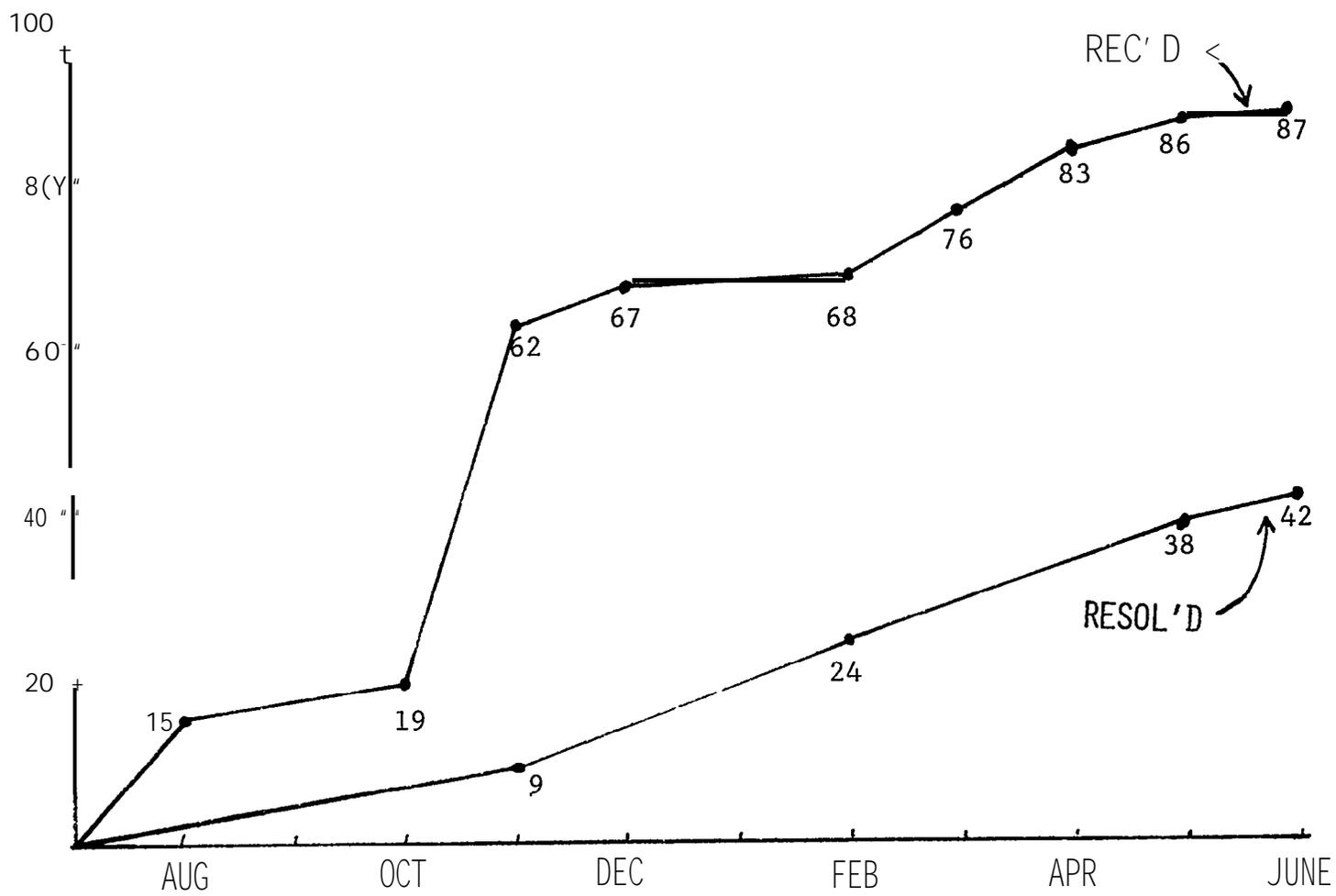
- 1) If the area of the program causing the problem is easily identifiable, it would be appreciated if only the problem area was submitted. However, if there is uncertainty as to the relevant portion of the program, the entire program or a suitable simulation of the entire program should be submitted.
- 2) In Alkon, if nonstandard norms are used to generate data relating to the problem area, it is important to include these or a simulation of these as part of the documentation.

SEND TO: REAPS LIBRARIAN  
 IIT RESEARCH INSTITUTE  
 10 WEST 35 STREET  
 CHICAGO, ILLINOIS 60616

A R PROCESSING

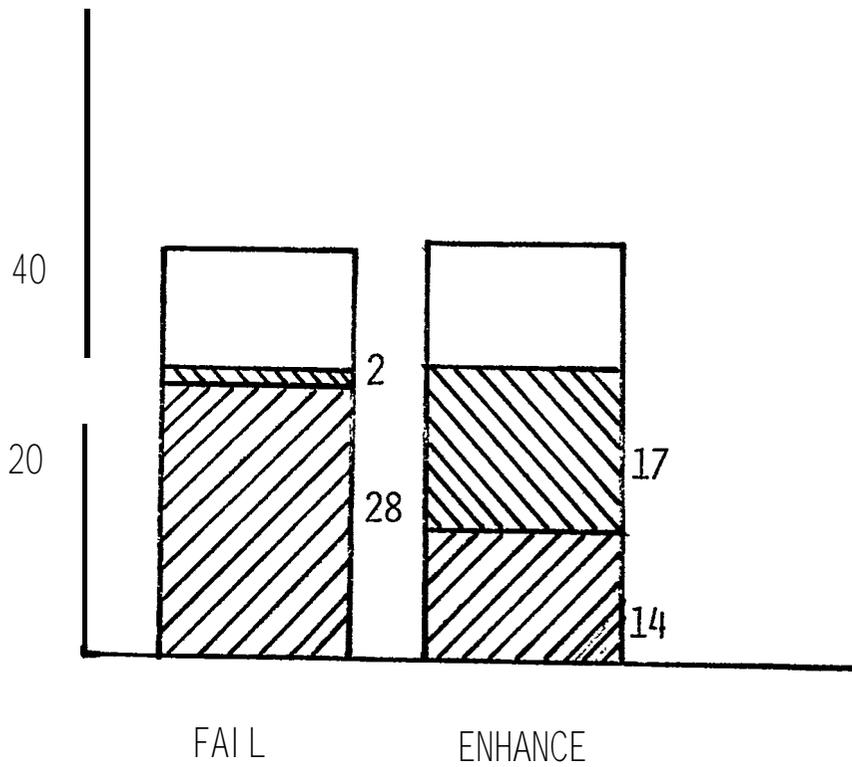


SLIDE 5



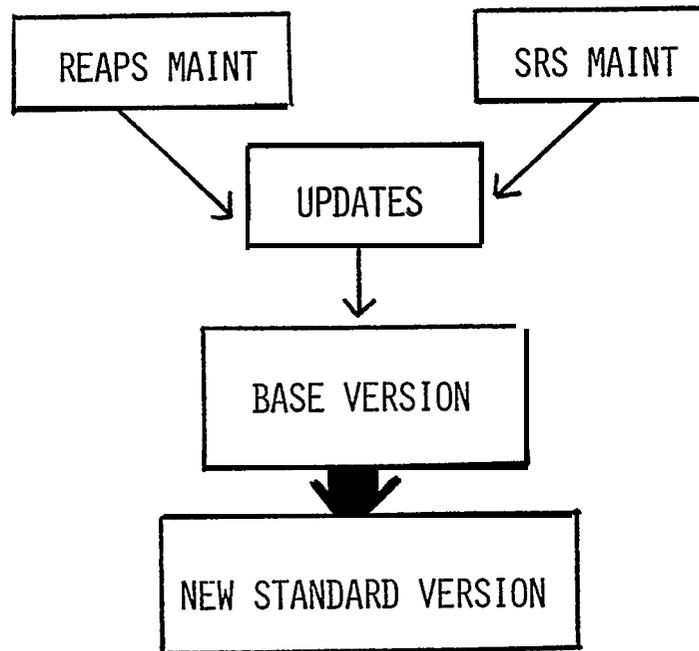
A R ACTIVITY

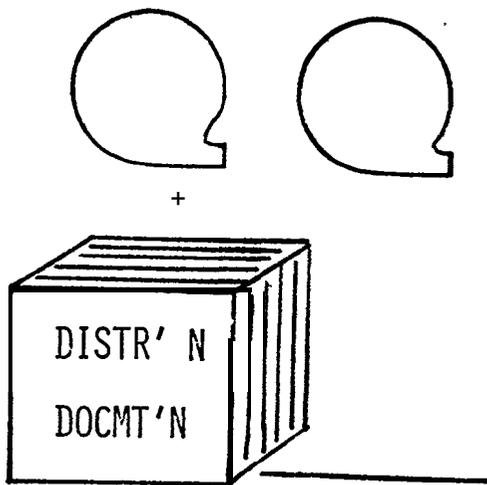
SLIDE 6



A R PROCESSING

-  UNRESOLVED
-  RESOLVED
-  EXTENSIVE





- SYS TAPES

- BASE - vs "A" VERSION
- EXPLAIN UPDATES
- IMPL'N PROC
- DOCMNT'N CHGS
- ACC TESTS

SLIDE 9

Tabulation of Individual Updates

A REFERENCE OF ALL UPDATES APPLIED TO AUTOKON SYSTEM MODULES TO CREATE STANDARD VERSION A

MODULE	SUBRTN	CHANGES AND REAS'ONS
....."	.....0	.....".....".W.....".....".....09.....-W..
ALKON	----- AR 74-033	INCORPORATE LISTVOC COMMAND AND FIX IMPROPER NUMBER OF LINES PER PAGE AS REQUESTED IN AR 75-006. *
		LSTVOC LST-(C11500) t02100-02200- (02300)*015100
ALKON	----- AR 74-016	FIX ERROR IN PRINTING VERY LARGE NUMBERS AS ZERO INSTEAD OF WITH ASTERISKS *
		NUMFT NUM,02501
ALKON	----- AR 74-024	INCORPORATE OPTION Z TO CONTROL STACK TRACE OR STACK DUMP *
		OPT.2 OPT,03700,04200,04201,04801-04805
ALKON	----- SRS&REAPS	OPTIMIZE I/O AND STACK ROUTINES, ALLOW NEW OR EQU AFTER DO-LOOP (AR 74-001). *
	OUT1	OUT,01400-01500,01501,03301-03303,03900,(04000),04401,04500,(04600),05100,(05200),05700,(05800),06300,(06400),06900-07000,(07100),07600,08200,08201-08204,08700-08800,(08900),09400-09500,(09600),10100,11000,(11100),11600,12101,12600,12601,13700,14700,14701,15600,15800,15801,18500,19300-19400,19901-19905,21100,21700-22200,22201-22205,22900,22901,23300-23900,(24000-24400)
ALKON	----- REAPS&SRS	MODIFICATION TO MODULE VERSION NUMBERS, REMOVAL OF PASS 0 *
	PART2	PAR,01600,01601,01900,04100,(04200-04300),04600

SLIDE 10

VERSION "A"

<u>MODULE</u>	<u>"A"</u>
(*) AUTOBASE	3
(*) GENPUR	5, 1
* FAIR	4, 1
DRAW	3
* TRABO	5
* MISCELLANEOUS	
<b>DINIT</b>	2
DFREC	1
DFDEC	1
DFDTT	1
DFPPT	1
CHNAME	2
RSI	1
DFCHAR	1
DFOPT	1' 1
GEJOL	1
TRJOL	1
RECUT	1
* DUP	2
SHELL	2
TEMPLATE	2
LANSKI	1
PRODA	1
* ALKON	9, 1
NEST	<b>1</b>
(*) ALKNES	<b>1.1</b>

\* UPGRADED AUTOKON MODULES

(\*) UPGRADED AUTOKON" SERVICE ROUTINES

## VERSION "A" IMPROVEMENTS

- AUTOBASE

PERFORMANCE IMPROVEMENTS 20%/50%  
PROTECTION

- ALKON

PERFORMANCE IMPROVEMENTS 50%/50%  
NEW USER CAPABILITIES  
OPTIMIZATION  
USER DOCUMENTATION  
ELIMINATION OF BUGS

- FAIR

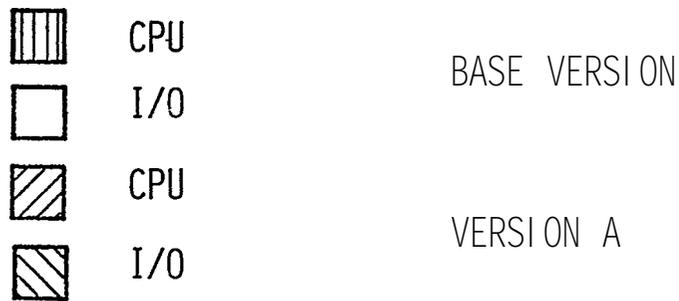
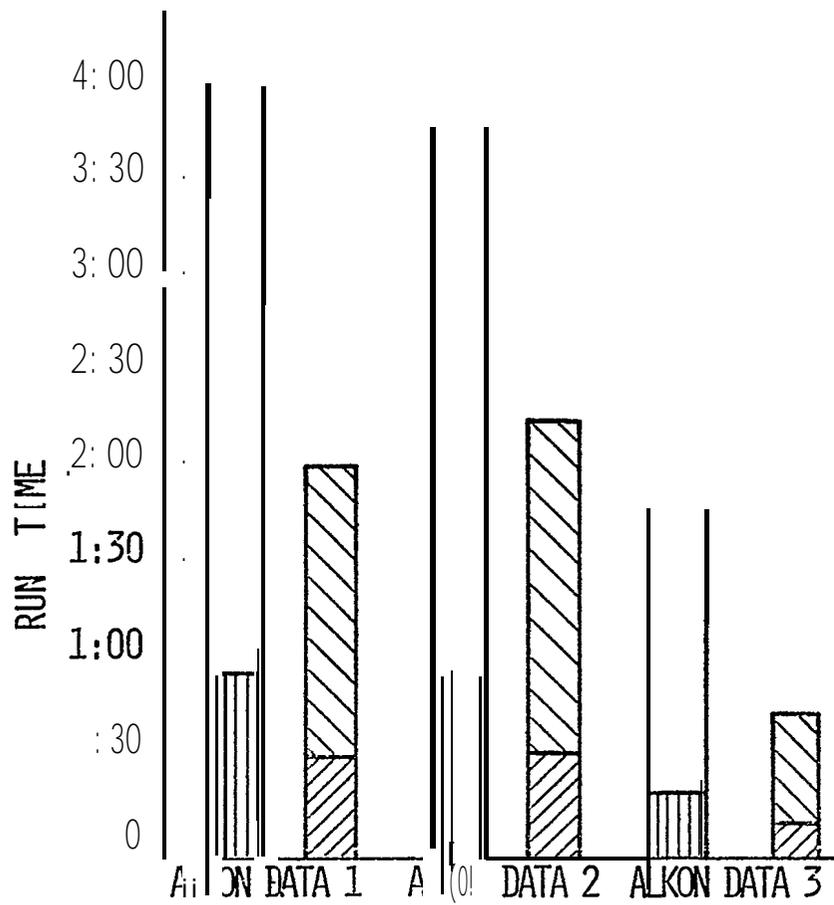
FREE FORMAT INPUT  
NEW ERROR MESSAGES  
ELIMINATION OF BUGS

- DUP

NEW USER CAPABILITIES  
USER DOCUMENTATION

- MISC

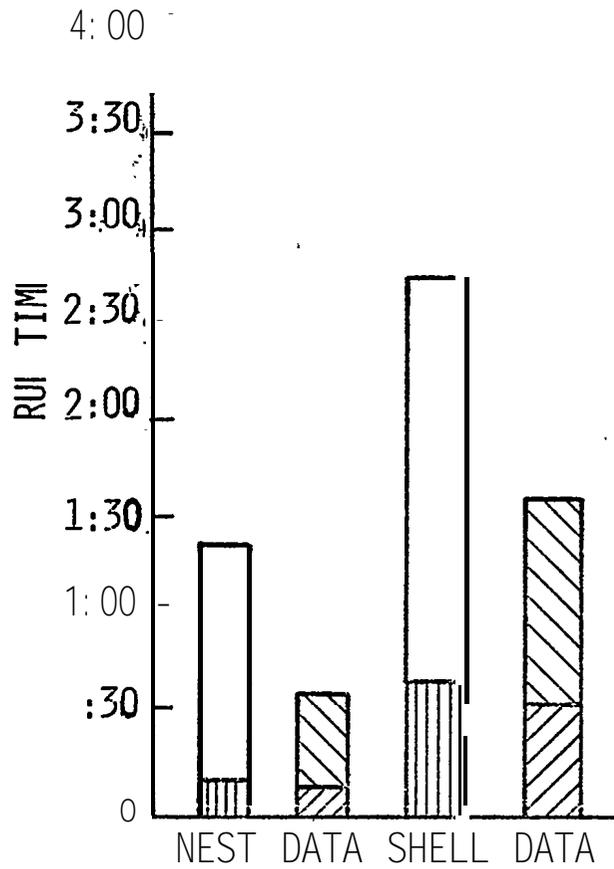
NEW USER CAPABILITIES  
USER DOCUMENTATION



CPU IMPROVEMENT
I/O IMPROVEMENT

ALKON 43X
51%

IMPROVED ALKON PERFORMANCE



■■■ CPU  
 □ I/O  
 ■■■ CPU  
 ■■■ I/O

BASE VERSION

VERSION "A"

	<u>CPU IMPROVEMENT</u>	<u>I/O IMPROVEMENT</u>
NEST	27%	81%
SHELL	7%	53%

IMPROVED DATABASE PERFORMANCE

SLIDE 14

## AUTOBASE

### SYSTEM

- PROTECT DATABASE IF RUN ERR

- PERFORMANCE IMPROVEMENTS

CPU: 7-27%

I/O: 50-80%

# AL KON

## USER

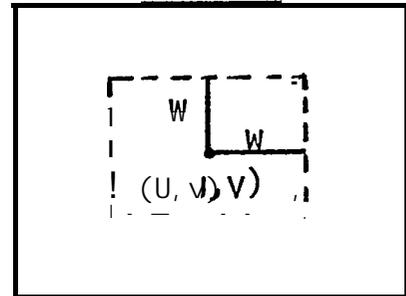
- NEW CONTOUR INTERSECTION COMMAND

INT (+U+V+W)

(u, v) = COORDINATES OF POINT

w = WINDOW HALFWIDTH

SLIDE 21



- 14 NEW USER FUNCTIONS

LISTVOC

TANH

EXP

LN

LOG

TRUNC

MOD

MAX

MIN

SIGN

DIM

FEET

INCHES

FRACT

LISTVOC OUTPUT

ALNON VOCABULARY

WORD	GROUP	VARIANT
A	8	0
ABS	6	10
A6UF	10	0
ACC	12	10
ACCOM	3	61
ACON	12	2
ACOS	6	16
ALIST	9	0
ALPHA	12	3
ANGLE	7	
APAR	1	79
ARCL	12	7
ARG	8	29
ASIN	6	15
AT	0	1
AT ACCoM	3	69
ATAN	6	17
ATANTO	6	18
ATCASING	3	67
ATDECK	3	55
ATFLOOR	3	51
ATFOCSTLE	3	71
ALGIRDER	3	54
ATHFRAME	3	57
ATLBULK	3	52
ATLFRAME	3	53
ATPLSURF	3	73
ATPLTF	3	70
AIPOOP	3	72
ATSELL	3	49
ATSSTRUC	3	68
ATSTRINGER	3	57
ATTFRAME	3	50
ATTTOP	3	56
AUXLIST	9	27
AUXT	12	9
AX	8	26
AXIS	3	5
AXLIST	9	26
	8	1
BBUF	10	1
BETA	12	4
BKT	3	3
BLIST	9	1
c	8	2
CASING	3	59
CASINGHB.1	7	33
CBUF	10	2

# ALKON

USER (CONT'D)

- NEW NORMS
  - MAXI (ARG1+ , , , )
  - MINI (ARG1+, , , )
- CORRECTED NORMS
  - HOLE102
  - BKT22
  - ROUT3
- STACK TRACE OR DUMP CONTROL
  - % Z VAL**
- NEW AND EQU PERMITTED AFTER DO-LOOP
- DEFAULTS (OPTIONAL)
  - ON(CT)
  - SPT '
- 26 CHANGED ERROR MESSAGES
- 4 NEW ERROR MESSAGES

SLIDE 18

# ALKON

USER (CONT'D)

- DOCUMENTATION

VOLUME 1 ALKON HANDBOOK

- DEFINE ALKON LANGUAGE
- EXPLAIN DATABASE PROCEDURES
- EXPLAIN ERROR MESSAGES

VOLUME 2 ALKON PROGRAMMERS GUIDE

- DESCRIBE LANGUAGE APPLICATION
- GIVE NUMEROUS EXAMPLES

VOLUME 3 NORMS DESCRIPTIONS

- DESCRIBE STANDARD NORMS LIBRARY

ALKON REFERENCE CARD

- QUICK REFERENCE
- USER ERROR MESSAGES
- DEBUG INFORMATION

SLIDE 19

Prefix Word . Word in word ,grOup 0 with variant 1 which can be used as a prefix to define two-part vocabulary words.

2-111 -D.2; see also Word Group 2.

Primary Side " See MAINSIDE;

PRINT CON (PRINTCON) Major word which causes a crude.plot of the contour matrix in xBUF to be drawn on the printer.

PRINT CON [+xBUF] [ (+-matrix)]

defaults: xBUF? = SBUF," matrix = CONMO

2-111-C2, 2-V-B3

Print Contents of a List See ROUT 408.

**R**esearch and  
**E**ngineering for  
**A**utomation and  
**P**roductivity in  
**S**hipbuilding

**ALKON**

**REFERENCE DATA**

for  
**AUTOKON**  
**VERSION "A"**



6/75

# ALKON

## SYSTEM

- TRANSLATION PASS REMOVAL
- **FORTRAN** → ASSEMBLER CODING
- OPTIMIZATION OF NORM, RECORD STORAGE
- OPTIMIZATION OF STACK ACCESS
- IMPROVED AUTOBASE ROUTINES
- REMOVAL OF SYSTEM BUGS

FALR

USER

- FREE FORMAT
- COMMENTS
- UNITS SPECIFIER
- SCANNER
- FIX BUGS

SLIDE 23

FAIR Data Encoded Under FFP

EXEC,  
 FAIRING-COURSE FOR SHIPHULLS YN 1 AFTBODY  
 BOUNDARY CURVE 3.MM IN FRONT OF MIDFRAME COMPARED TO 1108 ACC. TEST  
 FOR FAIR-1, THE VOCABULARY CARDS SHOULD BE CHANGED  
 TEST OF USA-VERSION: INPUT IN DEC. FEET: AND FEET.  
 INCHES AND 16THS 9-3-73 R.A.K  
 OPTIONS,1,0,1,1,1,0,0,  
 TFRS  
 -8,15,02,001  
 15,55,02,789  
 55,56,011,483  
 56,57,07,546  
 57,58,70609  
 58,70,150701,FIN  
 WLSF  
 0,19,03,281  
 19,20,02,297  
 20,21,40303,FIN  
 TFRF  
 55,56,4  
 56,57,2  
 58,70,4,FIN  
 WLFR  
 0,1,4,FIN  
 BRD,063,894  
 HEIG,068,898  
 RIS,00,328  
~~SAX,03,084~~  
 BILG,05,906  
 YN,541.  
 AFTB  
 BNDR  
 STMW  
 6,11,00,12.  
 5,10,00,31.  
 2,11,00,31.  
 0,13,0,51.  
 16,8,0,31,FIN  
 STEM  
 -7,042,815,12,S  
 -6,040,305  
 -5,381103  
 -4,371114  
 -3,370202,11.  
 1,033,963,31.  
 8,028,363,11.  
 9,027,444  
 10,251014  
 11,221104,12,FIN  
 TANG  
 19,0,51,FIN  
 TANK  
 21,003,353,51,5  
 25,50405,1.5  
 32,100108  
 39,150507

SLIDE 24

FAIR Data Encoded Under FFP

EXEC  
 FAIRING-COUKSE FOR SHIPHULL5 YN 1 AFTBODY  
 BOUNDARY CURVE 3. MM IN FRONT OF MIDFRAME COMPARED TO 1108 ACC. TEST  
 FOR FAIR-1, THE VOCABULARY CARDS SHOULD BE CHANGED  
 TEST OF USA-VERSION? INPUT IN DEC, FEET AND FEET.  
 INCHES AND 16THS 9-3-73 R.A.K

						\$
OPTIONS	1,	9,	1,	1,	1,	0. 0.
						UNITS DECIMAL FEET
						\$ CURVE SPACINGS
TFRS	- 8	15	2,001			
	15	55	2,789			
	55	56	11,483			
	56	57	7,546			
						UNITS FRACTIONAL FEE
	57	56	70609			
	58	70	150101	FIN		
WLSP						UNIT D
	19		3,281			
	19	20	2,291			
						UNIT F
	20	21	40303	FIN		
TFRF						
	55	56	4			
	56	57	2			
	58	70	4	FIN		
WLFR						
	0	1	4	FIN		
						\$ MAIN DIMENSIONS
						UNITS DEC. FT.
BRED	65,894					
HEIG	68,898					
RISF	0.328					
GARB	3.084					
BILG	5.906					
YN	541.					
AFTB						
						\$ BOUNDARY DESC.
BNDR						
STMW						
	6,	11,	0,	12,		
	5.	10.	0,	31,		
	2.	11,	0,	31,		
	0.	13,	0,	51,		
	16,	-8.	0,	31,	FIN	
STEM						
	- 7,	42.815	12.5			
	- 6.	40.305				
						UNIT F
	- 5,	381103				
	- 4.	371114				

SLIDE 25

FAIR output in SCAN mode

\*\*\* SCAN FAIR INPUT \*\*\*

OPTIONS 1. 0. 1.. 1. 1.

OPTIONS 1, 0. 1. 1, 1.

\*\*\* WRONG NO. FIELDS FOUND. MIN= 8 MAX= 8 FOUND= 6

TFRS

- 8 15 D-2.001  
15 55 D2,789  
55 56 D11.4~3  
56 57 D7.546  
57 58 70609  
58 70 150701 FIN

WLSP

0 19 03.281  
19 20 02,297  
20 21 40303 FIN

TFRF

55 56 4  
56 57 2  
58 70 4 FIN

WLFR

0 1 4 FIN

HEIG

D68,898

RISF

DO.328

GAHB

D3.084

BILG

D5,906

~~KN~~

~~541~~

AFTB

BNDR

BRED

D63.894

BRED

D63.894

\*\*\* DATA OUT OF ORDER OR FIN MISSING TYPE EXPECTED=BOUNOARY

STMW

6.	,	DO.	12.
5.	10.	DO.	31.
2.	11.	DO.	31.
0.	13.	0.	51.

\*\*\*ILLEGAL CHARACTER IN COLUMN 1 OF FIELD \*\*?.

16, -8. ?0. 31.

STEM

STEM

\*\*\* FIN MISSING

-7\* D42,815 12,5

-7, D42.815 12,5

\*\*\* UNKNOWN CARD TYPE FOUND \*\*\*

SLIDE 26

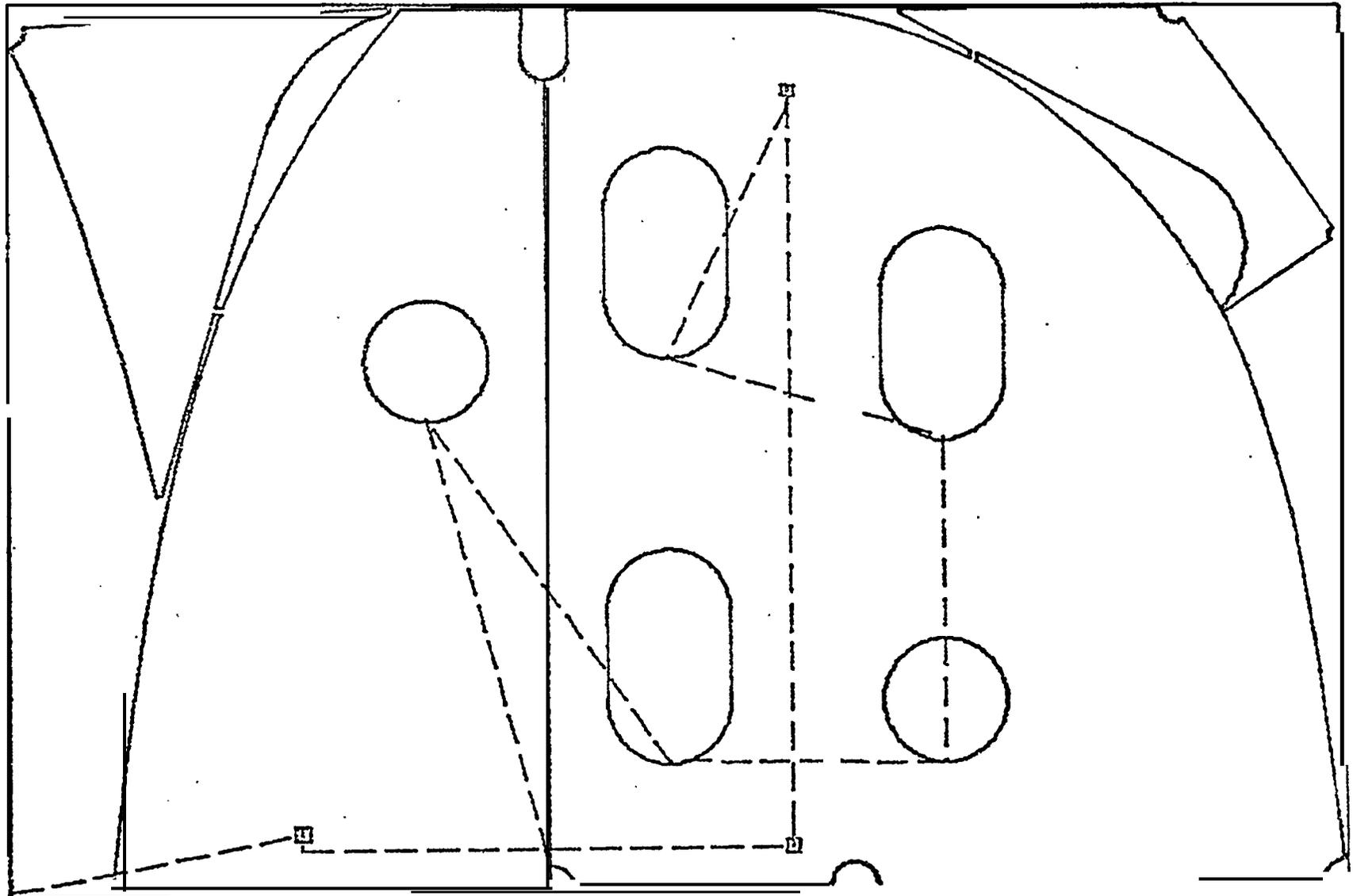
## DUP

- SAVE/DELETE NON-ACTIVE RECORDS
- 3 USER DUMP COMMANDS
- VOLUME 4 DUP USER DOCUMENTATION

## MISC

- SAVE/DELETE NON-ACTIVE RECORDS
- VOLUME 4 MISC USER DOCUMENTATION

NEST

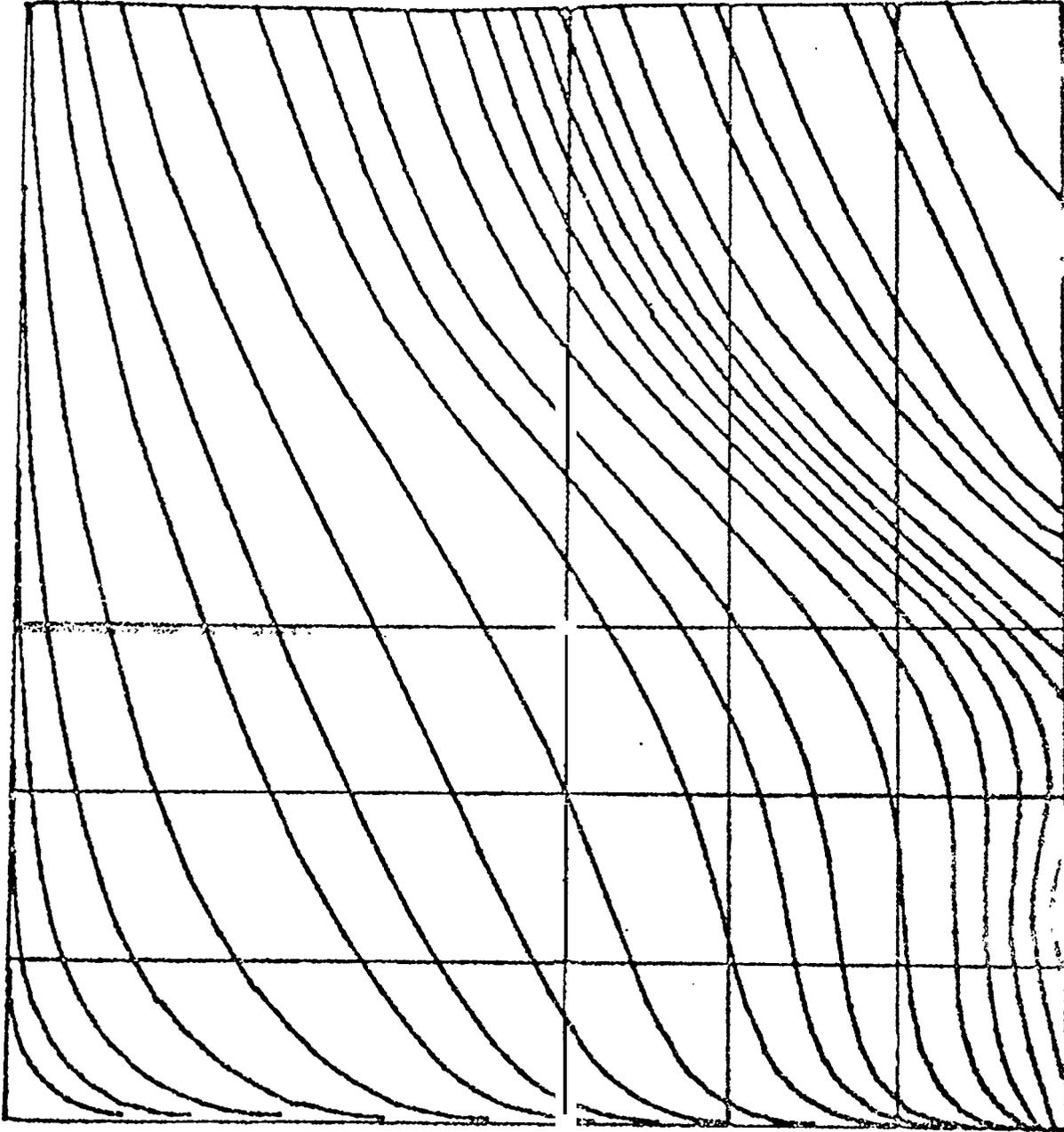


50

ACC TEST II/EX.1

SLIDE 28  
QUIK-LOOK TEKTRONIX OUTPUT  
FROM ESSI-POST PROCESSOR

DRAW



OUI K-LOOK TEKTRONIX OUTPUT  
FROM ESSI POST-PROCESSOR

SLIDE 29



REAPS LONG RANGE PLANNING:  
WHAT DO YARDS WANT; WHAT IS BEING DONE

Hunter H. Shu  
IIT Research Institute  
Chicago, Illinois

Since 1972, Dr. Shu has been responsible for long range planning with two groups of industrial sponsors to identify manufacturing developments. His past experience includes: employing elastomeric components for protection and isolation from mechanical vibrations and shock, devising laboratory procedures for the determination of viscoelastic properties of elastomers, and studying the problem of heat dissipation of energy absorbers.

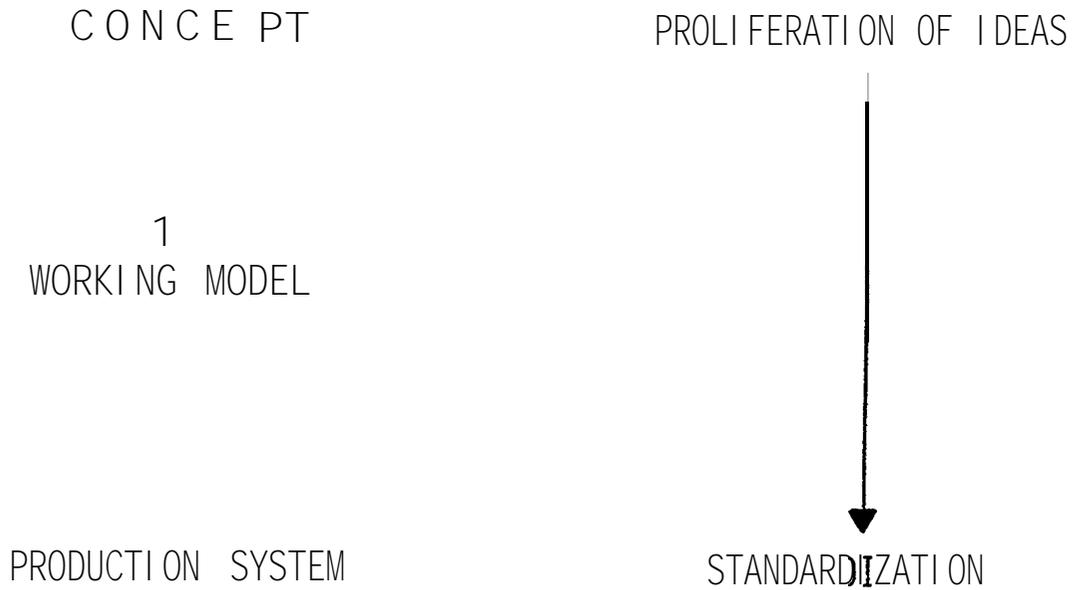
Between 1969 and 1971, Dr. Shu was invited to teach at National Taiwan University in the Republic of China. Courses taught were numerical analysis, computer languages and programming, and analog computation. He also served as an Adjunct Professor in the Institute of urban planning, Chung Shin University, Taiwan, lecturing on planning methods and quantitative techniques which introduced probabilistic simulation and operations research topics.

TO IDENTIFY OPPORTUNITIES  
AND  
TO FORMULATE PLANS  
OF  
RESEARCH AND DEVELOPMENT  
FOR  
THE REAPS COMMUNITY

TYPES OF PROJECTS

- HARDWARE TO IMPROVE BASIC OPERATIONS
- SOFTWARE TO CONTROL AND/OR DIRECT HARDWARE
- TECHNICAL INFORMATION GENERATION AND TRANSFER
- SHIPYARD MANAGEMENT AND PRODUCTION CONTROL

## PROJECT LIFE CYCLE



## WHAT DO THE YARDS WANT?

- o TO FORMULATE AND TO PLAN ORDERLY DEVELOPMENTS
- o TO MAXIMIZE USEFUL RESULTS
- o TO ASSURE COMPATIBLE OUTPUTS

## SHIPYARD MODELING

- IDENTIFY FUNCTIONS IN THE SHIPYARD AND MATERIALS, INFORMATION AND RESOURCES REQUIRED TO CARRY OUT THESE FUNCTIONS ,
- INTERRELATE THESE FUNCTIONS IN A MEANINGFUL MANNER FOR ANALYSIS ,
- CURRENT MODEL CONTAINS 11 MAJOR FUNCTIONS AND 53 SUB-FUNCTIONS IN A HIERARCHICAL STRUCTURE,

### FUNCTIONS IN A SHIPYARD

A, 1 MASTER SCHEDULING & CONTROL

A, 1, 1 ESTABLISH KEY EVENTS SCHEDULE

A, 1, 2 ESTABLISH ERECTION SEQUENCE

A, 1, 3 ESTABLISH ERECTION SCHEDULE

A, 2 SYSTEMS ENGINEERING

A, 2, 1 ENGINEERING SCHEDULING & CONTROL

A, 2, 2 SUPPLEMENT Q, At MANUAL

A, 2, 3 STRUCTURAL ENGINEERING

A, 2, 4 PROPULSION ENGINEERING

A, 2, 5 ELECTRICAL AND ELECTRONICS ENGINEERING

A, 2, 6 ENVIRONMENTAL SYSTEMS ENGINEERING

A, 2, 7 SYSTEMS INTEGRATION

- A, 3 DETAILED DESIGN
  - A, 3.1 DETAILED DESIGN SCHEDULING & CONTROL
  - A, 3.2 STRUCTURAL AND FOUNDATION DESIGN
  - A, 3.3 ELECTRIC AND ELECTRONIC DESIGN
  - A, 3.4 HVAC AND MISCELLANEOUS DESIGN
  - A, 3.5 DESIGN COORDINATION AND VERIFICATION
  
- A, 4 PROCESS PLANNING AND LOFTING
  - A, 4.1 PROCESS PLANNING SCHEDULING & CONTROL
  - A, 4.2 PRODUCE STRUCTURAL WORK PACKAGES
  - A, 4.3 PRODUCE NON-STRUCTURAL WORK PACKAGES
  - A, 4.4 ESTABLISH SHOPFITTING PROCESS
  - A, 4.5 ESTABLISH ERECTION PLAN
  - A, 4.6 ESTABLISH OUTFITTING PROCESS
  
- A, 5 SHIP PRODUCTION SCHEDULING & CONTROL
  
- A, 6 PURCHASING/RECEIVING
  
- A, 7 NON-STRUCTURAL FABRICATION
  
- A, 8 STRUCTURAL FABRICATION & SHOPFITTING
  
- A, 9 ERECTION AND LAUNCHING
  
- A, 10 OUTFITTING
  
- A, 11 SEA TRIALS

CRITICAL COMPONENTS

(BY FUNCTION)

- o SCHEDULING & CONTROL AT ALL TIMES
- o ENGINEERING COORDINATION
- e DETAILED DESIGN VERIFICATION
- o PRODUCTION OF WORK PACKAGES

CRITICAL COMPONENTS

(BY LABOR)

	<u>% TOTAL LABOR</u>
WELDING	9,0
SHIFITTING	8,2
ENGINEERING	5,0
PIPEFITTING	4,5

## DESIRED SYSTEM CAPABILITIES

( SHORT RANGE )

- o IDENTIFICATION OF AUTOKON DEFICIENCIES
- o COMPARING WITH OTHER SHIPBUILDING SOFTWARE SYSTEMS
- o DEFINING ENHANCEMENT PROJECTS (14 DEFINED)

## DESIRED SYSTEM CAPABILITIES

(MEDIUM & LONG RANGE)

- o SNAME O-34-1 RECOMMENDATIONS ON TECHNICAL AND RESEARCH PROGRAMS ,
- o VARIOUS TECHNICAL FORECASTS AND STUDIES
- o THE REAPS COMMUNITY
- o U , S NAVY AND OTHER SOURCES

## LIST OF POTENTIAL PROJECTS

- o SHIP DESIGN, CONSTRUCTION AND OPERATIONS TASKS DOCUMENTATION
- o EFFECTS OF PART TOLERANCE, WELDING DISTORTIONS, FLIMSINESS OF CROSS SECTIONS; NON-RIGID FOUNDATIONS, ERROR IN POSITIONING, AND MEASUREMENT TECHNIQUES ON DIMENSIONAL CONTROL
- o COMPUTER-AIDED SHIPYARD PLANNING, PRODUCTION AND MATERIAL CONTROL SYSTEM
- o AUTOMATED PIPE FABRICATION
- o ALL POSITION HIGH - DEPOSITE WELDING
- o AUTOMATED STEEL YARD
- o TRANSPORT AND HANDLING SYSTEMS FOR SUB-MODULES
- o ADAPTIVE NC PLATE WARPING MACHING
- o COMPUTER-AIDED PROCESS PLANNING FOR STEEL FABRICATION AND SHOPFITTING
- o AUTOMATED DRAFTING FOR ENGINEERING AND DETAILED DESIGN

## TARGET SYSTEM OBJECTIVES

OBJECTIVE 1: MINIMIZE SHIPFITTING COST:

- o MINIMIZE ENGINEERING CHANGES
- o BETTER FABRICATION & ASSEMBLY INFORMATION
- o MORE ACCURATE PART PRODUCTION
- o BETTER MATERIAL HANDLING METHODS

OBJECTIVE 2: MINIMIZE PIPEFITTING COST:

- o STANDARDIZATION IN PIPING DESIGN
- o BETTER FABRICATION & ASSEMBLY INFORMATION
- o AUTOMATION IN PIPE FABRICATION
- o MORE PREFITTING PRIOR TO ERRECTION

OBJECTIVE 3: MAXIMIZE CONTROL OVER PRODUCTION:

- MORE FLEXIBLE PLANNING FOR PROCESSES
- MORE REALISTIC SCHEDULING
- BETTER SYCRONIZATION OF RESOURCES
- o BETTER CONTROL OVER MATERIALS

## WHAT IS BEING DONE ?

- MODEL SHIPYARD FUNCTIONS
- IDENTIFY CRITICAL SYSTEM COMPONENTS
- VOCALIZE DESIRED SYSTEM CAPABILITIES
- ESTABLISH LONG RANGE TARGETS
- FORMULATE DEVELOPMENT PLANS



APPLICATION OF MINICOMPUTERS  
IN THE SHIPBUILDING INDUSTRY

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## SUMMARY

Mini- and micro computers will be playing an increasingly important role in the shipbuilding industry, partly as a substitute for - and partly in addition to the presently used larger computers.

This paper discusses some reasons for this development, illustrated by current applications and developments in Norway.

1. INTRODUCTION

When the mini-computer "boom" started some years ago, it was heralded as the small companies' entree to the computer age. And so, indeed, it has been. Today mini-computers\* can be found in many companies which earlier regarded a computer as an unattainable luxury.

This paper intends to discuss some areas and applications in a shipyard where the minis can be favorably introduced. Current applications and developments in Norway will be used as examples.

This paper will also discuss future development of micro-computers\*\* dedicated to shipyard applications.

The use of mini-computers in direct control and automation of production processes, etc., will not be treated in this context, even though it is of great importance to an industry where shortage of skilled labor is becoming a main problem.

2. ENVIRONMENT

Most of the hardware and software development in Norway concerning the shipbuilding industry, is done in close cooperation among:

---

A mini-computer is often defined as EDP-equipment, small in volume and low in price (\$ 10,000 - 20,000), connected to different types of peripheral equipment; several compilers are available using a simple operating system. The same hardware equipment can be used for several purposes.

Low-price EDP-hardware, based on a new hardware technology. Dedicated for one purpose. The processing costs are very low. Increasing the hardware capacity is easy.

Central Institute for Industrial Research  
Norwegian Ship Research Institute  
Det Norske Veritas  
Aker Group

and the Norwegian hardware companies.

These institutes and companies are joint owners of A\S Fjerndata, which owns and runs a Univac 1110 and IBM 370\158. In addition to this centralized computing power, a number of smaller installations have popped up during the last years and connected to these remote computers.

3. WHY USE MINI OR MICRO?

Before answering this question in general, let us examine a typical development of EDP competence in a shipyard. Let us regard this development to be split up into five different phases (there are no doubt more phases to come after these):

Phase 1: The yard has no internal EDP-competence at all. Tasks requiring computing power is carried out by means of consultants, using service bureau facilities. As an example, the author's company (SRS) each year carries out a number of service jobs like hydrostatic calculations lines fairing, shell expansion etc. for several yards.

Phase 2: The yard gets an in-house terminal, and builds up user experience. The bulk of the EDP-processing is often administrative routines like patrolling, but technical calculations are also carried out.

Phase 3: This Phase is characterized by a rather large use of EDP, with a corresponding extension of the EDP-staff. If big enough, the yard may have acquired "its own large computer, or may have access to several computers by means of a multi-machine terminal. The attention will be focused on application systems rather than hardware. Systems developed or acquired will be rather ~ sophisticated.

Phase 4: Flexibility, reliability and overall economy start to play a more vital role. Information systems are introduced, including more strategic and long range systems. On-line applications are taken into use. The user is in focus, and some years ahead.,

Phase 5: Integrated hardware and software systems are developed by highly professional EDP companies. Each "box" is designed and dedicated for one special purpose (master scheduling, job shop scheduling, material administration etc.) . The micro system can be used stand-alone or in connection with a remote computer, accessing the common data bases.

Assuming a yard is in phase four of the rather schematic development line that is sketched above, why should it choose to introduce mini-computers, and for which applications?

The primary consideration is cost. Grosch's law ("twice the computer cost gives four times the computing capacity") no-longer applies. The high overhead costs connected with a time-shared large computer will often favor ' mini-computers, and so **will** the recent **years'** change in the cost ratio of software\ hardware. This applies especially for the new range of



applications that have been introduced lately. Generally speaking, minis may be the best choice in combinations of on-line operation, when one application can fill the capacity of one mini in longer periods of time and in some applications with much in/out and little processing.

Improved accessibility is another major point when choosing the mini. This is especially important, of course, in connection with on-line systems. One simply cannot expect the first line user to wait through a time-shared computer's usual turn-around time to find out, for instance, whether an item is in stock or not, while an impatient person is waiting for the answer on the other end of a telephone line or at the other side of the counter.

Use of mini-computers will often go together with decentralization of responsibility. An in-house mini-computer will be more manageable than a far away larger computer shared by many other users, and may boost the manager's feeling of having control with his own data. And, indeed, this may often be a fact more than just a feeling.

In applications where immediate control of input is of importance, a mini-computer either alone or in connection with a large computer may be of benefit. The reason for this is, of course, that the mini - even if too small to handle the actual processing - can do all required control of logic and syntax and immediately reject erroneous input. This is also a matter of cost. Let us consider that a typical registration costs kr. 0.50 - kr. 0.75 (10-15 US cents). If such a registration contains an error, the cost may well be kr. 50,- - kr. 75,- (10 to 15 US dollars), and sometimes considerably more. With a volume of say 100,000 registrations a month, you can go a long way towards input control and still save money on it.



Another important point with the on-line input control (which by the way does not necessarily require a mini-computer) is that it is possible to move the data registration closer to the first line user. In addition to controlling, the mini can be programmed to guide the user through the registration process. Training and instruction can be reduced to a minimum, and even infrequent users can do rather complex registrations. By having, for instance, a ware-house attendant or a shop foreman feeding data directly into the computer, the need for key-punching and editing of input is reduced, and, hopefully, many sources of errors are eliminated. A frequently heard prophesy is that key-punching departments will be non-existent within a few years.

Having briefly looked into the main reasons why it may be of benefit to choose a mini-computer, let us next examine in more detail the projects within the Norwegian shipbuilding industry where this type of equipment is in use.

4. PHASE 3 AND 4  
ON-LINE/BATCH AND THE USER IN FOCUS

How can we identify the user? What functionally is he doing in the shipyard environment? Does he need any automated routines, on-line access, data base etc. ? How frequent is the information flow between this function and the other functions in the shipyard information system? And how much information is processed?

The answers to these questions will give:

Operation of the software (on-line and/or batch)

Hardware configurations (remote, mini, micro)



Data storage (common data base, local data base etc. )

Processing, centralized or de-centralized

Access time requirements

System connections (data base, manual routinesl  
"mail-box", etc.)

The detailed analysis of these problems will be the frame-work for development of a shipyard information system. Fig. 1 is a very simplified version of this information system, concerning the function scheduling and material administration, and the current applications:

<u>Function</u>	<u>System Name</u>	<u>Operation Mode</u>	<u>Data Base</u>	<u>Configuration</u>
Master Scheduling	BEPLA	On-line/Batch	Centralized	Mini/Remote Computer
Job Shop Scheduling	PLASIS	Batch	Centralized	Remote Computer
Scheduling Dock Erectio] and Out-fittig	OPTIMA	Batch	Centralized	Remote Computer
Material Admini- stration	MAPLIS	On-line/Batch	Local and Centralized	Mini/Remote Computer
Steel Admini- stration	AGSIS AUTOSTEEI	On-line/Batch	Local and Centralized	Mini/Remote Computer

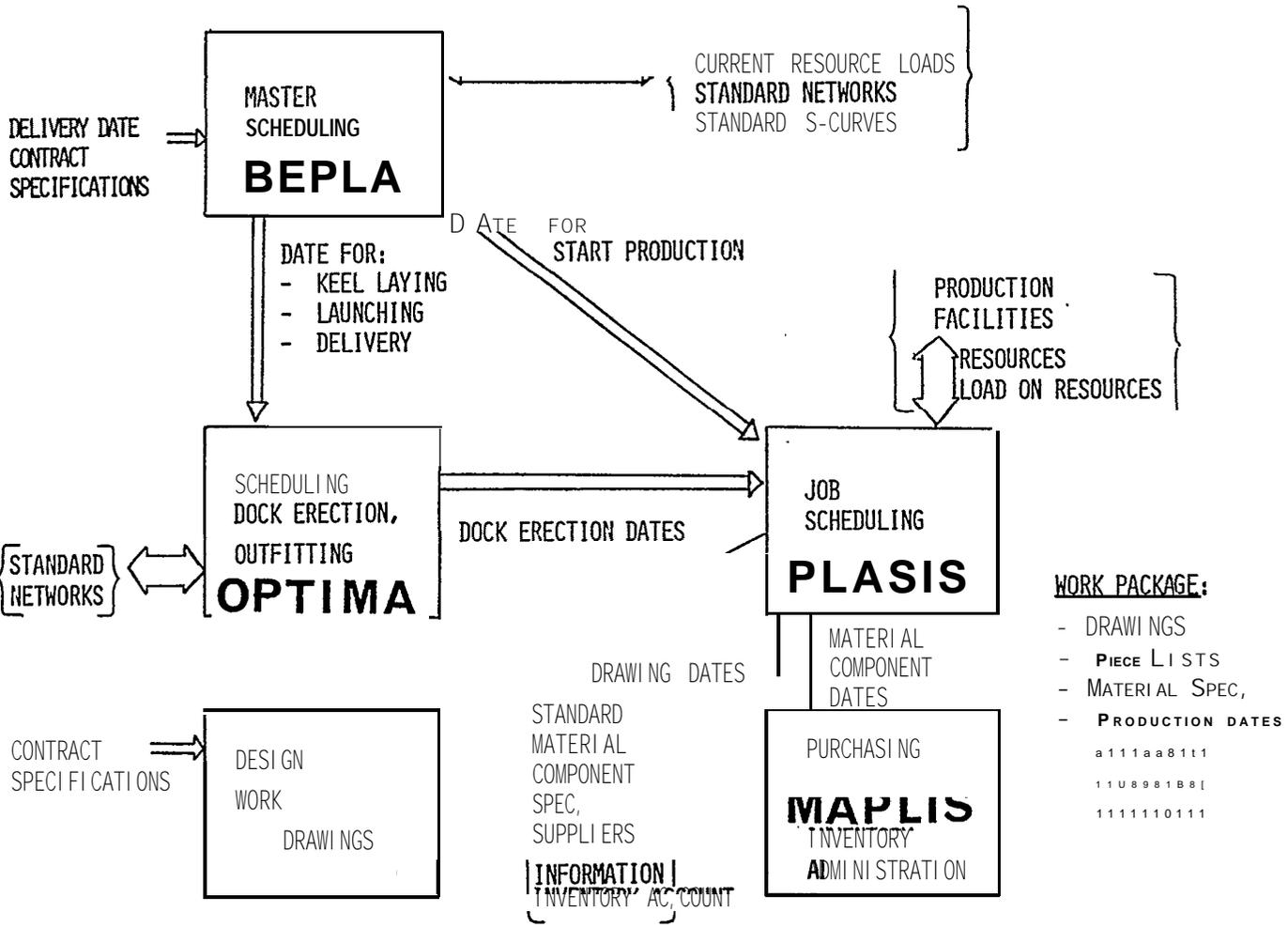


Fig. 1 : Shipyard Information System

- Functions: - Scheduling
- Material Administration

5. EXAMPLES OF CURRENT APPLICATIONS

5.1 MAPLIS - a material management tool

Material management is a complex yet all-important task in a shipyard. The cost of material often exceeds 60% of the total cost of a ship. If some materials are not available when they should be, the whole production can be delayed. Misunderstandings concerning specifications or timing can be critical.

To help solve" - the problems of material management, the information system MAPLIS is now being developed at the Aker Group's Stord Yard.. The aim is "to serve all departments working with information concerning materials, and to give the users in these departments easy access to information at the time they need it to do their job". This means that the system must serve an array of functions like design and engineering, planning, purchasing, stores administration, accounting, etc.

Concerning the basic design, three solutions were considered:

- a. Running the system in batch on a remote large computer (at Fjernd.ata in Oslo).
- b. Operating partly in batch, partly on-line on a remote large computer.
- c. A combination of local on-line and remote batch system.

A complete batch operation would have given the most straight-forward solution. Both development and operation costs would've been relatively low, and there would be no need to invest in additional equipment. The price of one transaction was calculated to be lower than for the former manual operation.



(This factor is not, however, regarded as a main criterion for the system's validity!).

From the user's point of view, a batch system would mean serious drawbacks. The system does not meet the demand for easy access to stored information, and will not provide immediate answers to the many questions that will be asked every day. Further, one would lose the on-line system's possibilities of immediate control of input data. A batch system would also mean more potential error sources in the input and output process.

Alternatives b. and c. would be equally good from the user's point of view, provided that the large computer's response time was good enough, and that the information most frequently asked for could be stored on the local computer. Alternative b., however, would mean less investment in equipment (only local registration equipment would be needed) , and development costs would probably not be considerably higher than for a pure batch system.

To test further the relative merits of alternatives b. and c., Stord Yard undertook a rather extensive test. An on-line registration and inquiry sub-system for stock materials was developed and run for some months over telephone line to the UNIVAC 1110 in Oslo. This exercise proved . the response time to be too long, and the cost per transaction was approximately seven (7) times the cost of the similar manual operation. (Reference (2)) .

As a result of this test, alternative c. was chosen. On-line registration and inquiring is done on a local mini-computer. The most frequently used data are stored locally, and once or twice a day transactions are transferred to the remote computer for updating of the data files there.



The complete database will be on the large computer. Large report, statistics, etc. is done in batch-mode on the large computer. The same applies to answers on inquiries where the pertinent data is not stored locally. The equipment used in connection with MAPLIS is shown in figure 2.

ON-LINE terminals for data collecting and quering:

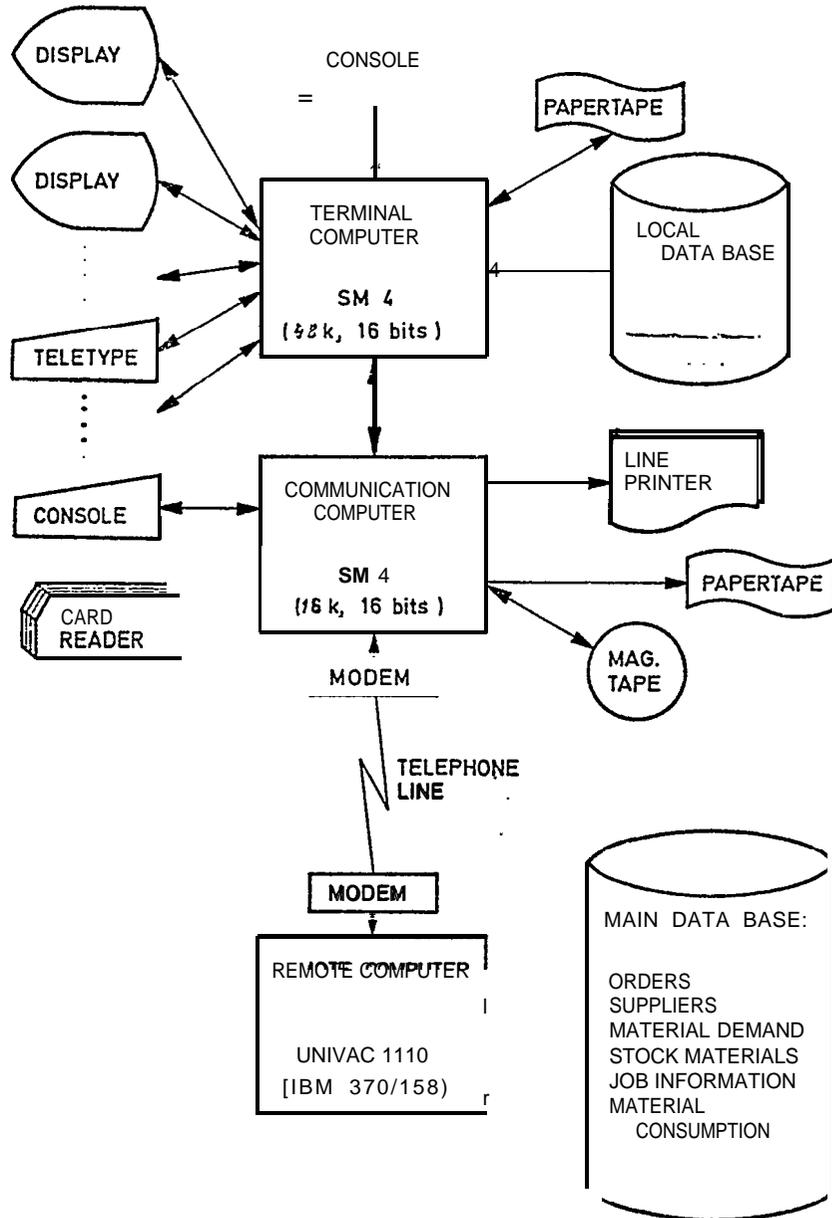


Fig. 2: Hardware equipment



The MAPLIS system consists of a number of stand-alone modules. Each module corresponds roughly to one function in the material management.

#### AUTOSTEEL - a local steel information system

The AUTOSTEEL system, fig. 3, - currently under development at the Aker Group's Bergen yard (Bergens Mek. Verksteder) - intends to handle all information about steel materials that is needed in the yard. This means that the system must serve tasks like:

- Stockyard marshaling
- Requirement specification from. the drawing offices
- Steel ordering
- Control and registration of received steel shipments
- Registration of steel consumption
- Production planning

The AUTOSTEEL system will be linked to other systems, partly manually (e.g. to the unit production planning system PLASIS) , partly by having direct access to another system's data base (the Aker Group's steel information system. AGSIS) .

ON-LINE terminals for  
data collecting and quering:

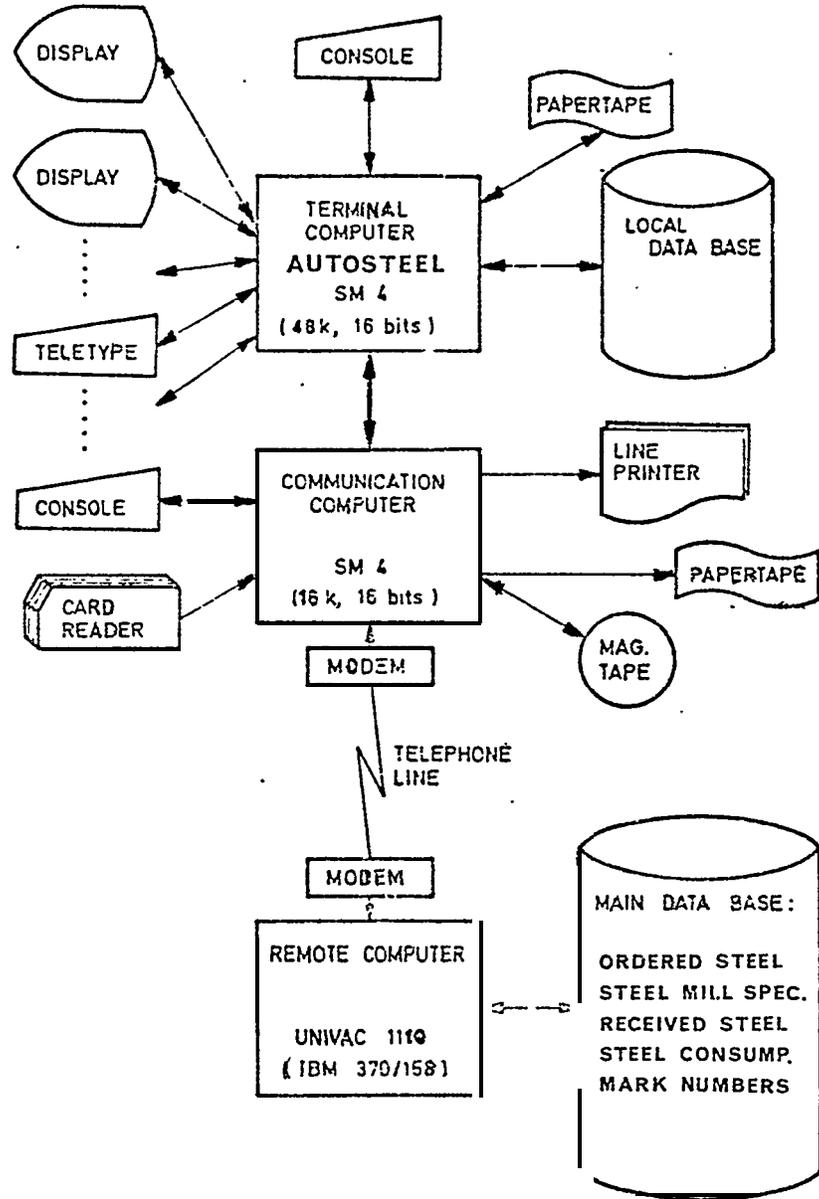


Fig. 3: Hardware equipment  
AGSIS/AUTOSTEEL

The system is designed as an on-line, real-time system, but can also be operated in batch-mode. It will be run on a dedicated 32 k mini-computer (Kongsberg SM-4) with a disc drive. Other peripherals are not finally decided. A number of terminals (teletypes or visual display units) will, however, be located in the yard, initially in the drawing office, in the planning office, and close to the steel stockyard.

The AUTOSTEEL is a local operation with much in/out and little processing. Except for some input data exchanged in batch with the AGSIS system, all registration and inquiries are done locally in the yard;. For this particular application, the mini-computer was found to be the best choice, both economically and to satisfy the user's demand of guided on-line registration and immediate response on inquiries.

### 5.3 An on-line accounting and ledger system

The Aker Group's yards are combining shipbuilding with other activities like ship repairing, building of engines and equipment, and. general metal working production. This is the case with the downtown Oslo yard (Nylands Verksted) where they have found it desirable to get better control over both suppliers' and customers' ledgers. A system that is developed for this purpose results in a considerable reduction of unsettled customers' accounts, and reduces both the costs and errors of today's semi-manual routine.

The following demands are placed on the new system:

It must be possible to input data, ask questions and get answers on different types of equipment.

- The format of an input transaction must be indicated automatically on the screen/printer, and the operator must be guided in the registration if necessary.
  - Both syntax and logic of the input must be controlled while the registration takes place.
  - Input errors must immediately be pointed out and necessary corrective measures indicated.
- It must be possible to retrieve data by inquiring on several different criteria.
- The system must be flexible and allow new transaction types, new files, and new inquiry routines to be introduced.
  - It must be possible to extend the hardware's capacity.

To meet these demands it has been decided that the system shall operate on a mini-computer for inquiries and for registration and updating of certain data, while the main processing of data will take place on a large central computer (IBM 370/158) .

#### 5.4 Computer aided design

Computer aided design (CAD) is an interesting area for application of mini-computers. A current example is the NEST module of the AUTOKON system. A new development will allow the draftsman to take out relevant information from the system's data base, and do the nesting of parts in an interactive mode by means of a mini-computer and a data screen ("Storage tube"). When a satisfactory result is achieved the final information is transferred back to the main system's data base.

Another possible project in the AUTOKON field is a programme to search out and update norms (a norm is a coded standardized geometrical description, for instance of a cut-out or of a sub-assembly) . It is believed that such a programme will help the designer to easily find the norm he is searching, and to control it visually on the spot.

A new CAD application which will be using mini-computers and data screens in the Aker Group is AUTOFIT, a major development project for a system for design and production of pipes and related components. Possible mini-computer applications in this connection could be interactive completion of piping sketches, as well as changes and modifications to such sketches. The main benefit is that the designer can get the visual picture of the existing arrangement and constraints, and can immediately see the result of his work. Once he has reached a satisfactory result, this result is stored numerically in the data base and is available for other users, for further changes, and finally for production.

#### 5.5 Miscellaneous applications.

In addition to the applications of mini-computers in local or local/remote data processing, mini-computers are used as remote job entry terminals (RJE) in several of the Aker Group's companies. Mini-computers are also working as directors in N/C applications.

Several of the mini-computers are linked together in so-called data nets or computer networks. An example of such a network can be found in the Bergen yard, fig. 4, where 4 Kongsberg SM-4'S are installed: two in the EDP department, one in the engine factory (about 20 kilometers away), and one at the drawing center.



6. PHASE 5: THE DEDICATED MICRO COMPUTER

The Norwegian institutions, Norwegian shipowners, and the hardware company Data Industri have recently started working on a new project:

The dedicated micro computer for shipowners and shipyards.

The main reasons for starting this project were the facts that the software and hardware integration by using micro will:

Give the users access to software packages, especially written for these types of industry, without a very high investment in hardware, installation, training, etc.

Give the remote or mini-computer user a possibility to increase his processing capacity (add another CPU, 2K bytes ROM etc.) less expensively than for normal hardware extensions.

When integrating the hardware and software, the operating system will be very simple, the reliability high and the error frequency low.

The costs concerning software development will increase by using micro, because the error frequency must be as low as possible. If fatal errors occur in the software, the user has to return the whole micro unit.

What can the dedicated micro be used for in the shipbuilding industry? In fact, for the same functions as indicated on fig. 1, The hardware solutions depends on the information flow and whether there is a need for access to a centralized data base or not.

All these computers are linked to each other, and each may be connected to either the UNIVAC or the IBM computer at Fjerndata in Oslo, as well as to two other computer centers.

An interesting development in this context is the so-called Flexible User Terminal. This terminal will be a mini-computer acting as a "switch-board" between other computers and between computers and peripheral equipment.

A general (if not un-biased) presentation of features, advantages and applications of computer networks is given in reference (3). The reader is also referred to the philosophy of "communicating data processing" in a shipyard as presented by professor Reenskaug at last year's ICCAS Conference in Tokyo (Ref. 5).

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Future Micro Applications:

Function	Operation Mode	Data Base
Master Scheduling	Micro stand-alone or network	Local
Job Shop Scheduling	Micro/Remote computer	Local and centralized
Dock Erection and Outfitting	Micro/Remote	Local and centralized
Material Administration	Micro/Remote	Local and centralized
Pre-estimation/post calculation	Micro/Remote	Centralized
Follow-up	Micro network/Remote	Local and centralized

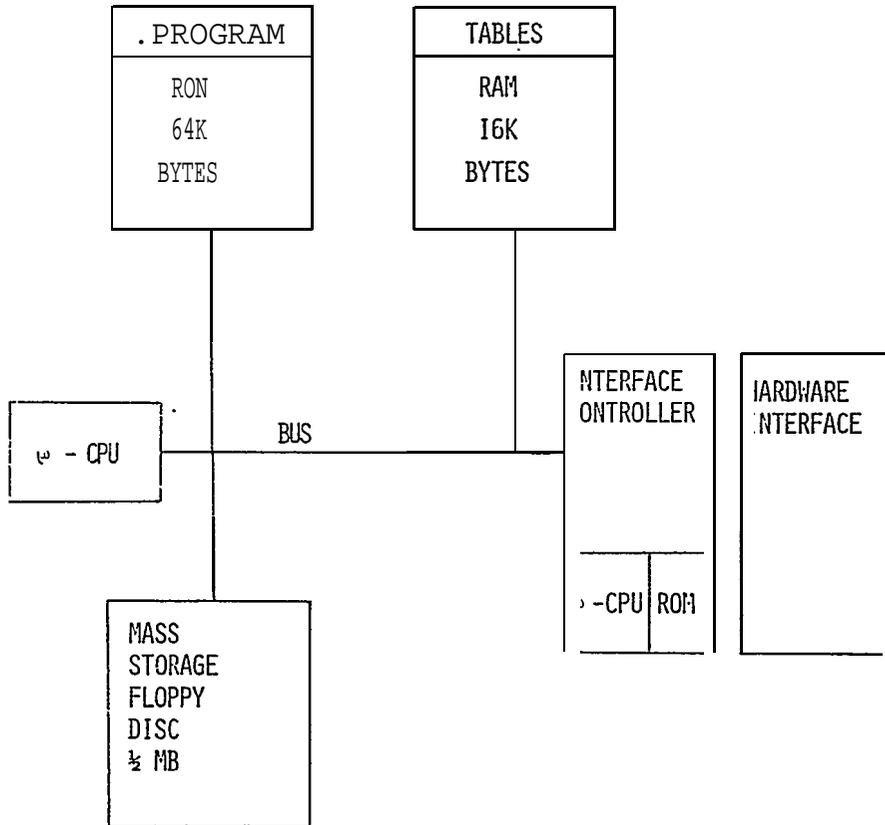
Fig. 5 indicates one micro computer structure <sup>x</sup>.

Some micro/remote computer hardware configurations are given on fig. 6:

1. The micro as a direct extension to the processing capacity of the remote computer. The micro contains the user software.
2. The micro as partly stand-alone with a local data base. Access to the remote computer is via a slow speed line.
3. Stand-alone ("the master scheduling machine", etc.) with data base and peripheral equipment.
4. As a network of micros and remote computer.

\* ROM = Read-Only-Memory. RAM = Random-Access-Memory

MICRO COMPUTER



HARDWARE COST : \$ 14,000

Fig. 5

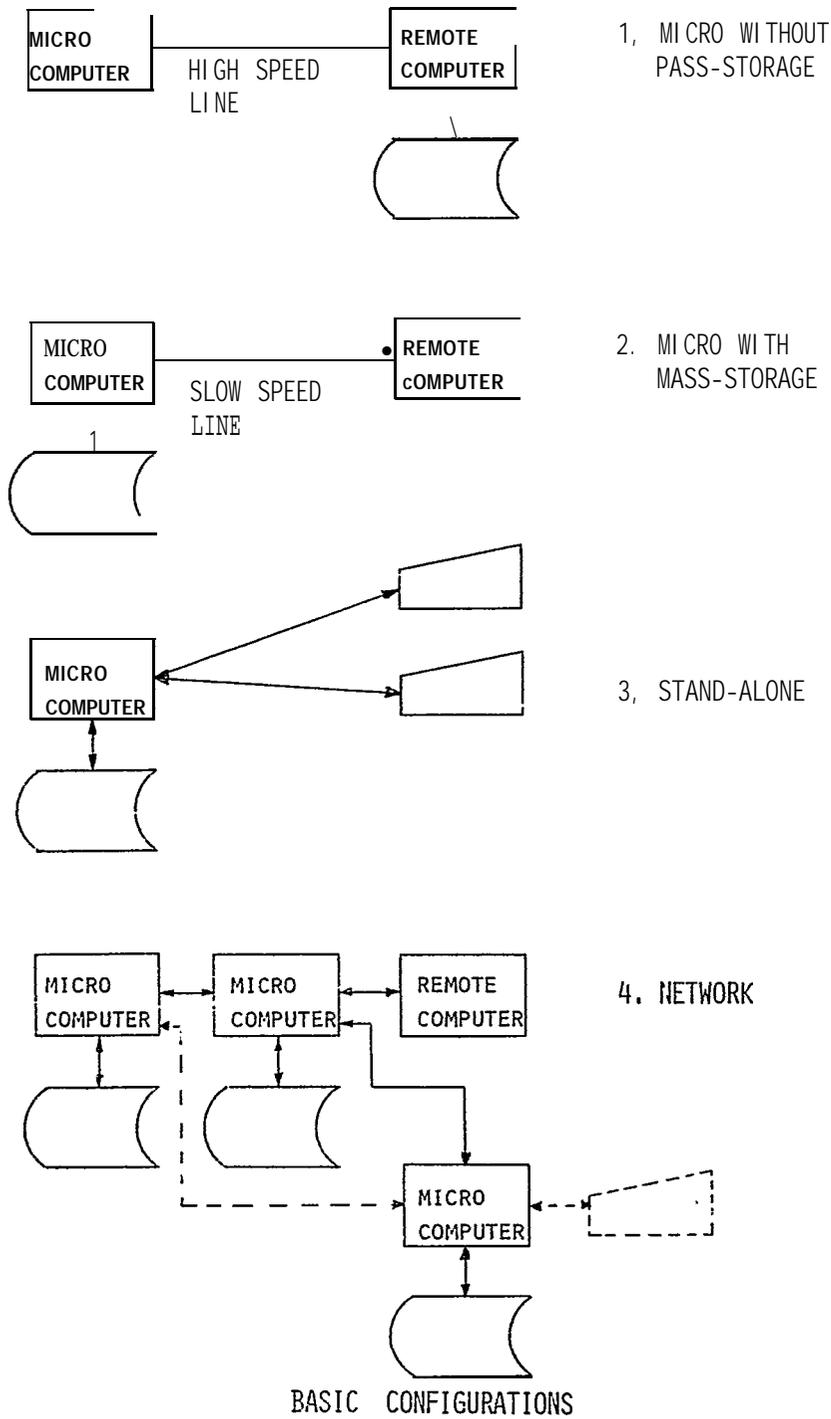


Fig. 6

## 7. CONCLUSIONS

As the application of mini- and micro-computers for administrative purposes increases, there seems to be two different development directions in the use of such machines. One is that local applications are done on dedicated computers, which to a certain extent can utilize the in/out equipment of a common communication computer. The communication computers and the peripheral equipment should be standardized, while the hardware required to each local application can be tailor-made as long as it can be interfaced with the communication computers and the peripherals. Another possibility is to use more sophisticated local computers that can take care of both communication and local processing.

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SOFTWARE ENGINEERING FOR A  
DIGITIZER/MINICOMPUTER BASED  
PIPING DATA SYSTEM

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Newport News, Virginia

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## 1. INTRODUCTION

The preliminary system design phase reported here consisted of an in depth study of the hardware and software requirements for piping digitizing, and for pipe manufacturing documents generation~ followed by evaluations of hardware and software vendors. A specification describing the requirements for piping digitizing, was prepared and mailed to 17 vendors.

A preliminary evaluation indicates that the available packaged interactive graphics systems are probably not suited for this project because of their high cost and lack of strong data base software. This is discussed in Section 2. A systems design was done to evaluate the cost of in-house development of software.

The first task of the system design was to define a feasible set of capabilities for the digitizer-mini-computer system. Selected capabilities are listed in outline form in Section 3.

A number of simulations of different input languages were performed using a mockup digitizer and design station. The conclusions from this work are that operator productivity is dependent on the number of steps which the computer can perform automatically, rather than on the specific input language. If the operator worked without stopping for breaks, the operator throughput rate with automatic component selection using decision rules and a catalog. file was 3 parts per minute per station. This is equivalent to one large tanker detailed every 5 months, with only one design station. This is, of course, not a realistic pace for a single

detailer to sustain all day long. It does indicate the high productivity potential of the system, however.

A key feature of the in-house design proposed here is software portability. This can be achieved through the use of a very clearly defined "software environment" inside of which all front-end programs are written in ANSI standard FORTRAN. This "software environment", described in Section 5, could be established on a number of different makes of computers.

A study of response times, disk accesses, and computational requirements, described in Appendix A, shows that implementation of the front-end software on a mini-computer is the most economical approach. Although the disk and core storage requirements of the software are modest in terms of large computers, a concentrated amount of accessing and processing is performed on this data. Real-time response to four active digitizer stations would tie up 25% of the time of a main computer. The resulting computer time charges could in one year exceed the purchase price of the front-end mini-computer proposed. The proposed hardware configuration is outlined in Section 4. Cost estimates are listed in Appendix F.

The overall benefits of a computer based piping design system are reduced manufacturing costs through:

- (1) early detection and elimination of design errors,
- (2) generation of specific manufacturing instructions for each manufacturing operation, and
- (3) reduction of scrap material through more careful calculation of pipe lengths.

A pro-forma examination of the costs and benefits of the proposed system is presented in Appendix C.

## 2. PRELIMINARY VENDOR EVALUATION

Preliminary evaluation of vendors indicates two options:

- (1) Start with one of the existing systems for interactive graphics design, and add data base management capabilities and applications programs.

Advantages:

- (a) Hardware performs some visible task as soon as it arrives.
- (b) Digitizer input and graphic display software is furnished.
- (c) System has proven ability to function in a heavily interactive environment.

Disadvantages:

- (a) Available systems do not use standard manufacturer's operating systems, limiting program development facilities and multi-tasking architecture.

- (b) Add-on data management capabilities are limited and difficult to change and grow with. Adding additional data elements and chains to the data base at a later date is difficult.
- (c) Applications programming is generally expensive to implement.
- (d) The systems are relatively expensive, both for prototype and for following systems for other shipyards.
- (e) No software portability to different hardware.

(2) start with a standard mini-computer configuration with a multi-tasking real time operating system, FORTRAN compiler capable of generating re-entrant code, and a CODASYL type data base management package.

Advantages:

- (a) provides software standardization and portability.
- (b) Provides comprehensive treatment of data base, including segmentation into small files, efficient buffering of mass storage, backup, and future growth capability.
- (c) Makes available lower hardware cost to user shipyards.

Disadvantages:

- (a) Lack of graphics software.
- (b) Response with generalized data base may be slower than with specialized graphics data files.

Our experience has indicated that most graphics software is actually 75 percent data base manipulation. Adding data base software to existing graphics systems appears to be more expensive than adding graphics software to a standard data base management system

### 3. CAPABILITIES OUTLINE FOR INPUT STATION

The phase one proposal describes the general operating objectives sought in the input station system. In order to achieve these objectives the following capabilities must be developed.

#### 3.1 Input Subsystem

##### 3.1.1 View Definition

A view is a specific area of the ship which maps to a rectangular region on the input drawing, the CRT, or the plotter. The location and orientation of views shall be definable by three methods:

- (a) The position in space of plan., section, or elevation views may be given by locating several structural reference points within the space.
- (b) Views may be defined looking down a pipe leg, or looking normal to a pair of pipe legs. This capability is particularly useful for composing pipe detail plots.
- (c) Views may be defined as cross-sections through an existing view.

##### 3.1.2 Point Location

One or more coordinates of points in a ship may be defined by the following methods:

- (a) touching the digitizer (or CRT cursor) to a point within one of the defined drawing views,
- (b) typing in the absolute coordinates at the keyboard.
- (c) typing in dimensions relative to ship's structure, such as "10 inches aft of frame 120".
- (d) typing in dimensions relative to other piping points previously input.

### 3.1.3 Pipe Run Definition

A string of points, located as defined above, may be declared to be a pipe run. As a minimum, a diameter must be specified for the pipe run, and an attribute must be declared for each point. Allowable attributes are END, BEND, or BRANCH for pipes, and CENTER, END, or DATUM for fittings and valves. Some indication of the type of fitting is required. Attributes are also allowed where the type of fitting will be determined later. An example is TURN, which may become a bend, or a 90° or 45° elbow.

### 3.1.4 Fitting and Valve Definition

Fitting geometry may be entered in a local coordinate system convenient for the fitting. Two steps are required:

- (a) Define the basic fitting prototype. A prototype defines a basic shape, such as a Tee or 90° elbow. A language will be provided for defining new prototypes, but the initial set of approximately 100 prototypes provided with the system will cover most fittings and valves.

(b) Input the dimensions of the specific fitting, referring to the appropriate prototype. This step should be rapid. A 90° elbow, for example, only requires the entry of 5 dimensions.

## 3.2 Processing Subsystem

### 3.2.1 Fitting Selection

Using a file of component selection rules, replace designer input statements such as TURN, BRANCH, OR MECHANICAL JOINT with reference to specific components.

### 3.2.2 Component orientation

When specific fittings or valves have been input by the designer, or automatically selected as described above, determine the orientation in space from the component local geometry and the geometry of the connected piping.

### 3.2.3 Error Detection - Pipes

Compare the geometry of bent piping with the geometry of the available pipe bending machines, to verify that the pipe can be bent.

### 3.2.4 Error Detection - Joints

Check the diameter, end type, and alignment of all parts meeting at joints.

## 3.3 Output Subsystem

### 3.3.1 Graphical

Any view defined by the view definition process described in Section 3.1 may be output to the plotter. This includes the

capability to generate operator composed pipe detail and pipe assembly drawings, and centerline check prints. Fittings will be drawn according to their prototype envelope definition. Figure 1 shows an example of an output plot.

### 3.3.2 Alphanumeric

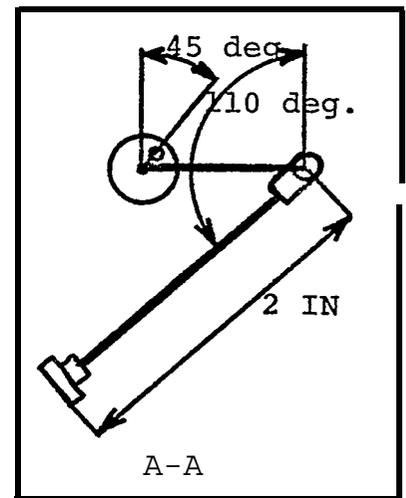
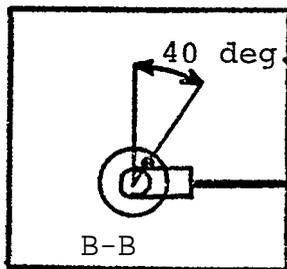
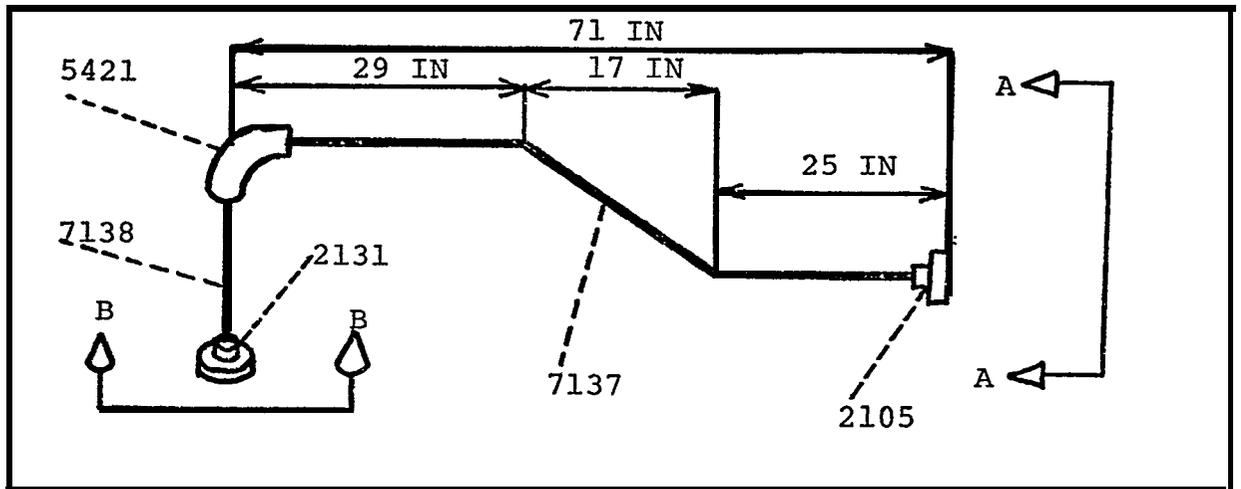
A list of the components entered by the designer and/or selected by the computer may be printed on a printer, or may be output at a specified location on drawings produced by the plotter.

## 4. HARDWARE ENVIRONMENT

The projected hardware environment is shown in Figure 2. Included is a mini-computer with several million bytes of mass storage, removable serial media for off-line storage of data, an interface for communication with a main host computer, and one or more design stations. Each design station consists of an input digitizer, a keyboard, an output graphical display device, and an output display device for alphanumeric messages.

## 5. SOFTWARE ENVIRONMENT

The proposed environment in which the piping applications programs would operate is shown in Figure 3. The proposed environment consists of a master program (multi-tasking real-time operating system) which controls and schedules the



<u>ID</u>	<u>TYPE</u>	<u>SIZE</u>	<u>SOURCE</u>
2131	Flange	3 in	SN71344
2105	Flange	3 in	P0591-73-661
5.421	Elbow	3 in x 3 in	P0591-77-005
7137	Pipe	3, in x 62.5 in	SN62131
7138	Pipe	3 in x 12.0 in	SN62131

FIGURE 1. TYPICAL PLOTTER OUTPUT

INPUT

STORAGE

OUTPUT

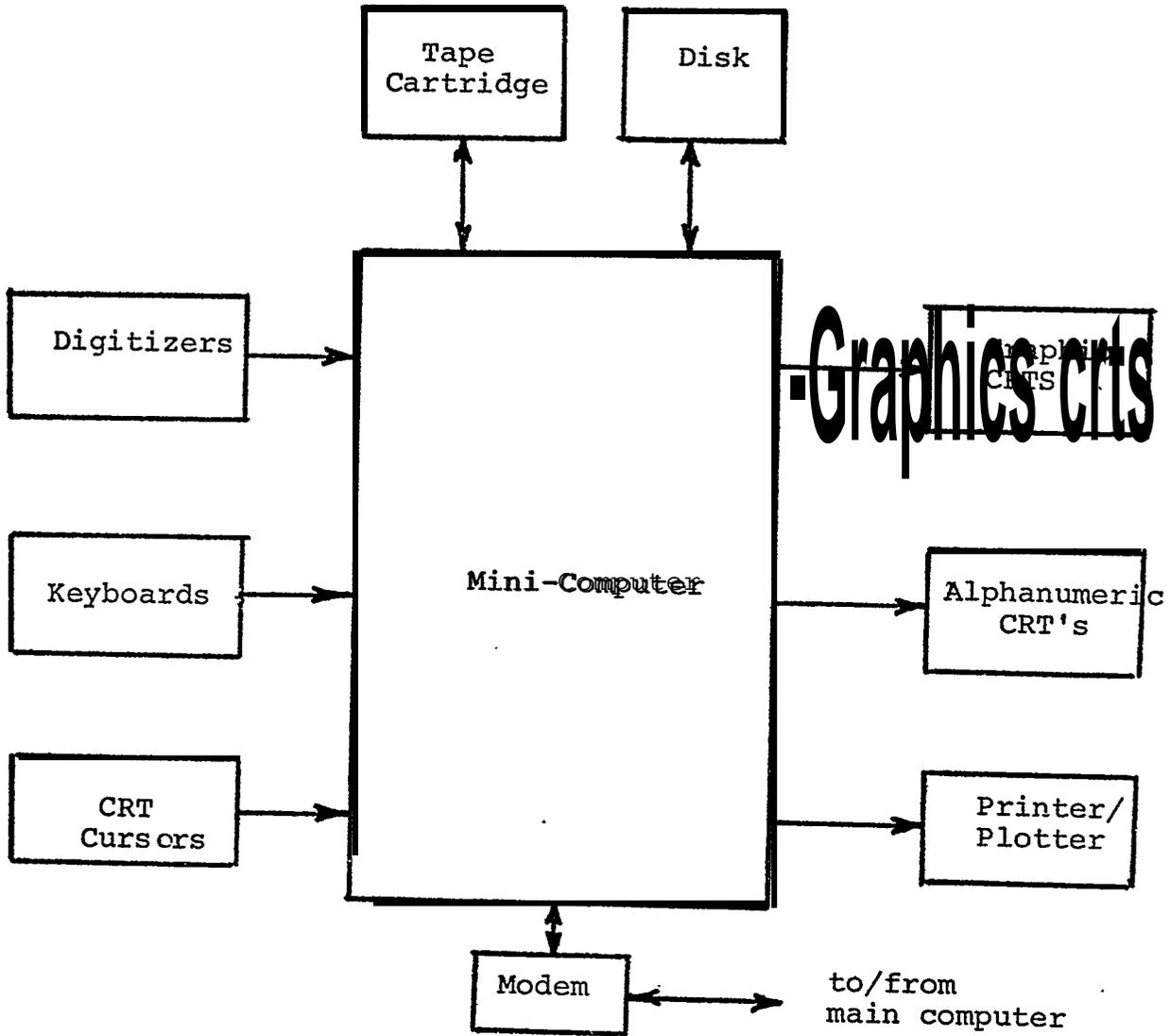


FIGURE 2 - HARDWARE ENVIRONMENT

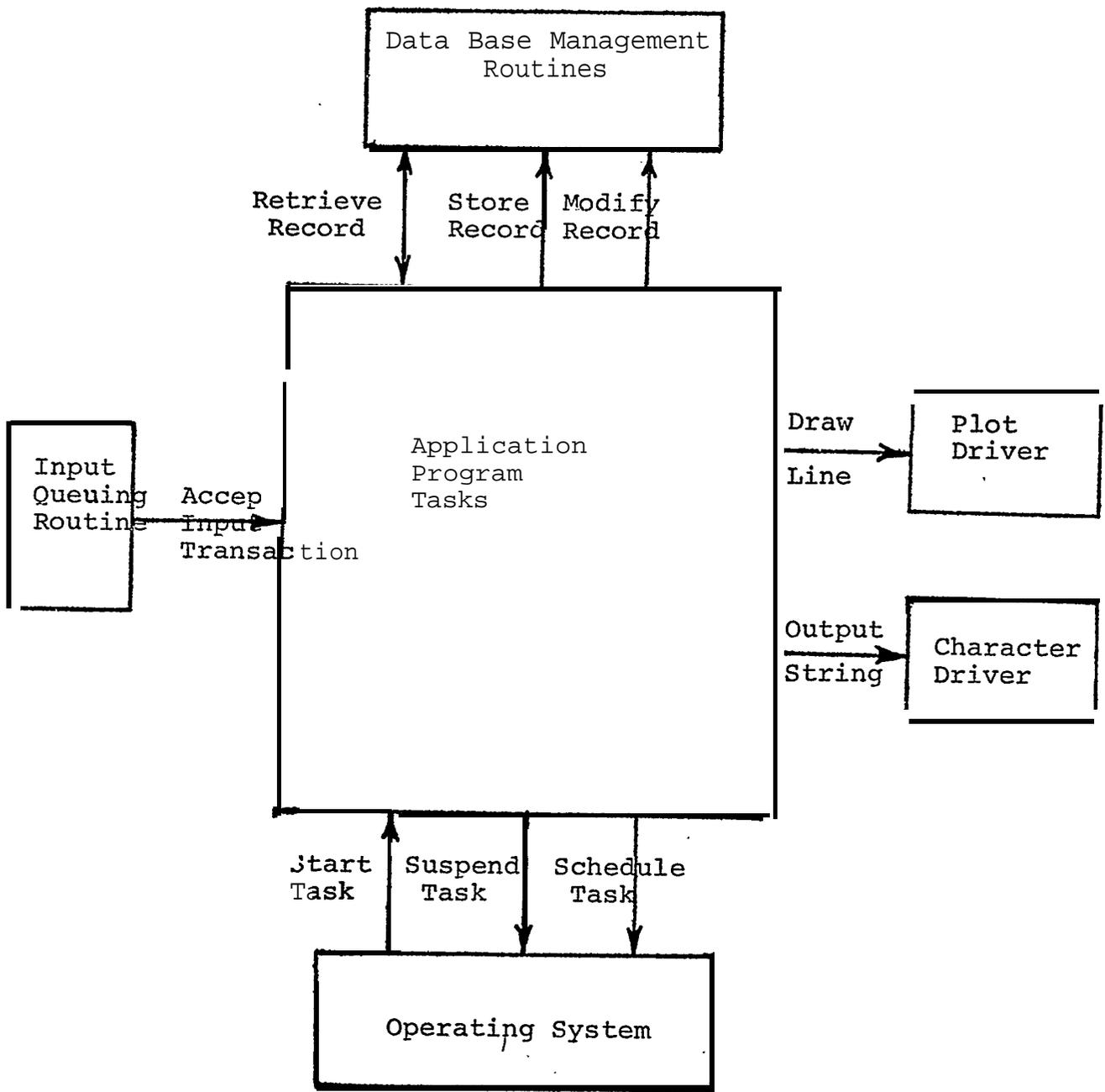


Figure 3 Software Environment

execution of the application programs tasks, and coordinates all input and output. Under control of the operating system would be a utility routine to accept input from digitizers, keyboards, and CRT joysticks. This routine would translate digitizer bit strings into x, y coordinates, attach a source device identification, and place it in a queue. Output from the applications tasks to the graphic displays would be via a standard plot routine accepting x, y coordinate pairs and a "pen up" or "pen down" code. Output of strings of characters to the displays would be through another routine.

The most important piece of non-applications software forming the software environment would be the data base management program. This package must include callable routines for storing, retrieving, and modifying records in the data base. The language of the applications programs will be ANSI standard FORTRAN IV. For reasons of portability, it is desirable that the data base management program conform to the form recommended by the CODASYL committee.

TABLE 1  
DATA BASE SIZE AND POSSIBLE SEGMENTATION

File Type	Kbytes/file	Files/ship design	Total files 5 ship designs	Total Kbytes 5 ship designs	Expected Files on-line	Kbytes on-line
AUTOKON hull data files	100	30	150	15000	8	800
Machinery nozzles files	200	2	10	2000	3	600
Naster pipe & fittings catalog	110		10	1100	5	550
system pipe & fittings catalog	61	30	150	9150	3	183
Component selection schedule files	12		50	600	3	36
Pipe geometry files	140	900*	4500	630000	8	1120
					30 files on-line	3.3 Megabytes on-line

\*300 pipe geom files (drawings)/ship class, but an average of 3 versions of each file

FIGURE 1. POSSIBLE HARDWARE CONFIGURATION

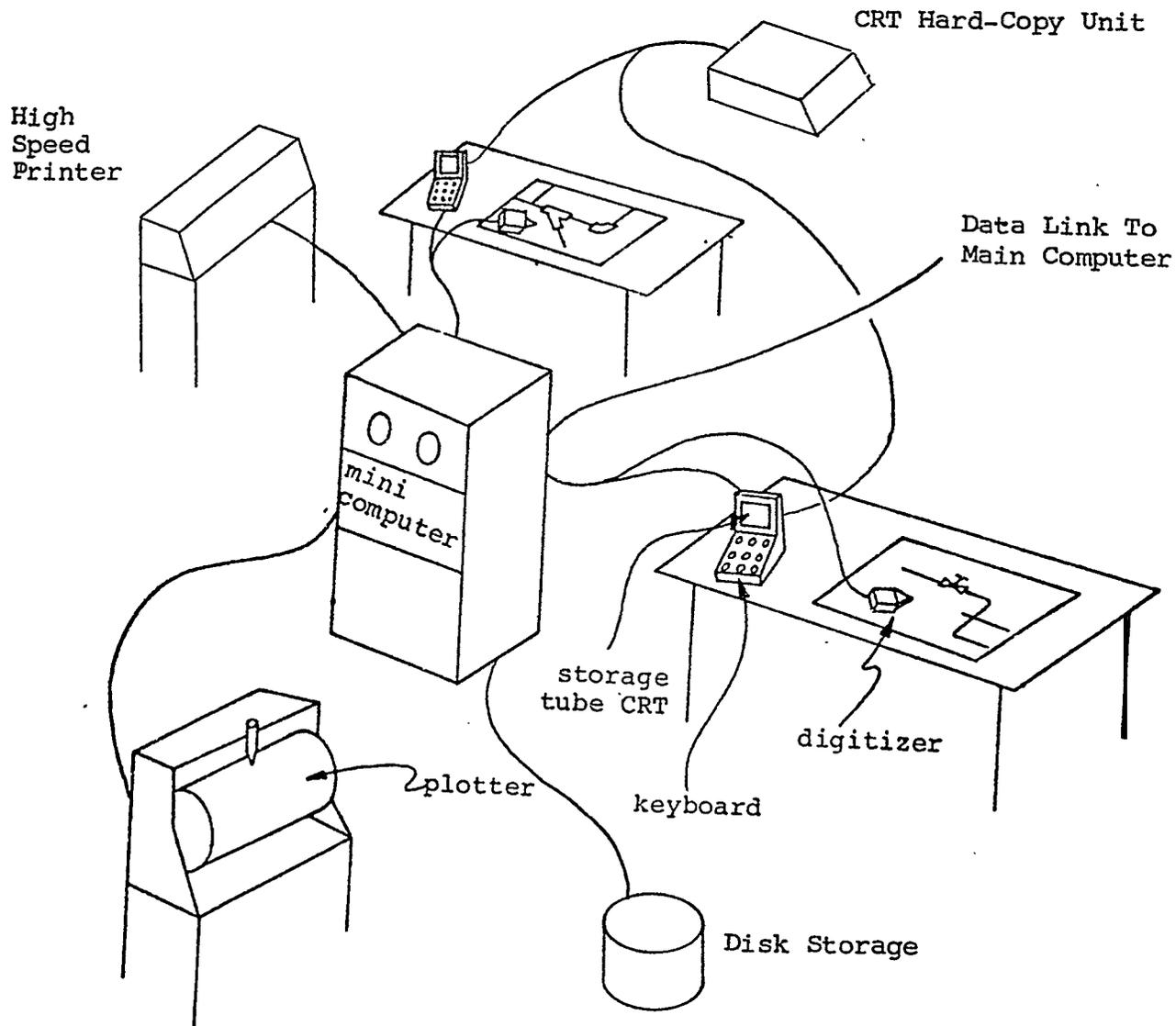


TABLE 4  
PROJECTED PEAK LOAD

<u>System Configuration</u>	<u>Data Base Accesses</u>	<u>Control Ops</u>	<u>Vector Ops</u>
2 digitizers	70/sec.	500/sec.	500/sec.
4 digitizers	120/sec.	900/sec.	900/sec.
4 digitizers + future tasks	220/sec.	1100/sec.	1500/sec.

FIGURE 8

ALLOWABLE DISK ACCESS TIME VS. PAGE FAULT RATIO

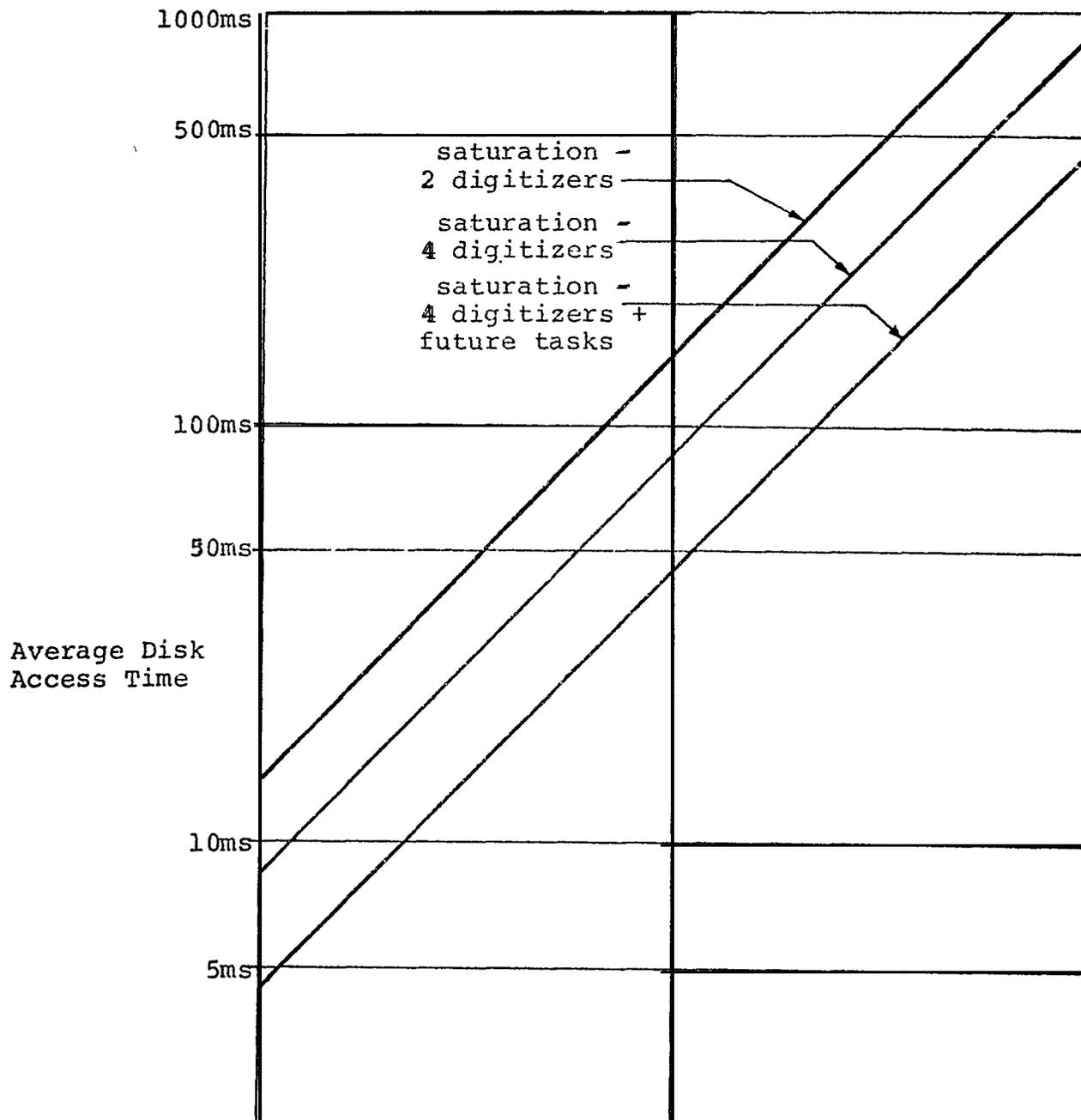
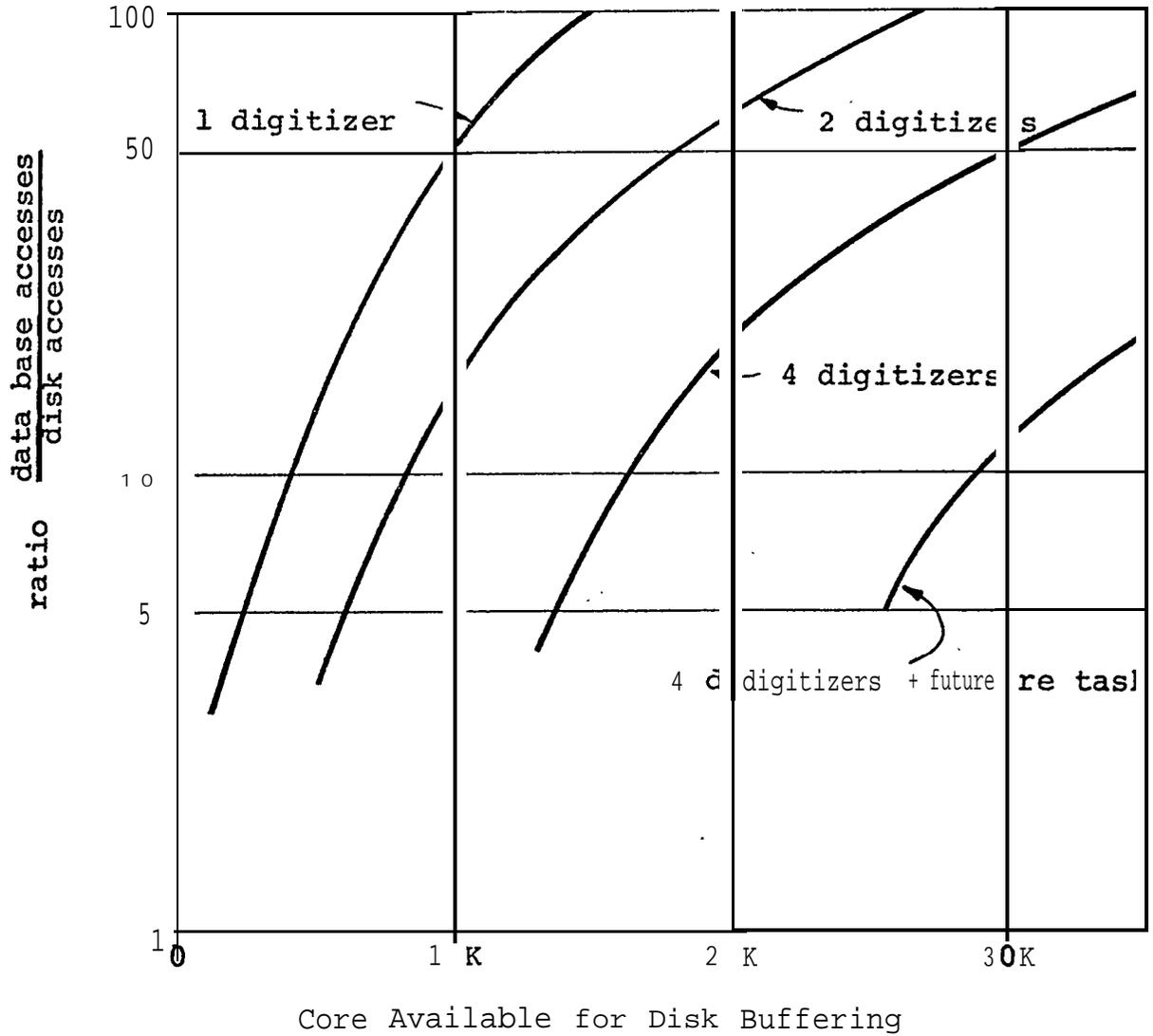


FIGURE 9

ESTIMATED PAGE FAULT RATIO VS.  
MAIN MEMORY AVAILABLE FOR DISK BUFFERING



## APPENDIX C

### Pro Forma Cost Analysis

Cost savings from the use of the system proposed here are in three areas:

- (1) direct labor savings in design and manufacture,
- (2) material savings resulting from a more accurate estimate of pipe lengths,
- (3) secondary labor and material savings from a more error free design.

Over and above these factors, one of the most important real reasons for going to computerized piping design is that the simplified and very specific manufacturing instructions generated reduce the skill level required in the pipe shop . This is not intended to replace skilled pipe fitters. It is instead a survival technique in the face of chronic shortages of skilled pipe fitters.

Tables C-1 through C-3 present a pro forma cost analysis for the use of the system described in this report. Labor rates, average manhours and error rates with and without the mini-computer, must be determined by each yard to their own satisfaction for their particular method of operation. As a starting point for discussion, some round numbers are listed in the tables. These do not represent Newport News Shipbuilding costs, but they are at least within the right" order of magnitude. Unit costs are stated in terms of pipe detail assemblies. A large tanker has, approximately 9000 detail sub-assemblies , while most other large commercial ships have in the vicinity of 3000 details.

Variable Costs (per pipe detail sub-assembly)

Design	<u>Manual</u>	<u>Computer- Aided</u>	<u>Difference</u>
Lift geometry, compose views, select specific components	\$64	\$ 48	-16
Prepare shop manufacturing documents	16	8	- 8
Material takeoff	1	0	- 1
			\$-25
Design Error Rate	5%	2%	- 3%
Manufacturing			
Material	100	95	- 5
Shop labor	100	90	-10
Ship labor	100	100	0
Rework/Ripout Material	5	2	- 3
Rework/Ripout Ship labor	5	2	- 3
Rework/Ripout Ship labor	5	2	- 3
			<u>\$-24</u>

Table C-1

Fixed Cost

In-house study of costs/benefits	\$ 10,000
Digitizer and mini-computer hardware	100,000
Mini-computer data base mgt software	10,000
Piping applications software	free
Convert data file and pipe bending, joint map programs to main computer	10,000
Interface data file to own material inventory system	10,000
Train personnel	<u>10,000</u>
	\$150,000

Table C-2

Return on Investment

Manufacturing only

$$\frac{\$150,000}{\$ 24} = 6,250 \text{ detail sub-assemblies}$$

Detail only

$$\frac{150,000}{25} = 6,000 \text{ detail sub-assemblies}$$

Typical yard:

builds/year one tanker @ 9000 sub-assys.  
one bulk  
carrier @  $\frac{3000}{12000}$  sub-assys  
mfgr. sub/assys/year

design one bulk carrier every two years @ 3000 sub/assys  
1500 designed sub/assys/year

variable cost savings =  $12000 \times 24 + 1500 \times 25 = \$325,500/\text{yr.}$

return on investment =  $\frac{150,000}{325,500} \times 12 \text{ months} = 5.5 \text{ months}$

Table c-3

APPENDIX F

Target Costs : Mini-Computer Digitizer System

Design Stations

Digitizer, 40 x 60 inch	6000	
Graphic display device	6000	
Alphanumeric display device	2000	
Drafting board, hardware	<u>2000</u>	
		\$16,000/station

Mini-Computer

Supporting 1-2 Design Stations:

Mini-computer with 64 k words main memory, 5 megabytes disk storage one 9 track tape drive, communication multiplexer, 8 RS232 communi- cations ports, floating point processor, 1200 baud modem		\$60,000
---	--	----------

Additional Hardware to Support 3-4 Design Stations

Additional 16 k words memory, 8 additional RS232 communi- cations ports, additional 5 megabyte disk		15,000
--	--	--------

Options

Local off-line storage using cartridge tapes or diskettes		<b>9,000</b>
Combination printer and 22 inch plotter		12,000
or		
Line-printer		7,000
Plotter, 36 inch width		18,000

FASTDRAW  
INTERACTIVE GRAPHIC SYSTEM

Gerald W. Folk  
and  
Odell A. Pritchett

McDonnell Douglas Automation Company  
St. Louis, Missouri

Mr. Folk is Senior Section Manager in the programming sciences department of McDonnell Douglas Automation Company. He has over 23 years experience in structural engineering and scientific computing. He is responsible for the development and support of graphic systems and pre-postprocessors at MCAUTO.

Mr. Pritchett has been actively involved in the development of interactive computer aided design systems, having developed the first application program for McDonnell using computer graphics on the IBM 2250 during the Project Mercury Space Program. He has been implementing applications such as APT and other numerical control disciplines in computer aided manufacturing during his 18 years with the company.

# **FASTDRAW**

**A LOW COST INTERACTIVE GRAPHICS SYSTEM  
THAT ALLOWS USERS TO:**

- **BUILD COMPLEX MODELS USING SCALED SKETCHES  
OR CONVENIENT DATA GENERATION FEATURES**
- **REVIEW AND UPDATE MODELS CREATED FROM  
ANALYSIS INPUT DATA**
- **REVIEW ANALYSIS OUTPUT**

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## **FASTDRAW FEATURES**

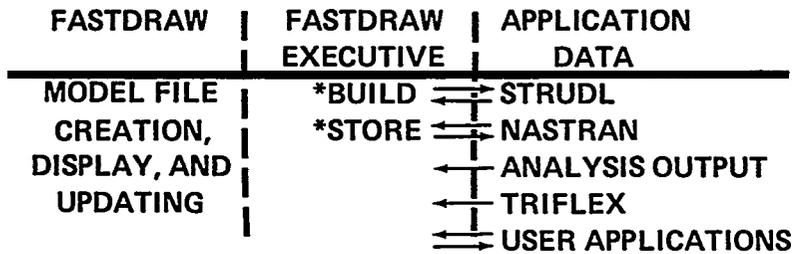
- **APPLICATION INDEPENDENT**
- **TERMINAL INDEPENDENT**
- **REVIEW AND UPDATE IN 2 OR 3 DIMENSIONS**
- **OVER A DOZEN GEOMETRY CONSTRUCTION COMMANDS**
- **USER CAN CREATE HIS OWN ELEMENT LIBRARY**
- **POWERFUL DATA GENERATION COMMANDS**
- **FLEXIBLE LABELING FEATURES**
- **LARGE NUMBERS OF POINTS AND ELEMENTS**

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# FEATURE APPLICATION INDEPENDENT

- GRAPHICS COMMANDS DISPLAY AND UPDATE MODEL FILES
- EXECUTIVE COMMANDS TRANSLATE DATA TO AND FROM ANALYSIS FORMAT



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```

//fastdraw
*build sample from sample
MODEL FILE EXISTS. CHANGE NAME (Y/N)
?n
LANGUAGE
:strudl
ERRORS TO TERMINAL OR ICESLOG
>terminal
BEGIN SCAN.....

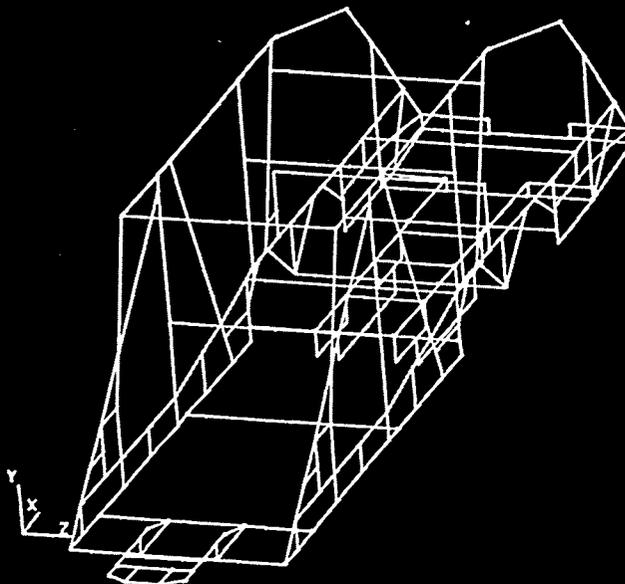
END SCAN.....
NUMBER OF ERRORS DETECTED: 0
  
```

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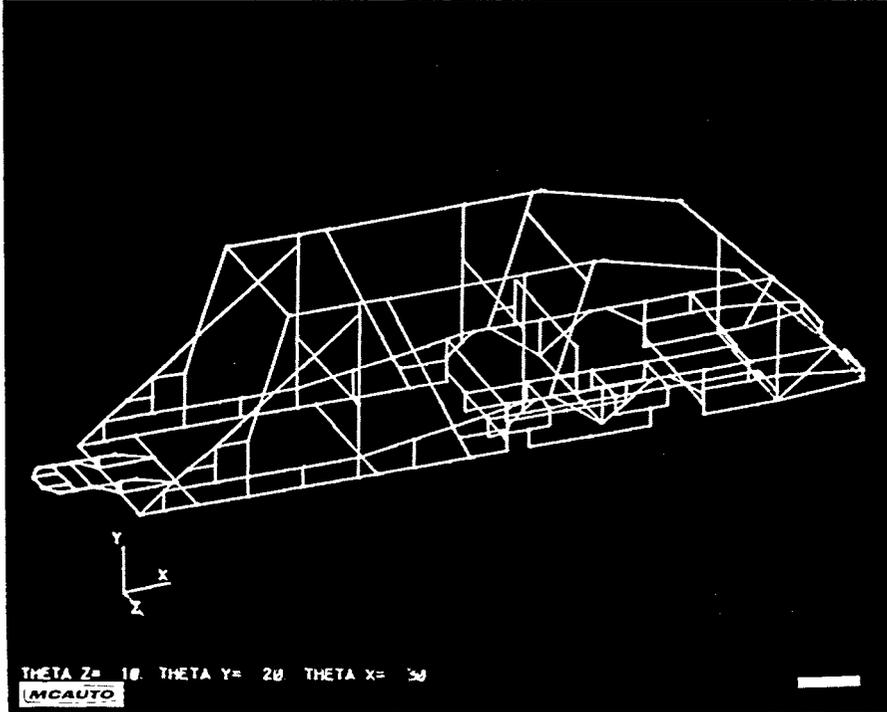
```
*USE SAMP11#  
*STORE SAMP11#  
BEGIN STORE.....  
195 JOINTS PROCESSED  
302 MEMBERS PROCESSED  
END STORE.....
```

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THETA Z= 50. THETA Y= 60. THETA X= 50.

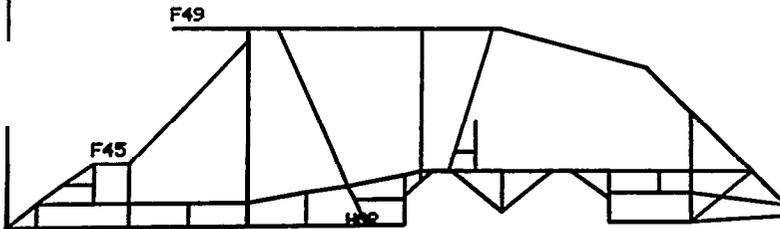
MCAUTO



```

2-D MODE. SCALE=.158932E-01 XY PLANE,ZREF IS .000
>LAB
ALL
POINTS
REACTS
ELEMENTS
MEMBERS
>>D
ENTER THETA Z, THETA Y, THETA X
: 10,20,30

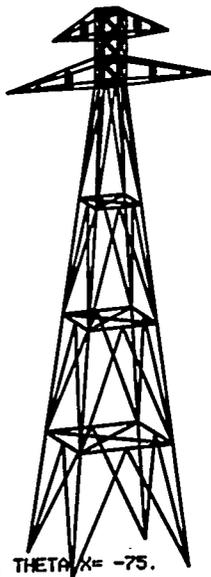
```



THETA Z= 0. THETA Y= 0. THETA X= 0.

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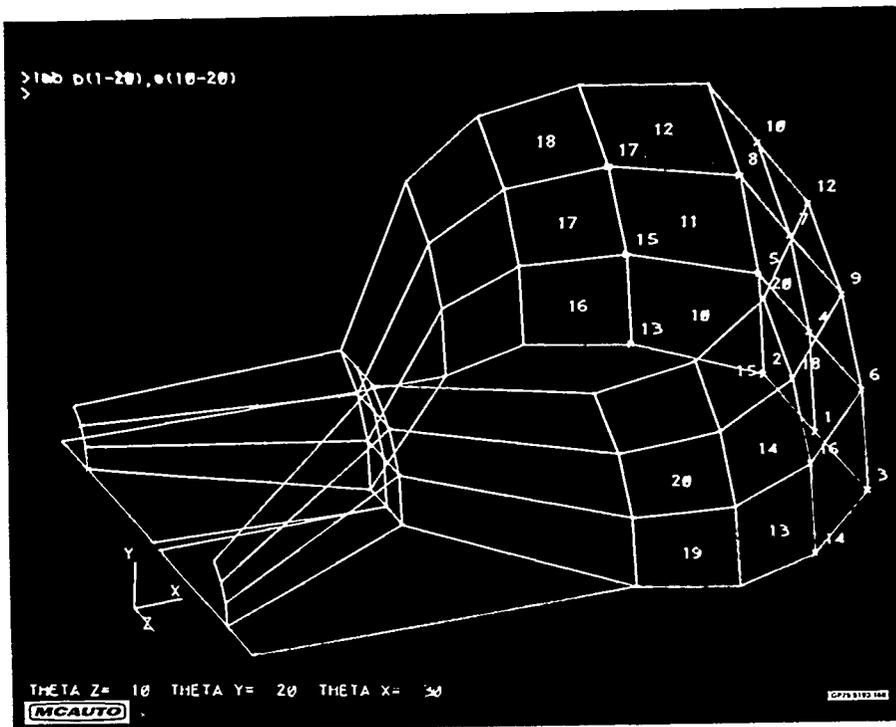
3-D MODE  
SEND



THETA Z= 5. THETA Y= 20. THETA X= -75.

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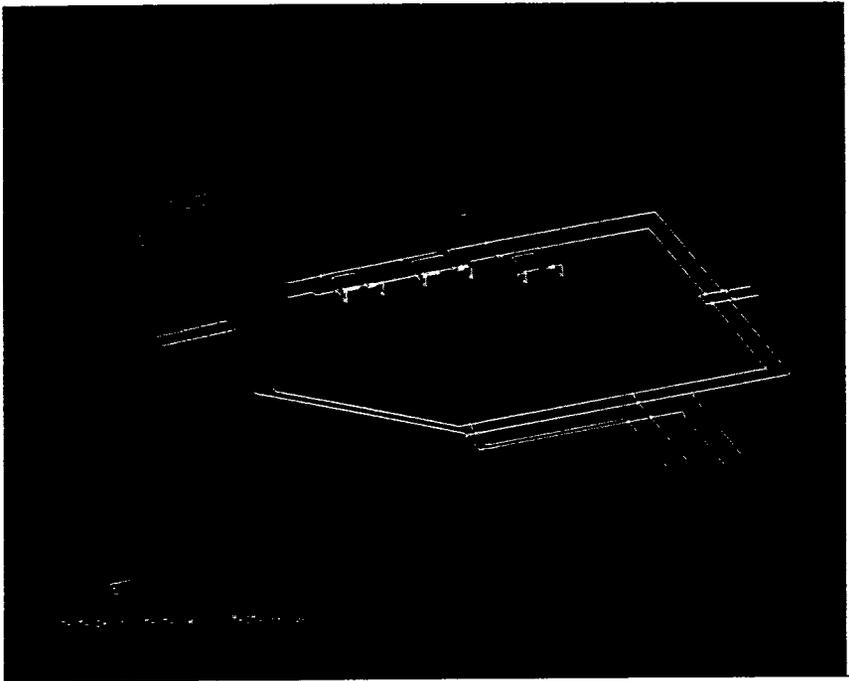
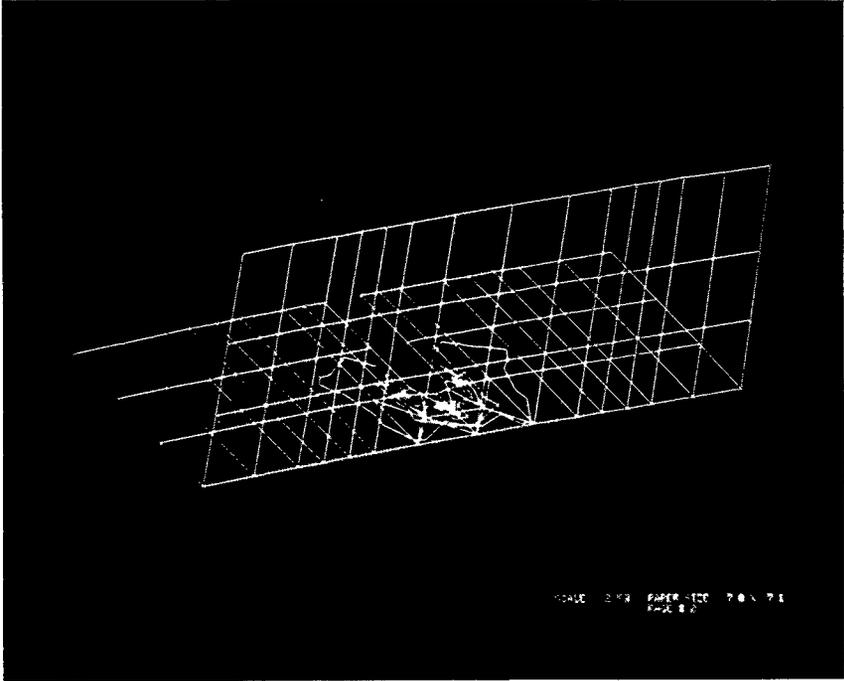


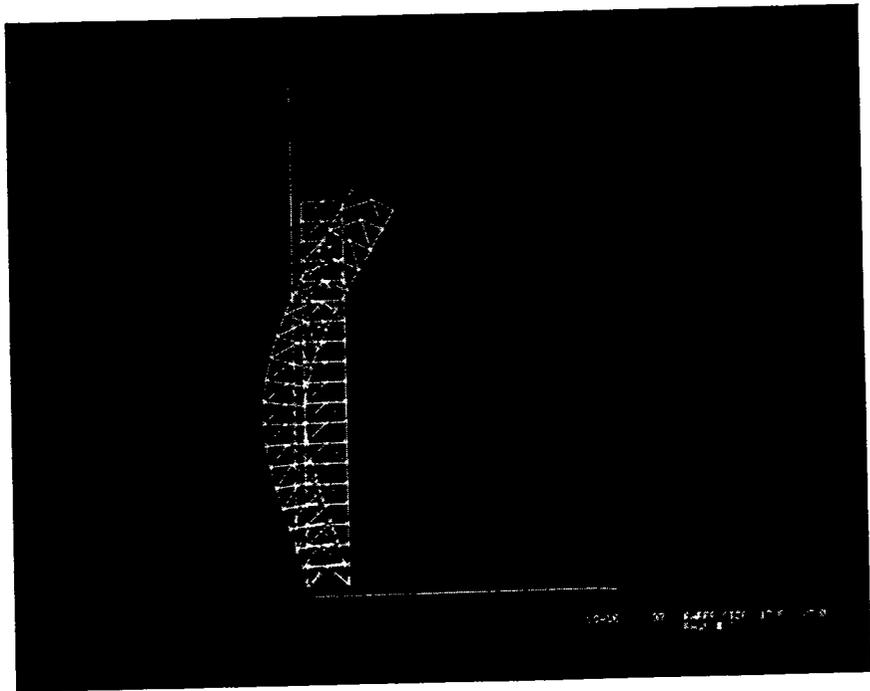
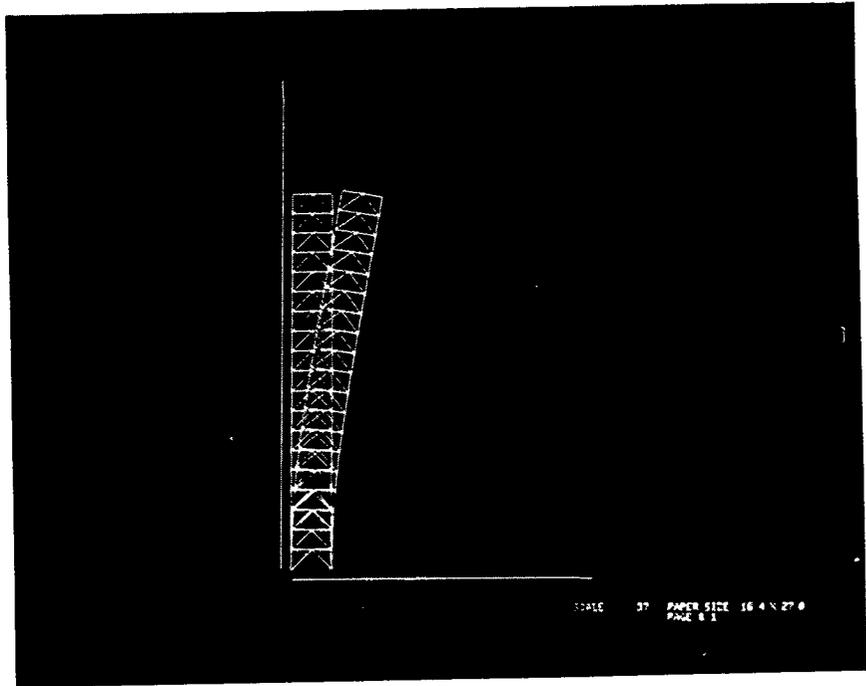
> 100 D(1-20), O(10-20)  
>

THETA Z= 10 THETA Y= 20 THETA X= 30

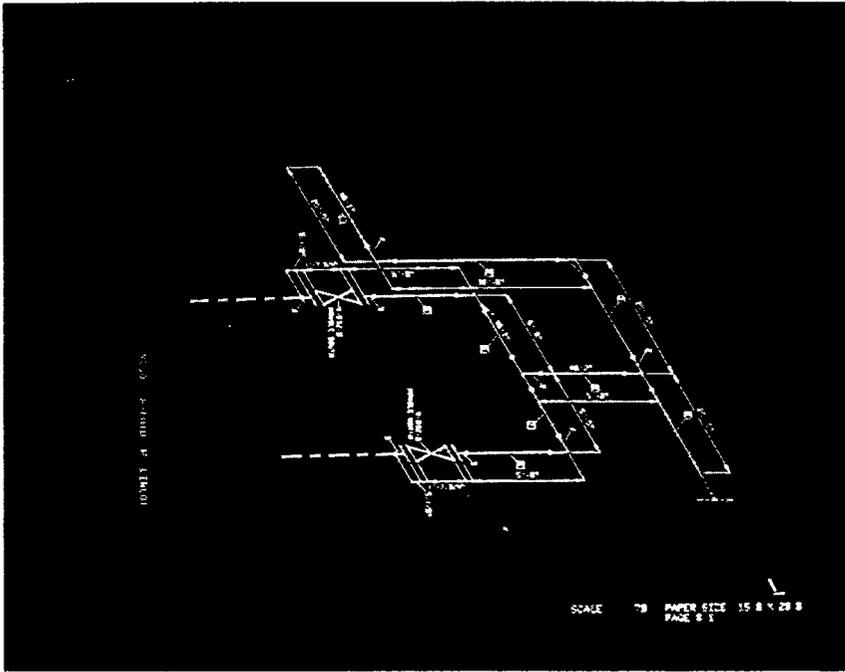
**MCAUTO**

GPB 8103 100





L18



# FEATURES: TERMINAL INDEPENDENT

- ALL FEATURES AVAILABLE WITH OR WITHOUT A TABLET

- CURRENT SUPPORTED DEVICES

TEKTRONIX	4014	T14/Txx
	4010	TEK/TXX
	4012	TEK/TXX
	4013	TEK/TXX

COMPUTEK	300	C30
	400	C40

CONOGRAPHIC	10	C10
	12	C12

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## FASTDRAW FEATURES USER-DEFINED ELEMENTS

- MODEL FILES OF ARBITRARY COMPLEXITY CAN BE DEFINED AS ELEMENT FILES
- UP TO 40 DIFFERENT ELEMENT FILES CAN BE USED IN ONE MODEL FILE
- A VARIETY OF DEFINITION OPTIONS PROVIDE DIFFERENT LEVELS OF CONTROL
- APPLICATION ORIENTED DATA CAN BE ATTACHED TO ELEMENTS FOR USE BY THE STORE COMMAND
- LIBRARIES OF ELEMENTS CAN BE BUILT TO REDUCE MODEL CREATION TIME AND INCREASE FLEXIBILITY

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```

3-D MODE
>DEF
DISPLAY CURRENT MODEL DEFINITION PARAMETERS (Y/N)
↑N
HOW MANY DEFINITION POINTS ( 1,3,4, OR ALL )
↓3
DIGITIZE 3 REFERENCE POINTS
CHOOSE POINT FOR LABEL
CENTROID
ENTER NUMBER OF ATTRIBUTES
:0
ELEMENT DEFINITION COMPLETE

```

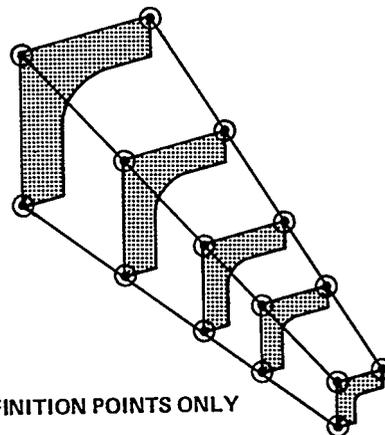
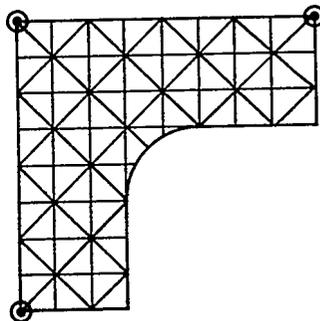


THETA Z= 90. THETA Y= 0. THETA X= 90.

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## DEFINE ELEMENT 3 POINT OPTION



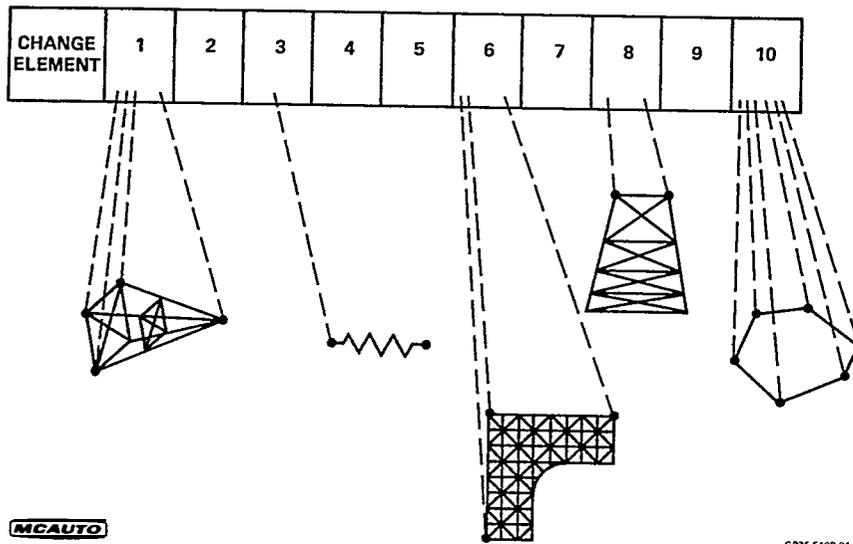
• SCALING IS DONE IN PLANE OF DEFINITION POINTS ONLY

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## CHANGE ELEMENT

- ASSIGNS APPLICATION ELEMENTS AND SUB-STRUCTURES TO ELEMENT MENU BOXES



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## THE ELEMENT COMMANDS

### >DEFINE

DEFINE CURRENT MODEL FILE AS AN ELEMENT;  
DETECT 'DEFINITION' POINTS

### >ELEMENT

"ATTACH" AN ELEMENT FILE DEFINITION TO THE  
CURRENT MODEL FILE

### >ELEMENT <sub>n</sub>

DIGITIZE AN ELEMENT WHOSE DEFINITION IS  
KNOWN WITH DETECTED POINTS

### >CONVERT

CONVERT A USER DEFINED ELEMENT TO  
COMPONENT APPLICATION ELEMENTS

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# FEATURE POWERFUL DATA GENERATION COMMANDS

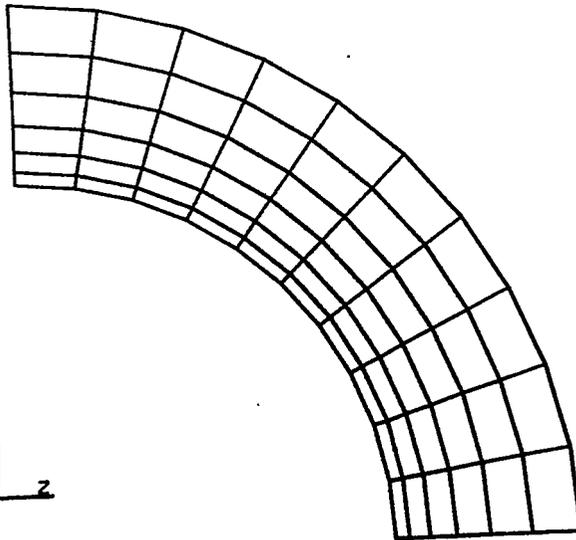
- USER CAN DETECT OR SPECIFY LABELS OF ELEMENTS TO GENERATE

TRANSLATE	2D
ROTATE	2D
DUPLICATE	3D
TRAVERSE	2D/3D
REJECT	

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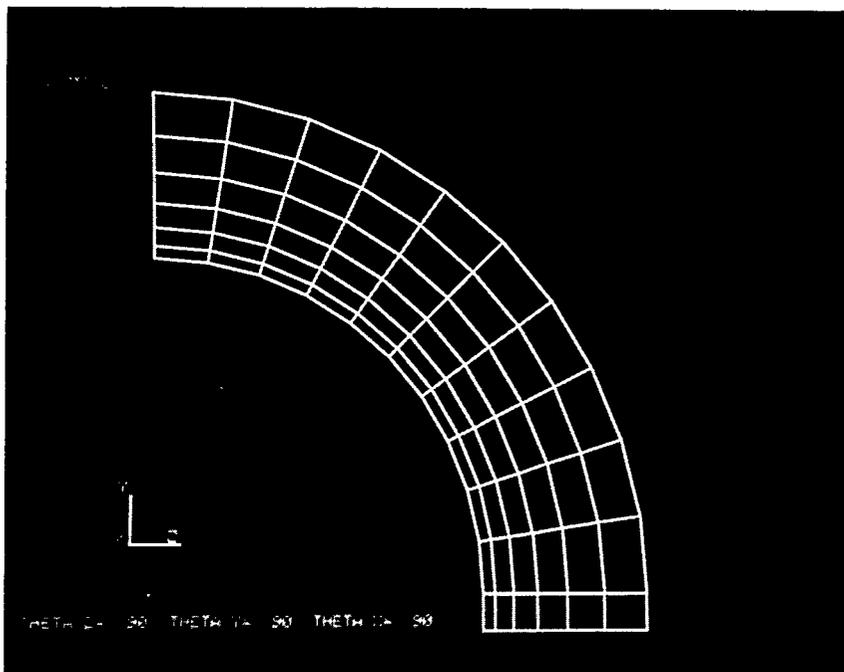
3-D MODE



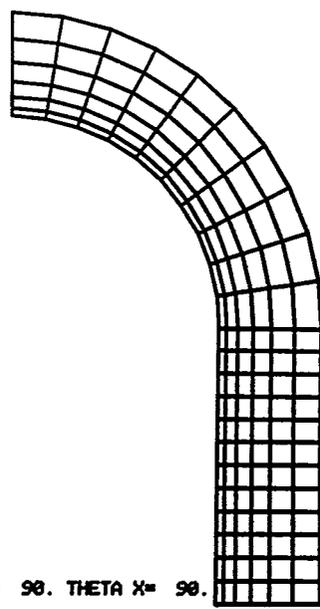
THETA Z= 90. THETA Y= 90. THETA X= 90.

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GP75-5193.10



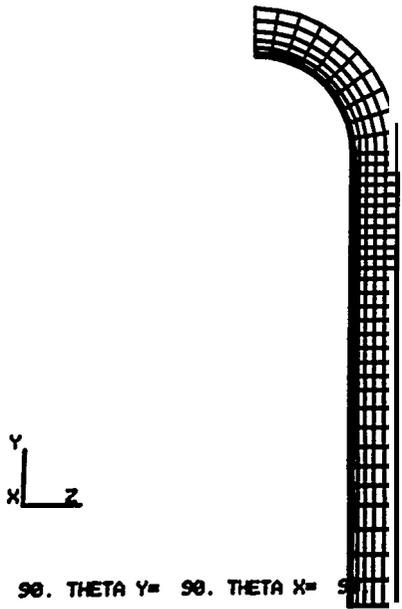
3-D MODE



THETA Z= 90. THETA Y= 90. THETA X= 90.

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07754100 110



THETA Z= 90. THETA Y= 90. THETA X= 90

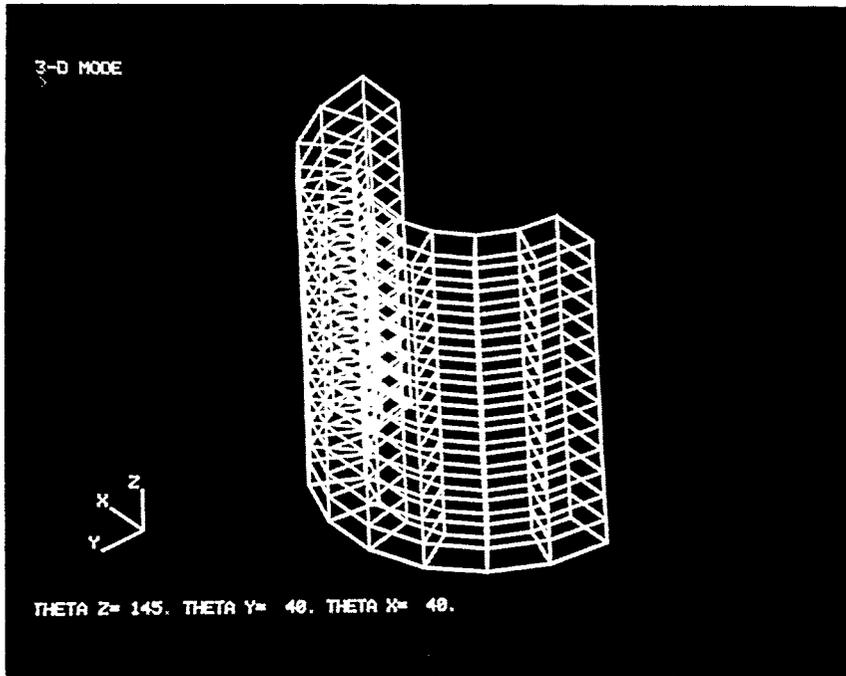
**MCAUTO**

```

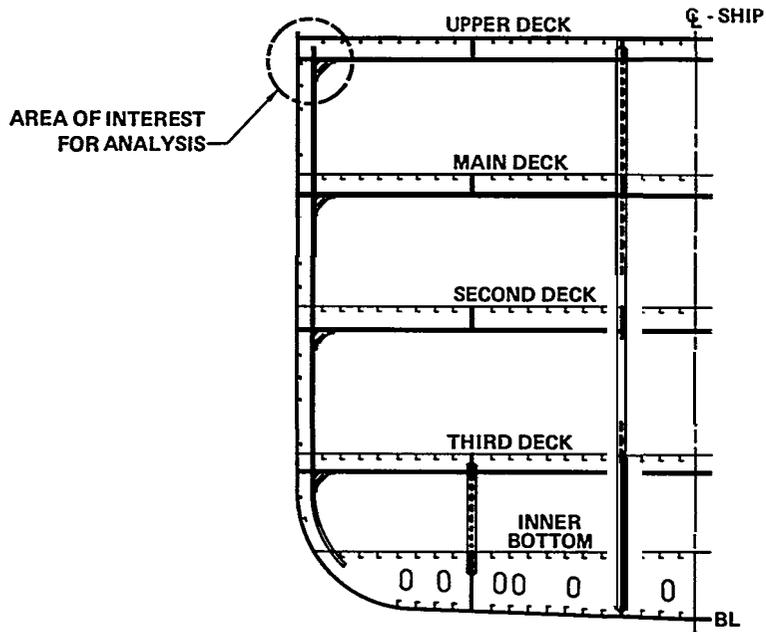
3-D MODE
DUP (ELEM 1-999)
DO YOU WANT TO DUPLICATE ONLY THOSE ELEMENTS
THAT GENERATE NEW POINTS(Y/N)?
1
DIGITIZE THREE REFERENCE POINTS ON CURRENT STRUCTURE
DIGITIZE NEW LOCATIONS OF THOSE REFERENCE POINTS
HOW MANY TIMES DO YOU WANT TO DUPLICATE
12

```

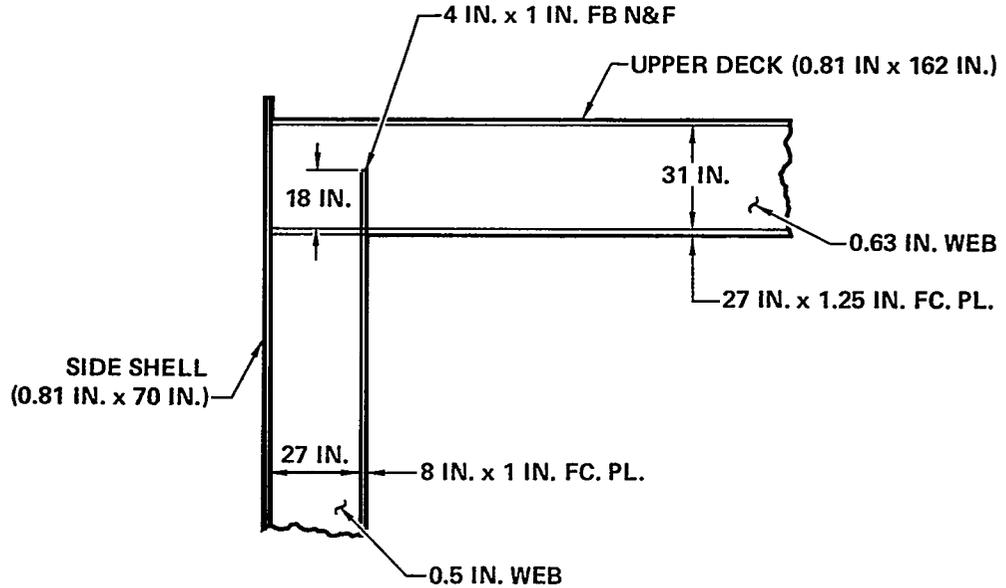
THETA Z= 145. THETA Y= 40. THETA X= 40.



## TRANSVERSE HULL WEB FRAME



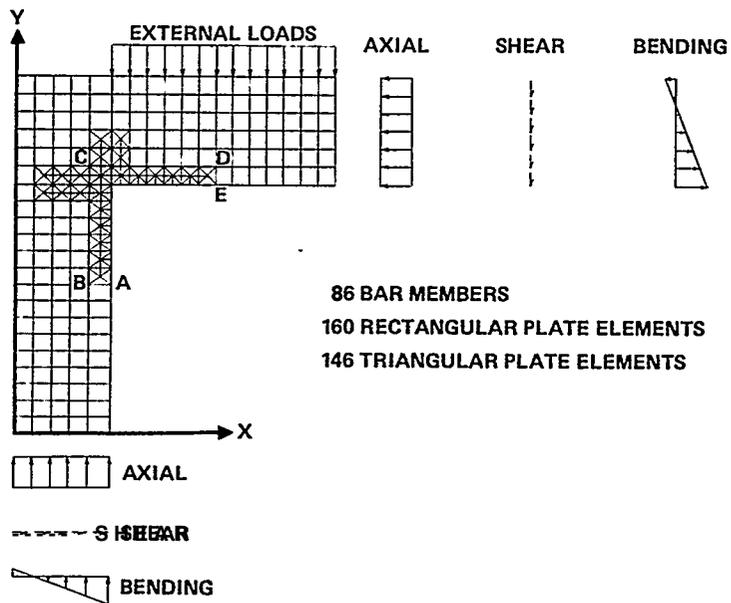
# DESIGN NO. 1



MCAUTO

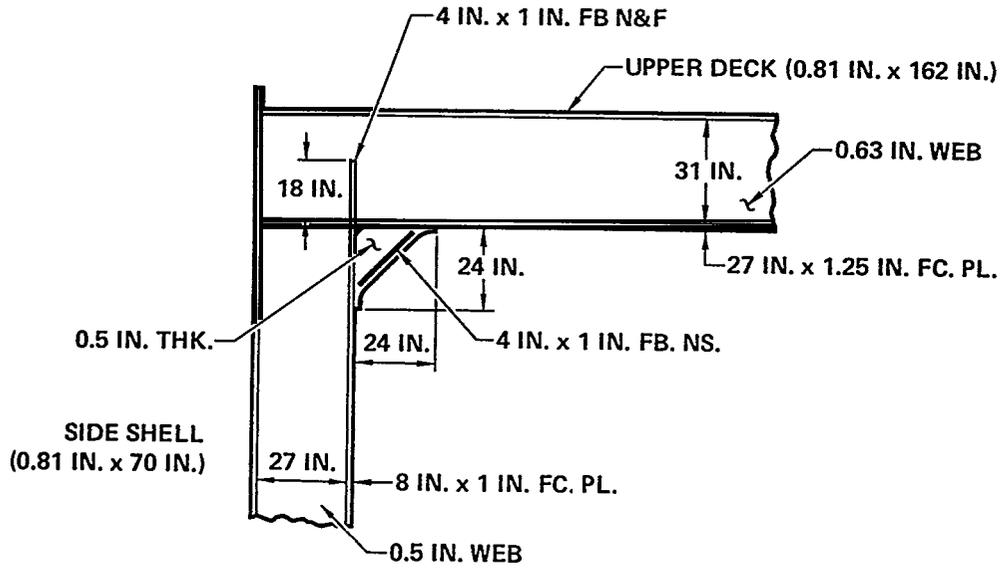
GP75-5288-4

## FINITE ELEMENT MESH FOR DESIGN NO. 1 SHOWING AXIAL, BENDING AND SHEAR STRESSES



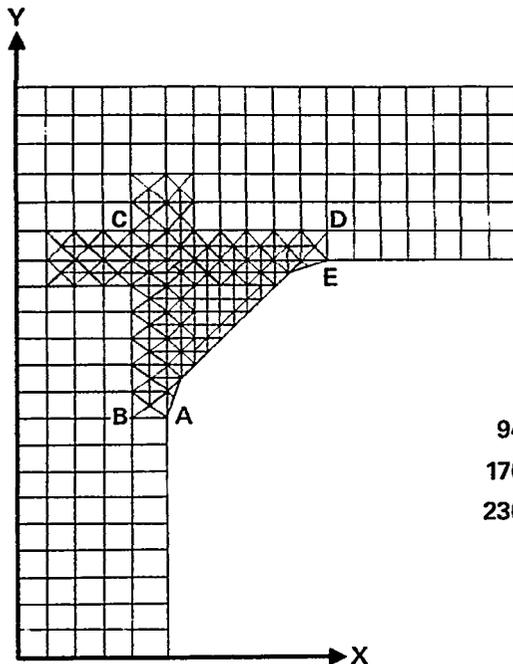
GP75-5288-8

## DESIGN NO. 2



GP75-5288 5

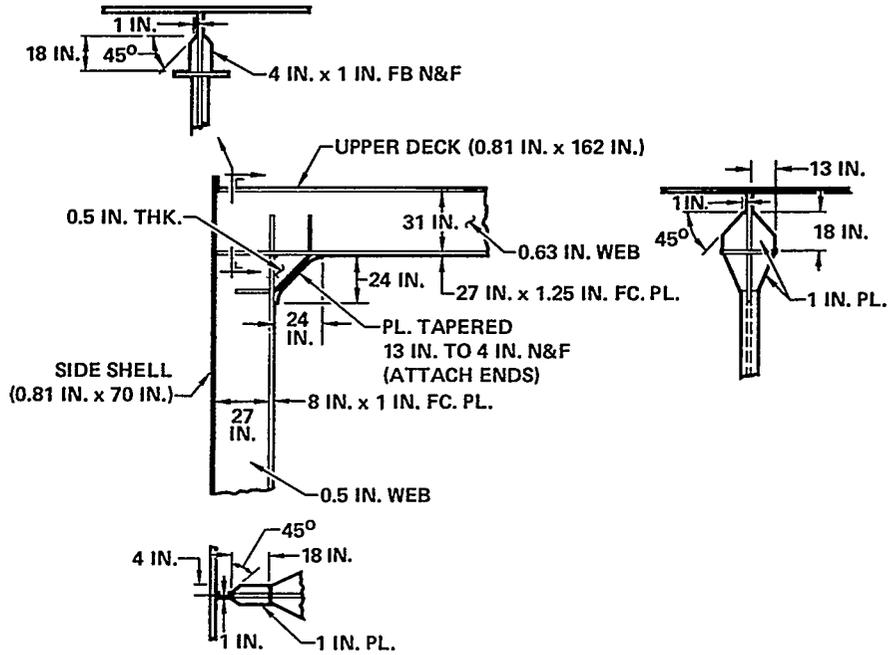
## FINITE ELEMENT MESH FOR DESIGN NO. 2



94 BAR MEMBERS  
 170 RECTANGULAR PLATE ELEMENTS  
 230 TRIANGULAR PLATE ELEMENTS

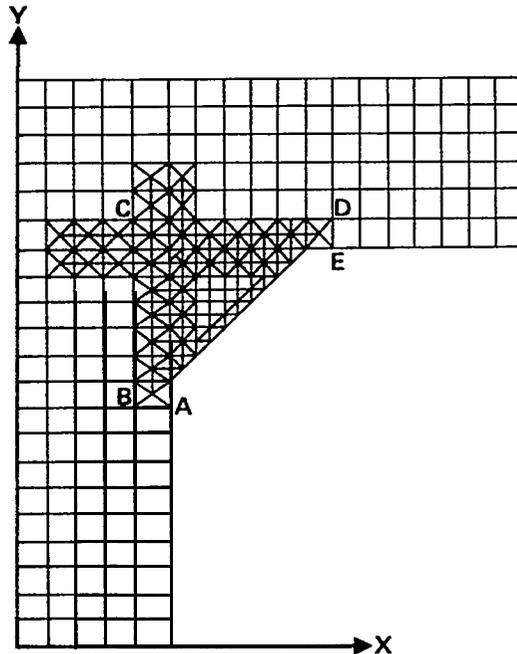
GP75 5288 9

### DESIGN NO. 3



GP75 5288-6

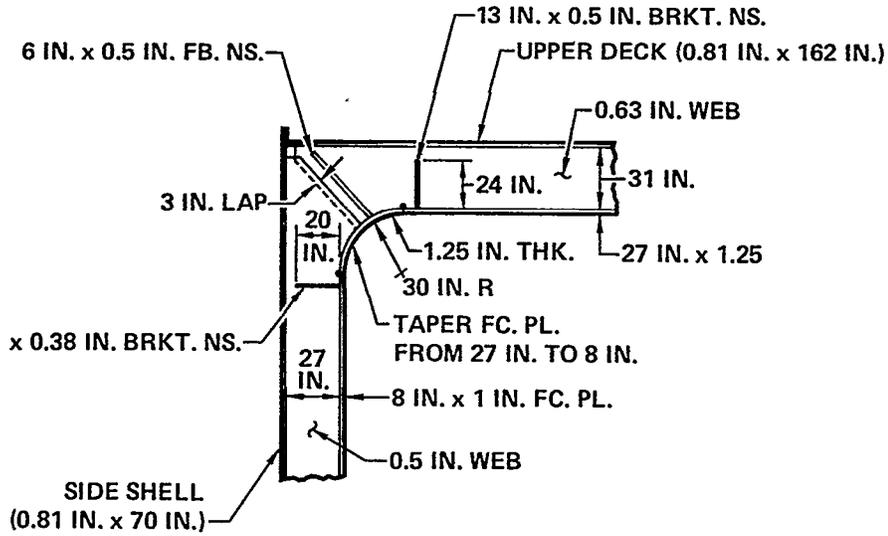
### FINITE ELEMENT MESH FOR DESIGN NO. 3



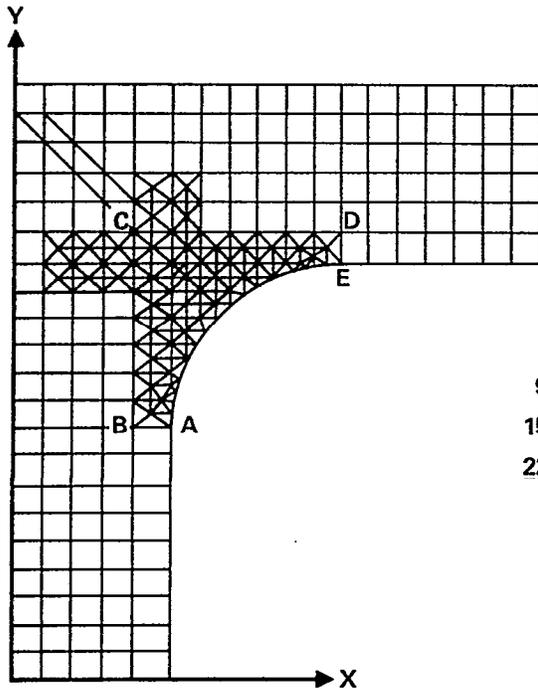
103 BAR MEMBERS  
 170 RECTANGULAR PLATE ELEMENTS  
 226 TRIANGULAR PLATE ELEMENTS

GP75 5288-2

## DESIGN NO. 4



## FINITE ELEMENT MESH FOR DESIGN NO. 4



90 BAR MEMBERS  
 156 RECTANGULAR PLATE ELEMENTS  
 227 TRIANGULAR PLATE ELEMENTS

## FEATURE GEOMETRY CONSTRUCTION

POINTS:      KEYIN RECTANGULAR  
                 OR CYLINDRICAL COORDINATES  
                 DIGITIZE  
                 INTERSECT SHAPES  
                 SUBDIVIDE SHAPES  
                 PARALLEL TO AN AXIS

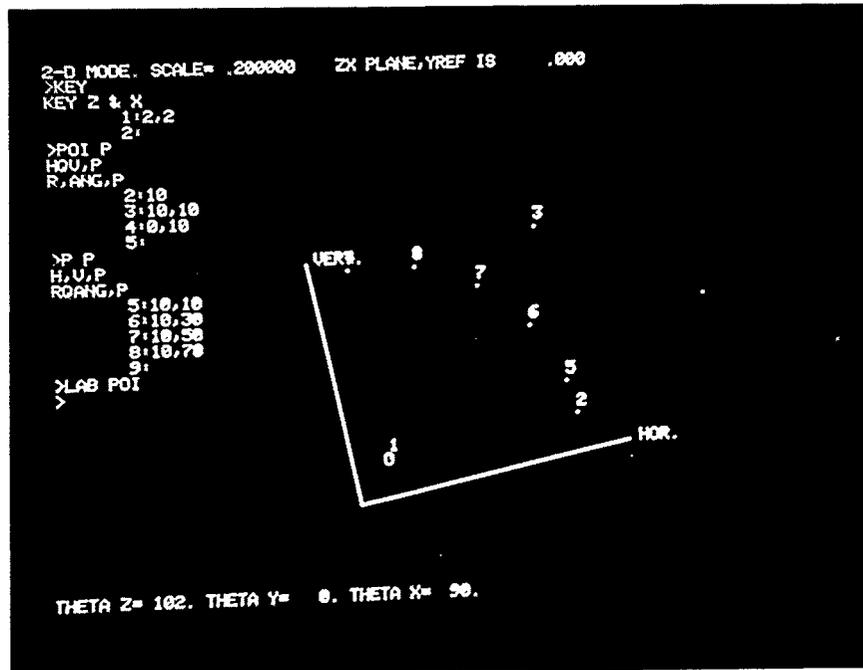
LINES:        PARALLEL TO AN AXIS  
                 OR A LINE  
                 THROUGH 'N' POINTS

ARCS:        THRU 3 POINTS  
                 TAN TO 3 LINES  
                 RADIUS, TAN TO 2 LINES

CIRCLES:     RADIUS AND CENTER  
                 CENTER AND CIRCUMFERENCE  
                 3 PTSON CIRCUMFERENCE

TEXT:        ATTACHED TO A POINT

**MCAUTO**



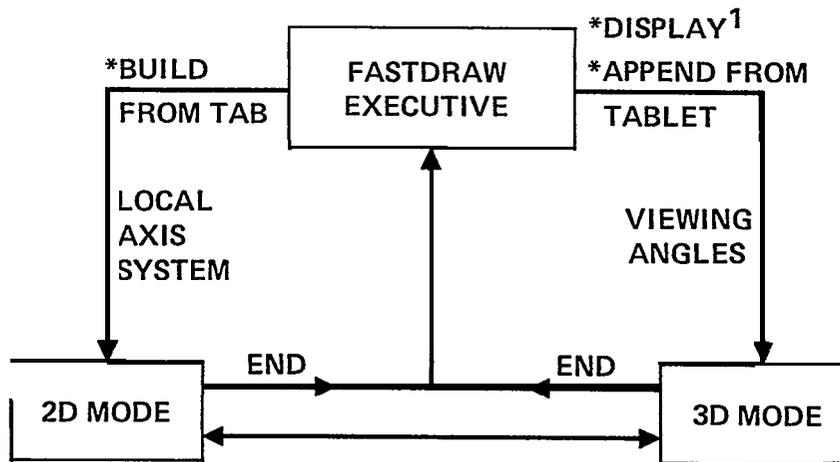
# FASTDRAW EXECUTIVE

- BUILD refile FROM file
- USE refile
- APPEND FROM tablet
- DISPLAY
- STORE file
- SCRATCH file
- END
- STATUS
- LIBRARY



GP75 5193 11

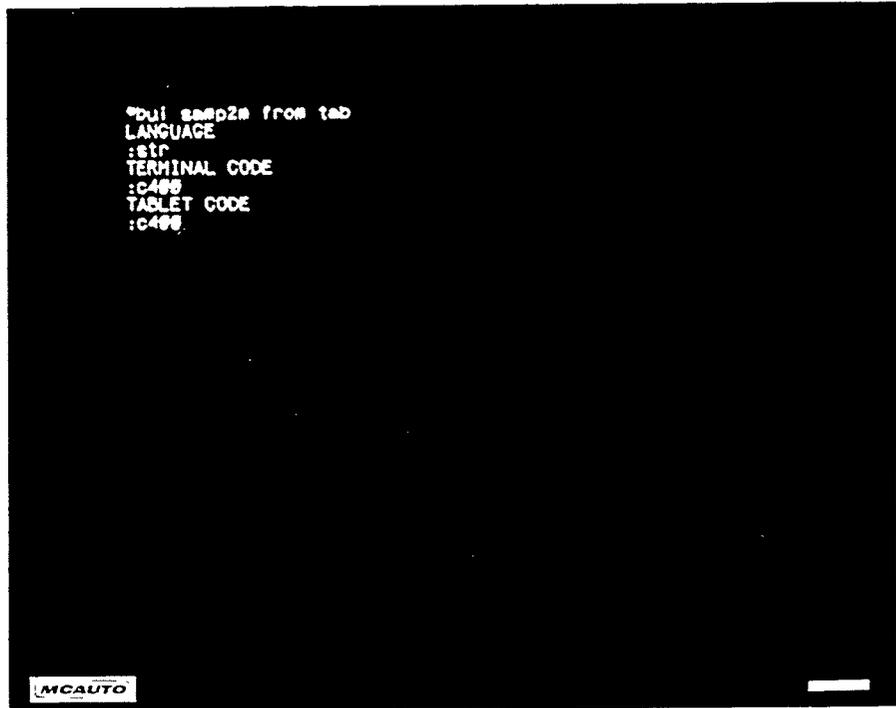
# MODE SCHEMATIC



1 ENTER 2D MODE IF APPLICATION IS 2 DIMENSIONAL



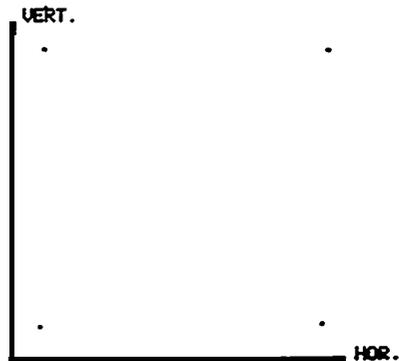
GP75-5193 14



```

2-D MODE. SCALE=.300000E-01 XY PLANE,ZREF IS .000
>2D
IDENTIFY TABLET COORDINATES
TYPE HORIZONTAL THEN VERTICAL AXIS (XY,YZ, OR ZX)
:XY
ENTER SCALE FACTOR
:1.03
ENTER X,Y,Z COORDINATES OF SKETCH ORIGIN
:0.0,100
DIGITIZE LOWER THEN UPPER POINT ON X AXIS
FOLLOW WITH A POINT ON THE POSITIVE Y AXIS

```



THETA Z= -0. THETA Y= 0. THETA X= 0.



GP5 5102 110

# STRUDL/NASTRAN

## ACTIVE MENU

2D	KEYIN POINTS	SETLABELS	REORIENT	MOVE	TRAVERSE	DUPLICATE	PLOT	TRANSLATE	ROTATE	HELP
REDRAW	LABEL	COORDINATES	DEFINE ELEMENT	DELETE	ACCESS	SEGMENT	HORIZONTAL	VERTICAL	DIGITIZE	PLANE
CHANGE ELEMENT	ELEMENT 1	ELEMENT 2	ELEMENT 3	ELEMENT 4	ELEMENT 5	WINDOW	PAN	FULLSIZE	3D	END

MCAUTO

GP75-5193-6

# STRUDL/NASTRAN

## GENERAL MENU

MODE	REORIENT	2D	PLANE	3D	END															
DISPLAY	ANNOTATE	AR'S	DRAW	FULLSIZE	PAGE	PAN	PLOT	REDRAW	SEGMENT	WINDOW										
UPDATE	CONVERT	DEFINE ELEMENT	DELETE	MOVE																
MENU	ACCESS MENU	COMMAND ASSIGNMENT	HELP																	
POINT	P	DIGITIZE	E	PE	ZE	KEYIN	HORIZONTAL	VERTICAL												
LINE	P	MP	E																	
ARC	3P	ZE	ZE																	
CIRCLE	P	2P	3P																	
TEXT	P																			
CHANGE ELEMENT	ELEMENT 1	ELEMENT 2	ELEMENT 3	ELEMENT 4	ELEMENT 5	ELEMENT 6	ELEMENT 7	ELEMENT 8	ELEMENT 9	ELEMENT 10										
PRINT	LABEL	COORDINATES																		
CHANGE	SETLABELS	REACTIONS																		
GENERATE	TRANSLATE	ROTATE	DUPLICATE	TRAVERSE	REJECT															
FOR COMPUTER 400 (C40)																				
MCAUTO																				

FASTDRAW - MENU  
STRUDL/NASTRAN  
GP75-5193-112

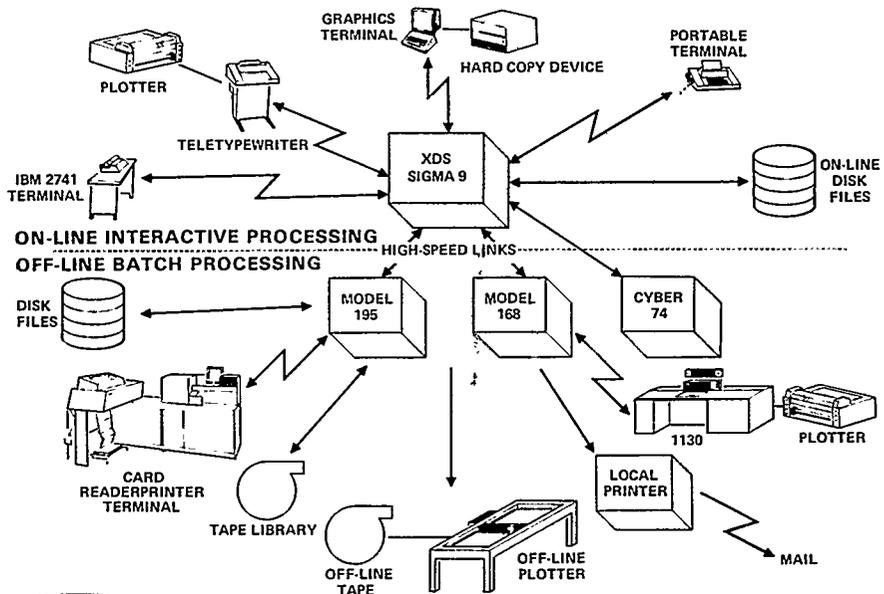
# DISPLAY COMMANDS

- |           |              |          |
|-----------|--------------|----------|
| >REORIENT | >ANNOTATE    | >PAGE    |
| >2D       | >AXIS        | >PAN     |
| >PLANE    | >COORDINATES | >PLOT    |
| >3D       | > D R A W    | >REDRAW  |
| >END      | >FULLSIZE    | >SEGMENT |
|           | >HELP        | >WINDOW  |
|           | >LABEL       |          |

MCAUTO

GP75-5193.63

## DIRECT ACCESS COMPUTING HOST SYSTEM



MCAUTO

GP 75-5193

## HOST PERFORMS A VARIETY OF SERVICES, INCLUDING:

- TRANSMISSION OF FILES OVER THE NETWORK LINKS
- GENERATION OF JCL (JOB CONTROL LANGUAGE) FOR JOBS TO BE PROCESSED BY NETWORK COMPUTERS
- SYNTAX CHECKING OF APPLICATION *PROGRAM* INPUT DATA BEFORE TRANSMISSION
- DIRECTION OF OUTPUT TO A DAC DISK STORAGE FILE OR A REMOTE BATCH TERMINAL
- STATUS OF PREVIOUSLY TRANSMITTED JOBS

**MCAUTO**

GP75-5193-47

## SAMPLE TERMINAL SESSION

#HOST

+LANGUAGE STRUDL

+SCAN STRUDLDATA

+DESTINATION STL

+TRANSMIT STRUDLDATA

+ END

}

CHECKS SYNTAX OF STRUDL DATA FILE

}

TRANSMIT DATA FILE FOR ANALYSIS ON IBM 370/195 IN ST. LOUIS

**MCAUTO**

GP75 5193 52

## HOST UTILITIES

**PRINT** – FILE STORED ON DAC COMPUTER CAN BE LISTED AT A NETWORK COMPUTER LINE PRINTER OR AT ONE OF ITS BATCH TERMINALS.

**PUNCH** – CARD IMAGES OF FILES STORED ON A DAC COMPUTER CAN BE PUNCHED AT A NETWORK COMPUTER OR AT ONE OF ITS BATCH TERMINALS.

**MOVE** – MOVES FILE BETWEEN A DAC COMPUTER AND A NETWORK COMPUTER

**MCAUTO**

GP75.5193.61

CONSIDERATIONS FOR USING AUTOKON

AT A 13XMOTE SITE

Bernard J. Breen

and

John M. Wallent

General Dynamics Corporation

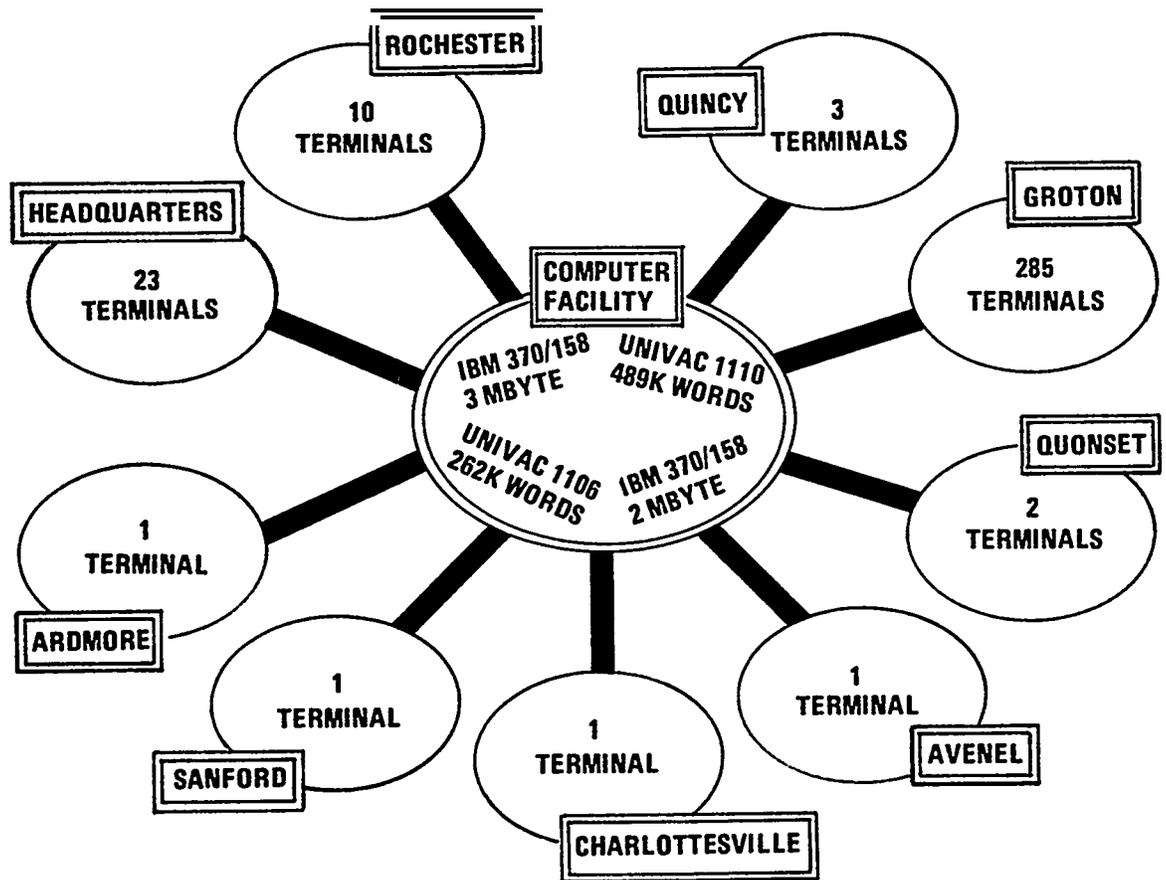
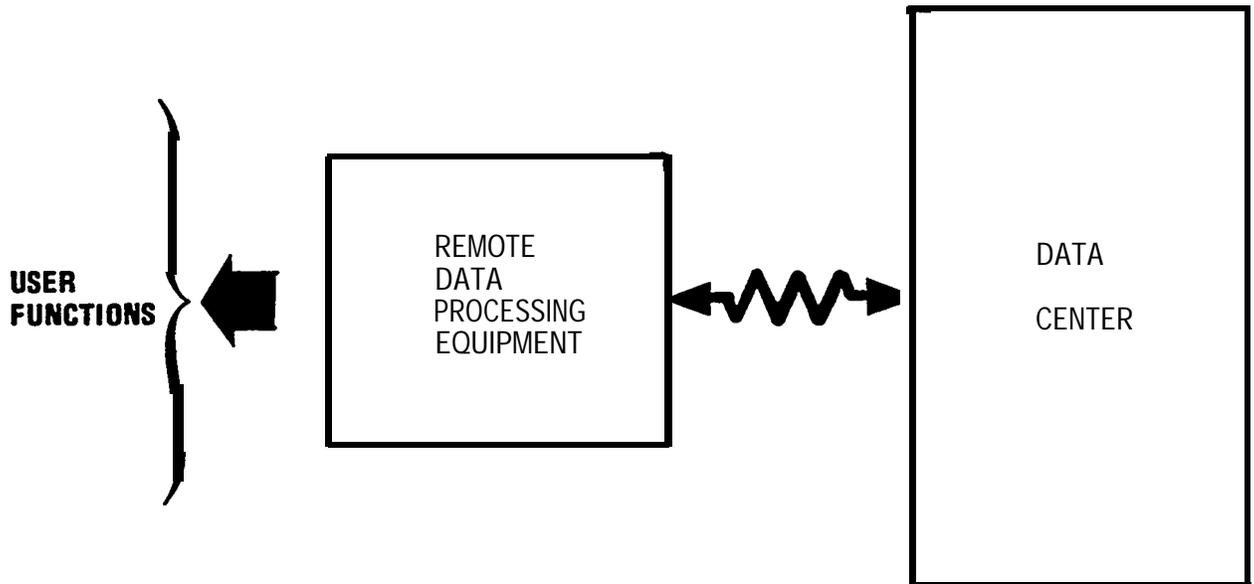
Quincy, Massachusetts

Mr. Breen is a Management Systems Specialist with General Dynamics Corporation's Eastern Data Systems Center in Groton, Connecticut. He is responsible for computer-aided design and manufacturing software supporting General Dynamics' shipbuilding divisions.

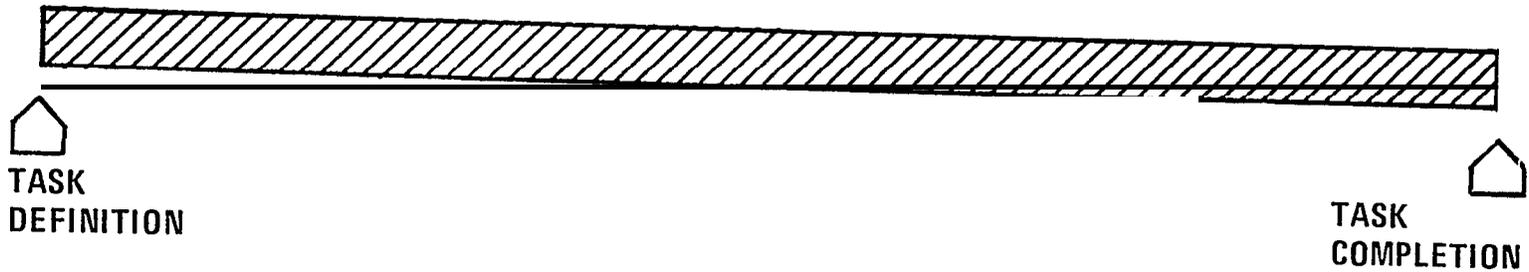
Mr. Wallent is Manager of Automated Processes with responsibility for N/C production related operations at General Dynamics' Quonsett facilities.

# DATA PROCESSING SUPPORT

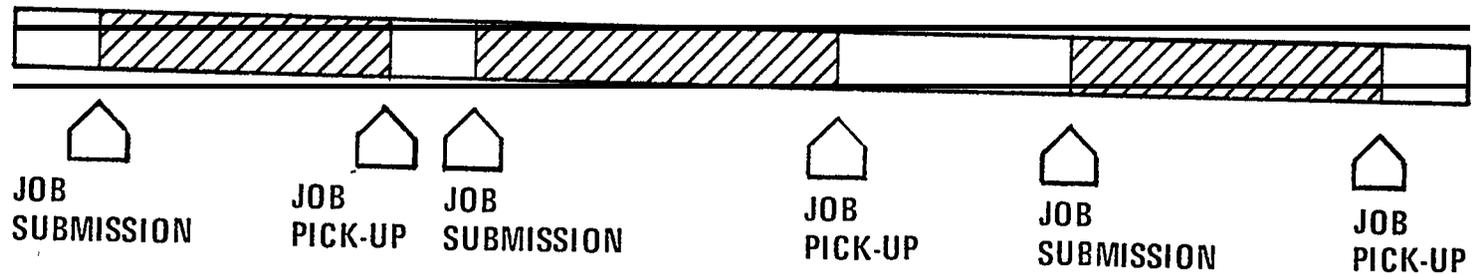
## REMOTE SITE



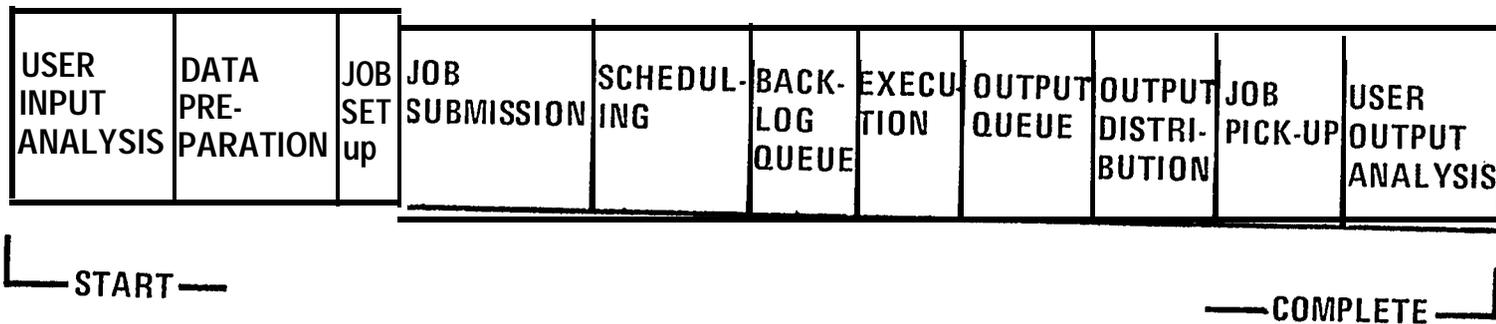
# MANAGEMENT VIEW OF TURN-AROUND:



# USER VIEW OF TURN-AROUND:



# "TRUE" VIEW OF TURN-AROUND:



# TURN-AROUND FACTORS WHICH CAN BE AFFECTED BY ESTABLISHING A REMOTE SITE

- DATA PREPARATION
- JOB SUBMISSION
- SCHEDULING
- OUTPUT DISTRIBUTION
- JOB PICK-UP

## REMOTE SITE HARDWARE DETERMINANTS

- APPLICATION SOFTWARE TO BE EXECUTED
- USER WORK LOAD
- DISTANCE OF REMOTE SITE FROM DATA CENTER

# ASSUMED DETERMINANTS

- PRIMARY APPLICATIONS ARE THE EXECUTION OF THE AUTOKON SYSTEM PARTS GENERATION AND NESTING PROGRAMS
- THE USER WORKLOAD IS THE PROCESSING OF AN AVERAGE OF 100 INDIVIDUAL USERS PROGRAMS IN AN 8-HOUR WORK DAY
- THE REMOTE SITE IS OUTSIDE THE "NEIGHBORHOOD" OF THE DATA CENTER

## RESULTING DATA PROCESSING FACTORS

- . A LARGE SCALED COMPUTER HARDWARE SYSTEM MUST BE UTILIZED
- 100 PROGRAMS WILL GENERATE:
  - 2500 PUNCHED CARDS INPUT
  - 1000 PAGES PRINTED OUTPUT
  - 1500 FEET PAPER TAPE OUTPUT

# PERSONNEL REQUIREMENTS

● KEYPUNCHING	- 2
● TERMINAL OPERATIONS	- 1
● GRAPHICS OPERATIONS	- 1
	<hr/>
	4

# TERMINAL HARDWARE REQUIREMENTS

- MINI COMPUTER (12K 10 16K MEMORY)
- CARD READER (MEDIUM SPEED)
- LINE PRINTER (LOW SPEED)
- PAPER TAPE PUNCH (MEDIUM SPEED)
- MASS STORAGE (1 - 4 MILLION BYTE CAPACITY)
- OPERATORS CONSOLE

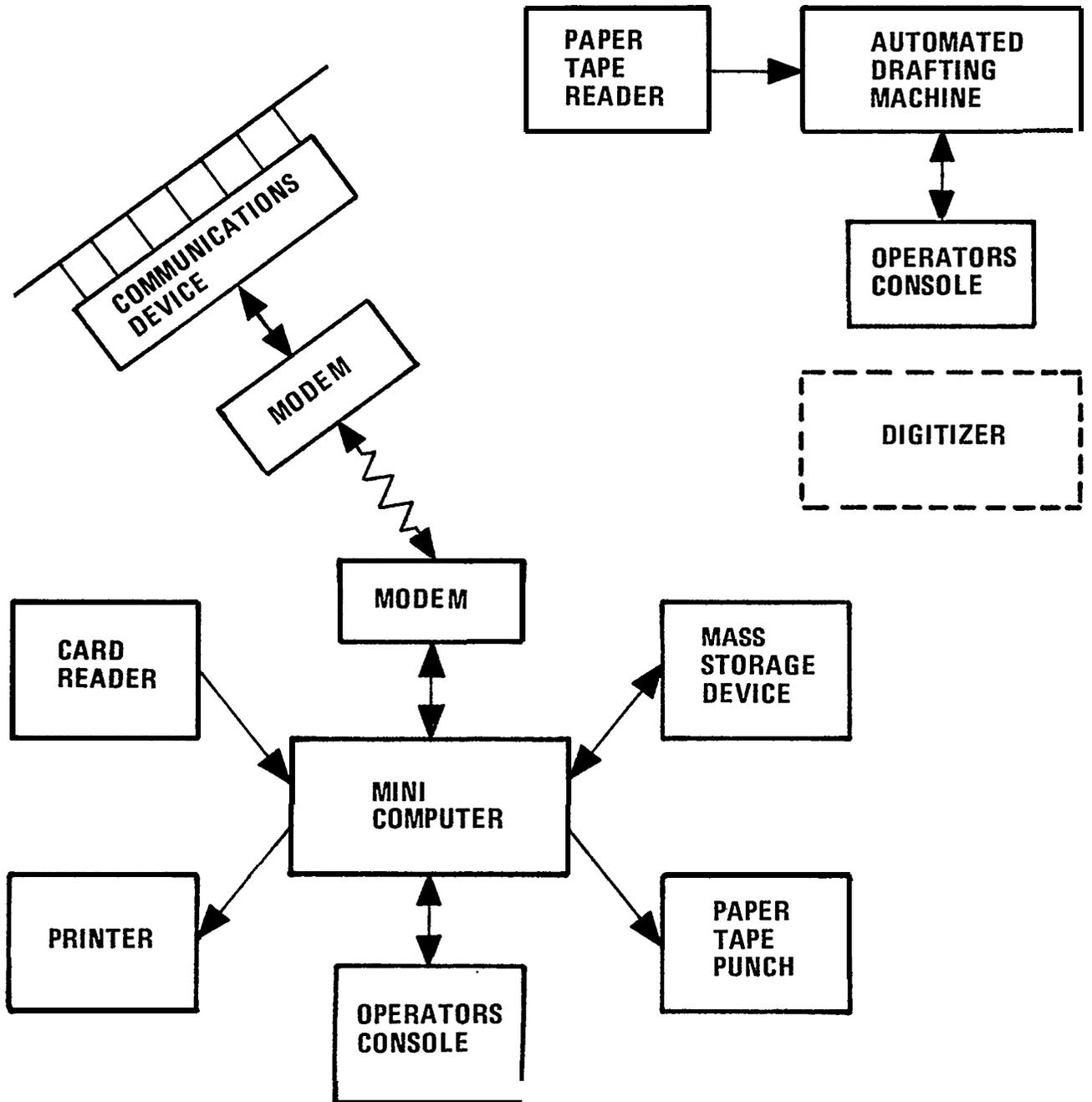
# OTHER HARDWARE REQUIREMENTS

- AUTOMATED DRAFTING MACHINE
- DIGITIZER (?)
- DATA SETS - 2
- DATA CENTER COMMUNICATIONS INTERFACE
- TELEPHONE LINE
- ENVIRONMENT

# TERMINAL SOFTWARE CONSIDERATIONS

- EMULATION
- UTILITIES
- PARTS GENERATION PREVIEW PROCESSOR
- QUICK LOOK
- INTERACTIVE GRAPHICS

# DATA CENTER MAIN FRAME COMPUTER



# **USER CONSIDERATIONS**

## **KEY EVENTS**

- \* DETERMINE THE PROPER SITE-HARDWARE AND PERSONNEL
- \* ORDER FLAME CUTTER (S)
- \* ORDER DRAFTING EQUIPMENT
- \* ORDER DATA TERMINAL AND PERIFERALS
- \* ESTABLISH DATA PROCESSING AND WORK CONTROL PROCEDURES
- \* HIRE OR SELECT PERSONNEL FOR N/C CODING, EQUIPMENT OPERATION,  
AND MANAGEMENT OF NEW PROCEDURES
- \* TRAIN PERSONNEL
- \* SET UP PRODUCTION WORK FLOW, PLANNING, AND WORK PACKAGING TO  
INTERFACE WITH MANUFACTURING.

# **SITE SELECTION**

- \* DETERMINE THE PEAK WORKLOAD REQUIREMENT**
- \* SIZE THE HARDWARE SPACE REQUIREMENT**
  - DATA TERMINAL**
  - DRAFTING MACHINE**
- \* SIZE THE PERSONNEL WORKSPACE REQUIREMENT**
  - SOFTWARE SUPPORT**
  - SHOP PLANNING**
  - HULL FAIRING**
  - CODING**
  - VALIDATION**
  - NESTING**
  - SUPERVISION AND CLERICAL**
- \* CONSIDER THE ENVIRONMENT**
- \* CONSIDER THE WEIGHT OF EQUIPMENT**
- \* KEEP THE VARIOUS FUNCTIONS TOGETHER**

# **HARDWARE SELECTION**

\* DATA TERMINAL - BY E.D.S.C.

\* FLAME CUTTER

- QUANTITY OF PIECES TO BE PROCESSED
- SIZE OF MAXIMUM WIDTH
- CUTTING MODES: MIRROR-LOOK ALIKE-3 AXIS
- NUMBER OF CUTTING HEADS - MASTER HEADS

\* DRAFTING EQUIPMENT

- QUANTITY OF PIECES TO BE PROCESSED
- SIZE OF MAXIMUM DRAWING
- VERIFICATION PACKAGE

## **ESTABLISH PROCEDURES AND PRODUCTION WORK FLOW**

\* DATA PROCESSING

- ESTABLISH WORK FLOW HANDLING AND LOG KEEPING

\* SHOP PLANNING

- MAKE PREDETERMINATION OF MANUFACTURING CONTROLLED ITEMS

EXTRA STOCK ALLOWANCES

BEVEL REQUIREMENTS

- LIST PARTS AND OPERATIONS TO BE PERFORMED FOR SPECIAL FORMING ETC.

\* WORK CONTROLS

- ESTABLISH RECORD KEEPING PROCEDURES TO TRACK WORK IN PROCESS, ASSIGN TAPE NUMBERING, VALIDATE PARTS AND NESTS AND TO MONITOR SCHEDULES

# SELECTION AND TRAINING

## \* SELECTION

- GENERAL CODING GROUP – PERSONNEL FAMILIAR WITH SHIP PLANS AND/OR N/C PRACTICES
  - LOFTSMEN (AIRCRAFT OR SHIP)
  - STRUCTURAL SHIP DRAFTSMEN/DESIGNERS
  - N/C USERS FROM OTHER COMPUTER APPLICATIONS

## \* TRAINING

- HULL FAIRING – 2 WEEKS
- PART CODING – 2 WEEKS
- NESTING – 1/2 DAY

A STATE OF THE ART REVIEW OF N/C

John C. Williams  
IIT Research Institute  
Chicago, Illinois

Mr. Williams is responsible for the direction and management of projects which involve operations research, computer aided manufacturing development, numerical control applications engineering, industrial and systems engineering, manufacturing planning and technological forecasting, These projects span a wide geographical and technological range.

During the ten year span from 1960-1970 we have seen some startling developments in metal cutting technology. We have seen the one-man/one-machine conventional technology of 1960 give way to numerical control machines. In this system, man is in both sides of an information loop linking the computer with the machine tool. Man enters raw data into the computer and receives a punched tape which he enters into the machine tool and receives machined parts.

This process, in turn, has given way to the direct computer control of machine tools. In this system, man is in only one side of the information loop. He submits raw data to the computer which processes it and supplies it directly as control data to the machine tool.

Finally, in 1970 we stood on the brink of a totally computer aided manufacturing system. In this concept, all interaction within the loop is between the computer and the machine tool. Man will provide his data through another system in the hierarchy of computers. Technologically, this track of developments is well beyond the laboratory feasibility stage. However, if we look at some statistics, we will see a symptom of something drastically wrong. The total number of conventional machines still in operation today is approximately 3,000,000 tools. The total number of NC machines in operation today is 30,000. The total number of Direct Computer Control machine tools in operation today is less than 30. (This data was extracted from the 11th American Machinist Inventory of Metalworking Equipment.) Computer

aided manufacturing is such an undefined area no positive count is possible. The significant point is the accelerating rate of technological developments vs. our ability to implement and use them. Evidence of this is displayed by our machinists who have barely accepted the fact that we took the overhead belt drive off and put the power plant in the head stock. (Why do you need all those motors when only one motor would do it before?)

Yet in this ten year period, we saw NC make small but highly successful penetrations into many industries. The list includes textiles, metal forming, assembly, woodworking, glass cutting, pattern making, etc. I'm sure there are many others. The penetration, though well scattered, was not deep-- not even in the metal cutting industry where the big thrust really occurred. After 50 years of relative stagnancy in metal cutting technology, this kind of overnight growth was too much.

As recently as 1971, statistics released by the Department of Commerce showed the sales value of NC machines in the third and fourth quarters represented only 24% of the total dollars spent on machine tools in the same period. Considering the cost ratio of NC to conventional equipment, it's rather easy to extrapolate that in numbers of machines, conventional is outselling NC 100/1. This is certainly not the much heralded second industrial revolution we were all predicting a few years ago.

This is even more startling when you consider the figures on productivity released by the Department of Commerce in early 1973. They show a productivity gain from an index of 67 in 1960 to 114 in 1969 (this is based on an index of 100 in 1967). During that same period manufacturing employment edged up only 13%. That's almost a 100% gain in productivity with only a 13% rise in employment. That's quite a tribute to technology. It's pure conjecture on my part, but I feel it's quite a tribute to NC technology. Those years, 1960 through 1969, were the peak years of new NC starts. In fact, the vector of the acquisition curve for NC machines almost matches the vector of the productivity increase curve. It's interesting to speculate on just what the productivity gain might have been, had we been more successful in implementing NC. So much for what might have been. Let's look at some more specifics of what really is.

In the United States in 1968 small job shops employing less than 100 people comprised 83% of the metalworking industry. At that time, those shops owned, controlled and operated 22% of the total domestic NC inventory, while the other 17%, the large businesses, had 78% of the NC inventory. More recently in 1973 the small shops have grown in number and comprise 87% of the metalworking industry. Concurrently, their NC inventory has grown to 31% of the total. So the small shops are beginning to buy NC. The number of small shops is up 4% and their NC inventory is up 9% in 5 years. One

of the fundamental reasons for this is the reduced capital investment. The cost of control systems is lower than it was five years ago and also some used NC machines are beginning to appear for sale. High capital investment was the greatest deterrent to NC in the small shop. The second largest deterrent, closely linked with the first, was a lack of appreciation for NC practices. The potential of mini-computers and the promise of lower cost integrated circuitry indicates the overall cost of control systems should be coming down even farther. Consequently, it appears that the trend to more and more growth of NC into the nation's small shops because of lower costs will continue. There have been many barriers and the removal of these barriers has been slow.

Typical of the bulk of the NC machines currently in operation is the old hard-wired paper tape reading NC machine. They are state of the art in use. There is also the state of the art which is not yet in significant use but is completely developed, typified by the new GE control for NC; the 550 TX control unit. It has program storage capability and can store up to the equivalent of 100 feet of paper tape. It has a tape punch, tool changer, tool offsets, gives total machine status read out in terms of actual position locations of the average feed rate of 800 inches per minute, but that is state of the art in development not state of the art in use. In fact, to give you an idea of how slow we are to change in NC, we have a programming capability that has a computational accuracy of .00005 of an inch; we have electronic control

units that can control signals equally precise; we have a machine tool that is designed and built to have an absolute position accuracy of .0003 of an inch. In the midst of all of this accurate capability we set up the tools on the machine by hand with a pair of micrometers. We have yet to learn to use the capabilities that are built into the system to do the full job.

Another problem area is typified in the shipbuilding industry by the multiple capabilities of computer part programming, i.e. SPADES, AUTOKON, STERBEAR and so on. In the world of NC there are a great number of systems for part programming, in fact at last count there were some 49 different NC part programming languages and this creates problems such as the difficulty of evaluating which one to use, the loss of R & D resources, etc.

With all of these problems we have realized significant productivity growth as a result of the application of numerical control, as mentioned earlier, productivity growth that has almost doubled during the peak years of NC acquisitions (1960-1969), and at the same time our manpower growth went up only 13%. That's quite a tribute to NC technology.

But enough about the past, what's in the future in numerical control? Where will we go from here? Well, one thing that's certainly in the future, is the proliferation problem. I don't believe that it will be a proliferation of languages, so much as it will be a proliferation of systems. I'm referring to NC systems, DNC systems, CNC systems, CAM

systems, and so on even though we can't even agree on the definition of some of those terms. You know, CAM is a unique term that I define this way. I compare it to a system such as FORTRAN. FORTRAN doesn't solve any problems; it doesn't do anything; it is only a language that a computer programmer can use to set up and solve problems on a computer. The APT-part programming language is much the same. It does not write part programs for you; it doesn't describe parts for you; it is simply a language that can be used by a part programmer to describe a part. AUTOKON and SPADES, are the same thing; they don't solve problems either. They are only languages. It is my contention that CAM is also the same. It does not and will not solve any problems for you or do anything for you. Rather it is a language much like mathematics, a language that permits the user to resolve his own problems in his own environment.

There has been some progress towards CAM. One particular effort I can recall was a CAM project on which we at IITRI worked. Fundamentally, it was a DNC system that had a PDP-11 controlling a Sunstrand Omnimill. We developed and added to that the software and hardware necessary to monitor the work that was being done on that machine, the software necessary to schedule that work, the software necessary to do the machine loading and the software necessary to collect job histories on every job run. We also established within that system a communications link between the PDP-11 and a large CDC computer located roughly 1000 miles away. The last

development and far from the least was the expanded system capability. This permitted the PDP-11 to control not only the Sunstrand Ommill but four other NC machines as well--all of this concurrent on the one PDP-11. So some progress towards a CAM system is being made.

Other activities that are on-going right now use robots in the industrial environment. Robots are useful where jobs are either dangerous or distasteful to the worker such as in hot forging press work, in heat treating and in painting.

Another area that is beginning to find its own level is the use of stacker cranes. A stacker crane is nothing more than an extremely tall lift truck that can automatically access a stacked array of pigeon hole bins each containing cataloged material. The computer knows what bin holds what material, sends the stacker crane to that bin, removes it, and brings it down to a delivery system. Delivery systems can take the form of a cart that follows cables buried in the floor. Material can be loaded onto these carts and then directed by-the computer to any particular station in the shop that is serviced by those cables. Thus far, I know of several installations that are using systems of this kind: the stacker cranes are being used by GE appliance factories. GM plants are also using them to supply parts to their accessory manufacturing plants. The buried cable carts are being used in a number of army depots to fill requests and orders for material.

One of the most unique applications I've seen was in a hospital in Fairfax, Virginia, where buried cable cars are used

to deliver linens and meals to various patients in various rooms. This gives the hospital staff positive and absolute control over the particular dietary restrictions of a given patient in a given room.

Another more recent development is one by Ekstrom-Carlson who is now manufacturing a numerical control wood router. The routing machine, which is quite unique, has a feed rate of 400 inches a minute, has a 4 ft x 10 ft. table, a control resolution of about .001 of an inch and sells for \$50,000. The largest single productivity problem in using the machine is getting the chips away from it fast enough.

A quick look at what's going on overseas, Japan for example. Japan has a plant which has a series of DNC machines. These machines are producing parts that are actually being used. It's not a laboratory set up; it uses robots to service those machines--to bring in the raw material, to load the material on the machine and to remove the finished part from the machine. This is all under the control of one computer and all in one plant. This kind of international competition is what makes our life difficult; it makes productivity enhancement in American shops much more important. It makes the continued growth of the NC concept into areas other than metal cutting vital to our industrial survival.

This is the world of NC, the state of the art in use and the state of the art in development. When American industry learns to implement technological development at the same rate that our foreign counterparts do, then perhaps our productivity rates can be as good as theirs.

PRELIKON AT MARAD

Fred T. Johnson

and

Emmanuel N. Castrinakis

Maritime Administration

Washington, D.C.

Mr. Johnson is responsible for creating, modifying and maintaining engineering application programs for the naval architects and engineers at MarAd. He and his staff are also called upon by contract engineers in MarAd,s Office of Commercial Development for technical aid on computer-related R & D projects, such as AUTOKON and PRELIKON. Mr. Johnson has served during the past two years as a project engineer for the further development of PRELIKON.

Mr. Castrinakis is a naval architect on Mr. Johnson's staff.

## 1. INTRODUCTION

The use of the computer as a tool in the design and construction phases of shipbuilding is a reality which will intensify and continue to spread throughout the world marine industries. It is inconceivable that any but a handful of decision makers in the U.S. shipbuilding and shipping industries still believe that computer applications in the industries are a fad which will eventually disappear. As promoters of the U.S. Merchant Marine, and in view of the goal of the Merchant Marine Act of 1970 -- to restore the United States to the rank of a first class maritime power--the Maritime Administration is decidedly interested in the exploitation of automation and **EDP** hardware and software which have the potential to improve designs and increase shipyard productivity.

Further, the mission of the Office of Ship Construction at MarAd includes such activities as:

- 1) Studies in naval architecture, marine engineering, electrical engineering, and engineering economics.

- 2) Development of preliminary designs establishing the basic characteristics of proposed ships.
- 3) Review and approval of ship designs submitted for Government subsidy.
- 4) Recommending and, upon request, conducting R&D projects in ship design and construction.
- 5) Development or approval of contract plans and specifications for the construction, reconstruction, conversion, reconversion, reconditioning and betterment of ships.
- 6) Providing naval architectural and engineering services in connection with the construction of special purpose ships for other government agencies.
- 7) Maintaining current records of facilities, capacities, work load, and employment in commercial shipyards.
- 8) Development of requirements for mobilization ship construction programs.

In view of the Agency's goals and the mission of the Office of Ship Construction, the Maritime Administration **purchased AUTOKON '71 from Shipping Research Services A/S, Oslo, Norway, in 1973. AUTOKON's** co-system, **PRELIKON**, was part of the package purchased; and the total package was licensed as a proprietary system to interested U.S. shipyards. Realizing that the greater segment of potential users of **PRELIKON** were not necessarily potential **AUTOKON** users, MarAd immediately negotiated with SRS to free **PRELIKON** from proprietary status. The results of those negotiations will be discussed in the body of this paper.

It is our main intention here to describe how **PRELIKON** will be used as a tool in the performance of the activities listed above.

## 2. What IS PRELIKON

The **PRELIKON** System is a system of preliminary lines design programs integrated around a common data base. The system is composed of a number of modules -- some of which were developed by the Bergen Shipyard of the Norwegian Aker Group, and others by Det Norske Veritas. All of the modules were intended for general application and were used independently by the developers for several years on a non-sequential basis. Further, the system has been used with the **AUTOKON** System by numerous shipyards and design agents throughout Europe and by a few yards in America.

The version of **PRELIKON** included in the **AUTOKON** '71 purchase was the Oslo version -- the Univac-1108 version. The Oslo version required a large central memory, and a heavy overlay structure (segmentation). In spite of the heavy overlay structure, a Univac installation required approximately 52k words (208-234k bytes on the IBM 360/370) .

In an effort to make the system readily and economically available to any interested **U.S.** installation (including

**MarAd**, who uses the Control Data Corporation (CDC)-6600 computer via the **CYBERNET** Service for engineering applications), MarAd contracted Shipping Research Services, Inc. (**SRS**), Alexandria, Virginia to:

- 1) Redesign and improve the overall, modular design of the system.
- 2) Convert and install a CDC-6600 version of PRELIKON.
- 3) Improve and further develop existing modules of **PRELIKON**.
- 4) Provide user and maintenance documentation and training.
- 5) Incorporate the improvements in the original STOCK versions (Univac and IBM, as referred to in the AUTOKON contract), creating new STOCK (**or STANDARD**) versions of **PRELIKON**.

This effort has been essentially completed and the resulting version of the system, designated as PRELIKON D, is available to the public from the REAPS Program Library.

Further, MarAd proposes to develop a link between **PRELIKON** and certain MarAd programs and integrated systems, such as: the Hull Scientific Package (Bonjeans/Hydrostatics, Longitudinal Strength, Capacities and Damaged Stability, and Floodable Length), the **POWERING (EHP/SHP)** program using Taylor standard series, etc. The completion of these tasks will result in a new MarAd version which will be referred to as PRELIKON D1.

## 2.1 THE MODULES OF PRELIKON (Figure 1)

The **CDC** version of **PREIKON** consists of 23 different modules which may be divided into three logical groups as follows:

- . The input modules: Define the Hull Form

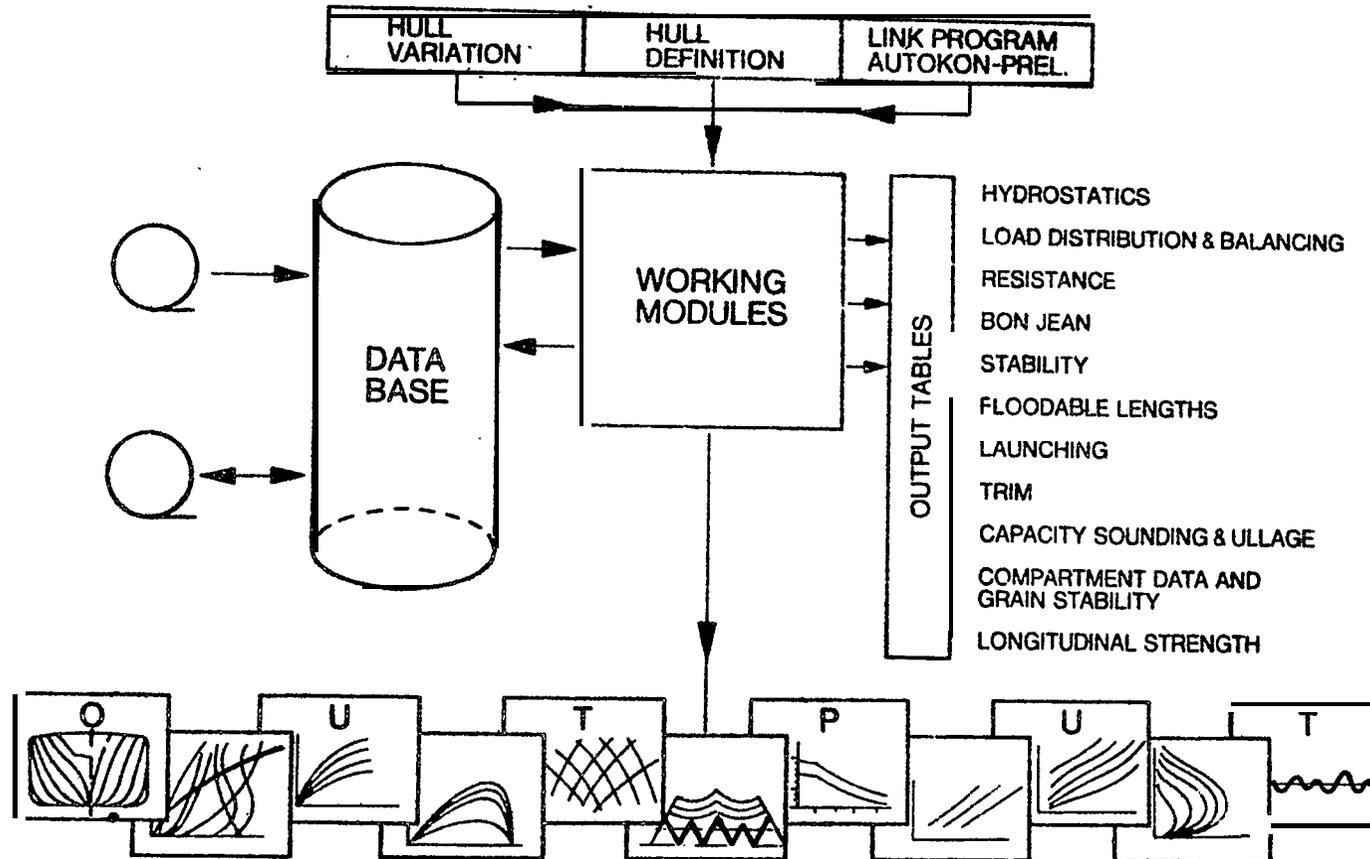


Fig. 1. Pictorial Representation of PRELIKON

- . . The working modules: Perform the calculations and prepare the output
- . . . The service modules: Perform mainly data utility functions

The Input Modules consist of:

- BV101 : The main HULL DEFINITION module
- BV 102: The LINK AUTOKON-PRELIKON Module
- BV 105: The HULL VARIATION Module

The Working Modules consist of:

- BV106: The HULL DRAWING Module
- BV110: The HYDROSTATIC Module
- BV125: The LOAD DISTRIBUTION AND BALANCING Module
- BV130: The RESISTANCE Module
- NV208/209 : The BONJEAN Module
- NV210/NV212: The TRANSVERSE STABILITY Module
- NV215: The FLOODABLE LENGTH Module
- NV220: The LAUNCHING Module
- NV241/242: The TRIM TABLE Module
- NV251/252: The CAPACITY, ULLAGE & SOUNDING Module
- NV253: The COMPARTMENT DATA Module
- NV260: The LONGITUDINAL STRENGTH Module

The Service Modules consist of:

- DBINIT:** The Data Base Initialization Module
- NV202 :** The Tape Storage & Retrieval Module
- NV270 :** The Hull Data Transformation Module

**PREL:** The Control Card Management Module

A general description of each of the modules (except DBINIT and PREL) is given in APPENDIX A of a paper "PRELIKON CAPABILITIES", presented at the REAPS Technical Meeting, June 26, 1974 by Mr. Svein Hansen of SRS.\*

**2.2 THE INPUT MODULES**

In order to insure the accuracy of results and the availability of necessary input data for the working modules, it is important that the hull form is carefully and properly defined. To simplify the "bookkeeping" in preparing input data, the data required to define a complete hull form is divided into logical groups, called MAIN TYPES. This concept is used to identify parts of the hull for storage and retrieval to and from the data base for both the basis ship and the varied ship when hull variation is required. When changes or amendments are made, only the affected MAIN TYPES are resubmitted to the Hull Definition program.

Input to the Hull definition program (BV101) is prepared on 11 input forms and their relationship to the **MAIN TYPES** are as follows:

<b><u>FORM</u></b>	<b><u>MAIN TYPE</u></b>	<b><u>COMMENT</u></b>
PI	MT1	Module card & main dimensions
P2		Coordinate system & reference point
P3		Station 7 frame table

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Proceedings of the REAP Technical Meeting; June 25-26, 1974;  
pp. 245-270.

P4	MT2	Sheer curves
P5	MT3	Camber curves
P6	MT4	Definition of decks
P7	MT5	Definition of sections
P8	MT6	Definition of boundary
P9	MT7	Definition of Appendages
P10	MT8	Definition of Deck house
P11		End of module card.

### 2.3 WORKING MODULES & OUTPUT

The working modules of PRELIKON perform the engineering calculations and prepare the output. Each module performs the calculation or generates the output indicated by its descriptive name.

### 2.4 PREL AND DBINIT

The two service modules which are not described in Appendix A are PREL and DBINIT. The former, PREL, is a utility program which frees the user from manipulating computer system control cards in the selection of modules from the input file and monitoring the job stream. And **DBINIT**, as the descriptive names implies, initializes and closes the data base.

### 3. Using PRELIKON in Preliminary Design

Starting with the main dimensions, owner's requirements and a general arrangement layout, the designer may proceed by:

a. Manually developing a lines plan and a subsequent lifting of all adequate data to the **HULL DEFINITION** program, or

b. Using the **LIBRARY** of hull forms and selecting the parent ship believed to be most suitable for the particular design.

(See Figure 2).

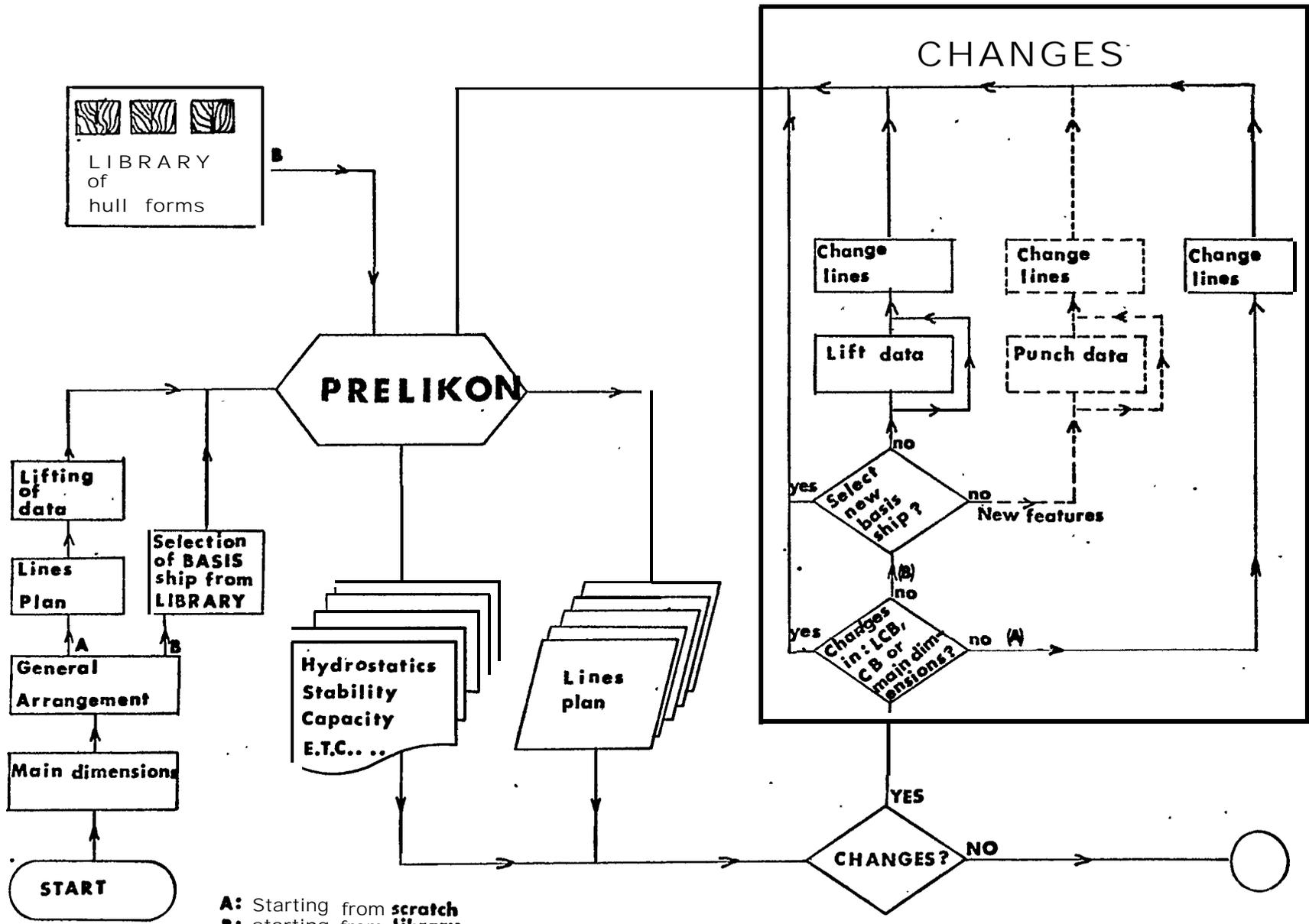
In the following, we will assume that the Library concept is used.

The first approach to the new design will be to transfer the basic form to **PRELIKON (SR500)**, to perform **HULL VARIATION (BV105)** and to draw the preliminary lines plan (BV106).

In addition, some of the other modules may be used to obtain key results such as Hydrostatics, Stability, Capacity, etc.

The first approach may not meet all requirements and changes may have to be introduced.

Automatic changes such as alterations in LCB, CB or main dimensions may be done by **PRELIKON** via the module BV105.



**A:** Starting from *scratch*  
**B:** starting from *library*

Fig. 2. The use of PRELIKON in the Preliminary Design

Manual changes such as amendments in the bow and stern sections may be performed by utilizing the **UPDATE** mode of the BV101 module.

In case manual changes are extensive such as changes in the deck line, etc., the varied ship definition may be punched on cards. Manually, alterations may be imposed, new decks, deck-houses and appendages may be added and the re-designed ship may be restored in the data base and made available for further calculations.

The change-loop in Figure 2 may be repeated until a satisfactory result is obtained.

Even if some savings in computer cost may be obtained by the Improved design, the main advantages will be the reduced manhours to impose modifications, which in turn allow the designer to evaluate several alternatives for a new design.

#### **4. PRELIKON D1**

The integration of MarAd programs with PRELIKON Data Base, will result in the PRELIKON D1 version. The purpose of this task is to increase the total scope of PRELIKON by attaching valuable modules from the MarAd Hull Scientific Package to the PRELIKON System. A prestudy was performed to evaluate what modules should be included. At present, the following modules are considered:

1) Link program between MarAd Hull Description and PRELIKON.

This program will add a valuable library of hull forms to the PRELIKON System.

2) The powering (EHP/SHP) program using Taylor standard series and Gertler data (Program code 034).

3) The MIT seakeeping program to predict seakeeping performance in ship design. (Program code 100).

4) The damage stability program (Program code 079).

5) An available drawing program for the drawing of hydrostatics curves.

#### **4.1 Interactive Operation**

A pilot interactive version of PRELIKON currently exists. The purpose of this task is to study the feasibility of further developing this version - enhancing it with graphic input/output and real-time conversational operation.

#### **4.2 Further Development**

Once the tasks of this project are finished, further development of the system will depend heavily upon feedback from use of the system by the American shipbuilders and design agents. Should the industry prefer hull scientific programs other than the MarAd or SRS programs, it is possible to either substitute or attach the selected programs to the system. However, major changes must be agreed upon by a majority of industry users.

USE OF CAPICS FOR CABLE LAYING  
AND SIZING IN TANKERS

F. M. Priborsky  
Electrical Research Association  
and  
J. McIver  
Cammell Laird Shipbuilders

Mr. Priborsky has a degree in Electrical Engineering from the College of Advanced Technology, Birmingham, England. He has held posts as a design engineer and programmer with a petrochemical contracting organization and systems analyst with a cable manufacturer. He currently manages the systems team in the CAD engineering unit at ERA.

Mr. McIver, with Cammell Laird Shipbuilders, collaborated with Mr. Priborsky in writing this paper.

Towards the end of 1969 the National Research and Development Council, a government body in Britain, was approached by three major engineering companies acting as an ad-hoc committee:

British Nuclear Design and Construction Limited, Humphrey's and Glasgow (petrochemical contractors) and James Kilpatrick & Son Ltd. (design engineers). Each of the firms had developed computer programs to handle different aspects of the work involved in designing, installing and commissioning electrical cabling projects. Together they saw the need for a complete and unified system, which would be of national value but which would be too large an undertaking to be economically justified by any one firm individually. After discussion and negotiation, the NRDC commissioned the Electrical Research Association (ERA) to develop and exploit a set of linked computer programs to handle the total task.

The system is known as CAPICS, an acronym for 'Computer Aided Processing of Industrial Cabling Systems'. The development was entirely funded by the NRDC and was completed towards the end of 1971 at a cost, up to that date, of £120K. Since that time ERA has been selling copies of CAPICS and has created a computer service bureau based on the package. CAPICS has been used, for example, for the cable design of three power stations, several chemical plants and oil refinery extensions. CAPICS is also being used at present in the cable design and installation phases of six off-shore oil production platforms in the North Sea. Relevant to this symposium is the fact that Cammell Laird Shipbuilders are using CAPICS for all their ships now and in the future.

Although CAPICS was not originally conceived for use in ships, I will try to demonstrate its application to the problem of cable system design in ships. In order to do this, I will draw very heavily on information supplied to me by the Cammell Laird Shipbuilders, obtained through personal interviews with the people using the system and through my own involvement.

At this juncture I should like to go into a little detail in order to familiarize you with some of the features that CAPICS offers. Figure 1 is a pictorial representation of the CAPICS system.

The designer has to provide the following data:

1. Basic Project Data
2. Route Segment Data
3. Cable Details
4. Equipment Data
5. Current Rating Data

The Basic Project Data required is details of the contract name and number, ambient temperatures likely to be met in different areas, tables of fuse ratings to be used as well as requests for different interrogation facilities.

The Route Segment Data is required to allow the computer to hold a representation of the available permitted cable ways that the designer has established on the layout drawings for the vessel. The designer defines his permitted cable routes SEGMENT by SEGMENT describing the environment through which the cables are to pass. At the end of a segment is a NODE

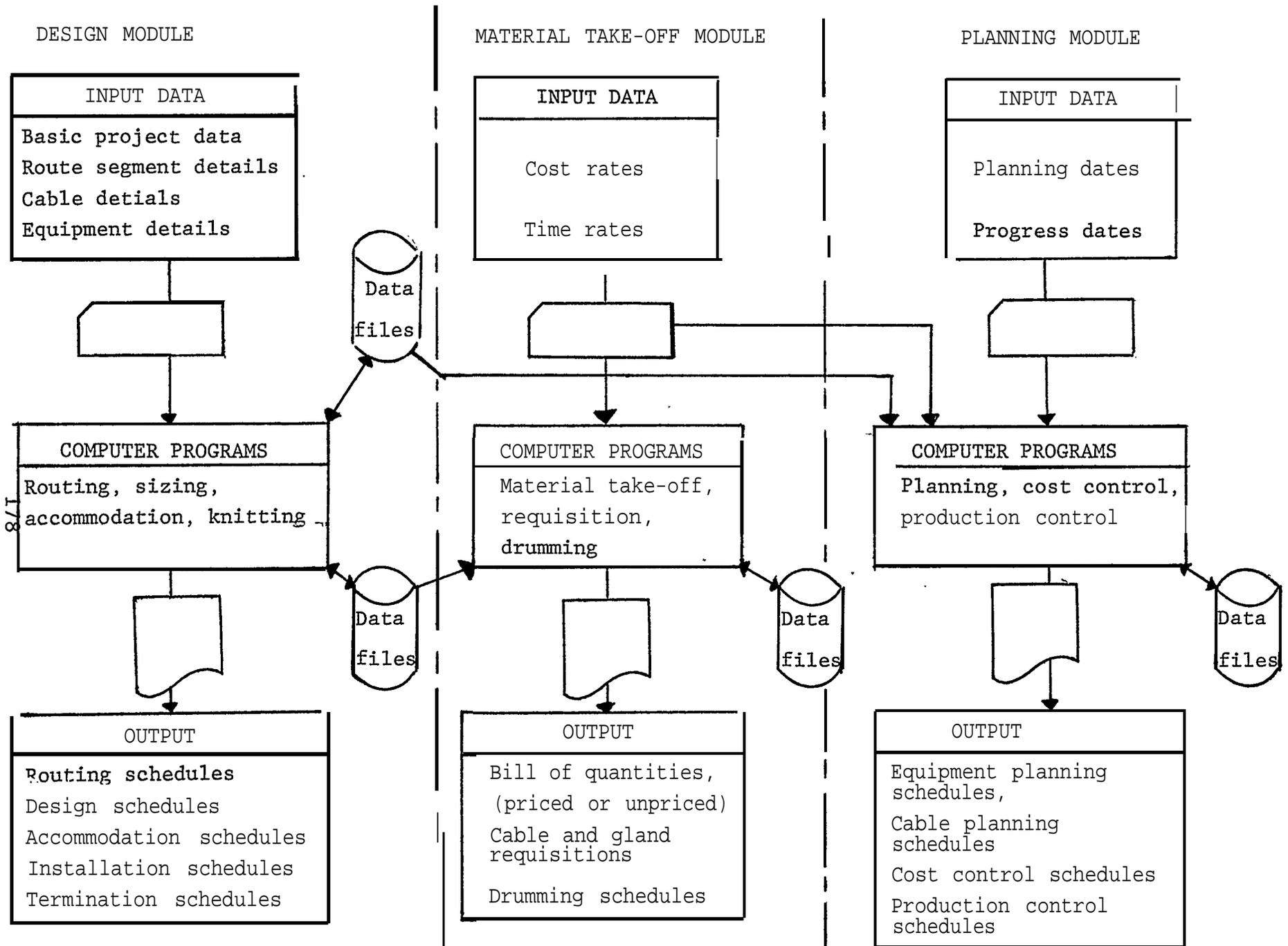


Figure 1. CAPICS Modules

uniquely identified by a 4 character code eg. , SA04. The alphas may represent an area or equipment on board such as MAIN DECK (MD) , ENGINE ROOM (ER) , SHAFT ALTERNATOR (SA). In Figure 2, the heavy black lines represent cable segments, and the dark circles at the ends and connecting points are nodes.

Information for each cable is entered, such as the start point and destination, cable type and the type of equipment that the cable is feeding. The cable numbering method can be chosen to represent ships supply systems e.g., generation, primary distribution, DC systems, and must reflect the cable function (chosen from a table) .

Equipment numbers can be chosen to represent the vessel section, compartment, sub-compartment and can also be used to identify the department responsible for ordering the equipment.

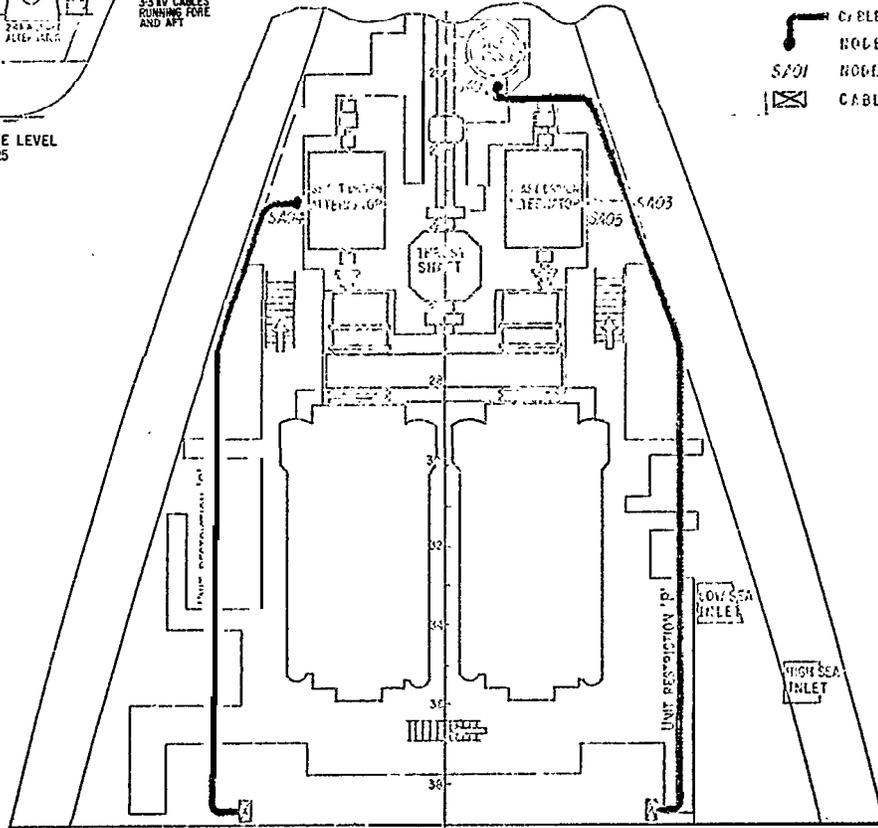
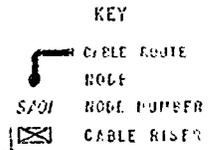
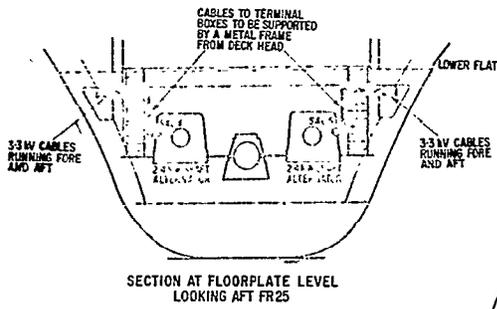
The design module of CAPICS will then perform the following functions:

- Create the routing matrix.

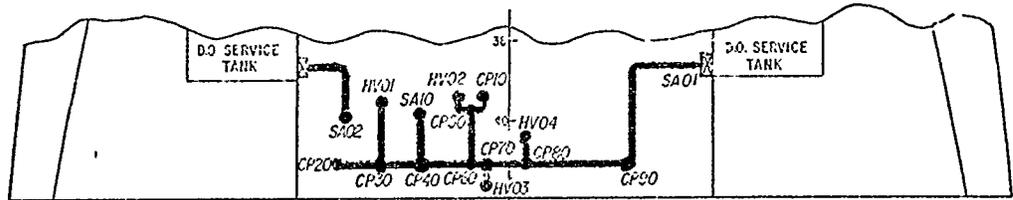
- Find the shortest route available for each cable, taking into account any restrictions imposed by the designer e.g., port side cable run only.

- Examine the routing matrix and scan each cable route considering the environment of each segment.

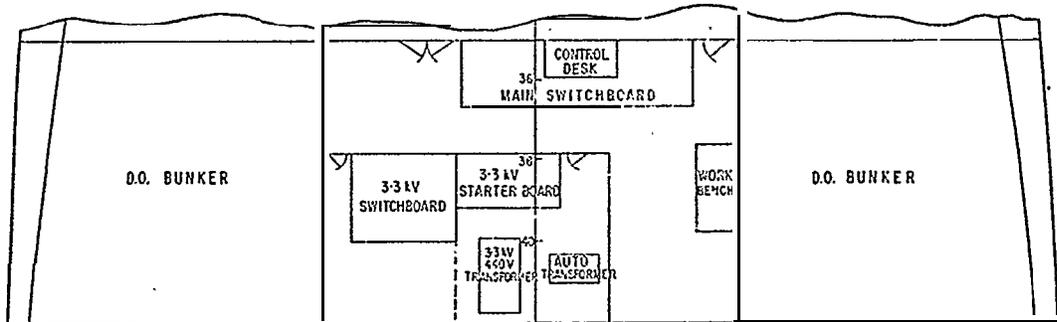
- Calculate a rating factor for the cable taking into account the thermal effect of neighboring cables in accordance with published ERA standards or other standards.



PLAN AT FLOORPLATE



PLAN AT LOWER FLAT



PLAN AT UPPER FLAT

SHIPBUILDERS LTD		ISSUE AND AMENDMENT	DATE	CHKD.	TITLE
DRG. NO.	CONTRACT No.				
1					3.3 kV CABLEWAYS

Fig. 2. Vessel Layout Drawing Showing Cables  
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The rating factor thus calculated is used in conjunction with the electric data within each cable record to calculate the smallest cross-sectional area necessary to fulfill the following criteria:

1. Current carrying capacity
2. Voltage drop within limits (at start and normal load)
3. Short-circuit capacity
4. Fuse size
5. Bursting limit

There is also a facility which will allow various types and combinations of types to be compared with each other in order to find the smallest cross sectional area given a choice.

CAPICS calculates the space required to accommodate the cables within each route segment and indicates whether or not overflow has occurred. (See Figure 3.)

CAPICS attempts to minimize cross-overs along every route and produces a report of cables per segment with the cables arranged in the correct order for laying. (See Figure 4.) At this point the designer may enter any changes that may occur either to the routing matrix or cable data, perhaps due to late arrival of data or design changes. The system will automatically take due regard of any changes which could affect the routes and/or sizes of previously entered cables. For example, if it is necessary to remove a particular segment from the routing matrix, then the system will automatically put any cables which are already in that segment back into the system

CAPICS-ERA  
PRINT DATE 06/08/73

PROJECT NO. C/001364

ROUTE SEGMENT DETAILS SCHEDULE  
PROJECT NAME ESSO TANKER

SHEET NO. 22  
DRG. NO.

①	②	③	④	⑤	⑧										⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯
FROM NODE	TO NODE	SEG LENG.	RESTR SEG U	LEV NO.	WEIGHT	DIA POWR	DIA POWR	DIA COHT	NO. OF MULT	CABLES SINGLE	AND CORE	CIRCUITS COHT	SUB SEG	INST CODE	SUB LENG	LEV NO.	RF SUB	NO. MOD	NO. LAY.	SP. USED.	SPACE +AVAIL	SPACE -OVR/F
PD18	PD24	2		1	0.00	0.0	0.0	0.0	0	0	0	0	1	BBQABDQ	2	1	0	99	5	Y	0.00	+14.85
PD18	PD40	1		1	0.00	0.0	0.0	0.0	0	0	0	0	1	BBQABDQ	1	1	0	99	5	Y	0.00	+14.85
PD19	PD20	1		1	0.00	0.0	0.0	0.0	0	0	0	0	1	BBQABDQ	1	1	0	99	5	Y	0.00	+14.85
PD19	PD26	2		1	0.00	0.0	0.0	0.0	0	0	0	0	1	BBQABDQ	2	1	0	99	5	Y	0.00	+14.85

① SEGMENT  
FROM NODE TO NODE

② SEGMENT LENGTH  
IN METERS

③ RESTRICTIONS  
SEGMENT AND UNIT.  
"Y" - NO RESTRICTION

④ LEVEL  
SEPARATION LEVELS AVAILABLE  
ALONG THE ROUTE SEGMENT

⑤ WEIGHT  
TOTAL IN KILOGRAMS PER METER

⑥ DIAMETER  
AVERAGE DIA. OF EACH TYPE  
OF CABLE IN KILOMETERS

⑦ ASTERISK  
WHEN PRESENT, INDICATES  
WHICH CABLE OVERFLOWED

⑧ NUMBER OF CABLES & CIRCUITS  
MULTICORE, SINGLE CORE AND  
CONTROL/INSTRUMENT. FOR  
SINGLE CORE CABLES, NUMBERS  
OF PHASE & NEUTRAL CABLES, AND  
NUMBER OF CIRCUITS ARE LISTED  
SEPARATELY

⑨ SUB-SEGMENT NO.  
SEGMENTS CAN BE DIVIDED INTO  
"SUB-SEGMENTS" SO THAT SOME  
CABLES MAY RUN ON TRAY, OTHERS ON  
J HANGELS, ETC. IN GENERAL  
SUB-SEGMENTS SAME AS SEGMENTS.

⑩ INSTALLATION CODE  
THIS DESCRIBES THE METHOD OF  
INSTALLATION OF CABLES. THE  
INFORMATION IS USED BY THE  
COMPUTER

⑪ SUB-SEGMENT LENGTH  
SAME AS SEGMENT LENGTH

⑫ SUB-SEG. RATING FACTOR  
CALCULATED BY THE COMPUTER,  
WHERE APPLICABLE

⑬ NUMBER OF MODULES  
1 MODULE IS EQUIVALENT TO  
0.15 METERS WIDTH OF TRAY.  
"99" INDICATES WIDTH NOT  
SPECIFIED

⑭ NUMBER OF LAYERS  
OF CABLES ON TRAY

⑮ SPACING  
BETWEEN CENTERS, IN METERS.  
T - TOUCHING

⑯ SPACE USED/AVAILABLE  
WIDTH OF TRAY, IN METERS MINUS SIGN  
INDICATES OVERFLOW - MAY MEAN AN  
EXTRA LAYER OF CABLES

Figure 3 ROUTE SEGMENT DETAILS, SAMPLE OUTPUT

CABLE NO. COMPUTER NO. USER NO.	H1 NO. PHASE NEUT	TYPE CABLE DESCRIPTION	CSA PHASE NEUT	FROM		TO		LENG	DSL	CABLE ROUTE NODE NUMBERS	REMK REV. DATE
				NODE GLAND	EQUIPMENT NO.	NODE GLAND	EQUIPMENT NO.				
EQUIPMENT DESCRIPTION				DRAWING NO.							
SET-AB LEVEL-1											
2002M0/1-3 AB	S 05	3 CORE 3300/3300V ST. CU CSP HOFBR SHEATH.	95.00	SA04	AA	SA02	AA	25	D	SA04 SA02	
ROM = NO2 SHAFT ALTERNATOR STBD O = NO2 SHAFT ALTERNATOR BREAKER											

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- ① **CABLE NUMBER**  
SUFFIX INDICATES TYPE OF CABLE:  
C - CONTROL  
F - TELECOMS  
H - PNEUMATIC PIPING  
I - INSTRUMENT  
K - 6-6KV POWER  
M - 440V & DC POWER  
N - 440V TREFOILS  
P - PRESIZED POWER  
(THESE SUFFIXES MAY VARY)
- ② **SET**  
ALL CABLES WITH A COMMON START NODE HAVE THE SAME "SET"
- ③ **LEVEL**  
SEPARATION LEVELS:  
1 - 440V & D.C. POWER  
2 - 440V TREFOILS  
3 - 6-6KV POWER  
5 - CONTROL  
7 - INSTR. & PNEUMATIC
- ④ **RESTRICTION**  
A CABLE BEARING A "UNIT" RESTRICTION LETTER WILL BE ROUTED ONLY ALONG SEGMENTS WITH THE SAME OR NO RESTRICTION. THOSE WITH "SEGMENT" RESTRICTION LETTERS CANNOT BE ROUTED ALONG SEGMENTS BEARING THAT RESTRICTION LETTER. THIS INFORMATION IS USED BY THE COMPUTER FOR ROUTING CABLES
- ⑤ **CABLE TYPE H1 NUMBER**  
THIS NUMBER UNIQUELY IDENTIFIES THE TYPE AND SIZE OF CABLE.
- ⑥ **CABLE DESCRIPTION**  
ABBREVIATED DESCRIPTION OF CABLE AND SYSTEM
- ⑦ **CROSS SECTIONAL AREA**  
OF CONDUCTORS IN SQ.MM. ALSO SHOWN FOR NEUTRAL CONDUCTOR IF DIFFERENT FROM PHASE C.S.A.
- ⑧ **NODES**  
NODE REFERENCES AT WHICH CABLE STARTS AND FINISHES
- ⑨ **GLANDS**  
GLAND-TYPE CODE FOR EACH END OF CABLE
- ⑩ **FUSE**  
CIRCUIT FUSE OR BREAKER RATING IN AMPERES
- ⑪ **DRAWING NO.**  
(THIS FACILITY NOT USED)
- ⑫ **CABLE LENGTH**  
IN METERS
- ⑬ **DSL MARKER**  
LETTER INDICATES THE DESIGN STAGE REACHED ON CONSTRUCTION ISSUES. THIS LETTER SHOULD ALWAYS BE "D"
- ⑭ **CABLE ROUTE**  
EVERY NODE THROUGH WHICH THE CABLE PASSES IS LISTED
- ⑮ **REVISION DATE**  
IF CABLE IS ALTERED DATE IS PRINTED HERE

CABLES LISTED IN ALPHA-NUMERIC OR SET AND LEVEL ORDER ACCORDING TO MODULE

Figure 4 INSTALLATION CABLE SCHEDULE, SAMPLE OUTPUT

and automatically reroute them. Likewise, if a change is made which could affect the size of a cable, then the system will automatically take care of that situation not only re-sizing the cable in question but automatically rechecking the size of all neighboring cables and recommending any size changes. The final action to be taken is then up to the discretion of the designer.

Besides the route segment details schedule and the installation cable schedule, CAPICS' Design Module also generates a design cable schedule, accommodation schedule, termination schedule, equipment schedule, and a cables-per-segment report.

Considerations will now be given to the reasons for Cammell Laird's examining the use of computer systems. Cammell Laird's initial task was to find a system for cable scheduling of merchant vessels which would allow the cable length and route to be predetermined with a greater degree of accuracy than was currently being achieved.

Another requirement was to be able to cut individual cable lengths in the stores and then group them together in a logical manner so that they could be arranged on the cable ways in the correct order. Thus the short term requirement was to create a cable processing system which controlled the usage of cable from the drawing board stage to installation. The long term requirements were to have a cable processing system capable of being integrated into the company's activities and compatible with the company's aim of reducing vessel building times. To paraphrase, Cammell Laird's basic requirements

of a cable processing system were as follows bearing in mind that the selection and sizing of cables and subsequent installation is one cost which is directly controlled by the ship-builder):

The method of cable sizing should be logical and defined.

The route that a cable is to follow should be predetermined and adhered to.

The individual lengths of cable should be cut at the stores and grouped for ease of installation without measuring at the vessel.

The initial reactions of Cammell Laird to CAPICS were:

- 1) The following features which they required were present:
  - a) logical cable selection and sizing
  - b) shortest route capability
  - c) installation information was contained in CAPICS.
- 2) The CAPICS programs were not designed specifically for ships and might need modifications before they could be applied.
- 3) There were some programs that would not be used, at least in the short term.
- 4) The number and variety of computer input sheets appeared to worry and confuse uninitiated drawing office staff.
- 5) Cammell Laird's small computer could not handle the programs.

6) The fixed format of the input data could be tolerated but might be restrictive.

Cammell Laird decided to apply the CAPICS Design and Materials Take-Off modules to a 20,000 DWT products tanker, the "Esso Severn". This vessel was similar to two other vessels, the "Esso Mersey" and the "Esso Clyde". This similarity enabled Cammell Laird to use the drawings of the earlier vessels and allowed the section in the Drawing Office dealing with the CAPICS evaluation to devote their whole attention to operating the CAPICS system. It is probably worth noting here that most of the staff in the drawing office were men of maturity having had no previous exposure to computer-based systems.

Cammell Laird realized at the outset that they would like to modify/simplify some of the output but decided to use the existing programs with some modifications in order to appreciate in detail, their full scope and extent.

The timescale of the exercise was:

Feb. 1973	CL learn of CAPICS.
April 1973	Contract placed.
June 1973	ERA Training Course.
Dec. 1973	Majority of input complete and output received.
March 1974	Vessel launched.
Oct. 1974	Vessel scheduled for hand-over.

At the same time as the technical evaluation, a financial exercise was initiated to evaluate the possible benefits. The components of cost considered for evaluation were:

Drawing office time to prepare input data  
ERA charges for computer time and engineering assistance

Drawing office time for checking output results  
Program modifications to suit Cammell Laird.

The total number of manhours used for the first two tasks was 1913. This time, of course, includes "learning time". It is not easy to assess the reduction as experience is gained, but Cammell Laird's own estimate is that the figure could be reduced to 1000 hours for the same number of cables, which was in fact 1730.

Due to Cammell Laird's limited computer capacity, they bought time on the ERA computer and dispatched data sheets to ERA for processing. This also gave CL reassurance knowing that ERA would be examining the input and output. The standard of the drawing office work was quite high; their input error rate was very, very low especially when considering that this was their first attempt.

The cost of the services provided by ERA at 1972 prices was £3500. Program modifications were implemented at a cost of £2K, and these modifications are available to all CAPICS users.

Thus , the balance sheet of costs was:

Drawing Office	1900 HOURS at £1.25/H =	2500
ERA changes		= 3500
Miscellaneous		= 500
		<hr/>
		6500
Program modules (which will be spread over several ships.)		2000
		<hr/>
		£ 8500

As a result of this evaluation and the quality of the control it produces, CL is using CAPICS on all their current and future vessels. These are:

- 4 32,000 DWT Product Tankers
- 5 55,000 DWT Product Tankers
- 2 55,000 DWT Product Tankers (but with different electrical systems)

The cost of using CAPICS on each vessel will be around £2000 per vessel. The cost of cable installed per vessel is approximately £40-50K and the estimated savings on materials per vessel at present are estimated at 10%.

Cammell Laird has put forward the following as advantages to be gained by using CAPICS:

1. The format of the input data sheets places a discipline on the draftsman, and the overall program for maintaining the progress of the data sheets enables the drawing office manager to exercise better control of the office.
2. The cable sizing aspect of CAPICS has caused CL to reassess some of its established ideas on cable sizing and ratings.
3. The material take-off and cable requisition documents have caused CL to evaluate the production of a range of preferred cable sizes--leading to standard cables.
4. For similar ships the same completed data files can be used, drastically reducing the amount of input data for successive vessels.

5. The cutting of cables in the stores (and the other systems developed to support this) has saved cable, reduced installation time and provided a basic tool for maintaining installation progress.

One of the main problems for CL was the turnaround time since they used a bureau located at a distance. There are two major developments taking place at the moment which will enable turnaround to be reduced greatly and also to realize one of the requirements mentioned earlier--fully integrating CAPICS into the company's activities.

Cammell Laird is currently setting up and using the Honeywell Database Management System established on the Honeywell Mark III Timesharing Service (HTS). After using the system for some weeks, it became apparent that most of the data necessary for entry to CAPICS is contained within the database. The obvious move now is for Cammell Laird to allow ERA access to its files which will be interrogated in such a way as to make the cable data acceptable to CAPICS. This will involve comparatively minor software changes.

CL cable data will then be processed on the computer at ERA and the results put up on the Mark III Timesharing Service where CL will access the various output and either update their DMS directly or allow their designer to make design changes.

Initially, the data checking will still be done within CAPICS, but it is only a matter of time for CL to obtain an intelligent terminal or programs written for the HTS to do

most of the data checking. This will serve the dual purpose of speeding-up turnaround time and giving the designer a greater sense of involvement and control.

The DMS control language is very simple but powerful allowing complete flexibility when interrogating the results and creating hand copies of final results--thus freeing CL, or indeed any user, from the necessity for using formats which might or might not suit the organization.

The structure of the Cammell Laird database embraces the following activities:

1. Cable Control: cable requisitions, order, receipt, and invoice.
2. Cable Stock: An inventory of existing cable stock which will also receive an output from the cable control file when cable is received.
3. Transit Schedule: Defines the cable lengths to be cut and the sequence of dispatch to the vessel.
4. Cables Allocated: As cable is cut, the cable stock is correspondingly reduced and the cable required for each vessel is recorded.
5. Connection File: List of terminal connections, up-



follows:

1. The exercise has led to the imposition of a disciplined approach to cable system design and installation.
2. There were savings on materials and it is not too optimistic to assume an increasing saving in manpower as experience increases.
3. This has helped the move toward integrating the design function with all the other activities within a company, thus increasing control.
4. The exercise resulted in a better understanding between CL and ERA of shipbuilders' problems, leading to definite future developments.

#### FUTURE CAPICS DEVELOPMENT FOR SHIPBUILDING

1. Fault level calculations (using expertise already well established within the CAD engineering unit).
2. System discrimination.
3. Economic comparisons of different systems to be evaluated.
4. Calculation of the voltage drop at all subdistribution boards in the system.
5. Calculation of the volume of the cable way required and the weight of cable per meter to determine the cable way dimensions and supports.
6. The material take-off module can be further developed to define cable hanger requirements together with support attachments.

Figure 6 illustrates CAPICS' operation on a world-wide scale.

HONEYWELL MARK III  
TIMESHARING:  
DATABASE MANAGEMENT SYSTEM

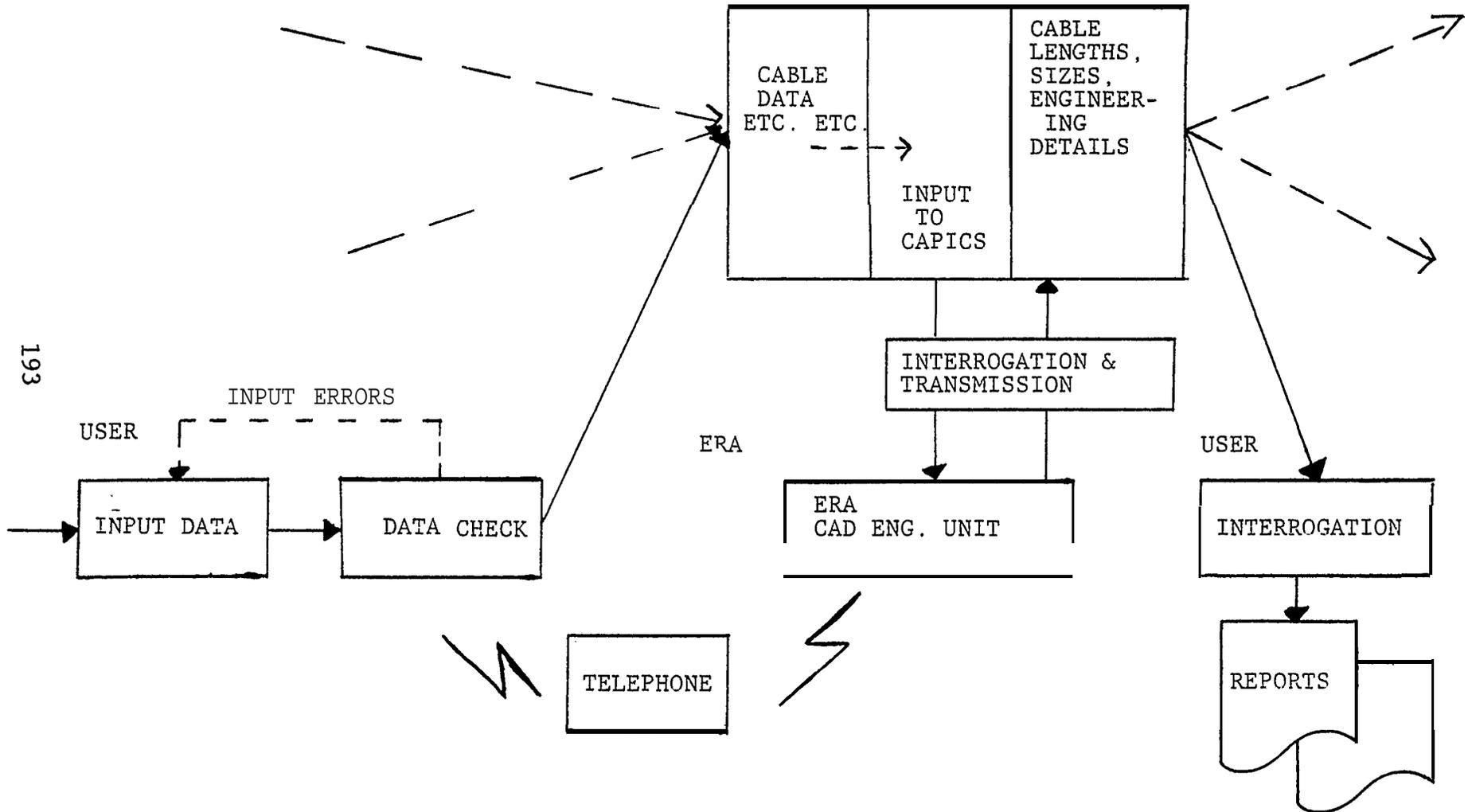


Figure 6. CAPICS World-Wide

## FUTURE GENERAL CAPICS DEVELOPMENT

At present the system processes data from layout drawings and equipment data which must be manually prepared on input forms and punched on cards. This data preparation and subsequent modification for cable and route segment input and the preparation of cable routing drawings are the main manual operations involved. The system will benefit most if on-line design methods are introduced in this operational area.

The equipment for on-line data preparation and modification should satisfy the following requirements:

- a) Be compatible with the existing system,
- b) Be operable by capable but not necessarily highly qualified staff.
- c) Provide visual and automatic verification.
- d) Allow subsequent data modification,
- e) Have capability for output plotting.

The operational methods considered at present require the following equipment available on the market:

- a) Digitizing drafting table with menu tables and coordinate sensing device and full keyboard for alphanumeric input.
- b) Minicomputer.
- c) Graphics controller and storage tube display.
- d) Magnetic storage media.

The work carried out on this equipment will basically consist of placing the plot plan onto the digitizing table and beginning to plot the available cable routes, segment by segment.

For each route segment the additional information, such as elevation, alpha-numeric coded input for method of installation, number of modules, restrictions etc., will be provided through the keyboard or menu tables. Each set of segment data input will be displayed onto the display panel for visual verification and amendment through the same media if errors are found. The visually verified segment data will be processed through the minicomputer, edited for logic errors, and using the graphics controller, displayed on the storage tube with an indication of any errors detected by the computer. After correction, the verified segment data will be stored. The processing of cable data will follow the same procedure,

The segment and cable data will then be processed in the normal way through the CAPICS design module to obtain the necessary design output .

The quicker data preparation and on-line verification leading to better accuracy should increase the efficiency of the operation, and at the same time reduce the involvement at the detailed job level of more highly qualified technical staff. Furthermore, since the route segments will be described using three-dimensional coordinates, graphic output of the cable routes can conveniently be obtained using standard data plotters. This would remove, in some instances, the need for manually prepared cable routing drawing thus further reducing the time factor and improving the overall efficiency.

In conclusion, I should like to acknowledge the very considerable help given to us by Cammell Laird Shipbuilders in allowing us to give some insight into their method of operation and for allowing us time to tell you something about CAPICS and what we feel future trends should be in cabling system design.

Thank you.

UNIFIED HULL DEFINITION SYSTEM

Michael Aughey  
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Mr. Aughey is a naval architect in the Special Projects Section of the Naval Ship Engineering Center. His 15 years of computer experience with naval architecture were gleaned through marine engineering at Newport News Shipbuilding and Dry Dock and computer aided ship design at NAVSEC.

## UNIFIED HULL DEFINITION SYSTEM

### Background

The Navy's CASDOS system as originally conceived was supposed to interface with a computerized fairing system developed by another agency. The fairing system didn't pan out, and Arthur D. Little, Inc., the CASDOS contractor, was asked to "review and evaluate previous work done on the lines fairing problem to determine the most appropriate approach for solution" as a preliminary step to developing a lines fairing system.

The result of this effort was a 100-page report entitled "Approaches to Computerized Lines Fairing" dated February 1971. This report details the mathematical techniques used in smoothing points, lines and surfaces, and more importantly, details the known problems, deficiencies and loftsmen's objections to these methods.

Rather than performing independent research for this discussion of the Unified Hull Definition System, I have taken the liberty of abstracting and quoting freely from the ADL report, and wish to credit its authors for critiques of various lines fairing systems just in case the shortcomings of these systems are not as grievous in 1975 as in 1971.

Among the recommendations of the ADL report is the following:

Quote: Because none of the existing fairing systems work sufficiently well and because so many people in the ship building industry have their own viewpoints regarding the best approach to lines fairing, we believe that any new approach would have a great deal

of difficulty gaining general acceptance. We feel what is really needed is just a simple procedure of producing a mathematical hull definition from offset data.

We feel that under these circumstances, the best policy is to develop a system based on the "quick-look" component of CASD3S. END QUOTE

## General Nature of a Ship's Hull Surface

Consider the surfaces of the port half-shell in Fig- 1 bounded by the various control lines. The ship's surface in the region bounded by the centerline and the half-siding line will be a flat plate. Similarly, the surface in the region bounded by the half-siding line and the bottom tangent line will be flat, or straight, in the transverse plane. The surface in the region bounded by the bottom tangent and the knuckle line exhibits the properties which are most important to this discussion. Any line on this surface will be smooth and continuous in first and second derivatives, and will have only one or two widely separated inflection points. A similar statement can be made about the region between the knuckle line and the main deck.

By looking at frame lines, we see that when two regions are joined at a knuckle line the surface has a first derivative discontinuity. Similarly, when we consider regions connected at tangent lines, we discover first derivative continuity but second derivative discontinuity.

The nature of a ship's surface, and of lines within the surface, suggest the use of a mathematical spline curve which is an approximation to the draftsman's batten. Problems associated with large slopes in the use of mathematical splines have been overcome by the method of parametric curve fitting suggested by Ahlberg, Nilson, and Walsh (1967), "The Theory of Splines and Their Applications." Such parametric splines are used to define all lines in the CASDOS and Unified Hull Definition Systems. The CASDOS Hull Definition System used parametric splines to define the edges of a series of Coons patches, which were arranged in stacks between transverse planes. Unfortunately, the Coons patches as implemented did not maintain even first derivative

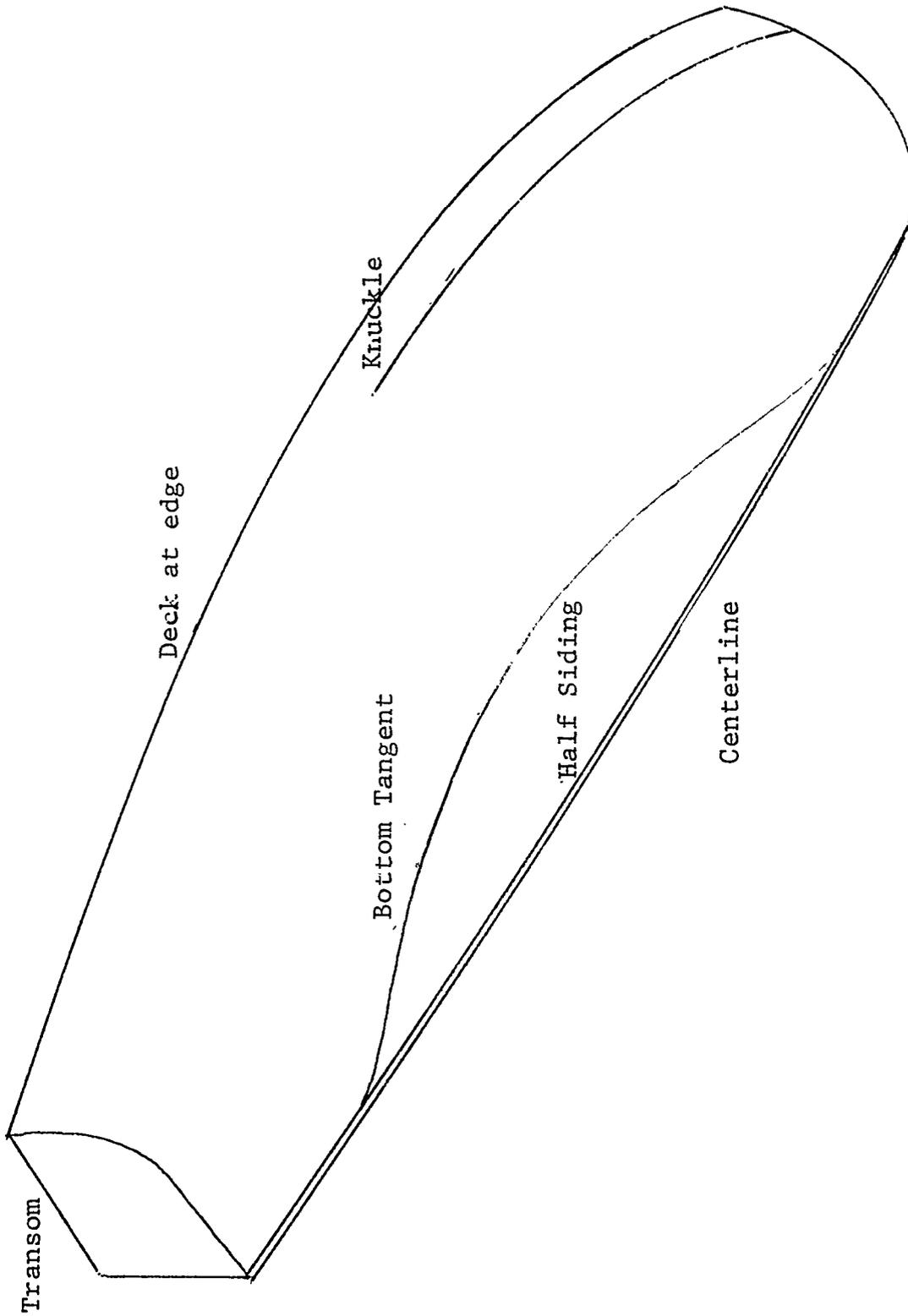


Figure 1 - Isometric of port half-shell

continuity across their boundaries, thus a hull surface so defined contained cusps or ridges at patch boundaries.

Due to this deficiency, the recommendation for a lines fairing system based on the "quick-look" component of CASDOS was rejected and the new Hull Definition System was begun.

#### Objectives of the New System

The Unified Hull Definition System is intended to produce many of the elements of the ship design and construction process which require a mathematical and/or graphical description of the hull. Among these are:

- a. the traditional three-view lines plan of faired stations  
(or frames), waterplanes, buttock planes and diagonal planes
- b. a table of offsets including first and second differences
- c. N/C instructions for the automatic milling of hull models
- d. deck and bulkhead outlines for arrangements
- e. input for hull characteristics (volumes, areas, centers, etc. )
- f. input for theoretical analyses such as Speed/Power and Seakeeping
- g. shell expansion drawings, plate seam and butt locations, and traces of shell stringers
- h. curved plate development, roll templates for curved plates, and N/C instructions for cutting plates.

The system is further intended to provide a single mathematical description of the ship starting in the early stage of preliminary design in order to avoid the inconsistencies which occur in present day manual practice. For example, the hull model tested for speed/power and

maneuvering will match the lines as faired; similarly, the deck and bulkhead outlines for arrangements and the hull characteristics will be consistent with the faired lines.

Moreover, the system is designed to provide the user with total control over the hull shape. The loftsmen or Naval Architect specifies the shape and modifies it repeatedly after reviewing plots and tables of offsets until the shape satisfies his own notion of "fair". Because of the interaction required between loftsmen and computer, this system is called "Hull Definition" rather than "Lines Fairing" although the mathematical batten utilized to define lines provides a considerable measure of fairing.

#### Selection of Line Type

Existing hull definition systems (CASDOS, AUTOKON, etc.) were known to suffer from a lack of longitudinal definition. Discrete frames or stations are defined, but interpolation techniques are required to determine the shape of the hull between frames. Experience has shown that no interpolation scheme is entirely suitable.

It was therefore decided to define the hull with a set of longitudinal lines, and to generate any required transverse line by connecting the sequence of points at the transverse planes intersection of the longitudinal lines. The tool used for connecting the points is the parametric spline or mathematical batten.

To gain an appreciation of the longitudinal line surface definition, consider the hard-chine, straight frame segment supply vessel of figure 2. It is clear that the precise definition of any frame or station can be found by intersecting the centerline, chine line and deck at edge with the required transverse plane, then connecting the points with straight lines. The coordinates of any point on the station can then be found by intersecting the straight line segments with the desired waterplane, buttock plane, diagonal plane or skew plane. Thus the vessel is entirely defined by the three longitudinal lines and the transom.

A simple extension of this concept is illustrated in figure 3. This destroyer-type hull form is sufficiently defined by the control lines (centerline, half-siding, knuckle, deck at edge and transom) and by the series of lines extending from the centerline-knuckle line intersection to the transom.

Note that this series of lines is formed by the parametric spline connection of corresponding girth fraction points on a selected set of faired stations. Since each line is smooth and continuous in first and second derivatives, we can hope that the surface defined by an infinite number of such lines will also be smooth and continuous. The realities of computation require that we limit this infinite number somewhat. Sufficient iso-girth fraction lines must be defined to describe the desired hull shape, but the fewer the better.

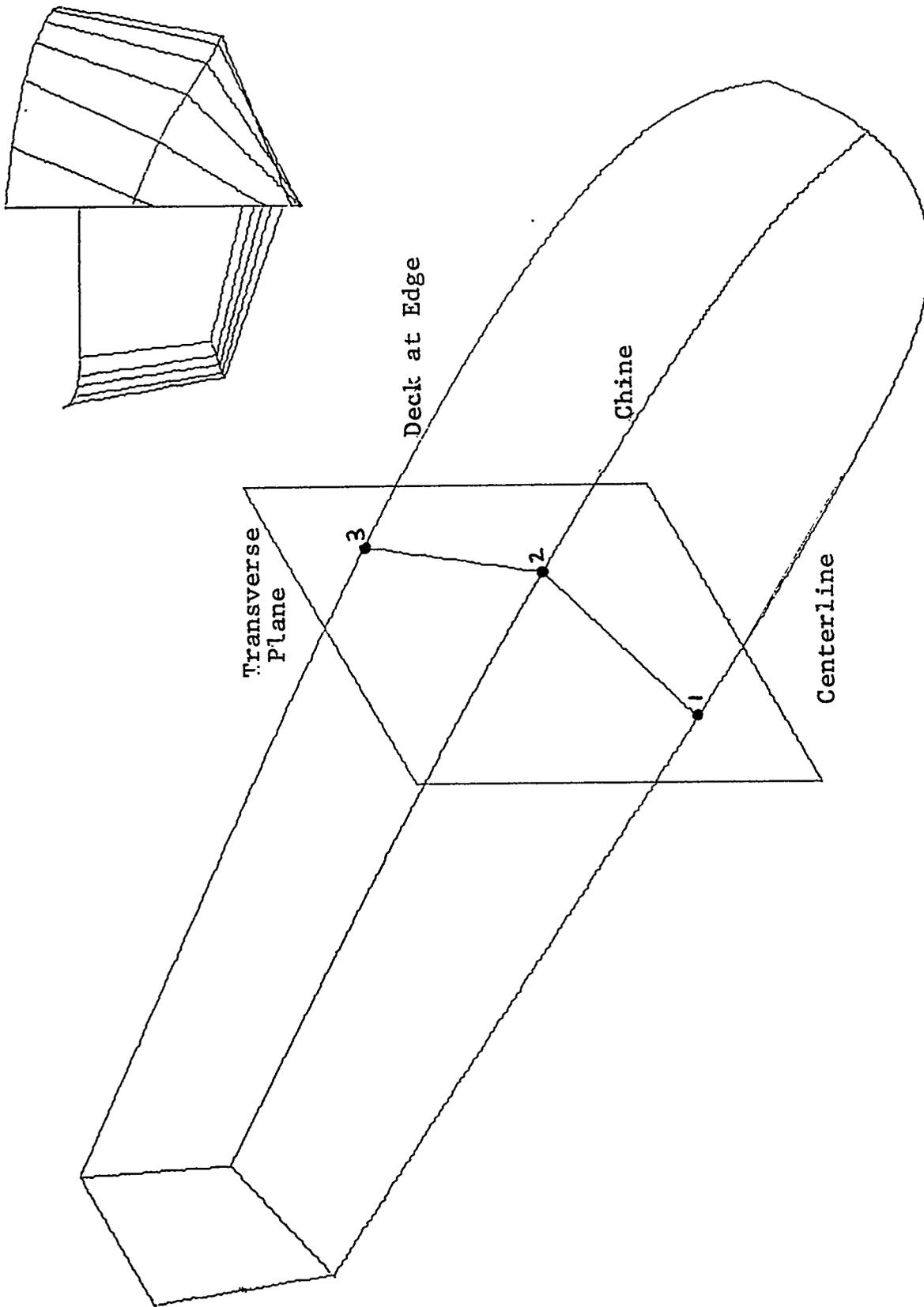


Figure 2 - Hard Chine, Straight Frame Segment **Vessel**

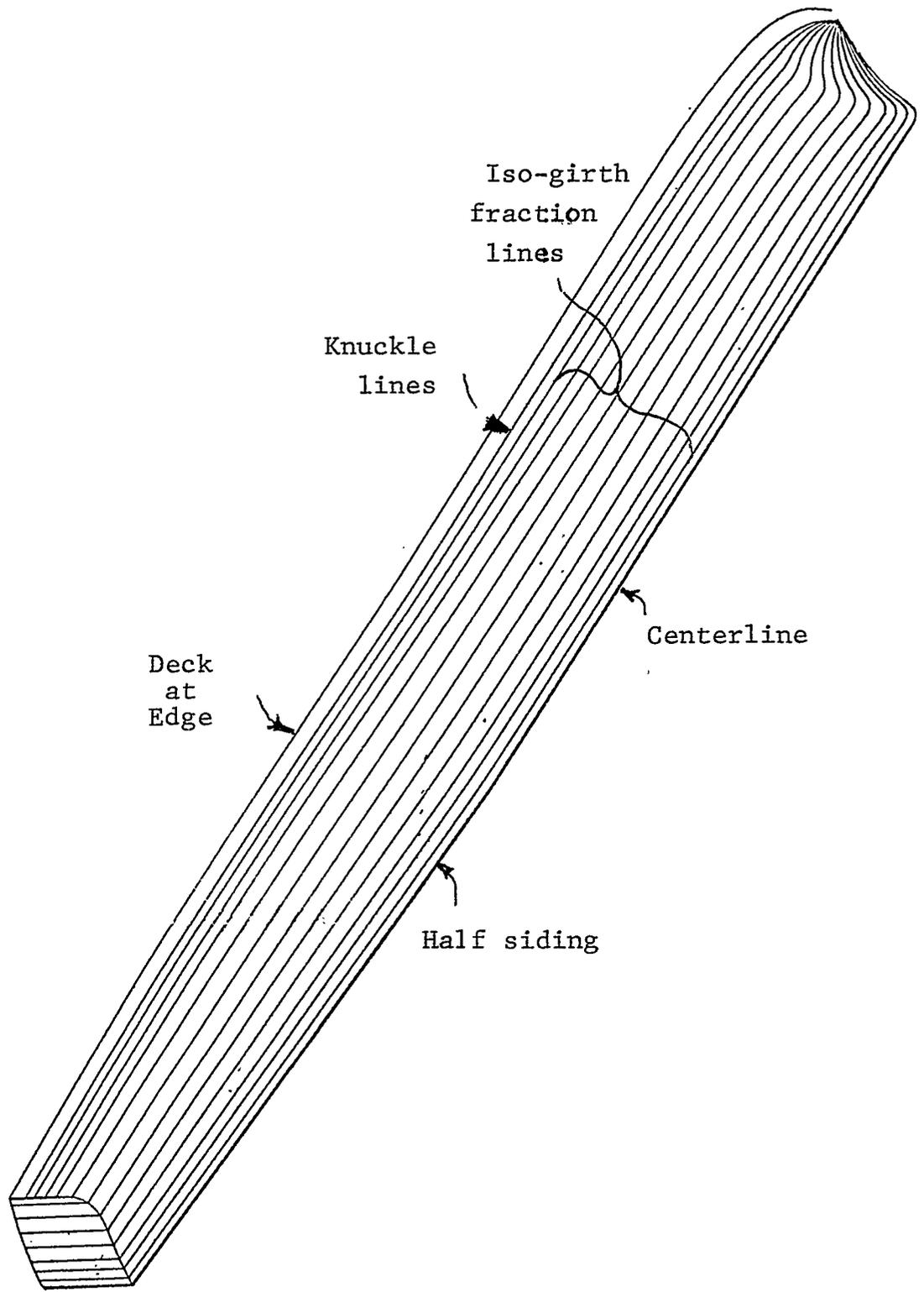


Figure 3 - Destroyer Type Hull Form

Experience to date with this system has been more than encouraging. Ships featuring bulbous bows, bottom and side tangents, tunnel sterns, etc. have been simply defined and judged "fair". NAVSEC has prepared the contract lines drawings for the two most recent designs utilizing the system, and more will follow shortly. A direct link has been provided between the hull definition-lines fairing portion of the system and the hull characteristics program, such that the volumes, centers and coefficients can be immediately examined by the Naval Architect.

The system can also presently provide the table of offsets in feet-inches-sixteenths or decimal(metric), prepare frame, bulkhead and deck outlines for arrangements and provide the inputs for seakeeping analysis.

Short range plarming includes an interface with a computerized arrangements program. Hopefully, as confidence is gained with use, the Unified Hull Definition System will provide the N/C tapes for automatically milling hull models end cutting steel for the fabrication of the full sized vessel.

## ROBOTS IN SHIPBUILDING

Dennis W. Hanify  
IIT Research Institute  
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Mr. Hanify is responsible for the promotional, technical and administrative activities of a group of engineers engaged in the areas of vehicle research, shock and vibration, computer simulation for design and development, vehicle dynamics, automated inspection, ordinance design, automatic and special machines development and fabrication, manufacturing processing and cost analysis.

## INTRODUCTION

Industrial robots are generally considered to be a "new" area of automation although robots have been available since the early 1960's. Most companies are not even aware of the existence of real world robots capable of working in industry, let alone know what they can do or how to apply them. For this reason most papers written for meetings of this type start out with a "This is a Robot" section, followed by a "Robot can do this" and a "Robots have been used here" section. Often this is followed with "Robots will save you this much". But I am not going to do the standard robot bit for this meeting, because I do not believe that the normal robot has a role to play in your industry. Your products are too big and your production runs are too short to be cost effective. Robots are best suited to short and medium production runs that are too slow and too short to justify hard automation and simple enough not to require people. Heavy (in human terms), dull and hazardous work, such as loading and unloading punch presses, die casting and injection moulding machines, spot welding automobile bodies, transferring, palletizing and paint spraying are suitable tasks for today's robots. Tomorrow's robots, equipped with vision and tactile feedback and more powerful control computers will be assembling washing machines, small engines and the like, but not ships. There may be applications in the fittings area or possibly the welding of subassemblies using conventional robots but ships will require something special.

To the best of my knowledge, no shipbuilder is using a robot and no development work in this country is being directed toward shipbuilding robots. In fact, very little robot work is going on in the United States even though the Japanese government is spending millions of dollars in this area; some of it I am sure directed at the shipping industry.

What I am going to present here is a brief review of two robot programs that are being conducted at IIT Research Institute and relate this methodology to some ideas on how robots could be used for shipbuilding if developmental effort were directed to that end.

Industrial Robot Analysis, Multiclient Industrial Program  
(Texas Instruments, Boeing, Northrop, Universal Oil Products, etc.)  
The IIT Research Institute's Robot Technology Center initiated a multiclient industrial assistance program in February of 1974 to perform technoeconomic feasibility studies for clients contemplating the use of industrial robots for the first time. In performing these analyses, we send our roboticists into the clients' plants for a period of two weeks to assess the requirements of the companies' individual production processes relative to the capabilities of current and near future industrial robots. Where a potentially feasible robot application is found a detailed technoeconomic study is performed using techniques we have derived. During these studies, engineering personnel from the client companies are instructed in the feasibility methodology. When the company is willing to provide the necessary cost data an economic risk analysis is also performed using the IITRI ESA (Economic Systems Analysis) computer program.

The techniques utilized in this program, both technical and cost, have direct application to both the state of the art assessment and the cost/performance trade off analysis of virtually any potential robot application, particularly those requiring the development of new systems.

TNT Pilot Plant and Sampling System, U.S. Department of the Army, Picatinny Arsenal, Contracts DAAA21- 73- C-0743 and DAAA21- 74-C-0419. The design, fabrication, and installation of processing systems is also a major activity at IITRI. One example is the low temperature TNT pilot plant that we are currently developing for Picatinny Arsenal.

The TNT pilot plant is one of many experimental pilot operations that will be installed in research building 1031 at Picatinny Arsenal. All of these pilot operations are judged extremely hazardous and must be remotely controlled by both humans and computers from a reinforced concrete laboratory building several hundred feet away. Since people will not be allowed in building 1031 during process operations, drawing off samples from points along the process lines becomes a problem. To solve this problem we have designed and are building seven remotely controllable special purpose explosion-proof robot teleoperators (Figure 1) to draw off 30 ml. samples of the explosive compounds. Working with special explosion-proof sampling valves and refrigerated containers that we also designed and build, the robot teleoperators draw off samples from up to 30 points in the building and place the container on an overhead conveyor system (Figure 2) for transport to the laboratory for analysis. The entire process is monitored by television cameras mounted on each of the seven robots. All systems have been designed to operate in an explosive atmosphere containing vapors of sulfuric, nitric, and acetic acids and acetic anhydride.

At the present time the system is being implemented as a human operated teleoperator. This was done because it was not cost effective at this point in time to automate some of the load/unload functions in building 1031. However the system is designed for computer control and when the operating cycle becomes high enough to justify the cost, the arms will be retrofitted to convert them to true robots.

Once again the technology developed in this program is directly applicable to the tradeoff, design and implementation of any teleoperator or robot system.

#### ROBOTS FOR SHIPBUILDING

Based on the technology we have developed, our knowledge of what the rest of the world is doing in robots and teleoperators, and a brief interface with the engineers at Bethlehem, Sparrows



Point, it seems technically feasible to automate four areas of shipbuilding using robot-like systems. In order of increasing complexity, these areas are painting, sandblasting, grinding, and welding. These four tasks arrange themselves into two groups of similar technology, painting and sandblasting are reasonably straightforward given today's technology while grinding and welding are pushing the state of the art.

### Painting and Sandblasting

Figures 3 and 4 show artists concepts for a robot paint spraying system that is technically feasible, requiring only the development of special purpose hardware. As shown in these figures, both large inside areas such as holds and fuel bunkers and outside surfaces could be painted by the-same basic system. Development of the mechanical arms presents no particular problem even though they are unusually large. The control system however presents some interesting tradeoffs. The system could be man-operated, in which case the machine becomes a very large sophisticated special purpose cherry picker. The system could also use an open loop computer control system. In this case the contours of the surface to be painted, the hull, etc. would have to be programmed into the computer. The computer would then direct the arm to paint the surface even if the surface was not there, or worse yet, it could run the arm into the ship damaging the arm. The most practical and the most sophisticated control system would utilize a closed loop computer control system capable of sensing the presence of the ship. In this case the spray head on the arm (Figure 5) would contain proximity sensors to measure the distance between the spray head and the surface. This information would be transmitted to the control computer that would maintain the proper clearance between the spray head and the surface. Only the general configuration of the surface (end points, corners, openings , etc.) would be programmed and the computer would be told what pattern to paint. Then the computer would direct the arm to paint the required pattern in the x-y plane

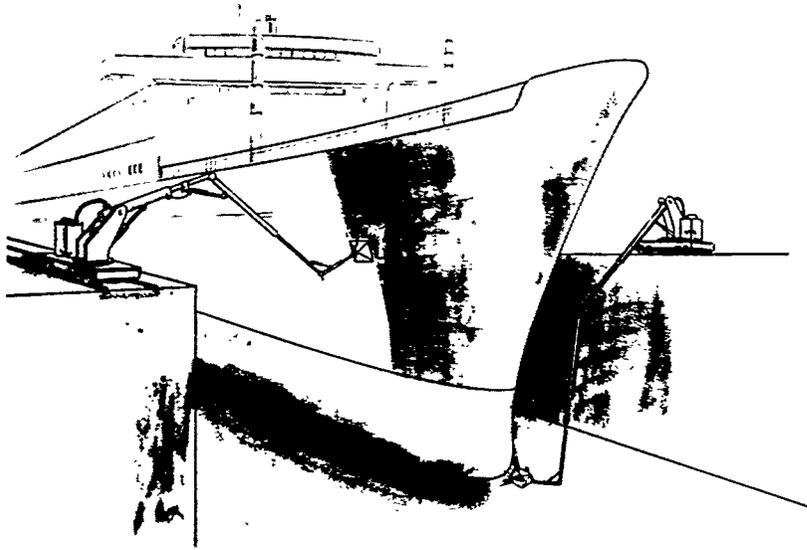


Figure 3 EXTERNAL SHIP PAINTING SYSTEM

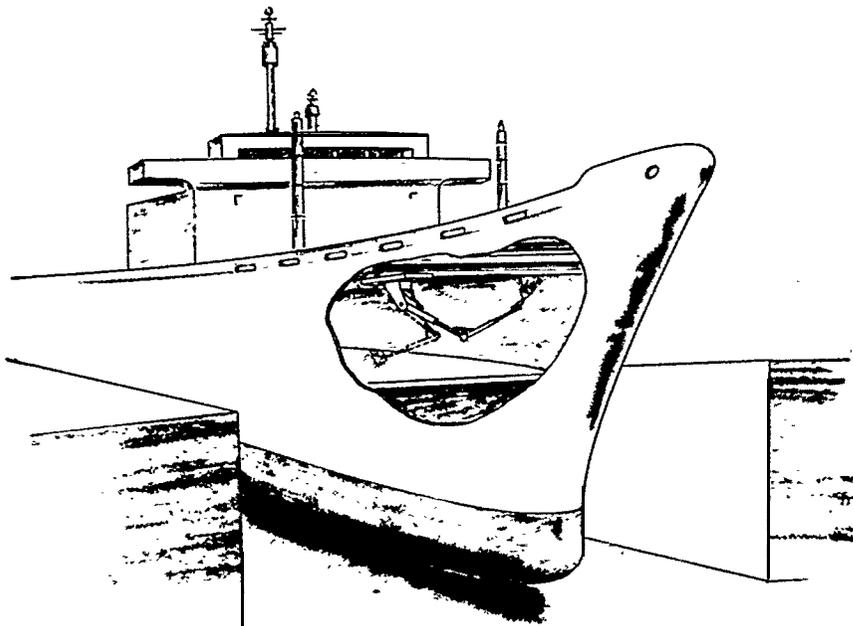


Figure 4 INTERNAL SHIP PAINTING SYSTEM

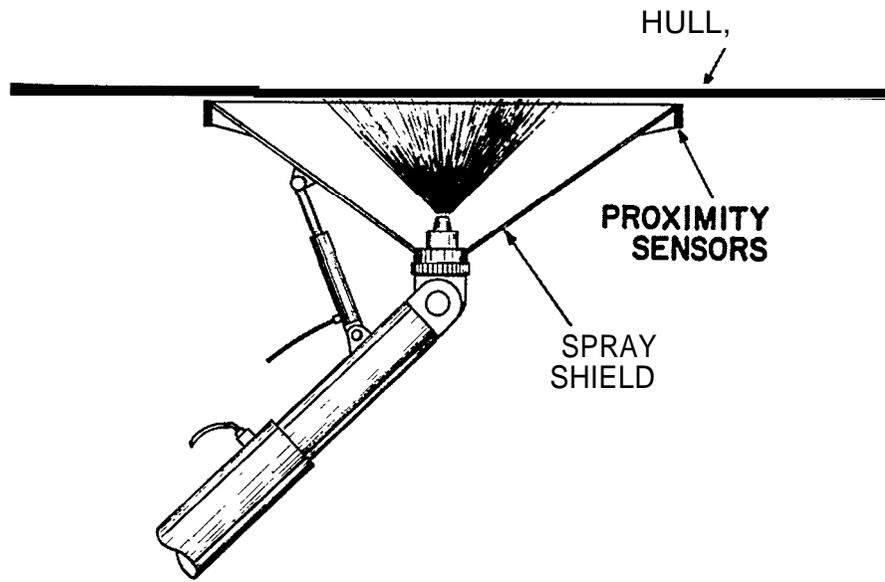


Figure 5 SPRAY HEAD

while the proximity sensors provided the necessary feedback to control the z-plane motions.

Sandblasting would be accomplished in the same manner using a somewhat stronger arm. In fact, both jobs could be accommodated with the same arm using quick change heads.

### Grinding and Welding

Grinding and welding applications use the same basic hardware concepts for the arm; the control system, however is significantly more complex. Feedback and position control are necessarily more precise by at least an order of magnitude and probably two. Feedback in two dimensions will also be required. Z-plane control to position the rod tip/grinder head relative to the work surface would be similar to that used for spraying and blasting but more precise. X- or y-plane control would be in the form of a line tracker to provide precise positioning of the rod tip relative to the joint. The computer would position the rod tip in the general area while the line tracker system would provide the "fine tuning" required. Grinding operations would require similar control but with less precision.

THE CASE WESTERN RESERVE  
N/C FRAME BENDING MACHINE

Donald C. Braun  
Case Western Researve University  
Cleveland, Ohio

Mr. Braun has a B.S. degree in Electrical Engineering, an M.S. degree in Computer Engineering, and is currently completing his Ph.D. in Computer Engineering at Case Western Reserve University. He has worked in the areas of real time process control, digital signal processing, interactive computer graphics, artificial intelligence, pattern recognition, computer operating system architecture, and digital logic design.

## ABSTRACT

A ship frame bending machine which can operate under self-adaptive computer control is described. The entire system is being developed at Case Western Reserve University by a team of specialists in machine design, structural mechanics, and computer control. Advantages of this automated cold-forming system compared with conventional cold-forming and hot-slabbing bending processes include: (1) complete elimination of the need for lofting or templates of any kind; (2) direct compatibility with data generated by the AUTOKON computer program package for ship design; (3) reduced construction costs and time; (4) replacement of a costly labor-intensive activity with a more efficient capital-intensive process; (5) reduction of assembly costs due to more precise frames because out-of-plane deformation, buckling, and twisting can be virtually eliminated; (6) improved international posture for American shipyards. The primary emphasis of this paper is on the computer control algorithm used to accomplish the bending.

## MOVIE

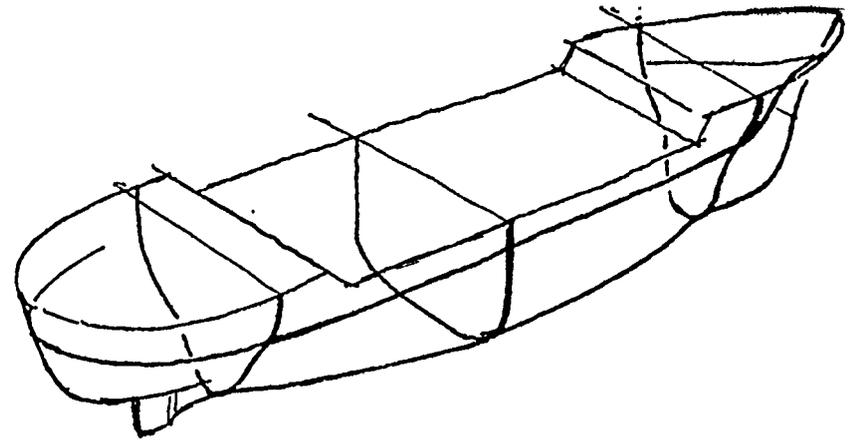
Presentation of the paper is preceded by a 10 minute, 16 mm, sound, color film titled "Automation in the Shipyard: First the Frame." (The film was produced for NSF/RANN by Image Associates, Washington.) This movie shows the Case Western Reserve Frame Bender in operation, illustrates conventional hot-slabbing techniques, and discusses the research goals of the project.

## INTRODUCTION AND BACKGROUND

Because U.S. shipbuilding wage rates are the highest, domestic materials (e.g., steel) the most expensive, and labor productivity the lowest in the world, a U.S. shipyard labor force of 14% of the **world's shipbuilding industry produced only 6% of the world's ships** in 1970. One obvious way to correct this situation is to attempt to make the shipbuilding process less labor intensive and more capital intensive. To solve this problem a team of specialists in machine design, structural mechanics, and computer control in the School of Engineering at Case Western Reserve University is developing a self-adaptive, computer-controlled, cold-forming machine for the fabrication of ship frames (see Figure 1). Expected benefits of automated ship frame bending include (see Figure 2):

1. complete elimination of the need for lofting or templates of any kind;
2. direct compatibility with data generated by the AUTOKON computer program package for ship design;
3. reduced construction costs and time;
4. replacement of a costly labor-intensive activity with a more efficient capital-intensive process;

AUTOMATED  
SHIP-FRAME  
BENDING



RESEARCH GOAL

*DEVELOP A SELF-ADAPTIVE,  
COMPUTER CONTROLLED, AUTOMATED  
BENDING MACHINE FOR THE  
FABRICATION OF SHIP FRAMES*

SCHOOL OF ENGINEERING  
CASE WESTERN RESERVE UNIVERSITY

# BENEFITS

## *REDUCED CONSTRUCTION COSTS AND TIME*

- *REDUCTION OF ASSEMBLY COSTS DUE TO MORE PRECISE FRAMES*
- *IMPROVED INTERNATIONAL POSTURE FOR AMERICAN SHIPYARDS*

Figure 2.

5. reduction of assembly costs due to more precise frames because out-of-plane deformation, buckling, and twisting can be virtually eliminated;
6. improved international posture for American shipyards.

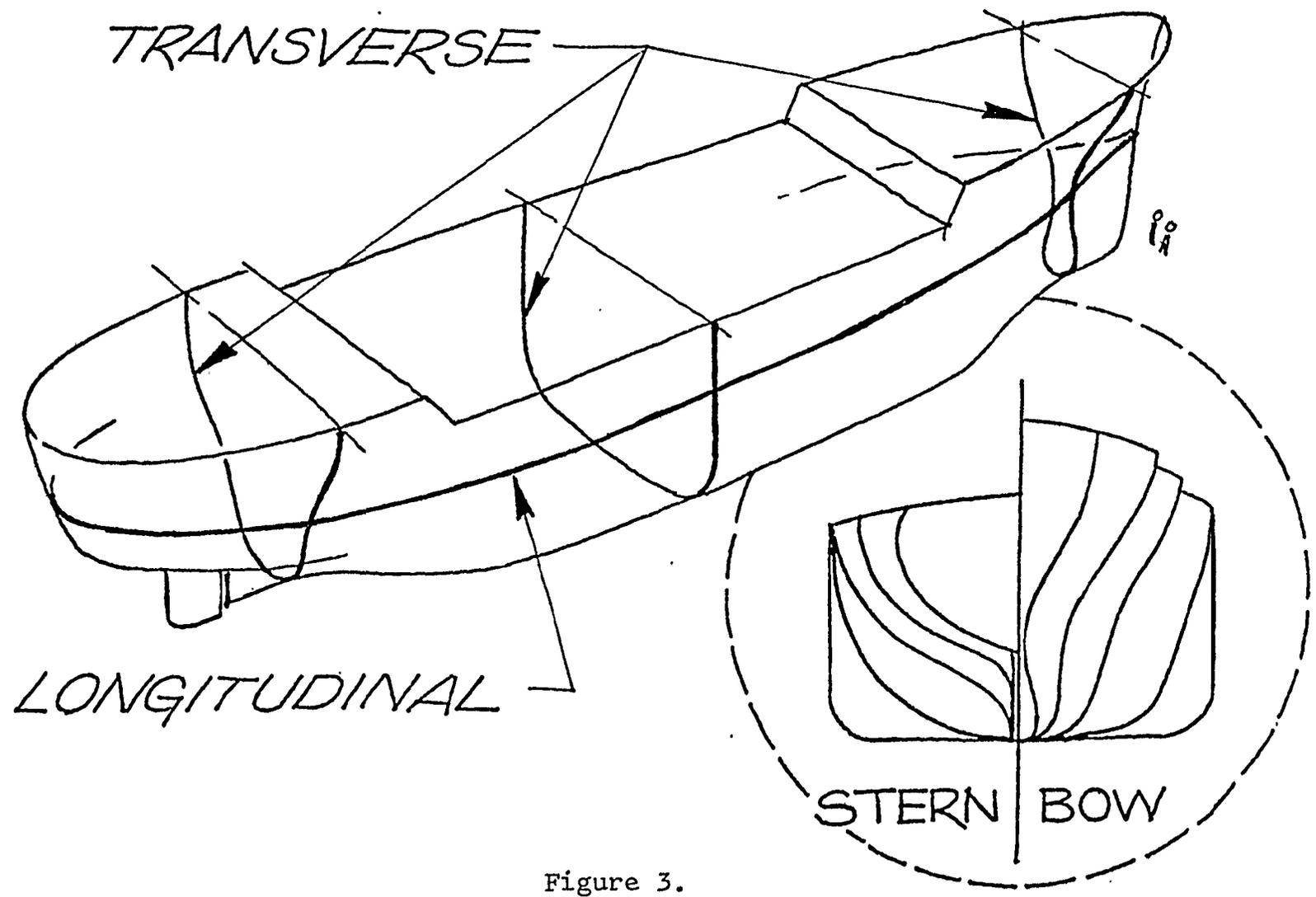
#### CAPABILITY OF THE MODEL BENDER

The present model of the bender is designed primarily to handle planar transverse ship frames rather than longitudinal frames which are required to have a prescribed twist to follow the shape of the hull. Figure 3 illustrates the wide variety of shapes required for transverse frames near the stern and near the bow of the ship. The present model, which is about 1/6 the size of a full scale bender, can bend such shapes with a minimum arc radius of two feet. Frame member cross sections which can be accommodated in the bender include flat bars, equal or unequal leg angles, tees, and channels (see Figure 4). Although dies could be built to handle bulb angles and bulb flats also, American yards do not use these sections because American mills no longer roll them. It is interesting to note that bulbs are used almost exclusively in European yards and that there is intense cooperation between their rolling mills and their shipyards.

#### CONVENTIONAL BENDING PROCESSES

In order to better appreciate the advantages of the Case Western Reserve Frame Bender, it is helpful to compare it with conventional bending processes. Ship frames are currently bent by two methods. The oldest and probably most widely used technique is hot slabbing. For this method the frame material is heated in a furnace

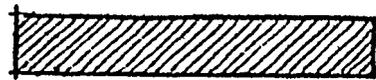
# SHIP FRAMES



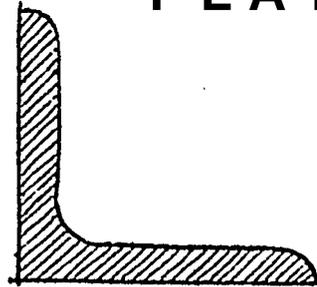
225

Figure 3.

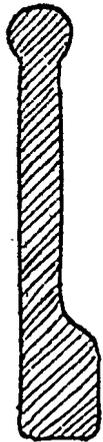
# FRAME MEMBER CROSS SECTIONS



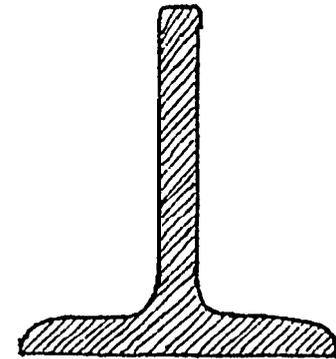
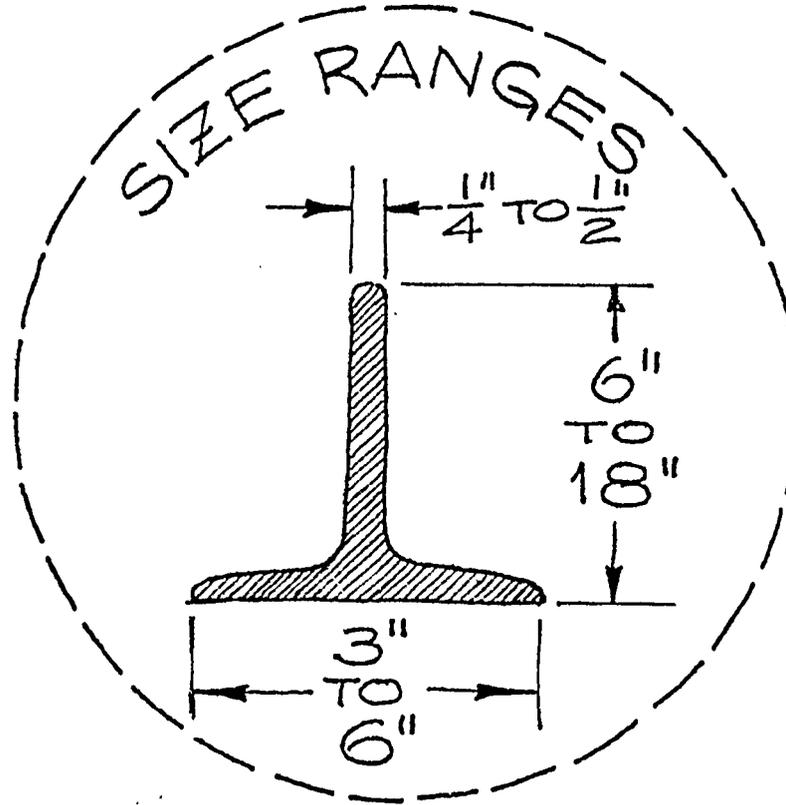
PLATES



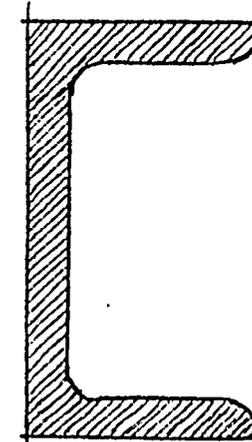
ANGLES



BULBS



TEES



C CHANNELS

Figure 4.

until it is plastic and then it is bent against a template by a portable hydraulic jack (as illustrated in the movie) with workmen hammering out local discrepancies. The disadvantages of this method include the following.

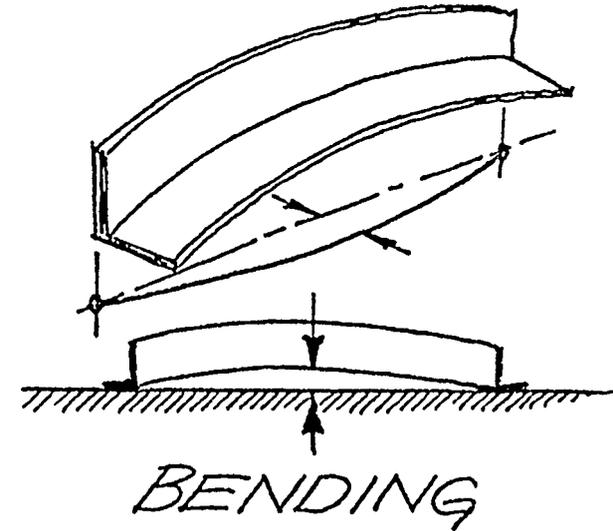
1. It is slow.
2. It requires a furnace facility.
3. It requires the layout and fabrication of a template.
4. It requires a team of four men to perform the bending.
5. A hot-bent beam is changed to an annealed state with a consequent low yield stress.

A second method is called 3-point cold form bending (see Figure 5). Here the desired frame profile is achieved by a succession of bends produced by applying a force between two fixed points supporting the beam. The disadvantages of this method include the following.

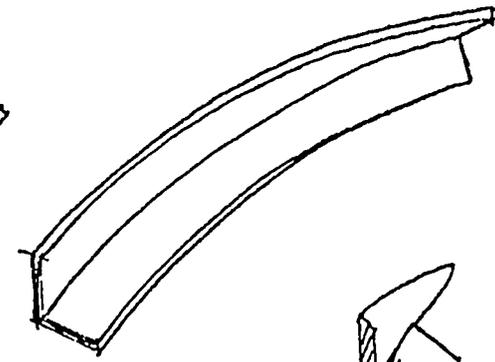
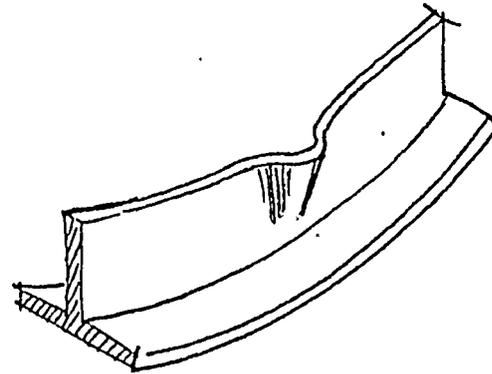
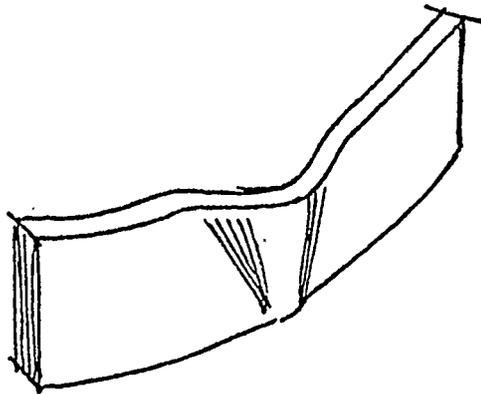
1. It is a slow process.
2. It requires a massive, brute-force machine which costs more than \$100,000.
3. It requires the layout and fabrication of a full scale template.
4. It is very "arty" and therefore must be done by experienced operators.

# CURRENT PRACTICE

## 3-POINT BENDING



## FAULTS



BUCKLING  
and CRIPPLING

TWISTING

Figure 5.

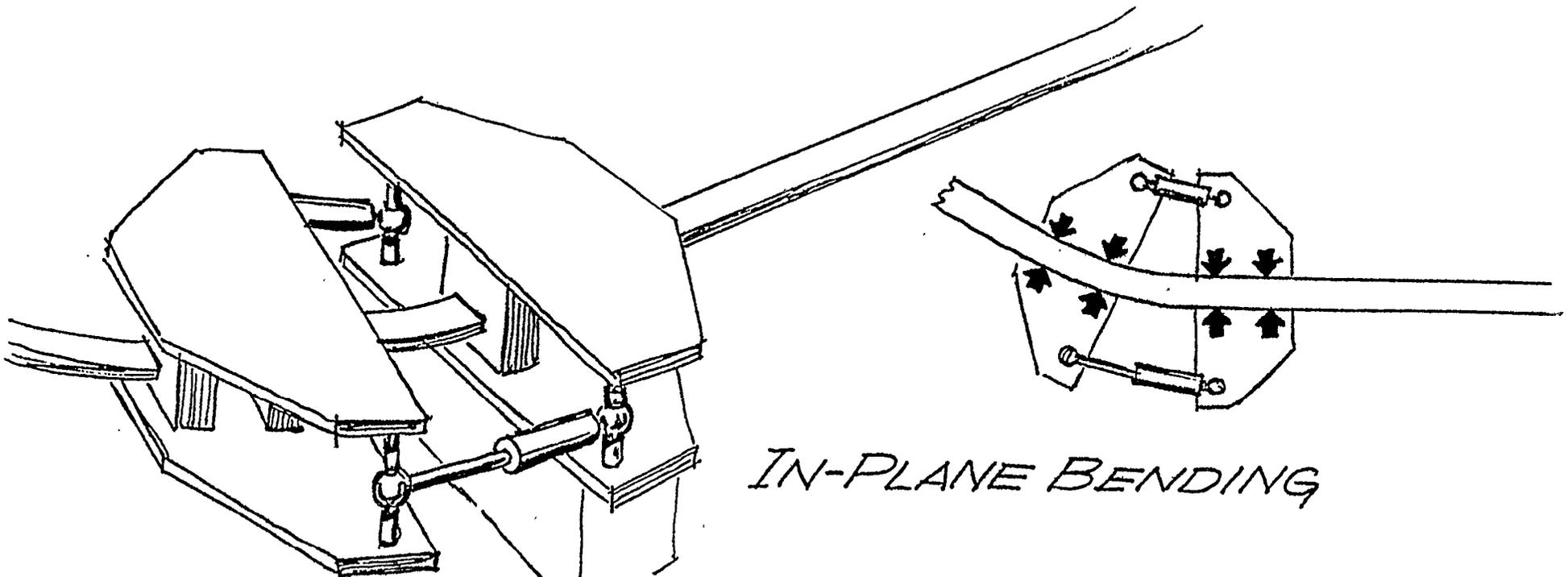
of these two planes is not controllable. Buckling results from insufficient stabilizers (if any) on the web during bending. Twisting moment is produced because shear forces, and hence shear stresses, are very high in 3-point bending.

In summary, the conventional processes are crude, time-consuming, and produce an unsatisfactory product whose error in shape results in severe and costly manufacturing problems throughout the hull construction.

#### OVERVIEW OF THE CASE WESTERN RESERVE SYSTEM

In contrast to conventional bending techniques, the Case Western Reserve system uses a physical configuration (illustrated in Figure 6) permitting application of a pure bending moment in an appropriate plane (which varies with the cross-sectional geometry). Bending is produced only in one principal direction, so there is no out-of-plane bending. Buckling, even for beams with high aspect ratios (e.g., 24 to 1 for a flat bar 3 inches deep and 1/8 inch thick), has been minimized by developing special stabilizers. Twist has been eliminated by applying a pure moment to the work section using a 4-point bending technique.

The model bender was designed and built in 1/6 scale with all of the necessary full scale requirements of interchangeable dies, automatic clamping, automatic feeding, and with suitable transducers to permit the machine to be operated under autonomous computer control as well as by manual control (see Figure 7). The heart of the computer control in the feedback loop shown in Figure 8 is a



*IN-PLANE BENDING*

**PROPOSED SHIP-FRAME BENDING SYSTEM**

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*IN-PLANE + OUT-OF-PLANE BENDING*

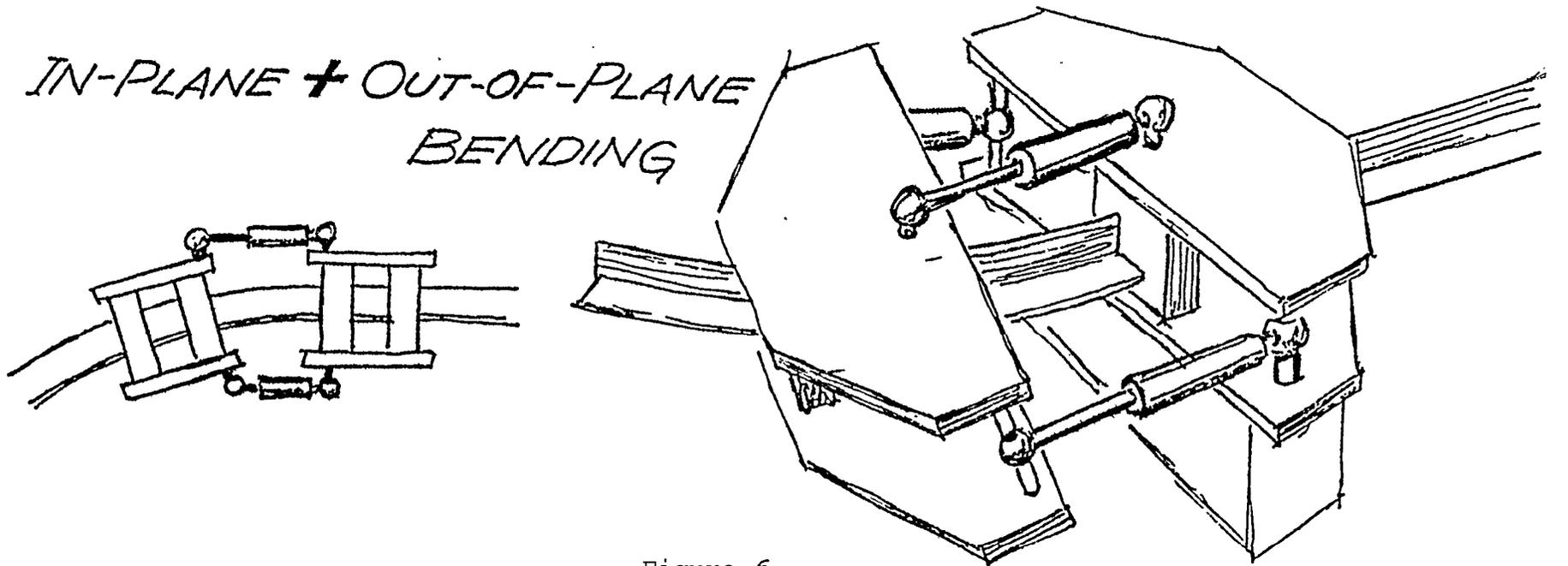


Figure 6.

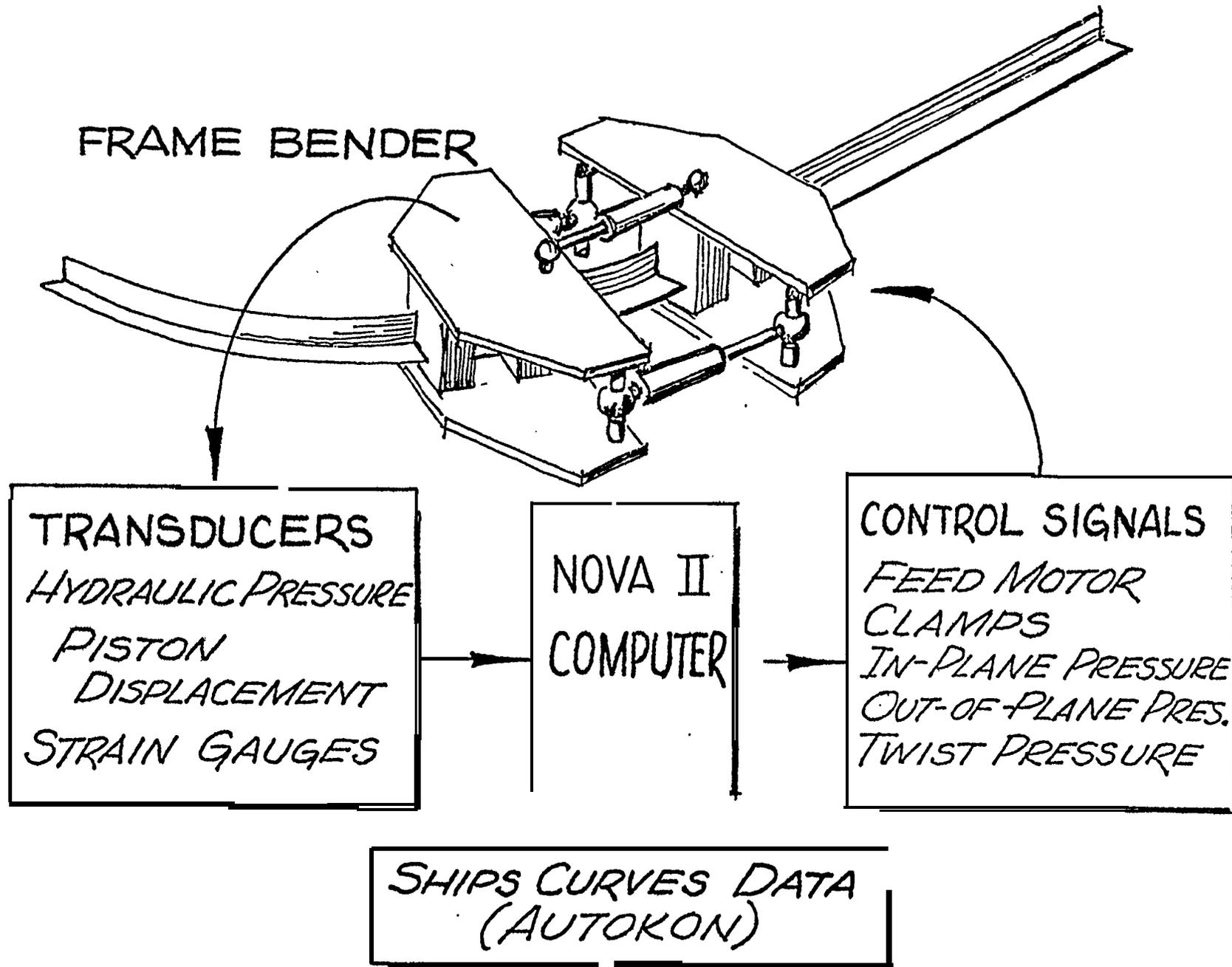
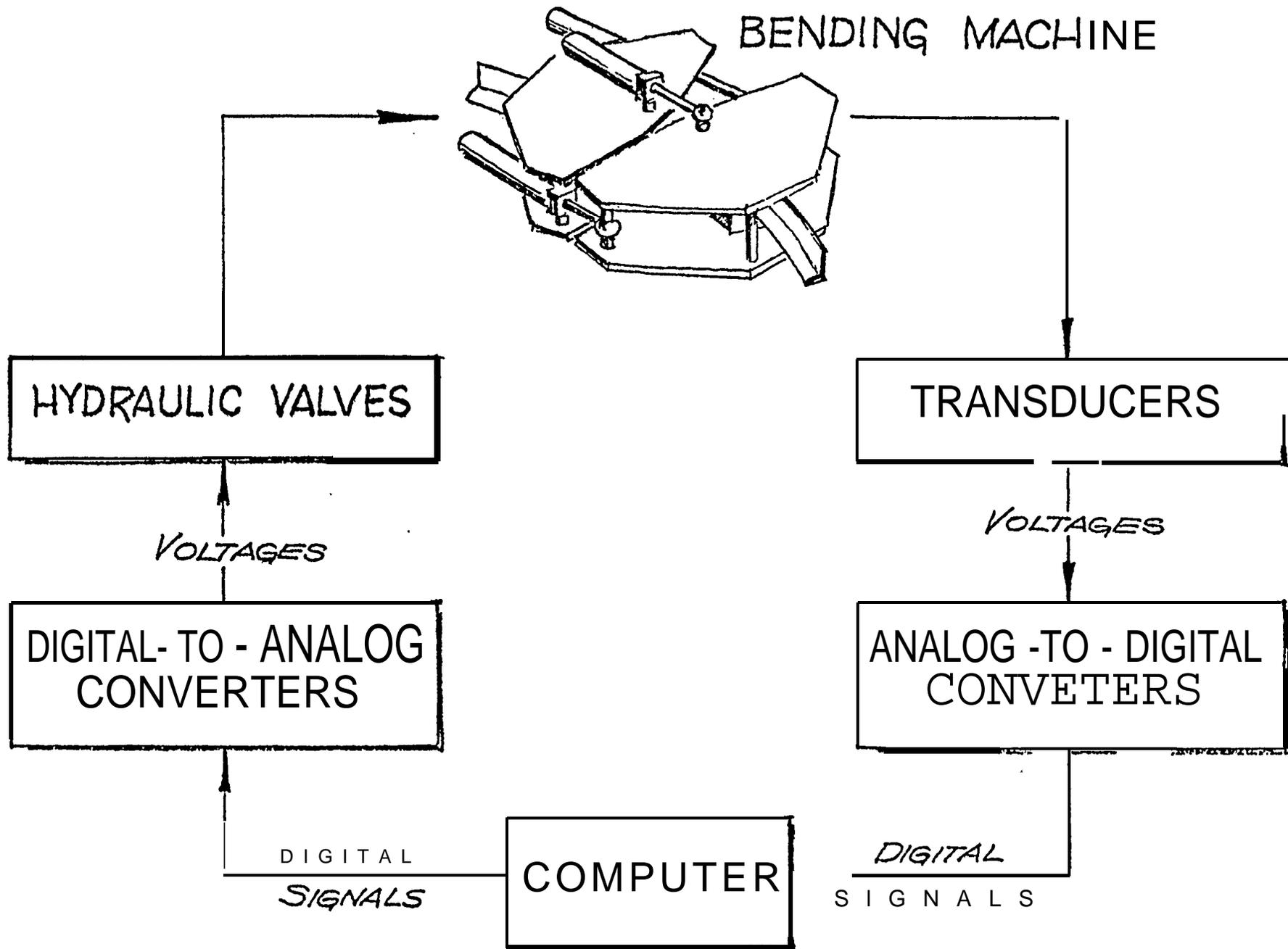


Figure 7.

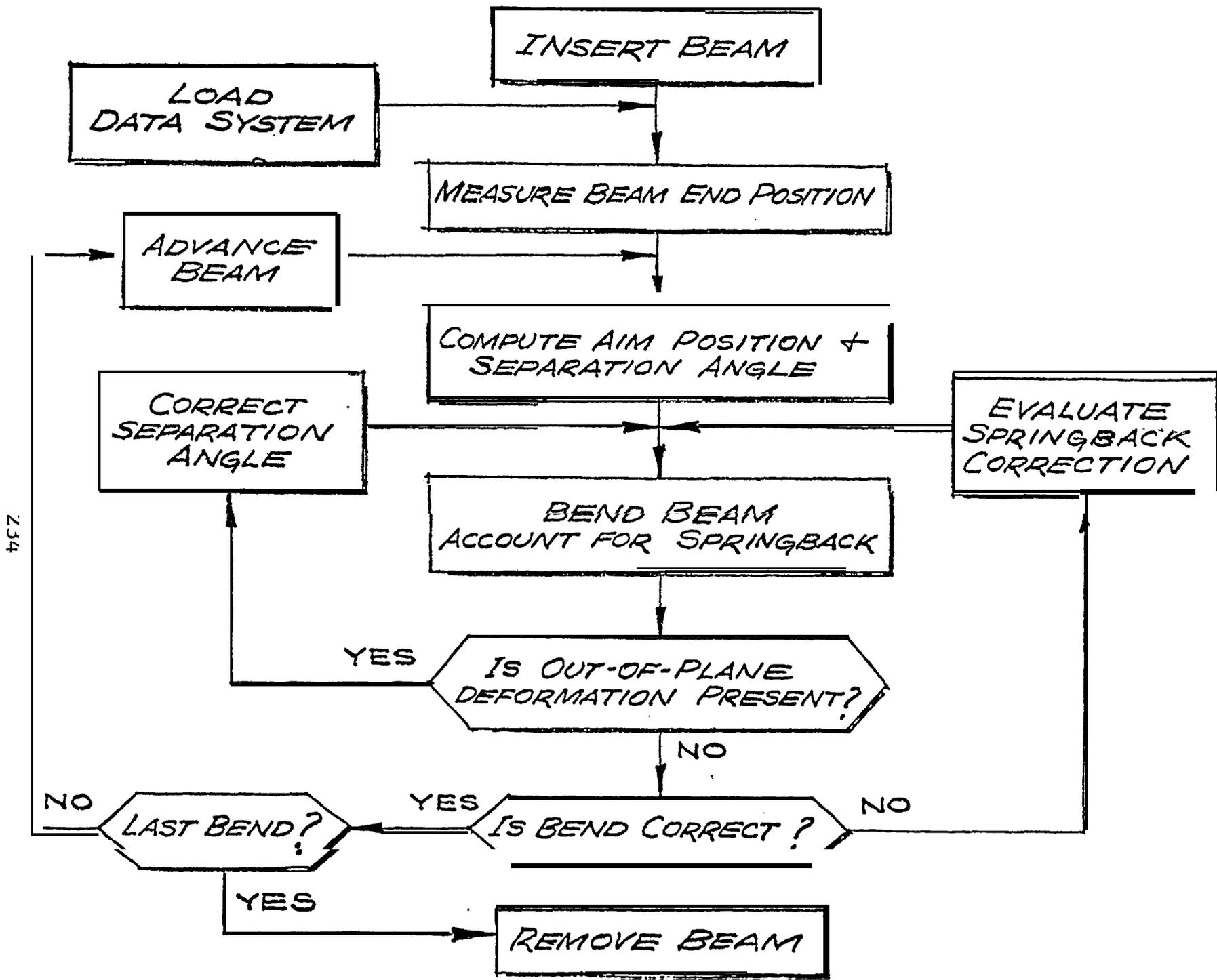


NOVA-2/10 minicomputer with 32,000 words of 16 bits/word core memory, a multiplexed 12-bit analog-to-digital converter to sense the transduced signals which tell what the bender is doing, and several channels of voltage outputs to control the hydraulic valves.

### COMPUTER CONTROL ALGORITHM

The simplified flow diagram in Figure 9 integrates two related subsystems which together control the automated bending of a beam. After an operator inserts the beam into the bender and loads into the computer the data describing the shape to be bent, the NOVA minicomputer sequentially processes one work section of the beam after another. For each work section the aim position for bending is calculated to minimize cumulative error, the beam is bent to this aim position, the springback is measured, and the work section can then be rebent iteratively based on the computer's updated estimate of how much springback to expect. For non-symmetrical sections, hard-wired circuitry minimizes out-of-plane bending by adjusting a servo valve to maintain the proper ratio of in-plane moment to out-of-plane moment. In other words, the circuitry maintains the correct separation angle between the plane of desired deformation and the plane in which the net moment is applied.

Figures 10a through 10d illustrate some of the mechanical steps controlled by the computer during the bending of a single work section. Figure 10a shows a simplified top view of the bending machine with a beam inserted. A few work sections have already been



734

Figure 9.

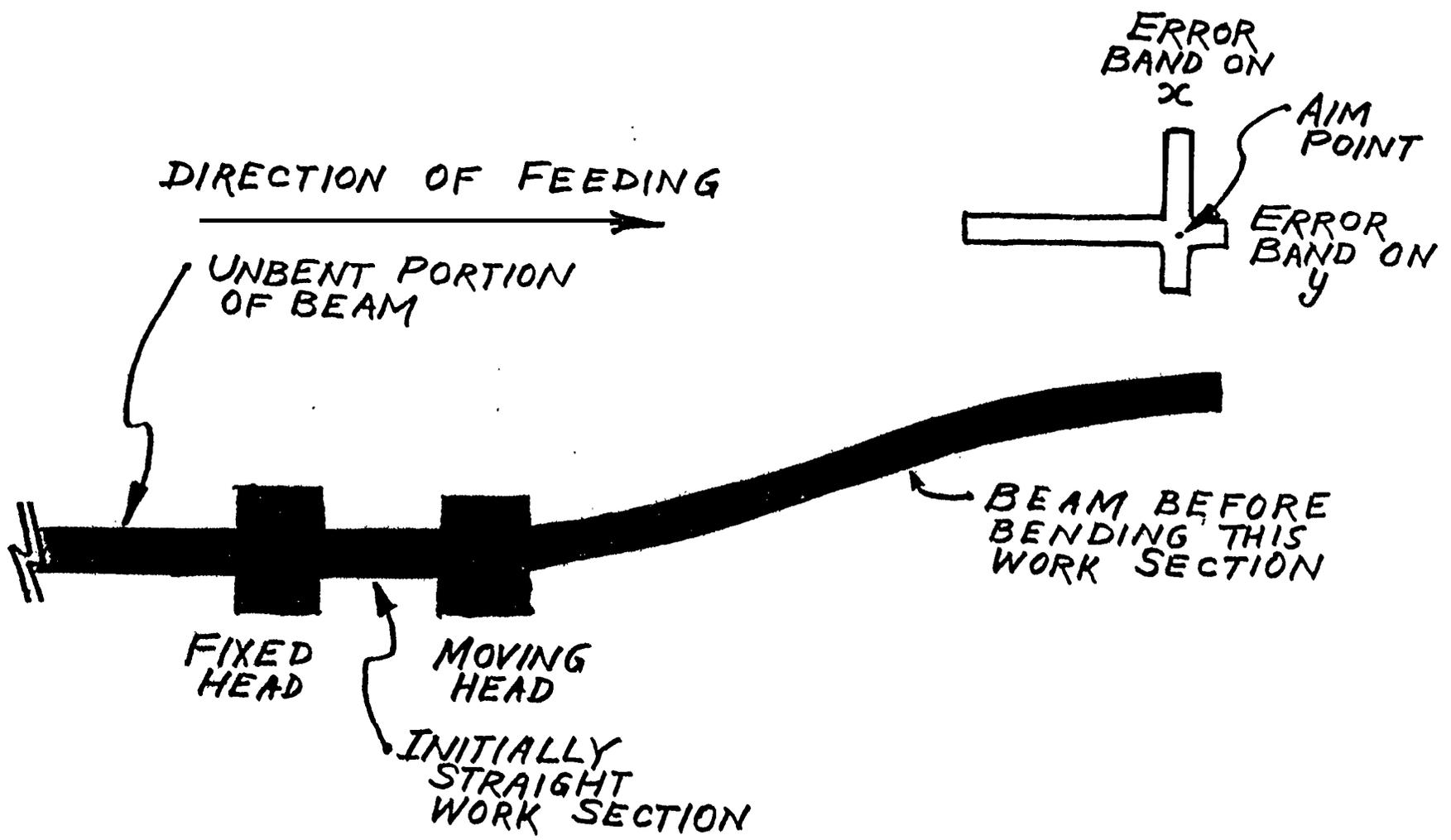
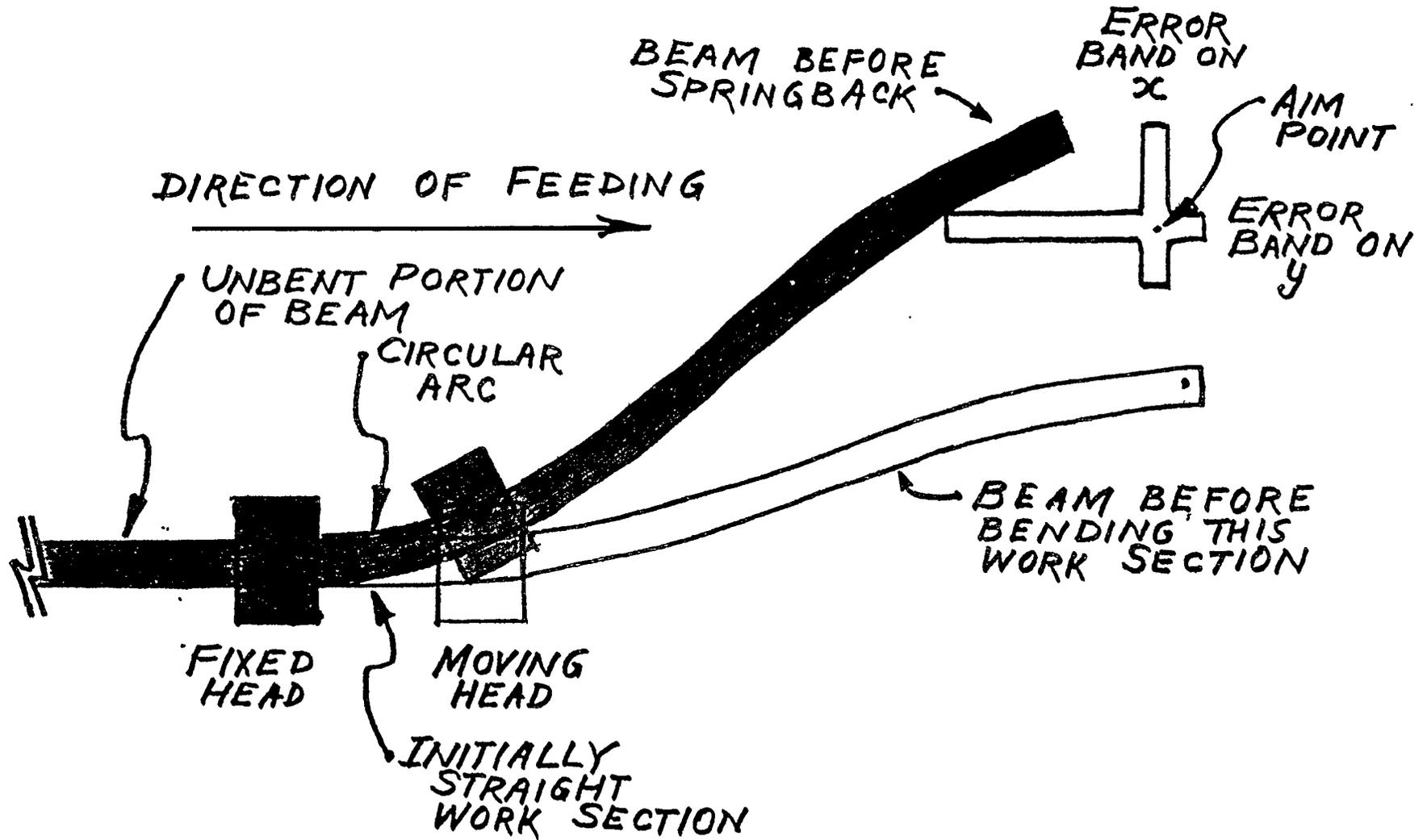


Figure 10a.



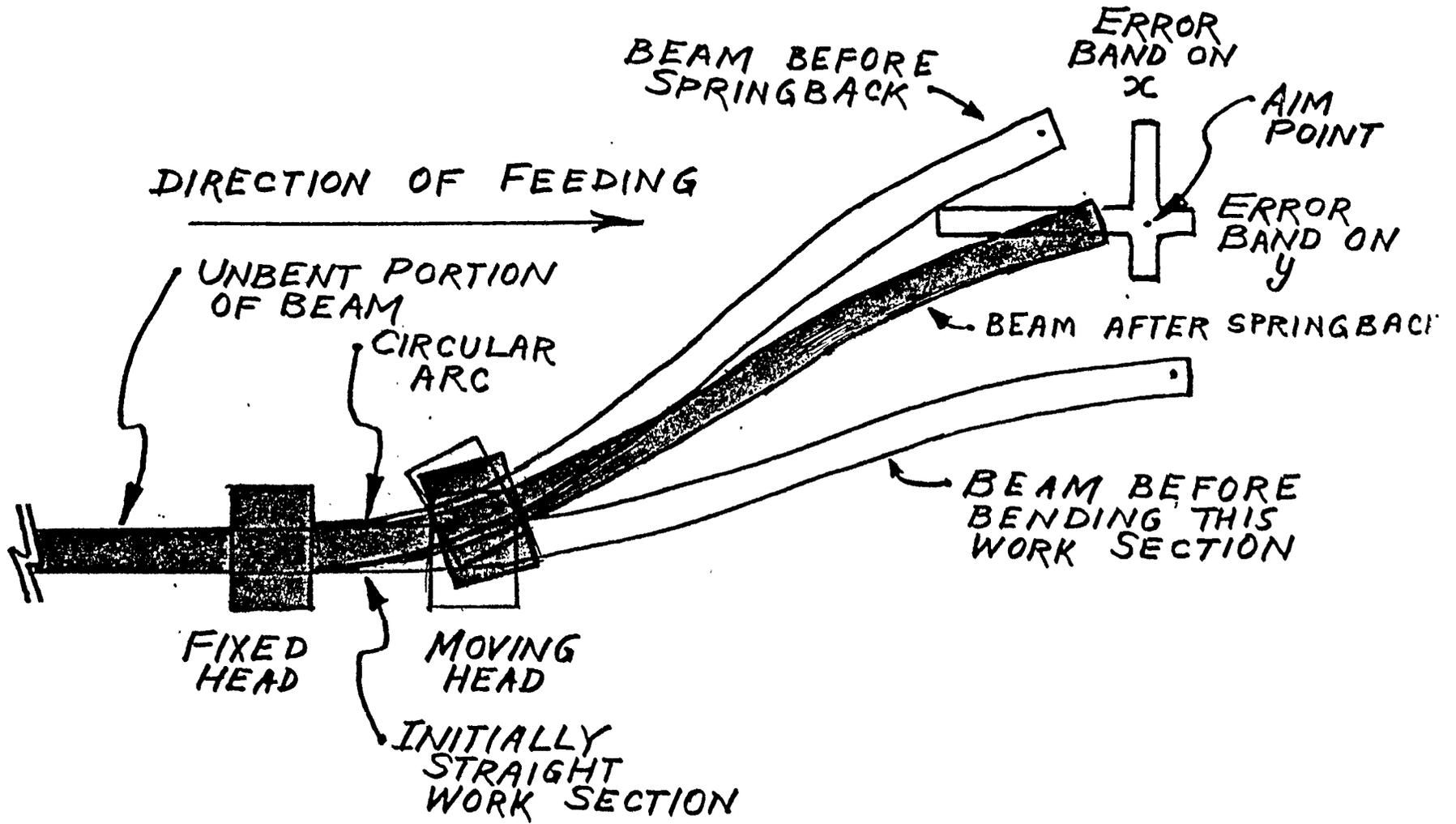
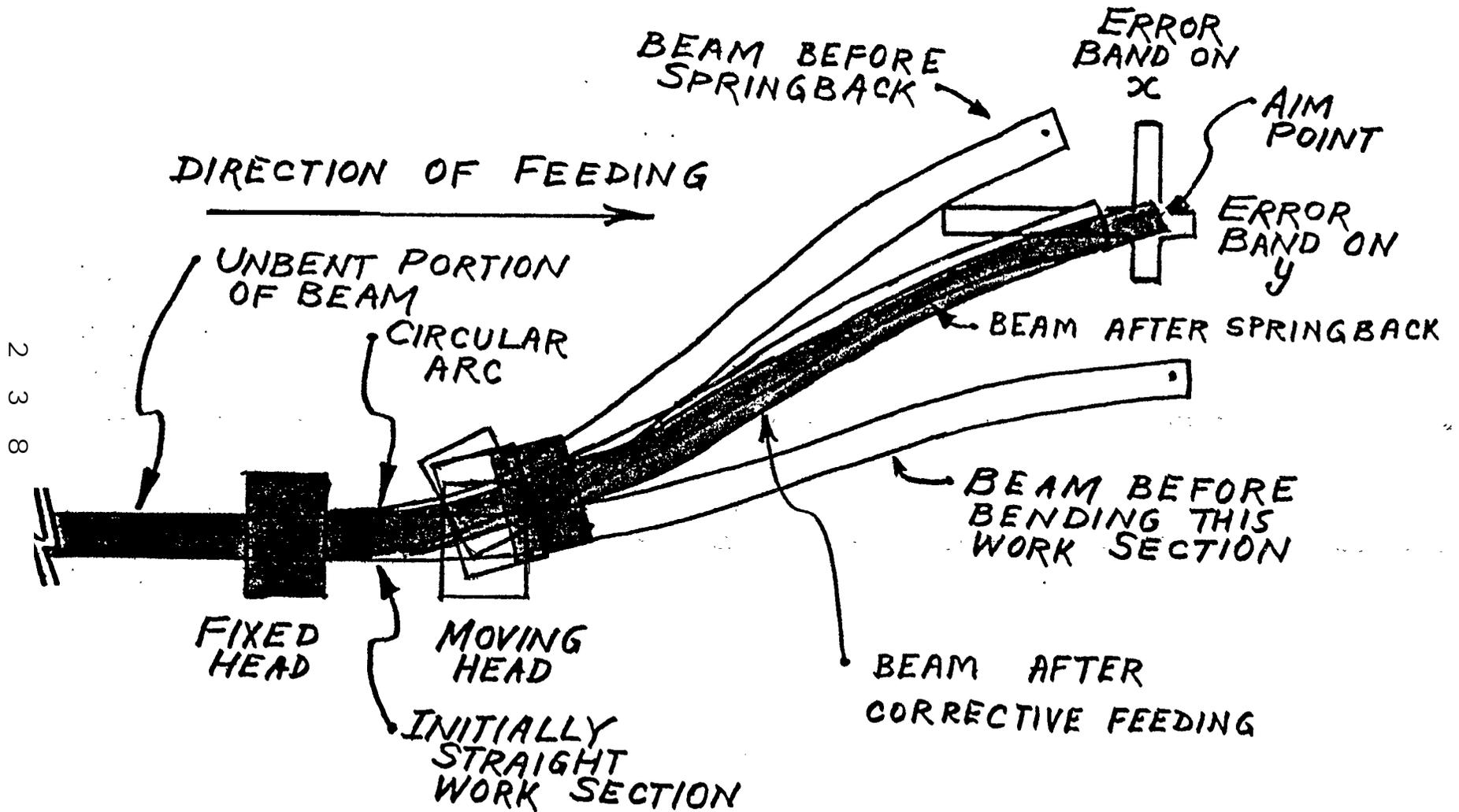


Figure 10c.



bent near the initial end of the beam. The beam has just been fed forward and the moving head of the machine has been adjusted to position the next unbent work section between the fixed and moving heads. The dot near the end of the beam denotes the reference point at which an X-Y carriage clamp is attached to the beam. Displacement transducers mounted on the carriage permit the computer to read the (x, y) coordinate position of the carriage clamp. The computer now calculates the aim point at which the reference point should ideally be located after this work section has been bent properly. When the computer has estimated how much springback to expect, the work section is over-bent (see Figure 10b) enough so that after the bending moment is released and the work section springs back (see Figure 10c), the reference point on the beam should be at the Y-coordinate of the aim point. If the reference point does not come within an allowable error band on Y, the springback estimate is revised on the basis of how much springback was just observed. The same work section is then bent again based on the new springback estimate unless the beam was already bent too far. Finally, the beam is fed until the reference point on the beam stops within the tolerable error band centered around the X-coordinate of the aim point (see Figure 10d). Feeding is accomplished by pulling the beam with the moving head while keeping the fixed head clamps open.

In order to perform all of the necessary calculations while bending a beam, the computer maintains in its memory three distinct mathematical models of the beam. These are called the ESSI model, the ideal model, and the actual model. The ESSI model (see Figure 11) is produced by AUTOKON and is input to the NOVA-2/10 to specify the

EXAMPLE OF AN ESSI MODEL AND ITS IDEAL WORK SECTION MODEL

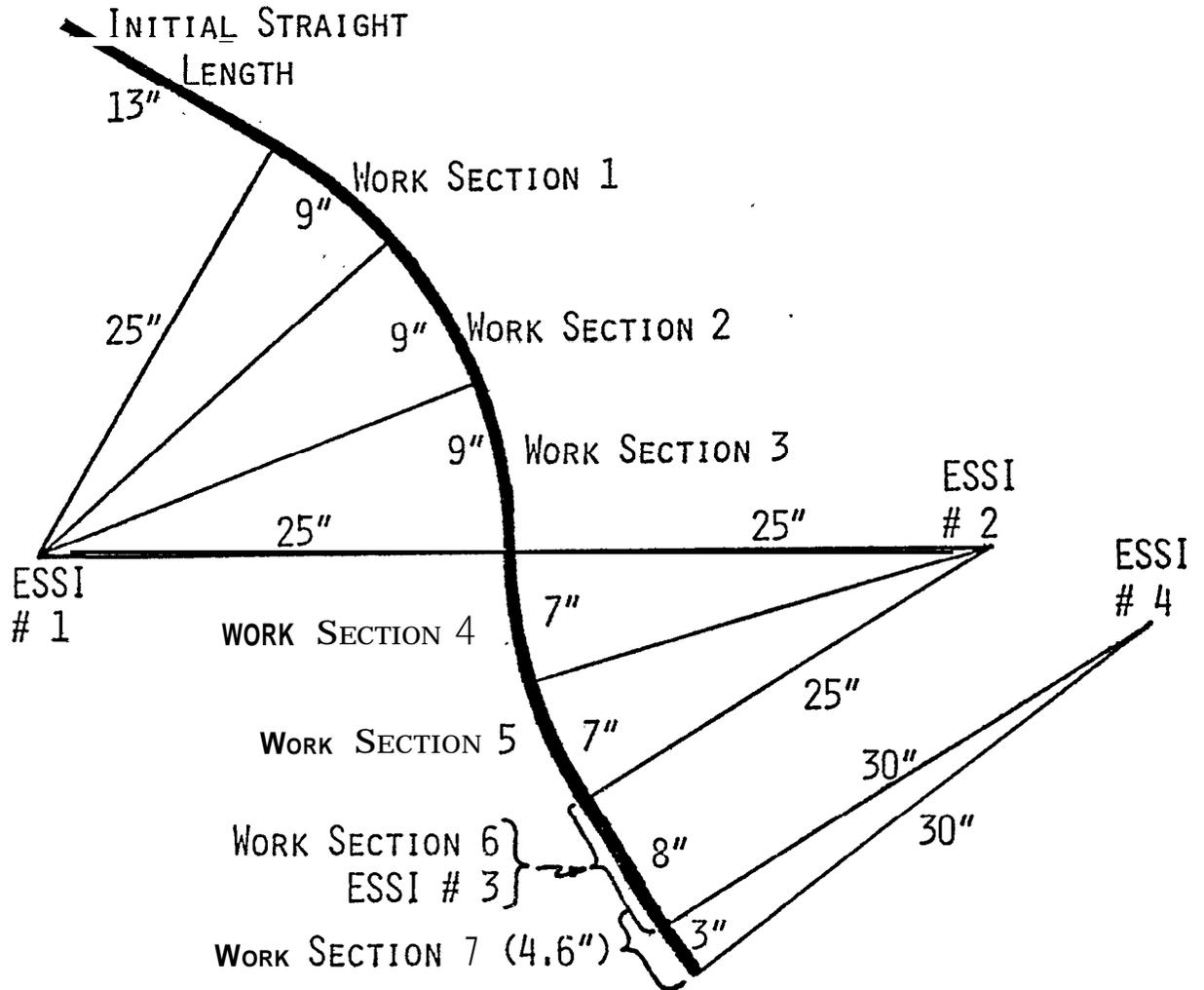


TABLE OF ESSI ELEMENTS (100 UNITS/INCH)

1322	-2205	-1178	-2205	-
382	-1328	2500	0	+
425	-678			
172	-246	2542	1594	+

Figure 11.

desired shape of the beam in terms of straight segments and circular arcs. Other mathematical specifications for a beam (e.g., a piecewise linear model or a table of offsets from a chord) can easily be converted into straight ESSI elements.

Before any bending takes place, the NOVA-2/10 determines the ideal model by dividing the ESSI model into work sections according to a set of rules. The most important rules are listed below.

1. The length of each work section must be between the minimum and maximum limits specified by the operator.
2. Work points (i.e., junctions between adjacent work sections) are preferred to coincide with junctions of consecutive ESSI elements to avoid including an inflection point within a work section whenever possible.
3. Long ESSI elements are divided into the smallest possible number of nearly equal work sections to speed up the bending process by keeping the number of bends small.
4. Nonoverlapping work sections are generally used; however, because extrapolation of the ESSI model is not permitted, the previous three rules may force the last work section to overlap with the second last one. Figure 11 illustrates an example of this condition.

At each work point in the ideal model a vector which is tangent to the ESSI model is calculated. These tangent vectors are used for alignment of the beam at the fixed head when aim points are calculated.

The third model, called the actual model, is developed by the NOVA-2/10 while the beam is physically being bent. This mathematical model is based on the curvatures that were actually

bent and on the work section lengths that were actually fed. The computer control program can use the actual model to print a table summarizing the detected bending discrepancies. The primary use for the actual model, however, is to locate a new reference point if the X-Y carriage clamp is moved to a different point on the beam between times of bending. This provision for moving and re-clamping the carriage as often as once for each work section is included in the control algorithm to allow the carriage to be much smaller than the total length of the beam being bent.

A summary of the computer control algorithm is outlined in Figures 12a and 12b.

#### FUTURE WORK

As the development of the 1/6 scale model bender nears completion at Case Western Reserve University, plans are being made for the commercial development and construction of three full size automated frame bending machines, each of a different capacity. (See Figure 13.) Such development will be based upon engineering and economic data to be gathered on shipyard use. Consideration is also being given to the potential application of similar techniques with another machine to form ship hull plates. Finally, the Case Western Reserve computer-controlled frame bending machine could be applied to national needs besides shipbuilding, such as the forming of stiffening elements for nuclear power reactor components.

## CONTROL ALGORITHM

1. OPERATOR INSERTS BEAM INTO FRAME BENDER
2. OPERATOR CLAMPS TRANSDUCER AT END OF BEAM
3. INPUT THE DESIRED BEAM SHAPE
  - A. ESSI MODEL OF CIRCULAR ARCS AND STRAIGHT LINE SEGMENTS  
(CAN BE PIECEWISE LINEAR)
  - B. FROM AUTOKON PAPER TAPE, TELETYPEWRITER, OR DISK FILE
  - C. ASCII OR EIA CHARACTER CODES
4. INPUT THE BEND PARAMETERS
  - A. WORK LENGTH MINIMUM AND MAXIMUM
  - B. INITIAL UNBENT LENGTH AT END OF BEAM
  - C. CLAMPING MODE
  - D. TOLERANCES FOR FEED DISTANCES AND BEND ANGLES
5. CALIBRATE TRANSDUCERS WITH A/D CONVERTERS
6. SET UP IDEAL MATHEMATICAL MODEL OF BEAM
  - A. WORK POINTS ARE PREFERRED AT JUNCTIONS OF ESSI ELEMENTS
  - B. THE LAST WORK SECTION MAY OVERLAP THE SECOND LAST ONE
  - C. THE TANGENT VECTOR AT EACH WORK POINT IS DETERMINED FROM THE ESSI MODEL
  - D. A TABLE-SUMMARIZING IDEAL MODEL OF BEAM CAN BE PRINTED

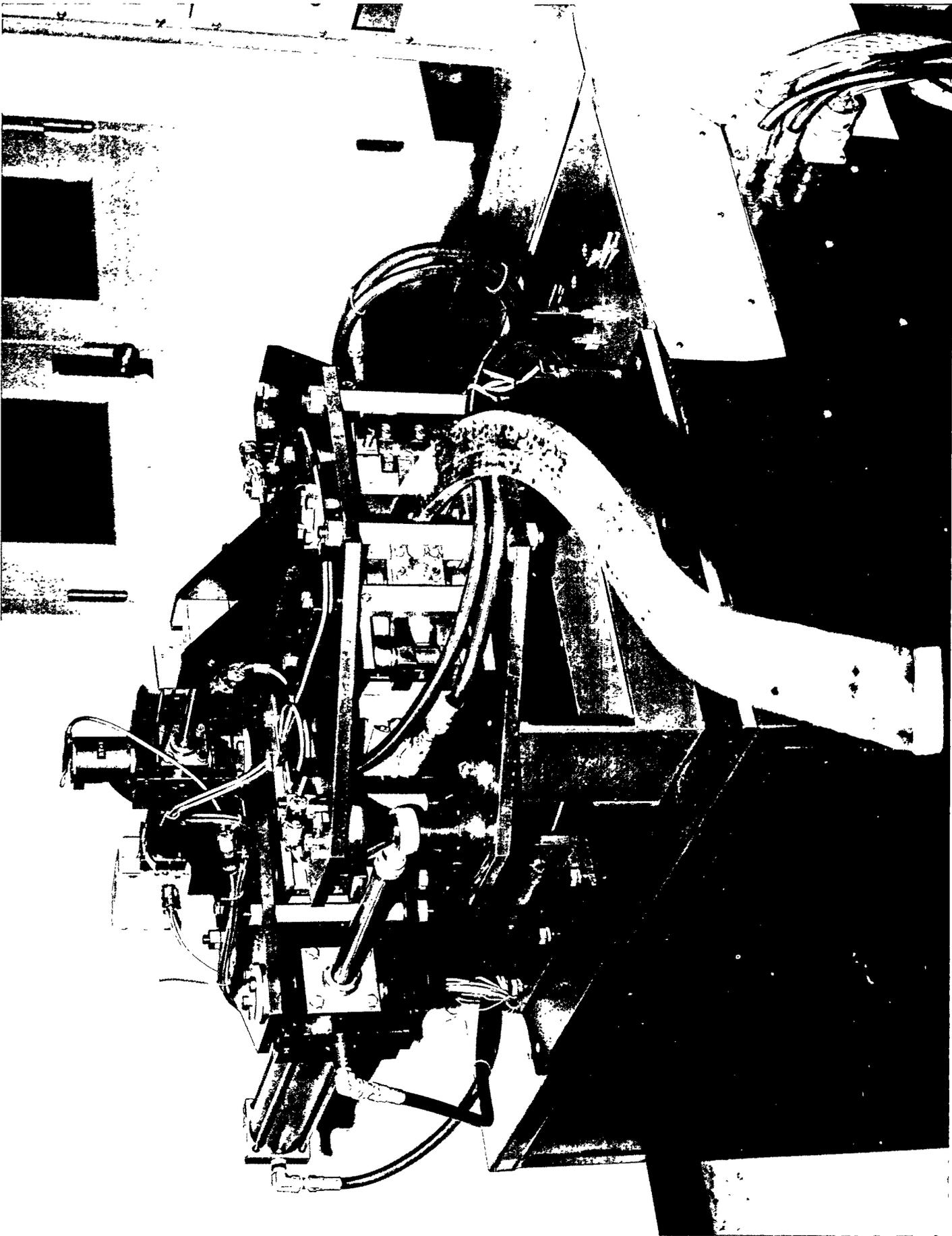
CONTROL ALGORITHM (CONTINUED)

7. EACH WORK SECTION IS PROCESSED AS FOLLOWS:
  - A. **FEED BEAM AND ADJUST MOVING HEAD TO POSITION NEW WORK SECTION BETWEEN THE FIXED AND MOVING HEADS**
  - B. **UPDATE MODEL OF ACTUAL BEAM TO REFLECT FEEDING**
  - C. **IF NECESSARY, MOVE TRANSDUCER TO NEW POINT ON BEAM, FIND NEW REFERENCE POINT ON MODEL OF ACTUAL BEAM, AND FIND CORRESPONDING POINT ON IDEAL MODEL**
  - D. **CALCULATE (X, Y) AIM COORDINATES FOR TRANSDUCER REFERENCE POINT FROM IDEAL MODEL**
  - E. **BEND TO Y COORDINATE OF AIM POINT, RELEASE, AND MEASURE SPRINGBACK**
  - F. **UNTIL BEND ANGLE TOLERANCE IS SATISFIED (BUT NEVER MORE THAN 2 ITERATIONS), RECALCULATE REQUIRED "OVERBEND" BASED ON SPRINGBACK JUST OBSERVED, BEND TO NEW Y COORDINATE, RELEASE, AND MEASURE SPRINGBACK**
  - G. **UPDATE MODEL OF ACTUAL BEAM TO REFLECT BENDING OF THIS WORK SECTION**
  - H. **FEED TO X COORDINATE OF ORIGINAL AIM POINT**
8. WHEN ENTIRE BEAM IS FINISHED, OPTIONALLY PRINT A TABLE SUMMARIZING THE MODEL OF THE ACTUAL BEAM
9. OPTIONALLY PRINT A TABLE COMPARING THE IDEAL MODEL WITH THE MODEL OF THE ACTUAL BEAM

# FUTURE WORK

- DEVELOP FULL-SCALE EQUIPMENT FOR SHIPYARD USE
- OBTAIN ENGINEERING AND ECONOMIC DATA ON SHIPYARD USE
- EXAMINE POTENTIAL APPLICATION TO FORMING SHIP-HULL PLATES
- APPLY SYSTEM TO OTHER NATIONAL NEEDS  
e.g. FORMING OF STIFFENING ELEMENTS FOR NUCLEAR POWER REACTOR COMPONENTS

Figure 13.



USE OF THE SPADES SYSTEM  
DURING THE  
ENGINEERING, DESIGN AND DETAIL PHASES

Lonnie W. Lowery  
Cali and Associates  
Metairie, Louisiana

Mr. Lowery is responsible for development and implementation of marine engineering and numerical control systems, utilizing interactive graphics as a tool for communication between the system and the users.

## Introduction

In order to apply optimization techniques to the earlier stages of ship design, one must be able to recognize a logical pattern in the design process and define it in a mathematical sense so that design algorithms can be developed. Structural design by computers in the shipbuilding industry is still a relatively young discipline but has quickly gained much popularity. Contract design concepts are also beginning to enjoy growing acceptance. On the other hand, numerical control and manufacturing aids in shipbuilding have been widely accepted and extensively refined. American shipbuilding has for several years applied computerized techniques to the areas of numerical *control*, part generation and manufacturing aids but has directed little effort recently toward the engineering functions.

As the 'SPADES' System became more sophisticated, in order to better help the lofting effort, the increased features made it useful to a considerable degree for engineering purposes. It is the intent to further develop the System to provide the engineer and draftsman with the most efficient tool.

The purpose of this paper is to outline a procedure by which the System can be used as it is today during the engineering design and detailing effort and how future modules may improve on these applications. Such a use will not only benefit engineering, but will also reduce considerably the work that would otherwise have to be done downstream by the mold loft.

procedure will cover the use of the 'SPADES' System, assuming for the sake of clarity, that the engineering functions can be categorized in the following phases:

- Hull Form Definition
- Scantlings Definition
- Detail Working Drawings
- Drawings Revisions

### Hull Form Definition

It is assumed that at the beginning of this phase, the naval architect has already established a set of lines representing his first approximation of the hull form required to meet the performance requirements of the ship, and that he is ready to start the iterative process between hull form and calculation to refine this first approximation.

This process can be done through the use of the 'FAIRING', 'HULLCAL' and 'HULLLOAD'

Modules of the 'SPADES' System, using the following procedure:

1. Load through 'FAIRING' the initial lines, No actual fairing will be done.
2. Check that the lines, as loaded, are fair enough for calculation purposes. If not, change data and/or make a fairing run, as needed.
3. Compute the Curves of Form through the 'HULLCAL' Module. If the hydrostatic properties appear to be satisfactory, proceed with the next step. If not, modify the lines as desired and repeat Step 2 above.
4. Compute Cross Curves of Stability and Floodable Length Curves, using 'HULLCAL'. Change lines and repeat from Step 2 above if the results are not acceptable.
5. Read through 'HULLLOAD' all Main Bulkheads and Decks. Compute preliminary tank capacities and damage stability, if required. Make changes if needed and repeat any necessary steps.
6. Review and complete definition of Hull Control Lines and proceed with final fairing.
7. Generate all construction frames and load on them all main 'Bulkheads' and 'Decks'. Final Mold Loft Offsets for Control Lines, Buttocks, Waterlines and Deck/Bulkhead Traces can now be printed.
8. Extract through 'DRAWING' the final Lines Plan and a Body Plan on frames.
9. Rerun through 'HULLCAL' all calculations including Bonjean Curves, and generate the final corresponding drawings.

There are, of course, other factors which affect the finalization of the hull form.

The introduction by the naval architect of these factors in the design iteration will not reduce the validity of the procedure described above.

### Scantlings Definition

This is the phase during which the designer establishes the scantlings of the hull structure.

The 'SPADES' System does not offer any specific assistance in the determination of the scantling except for its capability of executing Longitudinal strength calculations in still water, hogging and sagging. The system will, however, give valuable assistance in the generation of the scantling and general arrangement drawings and create in the process the bulk of the data needed in the data base during the following phases of the shipbuilding process.

The procedure described herein is for a longitudinally framed vessel. The suggested sequence would require some changes in the case of a transversely framed ship. This sequence is also, to a certain extent, arbitrary; and changes will be required to suit each design and the specific practices of each engineering organization.

1. Load through 'HULLLOAD' all shell traces in the mid-ship area, defining specific locations or relative spacing such as stiffeners spacing or plate width.
2. Extract through 'DRAWING' <sup>1</sup> preliminary Shell Expansion Drawing.
3. Modify and extend toward the ends all traces. Load changes on the Data Base.
4. Generate a body plan view of the traces. Modify and complete the definition of the traces in the transverse view. Load changes on the Data Base.
5. Re-draw from the Data Base the Shell Expansion and Body Plan of all traces. If further changes are needed, repeat as much of the process as necessary.

6. Finish Shell Expansion Drawing by hand (lettering & general notes).
7. In parallel with the above, define stiffener traces and seams on Decks and Longitudinal Bulkheads through 'HULLLOAD'. As for Shell Traces, start the definition in the mid-ship area and by reviewing preliminary drawings extracted from the Data Base, modify and extend the traces towards the ends.
8. Using 'PARTGENI', create and store in the Data Base the image of each entire Deck or Bulkhead.
9. Using 'PARTSEP', extract to the proper scale any portion of each image needed for each scantling or general arrangement drawing.
10. Using 'HULLLOAD' first and 'PARTGEN', create all necessary scantling drawings for transverse bulkheads.

At the most appropriate time during the above process 'HULLCAL' should be used to run the Longitudinal Strength Calculations for the various operating conditions.

#### Detail Working Drawings

Within the context of this paper, these drawings can be divided into two groups:

- A. Detail structural drawings to be used for hull construction
- B. Record and information drawings, such as 'C & A' drawings, arrangement drawings and composite drawings.

Because of the different purpose and in order to accrue the maximum benefit from the use of 'SPADES', the two groups will be treated separately.

It will be assumed for both that standard cut-outs or notches for through stiffeners have been defined and loaded on the data base. Stiffeners' size and characteristics will also have been loaded onto the data base.

#### Group A:

The format of these drawings has traditionally been the one most suitable for submittal to and structural evaluation by the regulatory bodies. The format most suitable for construction would be that corresponding to the work units (sub-assemblies, assemblies, modules, etc. ).

This conflicting requirement has been solved in some shipyards by creating another set of drawings or sketches geared to work units. This solution, besides increasing the drafting manhours, has also the problem of maintaining two duplicate sets of drawings. The procedure suggested herein should satisfy both requirements with one set of drawings.

The majority of drawings in this group deals with surfaces such as hulk heads, flats, floors, girders, etc. All these drawings must be generated as if the structure, regardless of the size, were a single part to be processed in the N/C cutting machine, so that through the use of 'PARTSEP', smaller parts can be easily extracted.

Those drawings relating to non-flat surfaces, such as a deck with sheer and camber, will be generated following the same procedure but they will not be utilized ultimately to extract the actual parts to be cut.

The following sequence of steps covers the case of generating the drawing(s) necessary to obtain a flat deck with or without sheer. The same procedure would be applicable with slight variations to any other ship's structure.

1. Generate through 'PARTGEN' a "part" comprising the entire deck.
2. Using 'PARTSEP', divide the deck into the various portions associated with each work unit. During this step, generate as many illustrative details as needed. Plot each portion and details in separate sheets.
3. Finish by hand (welding details, lettering and general notes), and issue as a multiple sheets drawing for submittal to regulatory bodies and owner.

When this process is repeated for other drawings, the various sheets from each drawing can be used to put together a multiple -sheets drawing with all the information necessary for building a work unit.

The mold loft can, through 'PARTSEP', further divide each portion of each structure into the actual pieces needed for nesting.

#### Group B:

These drawings will not be utilized by the mold loft to obtain parts. They can, therefore, be generated taking into account only the engineering needs.

The suggested procedure is as follows:

1. Generate through 'PARTGEN' and store in the data base "master" drawings of large areas in the ship. Generally, each one of these drawings will cover an entire deck and will include all boundaries, stiffeners layout and cross-section, and all access openings.
2. Using 'PARTSEP'. any portion of any drawing at any desired scale can be extracted for use by the various engineering groups for different applications. In the process of extracting the desired portion, additional details pertaining to the intended purpose of the drawing can be added.

#### Drawing Revisions

It is implied by the use of this procedure that Engineering assumes full responsibility for the loading and maintenance of the 'SPADES' data base.

The initial task of generating a drawing (scantling or detail) is done in an iterative mode, i. e. , the coding is changed and a new drawing plotted in the drafting machine until the desired result is obtained. At that point, the drawing is finished by hand, by adding any necessary detail and lettering.

From this point on, it will generally be more economical to handle the re - vision activity by conventional methods. It is, however, of the utmost im - portance that the data base be changed accordingly whenever a revision is made, and issue of the revised drawing will imply that the data base has been revised.

### Interactive Graphics Module

An Interactive Graphics Module for the 'SPADES' System is currently under de - velopment. This module is designed to improve the throughput of the entire 'SPADES' System. Since the graphics module is virtually hardware independent, it can easily be adapted to most graphic hardware presently in production.

Although the 'SPADES' Graphic Module is being designed primarily to support production-oriented software, let us look at benefits derived on the engineering level for the aforementioned items:

1. Hull Form Definition  
While the 'CRT' output may not be satisfactory in checking cross curves, floodable length or Bonjean curves, the checking and on-line updating of data would expedite the entire iterative process.
2. Scantling Definition.  
The graphic display capabilities would provide instant visual checks for scantling and general arrangement drawings.
3. Detail Working Drawings.  
The process of generating the drawings of entire decks through an inter - active Partgen Module with graphic display capabilities will allow the user of the System to produce drawings in a fraction of the time required by 'batch' processing. As an error is encountered, the user will have the ability to immediately correct by returning to a deletion level as provided by the System, and then to continue as desired. This capability reduces the number of runs required to produce a correct drawing, minimizes keypunch errors, and increases overall efficiency.

WHERE IS COMPUTERIZATION OF SHIPBUILDING TODAY;

WHERE IS IT GOING

W. Barkley Fritz

Sun Shipbuilding and Dry Dock Company

Chester, Pennsylvania

Mr. Fritz is Manager of the Engineering Computing Center at Sun Shipbuilding and Dry Dock Company. He joined Sun in January 1975, following a successful career with Westinghouse. His background covers a wide spectrum of computer related activities including computer programming, direction of computer resources, and data management systems.

Having recently joined this industry, I am hardly qualified to discuss this topic from a total industry perspective. However, I do have a good understanding of Sun Ship situation and hopefully can briefly present a clear indication of where Sun Ship is today and where we are going, at least computer-wise.

Our shipbuilding program at Sun is highly dependent on the effective use of computers. Steerbear (as reported by Mr. Schorsch at last year's REAPS meeting), is the "big picture" in the very important lines fairing and hull construction area. Steerbear is continuing to prove itself an effective tool and today represents over 35% of the computing load being processed by Sun Ship. We are continuing to use the PL/1 version with excellent results.

Our approach to the use of Steerbear, as in all of our other applications, involves use of computer terminals, a communications interface and a variety of network computer services, as illustrated in Figure 1. In all, about 12 computer networks are in active use, providing a means whereby we access literally hundreds of computer programs.

The variety of application areas in our industry has been documented in the final report in the MarAd/Avondale "Research on Computer Applications to Shipbuilding", Volume 1 dated May 1975. I have chosen to summarize Sun Ship usage in a somewhat different manner, classifying that usage by the technology or the engineering discipline involved. This approach is listed in Figure 2.

At Sun, the Engineering Computing Center is organized so as to provide rapid turnaround on short runs and to schedule production runs so as to meet user requirements. Our responsibility, as a computer service organization, is to help clients exploit available computer technology and to provide assistance to all organizations within Sun Ship who require service.

The total cost of the computer load being processed involves an expenditure of over \$30,000 per month. In excess of 100 individual requests for service are processed daily. Although this load would seem to justify a moderate-size in-house computer, the flexibility provided by our usage of outside computer service bureaus, allows us to select the most effective programs providing the best price/performance without having to support the overhead of the relatively high fixed costs associated with an in-house facility. This approach allows us to use (and pay for) only what we need, and not fall into the "trap" of using the in-house computer just because it is there.

In addition to computer network usage - including the very significant roles of RJE, time sharing and interactive graphics - Sun Ship is also making use of minicomputers as part of its plasma arc burning tools, and for on-line control of its new drydock (which incidentally is capable of handling ships sized up to 400,000 dwt). Micro-processors are also a part of onboard engine room and bridge systems.

For the future, I believe computerization will be simultaneously going in two distinct directions. First, the application support programs will continue to become more sophisticated, will grow larger and more complex, and will continue to represent, more realistically, the technology of the more complex ships of the future. The requirements of the classification and regulatory agencies, plus the real needs of the ship owners require continually more careful, more economical, and more efficient ship design and construction. Shipbuilding is rapidly becoming a high technology industry.

Progress in computerization, however, requires use of the computers at both extremes of the state of the computer art. The largest, fastest, most reliable computer networks will be required, but at the same time, the direction is toward the effective use of the smallest microcomputers. Minicomputers have for some time been the vehicles for

gaining access to the larger computer networks. The new microprocessor devices are now being used as the basis of intelligent terminals, communication controllers, as well as for on-board navigation, speed and fuel monitoring and control devices, and in the yard, as parts-generation controllers. All of this new computer technology will help to support the growing sophistication in our industry.

Sun Ship is attempting to maintain a strong technological position in order to continue to supply to its customers a variety of well-designed, fine-lined, high-speed cargo ships of its own design. In the tanker and LNG area, Sun Ship is attempting to provide significant technological advances which are fully supported by adequate computerized studies.

We have recently completed a new ship construction facility at our Pennsylvania location on the Delaware River. With our recently expanded staff, and effective computer support capability, we believe we are in an excellent position to provide some of the best designed and finest built ships available in the world today. Our effective use of computers helps to support that capability at all levels and, in the years ahead, we expect to continue to advance in that technology.

Thank you.

# Sun Ship Computer Network

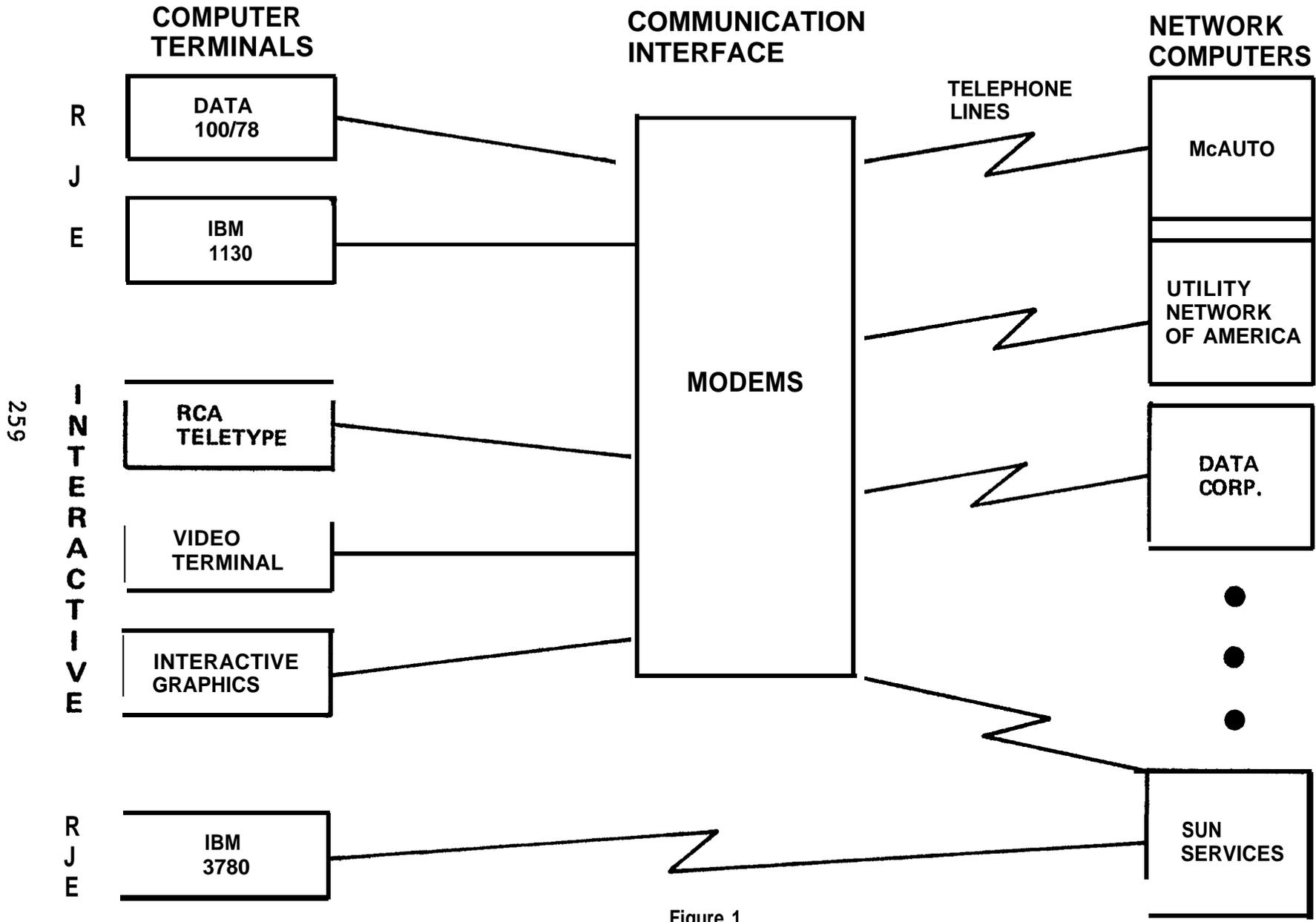


Figure 1

# Computer Program Application Areas

## NAVAL ARCHITECTURE

SHIP HULL CHARACTERISTICS

SPEED/POWER

WEIGHTS AND MOMENTS

PROPELLER DESIGN

LINES FAIRING (STEERBEAR)

SEAKEEPING ANALYSIS\$ (SCORES)

## MARINE ENGINEERING

HEAT BALANCE

SHAFTING DESIGN

PIPE STRESS AND FLOW

INTERFERENCE CONTROL

ELECTRICAL DESIGN AND ANALYSIS

## STRUCTURAL ENGINEERING

STRUCTURAL ANALYSIS (FINITE ELEMENT ANALYSIS)

N/C PARTS GENERATION AND LOFTING (STEERBEAR)

## PRODUCTION PLANNING AND INDUSTRIAL ENGINEERING

STEEL FABRICATION AND ERECTION SCHEDULING

MANPOWER LOADING AND SCHEDULING

WELDING PIECEWORK RATES

## MARKETING

DESIGN OPTIMIZATION

ECONOMIC ANALYSIS

INDUSTRY ECOMETRIC MODELING

COMMODITY MOVEMENT ANALYSIS

VESSEL DATA

Figure 2

AN INTERACTIVE GRAPHICS  
MINICOMPUTER BASED  
SHIPS ARRANGEMENTS PROGRAM

James R. Vander Schaff  
CADCOM, Inc.  
Annapolis, Maryland

Mr. Vander Schaff is currently a member of the technical staff at CADCOM where he is engaged primarily in the computer-aided ship design services area. Before coming to CADCOM, he was with the concept design and formulation group at the Naval Ship Engineering Center in Hyattsville, Maryland. While at NAVSEC, Mr. Vander Schaff worked on the ship structures committee's SL-7 containership project.

## I. INTRODUCTION

The task of arrangement design, like other aspects of ship design, is an iterative process. Each iteration either produces a better design or defines a non-feasible design within the limitations of cost and time constraints and desired ship performance. Because of the success achieved in applying computers to analytical aspects of ship design and because of the desire to improve the arrangement process, it was a natural development that they be applied to arrangement design too. However, this process has not achieved the same amount of success, primarily because arrangement design has relied more heavily on human judgment and experience than on analytic methods. The development of computer programs for arrangements has also proceeded in timewise steps, some with more success than others. While no program produced to date has proven completely adequate for all the requirements of arranging, the programs which have been produced have been useful in defining the steps required for future developments, as well as achieving modest success in their particular tasks.

It is not the intent of this paper to provide a review of all the arrangement programs which have been generated; rather it is the intent of this paper to describe a particular arrangement program, COGAP, and to detail the implementation (by CADCOM, Inc. ) of a portion of COGAP on a minicomputer based graphics system.

Additionally, it is intended to discuss software and

hardware advances which will aid particular aspects of arranging, in order to advance ship design and construction.

## II. COGAP

### II:1. Origin

The COGAP computer program was written by the Lockheed-Georgia Company for the Naval Ship Engineering Center, Washington, D.C. It was delivered in October, 1972. Since that time other organizations both within the Navy and outside, have added to the program. The following description does not address these additions (perhaps they could be the subject of later presentations) but rather describes the original COGAP program. <sup>1)</sup>

### II-2. Definition

COGAP provides for the synthesis and display of preliminary ship design on a computer graphics terminal. COGAP breaks the ship arranging task into four major divisions. The first two divisions are input functions: ship geometry definition and template (ship component) construction. The third division is basically an inquiry function: selective retrieval of components by specifying characteristics (statistical data). The fourth division serves as a manipulation function: processing and recursive definition of arrangements. Figure 1 illustrates the COGAP program structure.

The four major functions of COGAP described above were implemented on the Control Data Corporation (CDC) 6000 and 1700 series computers and 274 graphics console. In addition to the COGAP software, the I.T.I.S.2 (Interactive Terminal

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1. Lockheed-Georgia Company, "COGAP Operators'/Users' Manual",  
29 October 1972.

COGAP

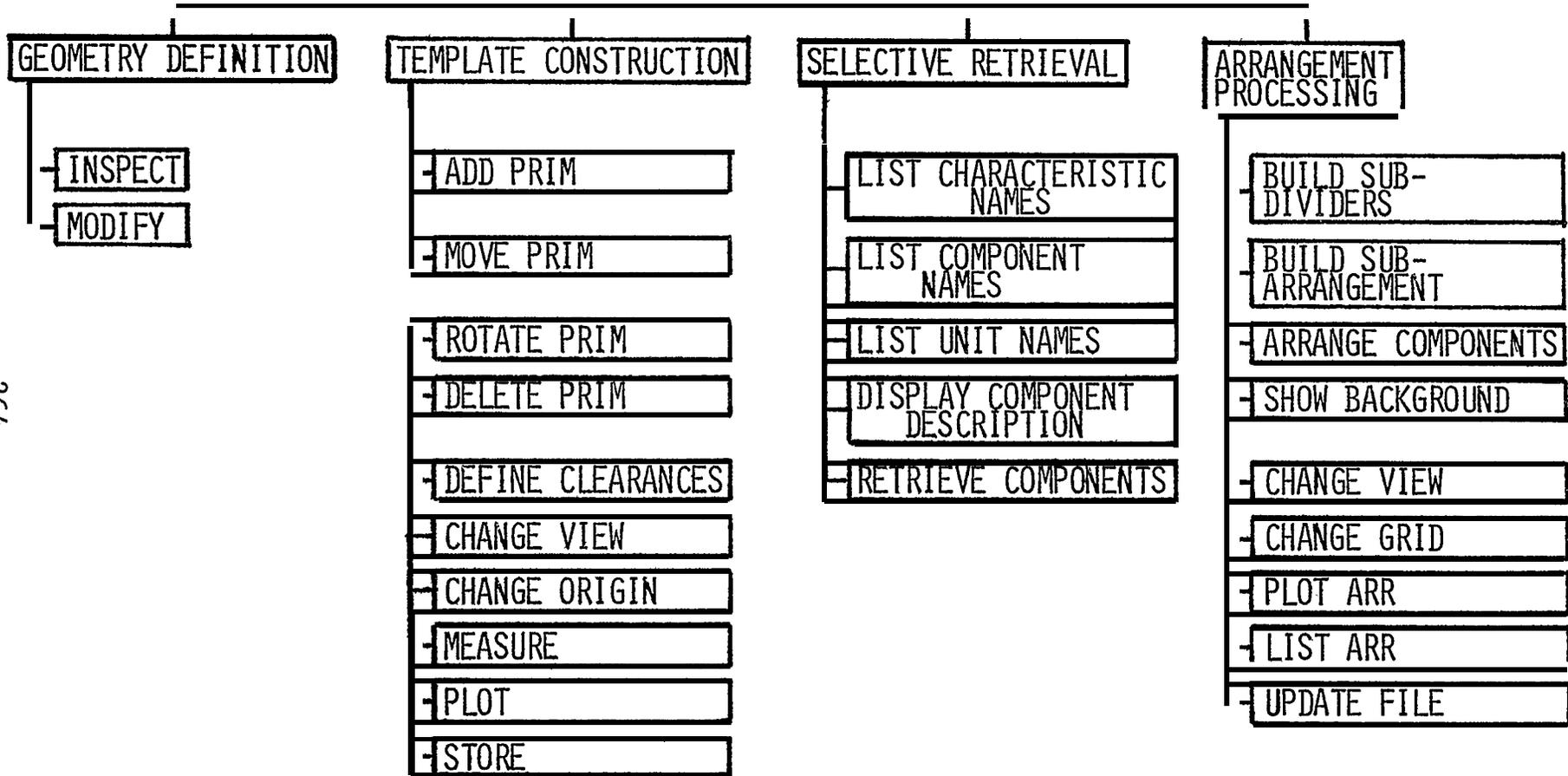


FIGURE 1.  
COGAP PROGRAM STRUCTURE

Interface System, version 2 software, and the DAM (Data Access Mechanism) software were used in the implementation.<sup>(1,2)</sup>

### 11-3. Operation

The graphics terminal (in addition to the standard alphanumeric keyboard) has a light pen which is used for system commands. In addition to the graphics console, COGAP requires some form of mass data-storage (disk or drum) for access to descriptive ship data. Hard copy output may be produced on a plotter or the printer. A card reader and card punch facilitate the transfer of information between COGAP and other computer programs.

To accomplish the task outlined above, COGAP maintains sufficient information on mass storage devices to describe ships and their components. This information is termed the data base. A logical subset of the data base, pertinent to only one particular ship, is defined to be a file. Having established his file environment by specified procedures, the user may request that the data in the file be displayed on the graphics console, plotted on a hard-copy device, Or written on a printing device. Examination and modification of the file data takes place at the terminal, and file updates reflecting the user actions, while performed automatically, take place only at the operator's request.

In addition to the file currently being accessed, the user has at his disposal another logical subset of the data

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2. Lockheed-Georgia Company, COGAP Systems Manual", 12 November 1972.

Interface ,System, version 2) software, and the DAM (Data Access Mechanism) software were used in the implementation. References 1 and 2 completely describe the COGAP system.

### II-3. Operation

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In addition to the file currently being accessed, the user has at his disposal another logical subset of the data

base termed the library. COGAP maintains only one library for all users. In this library are stored all data pertinent to ship components. Components are physical objects (ship equipment) which are used on many different ships. Components are represented by two types of descriptive data, statistical and geometric. The statistical data are called the characteristics of that component; the geometric data are referred to as the template.

#### II-4. Ship Geometry Definition

In the COGAP program, the term ship geometry means numerical data or displayed images which represent the ship hull (envelope), decks (platforms), and main transverse bulkheads.

Specification of decks and main transverse bulkheads is done independently of the hull definition, and COGAP makes the necessary computations to generate the intersections of the surfaces so defined and to construct the curves required to produce an image of the ship geometry on the graphics terminal. Relevant ship geometry may be constructed and displayed in plan, elevation, and section view simultaneously. Figure 2 illustrates the geometry program structure.

The three classes of ship geometry definition (hull, deck, and main transverse bulkheads) are input directly to a COGAP file from punched cards via an auxiliary batch program. The user has the opportunity to examine the content of the hull, deck, and transverse bulkhead descriptions in a particular file as well as monitor the calculation of the intersections of these surfaces. Additionally, the location of

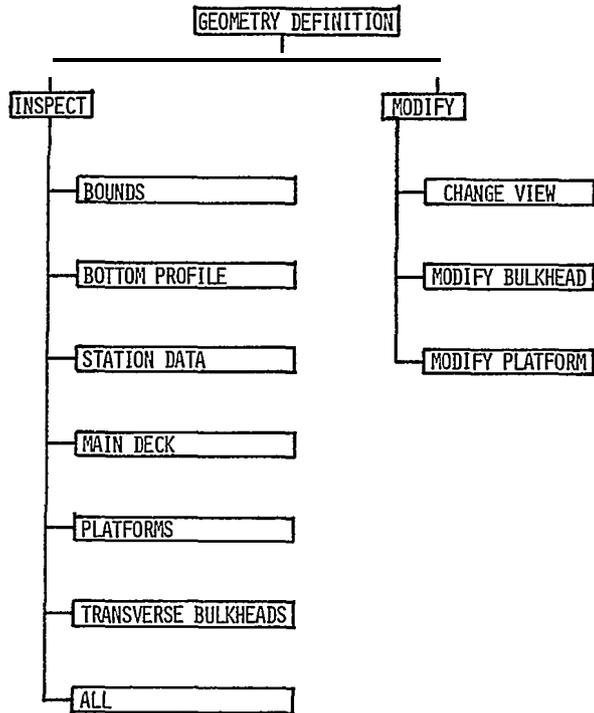


FIGURE 2.  
GEOMETRY PROGRAM STRUCTURE

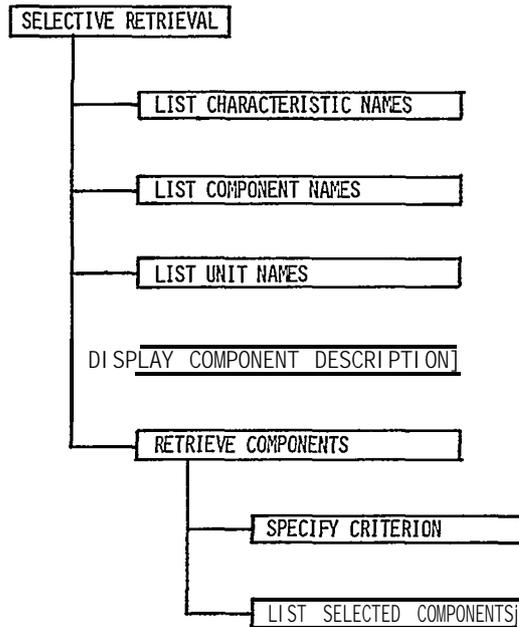


FIGURE 3.  
SELECTIVE RETRIEVAL PROGRAM STRUCTURE

decks and main transverse bulkheads may be modified by the user.

#### II-5. Selective Retrieval

A component (e.g., turbine, gun, radar) may have a description which consists of several characteristics. Each characteristic is given in terms of a characteristic name and a value in certain units. The characteristic names and unit names are defined to COGAP by means of a batch program. As part of the units definition, COGAP provides for the conversion between alternate units (such as horsepower into watts or tons into pounds) so that the specification of characteristic values may be made in convenient units. When all of the desired units and characteristics have been defined to COGAP, the user may assign a set of characteristic values to a given component by means of an auxiliary batch program. Figure 3 illustrates the selective retrieval program structure.

In the selective retrieval division of COGAP, the operator has the ability to selectively retrieve the names of all components which have characteristic values within specified limits. For example, if the operator wishes to know the names, of all components which (1) are turbines and (2) weigh between 5 and 7 tons and (3) deliver 10,000 shaft horsepower, he may specify these criteria and will receive a list on the screen of the names of only those library components whose characteristics satisfy all three criteria simultaneously.

The operator also has the capability of examining lists

of all characteristic names and unit names which have previously been defined, a list of the names of all library components whose characteristics are known to COGAP, and a list of all characteristics assigned to a given component (this is called the description of that component).

#### II-6. Template Construction

In COGAP, a template is a collection of solid geometric forms which, when taken together, approximates the volume and shape of a component. The solid geometric forms allowed by COGAP are a parallelepiped, a right circular cylinder, a right circular cone (or frustrum thereof), a sphere, and a wedge. These forms are termed primitives. A template occupies the space required by the union of all primitives of which it is composed. Figure 4 illustrates the template program structure. This portion of the program has been implemented by CADCOM, Inc., and will be described in detail on the following pages.

#### II-7. Arrangement Processing

Assuming that the user has provided for the necessary ship geometry and has the necessary templates available in the library, he may proceed to the arrangement tasks of COGAP illustrated in Figure 5. The arrangement process is a recursive one, consisting of the following three operations:

- (1) the selection of an existing arrangement,
- (2) the introduction of subdividers and/or component templates into the selected arrangement, and

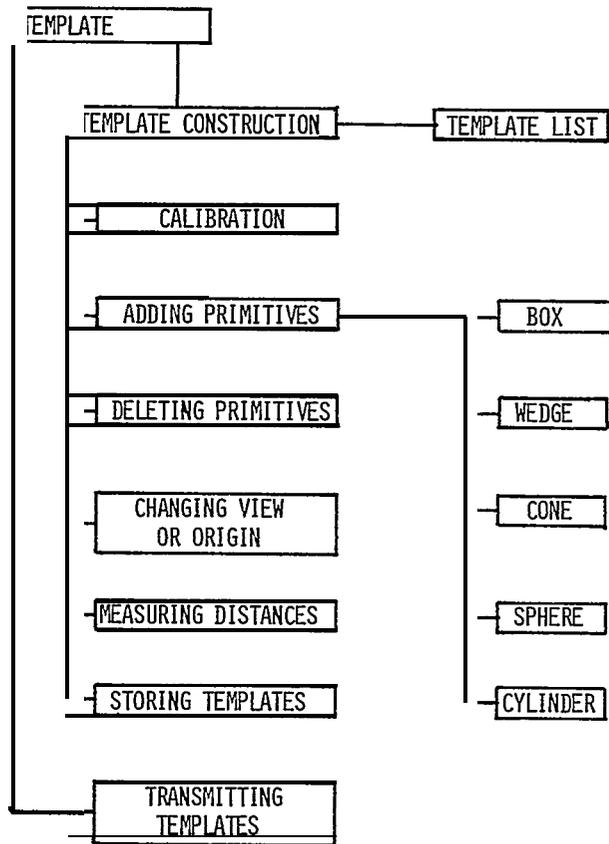


FIGURE 4.  
TEMPLATE PROGRAM STRUCTURE

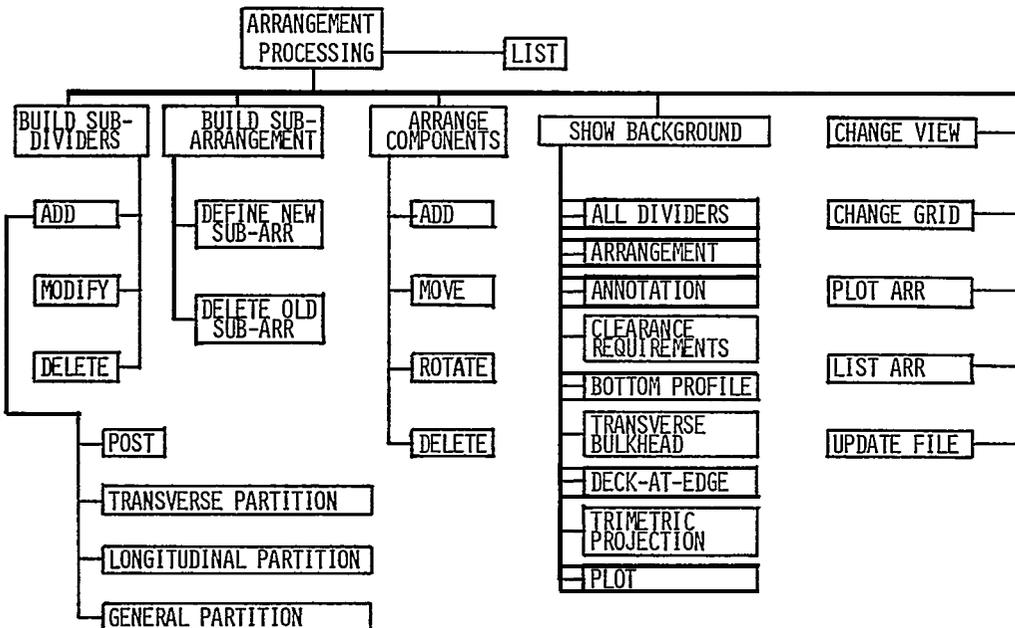


FIGURE 5.  
ARRANGEMENT PROGRAM STRUCTURE

(3) the designation of a subset of the boundaries of the selected arrangement and the subdividers introduced in operation (2) as the boundaries of a new arrangement.

In the COGAP arrangement process, the two-part recursive definition of arrangements is handled in the following manner: the first instance of arrangement definition is performed automatically by the geometry division of COGAP. This division defines each deck (main deck and all platforms) to be an arrangement whose name is the same as the deck name. Thus the user may specify one of these names to begin an arrangement process. For every instance of arrangement definition after the first definition, operation (3) denoted above is the process by which sub-arrangements of a given arrangement are created. Within operation (3), a name is assigned to the new arrangement, and that name may be subsequently used to begin an arrangement process on a more detailed hierarchically lower level. Since decks are the beginning of the arrangement hierarchy, they are sometimes referred to as zero-level arrangements, and sub-arrangements are called first-level, second-level, etc. arrangements as appropriate.

When an arranging process is initiated, the named arrangement will be displayed by COGAP. This display will consist of (1) the boundaries of the arrangement, (2) the subdividers currently defined in the arrangement, and (3) the component templates as currently positioned in the arrangement. For

decks, the boundaries are considered to be the hull and applicable transverse bulkheads. Therefore, the initial display of a deck in the arrangement division will consist of the deck-at-edge (hull/deck intersection) curve together with any internal transverse bulkheads; i.e., bulkheads that pass through the referenced deck. (Arrangements initially contain no subdividers and no components,)

Once an arrangement has been specified and is in display, subdividers may be added to it. Subdividers are either posts or partitions. posts are straight up-and-down line segments between a given platform and the platform above. They appear as points in a plan view. Posts may be used to specify the location and/or extent of any type of partition. A post is defined either by inputting coordinate information directly to the graphics terminal or by specifying a pair of non-parallel lines the location of whose intersection is to be the location of the post. In either case, however, once the post has been defined, it is considered to be a fixed location; i.e., a location which is independent of any other subdivider or boundary in the arrangement.

The second type of subdivider is the partition. Partitions are straight up-and-down planes bounded between a given platform and the platform above. They appear as line segments in the plan view. There are three different kinds of partitions: transverse (perpendicular to the ship centerline), longitudinal (parallel to the ship centerline), and general

(arbitrary orientation) . A transverse partition is defined by specifying a longitudinal location and a port and a starboard extent. The longitudinal location may be specified either by inputting coordinate information to the graphics terminal or by indicating a post or another transverse partition which has the desired longitudinal location. If a post is indicated, the resulting partition is said to reference that post. The port and starboard extents of a transverse partition may be longitudinal partitions, general partitions, posts, deck-at-edge curves, or any combination thereof. A transverse partition references its port and starboard extents. Likewise, a longitudinal partition is defined by specifying a transverse coordinate to the terminal or by indicating a post or another longitudinal partition which has the desired transverse location. If a post is indicated, the resulting partition referenced that post. The forward and aft extents of a longitudinal partition may be transverse partitions, general partitions, posts, deck-at-edge curves, or any combination thereof. A longitudinal partition references its forward and aft extents. A general partition is specified by picking, and thereby referencing, two posts which serve as its end points.

A subdivider (partition or post) may be modified at any time by respecifying one or more of the parameters originally used to define it. Such explicit updates will generate implicit updates to all partitions which reference that subdivider. In addition, all partitions referencing such auto-

matically updated partitions will themselves be automatically updated.

In addition to subdividing a given arrangement, the user may insert and position components in a newly defined arrangement, or he may add? re-position, or delete components from a previously stored arrangement. The tasks are very similar to those in template creation, except that primitive manipulation has been replaced by template manipulation. Once the arrangement has the desired design, the user may choose to store the configuration for later recall. At any time, the capabilities for plotting, measuring, and changing the displayed view are accessible to the user in the same manner as in the template-creation tasks.

As an aid to visualizing inter-relationships among various arrangements and other COGAP geometric and annotative constructs, COGAP supports a varied set of procedures for displaying background information. Background information is defined to be any displayable construct other than the information displayed as part of the named arrangement. Examples of background information include other arrangements, template clearance requirements, curves representing transverse bulkheads, decks, and the bottom profile, and annotation. Annotation is made up of text strings which can be used to label arrangements components and/or sub-arrangements within arrangements, etc.

Normally, arrangement processing takes place in one of the three standard-engineering views (plan, elevation, or

section) . In the background display task, however, a general trimetric projection capability is used. In any projection other than the three standard views, however, the subdividers and the annotation (being two-dimensional in nature) will not be displayed. In addition to the capability to display background information, COGAP may also be directed to plot background.

## II-8. Display Philosophy

### II-8.1. View-Cube

The central concept of the COGAP display philosophy is that of the view-cube. The view-cube may be visualized as a wire (cubic) frame of arbitrary size which may be placed with its center at any point in space and with its edges oriented in any triple of mutually orthogonal directions. The concepts of "size," "point," and "direction" in this description imply, of course, that some coordinate system has been imposed on the space in which the view-cube exists. When the display includes (or may include) surfaces of the ship (e.g., the hull, bulkheads, decks, etc.) such a coordinate system is seen to exist a priori, since these display elements were originally defined to COGAP in terms of such a system. The situation is somewhat different, however, when the task is the creation of a template, which may be placed in any part of a ship or even in several different ships. In this case, the view-cube, when first invoked for a particular template, imposes on the template creation space a COGAP-defined axis system. The origin of this axis system is said to be the

template origin.

In either case, the user may completely control the position, size, and orientation of the view-cube with respect to the space in which he is working. That is done by specifying the point, edge, axis, and spin of the view-cube.

The point (center) of the view-cube may be specified either by entering an ordered triple of numbers (the X, Y, and Z coordinates of the point) from the alpha-numeric keyboard, or (if the location to become the new point is currently within the view-cube) by moving a special display element called the tracking symbol to the desired point on the display. The edge parameter is a number which specifies the length of every edge of the view-cube. Since the same physical area on the display device is occupied by a face of the view-cube no matter what value is specified as the edge parameter, it follows that the smaller the value of edge, the larger display objects will appear; the process of increasing the size of a display element by this mechanism is known as zooming.

Once the position and size of the view-cube have been established by the above parameters, a view axis may be specified. To allow this specification, COGAP selects three of the six faces of the cube and designates them as follows: if a right-hand (orthogonal) axis system is oriented in the view-cube so that its origin is at the point of the cube, the face intersected by the positive Z axis is the top of the cube,

that intersected by the positive Y axis is the front of the cube, and that intersected by the negative X axis is the right side of the cube.

Once this nomenclature has been established, the view axis may be defined. There exists only one ray which is normal to the top of the view-cube and emanates from its point; this ray is called the view axis. If the view-cube is temporarily translated so that the point lies at the origin of the coordinate axes, it is evident that the view axis can be described by specifying: (1) the angle between the projection of the view axis into the  $Z = 0$  plane and the positive X axis (this angle is called the skew of the view axis) , and (2) the angle between the view axis itself and the positive Z axis (this angle is called the tilt of the view axis) . To specify the view axis, the operator types in on the alphanumeric keyboard an ordered pair of numbers representing the number of degrees of skew and the number of degrees of tilt desired.

At this point the orientation of the view-cube is still not completely specified; any rotation of the view-cube which leaves the view axis invariant (i.e., any rotation about the view axis) can be performed independently of the above parameters (recall that these parameters consist of: point, an element of the view axis and hence invariant by definition; edge, a scalar and hence invariant under any rotation; and view axis, invariant by definition) . This remaining degree of freedom is called the spin of the view-cube. From the

definition of view axis, it is clear that the most easily visualized effect of spin is the rotation of the top of the view-cube about its own center.

COGAP supplies default parameters for all view-cube specifications. The axis and spin specifications supplied by default ( $\text{skew} = \text{tilt} = \text{spin} = 0$ ) produce a view-cube whose top is parallel to the  $Z = 0$  plane, with X increasing toward the left side, Y increasing toward the front, and Z increasing toward the top of the cube. It should be noted that skew, tilt, and spin provide trimetric projections in each of the faces of the view-cube.

### 11-8.2. Screen Segmentation

The preceding discussion has described the relation between the view-cube and the space being examined. Next, the relation between the view-cube and the display appearing on the computer graphic console will be discussed.

In COGAP, the actual display may be composed of the top, front, and right side views of the view-cube presented simultaneously, or it may consist of only one of the above faces presented alone. In either case, the lines drawn are orthographic projections, onto these faces of the view-cube, of lines whose three-dimensional end points are known. In ship displays, the lines comprising the display are intersections between bounding surfaces (such as decks, bulkheads, hull, partitions) or the edges of the primitive shapes (box, cylinder, cone, sphere, wedge). To show these faces on a single

graphics terminal screen, the display area is divided into four equal quadrants. In the case that three views are displayed simultaneously, the view-cube is "unfolded" so that the top view occupies the upper left quadrant, the front view occupies the lower left quadrant, and the right side view occupies the lower right quadrant. (In the terminology of engineering graphics, this is third angle projection.) In the case that only one view is shown, the entire display area is used for that chosen view.

The upper right quadrant of the display screen is used for the display of three types of information: light-pen picks, keyboard entries, and system messages. Light-pen picks may be thought of as a list of possible imperative statements that the terminal user may make to COGAP, directing it to take some specific action. Keyboard entries may be thought of as imperative statements made by COGAP to obtain alphanumeric or numeric data it requires to comply with a user request. Systems messages may be thought of as declarative or imperative statements made by COGAP to the user, providing him with information concerning the status of his design efforts or directing him to take specific actions.

When COGAP requires that the operator select a point in space for some display purpose, it usually provides him with the option of either entering the coordinates of that point as keyboard input, or selecting it as a point within the view-cube. To exercise the second option, the user invokes a display

element known as the tracking symbol. The tracking symbol may be thought of as a single physical object within the view-cube which may be moved about by means of the light pen. As with any other object within the view-cube, three views of the tracking symbol are available: the view from the top of the view-cube, the view from the front of the view-cube, and the view from the right side of the view-cube. However, it should be remembered that the tracking symbol is logically a single entity and that what is really meant is "one of the three views of the tracking symbol."

#### II-9 . Data Structure

The data base maintained by COGAP is subdivided into a large number of individually accessible subsets called data blocks . A data block contains all the information relevant to a particular item under consideration, such as the data required to draw a geometric component template, or a list of all components in a compartment. The block is accessed by means of a ten character name, (usually) assigned by the user.

Each data block has a certain size; this size determines the amount of information which the block can contain. The effect of this on the COGAP user is that there are limits on the number of items which can be associated with any other item (e.g., the number of components which can be placed in a compartment)

### III. MINIMENTS

#### III-1. Introduction

A portion of the COGAP program, namely the template construction program, has been implemented on a minicomputer based graphics system. This implementation was performed by CADCOM, Inc., in late 1973 and early 1974. The purpose of this implementation is to provide an inexpensive, intelligent terminal system for interactively building, formatting, and transmitting to the COGAP data base complete template definitions which would be compatible with the existing COGAP data formats. "MINIMENTS" (MINIcomputer arrangeMENTS) is the name given to this software. The miniments system is illustrated in Figure 6.

The design of the system software was predicated on keeping the display philosophy and data formats identical to COGAP,

With respect to display philosophy, the concepts of the view-cube, the template origin, the template rotations, the process of zooming, the display faces, the trimetric projections, the screen segmentation, and the menu panels, were kept essentially identical. A method for inputting primitive definitions by digitizing space coordinates from a drawing, led to modifications which resulted in much more efficient template definition. In the original COGAP implementation, primitive dimensional data is entered on the graphics console keyboard, or, space coordinates are punched on cards and then read into the data base. If data is entered on the key-

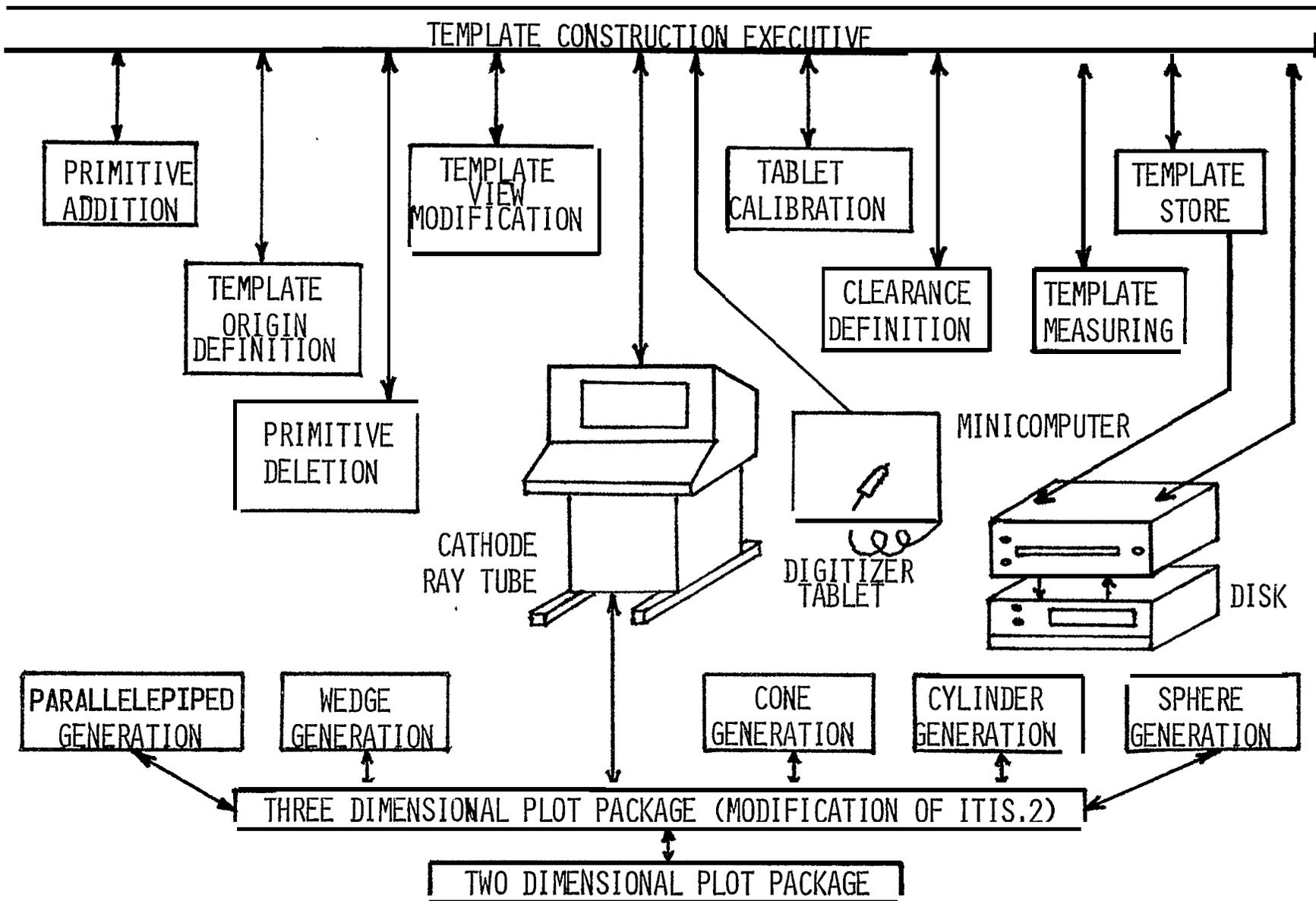


FIGURE 6.  
TEMPLATE CONSTRUCTION SYSTEM

board, it is necessary to move and/or rotate the primitive proper orientation. Now, using the minicomputer-digitizer system, the user need only digitize space points which represent key locations or dimensions of the primitive being created. The primitive then is displayed on the screen in the proper orientation immediately.

The template data structure is file oriented. A complete description of a template is generated on a file in the template construction process. This template data block can be translated into card image format and transmitted at any time to a remote computer for insertion in the template library via a COGAP auxiliary batch program.

### III-2. Hardware

The hardware for miniments consists of the following major components:

- A minicomputer with 16,384 16-bit words of semiconductor memory (Prime 200) for processing and transmitting the generated templates to and from mass storage, the graphics display and the CDC 6700, via standard communication links.

- A Cathode Ray Tube (CRT) interactive display with keyboard. The keyboard is used for commands to the minicomputer and the remote computer. The template construction process, the menu of commands and the output from the remote computer can be rapidly displayed on the CRT.

- A 36" X 48" Summagraphics digitizer for digitizing the space coordinates of the input primitives directly from

drawings or sketches.

- A Data Set for transmitting the stored templates to the remote computer.
- A dual spindle, 3.0 million word moving head disk storage unit for storing the data which describes the templates and the application programs which process and display the data.
- The remote computer (CDC 6700) stores the template descriptive data for processing by the other COGAP routines.

### III-3. Operation

A three view engineering drawing is used to input the graphic template descriptions. This drawing must first be calibrated with respect to the digitizing surface. The calibration process provides the information required for digitizing and displaying the primitives in the template construction process. Figure 7 illustrates the process of calibration.

Prompting messages appear on the graphics console in the order indicated in Figure 8. After a required action has been taken the next message will appear.

The location of the region center is determined by the user according to the layout of the drawing. Its purpose is to divide the drawing into four regions, three of which are the front, top and side views of the template to be built. It is *necessary* to use only two views of the template, since location of the point in three dimensions can be determined from the location of the point in a minimum of two orthogonal two-dimensional Views.

Next, the number of regions to be calibrated is specified. If all views of the template (which will be used) have the

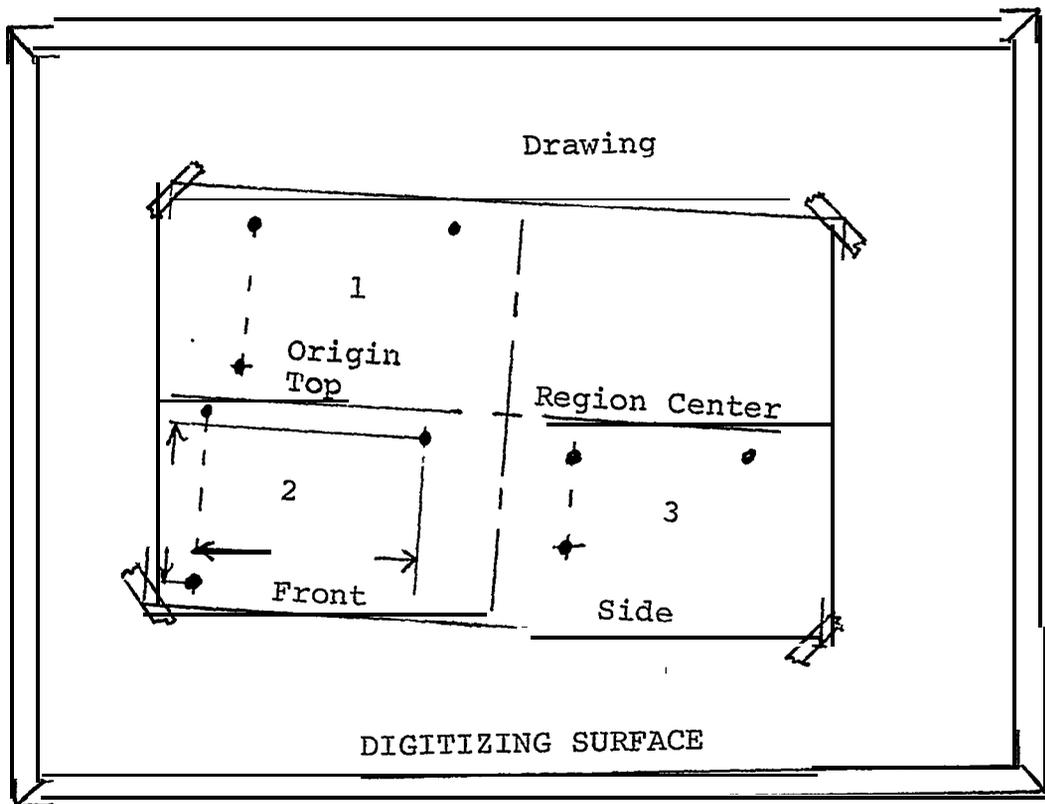


FIGURE 7.  
CALIBRATION

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10 MEASURE
11 LIMIT COORDINATE TOLERANCE .02...
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13 MESSAGE IS REQUIRED TO BE CALIBRATED 1
14 UNITS (1) IN (2) EI (3) 1
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FIGURE 8.

Prompting Messages

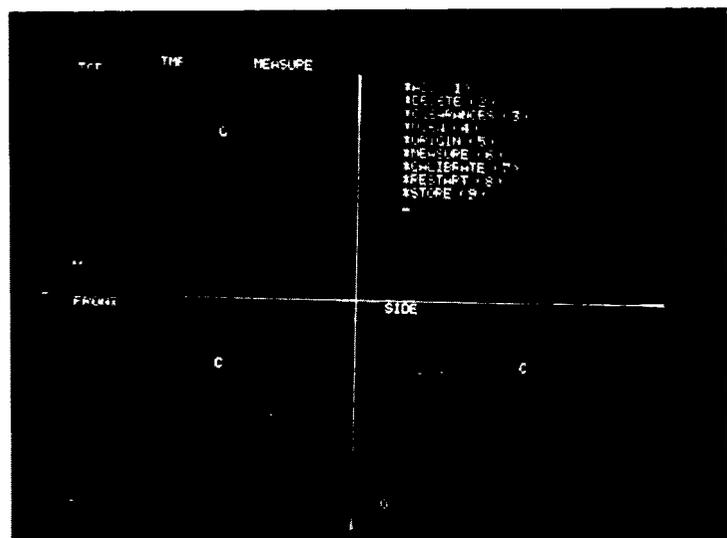


FIGURE 9.

Main Template Construction Panel

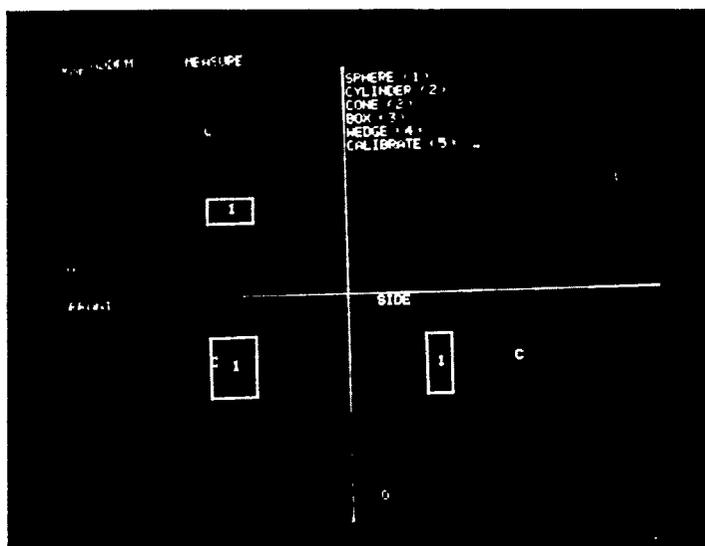


FIGURE 10.

Primitive Types

same scale and origin with respect to the region boundary, then it is necessary Only to calibrate one region. A maximum of three regions can be independently calibrated.

Step 3 (Figure 8) requires the user to pick a number corresponding to the full scale units (feet, inches, or eighths) which will be the units later provided by the user.

The next steps consist of digitizing the origin and two additional points for each region which is to be calibrated. These three points provide both scaling and orientation for the template construction process. The origin is the template origin. It is always necessary to digitize the origin in all three regions. If only two views are to be used in building the template the origin in the third region is effectively a dummy point. Of course, if three views are to be used the third origin definition is utilized. The message REPEAT STEPS 6 THRU 9 FOR THIS REGION. HOR. \_\_\_\_\_ VERT . \_\_\_\_\_ will appear for each additional region to be calibrated. Error messages are given for certain types of input errors and the user is prompted for the corrective action to be taken to continue calibration.

Figure 9 illustrates the choices available to the user following calibration.

### III-3.1 Add ~

The five different primitive types shown in Figure 10 are available to the user by typing the corresponding number. When a primitive type is chosen the user is informed of the primitive type and is prompted for pen input. All input consists

of three dimensional space points which represent the vertices (or centers ) of the primitive.

The paragraphs below specify the order in which the 3D points are input. For pen input the X, Y, and Z values for each point are obtained by digitizing the point in any two separate views. The values for the digitized points or radii are then displayed on the screen. The various primitive definitions are described below:

SPHERE(1) The first point is the sphere center, the second point is any point on the sphere surface.

CYLINDER(2) The first point is the center of one end of the cylinder; the second point is any point on the cylinder surface which is a radius away from the first end point. The third and fourth points represent the center and radius of the other end of the cylinder. Note that for a cone, the radius of one end is user specified to be zero.

BOX(3) The order of the four points is shown in Figure III

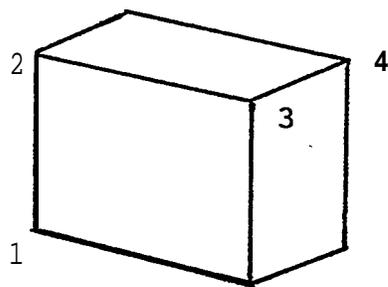


FIGURE 11.

Order of Box Input

WEDGE(4) The order of the four points is shown in Figure 12:

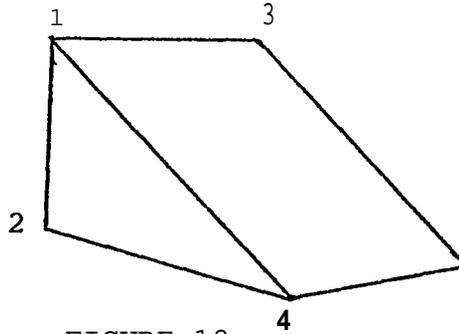


FIGURE 12.  
Order of Wedge Input

When the required points have been input, the primitive input is then displayed with a numeral as its center for identification (as shown for a box in Figure 10).

Since 3D space points are used instead of primitive dimensions, the primitives appear on the screen in the same orientation as they are digitized. This feature eliminates the requirement for moving or rotating primitives. This feature also allows the generation of non-right and/or non-rectangular boxes and wedges.

In every option discussed above, once the primitive is drawn, the user has the option of adding another primitive. If the number zero (0) is typed, control returns to the TEMPLATE CONSTRUCTION Panel. (Figure 9)

Error messages are given for two types of errors. **\*\*SAME REGION\*\*** is given when the two digitized points which represent one physical point are digitized in the same region. (They must be in different regions to generate an x, Y, Z coordinate triple.) **\*\*TOLERANCE\*\*** is given when the two digitized points (again representing one physical point)

do not have their duplicate coordinate within a specified tolerance. This duplicate coordinate occurs because the digitizing of two 2D points (to produce one 3D point) generates one redundant coordinate.

### III-3.2. Delete

By selecting the \*DELETE option (Figure 9) , the user may delete any primitive in the current template. The primitive to be removed is designated by an assigned identification number which was generated during the \*ADD procedure.

### III-3.3. Clearances

Clearance primitives may be used to define volumes not part of the template being constructed. They are added in the same manner as in the \*ADD option.

### III-3.4. Changing the View or Origin

At any time during the template construction process, the user may modify the orientation or size of the view-cube controlling the display. This is done by selecting the \*VIEW option (Figure 9).

The position of the view-cube center is always indicated by the letter C displayed in all views at its actual location. Likewise, the origin is indicated by the letter O. When this panel is initialized, the user is informed that the view-cube has center and edge as specified. The default values of X, Y, and Z are edge divided by two. The values are specified in user units. In addition, the user is informed of the face currently being displayed (this can be TOP, FRONT, SIDE or ALL) .

The user is also informed of the values of SKEW, TILT, and SPIN in degrees.

The user may change any of these parameters by typing in the number associated with the parameter. These parameters are described below and are listed in Figure 13:

CENTER(1) The two options TRACK(1) or TYPE(2) will be displayed. Selecting TRACK(1) requires that a point be digitized. Selecting TYPE(2) requires keyboard input. The effect of changing the view-cube center is to move the template on the screen by the amount of change in each view.

EDGE(2) ENTER EDGE\_\_\_\_\_ will be displayed. The new value, in user units may be entered. The effect of a new value smaller than the old value is to "blow up" or "zoom in" on the template.

FACE ( 3 ) Three choices, representing the changes which could currently take place, are made available. The user selects one of these.

SKEW(4), TILT(5), SPIN(6) Picking any of these choices allows the user to specify the new value in degrees. All rotations of the template are performed about the template origin.

ORIGIN(7) This choice allows the user to redefine the origin of the coordinate axis system within the template creation space. The location of the origin severely affects the behavior of the template when it is used in the arrangement division of COGAP. For this reason, the template origin should be chosen with care, and should not be changed after

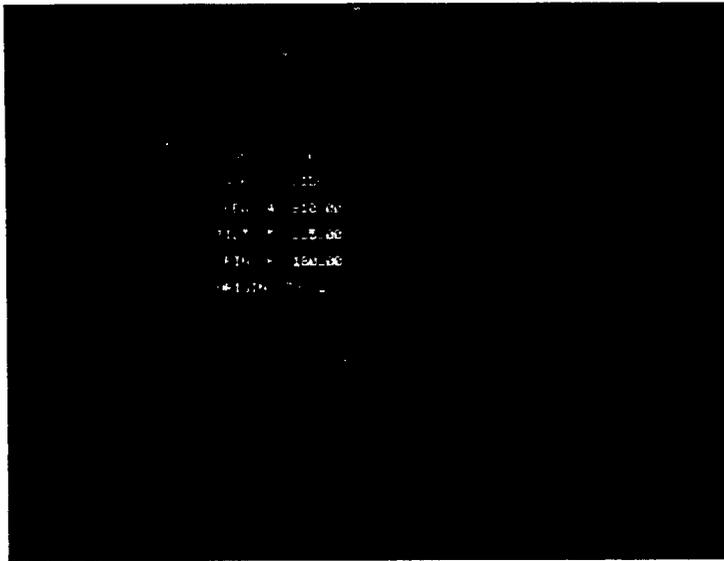


Figure 13  
View Parameters

the template is in use in several arrangements unless the user is willing to review these arrangements and correct any problems that the origin redefinition has created. If this choice is made, the user has the same options described in CENTER(1) above. Changing the origin does not move the template in the three views, but does move the symbol (0) which represents the origin's position.

### III-3.5. Additional Capabilities

Frequently it is desired to know the dimensions between any two points in the display. This service is provided by the \*MEASURE pick.

It is possible to restart (or backup) the template definition process at any time by choosing the \*RESTART(8) pick.

After a template is completely defined it may be stored on local mass storage for later modification or transmission to a host computer. The storing procedure is invoked by the \*STOre option.

Figures 10, 14 and 15 illustrate the process of adding primitives until the complete template is built. Figures 16 and 17 illustrate the completed template in three views (top and front) and one view (side) respectively.



#### IV. ENHANCEMENTS AND APPLICATIONS

In the preceding discussion, the focus has been on an existing minicomputer graphics system for the definition, manipulation and visualization of three-dimensional templates. It is recognized that this system is not complete, and that additional concepts need to be added to the system in order to aid the arrangement process. The following paragraphs discuss concepts which are being considered in one specific area of the ship arrangement process. The area relates to the detailed design process. Other applications are under consideration and include general arrangements and interfaces to piping and electrical design.

##### IV-1. Three-Dimensional Graphic Models

The use of physical models as an aid to Planning, engineering, manufacturing, communications, and training is well established in many industries. A recent MARAD/SNAME publication<sup>(3)</sup> describing the national shipbuilding research program estimated that the efficient use of scale models in shipbuilding could result in hull and machinery labor and material savings of six percent per ship.

It is suggested that an equivalent technique could be largely realized by the intelligent use of interactive computer graphics. Recent hardware advances should be considered in such an application.

Until quite recently, graphics terminals were restricted to the use of a display consisting of a light image on a dark

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3. MARAD/SNAME Publication, "The National Shipbuilding Research Program", 1973.

background. Hardware is now available, at a reasonable cost, to display color as well as shades of gray. The addition of color would certainly aid the visualization process.

Additionally, advances permit three-dimensional transformations to be performed by hardware. These transformations may consist of translations, rotation, scaling and perspective projection. Of course, it is possible to perform these transformations in software, but in general this process increases system response time. The tradeoff to be made depends on the particular application.

Hidden lines may be removed to aid the visualization process. This technique may also be employed selectively to ease the burden on the system.

The concept of a realistic graphic model promises high utility for the evaluation of certain compartments or modules of a ship where it is most difficult to visualize and plan the effective use of space and to consider accessibility and functionality. The software and techniques currently employed by the MINIMNTS system could easily provide the framework on which to develop such a system.

The development of the system should include the ability to arrange templates within a compartment, to manipulate them, to view the compartment or module from any point in space and to interactively modify them for an enhanced compartment arrangement. Additionally, it should include the ability to plot intermediate and final results for further analysis and

finally to interface the geometrical descriptions to a physical model building process once the final configuration is determined. It should not be necessary to construct a physical model in many applications, as the graphic model or its output will suffice. However, it is recognized that such a physical model could be very useful for construction and training purposes.

AUTOFIT  
COMPUTER AIDED DESIGN AND PRODUCTION  
OF PIPING SYSTEMS

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Oslo, Norway

Mr. Eng is a Chief Consultant in the Information  
System Development group of Shipping Research Services.

## INTRODUCTION

AUTOFIT is the name of a development project which was started in 1973. It is related to the problems of outfitting, and in particular, the design and production of pipe systems. Other systems, like electrical and ventilation, have been investigated to a certain degree, but so far, no further development has been done.

AUTOFIT concentrates on the parts of the outfitting process which will benefit from computer assistance. This means functions which are manhour consuming and which are critical as to calendar time. Lower priority has been put on activities which may have significant influence on the total economy and quality of the product, but which involve optimization by people who know this field by experience. In short, our aim is to leave more of the routine work to the computer, to give the qualified people more time to concentrate on finding better and more optimal solutions to their problems.

A second goal of today's development is to establish a base for a computer assisted information system. In the first phase of the project the information will consist mainly of technical data about the product to be produced. Once this information foundation is established, one is free to add related administrative data and programs for follow-up of the design process itself, for coordination with the steel design, Planning of production, ordering of materials and a number of other functions.

## MAIN FUNCTIONS

Figure 1 gives a rough sketch of AUTOFIT in relation to its surroundings and its main output. AUTOFIT will be implemented as a set of freestanding subsystems, which will each cover a limited number of functions. Today's plans provide for six subsystems:

1. Systems design, which will result in information corresponding to pipe diagrams. To a certain degree, this subsystem will be based on the yards' norms and design rules and standards for pipes, valves, etc.
2. Systems analysis, which will perform heat and mass balance calculations and other relevant analysis on the system proposed established by 1. An iteration between 1 and 2 will be the normal working procedure.
3. Systems arrangement. The function of this subsystem will be primarily to establish a numerical model (data base) of the arrangement. This includes definition of components, pipes, valves, etc., both with respect to its local parameters (physical dimensions, connections, space requirements, etc.) and its actual position in the final product. Since the arrangements usually will be very dependent on the steel structure, a model of the steel will be included. In cases where AUTOKON has been used for steel structure design, this part of the model may be established on the basis of an AUTOKON data base. Functions for finding the optimum path for pipes, interference checking or other

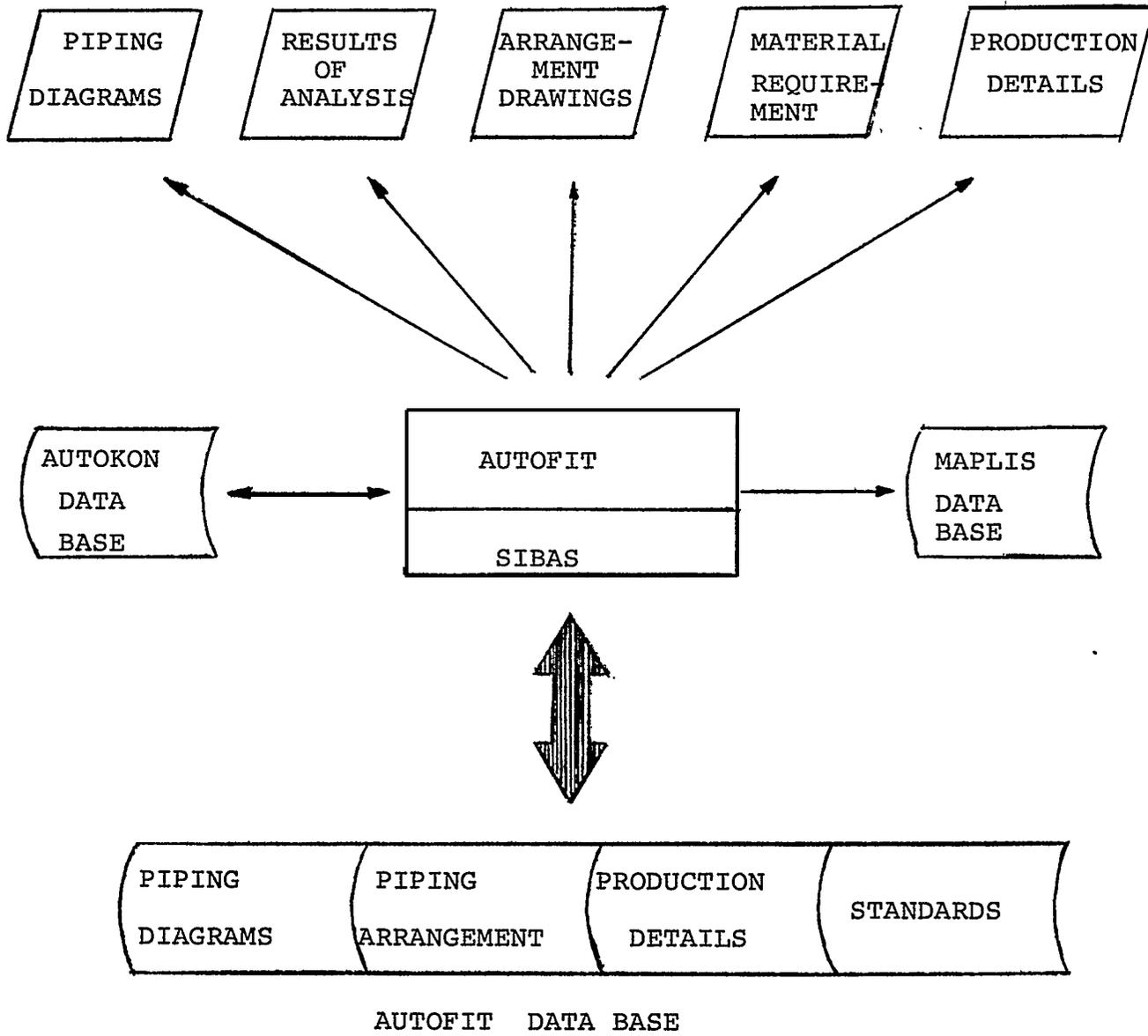


FIGURE 1. AUTOFIT - Main Characteristics

automated layout functions have so far been given second priority, but this may change. To be able to give the user full control of the correctness of the numerical model, advanced checking facilities will be included (primarily graphical). Most of the creative work in this part of the process will be put on the user, but he will have access to standards, production practice, pipe diagram information and steel structure as reference data from the system.

4. Arrangement calculations will cover programs for checking the arrangement as to resistance and stress in the pipes. In some cases there will be an iteration between 3 and 4.
5. Production preparation covers the preparation of necessary data for prefabrication and assembly. This is primarily an output function, which results in isometric drawings of pipes, shopdrawings (pipe sketches), piece lists, assembly lists, data for cutting and bending of pipes, etc. It also gives certain possibilities for breaking down pipes into production elements.
6. Material take-off. On the basis of the information in the data base, this subsystem will calculate the material requirements (pipes, fittings, bends, flanges, gaskets, etc.). This subsystem may be used on different stages in the design process, and the resulting material specification will be as correct and

detailed as possible from the state of the data base.

These six subsystems and the data base which will result from the use of these programs form the base of AUTOFIT.

#### TECHNICAL SOLUTION

The system will be structured as a set of self-contained subsystems, which may be used separately or together. The main communication between subsystems will go through a data base, which will be administered by SIBAS.

A fairly big part of AUTOFIT will be designed and implemented as on-line systems. Typical batch operations, like definition of a set of standards, will be run in batch mode. In subsystems where parts of the information is graphical, the communication with the system will go through a graphical terminal. The first version of the system will be based on a TEKTRONIX 4014 storage tube connected to a UNIVAC 1110. Whether to implement AUTOFIT wholly or partly on mini-computers will be considered after pilot operations.

#### BRIEF DESCRIPTION OF SUBSYSTEMS FIVE AND THREE

The subsystems are numbered according to the sequence in which they are used. From a systems development point of view, it would have been natural to develop and implement the subsystems in the same order. However, considerations within the Aker Group have resulted in a development sequence which starts with production and ends with tools for system design. A thorough system and data base design already carried out al-

lows this sequence to obtain practical results soon, without risking violation of the overall concept. The following subsystem descriptions are given in the order in which they are planned to be implemented.

Subsystem Five - Computer assisted system for preparation of pipe production.

This subsystem will be ready for pilot operation in the Aker Group by October, 1975. It will consist of five main functions (see Figure 2). The fourth and fifth functions are permanent, while the first, second and third will be covered by other parts of AUTOFIT when the complete system is operational. (Then the information registered by the first, second and third functions may be referenced directly,)

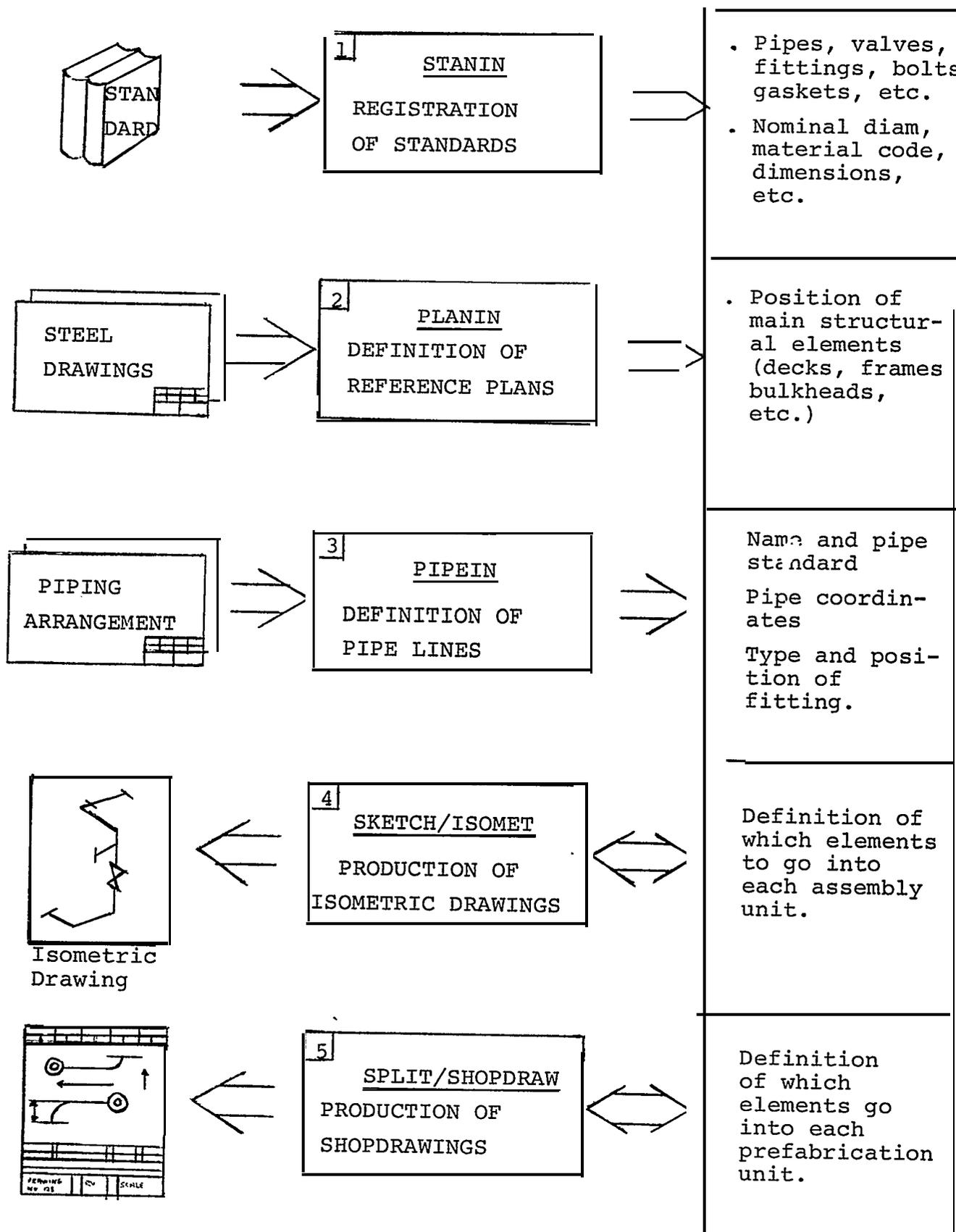
With reference to Figure 2, the five main functions are as follows:

1. Registration of standards.

Information about standardized elements like pipes, valves, fittings, etc. may be registered and stored in the data base. For each element, this information includes such items as nominal diameter, physical dimensions, type of material, etc.

2. Definition of reference plans.

since most pipelines in steel structures are specified relative to the steel, this program enables definition of a simple model of a steel structure. Only plane structures may be defined.



AUTOFIT

Figure 2  
Computer Assisted Preparation  
Of Pipe Production

3. Definition of pipe lines.

This will be a simplified version of the future tool for definition of piping arrangements (subsystem three) . Pipelines may be defined by giving coordinates relative to reference planes, pipe dimensions, type and position of valves and fittings, etc.

4. Production of isometric drawings.

Isometric drawings of pipes may be produced on the basis of the pipe definition stored in the data base. The user defines which pipes are to go into each drawing complete with control dimensions, pipe identifications etc. In addition, a list of pipes and fittings per pipe assembly may be produced.

5. Production of shop drawings.

When pipes are prefabricated, and there is a need for a detailed description of each piece of pipe, shop drawings may be produced. The drawings are produced rather automatically, and contain information about the pipe geometry, parts list, bending information, etc.

Subsystem Three - Computer assisted system for preparation of piping arrangements.

This subsystem is not yet specified in detail, but Figure 3 represents the scope of the subsystem.

It will be primarily a system for building up a numerical model (data base) of piping arrangements. It is estimated that the prime decisions as to arrangement, layout and details

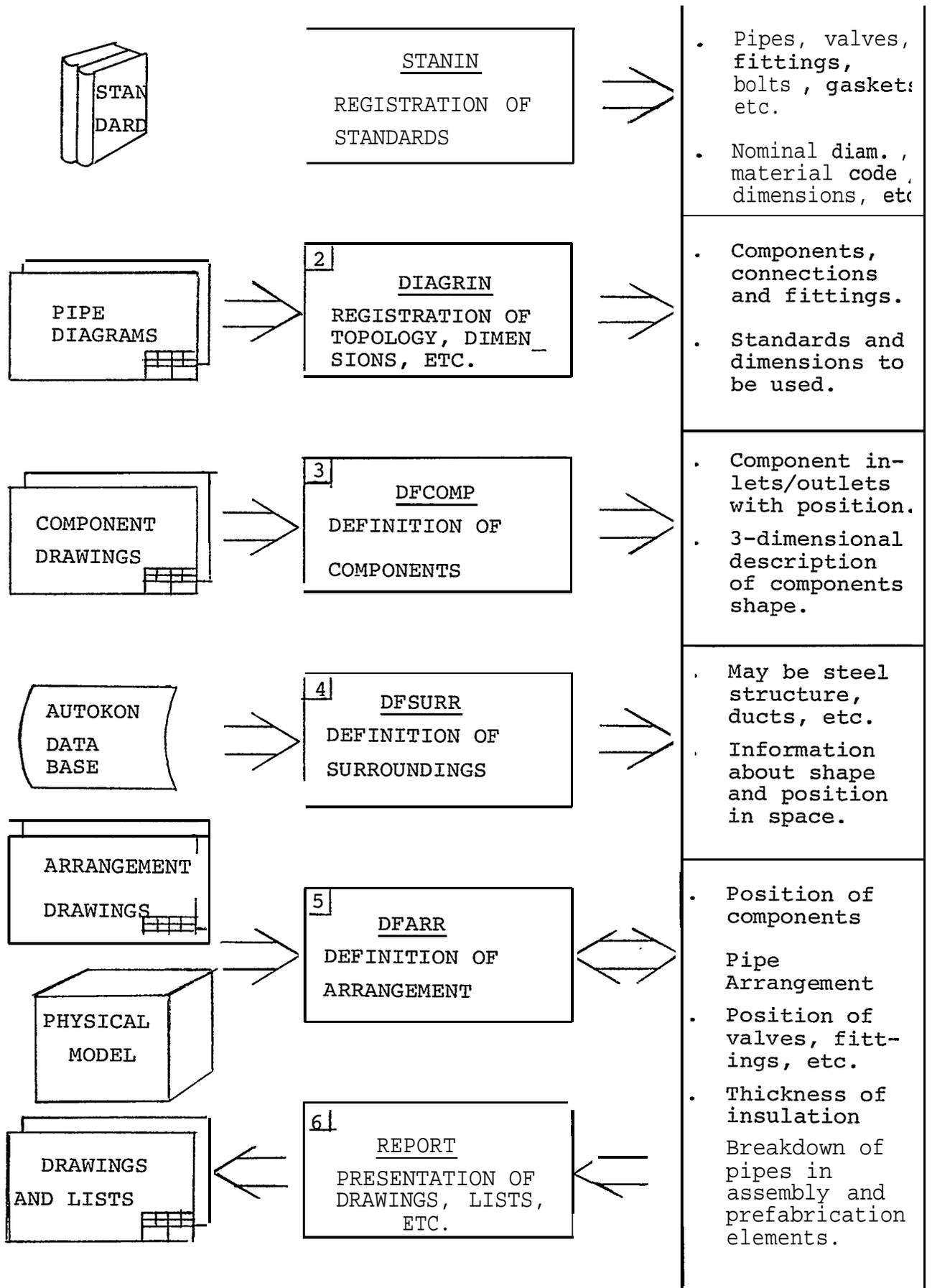


Figure 3

AUTOFIT

Computer Assisted Preparation Of Piping Arrangements

are made before the information is built into the numerical model. This means that most of the arrangement will have to be made either as a physical model or some kind of arrangement drawings. The system will serve as a copying and detailing system. In addition, it will serve as a fast draftsman and base for information about the arrangement.

The subsystem will consist of six main functions. The first two functions will be temporary, while the others will be permanent.

1. Registration of standards.

The same function as in subsystem five.

2. Registration of piping diagrams.

A preliminary program for registration of information about the topology and the main characteristics of systems. When subsystem one is used, this information will be available directly through the database.

3. Definition of surroundings.

This function is the definition of a reference steel structure based on an AUTOKON data base and information about ventilation ducts, cable paths, etc.

4. Definition of components.

This will be a general tool for definition of three-dimensional objects, but it will be used first for defining components (position of inlets/outlets, geometrical shapes, etc.)

5. Definition of arrangements.

This function includes positioning of components and

definition of pipe geometry and details. During definition reference may be made to predefined steel structures, components, pipes already defined and the set of standards to be used.

6. Report generation.

output consists of two types of information:

Permanent and predefined reports (lists and drawings for documentation purposes) .

Answers to questions about the arrangement (control drawings, control measurements, status in relation to piping diagram, feedback about pipe penetrations through steel structure etc.).

This part will be implemented as a number of programs.

Subsystem three will be implemented in two stages. A preliminary version in which certain simplifications are assumed is planned to be in pilot operation for the end of 1976 and a final version, one year later.

Subsystem Six - Material take off program.

The purpose of this subsystem is to aid the designer in the material take-off process. With this subsystem he may proceed systematically through the data base and register the amount of materials needed.

The use of the system is very dependent on the status of the data base. Normally, one expects all information to be in the data base, but preliminary pipe requirements may be established in a dialog between the user and the program.

This means that *the* user gives estimates on pipe lengths.

A direct communication will be established to the MAPLIS material administration system.

This subsystem will be implemented in 1976.

A REPORT ON THE  
1975 AUTOKON USERS CLUB MEETING

Haakon Saetersdal  
Shipping Research Services, Inc.

Mr. Saetersdal holds a B.SC in Naval Architecture and Marine Engineering which he received in 1966. Since then he has been working with technical EDP at the Bergen Yard of the Aker Group. Until summer, 1975, Mr. Saetersdal was Group Leader for the AUTOKON Maintenance Center in Bergen. At present he is responsible for the SRS programming group in the U.S.

The annual meeting of the AUTOKON Users Club took place in Bremen, Germany, on May 27-29, hosted by the Bremer-Vulkan Yard. About 70 participants, representing 14 European and two Canadian Yards were present, plus personnel from Shipping Research Services. The program consisted of lectures, discussions in assembly and in separate groups, and a visit to the Bremer-Vulkan Yard.

Reports from different yards using AUTOKON 71/74 revealed that they are very satisfied with the programs in the AUTOKON system mainly because:

- The programs are now very stable.
- The database programs, AUTOBASE, have been partly rewritten to provide better security of the database.
- The ALKON program has been optimized so it is now 40 to 60 percent cheaper to run.

The only serious complaint was **that** one yard had trouble with the shell expansion program. The reasons will be investigated by the maintenance group.

Reports were given by the yards Verolme and IHC in the Netherlands, Chantier d'Atlantic in France and the Aker group in Norway. Some of these yards are very ambitious in their use of AUTOKON and have spent a lot of money and resources in developing norms.

SRS presented the BOF system, which provides a facility for designing complex surfaces. It was originally intended for the automotive and aerospace industries, but can be adapted to any form of surface. In order to integrate this

system with **AUTOKON**, a link program has been developed. The **BOF** system is in use in some British car and airplane factories. It has **also** been used on the pontoons for a semi-submersible drilling rig for the Aker group in Norway, and a twin-screwed containership for the yard Verolme in the Netherlands. These two projects have provided very good results in less time than other systems. Both Verolme and the Aker group will continue to use the **BOF** system in the future.

Further developments for **AUTOKON** were discussed in connection with a lecture on an interactive nesting program, which is under development at the Central Institute of Industrial Research in Norway. This program will run on a minicomputer connected to a Tektronix 4014 graphic display unit and will be in operation by early autumn of this year. The parts to be nested must be generated, as now, with **AUTOKON** and transferred to the database on the minicomputer before the nesting can be started.

During his opening remarks, Mr. Sorensen from SRS stated that the batch versions of **AUTOKON** for the European users would be, more or less, frozen as they are now. The main activities here will be on developing norms. The future developments of programs is expected to come as interactive programs, possibly on minicomputers with graphic displays. It is not expected that all the work will be done on minicomputers; it will probably be shared with batch or interactive programs on big computers. This creates the need for flexible methods and programs for transformation of data between databases on large scale and

minicomputers.

Because many orders for big tankers have been cancelled, several yards have had to find employment in other fields. For example, the Aker group in Norway has developed semi-submersible drilling rigs, called Aker-H3 and -H5. Many of these have been ordered and are to be used in the North Sea. A lecture was presented on how to use AUTOKON on these structures. The Aker group has developed norm packages to cover the layout, classification and production phases for these rigs. Most of the norms are rather general and can be used on other structures as well. For rigs with pontoons of a complex form, the normal fairing and shell expansion processes have been used. For rigs with a simple form of pontoon, only the ALKON and NEST programs have been used. The total wire model was then built entirely by ALKON norms. Shell expansion was also performed by this program. A rather general data structure was implemented in the norms in order to split the structure into assemblies and subassemblies. In the near future one will also be able to calculate weights and center of gravity of any assembly.

Another group discussion dealt with methods for documenting norms and dividing them into groups. To cover as much of the design and production preparation phases in the yard as possible, the amount of norms can be very high. If the use of AUTOKON especially ALKON, is to be integrated in the normal procedures in the drawing offices, the norms have to be well documented. It is obviously important to have a *synoptic*

documentation to tell which norms are to be used in different stages in the process. Some of the participants were interested in exchange of norms between yards. They had the feeling that several yards developed norms for the same functions.

Some additional topics presented by SRS during the conference were:

BEPLA - a long range capacity planning system, using networks, S-curves and profiles. The system is used by the Aker group.

AUTOFIT - a computer-assisted preparation system for Pipe production.

SIBAS - a general database management system. It provides most of the capabilities specified by the CODASYL programming language committee. SIBAS is coded in ANSI FORTRAN, is available for several computers, and may be used in connection with languages supporting FORTRAN subroutine calls, such as PL/1, ALGOL etc. It is used in the BEPLA and AUTOFIT systems.

The yard ITALCANTIERI from Italy presented their system for automation of design and production of piping lines.

The last day was devoted to a visit to the Bremer-Vulkan Yard and an inspection of its use of EDP. They have a Siemens computer and use numerous teletype-like terminals. AUTOKON is one part of their system, which also consists of programs developed at the yard. After the tour of the yard, the conference for 1975 was concluded.

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\*Also presented at 1975 REAPS Technical Symposium. See report in this document.

The following appendixes contain those papers presented at this meeting which appear to be of most interest to U.S. {shipbuilders.

- Appendix A: BEPLA - A Long Range Capacity Planning system  
Mr. Yngve Strom, SRS A/S, OS10, Norway
- B: PRELIKON - AUTOKON,AS An Undivided Working Process  
Mr. Franjo Spincic, 3.MAJ, Rijeka, Yugoslavia
- c: Computer-Controlled Numerical Control For Flame-cutting  
Mr. G. H. Doornink, Smit Yard, IHC Holland,  
Netherlands
- D: Automation of Design and Production of Piping Systems  
Messrs, Guido Baccara, Aldo Toso, and paele  
Naschio, Italcantieri S.p.A., Italy
- E: An Interactive Computer Graphics Approach to the Problem of Nesting of Plane Parts on a Raw Steel Format  
Messrs. J. Oian, SRS, Norway; B, Hasselknippe, CIIR, and F. Lillehagen, CIRR, Norway
- F: The Application of AUTOKON to Drilling Rigs  
Mr. J. F. Mack, Aker Group, Norway

Appendix A

BEPLA - A LONG RANGE CAPACITY  
PLANNING SYSTEM

Paper presented at  
AUTOKON USERS CLUB MEETING

Bremen, May 1975

Yngve Strøm  
SHIPPING RESEARCH SERVICES A/S, Oslo

BACKGROUND

The design and construction of large seagoing vessels is extremely complicated task which requires exact planning at all stages in the process.

The use of EDP has come to play a vital part in many areas of production at a shipyard; we see it in software systems such as AUTOKON, PLASIS, PRELIKON, MAPLIS, OPTIMA etc.

During recent years, the production range at a shipyard has become more diversified, especially with the growing amount of various off-shore structures for the oil industry. This diversification has led to a less uniform production flow, with increased amount of data required in the planning process. Within the AKER GROUP in Norway, a need was felt for a long range capacity planning system which could handle the increasingly complex task of planning the long range construction schedule at a shipyard.

The answer to these requirements is BEPLA.

BEPLA BRIEF'S

PURPOSE, REQUIREMENTS:

A long range capacity planning system should be a tool primarily designed to aid the planning office in obtaining the maximum benefit from the human resources working there, without putting the planners under undue stress.

The planners must be the masters of the system, and be able to use it at will to obtain the optimal results for the benefit of the' production process. The system must, in short, be faster than manual planning methods, and produce better plans.

PRINCIPLES:

BEPLA is designed to tackle the production planning on a high level,

i.e., a course planing as opposed to systems like OPTIMA.

BEPLA is based on interactive network technique, with only modest automation: This gives the planner, the user of the system, overall control with a wide variety of modes of operation and a good selection of "paths through the network system".

When the planning office has the information which gives's picture of the production process of a structure, and the manhours involved in'the process , one can calculate the calendar time for the various stages in the construction process, provided the resource limits are known.

Vice versa, if the terms are fixed, one can calculate the necessary resource capacities. BEPLA is an aid in these calculations.

Planning with BEPIA uses a combination of S-curves and network technique. The network represents the inter-relationship between activities, (work-operations) , whereas the S-curves describe the resource utilization over the duration of each activity.

BEPLA is also a data base oriented system, and the general data base system SIBAS is an integral part of the whole BEPLA system.. What we call basic , or standard,data will be stored permanently in the data base.

This type of data will be standard network relationships, standard S-curves and profiles, basic data relating to the organization and resource structure of the shipyard, holidays etc.

By storing this type of data once and for all,but with the option of modification, the' amount of input to the system required-for each run is greatly reduced.

Two principal planning methods are provided for in BEPLA:

1. Key activities can be scheduled individuality, and"secondary" activities scheduled depending on the key activities.
2. The whole network can be scheduled as a whole, starting either from the beginning or from the end activity.

The scheduling may be done on several levels of detail, with respect to the organization and resource structures in the yard.

Depending on the overall time horizon, scheduling may be on a course, or less detailed level or it may be on a relatively detailed level.

Output from BEPLA. will be in the form of time schedules, resource load reports in various forms, and graphic output such as Gantt diagrams and histograms.

#### USE OF NETWORKS .

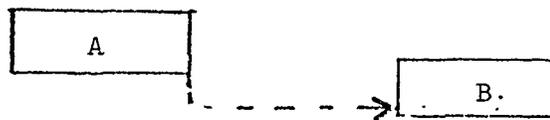
Activity-oriented networks are used in BEPLA.

Dependence between activities may be specified in three ways:

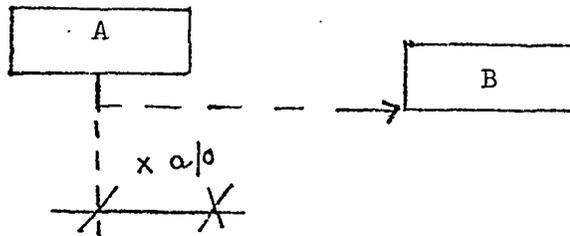
1. Start - to - start dependence



2. Finish - to - start dependence



3. Percentage - overlap - dependence



The networks are divided into sub-networks, or part-networks.

An activity in one sub- or part-network may be linked to an activity in another sub-or part-network.

The start date for any activity may be given directly, or it may be calculated dependently on the other activities,

If the start date is given directly, that activity is "locked" in time.

However, one has the possibility of "moving" activities along the time scale, if this is desirable from an overall planning point of view.

Further, activities can be "stretched" or "compressed" if so required, to smooth out the resource load curves or for other purposes.

Several "standard" networks, representing different planning alternatives for a particular construction project, may be held permanently in the SIBAS data base, thus providing for flexible planning.

In case of a network being redundant, several levels of priority may be associated with any particular activity, thus voiding the redundant dependencies.

#### S-CURVES AND PROFILES

Resource load and consumption are represented in BEPLA by the S-curves or related profiles.

An S-curve expresses accumulated resource consumption during a time span, whereas a profile represents the resource load at a given time.

Both time and resource may be expressed as absolute or relative units.

In the data base are stored the standard curves and profiles, expressed in relative units.

There may exist several curves and profiles for each resource type for any activity, representing different planning alternatives.

One distinguishes between ACTIVE and PASSIVE resources.

The duration of an activity is determined by the availability of active resources, whereas the consumption of passive resources is determined by the calculated duration.

To keep a check on the resource consumption for any activity, and to make sure that the work is progressing satisfactorily, "horizontal" and

"vertical" tests may be performed. These tests will show the actual resource consumption in relation to the anticipated consumption, and in relation to the work status.

Given the relative curves and profiles, planning alternatives, terms, dates and holidays; the duration of each activity is calculated, as well as the absolute curves and profiles.

#### PROGRAMSTRUCTURE

BEPLA is a modular system, governed by a "PROGRAM ADMINISTRATOR" module.

"BULKHEADS" between modules are provided for security.

Subroutines common to two or more modules, are designed as auxiliary routines, which cannot communicate directly with the modules, but must communicate via the Program Administrator.

Core requirements for BEPLA will be approximately 45 K words, including SIBAS with 20 - 25 K words.

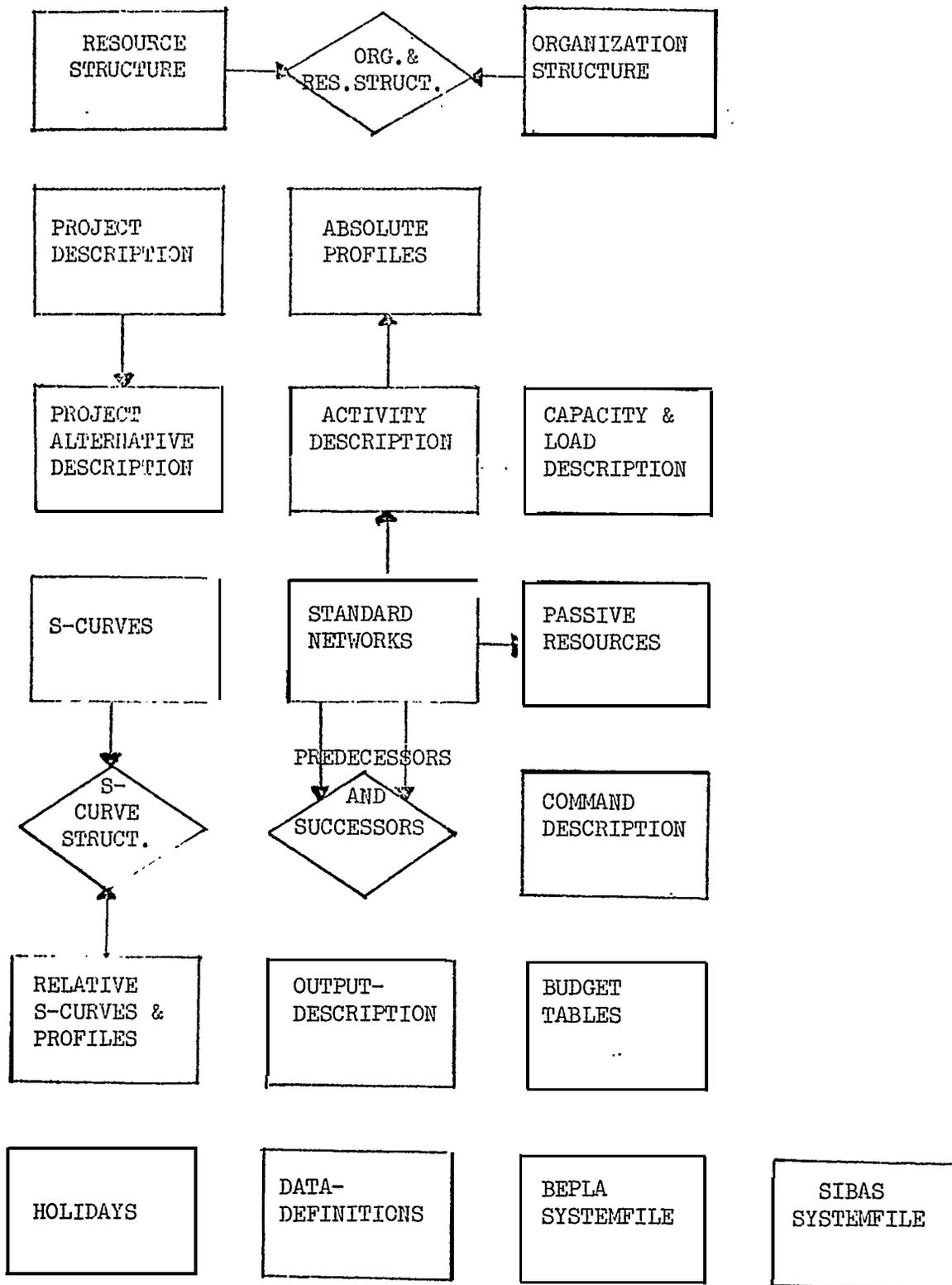
BEPLA is coded in FORTRAN., with some COBOL and ASSEMBLER subroutines.

#### DATA STRUCTURE

As already mentioned, BEPLA is a data base oriented system, using SIBAS as its D B system.

There will be several files in BEPLA, with a "clean" data structure, each file containing a relatively modest amount of data. The reasons for this approach is that a less complicated data structure is an advantage both for system maintenance, and for the user of the system.

The datastructure is shown on the next page.



## COMMAND LANGUAGE

### INTERACTIVE FACILITIES

BEPLA is both a batch and an on-line system. A special command language for use in both modes of operation has been developed.

There is one command instruction for each of the operations involved in the planning process.

The user has full control over the computer during the entire planning process, and he guides the BEPLA system from step to step during calculations. However, this does not lead to a cumbersome process as far as operator involvement is concerned, since the operator, or planner, is completely in command, as to how far he wants the planning process to develop between each new command.



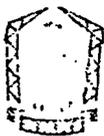
Appendix B

PRELIKON - AUTOKON AS UNDIVIDED  
WORKING PROCESS

Paper presented at :  
AUTOKON USERS CLUB MEETING

BREMEN ,MAY 1975

FRANJO SPINCIC  
E.D.P. - Technical Applications  
Group Leader



First we wish to show the use of PRELIKON connected with execution of those modules of AUTOKON which follow it immediately, and explain our opinion about this, pointing out those points which would be worth completing or changing so as to improve the AUTOKON/PRELIKON capabilities.

AUTOKON, and particularly AUTOKON 71 and 74 with PRELIKON is, no doubt, powerful software in the hands of skillful users, gives outstanding results in designing and constructively working out the hull.

However there are yards like ours, possessing several building berths of various sizes. At any time we have in our yard three different new constructions, and for this reason the acceptance of new types of ships is more frequent.

The diagram presented at AUC 1974 by Aker Group, shows that with a more even work load and reduction in design man-hours is achieved within the same period of time.

I have taken the liberty to generalize this diagram adding to it the projecting phase /see fig 1/. We consider it to be useful to focus our efforts on implementing corrections in the system which would have essential influence on shortening the diagram on the abscissa as well.

As the programs have their physiognomy, defined interdependence and communication with data bases, it is not possible and neither is it necessary to suggest general alterations to the system. Therefore, we shall try to analyze, in connection with work process, those points at which, to our opinion, improvements would bring about greater advantage. we shall tell something about what we are doing in Shipyard

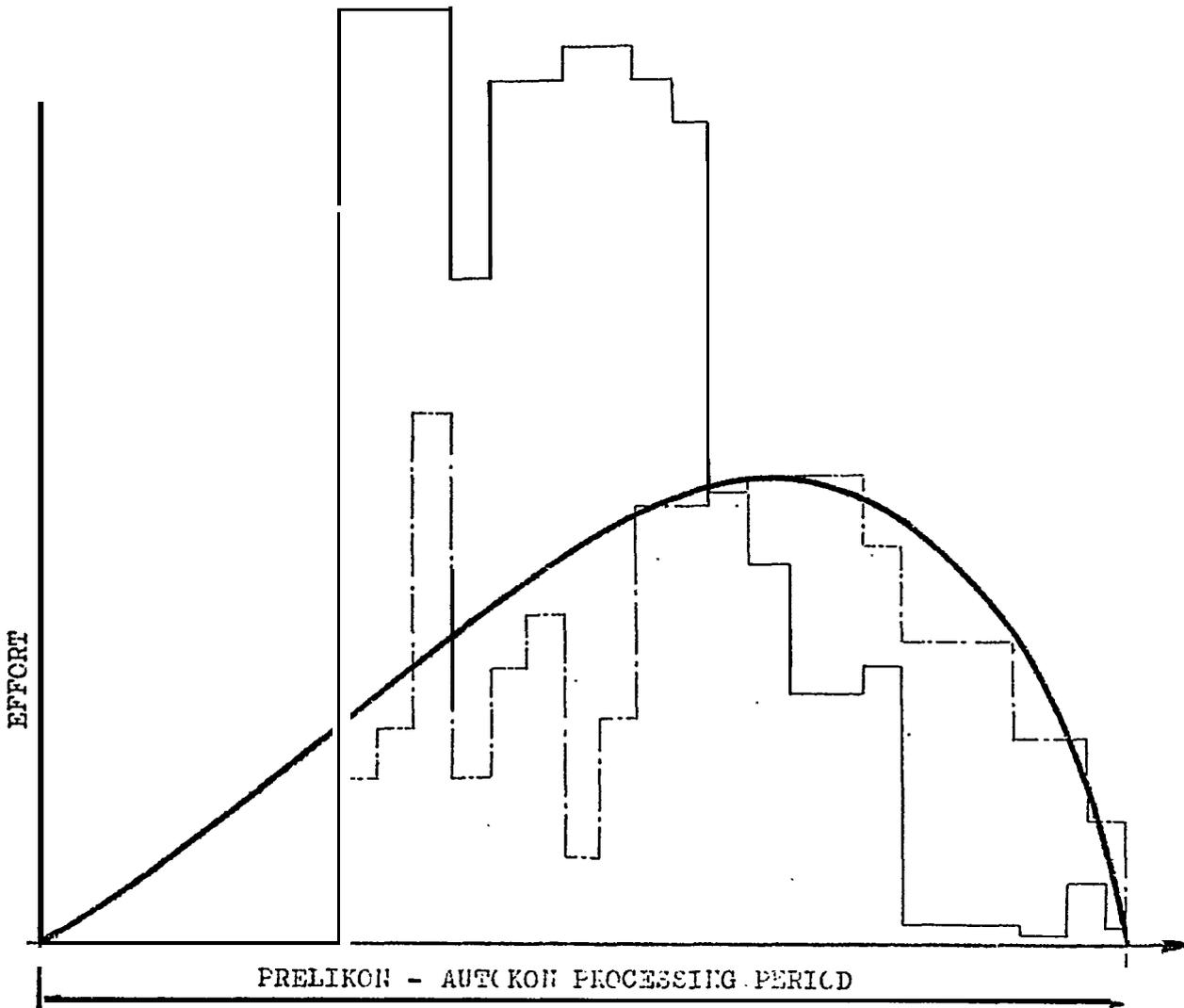


FIG. 1

"3.11aj" to achieve the same purpose: to shorten the period from the buyer's inquiry to the ready documentation. As a first thing, we are working out the system of programs INDES /Initial Design of Ships/. The aim of these programs is to help the designer when choosing main dimensions, the form of ships, making the calculation of hydrostatic values, speed calculation, capacity calculation, weight, position of ship's center of gravity and trim. The initial calculation is based on the regression analysis of reference data on ship's dimensions and forms. The system is conceived in such a way that with a rather small amount of input data the designer gets a sufficient basis for a possible further analysis through the PRELIKON programs.



Why have we decided upon the generation of INDES ?

It is known that PRELIKON is a common product of Aker Group's and Det Norske Veritas' efforts. Since it consists of modules each of which does detailed work independently, it is not quite appropriate for the preliminary design. We are aware of the fact that designers do not like to let the computer choose dimensions and "rid ships" form:-: We are of opinion that at this phase too, computers could be entrusted with greater work. Analysis of ship's weight, speed and the freeboard calculation are not covered or maybe insufficiently covered by PRELIKON. These operations without hydrostatic calculation are incomplete and for this reason we have added the hydrostatic calculation to INDES, but with fewer details and less input data. INDES will communicate with its data base which consists of General Data Set and project Data File. After the designer has evaluated the results obtained in this way, we *can* start defining the prelikon Data Base, so that the generation of a great part of punched cards for null definition will be left up to INDES.

The next- indispensable work by which the designer must bear out the accuracy of project and which is required by the rules as well - is stability and floating calculations of ship in damaged condition.

Det Norske Veritas possesses a very good program which covers this range. This is NV 216 Introduction of this program in PRELIKON would have a significant influence on the competitive power of PRELIKON .

After the designer has borne out his conception, he hands it over to the steel drawings office. . . The question is now whether the FILIP and FAIR2 programs are the most suitable means for realizing this link?

Today there exist numerous mathematical and semi-mathematical methods for form generation, lines fairing /such as FORAN, ANA, M-LOFT and others / We should think about shortening necessary time for fairing. Fairing of a ship with FAIR2 takes about two man-months work. Throwing away such a lasting work is a pity, while change of

several parameters in the FORAN form generation, can be done without hesitation, because after we have communicated the Parameters to the system, the form is intrinsically faired. i.e consider that improving FAIR2 would also manifest on the diagram /fig.1/, and addition to this,he said methodsinteresting not onl to potential users but also to the existing users of We have directed our efforts so that the results of our INDES program packace are the faired frames.

The LANSKI and SHELL2 programs have been used with success on several ships. Only with the SHELL2 program we "came across some anomalies but not to the extent as the users.from Holland did. We estimate that on the average, not more than 1-2 % plates were wrongly developed. This,obviously, does not cover plates on the bulbous bow area, which were developed manually.

Some plates close to the keel were hand developed after we had found out by checking that they were wrongly developed. Several times we had some difficulties with auxiliary functions. We solved this by manuallyly inserting the correct" stream of auxiliary function in the punched paper tape. We are pleased with the new improvement of SHELL program, however in this . work, i.e., in using the LANSKI and SHELL progra.ns we do not see further possibility of a more significant shortening of the whole process period. We could only say that there is a real need for the replacement of BSCIRK routine with another one such as KURGLA routine.

ALKON and NEST maybe do not belong to the context of this paper but as those are the works which are the most tineconsuming, please allow me to tell just a few words concerning our manner of work in connection with shortening the processing period.

We have selected four possible methods for preparing punched paper tapes at the production preparation phase:

1. manual coding
2. usage of ALKON on part coding level
3. usage of ALKON on level of AUTOKON 71
4. usage of ALKON on level of AUTOKON 74.



As we have the licence of AUTOKON 71 we use the first three ways.

Why all three?

After some observations we came to the conclusion that in using a remote computer for the work on new-buildings built in smaller series, the use of ALKON would represent a expensive solution. Therefore we decided to use ALKON only for parts of ships where it is comparatively advantageous. This decision, of course, is not firm. The improvement of the program and particularly the installation of a new computer will have an influence on the extent and level of usage of ALKON.

Interactive Nesting is a separate topic; it is not necessary to talk about its utility, and the-indispensable need for shortening the time for assembling nested formats.

As for the PRCDA program, we do not use it sufficiently and systematically we wish to use it, not only for its basic aim but also as source of reference data for the analysis of weight and center of gravity position, in new projects. To achieve this we would need several things, such as:

- More various databases for several types of ships.
- Possibility that PRODA works with record class 7.
- Possibility of calculating the center of gravity position for elements to be processed at classification phase.

with PRCDA output we have reverted to the data preparation for projecting. we went through AUTOKON/PRELIKON system, which we consider a living system, i.e., a system which is liable to change.

Besides, AUTGKON means an investment to us we wish to utilize well.

In this passage through AUTOKON/PRELIKON, we were thinking about how to make our path, from buyer's inquiry to the ready documentation shorter. If these opinions can help to direct the efforts in one direction so as to reduce not only man-hours but period of time too, then the aim has been achieved.

## Appendix C

### Computer Controlled Numerical Control for Flame cutting

#### I I C Holland's Experience

G.H. Doom ink

At the Smit yard of IIC Holland use is made of CNC for flamecutting since april 1974. The set-up of the system and the experience of one year will be discussed.

A U T O K O N      U S E R S C L U B      M E E T I N G

1975

## 1. HARDWARE DESCRIPTION

At the Smit yard a CNC installation is in use to control simultaneously two flamecutters (Messer Griesheim Omnimat S) and one plotter (Texas instruments 5640).

The installation is manufacture Kongsberg Vaapenfabrikk, mark CNC 500/FC. The system comporients are:

- 1 minicomputer SM4 16K words 16 bits/word
- 3 machine interfaces
- 3 papertape readers 300 chars/see
- 1 teletype ASR 390

With the installation, up to three flamecutters and one plotter can be control led,. and it can also be supplied with magnetic tape readers and a papertape punch.

Further characteristics are

- programming increment 0.1 mm
- programming tolerance  $\pm 0.64$  mm
- servo increment 0.01 mm
- maximum parameter 1 6 7 m

## 2. SOFTWARE DESCRIPTION

For its control purpose the SM4 mini is loaded with the NC System program. This program is present on papertape and is loaded via one of the tapereaders.

The System program consists of an operating system (MPOS) and a process program (Proc) for every tool to control. The operating system drives and controls the input and output devices and the process programs. The actual operation of a process program depends on the users' requirements. The input and output devices are the papertape readers (or mag. tape readers), the teletype and the interfaces (and papertape punch); The teletype is mainly used for the communication with the operating system and the proces programs (Messages and instructions to and from MPOS and Proc's).

### 3. FACILITIES

Due to the flexibility of the minicomputer compared with the fixed wired controllers, a number of facilities are available which otherwise are hard to obtain.

The most important ones are:

-input codes

a number of papertape codes can be used like ASCII, EIA, ESSI, EBCDIC.

- scaling

the FC programs can be scaled at any rate, even with different scaling factors for the X- and Y- direction.

- listing

the papertape can be listed

- changes

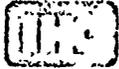
while executing an FC program information blocks can be deleted, changed or inserted.

- couplings

input devices, process programs or output devices can be interchanged.

- errors

found errors in FC programs are stated, and can be corrected.



At the moment it is considered to extend the process programs in two directions:

- man-machine communication

a better man-machine communication is wanted, in particular the process status.

(i.e. listing of auxiliary functions)

..

-management information

for cost accounting it can be useful to know the actual cutting, punchmarking and rapidtraverse times per job and totalize per day.

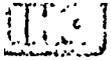
#### 4. SYSTEM CHOICE

When CNC and NC Systems must be compared, a number of subjects should be taken into account:

flexibility  
functions to perform  
performance  
diagnostic and correction possibilities  
man-machine communication  
management information  
price  
down-time risk  
complexity

For Smit yard the most important factors considered were:

p r i c e  
performance  
error detection and correction  
down-time, risk



## 5. EXPERIENCE

The Installation and testing of the CNC system was rather carefully planned to disturb production as 'little as possible. It took five weeks which was one more than planned. This was partly due to waiting for equipment and modification to one of the flamecutters.

Since the installation, some hardware troubles occurred~ they could be solved either by KV or by IHC service people without serious production stagnation.

The number of breakdowns allocated to software has been larger. A part of them could be explained by operator errors, while another Part is still unsolved. Further more, a number of improvements have been built into the software or discovered to be necessary at installation time.

In the software some gaps are felt to exist in connection with the man-machine communication and the management information, Actions are being taken to fill the gaps.

It should be mentioned that the existing yard Organization has to be made aware of flexibility and facilities of the system and that changes in the organization can be necessary to exploit them.

It can be stated that the CNC system is working to our satisfaction although from time to time errors or imperfections in the software are detected. moreover, the possibilities of CNC are not fully used, partly due to incomplete software and partly due to organization problems.

Guido BACCARA  
Head of technical application  
EDP and Organization Dept.

Aldo TOSO  
Manager of work preparation  
Technical Dept.

Piero MASCHIO  
Pipe shop project leader  
Development Dept. (IIC)

ITALCANTIERI S.p.A.

Appendix D.

AUTOMATIC DESIGN AND  
PRODUCTION OF PIPING SYSTEMS

Abstract

This report deals with  
in piping design and production by Italcantieri, with particu-  
lar reference to the automatic line in the pipe shops, to the  
techniques of preoutfitting and to the EDP systems covering this  
area.

## 1) INTRODUCTION

The aims of the technical evolution of the various fields of industry, particularly in shipbuilding, are substantially the following:

- a) Designing: carrying out a design that corresponds, besides of course to the technical specifications' being its presupposition, to criteria of economy and timely development and to exigencies of cost saving, in the production stage.
- b) Production: use of new organization techniques and of highly automated plants allowing cutting down of time and working costs along with an increasingly higher Safe guard against working accidents.

Along with this, the use of the computer becomes more and more important; by its means it is possible to rationalize and accelerate designing and to prepare the operational documents and supports at the base of production.

One of the fields within which we have recently witnessed an interesting approach to the above aims is that of piping. Let's then consider the present designing criteria and production methods at Italcantieri.

## 2) GENERAL PROCEDURE

The general designing and production procedure for piping is summarized in Fig. 1. It is to be noted that the Stages characterizing such procedures are as follows:

- a) definition of the functional diagrams;
- b) definition of the piping runs;
- c) issue of the operational documents and of the bills of materials;
- d) manufacturing of the piping elements;
- e) installation of the piping elements.

It must be borne in mind that the piping functional diagrams correspond directly to the individual ship's plants and services. the production' procedure of the piping instead calls for different exigencies, that is:

- a) the working documents for the pipe-shop must allow the best obtainable working load for the machinery available, which organize in highly automated

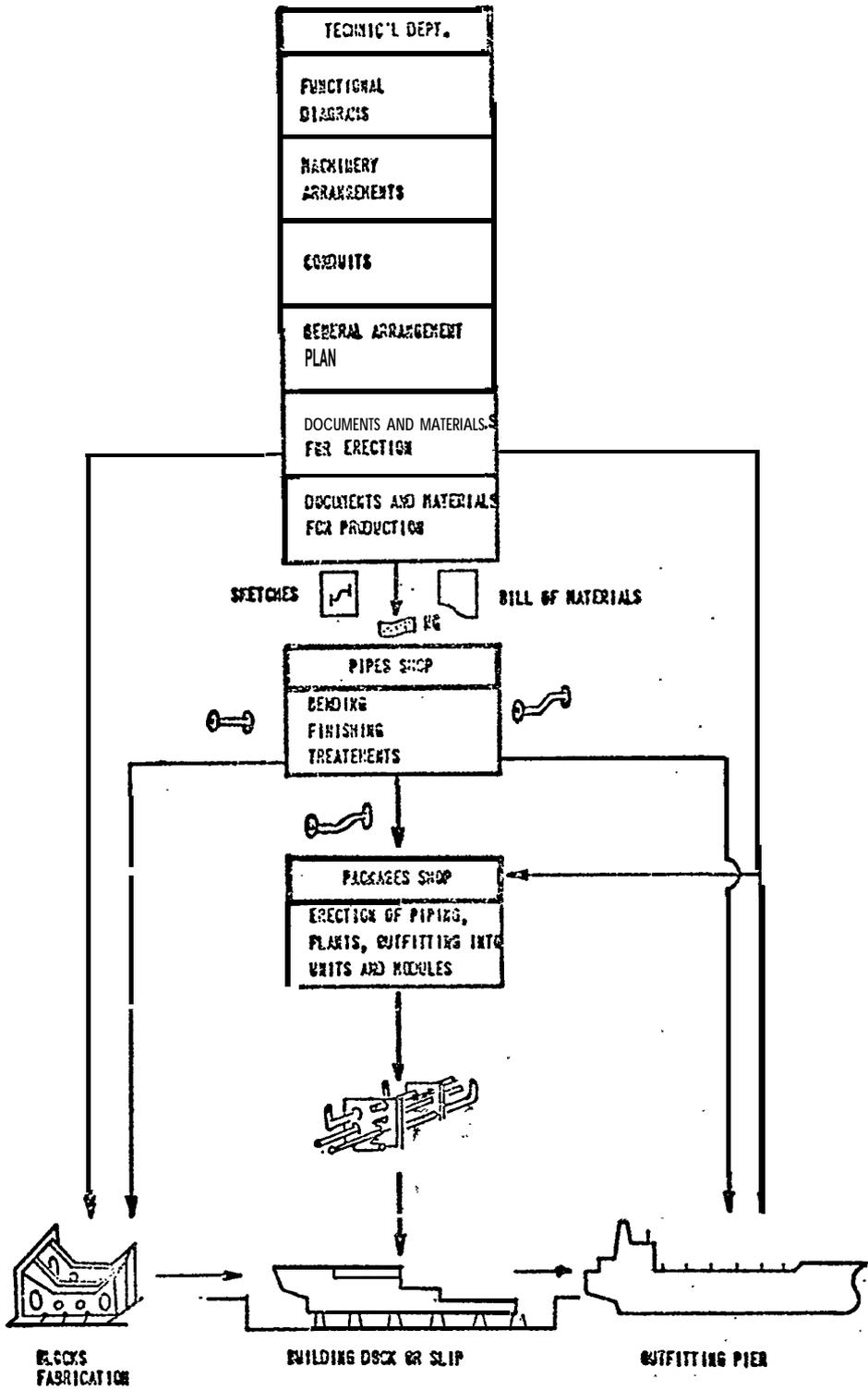


Fig. 1 - General procedure of piping design and production.

- lines as far' as possible;
- b) the working documents for the mounting must allow a parallel progress of-building and assembling of hull elements.

### 3)DESIGNING CRITERIA

During.the designing stag, the latter point mentioned above is taken into particular consideration. Infact, the coordination plan is defined by conveying together the piping system into prefexctial runs (conduits), as shown on Fig. 2; thus three important aims are reached:

- a) by splitting conduits it is possible to design autonomous groups consistin g of fitting-out elements, piping and plants (units and modules) that can be assembled in adequate work-shops and mounted on the blocks or on board;
- b) the exact detection of thebcalization ensuing facilitates the coordination of the scheduling of hull and fitting-out zones (see Fig. 3);
- c)the rationalization of the runs thus obtained brings about the possibility of an automatic definition of the runs by means,of the computer.

It is thus possible lastly to supply the pipe-shop with working lots pertaining to the fitting-out zones and planned according to the progress of the hull production and to the mounting methods, which can be:

- fitting up of single pipe" elements on hull blocks
- pre-assembling in units and modules
- fitting up of single pipe elements on board

### 4) ORGANIZATION\_OF THE PIPE-SHOP

It is, however, necessary that for the production of the lots thus defined, the working documentation and the bill of materials should refer to working "follows", into which the yard workshops are organised in relation to the various bending ways, the main types of which being:

- a) NC bending
- b) traditional cold bending
- c) composition bending (sectors and prefab bends)
- d) hot bending (of lesser and lesser extent).

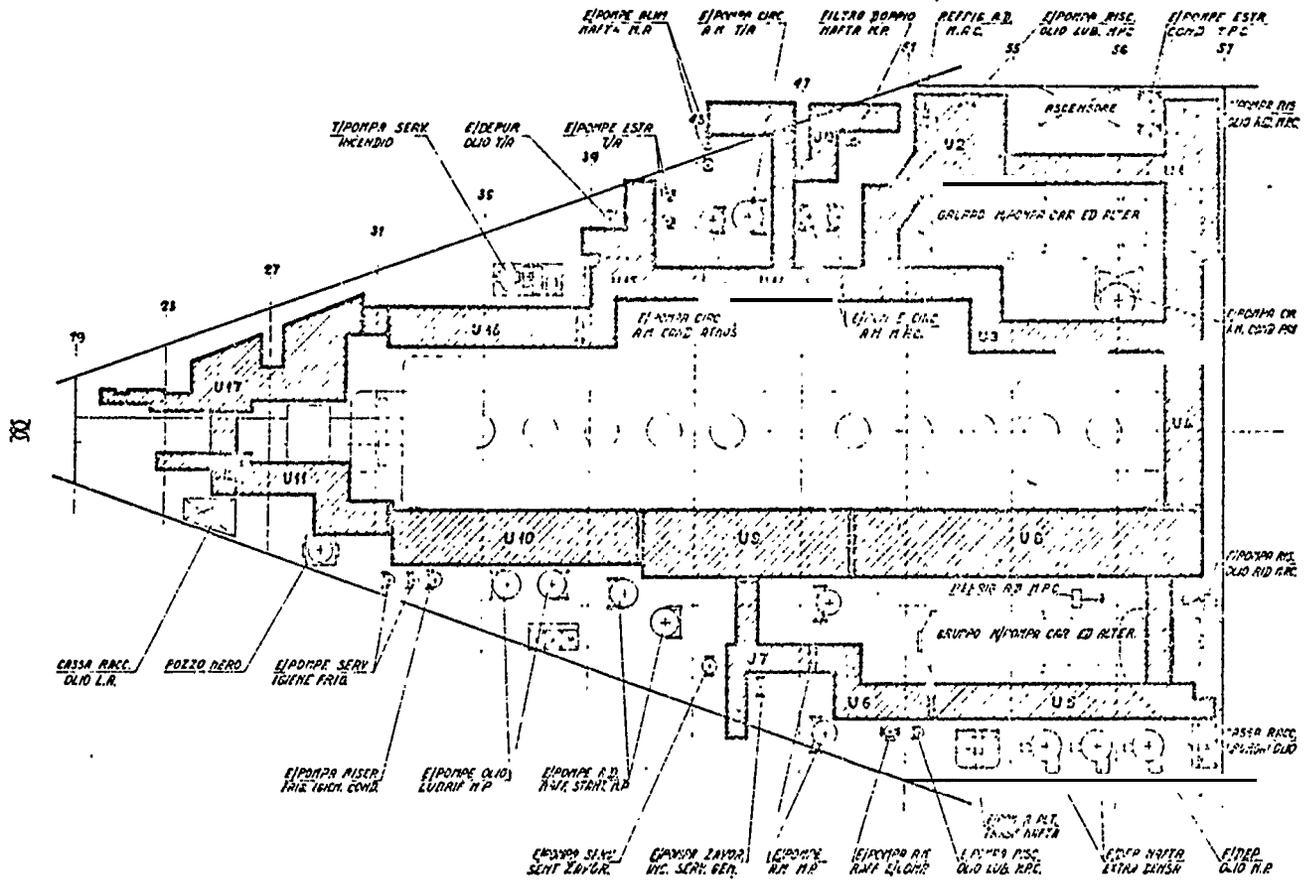


Fig. 2 - En example of conduits, splitted into pre-outfitting units.

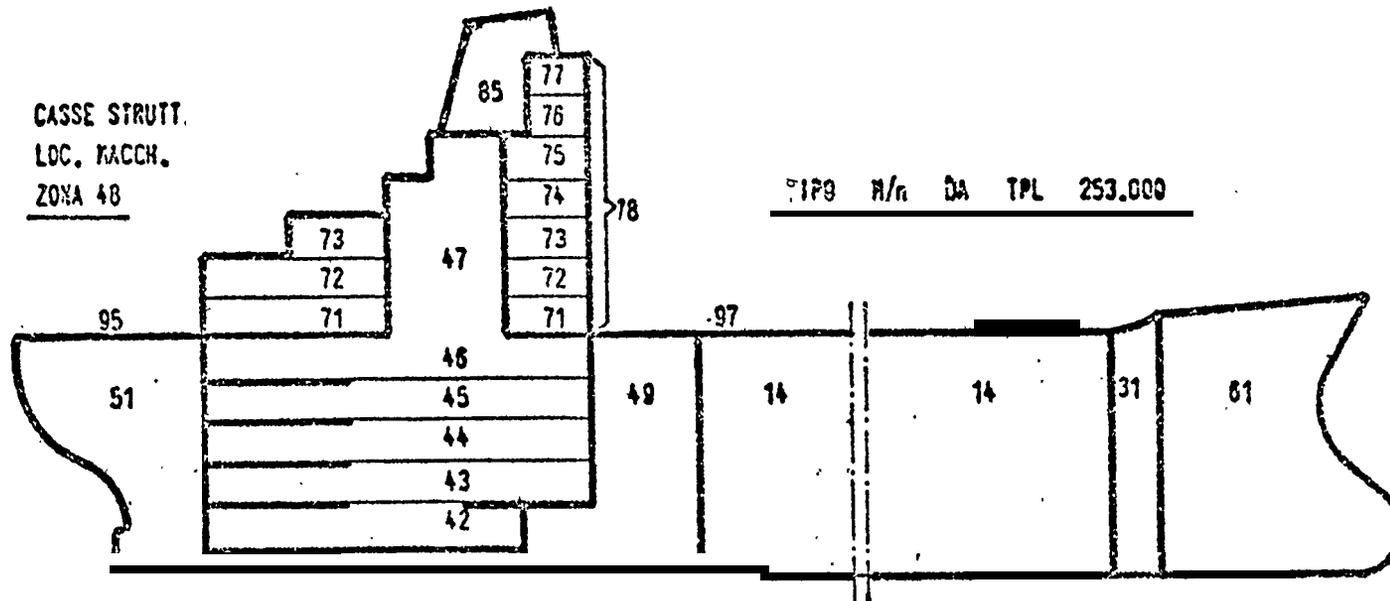


Fig. 3 - Standard outfitting zones for a tanker of 253.000 Tdw.

Further, the working documentation ought to contain the instructions referring to the store the raw material has to be drawn from and to the destination (palletting) of the finished elements with reference to both the treatments following working (X-raying, zinc-plating, painting, re-annealing, etc.) and the final destination into the various assembling groups (units, blocks, on board).

The structure of the pipe workshops at the Monfalcone, Genova-Sestri and Castellammare di Stabia shipyards of ITALCANTIERI is at present being renewed. Although each of the above yards specializes for its own production, the criteria by which such renewal is carried out are still the same. Therefore are going to describe the main features of the monfalcone yard pipe-shop, giving particular attention to the automatic pipeworking line of this yard, where mass production is expected to begin next autumn.

The workshops manufacture pipes with regard to lots. to be optimal for a week's production. Each lot, consisting of pipes for various zones of one or more ships, is conveyed to the workshops according to a pre-arranged program and subdivided into working flows, whereby each flow is singled out according to the working type

it has to go through. Figure 4 shows the sketch of said flows with the indication of the extent in percentage.

This Figure also specifies the type of pipes that, according to size, material and working, affect the working flows both in the traditional areas of the workshops and in the automatic line.

The workshops yearly nominal production capacity by one daily work shift is such as to cover the pipe requirement for 4,250,000 DWT MYT.

##### 5) AUTOMATED LINE

As can be seen in Figure 4, the employment of the automatic line finds its immediate and main reason in the high percentage (46%) of piping interested in it. Common steel tubes are concerned, having the characteristics shown in Figure 5.

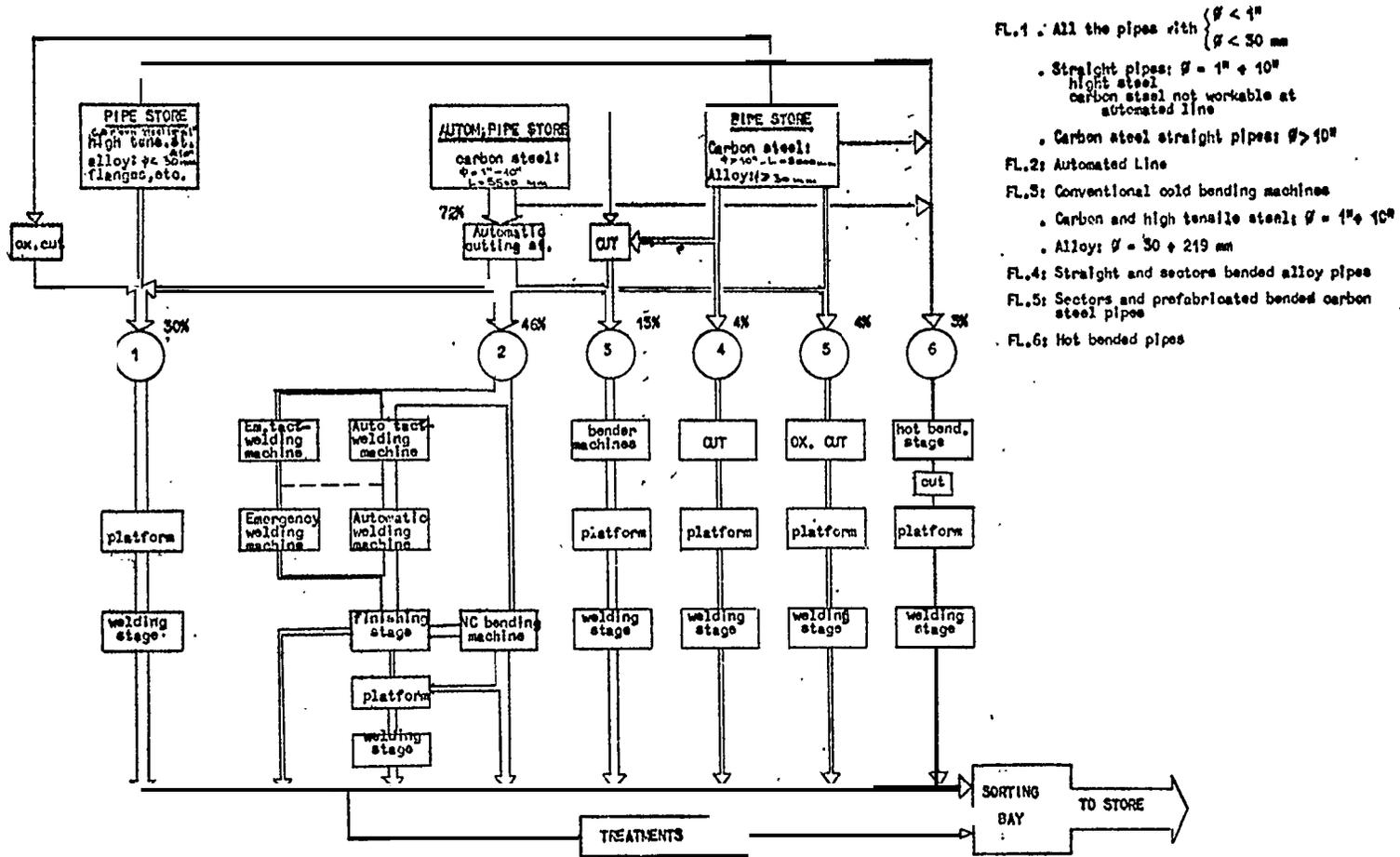


Fig. 4 - Pipe-shop "Flows".

DESIGNATION	NOMINAL DIAM. (mm.)	25	32	40	50	60	75	80	100	125	150	175	200	250	MATERIAL	
	INCHES	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8	10	12	16		
	OUTSIDE DIAM.	33.7	42.4	48.3	60.3	73.0	76.1	88.9	114.3	139.7	141.5	168.3	193.7	219.1		273.0
UNI 4991 - 68	STANDARD THICKNESS							3.60	4.00		4.50	5.40	5.90	6.30	Fe 45,2 III 663-68	
							5.20	3.60	6.30			8.00				
	OTHER THICKNESSES				6.30		5.40		10.00			12.50				
							8.00									
ASA B 36 - 10 1959	STANDARD THICKNESS	3.30	3.56	3.68	3.91	5.16		5.49	6.02		6.55	7.11		8.18	9.27	ASTM A 10 GRADE B
	SCHEDULE 40															
	EXTRA STRONG THICKNESS	4.55	4.85	5.08	5.54	7.01		7.62	8.56		9.52	10.97		12.70	12.70	
	SCHEDULE 80															
	SCHEDULE 120								11.13		12.7	14.27		18.26		
Tolerances out pipe diameter		+ 0.4 ; - 0.8 mm			± 0.8 mm			± 1 %								
Straightness		1.0 mm against 900 mm span														
L																

Fig. 5 - Characteristics of pipes for the automated line.

The automatic line consists of (see Figure 6):

- a - An automatic store made out of 4 racks in 2 independent sets, having a capacity of about 7,000 5,500 mm long pipes in the diameter range from 33.7 to 273 mm. Loading the store is done by an overhead traveling bridge crane laying the needed amount of pipes on the store floor, onto feeding skids. From these skids the pipes are transferred to the assessed stock rack by means of controlled sequence conveyors-elevators. This operation is console controlled by input of the following data:

- stockage chute number;
- number of repetition of the same operation, if any.

Drawing of pipes from the stores occurs through conveyors-elevators, controlled by a centralized console with input of the following data:

- pipe drawing chute number;
- number of 'pipes to be' drawn;
- destination skid (2 for the automatic cutting station and 1 for other destinations).

- b - An automatic cutting station consisting of:

- an automatic knife cutter capable of vertical and caulk cutting. The machine is console controlled by input of the following data:
  - feeding skid;
  - pipe thickness and diameter;
  - type of cutting and length of piece to be cut with capacity of storing up to three cuts for an automatic cutting sequence;
  - destination of the individual piece cut (work, remainder, scrap),
- an emergency disc cutter with preceding pipe scribing and marking station. Pipe carriage from the store drawing skids, feeding into the machine, cutting and discharge of the pipe for the next destinations are carried out by manual control from console.

All pipes being concerned with both the automatic line flow and the traditional working flows pass through the cutting station. This is

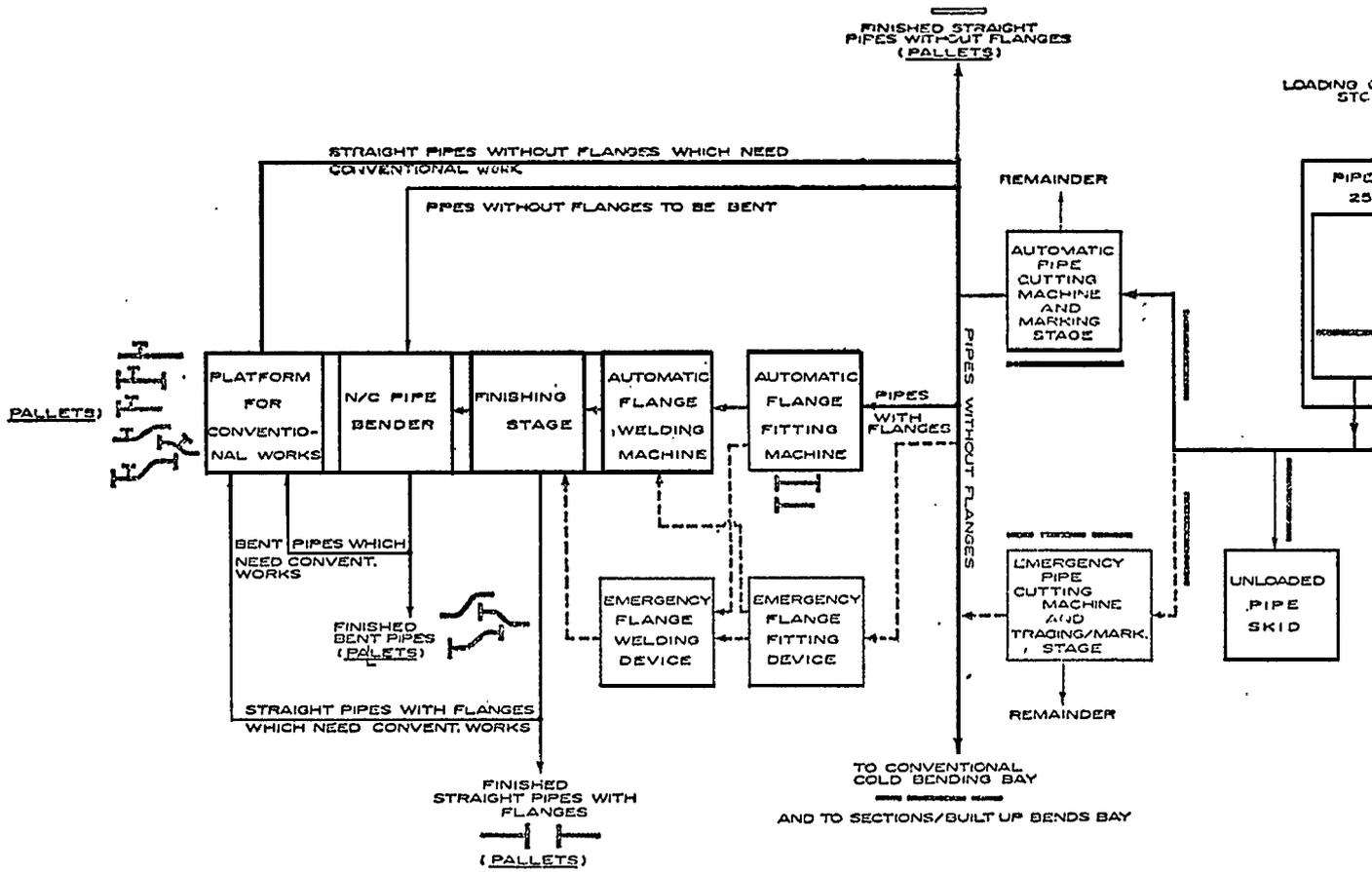


Fig. 6 - Flow chart of automated line.

done on an only cutting diagram for each diameter and thickness in order to reduce scrap to a minimum.

- c - A marking station of the cut pieces, in which an operator conveys the pipes to the automatic and the emergency flanging through a console, or to a flangeless NC bending, or else to the traditional working areas. Under 420 mm long pipes are not carried by automatic line.
- d - An automatic flange fitting/tack welding machine for flat flanges (NP 6, NP 16 or ASA 1S0) for not under 1,000mm long pipes. It is fully automatic sequence console controlled, by input of the following data:
  - drawing buffer (the machine has 2 drawing buffers);
  - flange type and rotation of a flange towards the other;
  - destination (to the automatic and emergency flange welding machines).

The machine is fitted with a built-in flange store which can contain two types of flanges in a certain quantity for the whole range of diameters. There is also an emergency flange fitting/tack welding machine for not under 420 mm long pipes with manual control on console. Tack welding is manual. The feeding of the flanged pipe to the automatic welding machine is performed by the same means which draws the pipes from the automatic welding machine. Feeding of the emergency welding machine occurs by means of, overhead guiderail.

- e - An automatic MAG (Metal Active Gas) flange welding machine for not under 1,200 mm long pipes, console controlled, by input of the following data:
  - welding parameters;
  - pipe diameter;
  - number of welding travels (passes).

There is also an emergency MAG flange welding machine where the single

sequence work operations are console controlled.

f - A manual finishing station where all welded pipes come to. Pipe feeding to the finishing station and the following destination . is console controlled.

g - A NC pipebending machine for pipes of 33.7 to 114.3 mm external diameter. The feeding of the pipe to the machine from the skids being downway of the automatic line is performed manually.

The automatic line is of Japanese supply, with the exception of the pipebending machine, which is of German manufacture. The same line, apart from the automatic flange welding machine and the emergency machines, is pre-arranged for NC integral punched-card operation.

#### 6) PACKAGES WORKSHOP

As stated above, a part of the pipes so manufactured is directly mounted on the blocks or even on board. A remarkable percentage, therefore, is conveyed to a package workshop where units and/or fitting-out modules, that is, preassembled groups containing elements of piping, of fitting-out (gratings, ladders, ventilations and so on) and of plants or machinery are mounted,

This mounting method has been taken into use with a view to cutting down fitting-out times, increasing at the same time the number of hours employed in shops by the best possible working conditions in regard of both equipment available and working ambient. The result is a greater Productivity per hour and a cutting down of the lay-time of the ship in the yard.

On a 254,000 dwt M/tanker recently built at Monfalcone, over 50% of the piping elements were mounted by such a technique.

#### 7) EDP SYSTEM, WITHIN THE PIPING FIELD

The organization and technical evolution described up to this point is based on an EDP system that has been in activity at Italcantieri since 1970; Fig.7 represents the latest version as it came into

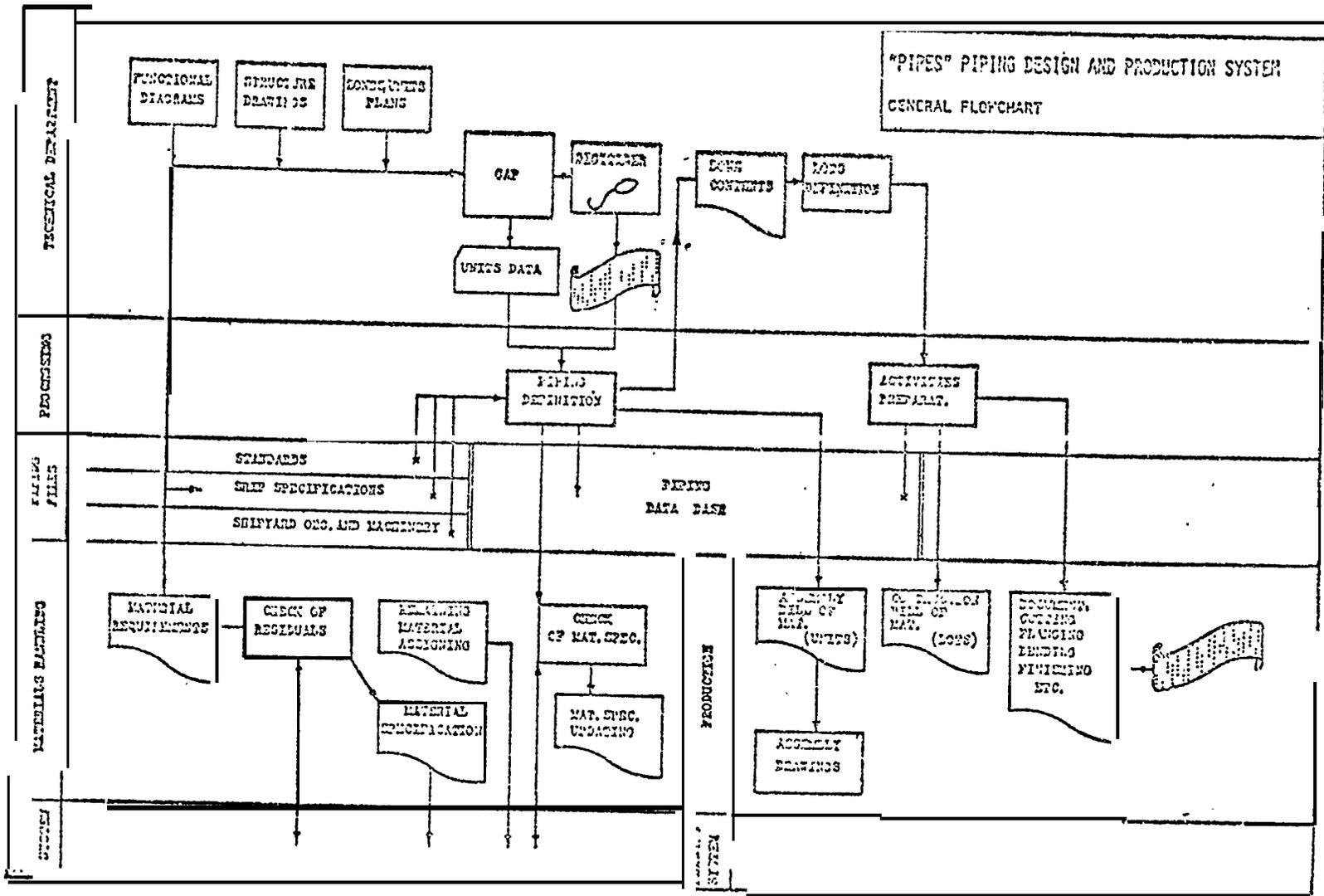


Fig. 7- General flow-chart of the EDP system.

operation at end. 1974.

The whole system consists of four fundamental stages:

- a) storing of general technical data;
- b) processing of the assembling groups;
- c) processing of workshops booklets;
- d) material handling,

### 7.1 Storing of general technical data

In a preliminary stage the loading of three files is provided for, which contain:

- a) the utilization criteria and the technical description of the standardized materials in the piping-field (pipes and fittings such as flanges, gaskets, couplings, etc.)
- b) the particular ship's specification relating to the piping field (employment of materials, treatments, working, etc.)
- c) the workshops organization and the equipment existing in the various yards with regard to the various types of working.

### 7.2 Processing of the Assembling Groups

Once the piping runs have been defined, the data relating to the various assembling groups are carried onto input data sheets (Fig. 8.) whereby the working conditions and the general geometric characteristics of each piping element are indicated.

On ground of such data and after a syntactical and logical check

workshop's Organization files, the methods of piping element manufacturing and the operational parameters for the bending itself. Particularly interesting in this field are the



- 
- routines developed for the NC pipe bending machine, making provision for a check on any possible interference of the pipe with the machine and the ground during the working cycle and the managing of the material spring back at the end of the bending;
- c) producing a mounting booklet consisting of symbolic sketches produced by the lines printer (Fig. 9) of the pipes composing the group and of a list of the mounting fittings (gaskets, bolts, valves, etc.);
  - d) storing the information gained up to this point into a data-base.

### 7.3 Processing of the workshops Booklets

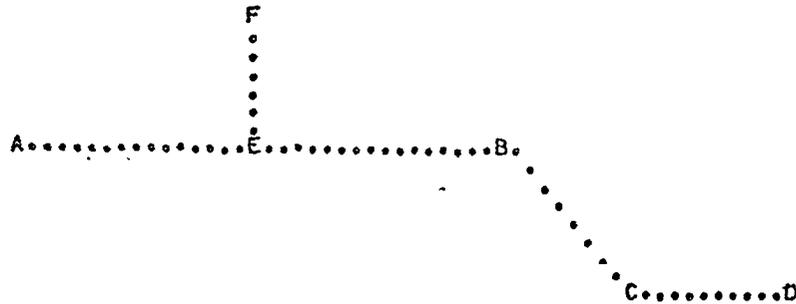
Working "lots" for the pipe workshops are defined on the basis of the quantity of the pipes in the processed zones and of their mounting method. The computer provides for supplying, on ground of the information contained in the data-base and for each individual working flow concerned:

- a) the documentation for the withdrawal of the materials needed for the manufacturing (pipes, flanges, couplings, etc.);
- b) the "cutting planes", that is, the instructions to obtain from the raw pipes having a fixed length the parts necessary to the work with the lowest possible scrap ;
- c) the operational supports, if any, (tables or punched tape) for the NC machines;
- d) the sketches for the traditional working and the finishing platform produced by plotter Calcomp (Fig. 10);
- e) the summarizing documentation for the coordination of the work progress and the handling of the lot and the flow contents.

### 7.4 Material Handling

At the same time a procedure for the handling of the materials needed for the working is being developed. It consists of two stages

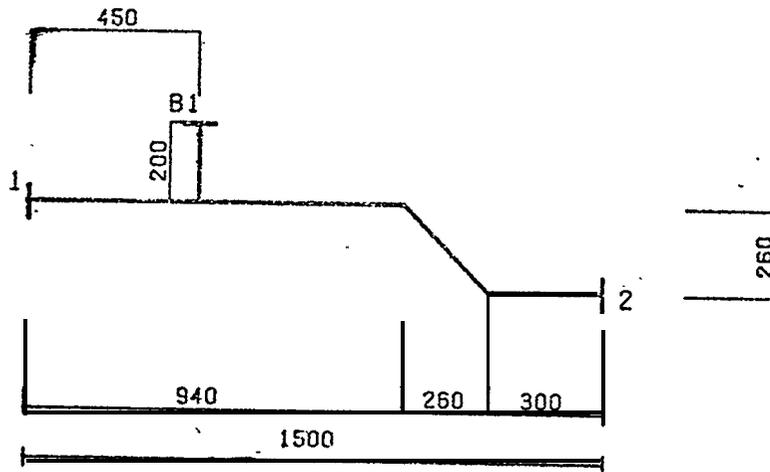
CANT: MARCA TUBO REP: PR.ESE. 2.0 : FLS. 2B PAG. 1  
 MO : 08/43/44/1 15/31: TE.ESE. 100. : PESO 15.5 KG  
 -----  
 ULTIMARE : PEZZI 1:



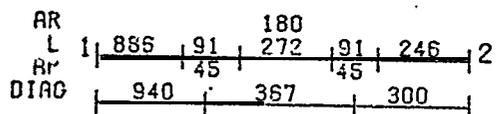
\* TP.0(A-D)~ TUBO = 60.3 X 3.91 ASTM A 106 GRADE B - L = 1576 MM  
 WIRTZ A C.H.  
 -----AR-----AP-----DX-----DY-----DZ-----ACCESSORI-----  
 B .0 45.0 : AB 940. 0. 0. : FLANGIA 2' N 409.10  
 C 180.0 45.0 : BC 260. -260. 0. :  
 D .0 .0 : CD 300. 0. 0. : FLANGIA 2' N 409.10  
 -----TOT 1500. -260. 0.-----  
 DIAGONALI : A-B= 940/B-C= 367/C-D= 300/

\* GR.1(E-F)~ TUBO = 60.3 X 3.91 ASTM A 106 GRADE B - L = 195 MM  
 TUBO PETTO / A-E = 450 MM / ANG. F-E-B = 90. GRADI  
 -----AR-----AP-----DX-----DY-----DZ-----ACCESSORI-----  
 F .0 .0 : EF 0. 200. 0. : FLANGIA 2' N 409.10  
 -----  
 DIAGONALI : E-F= 200/

Fig. 9 - Printed sketch for the assembling.



HILGERS R= 116 L= 1566 mm.



TP	60.3 X 3.91 ASTM A 106 GRADE B.	1 - FLANGIA 2' N 409.10 2 - FLANGIA 2' N 409.10
B1	60.3 X 3.91 ASTM A 106 GRADE B.	FLS FLANGIA 2' N 409.10 B1B

Fig. 10 - A sketch for manufacturing, produced by a Calcomp plotter 925/1036.

- a) storing of the material requirements in the stage of the drafting Of the functional diagrams and their automatic timing according to the ship building program
- b) check of the requirements during the storing of the as-  
smblying groups and signaling if necessary, any  
changes that may have occurred.

The above procedure will be integrated later on with the material handling sub-system being developed at Italcantieri.

## 8) CONCLUSION

The above procedure represents a remarkable organizational deVel-  
Opment, if-compared with the systems used until a few.Years ago When  
the piping was manufactured with conventional systems grouped  
'according to the board plants and services, an the basis of  
a documentation manually prepared.

This development allows new possibilities of subsequent  
realizations to be foreseen- that is:

- usage of the computer in the earlier stages of the design procedure,  
both with the automatic handling of the functional diagrams and with  
the computer aided definition of the general arrangement plan. The  
first presupposes a standardization of the diagrams, the second the  
availability of interactive graphical devices and an interface with  
a suited hull data-base;
- through further refinements of the design it would be possible to in-  
crease the percentage of usage of the automated line in the pipe-shop  
and of the units pre-assembling technique;
- on the basis of the Experience gained with the automated line, an on-  
line real time control system for the line itself could be realized.

Appendix E

AN INTERACTIVE COMPUTER GRAPHICS APPROACH TO THE PROBLEM OF  
NESTING OF PLANE PARTS ON A RAW STEEL FORMAT.

by

Jørn Øian, SRS

Bjørn llasselknippe, CIIR

Frank Lillehagen, CIIR (editor)

## ABSTRACT

The paper presents a new approach to the problem of nesting plane parts. The system developed is tailored for nesting production parts prepared by AUTOKON 71/74, however, the general design is believed to be independent of any particular part-coding system or application.

Geometrically, the problem of nesting is a two-dimensional one, and it is basically similar to any jig-saw puzzle or two-dimensional cutting-stock, ~problem if one disregards all the application considerations that constrain the solution.

The programs developed do not attempt any automatic optimization. The philosophy in designing the system has been that the user is capable of optimization whatever his objective is, if only the computer is able to supply the appropriate information. Defining and applying the constraints required to do automatic nesting not only becomes difficult, it becomes impossible as constraints on the parts layout change dynamically.

The system was developed and is, so far, implemented on the Norwegian mini-computers NORD-1 and SM-4.. The graphics display unit used is a Tektronix 4014-1 storage tube interfaced through a modified TTY - port :

The basic building blocks for the application programs were a set of subroutines to drive the Tektronix-display, Tektronix 4010/4014 Driver, and the AUTOBASE database system for minicomputers.

The system is designed to ease conversion to other computers and graphics displays and to interface to other part generation systems with or without databases.

#### HISTORY

Engineers in various industries have developed computer assisted or computer automated solutions to related two-dimensional allocation problems ( 5) (6)and (7), but.to my knowledge no such solution has been successfully applied to the nesting of steel parts for flamecutting (4 ).

Mathematicians have also shown interest in a general solution to the geometry of the problem. One mathematician's comprehension of the problem is included to demonstrate the difference in viewpoints:

"The. optimum two-dimensional allocation problem consists in taking'some two-dimensional resource, such as a piece of cloth, a sheet of metal, or a parcel of land, and cutting it up into a number of two-dimensional forms, such as clothing patterns, sheet metal parts, or parking spaces, in such a way that some objective, such as minimum waste of material or maximum total number of pieces, is achieved. This paper describes the results of an investigation into methods of handling this type of problem when linear, logical and geometric constraints, in addition to the usual area and non-overlapping constraints, are imposed on the allocations. The investigation is concerned with two-dimensional shapes that can be irregular and either simply- or multiply - connected" (3).

Recently rumors of numerous new developments under way have reached the project group.

## 2. STATEMENT OF PROBLEM

Given a piece of cardboard with fixed dimensions and several small pieces of irregular shape, the problem is to place the small pieces in such a manner on the cardboard that a copy of each may be cut out using as little material as possible. The leftover pieces of cardboard should be as few and as large as possible.

During the part preparation in a shipyard problem of the same nature arises. Frequently several detailed parts are cut from a single raw steel format. The steel cost of a ship is so high that high utilization of the plates is imperative.

During .part.production some extra complication will enter the picture. Local heating during the cutting process may easily cause the parts to bend away from the original position. In certain cases this may lead to serious inaccuracy; so to reduce this effect it is necessary to plan the sequences of cutting. At critical points narrow bridges may be ,left crossing the groove. These bridges will..then tie the parts together' and prevent'aby' appreciable bending away from the original position. The work connected with placing the parts on the format and specifying the sequences of cutting and positions of possible bridges, is the shipbuilder's DEFINITION OF NESTING.

The considerations for the cutting tool are what make the shipbuilders nesting so difficult. The operation of the torches and considerations for obtaining, as large leftover pieces as possible are the most important constraints on the layout of the parts.

The end result of the nesting operation is a geometry description and production information for completed formats. Numerical Control (NC) code of this and other information is edited and sent either off-line or on -line to the NC equipment.

3. SPECIFICATIONS

An AUTOKON study (2) of selected shipyards revealed that the major emphasis in a new system should be placed on features to enable fast changes to an already nested format. The main weakness of existing solutions is that the layout of the parts and the specification of the cutting sequence are computed simultaneously in a batch system. This means that once an error has been introduced it cannot be instantaneously corrected and any further work on the same nested format will be erroneous. Corrections require that the nesting . start from scratch.

ManuAl preparation of the input to the program that computes the geometry of the nested format is another major weakness.

Thirdly and lastly the user has no easy way of verifying the correctness of the parts: The activity of preparing templates is both costly and time consuming and should not be necessary for the nesting operation. If templates are used to simulate the layout their scale greatly inhibits the chances of detecting errors.

Input to the system

- a) Data describing a parts geometry and production information must be built up in a database on mass storage.
- b) The system must accept both manually coded parts as well as parts prepared by a computer program. Parts on NC tape are accepted.
- c) The user must have freedom to choose either predefined formats or to specify the format at any time during the layout of parts.
- d) The user shall have complete command over all system actions. The command language shall be adaptable to the user's needs and abilities.

Manipulation of data

- a) The system must be able to handle an unlimited number of parts on one format.
- b) The user must be able to display or reference single parts as well as multiple parts in one operation. The user must be able to page through the parts library.
- c) The user shall not be responsible for screen administration of data apart from the operations needed to do the parts layout.
- d)** The user must be able to select contour Parts from one part description, according to certain system or user defined criteria, both for the purpose of displaying information and for referencing.
- e) The parts shall be identified and manipulated either by name Or by means of a device pointing at the part image on the screen.
- f) Any action performed on data being displayed must be signaled back to the user.
- g) The user must have flexibility to perform all the basic transformations: translation, rotation, scaling and mirror-imaging, as well as actions combining these basic transformations.
- h) Zooming in on details in a display must be possible. This allows the user to inspect details in either a pre-set or specified scale.
- i) The user must have functions to modify part production information, such as bevel cutting, common cutting, text,

material handling no; thickness, steel quality etc;  
Functions to modify geometry are part of another module  
to be developed for part processing,

- j) The user must have functions to check the geometry of single parts or formats and nested formats. Overlap checks between single parts and neighbor parts are also important to ensure a correct layout.
- k) Parts should be displayed with lines drawn differently to distinguish between standard cutting, bevel cutting, common cutting, rapid traverses, punch marking and edge marking.
- l) The cutting sequence shall be specified by the user. The user must have freedom to start a new sequence and end a sequence wherever is convenient. When starting a torch, the torch shall be at a given minimum distance from the contour to be cut.
- m) The user must be able to make changes to, to store away and to relate groups of nested parts or nested formats. This is important where certain constellations of parts, patterns, repeat.
- n) The user must be free to delete information from both a certain displayed picture and from the system data areas.
- o) The user must have the option when to redraw (clean up) any displayed picture.
- p) The user must be able to save and restart, a job or to save one job and restart another. Jobs may also be dropped entirely.

Output from the system

- a) The system must give quick and easily understood responses to all user actions. Production information that may influence the user's next action must at all times be conveyed to the user.
- b) A geometric description of nested parts and relevant system data must be stored in the database whenever the user so desires.
- c) A standard edited NC tape is the end product or the NC information may be fed directly to an NC machine. The user may also store the NC information in the database.

General system design criteria

- a) The SIAG standard, of programming and documentation is strictly adhered to.
- b) The programs must be designed to allow for different ways of organizing and loading the programs and to meet requirements of limited core space.
- c) The system shall be easily expandable or reduceable in number of user functions.
- d) The system may be self-standing or a satellite-installation interfaced to a mother system, e.g. AUTOKON.
- e ) The system design should make every practical effort to ease the change of graphics display and database administration system.

#### 4. SYSTEM DESIGN

System specifications and programming considerations lead to the conclusion that the system comprises three distinguishable jobs or phases of operation:

- data preparation and verification (DPREP)
- part layout (LAYUT)
- cutting sequence (CUSEQ)

##### Purpose of DPREP

The purpose of DPREP is to verify the parts in the database on the minicomputer and to prepare the parts for input to the LAYUT phase. Verification is achieved by displaying the part contours and associated production information (text) with the possibility of generating hard copies. Data preparation involves reformatting and reorganizing data to meet hardware requirements and optimize data retrieval (No. of accesses and access times to the database), and data enhancement to minimize core requirements and processing times,

##### Purpose of LAYUT

The purpose of LAYUT is to place parts together on a format or in a two-dimensional area, taking care of the geometry of what is going to be a nested format. Correcting and verifying completed formats or nested parts is also done in this phase of the system. The geometry of the nested parts will later be the input to the CUSEQ phase.

##### Purpose of CUSEQ

The purpose of CUSEQ is to specify cutting sequences in order to OPTIMIZE the use of the flamecutters (torches). The NC information produced is generated on papertape or fed directly to the flamecutters. A copy is stored in the database.

4.1 PROGRAM AND DATA FLOW

Before the nesting system may be started a database must be built on the minicomputer. This database is initiated by the DINIT program (minicomputer version) and will receive parts (records) from the AUTOKON main database either on-line or off-line. Off-line data transfer may be done by the AUTOKON standard programs RECUT and DFREC, while on-line transfer is performed by two new programs, called PARTO and PARTI.

The system is developed to work on minicomputer databases that are private to one user and that contain parts from one and the same section of the ship (exceptions are allowed):

(An database storage standard for standard minicomputer is is designed, and there are no big changes in data organization between the version on the big computer and the version on the minicomputer.)

The part records sent to the minicomputer should contain some information, which is not usually in a part record on the main database. PARTO extracts and transfers correct part records for the minicomputer database. These data asked for by PARTO may not normally be in a part record or at all directly available:

Cutouts along the outer contour and holes should be marked such that the smooth silhouette contour may be readily retrieved.

- Kerf width compensation and shrinkage must be allowed for before the part is used in the DPREP phase.
- Circumscribing rectangles must be stored in the main database. They may; of course, be calculated in the DPREP phase, but this is not implemented in this version of the system,

Once a database of parts is established the DPREP phase may be started. DPREP, upon user request, reads all the pertinent information for a part to be nested from the part records on the minicomputer database.

## SI BLINDERN

Each system phase has a phase initiation program, which is responsible for first-time initiation or reinitiation. This involves establishing the communication links to 3 or records on the database. The system uses the AUTOBASE database programs both for the management of application data and for graphics and system data.

Before a part may be referenced in the LAYUT phase it must be passed as qualified for nesting in the DPREP phase. This involves transferring the contour description to a system record. A special table is maintained to control all the parts that have qualified for nesting. This system record and the associated table is our master reference data whenever a new copy of the part is needed or when the nested format record is built as an end result of the nesting operation. There is one more level in the data representation before a part becomes a picture for display. That level is the extracted desired contour parts of the master with transformations and graphics processing applied. We call this level the paint file representation, since this is exact copies, of the data going to the display driver.

Once the user has verified and prepared the desired parts, the layout of the parts may commence. The user must then change from DPREP to LAYUT phase and file doing so the system does a lot of background work on the database - garbage collection, back-up, closing old and opening new communication links. Any change of phase has these same effects on the database.

The complete sequential geometry description of a nested format is not built before the user requests NC information for the format. Until then all actions to do layout of the parts and specification of the cutting sequence result in parameters being stored in special system records. In this way the parameters are maintained throughout and changes are easily achieved.

The overall system program and data flow such that they allow for several ways of operating the system and ensure the user a safe and effective way through the system. There is full database security when changing between any two phases of the system. The program flow is basically controlled in two levels:

1. The phase is checked for each action.
2. When specifying commands, the user has complete control to return to the command processor.

The system program flow is, therefore in two levels once the system is up and running. The upper level is the command processor and the lower level is any branch of program responding to a command (an action).

#### 4.2 COMMAND PROCESSING

The general format of a command is:

```
<OPERator> <OPERand> parameter/argumentlist; )
( )= CR, carriage return)
```

In general the operator tells what type of action will be performed, while the operand tells what type of data is involved. The parameter may supplement both the operator, in which case it will modify the type of action taken, and the open and, in which case it will delimit or set values to the data involved.

The argument list, which may be either in a sequential list form or in an implicit do-loop form, defines values of the operand. Any command action detecting missing parameters or argument from the user will echo requests for specific input to the user. Old parameter values are echoed as well. This delayed dialog. communication is very valuable when default values or arguments with standard values are forgotten and the user may want to change values.

The commands may either be specified from a TTY, the display keyboard or from a menu on a picking device (e.g. tablet). The cross-hair is used extensively.

The user may edit his input. This, as well as other special command operations, is done by special characters as for most text editors.

4.3 COMMAND SUMMARY

	<u>Operator</u> , .	<u>Operand</u>	Phase Allowed		
			<b>DPREI</b>	LAYOUT	CUSEQ
1	BEVel	R I G h t LEFt	x x		
2	BRIdge	CHAnge REMOve SPEcify			x x x
3	CHAnge	DEFAult val. SIDE param AUTObase id.	x x x	x	x
4	CHEck	TOTAL AGAinst		x x	
5	CLEAn up	FRAMed format		x	
6	DEFine	CONture type TEXT PROductions Info	x- x x	x x	x
7	DIMension	Coordinates DISTance	x x	x x	x x
8	DISplay	P A R T s T E X t Production Info TABLEs	x x x x	x x x	x x
9	DROp	PARTs	x		
10	DUMp		x	x	x
11	ENTer	FORwards BACKwards RRVerse Horizontal. VERTical NORmal			x x x x x x
12	FRAMe	LEFt RIGht STArt E N D		x x x x	x x x x
13	FOLLOW	FORwards BACKwards POInt S E Q u e n c e TOTal MODesetting			x x x x x x

	<u>Operator</u>	<u>Operand</u>	<u>Phase Allowed</u>		
			DPREP	LAYOUT	CUSEQ
14	FORmat	SPEcify		X	
		Predefined		X	
		Completion		X	X
		CHAnge		X	X
		RECall		X	X
		STOre			X
		KILL			X
15	GENerate	TAPe			X
16	HELp		X	X	X
17	MIRror	Horizontally		X	
		Vertically		•	
<b>18</b>	<b>MOVE</b>	HORizontally		X	
		Vertically		X	
19	NEW	SEQuence			X
20	PART(s)	SPEcify	X	X	
<b>21</b>	<b>PLAce</b>	SIDe		X	
		POInt		X	
		INNer		X	
<b>22</b>	<b>REMove</b>	PART(s)		X	
<b>23</b>	<b>REShow</b>	SINGle picture	X	X	X
		DETail	X	X	X
		NESted format		X	X
		FRAMed format		X	X
24	ROtate	ABSolute		X	
		DEGrees		X	
25	SAVe	TEMporary	X	X	X
		SYStem	X	X	X
26	SElect	CONtourtype	X	X	X
27	SEt	MOde display	X	X	
		SCAle	X	X	
28	SHOw	SINGle picture	X	X	X
		DETail	X	X	X
		NESted format		X	X
		FRAMed format		X	
29	STArt	DPRep		X	X
		LAYOUT	X		X
		CUSeq	X	X	
30	TRAcE		X	X	X

(30 operators and 47 operands)

#### 4.4 USER FUNCTIONS/COMMAND ACTIONS

A brief explanation is given for each command as presented in the preceding section.

1. BEVel. To set/change bevel cutting on a contour Bevel marked on contour both on database and display.,
2. BRIdge. To specify, change or remove bridges on a format. Action both in bridge table and on display.
3. CHAnge. To change important system parameters. Common variables are changed.
4. CHEck: To check parts against each other for overlap. Check one against neighbors Or all against all. Message printed,
5. CLEn up. To clean up a messy picture. Removes from display and system any unwanted parts.
6. DEFine. "To define text-directly to the display or parameters to system data areas.
7. DIMension. To take control measurements from displayed information.
8. **DISPlay.** To display parts, prestored text, production information and tables over all parts nested parts and nested formats.
9. DRop. To drop parts from the. nesting system. The part records remain
10. DUMp. To dump system parameters and areas.
11. ENTer. To enter contours in different ways. Used when specifying bridges on the format.
12. **FRame.** To slide the format across the screen.

- 13. FOLlOW. To trace out the cutting sequence of the whole format or any part of a sequence from a user specified point.
- 14. FORmat. To specify a format partly or completely at any time during layout of parts. Formats may be stored and recalled from system records.
- 15. GENerate. To generate geometry and NC information for a nested format. Builds nested format record.
- 16. HELp. To give the user assistance in operating the system.
- 17. MIRror. To take the mirror-image of a part. New copy of the master for display.
- 18. MOVE. To translate the part. New copy of the master for display.
- 19. NEW. To start a cutting sequence. Giving point of entry on the format.
- 20. PARTs. To prepare parts for nesting to build master, and to display masters in the menu-area.
- 21. PLAcE. To transform parts. Combination of basic transformations.
- 22. REMove. To erase parts from a nested format.
- 23. REShow. To bring back an erased picture of single pictures, details, nested formats or framed formats.
- 24. ROTate. To rotate a part. New copy of the master is displayed.
- 25. SAVe. To save the system temporarily or permanently. Back-up is taken of system data area. Database is closed for a permanent save.
- 26. SELect. To select what contour parts of part masters should be displayed.

- 27. SET .        *To set display mode and user specified scale factors.*
- 28. SHOW,       *To display single pictures, details, nested formats  
                  **or** framed formats of previously built pictures.*
- 29. STArt.      *To start a new phase of the system. Any sequence of  
                  phase changes is allowed. Reinitiates a lot of system  
                  data areas.*
- 30. TRAcE.      *To set trace of certain system parameters.*

## 5.        HARDWARE

The system will be implemented on hardware shown in Fig. 1, where the absolute necessities are:

Minicomputer -(core space dependent upon program organization  
                  allowed by basic software).

Disc memory - preferably portable packs. 1,2 M.bytes.

Tektronix 4014 - 1 Display Terminal - hardcopy possibility  
                  provided.

Papertape reader/punch.

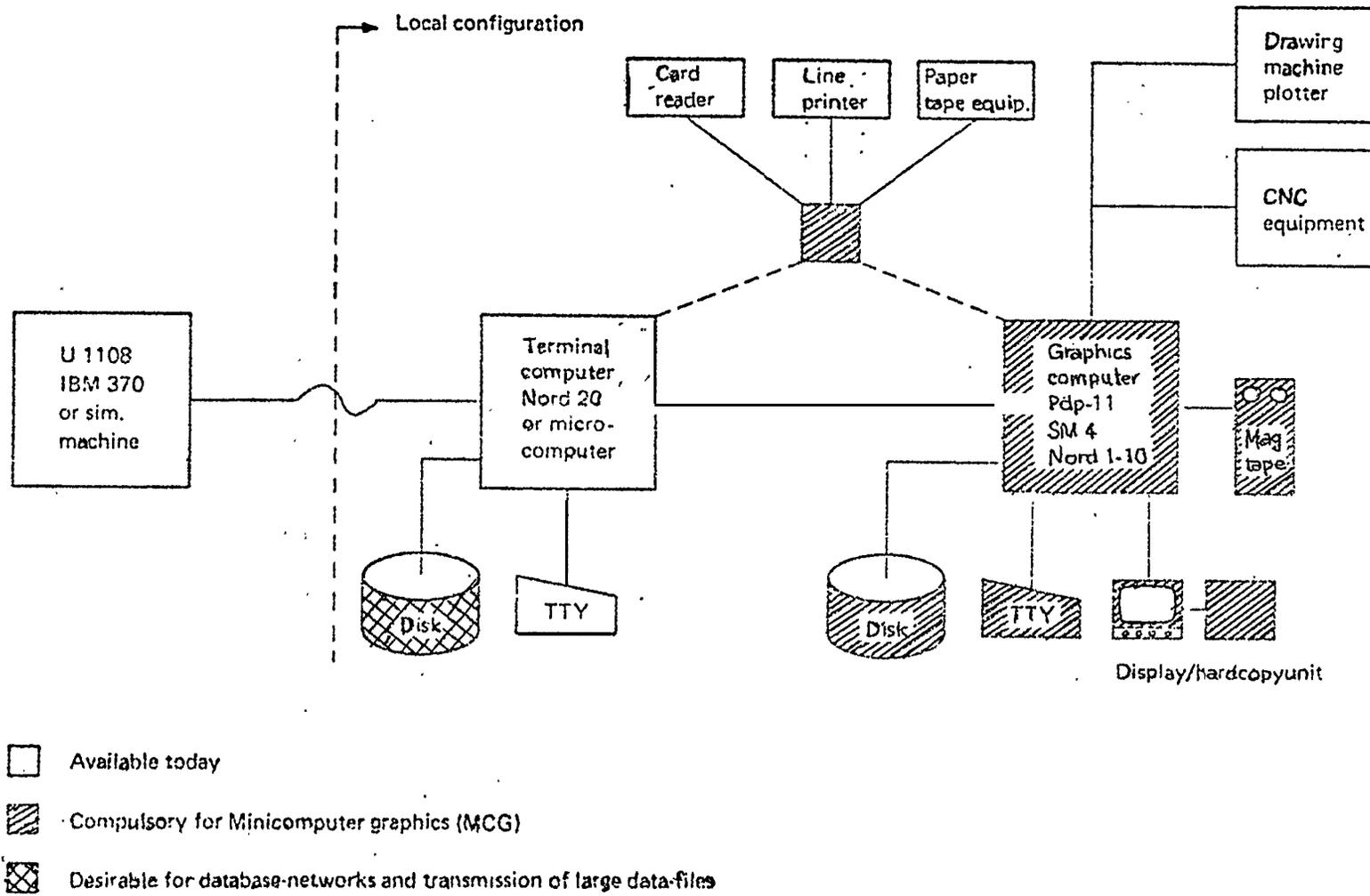
Teletype.

The Tektronix 4014. Display Terminal is a storage tube graphics display with a cross-hair cursor pointing device and an ASCII keyboard.

As a selfstanding system these components are a minimum configuration. The system will then probably occupy the computer completely. Operation on time-shared machines may result in very bad response times.

If the parts are generated on a mother system a direct connection between the mother system big computer and the minicomputer is desirable (Fig. 1). The interfacing may either be as a Remote Job Entry terminal or on a hired line.

Fig. 1



6. SYSTEM OPERATION

The system operation will, of course, vary from installation to installation depending on many circumstances. To discuss all these aspects is beyond the scope of this paper. However, since we will be working on minicomputers we cannot avoid the core space problem. This is usually no problem with modern minicomputers, but with older computers it is still a barrier.

6.1 PROGRAM ORGANIZATION

Being confined to design portable FORTRAN programs, this is what we have done to ease the core space problem. All precautions have been taken to allow the programs to be loaded either as one or three main programs or to operate the programs as a library of action routines. The latter mode of operation is probably what is most in demand and naturally it is the most difficult to achieve.

To enable these three modes we have put particular emphasis on database security and on command processing and program control.

6.2 DATABASE ADMINISTRATION

The minicomputer database is very much an output database. This means losing it is no tragedy. The worst that may happen is that saved jobs with incomplete or completed nested formats may be lost. To transfer databases or single parts between the mother database and the minicomputer database is a very important job. There are so far no provisions for automatic reporting between the two systems. To help administrate the minicomputer database the user may at the moment get these tables:

- a) Table of parts ready for nesting.
- b) Table of parts already nested.
- c) Table of completed formats.

6.3 EXAMPLES OF MAN/MACHINE DIALOGUE

Display of single parts

For verification purposes the user may display one or more parts on

the screen simultaneously, text and production information may be displayed, control measurements may be taken, text may be added and hardcopies may be generated (Fig. 2). This is done in the DPREP phase or in LAYUT before a nested format is specified or referenced.

#### Placing parts on the format

After having specified that nesting is started (defining format or nesting area) the screen will be divided in three viewports (Fig. 3). The upper viewport will be used to show as much of the format as possible (user defined scale). To enable this a sliding window is implemented that produces what we call a framed format. The framed format contains the region of the format where the user intends to place the next part(s). This is illustrated in Fig. 4.

Single parts, up to four at the same time, are brought into the middle viewport, where they are displayed in the same scale as the framed format in the upper viewport. The lower viewport is used for texts, messages and other alphanumeric information.

Placing a part is done by the user specifying a transformation command. The part itself and certain geometric reference points on it are identified as well as certain reference points on the format. Moving a part onto the format is done by either the PLace or the MOVe command (Fig. 5).

#### Taking details in a picture

Details in any picture may be enlarged for further inspection. The user specifies his area of interest by pointing to an approximate Center. The user may also give the desired scale or the default value will be used. The detail picture uses all of the screen area. The same detail may easily be displayed in different scales.

#### Specifying cutting sequence

When the user is satisfied with the layout of a group of parts or a complete format, cutting sequence may be specified. This is done using the cross-hair anti some simple command. Earlier specified sequences may be traced, changed or dropped. Replacing parts in a group of parts where cutting sequence is already specified is permissible. Changes only cause local complications.

# DISPLAY OF SINGLE PARTS

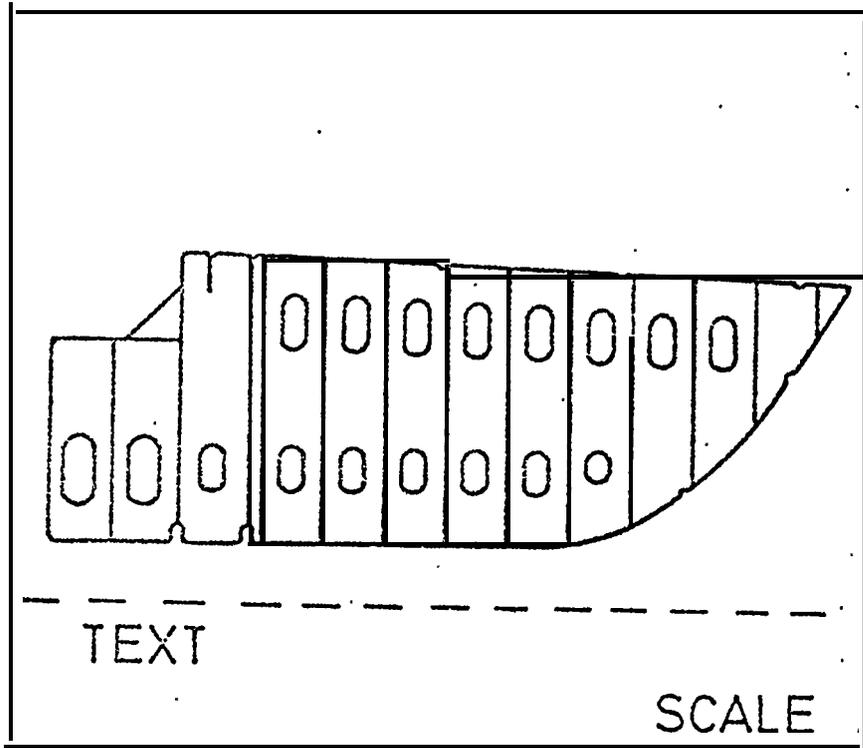


Fig. 2

# SCREEN ADMINISTRATION

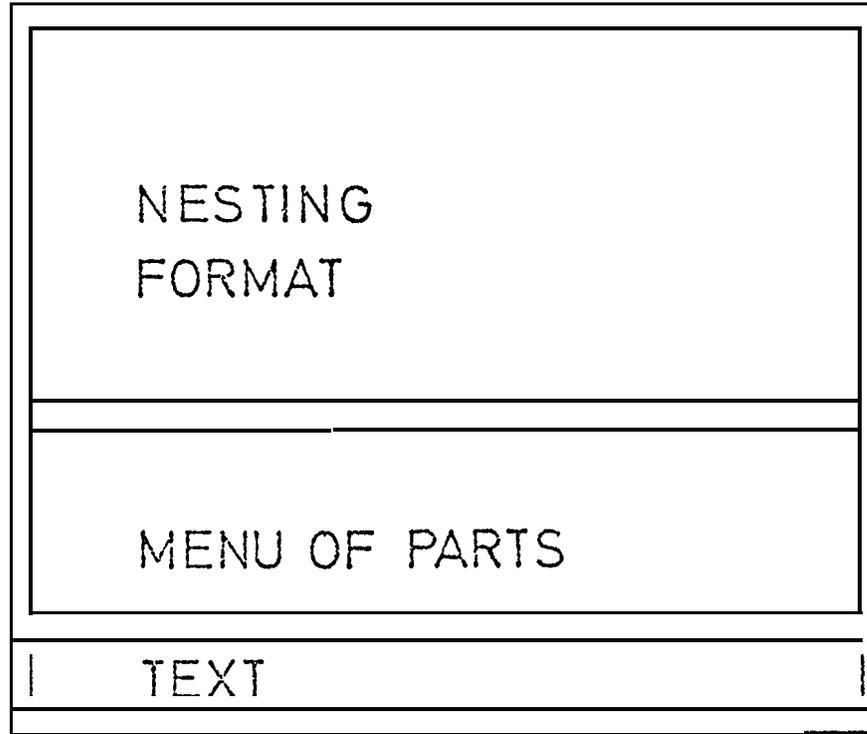
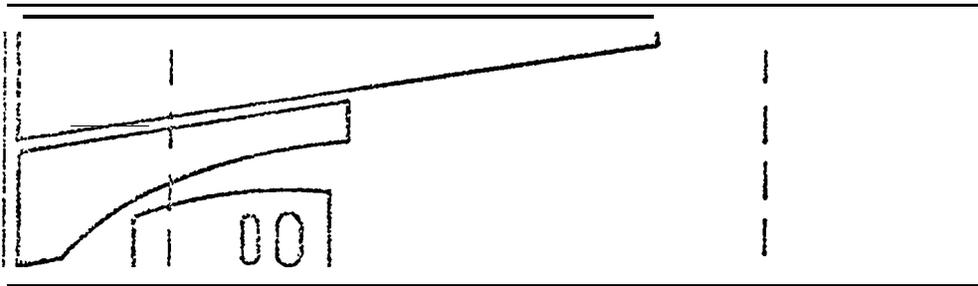
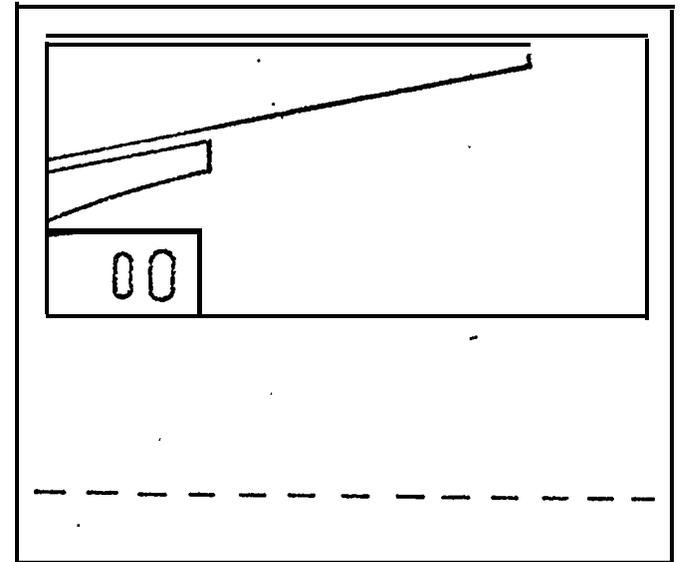


Fig. 3

THE SLIDING WINDOW PRODUCES FRAMED FORMATS



NESTED FORMAT



PROJECTED NESTED FORMAT

# PLACING PARTS ON THE FORMAT

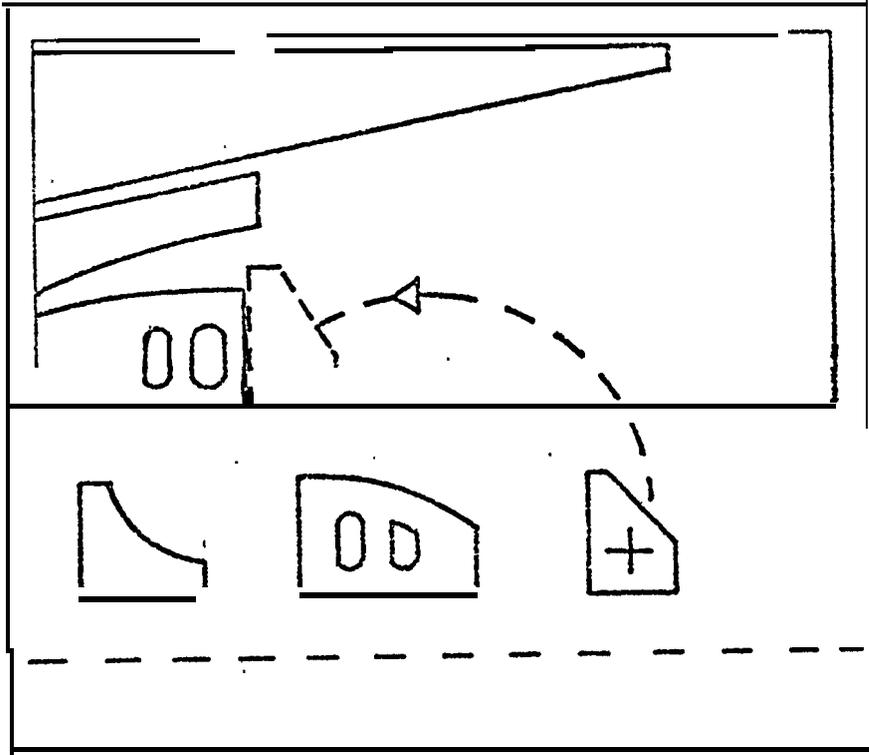


Fig. 5

7. SYSTEM STATUS

A test version of the system is being debugged at CIIR. A pilot version is expected to be ready in early June. The pilot version will be user acceptable in a simulated production environment, before we call it a production version. Stord Yard of The Aker Group expects to have the system installed for production just after the summer vacation.

SRS and Kongsberg Vapenfabrikk, who supply hardware to the project and the pilot version, will specify sales versions of the system in cooperation with the project group. The system should be available on the market in October this year. However, certain sales versions may require long delivery times, if radical changes to the production version being implemented at Stord Yard are desired.

8. FUTURE DEVELOPMENT

Interactive nesting is the first application in a series of five that will be designed for minicomputers and interactive computer graphics. All these projects are part of a development program called Graphical Generation of Production Information.

The project group has also started looking at other ship design activities that may be improved by introducing new technology. Basic research is also going on in the following areas:

3-dimensional (3D) systems for CAD and CAM.

New ways of 3D data input to CAD-systems.

New ways of representing objects and new *tools* for handling objects in the computer.

Some of these projects are joint Norwegian efforts partly government funded.

The presentation will concentrate on the use of the system.

Thank you.

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Contributions to specifications of the system have primarily been  
obtained from Mr. Christian Balchen, Aker Group, Mr. Leif Nilsen  
and Mr. K. Pedersen, Stord Yard and from people at Kongsberg Vapenfabrikk.

Appendix F

THE APPLICATION OF AUTOKON  
TO DRILLING RIGS

by J.F. Mack

This paper presents the work which is currently going on in the Aker Group to apply the Autokon system to types of steel structures other than ship in particular drilling rigs.

The paper also discusses the motivation and philosophy in general for using a database oriented numerical system for such structures.

AG/29th April, 1975

## 1. INTRODUCTION

The background may be found in the application of AUTOKON to ships in previous years.

Initially, the system was very much preoccupied with hull surface description, while the internal plane geometry steel structure was to a large extent left to the less systematic and sophisticated" approach of manual or semi-manual coding of parts.

The introduction of the problem oriented language ALKON, together with a much improved database management system (AUTOBASE) was in many ways a turning point. These modules in AUTOKON provided the necessary tool for a systematic description of scantlings.

ALKON was initially developed as a language for plane geometry description, but it also had many of the same capabilities as FORTRAN (in' which it was in fact coded) . Later ALKON was extended considerably to become an efficient tool for dealing with general data in matrix form. Perhaps the most important property of ALKON, however, is the possibility of applying pre-coded sequences (subroutines called NORMS).

Much of this paper deals directly or indirectly with work done in the field of norms.

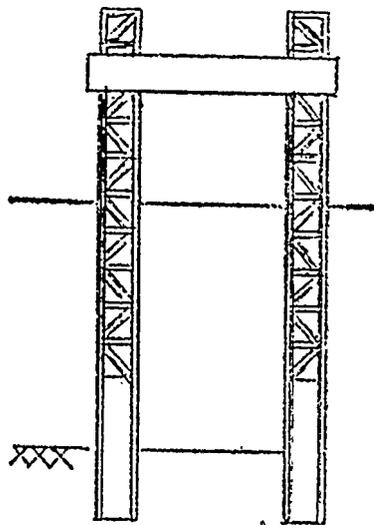
This is natural since, even for ships, quite a large part of the effort within the Aker Group has gone into the development of such.

For drilling rigs and other general structures, ALKON norms are, as we shall see, likely to play an even more dominant part.

## 2. DRILLING RIGS

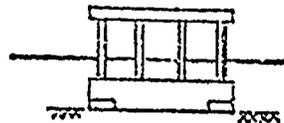
Mobile drilling units can be divided into two principal types: units which stand on the seabed while drilling, and units which drill from a floating position. Fig. 1 shows by means of typical examples a slightly more detailed grouping of units. In sequence of prevalence at present, these are

1. jackups
2. drillships
3. "semisubmersibles
4. submersibles



JACKUP

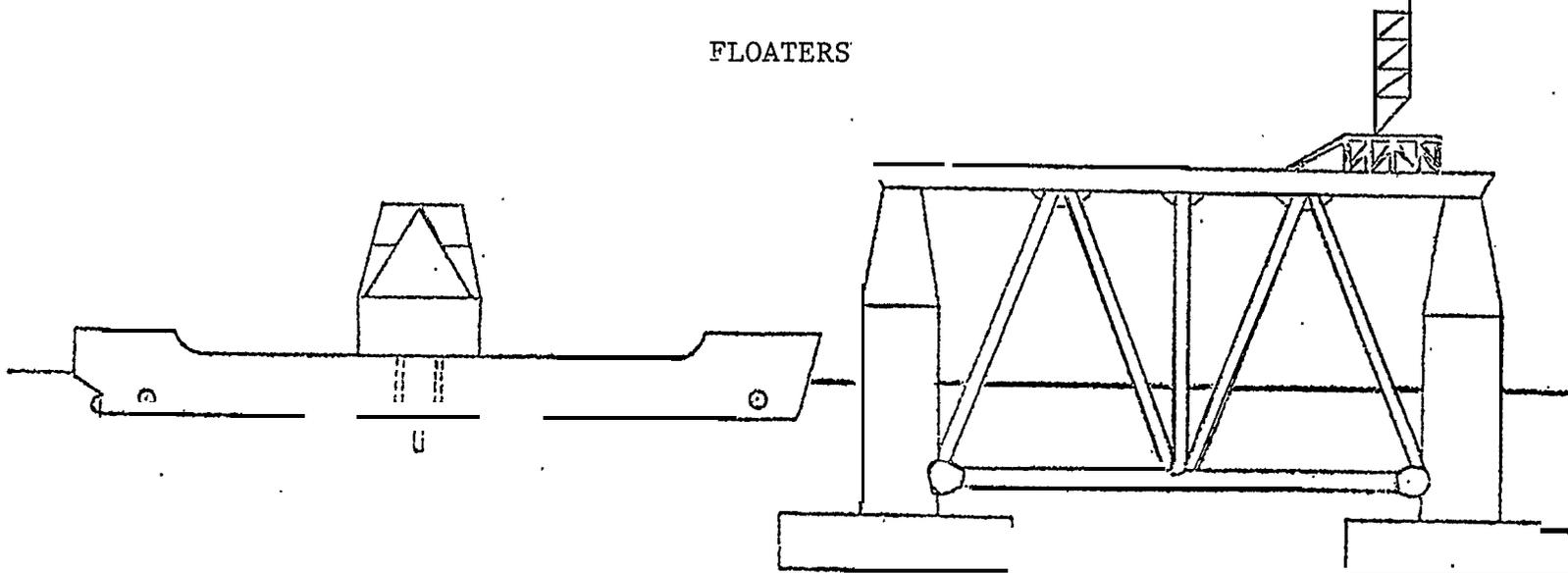
BOTTOM SUPPORTED UNITS



SUBMERSIBLE

387

FLOATERS



DRILLSHIP

SEMISUBMERSIBLE

FIG.1

1. Jackups are characterized by their legs which can be projected downwards until they stand on the seabed, supporting the main platform section which is jacked up clear of the surface of the sea during drilling operations. This section is watertight and is sufficiently buoyant and stable when floating to carry the whole structure during transit from one well to the next.
2. Drillships are usually ship hulls of more or less conventional design, fitted with drilling equipment, exceptionally powerful anchoring equipment both forward and aft, and a vertical drilling well, a so-called moon pool through the center of the ship 'below the derrick. Drilling barges are similar to drillships, however without propulsion machinery.
3. Semisubmersibles are floating drilling units. It is a characteristic of these units that they can be submerged by means of water ballast during drilling in such a way that the main buoyant elements are submerged in calmer water beneath the surface of the sea. This reduces the movements of the units in a seaway and also reduces strain on moorings. They are equipped with large, vertical columns which thanks to their waterline moment of inertia, contribute to the positive stability of the structure. Thus, stability requirements are decisive in the choice of diameters of these so-called stability columns; bottles or caissons.
4. Submersibles are platforms which stand on the seabed during drilling. They generally comprise a lower pontoon section with sufficient buoyancy to float the platform during moving operations. The pontoon section is brought down to the seabed and lifted to the surface by means of water ballast. The platform deck section is rigidly affixed to the top of supporting columns or trusses.

The Aker Group has mainly been involved in the production of semisubmersibles of which the H3 is a popular representative (fig. 2). The structure of an H3-like rig can be divided into the following logical units:

1. pontoons
2. Columns and trusses
3. Deck structures

In principle there is very little difference between a drilling rig and a ship, particularly as regards semisubmersibles.

They are both buoyant structures, implying some sort of hull surrounding and supported by a steel structure which is often very complex.

In addition to this, the pontoons of rigs like the H3 have been purposely built in a shiplike manner to allow traditional shipbuilding techniques and facilities to be used.

Fig. 3 shows the structure of an H3 pontoon.

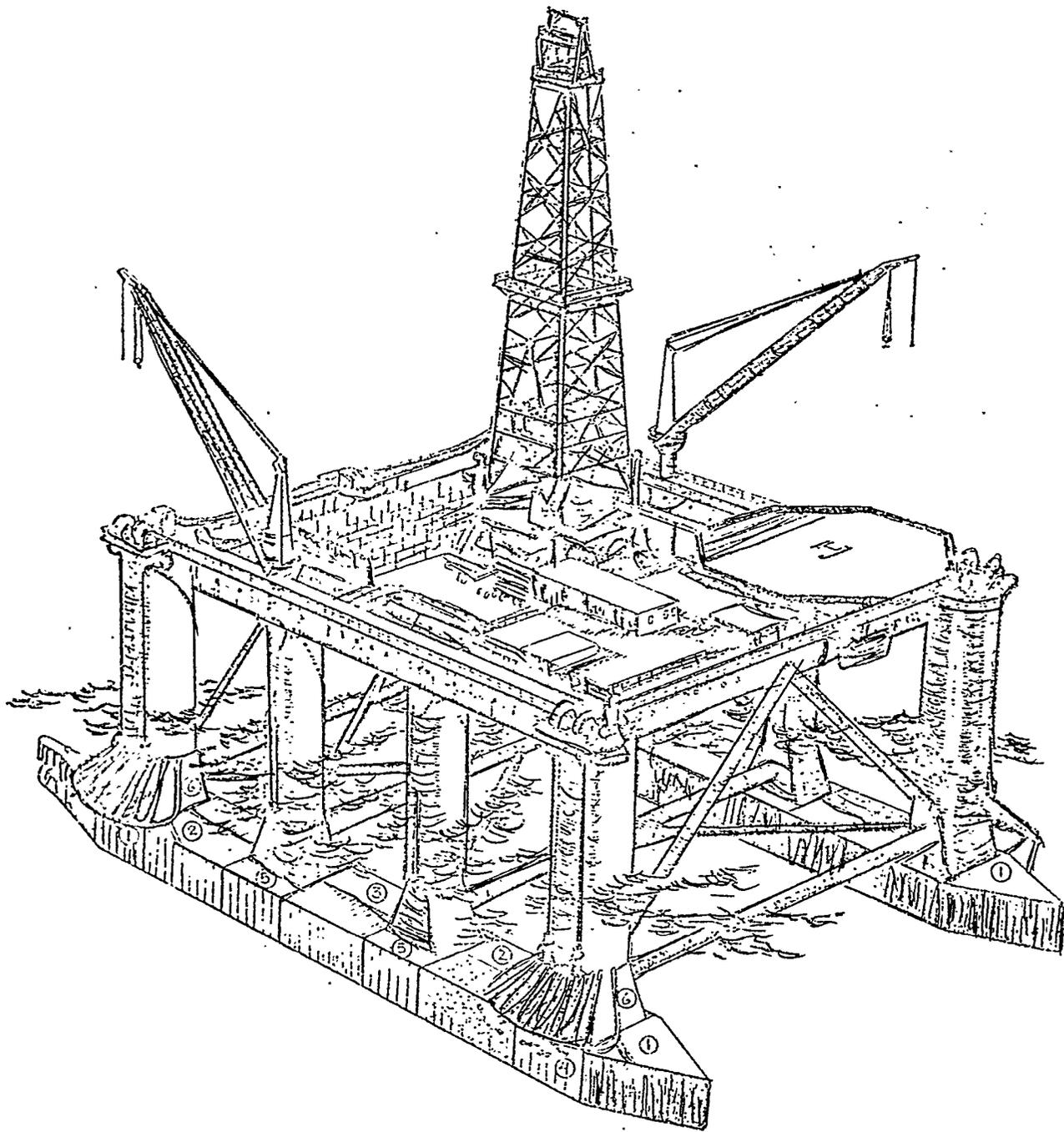
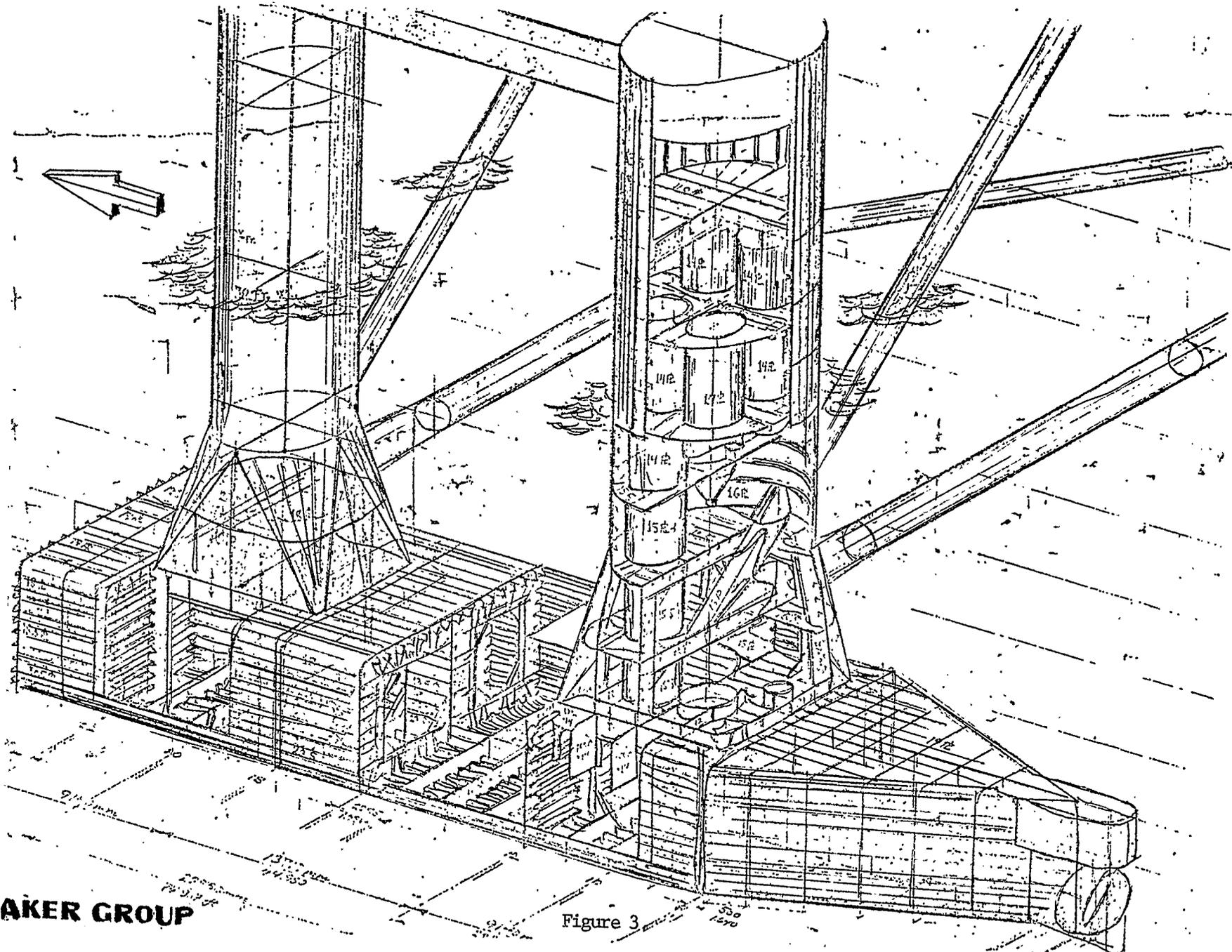


Figure 2.

# AKER H-3 THREEDIMENSIONAL SKETCH



**AKER GROUP**

Figure 3

If anything, the drilling rig tends to be simpler than a ship. Factors like propulsion and speed are often of minor importance, and the shape may consequently be a simple geometrical form.

Fig. 4 shows how the AUTOKON programs are situated around a common database. A large number of these programs originated to take care of the complex shape of the ship hull. Thus, in cases of simple geometrical forms, the ALKON module is sufficient to take care of the hull description. (If the shape is a complex one, the whole library of programs would be available of course.)

There is one other factor which must have some influence when deciding where the effort should be (concentrated when developing an efficient tool for drilling rigs. This is the importance of weight and C.G. calculations.

Even for snips there should be some incentive for reducing the very tedious work of weight estimates.

For semi-submersibles very accurate weight calculations are essential because of stability and payload considerations (experience data is also very scarce).

Quite a lot of effort is therefore, being concentrated in making a system which will give a near complete picture of a general steel structure in a database, and then extract various design and production data from this database.

### 3. PHILOSOPHY

#### 3.1 A Database for scantlings.

Building up a database containing a complete description of scantlings is of course a tremendous job if done by manual coding.

By introducing an extensive set of ALKON NORMS the time needed to build up such a database has, however, been drastically reduced.

These norms work in such a way that the necessary input is greatly reduced and simplified, but at the same time they impose few restrictions as regards the actual design.

This feature is about to open a new dimension to numerical shipbuilding in that the database now appears as the major source of hull information, and should also in the future provide a very important information link between various departments working on different, but mutually dependent tasks.

As we shall see, the scantlings database may in many respects be far superior to more traditional relays of information like drawings, and as such it would appear to be a rather powerful design tool.

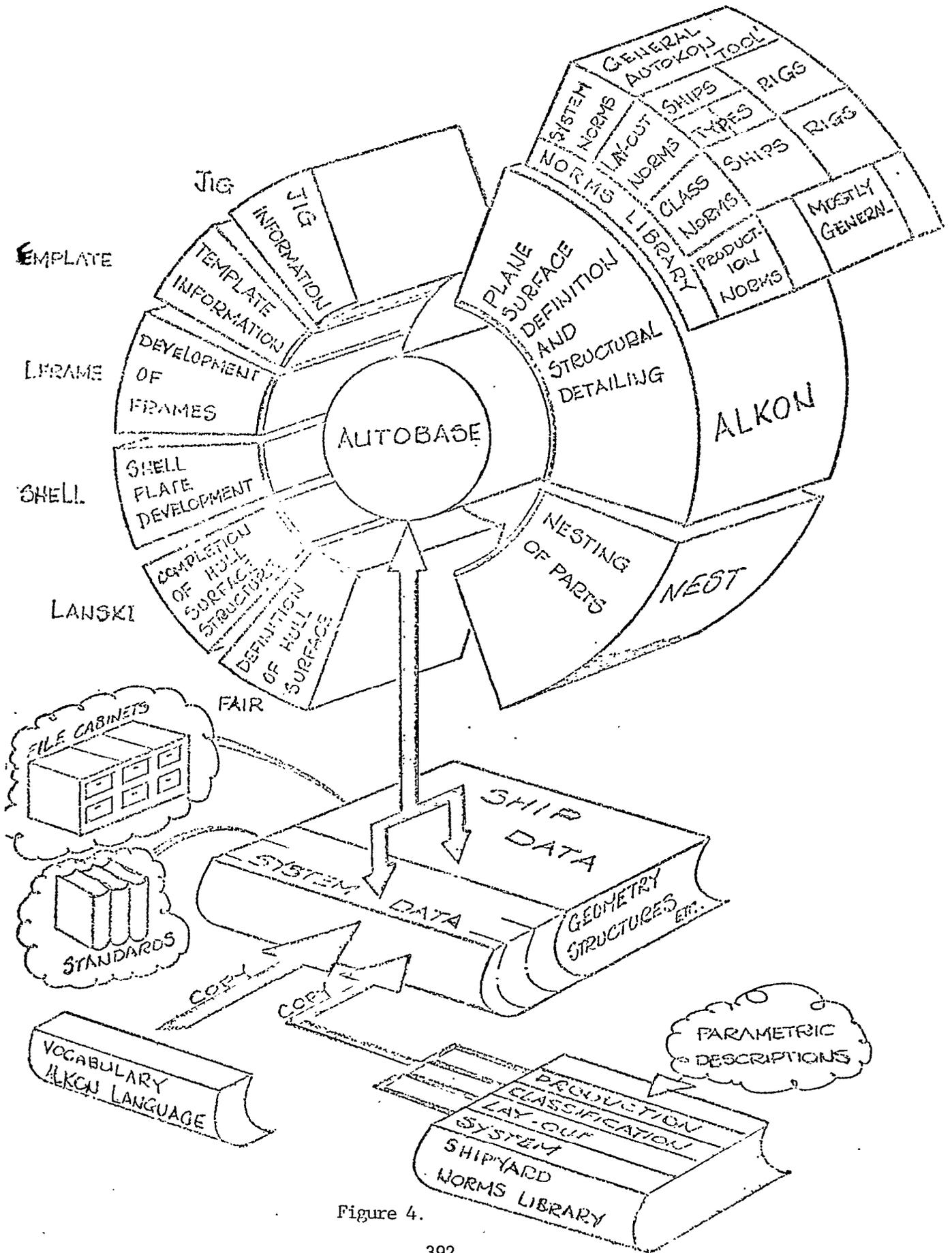


Figure 4.

In order to make it a successful tool, it is, however, necessary to fit it into the general datastream. The database should be built up gradually throughout design using a natural working sequence. Ideally the work of building it up should be done by the designers involved in the actual design work.

### **3.2 Utilization of the Database.**

To gain the full benefit from using a database as the main information device, it should be used to perform as many tasks as possible. In other words, it would be foolish not to use the database throughout the design process to the fullest possible extent if you are going to do the work of building it up anyway.

The database can, if properly maintained, answer some questions which traditional methods could not. This involves operations which in nature consist of adding more data than is possible if done manually (exact weights etc.) This of course also points out the possibility of doing previously cumbersome routine work in only a fraction of the time (material lists, material ordering) .

One can imagine that this sort of information, available at relatively short notice, would be a great advantage in design, particularly in structures where weights are very critical.

### **3.3 Generality of the tool.**

An important point regarding the norms which are to be used for building a database is the question of generality. It seems obvious that even if one could make entirely general norms throughout, the expenses involved would be prohibitive both from a development and from a running-cost point of view. On the other hand, a set of norms which could be used for one type of structure only, would be of very limited use.

The solution is a compromise.

There are in fact norms dealing with the steel structure at different levels, the "higher level norms" being, in general, more specialized.

These tend to depend more on constraints imposed by the actual geometry of the structure. Examples of such norms are those used for making design and production parts based on the basic lines and contours in a structure (these lines and contours, being stored in the database).

The "lower level norms" are on the other hand entirely general, and impose no restrictions on the geometry.

This norm configuration gives certain advantages in that "higher level norms" will use "lower level norms" as subroutines.

In this way new specialized norms catering to special geometrical solutions may be built up quickly if need arises.

Still, the aim is to give the designer a tool that, with hardly any limitations and without any alterations to the tool itself, will build up a database for a structure of any reasonable layout.

One way to attain this goal is by first building up a rough picture of the structure, and then modifying it until you get the wanted result.

This is, in many cases, a cheaper and more flexible solution. than building complex norms, giving a variety of, though still fixed, solutions.

### 3.4 Standardization.

In this context one should not forget, however, that fixed solutions may be an advantage rather than a drawback as regards some details in a structure.

I am thinking of standarization of brackets, stiffening etc., which can make production more efficient (limitation of no. of standard details) .

Such standardization can easily be built into the system. If you want to change the standard, you simply change the norm.

Standard Details:

The consequence of this philosophy is the introduction of a "Book of Standard Details".

This book contains a number of details such as cutouts, stiffener layout and brackets.

Each of these details represents some geometrical solution, but the parameters such as angles and dimensions are usually variables.

The mutual dependence of the parameters are governed either by algorithms or simply by input, according to choice.

This reduces the necessary input considerably when building up a database.

## 4. THE CURRENT PROJECT FOR DRILLING RIGS

### 4.1 Background.

The work of making a norm tool for building up a database has been going on in the Aker Group for some years.

For shipstructures, it is possible to build up a database in the early design stage, and then modify, update and replenish it with new data as this becomes available. Although the database until now has not represented a complete picture of the structure, and the output has been limited to NC tape for drawing and steel cutting purposes, experiences with and results obtained from this work have been valuable.

The effort this year has been to close the gap, making the tool for adding the remaining scantlings description and writing a number of norms for extracting valuable production data .

### 4.2 Objectives.

The aims of the project are as follows:

Adapt the existing norms for shipstructures to more general steel structures and to drilling rigs, in particular.

Make a basic tool for description of simple hull surfaces --norms which may substitute the LANSKI module for input of longitudinals.

Describe a datastructure which reflects the actual subdivision of the structure into a general hierarchical system, and by which all sorts of production data may be extracted for any logical construction unit. Write the necessary norms for building up this datastructure and then keeping it up to date.

Write norms which will give the following types of output:

- Drawings of relevant sections in the structure
- Basis for classification and production drawings (including stiffening)
- Numerical expansion of difficult geometries (various types of cones, truss connections etc.)
- Material lists for material ordering and for production
- Accurate calculations of weights and centers of gravity.
- NC tape for numerical flame cutters.

### 4.3 The Datastructure in -Production Phase.

#### 4.3.1 Demands on the datastructure.

General:

The same data should be represented only once. Data belonging to the same construction unit should be stored logically together.

- Data must be available for many different purposes (manipulation of data).
- Simple to update.
- It must be possible to check data visually.
- A general AUTOKON datastructure must be a framework which may be used by all yards whatever construction and production methods they use.

Special:

The datastructure must reflect the subdivision of the structure into assemblies, subassemblies etc. down to single parts.

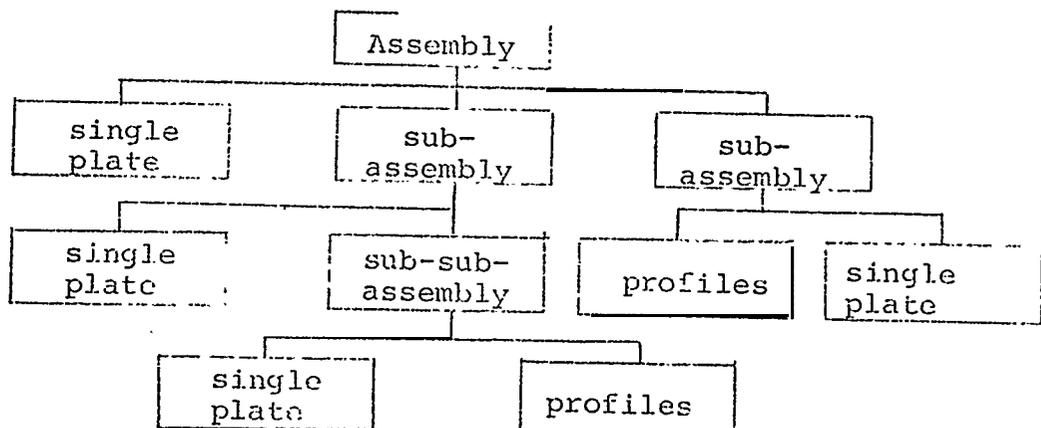
The datastructure must fit into the datastream from preceding design stages.

It must constitute a natural basis for the output function, i.e. production drawings, material lists, weights and centers of gravity.

#### 4.3.2 Description of datastructure.

The chosen datastructure reflects a general production practise today, the hierarchical order of construction units.

Single plates are welded together to form small assemblies. These together with ether single plates will, in turn, form larger assemblies etc. The number of such levels varies according to assembly, ship\rig and yard.



Each level is in principle the same. Whether you are dealing with assemblies, subassemblies or sub-sub-assemblies, these may be subdivided into single parts and/or smaller assemblies.

The datastructure is shown in principle in fig. 5 and 6.

Comments on fig. 5.

On top of the hierarchy is a catalog containing a list of all the assemblies (block-assemblies) represented on the database. The address of this catalog is  $4+0+0+0+0$ . The example deals with assembly 1610 in particular (max. 4 digits for main assemblies). One line in the catalog, therefore points to another address which contains information about this assembly.

Catalogs on level 1:

Address:  $4+1+N000+0+0+0$ <sup>x)</sup>

This catalog contains information on assembly N (1610 in fig.). As can be seen, subassemblies 1&2 are among the contents together with a production part with serial number 73.

The catalogs, therefore) contains a pointer to the data record where this production part is stored in the database, and also a pointer to records which contain information on each of the two sub-assemblies.

Catalogs on level 2:

Address:  $4+2+Nr+0+0+0$

This catalog contains information on sub-assembly n (2) in assembly N(1610).

Except that this catalog deals with the contents of a sub-assembly and not of an assembly, level 1 and 2 are in principle the same.

Catalogs on the lower levels are in principle built up the same way.

The equality of all the levels of subdivision is of course, significant when it comes to the programs using the data-structure, both because of the possibility of using loops, and because of the generality obtained.

x) RECORD CI,ASS 4 has been changed to fit this pattern and is now equal to R.C.5 as regards format .

Adress of catalogue  $14+0+0+0+0$

catalogue

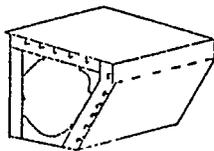
$4+1+260900+0+0+0$   
 $4+1+260900+0+0+0$   
 $4+1+260900+0+0+0$   
 $4+1+260900+0+0+0$

Assemblies in structure

$N = \text{assembly}$

Adress

$4+1+160000+0+0+0$



Pointers

$4+2+160000+0+0+0$   
 $4+2+160000+0+0+0$   
 $4+2+160000+0+0+0$   
 $4+2+160000+0+0+0$

Subassemblies and parts

in one assembly

RID2 => LEVEL

1 => assembly

2 => subassembly

3 => sub-sub

ets.

Adress

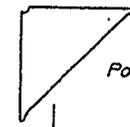
$4+2+$



Parts in subassembly

$P = \text{pos nr}$   
 $n = \text{subsubassembly (if any)}$

$5+0+1610073+0+0+0$

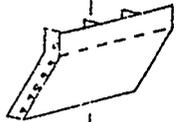


Pos 73.

CONM

MIDEM

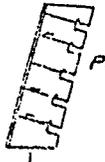
$5+0+1610069+0+0+0$



$5+0+1610069+0+0+0$   
 $5+0+1610070+0+0+0$   
 $5+2+1610035+0+0+0$

LEVEL 2.

$5+0+1610069+0+0+0$



Pos 69.

CONM

MIDEM

$5+0+1610070+0+0+0$



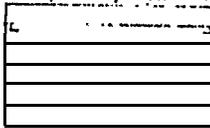
Pos 70.

CONM

MIDEM

$5+2+1610035+0+0+0$

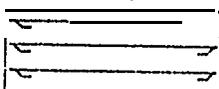
Shellplate - part nr 35.



CONM

Adress

$5+0+1610067+0+0+0$

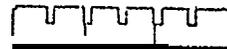


Pos 67.

CONM

MIDEM

$5+0+1610068+0+0+0$



Pos 68.

CONM

MIDEM

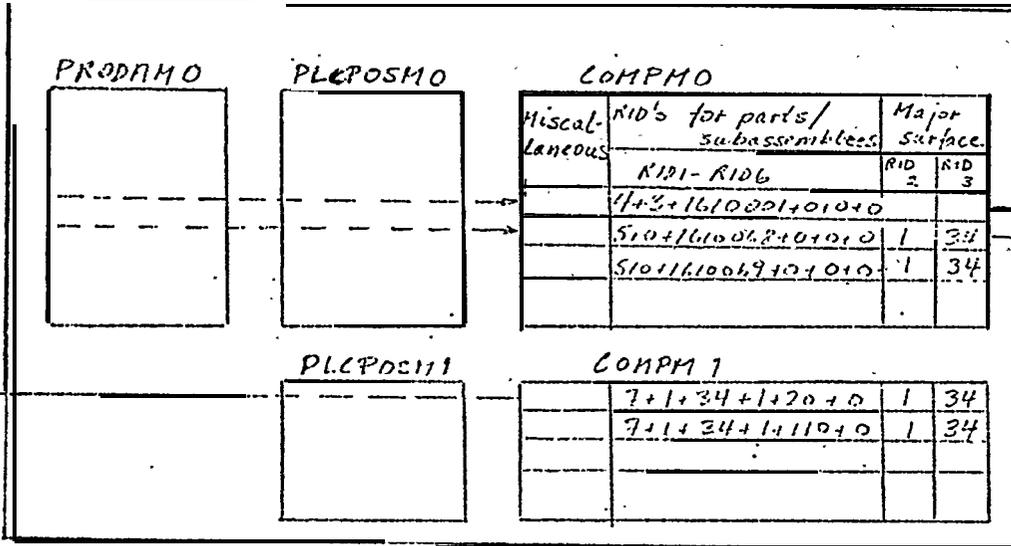
Example of one level in datastructure

LEVEL 2:

Contents of one sub assembly:

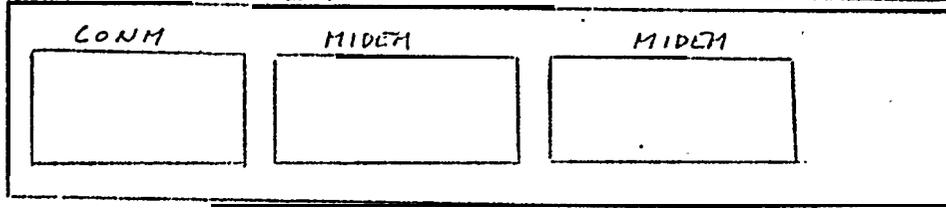
To the next Level

$4+2+1610002+0+0+0$



Production Parts

$5+0+1610068+0+0+0$



Design Parts

$7+1+34+1+20+0$

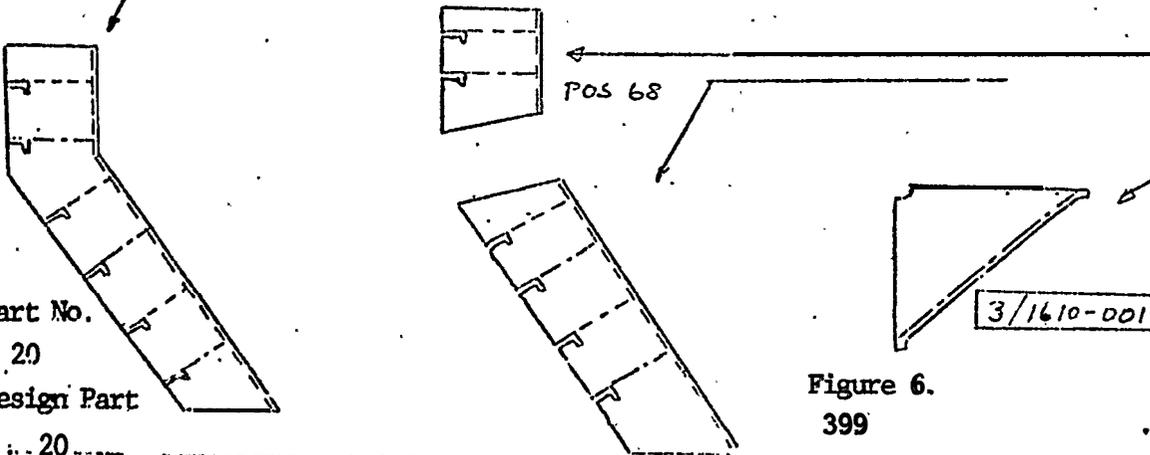
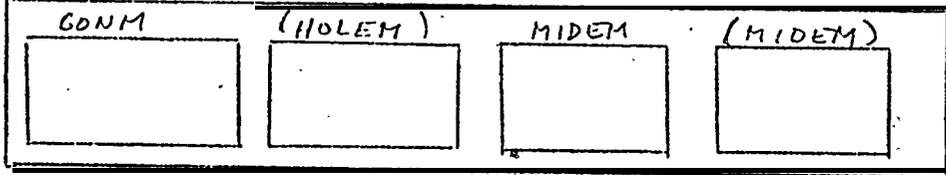


Figure 6.  
399

Comments on fig. 6.

The example shows the complete catalog for one sub-assembly (level 2).

A Composition Matrix (COMPM) contains the pointers to each unit in the sub-assembly. In case it is a part, it also contains information on the major surface in which the part is situated. (1-34 being a code for transverse frame no. 34). Note that a part is not necessarily stored as belonging to the particular assembly you are dealing with. It may, for example, be stored either as some standard part with a unique serial number, or it may be stored as belonging to some different assembly.

- A PLane Curve Position Matrix (PLCPOSM) tells you the exact position of the coordinate system in which the part has been coded.
- A Production Data Matrix (PRODM) contains various production data like weight, center of gravity etc. and also a reference to the raw format from which the plate is to be cut.

Fig. 6 indicates that there may be more than one set of matrices in each record.

This is due to the fact that it may be convenient to use a set of design parts, as well as actual production parts in the production phase.

These are large panel-like units which are later divided into the final parts.

The point is, however, that these parts may be contained within the same datastructure, but independently of the production parts.

#### 4.3.3 Possibilities.

For any of the units described in the datastructure, from the single part up to the complete structure, it is possible to do the following operations:

- Calculate weight
- Calculate center of gravity
- Calculate total length of stiffener of some dimension and quality
- Make tables of stiffener-length for given dimensions and quality
- Make the basis for working sketches for stiffening details.

Production drawings may be made by specifying design or production parts, or the entire main surface within an assembly.

Automatic treatment of stiffeners is possible: cutting, tapering ends and making scallops.

## 5. THE STATE OF ART

I will try to give a picture of the stage of development by referring to how the database is actually built up for a real case.

All through I will refer to fig.7.

### 5.1 Time of initiation.

Generally speaking, the database should be used all through the design process.

Perhaps I have to contradict myself, however, by saying that given the present tool and a basically new structural concept, a suitable time would be after the final decision on the main structure and scantlings.

The reason for this choice of time is that while major changes in the structural concept would involve rebuilding the entire database, the relatively small changes which occur later (even if numerous) can be dealt with relatively easier.

For ships, of course, one may usually start much earlier because ships are rarely entirely new concepts in design, but rather variations of old ones. In such cases, the layout norms will very quickly give you a new solution of sufficient accuracy.

### 5.2 Steps in the process.

These steps will describe the process for rigs which are similar to the Aker rigs in concept, that is, two or more pontoons, supporting some column arrangement which in turn supports a deck structure.

#### 5.2.1 Generation of lines plan (Box 1 of fig. 5).

The first step is to build a lines plan for pontoons and for other parts of the structure where this is required. If these have a complex shape, the AUTOKON modules for curved surface definitions may be used. If the geometry is relatively simple, it is not a big job using ALKON. The following indicates the necessary amount of input by the latter approach.

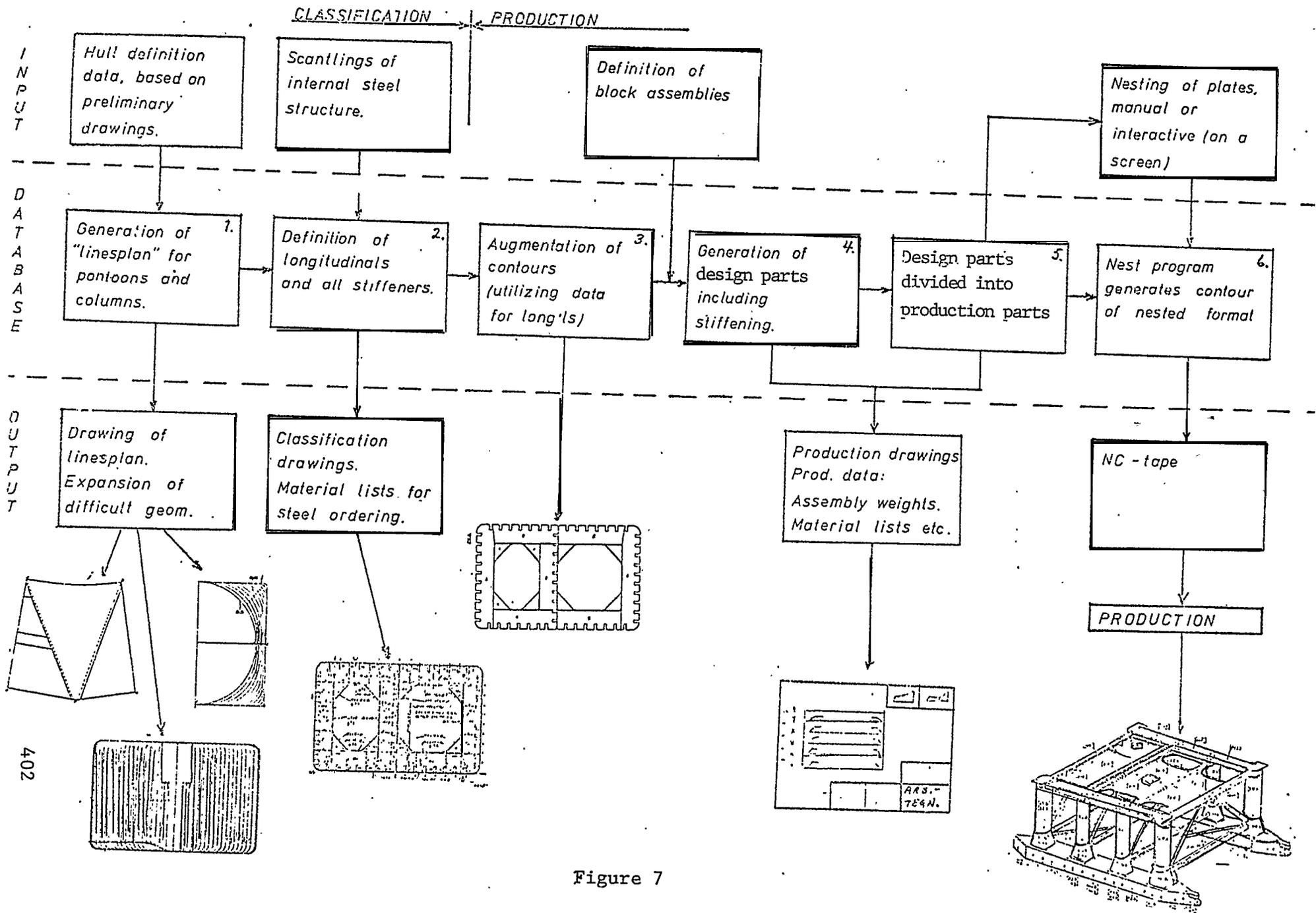


Figure 7

1. Generate and store projections of rolling lines in contour matrices (CONM) .
2. Generate and store curve catalog (COMPM). This catalog contains information on the exact position of each frame and at which address it is being stored in the database.  
  
Input therefore mainly consists of definition of origin for global coordinate system and framespacing.
3. Based on 1 and 2 the frames can be generated and stored by a norm. Offset tables are stored at the same time.
4. Generate and store sections of the conical parts of the columns. Input is the geometrical characteristics of each cone such as height radii at top and bottom, and breadth and length of base.
5. If the deck is to be included, the main contours of this are also generated and stored at. this point.

Output at this stage is a drawing of the lines plan, and the expansion of difficult geometries.

## 5.2.2 Longitudinals and stiffening details (Box 2) .

This box comprises the main input activities in the classification phase. The resultant database will contain most of the information necessary for classification purposes as regards scantlings.

1. Build <sup>UP</sup> MIDEM(s) for the shell. One table contains information regarding dimensions of all web frames.  
  
If ALKON is used throughtout, it may also be useful to add a MIDEM for the longitudinals. On this basis, a shell expansion drawing may be drawn.
2. Build DETail TABLE Matrix (DETTABM) for longitudinals at shell. This table contains all necessary information regarding dimensions and orientation of the longitudinals, and also the necessary information for later generation of the associated cutouts--- generated either directly by norms or from LANSKI data.
3. Build MIDEMs for bulkheads. The information for MIDEM at longitudinal bulkhead (s) is later used to make DETTABMs for the bulkhead(s) at each transverse webframe. Information on cutouts is added when using this norm package.

4. The inner contour for each webframe is generated and stored. A number of different norms is available for this purpose.
5. The local stiffening at the webs is added to the database. The norms for doing this make use of available data on longitudinals to give an initial solution. A set of updating norms is provided to modify this first result.

The output at this stage is a shell expansion drawing and basis for classification drawings including stiffening details. It is also possible to get preliminary material lists containing stiffening lengths, areas of "local stiffening-brackets" etc.

### 5.2.3 Cutouts (BOX 3).

This is the first activity in the production phase (Classification does not require cutouts) .

There is very little input involved as the necessary information has already been stored in the tables 01 longitudinal frames.

The special geometry of the CUTOUTS is represented in the book of standard details and the actual contour is made by norms.

(GEN ACON using CUTO internally.)

The augmented contours are drawn out for checking purposes.

### 5.2.4 Design Parts (Box 4).

The basis for these parts is the subdivision of the structure into block assemblies.

They represent large panels including stiffening (and seams) , and their main function is to be the basis for the actual production parts.

Norms and repetitions may be used extensively when making these parts, the input being some key parameters and previously stored contours (frame contours, various inner contours etc.) .

As previously mentioned, these parts are stored according to the datastructure in production phase.

output:

At this stage it is possible to extract some basis for production drawings, and also extensive material lists as regards the contents of MIDEMs. These are lists containing information for material ordering, and lists particularly suited for production (see 5.2.5).

Weight estimates for larger units like assemblies are possible if average thicknesses are acceptable.

#### 5.2.5 Production Parts (BOX 5).

These parts are obtained in two ways, depending on the type of part. The main parts, situated in what is called "major surfaces" are obtained by dividing the design parts. This is done by special norms and in the same run one may also subdivide. the MIDEIM for that particular design part.

The result is, in other words, the final contour for the production part and also a MIDEIM containing the stiffening . which belongs to it.

Smaller parts, defined by "Standard Details}" in a MIDEIM (i.e. situated in a "minor surface") are obtained directly.

Since all the parameters necessary to generate the bracket have been previously stored in the MIDEIM and as parts of contours, or are implicitly given by the Standard Detail, the necessary input at this stage is very moderate. To get the bracket situated on a transverse webframe towards a longitudinal, for example, the input is the number of the transverse frame and the number of the longitudinal.

output :

- Basis for production drawings.
- Norms draw single or a number of parts.
- Special combinations of parts are possible through the datastructure (like all parts in an assembly belonging to the same major surface).
- 0 Accurate weight and center of gravity calculations are possible for units ranging from single parts to assemblies.
- 0 Material lists for material specification. This activity may, if necessary, be executed after design parts have been generated, but is likely to be more accurate if somewhat delayed.  
  
The lists contain information on dimensions, steel quality, weight and some production parameters for the single pieces and total weight, lengths etc. for the unit considered.
- 0 Material information for production. Lists containing parameters for production like key coordinates, angle of mounting, weight etc. for single pieces. in an assembly  
Direct output of "burning and marking sketches" should also be possible.

### 5.2.6 NEST (BOX 6).

The actual nesting of the plates is at present a manual operation. The production parts are to be taken from the database, drawn in a suitable scale, and then nested on the plate format,

Key points for, contour start point, burning bridges and information on the local coordinate system of the part concerned, and burning sequence are input to the NEST 4 program together with necessary identification.

The nested format as generated by NEST may, if desired, be stored in the database.

## 6. FUTURE IMPROVEMENTS

The development of AUTOKON is going on continuously, the work being concentrated both in the field of program refinements and in fields which depend on innovations in hardware and equipment.

An example of fields which depend on the introduction of new equipment is Mini-Computer Graphics (dealt with by another paper) .

I will here mention briefly some general objectives as regards the development of 'AikON in the near future.

- 'Make an entirely integrated tool for building, updating and maintaining a database throughout the design process. The attention must be focused on obtaining a better dataflow between design and production stages.

Modify and make new part norms, norms which will yield a more flexible solution than is generally the case today. Some of these will rely on exact parameters as input. Other norms will use general design criteria like the interaction between local stiffening and brackets. The resulting parts will in turn be subject to splitting into the final design parts. This point must be seen in connection with the above.

As should be clear from this paper, the extraction of various production data will receive a lot of attention in the future.

Appendix A  
Agenda

## TUESDAY, JUNE 24

~~8:00~~ **REGISTRATION** FRENCH ROOM FOYER

8:45 **GENERAL SESSION** FRENCH ROOM

WELCOME  
M. Pitkin, U.S. Department of Commerce  
Maritime Administration

ACCOMPLISHMENTS AND EXPECTATIONS FOR THE  
REAPS PROGRAM  
J. C. Williams, IIT Research Institute

THE UPDATED REAPS AUTOKON SYSTEM  
P. D. Taska, IIT Research Institute

10:30 INFORMAL DISCUSSION PERIOD

11:00 **GENERAL SESSION** FRENCH ROOM

LONG RANGE PLANNING: WHAT DO YARDS WANT;  
WHAT IS BEING DONE?  
H. H. Shu, IIT Research Institute

APPLICATIONS OF MINI COMPUTERS IN THE  
SHIPBUILDING INDUSTRY  
T. Nystroem, Shipping Research  
Services A/S

12:00 LUNCH

1:30 **GENERAL SESSION** FRENCH ROOM

SOFTWARE ENGINEERING FOR DIGITIZER/  
MINI COMPUTER-BASED PIPING DATA SYSTEM  
P. W. Rourke, Newport News Shipbuilding  
and Dry Dock Company

SHIP DESIGN INTERACTIVE GRAPHICS WITH  
FASTDRAW  
G. W. Folk and O. A. Pritchett,  
McDonnell-Oouglas Automation  
Company

2:45 INFORMAL DISCUSSION PERIOD

3:15 A REPORT ON THE 1975 AUTOKON USERS CLUB

H. Saetersdal, Shipping Research  
Services, Inc.

CONSIDERATIONS FOR USING AUTOKON FROM A  
REMOTE SITE  
B. J. Breen and J. M. Wallent, General  
Dynamics Electric Boat Division

A STATE OF THE ART REVIEW OF N/C  
J. C. Williams, IIT Research Institute

~~5:00~~ **RECEPTION** FLORIDA ROOM  
~~6:00~~

8:30 MOVIES ON SPECIAL SYSTEMS FRENCH ROOM

ENGINEERING DESIGN WITH COMPUTER GRAPHICS  
O. A. Pritchett, McDonnell-Oouglas  
Automation Company

SYMBOLIC CONTROL  
G. P. Putnam, IIT Research Institute

## WEDNESDAY, JUNE 25

~~8:00~~ **REGISTRATION** FRENCH ROOM FOYER  
~~5:00~~

8:45 **GENERAL SESSION** FRENCH ROOM

PRELIKON AT MARAD  
F. T. Johnson and E. N. Castrinakis,  
U.S. Department of Commerce,  
Maritime Administration

USE OF **CAPICS FOR CABLE LAYING AND SIZING**  
IN TANKERS  
F. M. Priborsky, Electrical Research  
Association, Ltd.

A UNIFIED HULL DEFINITION SYSTEM  
M. Aughey, Naval Ship Engineering Center

10:15 **INFORMAL DISCUSSION PERIOD**

10:45 **GENERAL SESSION** FRENCH ROOM

ROBOTS IN SHIPBUILDING  
O. W. Hanify, IIT Research Institute

THE CASE WESTERN RESERVE N/C FRAME  
BENDING MACHINE  
D. Braun, Case Western Reserve  
University

12:00 LUNCH

1:30 **PANEL DISCUSSION** FRENCH ROOM

G. P. Putnam, IIT Research Institute,  
Moderator

WHERE IS COMPUTERIZATION OF SHIP-  
BUILDING TODAY, WHERE IS IT GOING?

Panelists:

- T. Corin, Naval Ship Research and  
Development Center
- B. Fritz, Sun Shipbuilding and Dry  
Dock Company
- G. Kinkald, Maryl and Shipbuilding  
and Dry Dock Company
- L. W. Lowery, Call and Associates
- P. Soerensen, Shipping Research  
Services A/S

3:30 **INFORMAL DISCUSSION PERIOD**

4:00 **GENERAL SESSION** FRENCH ROOM

COGAP: AN INTERACTIVE GRAPHICS MINI-  
COMPUTER BASED SHIPS ARRANGEMENT PROGRAM  
J. R. VanderSchaff, CADCOM, Inc.

AUTOFIT - A CONCEPT FOR OUTFITTING SHIPS  
O. Eng, Shipping Research Services A/S

5:00 **ADJOURNMENT**

Appendix B  
Attendance List

REAPS TECHNICAL SYMPOSIUM

Colonnades Beach Hotel  
Palm Beach Shores, Florida

June 24-25, 1975

AMERICAN SHIPBUILDING COMPANY  
400 Colorado Avenue  
Lorain, Ohio 44052

Ray Francis  
Technical Manager

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New Orleans, Louisiana 70150

Thomas H. Doussan  
VP & Chief Engineer

Vincent H. Nuzzo  
Asst. Supt. N.C. Mold Loft

Robert Pourceau  
N.C. Parts Foreman

BATH IRON WORKS  
700 Washington Street  
Bath, Maine

Peter E. Jaquith  
Planning Supervisor

BETHLEHEM STEEL CORPORATION  
Central Technical Division  
Sparrows Point, Maryland

Bruce G. Bohl  
Engineering Program Analyst

CADCOM, INC.  
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Annapolis, Maryland 21401

J. R. VanderSchaff  
Member of Technical Staff

CALI & ASSOCIATES  
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L. W. Lowery  
Consultant

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Graduate Student

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N/C Supervisor

Charles Purcell  
Manager, CASD & SPMIS

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Data Processing Director

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Management Systems Specialist

GENERAL DYNAMICS - ELECTRIC BOAT DIVISION  
Quonset Facilities  
Quonset, Rhode Island

John M. Wallent  
Chief, Automated Processes

GENERAL DYNAMICS - QUINCY SHIPBUILDING DIVISION  
97 East Howard  
Quincy, Massachusetts 02169

Charles E. Bergeron  
Mold Loft Foreman

Raymond W. Kucharski  
Hull Designer Computer Applications

HYDRONAUTICS, INC.  
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Laurel, Maryland 20810

Pramud Rawat  
Senior Research Scientist

IIT RESEARCH INSTITUTE  
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Douglas Martin  
George P. Putnam  
Hunter Shu

Patricia D. Taska  
John C. Williams  
Richard B. Wise

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U.S. Department of Commerce Building  
Washington, D.C. 20235

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Program Manager

Fred T. Johnson  
Engineering Computer Branch

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Baltimore, Maryland 21205

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Manager of Structural Engineering

MCDONNELL DOUGLAS AUTOMATION COMPANY  
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St. Louis, Missouri 63166

Odell A. Pritchett  
Principal Consultant

G. W. Folk  
Senior Section Manager Programming

NATIONAL STEEL & SHIPBUILDING COMPANY  
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San Diego, California 92011

J. W. Wasserboehr  
Senior Programmer

NAVAL SHIP ENGINEERING CENTER  
3700 East West Highway  
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Michael E. Aughey  
Naval Architect

John O'Brien  
Head, Surface Ship Structures Branch

NAVAL SHIP RESEARCH & DEVELOPMENT CENTER  
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Bethesda, Maryland 20084

Thomas Corin  
Head, Computer Aided Design Division

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Richard C, Moore  
Management Systems Specialist

**K. w. pleasant**  
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D. W. Stewart  
Department Head Mold Loft

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Thomas N. Williams  
Industrial Engineer

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H. Saetersdal

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Syed Mohammed  
Naval Architect

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