

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

September 1989
NSRP 0310

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

1989 Ship Production Symposium

Paper No. 16: Results From Use of an Integrated Schedule for Drawing Development and Equipment Procurement

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

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

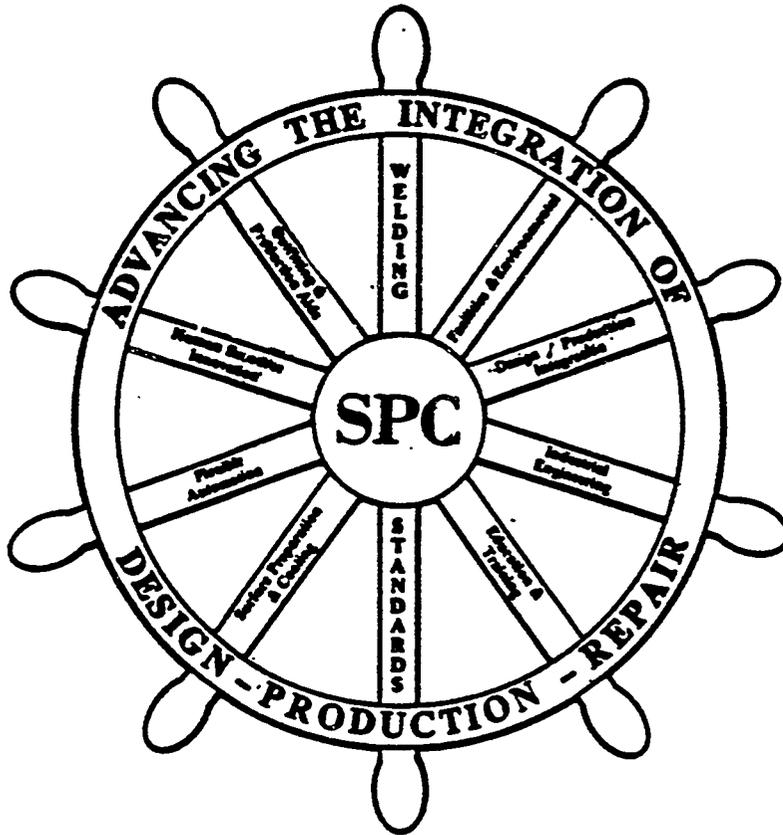
1. REPORT DATE SEP 1989	2. REPORT TYPE N/A	3. DATES COVERED -			
4. TITLE AND SUBTITLE The National Shipbuilding Research Program 1989 Ship Production Symposium Paper No. 16: Results From Use of an Integrated Schedule for Drawing Development and Equipment Procurement		5a. CONTRACT NUMBER			
		5b. GRANT NUMBER			
		5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S)		5d. PROJECT NUMBER			
		5e. TASK NUMBER			
		5f. WORK UNIT NUMBER			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Bldg 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700		8. PERFORMING ORGANIZATION REPORT NUMBER			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)			
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)			
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 22	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

DISCLAIMER

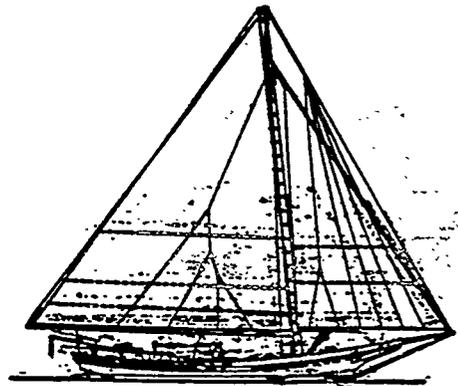
These reports were prepared as an account of government-sponsored work. Neither the United States, nor the United States Navy, nor any person acting on behalf of the United States Navy (A) makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness or usefulness of the information contained in this report/manual, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or (B) assumes any liabilities with respect to the use of or for damages resulting from the use of any information, apparatus, method, or process disclosed in the report. As used in the above, "Persons acting on behalf of the United States Navy" includes any employee, contractor, or subcontractor to the contractor of the United States Navy to the extent that such employee, contractor, or subcontractor to the contractor prepares, handles, or distributes, or provides access to any information pursuant to his employment or contract or subcontract to the contractor with the United States Navy. ANY POSSIBLE IMPLIED WARRANTIES OF MERCHANTABILITY AND/OR FITNESS FOR PURPOSE ARE SPECIFICALLY DISCLAIMED.

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM 1989 SHIP PRODUCTION SYMPOSIUM

NSRP
0310



SEPTEMBER 13-15, 1989
SHERATON NATIONAL
Arlington, Virginia



DIRECTED BY
HOSTED BY

IN COOPERATION WITH
THE CHESAPEAKE SECTION OF
THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

SPONSORED BY THE SHIP PRODUCTION COMMITTEE
AND HOSTED BY THE CHESAPEAKE SECTION OF
THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS



Results From Use of an Integrated Schedule for Drawing Development and Equipment Procurement

James R. Wilkins Jr., Member, Wilkins Enterprise Inc., Riva, MD

ABSTRACT

As part of an SP-4 project, a computer program was developed to produce integrated schedules for drawing development of drawings and equipment procurement. The program also can be used either to develop a schedule for the fabrication and assembly stages of the construction process or to receive data from an existing construction schedule. In either case, the construction data is used to ensure that drawings are produced and equipment is purchased in time to support production planning. The program uses a commonly available database program, is suitable for use on a minicomputer and will allow a network of terminals to be used to enter data and obtain reports.

This paper reports on the results of applying this scheduling program to a simulated shipbuilding program and highlights a number of significant results. The principal result was to clearly demonstrate that planning for the purchase of equipment must take into account the needs of the ship design process for data about the equipment being procured.

NOMENCLATURE

Because the program described herein was developed for application to modern, modular (zone-oriented) ship construction programs, and because the terminology used for such programs varies so greatly among shipyards, it is necessary to define each of the following terms. Readers should be able to make the mental transformation to the terminology used in their own shipyard or in other literature, given these definitions.

Unit The basic modular structural element used to construct a ship. With some exceptions, a unit is the first modular level at which outfitting is accomplished.

Outfitting - The installation of system elements into a unit or combination of units.

Block - A combination of several units, assembled together and outfitted prior to erection at the final building site.

Sub-Assembly - Combinations of parts which may be joined with other sub-assemblies or parts to construct units.

Machinery Package - A collection of equipment, foundations, piping, electrical fixtures, wiring, gauges, etc., which is constructed as an entity, pretested whenever possible, and loaded into a unit, a block or on-board the ship during erection. Effective design and use of these construction elements has greatly increased productivity as well as equipment operability and maintainability.

BACKGROUND

One of the major efforts in accomplishing a shipbuilding program is to buy the equipment used to build the ship. This procurement effort is controlled through a document usually identified as the Material Ordering Schedule (MOS). The principal elements of the MOS are a listing of every type of equipment which must be procured and the date by which each must be received in the shipyard in order to meet the construction schedule.

The length of time between the day on which an item is ordered and the day on which the vendor can have it delivered to the shipyard is known as the equipment's "lead time". When this duration has been determined, it is possible to compute the date by which the equipment must be ordered, or the Purchase Order Award Date (POA).

The POA date determined in the manner described above completely ignores the design process. But the equipment procurement process and the design process are inseparably linked. During the early stages of the design of each of the ship's systems, the designer must define the performance requirements of every piece of equipment in the system for which he or she is responsible. Thus information must be known before it can be provided to prospective vendors for preparation of their offers to the shipyard.

The design process, on the other hand, cannot be completed until after the equipment vendor provides

(a) Performance Data, describing the actual performance of the equipment being provided, and

(b) Configuration Data, providing the exact dimensions of the equipment.

Although the shipyards Request for Proposal (RFP) to the vendor will have defined minimum performance characteristics to be met by the equipment, the actual performance provided by the available equipment can be quite different. In such cases it is necessary for the system designer to review the design and, if necessary, make changes. Similarly, the configuration of the finally selected equipment may vary from that which was assumed during the earlier design stages.

Consequently, the design of systems cannot be considered complete until all of the detailed performance and configuration data have been received from the equipment vendor and the effect of any significant variations incorporated in the final drawings used to construct the ship.

Thus it will be seen that the POA cannot (should not, at least) take place before the equipment requirements are defined and the vendor has given adequate assurance that the performance and configuration requirements can and will be met. However, in the description, provided above, of how the required POA date is normally established, there was no consideration of the information needs of the design process.

The purpose of the task authorized by Panel SP-4 was to identify the information flow requirements that link the ship system design and equipment procurement processes, and to determine the interfaces between the two which control the scheduling of each. It was understood before starting the project that it should be possible to determine the lead time for equipment data and

the date by which that data would be required by the design process. With these data it would be possible to identify the POA date necessary to meet the design process's information needs.

Experience had made it clear that the POA date for equipment design information (software) is almost always earlier than the POA date determined from considerations of the hardware delivery. The goal of this study was to more specifically quantify the information flow interfaces, i.e. what data is required for the equipment ordering process from the design process, what information from the equipment procurement process is needed by the design process, and what are the points in each of these processes that the data must be known. It was recognized that, with this information, it would then be possible to develop integrated schedules for drawing development and for equipment procurement.

STUDY APPROACH

General

For the purposes of this study, the overall shipbuilding process was considered to be composed of three different, major processes - the design/drawing process, the equipment procurement process and the construction process. To conduct the study, it was useful to construct a process model of each, with all of their activities identified. Figure 1 illustrates the primary elements of the three process models that were used.

Design Process Model

The study identified three of the major elements of the overall design/drawing process to be involved in information interfaces with the other processes.

The first of these is the System Diagram Design Stage, during which system diagrams are developed. The second is the Composite Drawing Stage, during which all of the individual systems drawings are integrated into composites for various spaces in the ship. The third is the Construction Drawing Stage, when the Assembly/Installation and Part Fabrication Drawings are produced.

System Diagram Design Stage.

This stage was further broken down into four activities, which were identified as Phase One, Phase Two, Phase Three and the Calculation Phase. As illustrated in Figure 2, Phase One precedes the Calculation Phase, Phase Two follows the Calculation Phase, and Phase Three follows Phase Two.

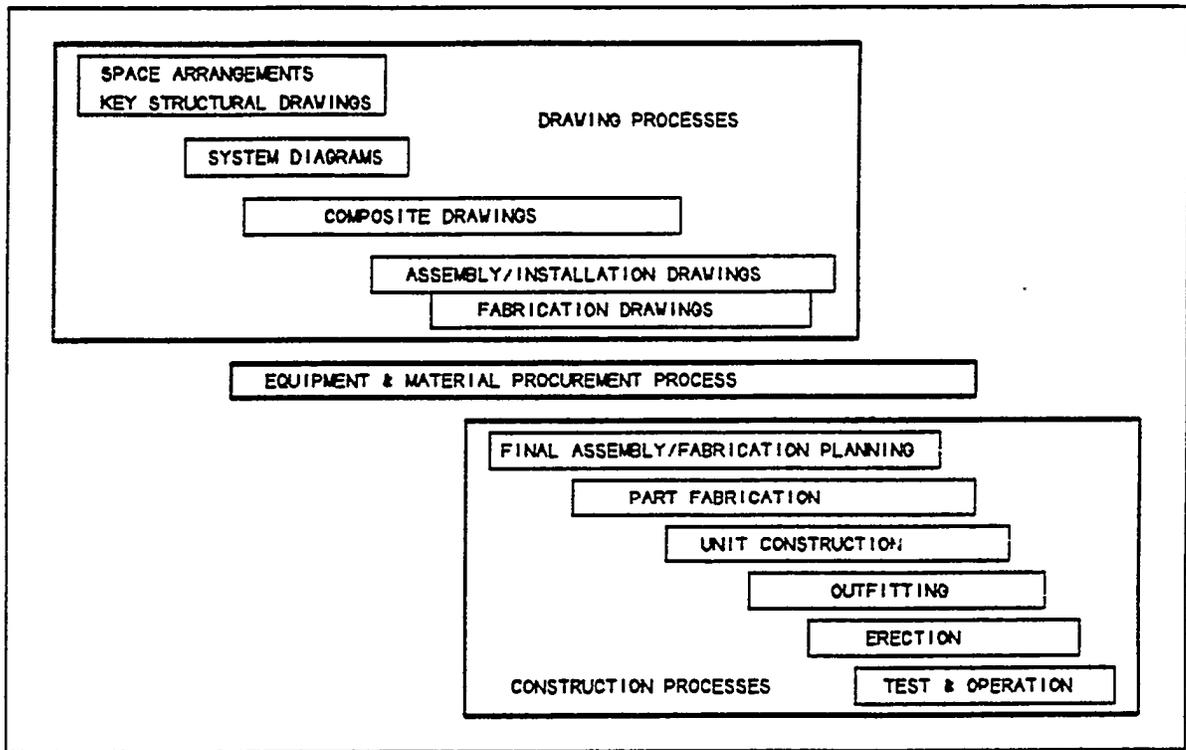


Figure 1. Shipbuilding Processes of Interest

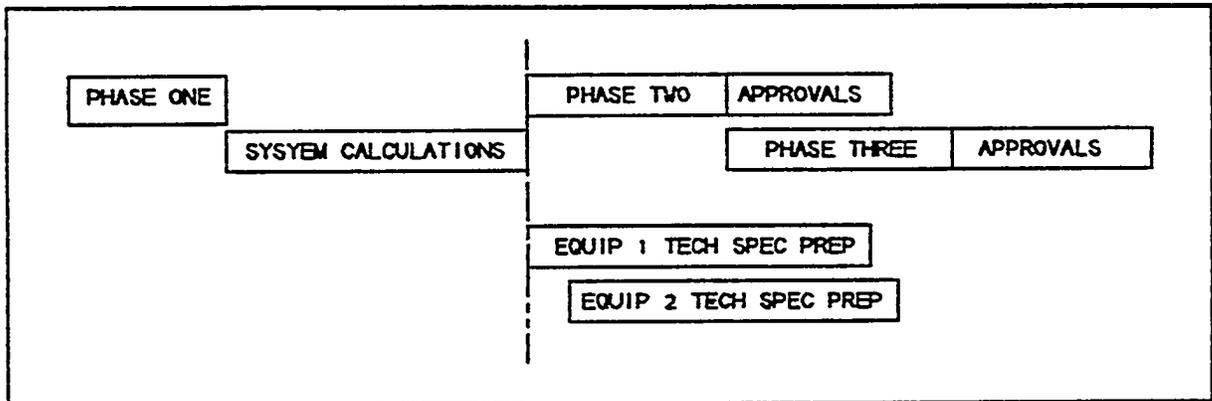


Figure 2. Diagram Process Activities

Phase One involves review of all ship specification documents which relate to the system being designed, plus the initial work which is prerequisite to being able to do the system design calculations. The System Calculation Phase covers all of the efforts which are required in order to determine the size of system components and the required performance characteristics of every equipment required by the system.

During Phase Two of the Diagram Stage, all of the major elements of the

system are placed on the drawing. These are normally shown in diagrammatic format, without dimensional details. It is becoming common for the backgrounds of system diagrams to provide at least an indication of compartmentation boundaries. At the end of Phase Two, the drawing is sufficiently complete for review by the owners and regulatory bodies, who need to assure themselves that their individual requirements have been satisfied by the shipyard's system design.

A Phase Three effort has been defined, because Diagrams are required to include tables which define the details of every piece of material and equipment which is used in the system, including manufacturer's names, model numbers, etc. These data are not required for design development, so can be added to the diagram after the rest of the diagram design process is complete.

Composite Drawing Stage. The Composite Drawing, often called an Interference Control Drawing, is a drawing showing the detailed layout of all systems in a ship or in a part of a ship. Composites in the past usually have been limited to coverage of specific areas in the ship, where there are many systems installed in limited volume, such as a machinery space, . For ship-building programs which apply modern, unit-oriented construction techniques, composites normally cover the entire ship. The use of computers for developing composites is now quite common in larger shipyards.

Because the composite includes all systems, it cannot be considered complete until the design of all individual ship systems are finished. For unit-oriented programs, it is essential that the composite drawing be carefully oriented to the unit breakdown of the ship construction process. In developing schedules, the schedule for completing of the composite for each unit must be considered.

Although the Assembly/Installation (A/I) drawings for a unit may be started before the unit's composite drawing is completely finished, the composite should be virtually complete to minimize the likelihood of having to waste manhours making changes to the A/I drawings to reflect last minute changes to the composite.

Construction Drawing Stage. As previously indicated, two types of drawing are produced during this stage. The Fabrication Drawings give production personnel all the information necessary for them to construct the parts which make up a system. These include the details for every piece of plate which is cut, every structural member which must later be welded to others, for every section of piping and fittings which must be fabricated, all ducting, wireways, etc., etc., etc. In the preferred modern construction practice, all parts related to a particular construction trade will be included in a drawing which relates to a single unit or block. Thus, for instance, all piping systems for one unit will be shown in one unit piping fabrication drawing package.

Similarly, a separate A/I drawing will be provided for each system-type in a unit or block. This drawing will show the dimensional details necessary to allow the production personnel to properly install all parts of the systems for which their trade is responsible in that part of the ship.

Actually, although the Fabrication Drawing is the first document to be used by the production personnel, it cannot be started until the Installation Drawing has been at least partially developed. The layout of a system on the Installation Drawing will determine where bends in a piping, ventilation or wireway system must be made, where support must be provided; etc.

On the other hand, the Installation Drawing cannot be considered complete until the Fabrication Drawing is complete, because fabrication considerations may make it necessary to make changes to the way the system is to be installed.

Equipment Procurement Process Model

General - The first steps in the equipment procurement process take place during the time that the shipyard is preparing its bid to build the ships in the prospective program. The contract design package provided by the owner will identify all major equipment requirements to the extent that they have been identified through the contract design stage. Each shipyard will contact equipment vendors for information concerning their equipment. The pricing and delivery information received as a result of these contacts will be used by the shipyard in its planning and cost estimating efforts for its proposal to the owner.

If an adequate Job of identifying its total ultimate requirements for data as well as hardware is done by the shipyard at this time, and if the shipyard receives good descriptions of the performance and configuration of the equipment as a result of this pre-award effort, the shipyards post-award design efforts will be simplified greatly.

Nevertheless, after award, the shipyard must recheck every element of the ship design, making its own determination of the performance requirements for each equipment.

Post-Award Activities - Final efforts for equipment procurement normally are delayed until the equipment's performance requirements have been finally established during the system calculation phase of the Drawing Process.

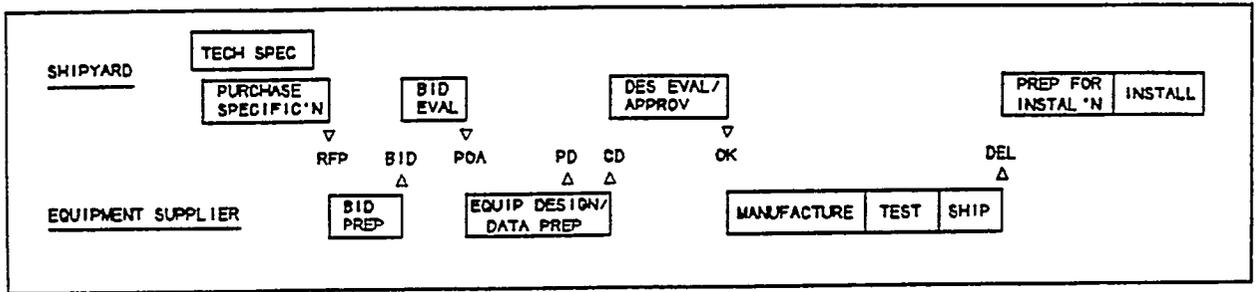


Figure 3. Equipment Process Activities

The first steps in the equipment procurement process include the preparation of the Equipment Technical Specifications, which define the performance requirements which must be met by the equipment being purchased. The preparation of the remaining portions of the RFP may go on in parallel with preparation of the Technical Specifications, since the two efforts are normally accomplished by two different organizations in the shipyard.

After the successful offeror has been selected, he must provide the shipyard with a number of different types of data in addition to delivering the hardware. For the purposes of establishing the interfaces between the drawing development and equipment procurement processes, it was found unnecessary to include Integrated Logistics Systems (ILS) data, although tracking the delivery of the several different ILS deliverables is, of course, vital to the ability to deliver a completed ship on time.

Figure 3 illustrates the post-award activities which were determined to be controlling in the development of schedules for the equipment procurement process and its interfaces with the other processes involved.

Interfaces

- Requirements. The first interface between the equipment procurement process and that of drawing development is the definition, by the shipyard designers, of the performance, configuration, data and any other requirements that the equipment vendor must satisfy. This information should be included in the RFP sent to all prospective vendors.

RFP Response. If the RFP as properly prepared, that is, if it asks for a complete description of the vendor's predictions of the equipment's performance characteristics and configuration, this information can be effectively used by the system designers. It not only will allow selection of the most desirable piece of equipment, but it also will allow the designer to

proceed confidently with the system design.

This information is easily provided when the equipment in question is already in production. However, if the requirement is for a piece of developmental hardware, the data provided by prospective vendors necessarily will be more suspect and will require validation after ward.

Performance Data. The first data that is needed from the selected equipment vendor is his prediction of the equipment's performance characteristics. Phase Two of the System Design Stage cannot be considered complete until this information has been obtained for every piece of equipment in the system.

In the best case this performance data submittal can be a restatement of what was submitted with the vendor's proposal, and should be available within days after POA.

In the case of developmental equipment, the vendor should be able within a few weeks to provide the shipyard with the actual performance criteria that are being used in their design efforts, which may for some reason differ from the RFP requirements. Although the actual performance results for developmental equipment will not be definitely established until the production equipment has been built and tested, the design and construction of the ship must proceed on the assumption that the predicted performance (which must meet or exceed the required performance) will be obtained.

configuration Data. Information about the exact geometric details of an equipment is needed for the Composite Drawing Phase. As in the case of performance data, this data should be available from the vendor immediately except in the case of developmental hardware. Actual configuration data for developmental equipment will be available as soon as the final drawings for the equipment's fabrication are complete.

Approval for Manufacture. In the case of developmental equipment, it is not uncommon for the shipyard to insist that the vendor not start the actual production effort on the equipment without the shipyard's prior approval. The shipyard may be required to obtain the owner's approval before any manufacturing costs are accrued on the equipment. (411 such review and approval efforts must be considered in the planning and scheduling processes to preclude unexpected shipbuilding delays.

Difficulties in obtaining approval for manufacture may result in equipment design changes. If there are resulting performance changes, the system diagram may have to be revised. If there are configuration changes, the composite drawings for all units in which that equipment is installed may have to be changed. If equipment production is delayed, the entire shipbuilding sequence may be adversely affected.

Thus, good management of the manufacturing approval activity is essential to the productivity of the entire shipbuilding process.

Hardware Delivery. The final interface with the shipyard, as far as this study was concerned, is the delivery of the tested hardware. The need and availability of vendor data and personnel for the final on-board testing and operation of the equipment is recognized, but does not influence the drawing development or equipment procurement processes.

Construction Process Model

Construction Stages - In modern shipbuilding practice each unit goes through several stages of construction. Most units proceed through a sequence of stages which include

(A) Structural Fabrication, when structural pieces are cut out and built into structural subassemblies.

(B) Structural Assembly, when subassemblies are joined into the complete unit. Some outfitting of subassemblies may be accomplished during this stage. For instance, parts of various systems may be installed on a deck section before the deck section is joined to the rest of a unit.

(C) Pre-Paint Outfitting, when additional system parts are installed on the as-built unit before the unit is blasted and painted.

(D) Post-Paint Outfitting, when those items which could be damaged by blasting are installed.

(E) In addition, machinery packages must be built. These go through most of the construction activities of the stages described above, but, for machinery package scheduling, the total effort may be considered a single stage. Machinery packages may be installed during any of the outfitting stages.

SCHEDULING CONSIDERATIONS

General

After evaluating the total information flow requirements that enmesh the three processes described above, it became clear that the completion date of the system calculations was a critical date for the entire process. But that date is controlled by any one of four other conditions. Figure 4 is a simplified illustration of how the various processes tie together.

System Path Condition

The first condition to be considered is that which would exist even if no equipment were required by a system, that is, if the entire system could be assembled using stock material that already existed in the shipyard storage facilities. This case is indicated in Figure 4 by the path A-A1-B-C.

This path illustrates that the System Diagram Phase Two must be completed before the composite drawing for any unit in which the system is located can be completed. Conversely, it shows that the earliest required UCD completion date (point C, which hereafter will be referred to as the System C-Date) will establish the required completion date for the Phase Two effort (point B), which in turn will establish A1. A1 is one possible required completion date for the System Calculation (point A).

It should be noted that the technique for determining the system C-Date is itself quite involved, and will not be discussed further herein. A full description is provided in Reference 1.

Equipment Related Paths

General. Once a piece of equipment is required, three other potentially controlling paths exist. Note that when more than one type of equipment must be procured for a system, all three paths must be investigated for every type.

Performance Data Path. As noted earlier, equipment performance data (PD) is required in order to complete the Phase Two Diagram effort. Thus the time frame between the finish of system calculations and the receipt of the PD

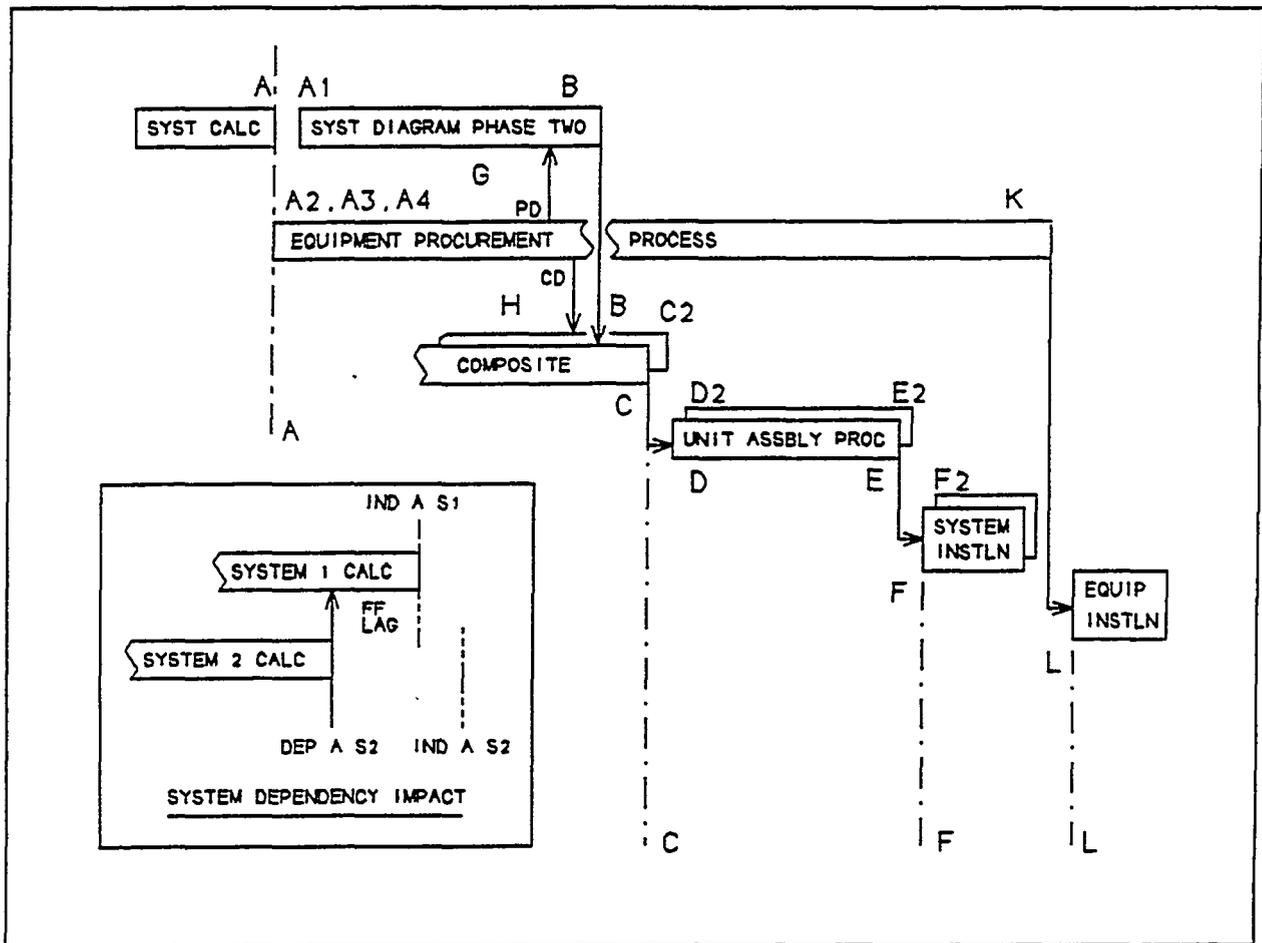


Figure 4. Schedule Control Activity Network

for the last piece of equipment in the system determines A2 for the given system's C-Date. This path, then, is A-A2-G-B-C.

Configuration Data Path. The configuration data (CD) from the vendor is used to confirm the composite drawing(s) for the unit(s) in which the equipment(s) are located. Some of a system's equipment will be located in different units than other equipment. Thus a calculation must be made for every equipment and every related unit to determine which combination creates the earliest A3, for path A-A3-H-C2.

Hardware Path. The date, L, on which each item of equipment is scheduled to be installed in a unit, in a block or on-board must be determined, and the lead time from start of writing the Technical Specification to installation must be defined. Then, working backwards along the path A-A4-K-L, another A-Date is determined.

Independent System A-Date

The earliest of all of the A-Dates determined as described above will define the System's Independent A-Date. That is the date by which the System Calculations would have to be completed if the system had no interfaces with any other systems.

Dependent System A-Date

Most systems, however, are not independent. Those which provide services to others must receive information about the requirements of the served system before their own characteristics can be definitized. The served system is then the dependent system from this point of view.

As depicted in the inset in Figure 4, if System 1 requires information from System 2, then System 2's calculations must be completed in time for System 1's calculations to be finished.

This may require System 2's calculations to complete earlier than if system 2 were an independent system.

The Dependent System A-Date is the final, controlling date for the system design effort.

COMPUTER PROGRAM

General

Having developed an information flow logic that was supposed to support development of integrated schedules, the next logical step was to use that information and develop the integrated schedules. To do so, two types of computer application programs were considered, a networking program and a relational data base program. Both types of program are available from several sources. Furthermore, applications of both types suitable for micro-computers, or PC'S, are available, as well as applications for mini- and main-frame computers. Because of the presumed greater accessibility of PC'S, and thus greater potential utility of a program which could be run on them, PC applications were examined first. Of the programs investigated, the database program was found to be simpler to use. Thus, the integrated scheduling program was developed on that system. The PC application was found to be fully capable of meeting the system requirements.

No attempt was made to try other available database programs or to utilize programs for larger computers. The information provided by the study effort serves only to demonstrate that one workable solution exists and to provide the information necessary for successful implementation of that solution. Any shipyard having an installed relational database system should be able to develop its own scheduling programs using the data provided in Reference 1.

Data Base

General. The relational database application program that has been used for this project is R:BASE FOR DOS, a product of MICRORIM. The basic elements of this program are Tables, Forms, Reports and the specific Application program that controls the operation of the system.

Tables. The Tables are used to store data. They can be considered as a matrix structure, with each row containing several columns of data.

Forms. The Forms element is an internal system which is used by the programmer to set up the appearance of

the computer screens used by those who will enter the data that will be stored in the Tables.

Reports. The Reports element is another Internal system that a programmer may use to develop the format for any and all reports which are to be obtained from the system.

Application Programs. By running various specific Application programs, operators may perform different functions, such as entering data into the database, modifying the data which has previously been entered, reviewing the data, or printing out the data in various formats. When using such an application program, the user is presented with a series of "menus" on the screen, from which the desired actions may be selected. This feature makes use of this system extremely easy and minimizes operator training efforts.

Specific Application Program

General. The specific application program that was developed during the study effort facilitates initial entry of all data concerning a ship's systems, equipment, and construction schedule.

All such data can then be modified as necessary whenever required. The program will do the calculations necessary to determine the early and late start and finish dates for each activity in the drawing development and equipment procurement processes.

Entry of the current estimated and/or actual start or completion dates of all controlling activities is then required. Thus, all the data necessary for producing printed reports of drawing and equipment schedules is developed by or entered into the database program.

By making appropriate selections from the options provided on the monitor screen, any desired report may be produced. The reports may be generated in whatever sorting sequence is preferred by the yard's data managers.

In addition, the program allows the current content of any of the database's Tables to be reviewed on the screen or printed out, a convenience for analyzing what combination of factors is controlling any scheduled date or for troubleshooting should any dates appear to be invalid.

computer Capability Required
The Relational Database System that has been used to develop the programs demonstrated herein is R:BASE FOR DOS,

available from MICRORIM. The full R:BASE FOR DOS 5.25 inch disk version of the program requires PC-DOS 2.0 or higher, 512K of main memory, a hard disk drive and one 5.25 floppy disk drive. plus a monitor. The 3.5 inch disk version requires PC-DOS 3.2 or higher for various versions. The 5.25 inch disk version was used for the subject application and all further discussion will be directed to that version.

The scheduling application program has been developed on an AT-clone with 512K of main memory and a 20 MB hard disk. It has not been prepared for network use, but this option is available with R:BASE FOR DOS and is considered a logical and desirable next step.

Approximately 4 megabytes of disc storage are required for installation of the full R:BASE FOR DOS product, although only about 2 megabytes are required for those elements of the program that are needed for this scheduling application.

The storage requirements for the scheduling application program and associated data will vary depending upon the amount of data stored. The requirements for a project which involves 125 different system diagrams, 1000 different items of equipment, 150 different units with an average of six system types per unit, where each system is installed in an average of ten units, is slightly over 1 MB. An allowance of a total of 2MB should cover any likely growth.

Using the Program

General - The following paragraphs provide a brief description of how the program can be used and what it will provide. A more detailed description of the basic elements of the scheduling program is provided in Reference 1.

Operation - There are at least three fairly different modes of operating the system, and it will probably be desirable to have different personnel available for performing these differing functions.

The first involves managing the system itself; making modifications to

the program as necessary to change the menu screen formats, to change the data entry or edit screen formats or to change the output report formats to suit varying requirements of different shipyards or different shipbuilding programs. This would be best accomplished by a single individual who will have to become familiar with the use of the R:BASE FOR DOS system and of the specific application program which has been developed. None of the other operators will need any understanding of computer programming.

The second operating mode involves entering the initial data and editing or updating that data. Ideally, initial data entry would be a one time effort, and in the vast majority of cases should be. Once a system or equipment and its supporting data, such as scheduled duration for the various activities relating to that system or equipment, are entered, it should not be necessary to make changes to those data. The values for these data should be determined by middle level managers, who could enter the data directly at their own keyboards, rather than having to write out the information for entry by others.

The third operating mode relates to the continual updating of current and actual dates for each of the activities being tracked and generating periodic schedule reports for various levels of management. Normally the input for these data will come from middle managers who will have marked up previous versions of schedule reports. It is probable that clerical personnel will be used to enter these data and produce the resultant reports.

Screens - The use of the program involves use of three types of "screens", or images which appear on the monitor, for the operator guidance.

Menu Screens - The first of the screen types provides the operator with a listing of choices of action. Selection of one of the options, which appear in a numbered vertical arrangement, as shown in Figure 5A, is made by entering the number of the desired choice. This choice may cause another menu screen to appear, giving the next logical series of choices. For example, selection of choice (1) from

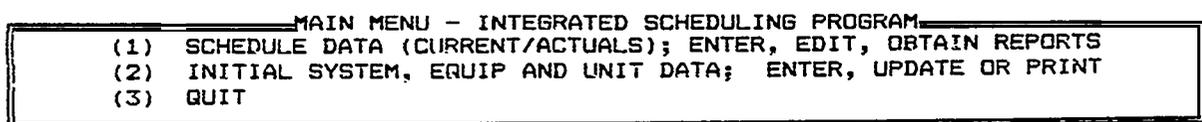


Figure 5A. Initial Menu Screen

- SCHEDULING DATA FUNCTIONS -

- | |
|--|
| (1) PRINT SCHEDULE REPORTS
(2) ENTER CURRENT ESTIMATED SCHEDULED AND/OR ACTUAL DATES
(3) UPDATE TABLES FOR NEW SYSTEMS, EQUIPMENT OR UNITS
(4) QUIT |
|--|

Figure 5B. Menu Screen for Scheduling Data Functions

- SCHEDULE REPORTS MENU -

- | |
|--|
| (1) TO PRINT DIAGRAM SCHEDULE SORTED BY SYSTEM
(2) BY START DATE
(3) EQUIPMENT SCHEDULES SORTED BY EQUIPMENT SYMBO.
(4) BY TECHSPEC START DATE
(5) BY PO AWARD DATE
(6) CONSTRUCTION DRAWING SCHEDULES SORTED BY UNIT
(7) BY SYSTEM TYPE
(8) UNIT COMPOSITE DRAWING SCHEDULE SORTED BY UNIT.
(9) TO QUIT |
|--|

Figure 5C. Menu Screen for Printing Reports

Figure 5A, will cause the next menu, Figure 5B, to appear. Selection of choice (1) from Figure 5B, "Print Schedule Reports", will bring up the Schedule Reports Menu, shown as Figure 5C. Selection of one of these choices will yield a printout of the desired report.

Data Entry Screens - The second screen type is for data entry. Separate data entry screens are provided for entering data for different purposes. An example is given in Figure 6A, which is the form provided for an operator to enter the initial estimates for current scheduled dates. The operator is led to enter a system symbol by having an area of the screen (just above "Early") highlighted.

As soon as the system symbol is entered from the keyboard, the program fills in the fields for the early and late scheduled dates, which have been calculated by the program and stored in their associated tables. Figure 6B shows how the screen appears after the system symbol, in this case "AF" for the AFFF system, has been filled in. The early and late scheduled dates are provided as an aid to the manager or operator in the initial selection of current dates.

Editing Screen - The third screen type, one of which is shown in Figure 6C, is provided for ease in making changes to information stored in the database tables. These data editing screens allow the operator to scan the data which exists in any chosen table and to change any data element in that

table. The example shown as very similar to Figure 6B, but Figure 6C shows all current scheduled and actual date data that has been entered into the table and shows it for two drawings at a time. The operator can modify only the current scheduled and actual fields in this particular screen, since all the other fields contain calculated data. Other editing screens must be used for modifying the data which are used for generating the calculated dates.

Output As previously noted, there are two types of reports generated by the program. All reports can be previewed on the monitor before printing, if desired.

(a) Schedule Reports - One type of report provides the schedules which are the primary reason for this whole effort. These reports show early and late scheduled start and finish dates, current estimated dates and any actual milestone completion dates. Separate reports are generated for the development of each type of drawing, i.e., for diagrams, unit composite drawings and installation and fabrication drawings, as well as for the equipment ordering schedule. Excerpts from a page of each of these report types are included as Figures 7, 8, 9, and 16.

Figure 7 as a Diagram Schedule Report. showing the information of interest relative to Systems Diagrams.

Figure 8 contains data for the Unit Composite Drawings. A different format has been used for this schedule,

Add Duplicate Edit again Discard Quit							
Enter/Edit Current Scheduled and Actual Dates For Diagrams :							
SYSSYMB	SHIPYARD DWG NO		CUSTOMER DWG NO		CONTR DES DWG NO		
	PHASE ONE		CALC		PHASE TWO		PHASE THREE
	START	FINISH	START	FINISH	START	FINISH	START
	FINISH	START	FINISH	START	FINISH	START	FINISH
Early:							
Late :							
Curr :							
Act :							
Early:							
Late :							
Curr :							
Act :							

[ESC] Done [F2] Clear field [Shift-F2] Clear to end [Shift-F10] More
Form: DIACRACF Table: DIACRACF Field: SYSSYMB Page: 1

Figure 6A. Data Entry Screen

Add Duplicate Edit again Discard Quit							
Enter/Edit Current Scheduled and Actual Dates For Diagrams :							
SYSSYMB	SHIPYARD DWG NO		CUSTOMER DWG NO		CONTR DES DWG NO		
	PHASE ONE		CALC		PHASE TWO		PHASE THREE
	START	FINISH	START	FINISH	START	FINISH	START
	FINISH	START	FINISH	START	FINISH	START	FINISH
AF	SYDNR	XXXXXD		555-12345678D		MM053D180	
Early:					06/29/90	08/21/90	08/24/90
Late :	05/18/90	05/29/90	06/01/90	06/26/90	12/28/90	02/19/91	02/22/91
Curr :	05/03/89	05/16/89	05/20/89	06/14/89	06/17/89	10/18/89	10/21/89
Act :							
Early:							
Late :							
Curr :							
Act :							

[ESC] Done [F2] Clear field [Shift-F2] Clear to end [Shift-F10] More
Form: DIACRACF Table: DIACRACF Field: CSPHASE1 Page: 1 Changed

Figure 6B. Screen After Entry of System Symbol

Edit Save Add new Delete Reset Previous Next Quit							
Enter/Edit Current Scheduled and Actual Dates For Diagrams :							
SYSSYMB	SHIPYARD DWG NO		CUSTOMER DWG NO		CONTR DES DWG NO		
	PHASE ONE		CALC		PHASE TWO		PHASE THREE
	START	FINISH	START	FINISH	START	FINISH	START
	FINISH	START	FINISH	START	FINISH	START	FINISH
AF	SYDNR	XXXXXD		555-12345678D		MM053D180	
Early:					06/29/90	08/21/90	08/24/90
Late :	05/18/90	05/29/90	06/01/90	06/26/90	12/28/90	02/19/91	02/22/91
Curr :	05/03/89	05/16/89	05/20/89	06/14/89	06/17/89	10/18/89	10/21/89
Act :	06/09/89	06/23/89	06/23/89	-	-	-	-
AS	SYDNR	YYYYYY		520-23456789E		MM055D16D	
Early:					06/29/90	09/04/90	09/07/90
Late :	04/27/90	05/22/90	05/25/90	06/26/90	12/24/90	03/01/91	03/04/91
Curr :	08/12/89	09/10/89	09/13/89	09/14/89	09/30/89	12/07/89	01/14/90
Act :	-	-	-	-	-	-	-

[ESC] Done [F2] Clear field [Shift-F2] Clear to end [Shift-F10] More
Form: DIACRACF Table: DIACRACF Field: SYSSYMB Page: 1

Figure 6C. Data Editing Screen

DIAGRAM SCHEDULE -

Based on Contract Award Date of 06/02/89
Printed on 07/11/89 at 11:57:11

SYSTEM NAME	SHIPYARD DWG NR		OWNER'S DWG NR		PHASE ONE		PHASE TWO		PHASE THREE	
	START	FINISH	START	FINISH	START	FINISH	START	FINISH	START	FINISH
AFFF DISTRIBUTN	SYDNR XXXXXD		555-12345678D							
E					06/29/90	08/21/90	08/24/90	10/16/90		
L	05/18/90	05/29/90	06/01/90	06/26/90	12/28/90	02/19/91	02/22/91	04/19/91		
C	05/05/89	05/16/89	05/20/89	06/14/89	06/17/89	10/18/89	10/21/89	12/07/89		
A	06/09/89	06/23/89	06/23/89	-	-	-	-	-		
AUX SW COOLING	SYDNR YYYYYY		520-23456789E							
E					06/29/90	09/04/90	09/07/90	12/04/90		
L	04/27/90	05/22/90	05/25/90	06/26/90	12/24/90	03/01/91	03/04/91	06/03/91		
C	08/12/89	09/10/89	09/13/89	09/14/89	09/30/89	12/07/89	01/14/90	03/22/90		
A	-	-	-	-	-	-	-	-		

Figure 7. Schedule for Diagram Phases

UNIT COMPOSITE DRAWING SCHEDULE -

Based on a Contract Award Date of 06/02/89
Printed on 07/11/89 at 12:02:15

UNIT	ORIG SCHED	CURRENT EST		ACTUAL	
	FINISH	START	FINISH	START	FINISH
1110	10/15/91	-	10/01/91	-	-
1120	09/17/91	-	09/03/91	-	-
1130	09/10/91	-	08/28/91	-	-
1210	06/18/91	-	06/04/91	-	-
1220	06/25/91	-	06/11/91	-	-
1230	07/16/91	-	07/02/91	-	-
1310	04/23/91	-	04/09/91	-	-
1320	04/23/91	-	04/09/91	-	-
1330	05/21/91	-	05/07/91	-	-
1411	02/12/91	-	01/29/91	-	-
1412	01/22/91	-	01/15/91	-	-
1413	03/12/91	-	02/28/91	-	-

Figure 8. Schedule for Unit Composite Drawings

which is only used within the shipyard since composite drawings have not been considered to be deliverables.

Figure 9 contains data relative to Installation and Fabrication drawings and for production planning efforts. Other schedule reports could be generated from the same data base for tracking the fabrication and installation of parts for each type of system in each stage of every unit.

The Equipment related data presented in Figure 10 is that which would be of greatest interest to the

Design Engineering department of a shipyard. All of the information that is normally provided in an Equipment Ordering Schedule (EOS) is available in the database and can be used to produce the complete MOS or EOS.

Figures 7, 8, 9 and 10 provide schedule data for various types of drawings in formats most suitable to each type. Each of these reports can be modified easily to present the data in other formats, on different sized paper, etc., as well as by various sorts, to meet the different needs or preferences of an individual shipyard.

SYSTEM TYPE UNIT ASSEMBLY PROCESS SCHEDULE
Based on a Contract Award Date of 06/02/89
Printed on 07/11/89 at 13:45:42

UNIT	SYSTYPE	ASSEMBLY DRAWING NR.		FABRICATION DWG NR.		UFF	
		UAD	UFD	UFP	UFF	START	FINISH
		START	FINISH	START	FINISH	START	FINISH
1421	P	1421-PI-40-A		1421-PF-40--			
Early:		04/29/91	07/05/91	05/20/91	06/28/91	07/15/91	08/02/91
Late :		05/16/91	07/22/91	06/03/91	07/12/91	07/29/91	08/16/91
Curr :		04/29/91	07/05/91	05/20/91	06/28/91	07/15/91	08/02/91
Act :		-	-	-	-	-	-
1422	P	1422-PI-30-B		1422-PF-30-C			
Early:		06/03/91	08/23/91	06/24/91	08/09/91	08/26/91	09/13/91
Late :		06/20/91	09/09/91	07/08/91	08/23/91	09/09/91	09/27/91
Curr :		06/03/91	08/23/91	06/24/91	08/09/91	08/26/91	09/13/91
Act :		-	-	-	-	-	-
1421	S	1421-SI-20-B		1421-SF-20-A			
Early:		04/01/91	06/21/91	04/22/91	06/14/91	07/01/91	07/19/91
Late :		04/18/91	07/08/91	05/06/91	06/28/91	07/15/91	08/02/91
Curr :		-	-	-	-	-	-
Act :		-	-	-	-	-	-
1422	S	1422-SI-20-A		1422-SF-20-B			
Early:		04/15/91	07/05/91	04/29/91	06/21/91	07/08/91	08/02/91
Late :		05/02/91	07/22/91	05/13/91	07/05/91	07/22/91	08/16/91
Curr :		-	-	-	-	-	-
Act :		-	-	-	-	-	-

Figure 9. Schedule for Construction Drawings

EQUIPMENT SCHEDULES AND STATUS						
Based on Contract Award Date of 06/02/89						
Printed On 07/11/89 at 12:06:14						
SYSTEM EQUIPMENT NAME	SYMBOL	PO NR.		PO AWARD	PD RECEIPT	CD RECEIPT
		TECH START	SPEC FINISH			
AFFF DISTRIBUTN AFFF HOSE RACKS	AFHRK	-	-			
Early Sched	06/29/90	07/17/90	09/25/90	01/29/91	02/12/91	
Late Sched	09/21/90	10/09/90	12/18/90	02/19/91	02/12/91	
Current Sched	10/16/89	11/03/89	12/15/89	02/16/90	03/02/90	
Actual	-	-	-	-	-	
AFFF CONC PUMP	AFPMP	-	-			
Early Sched	06/29/90	07/24/90	10/09/90	02/19/91	03/05/91	
Late Sched	09/21/90	10/16/90	01/01/91	02/19/91	05/28/91	
Current Sched	10/16/89	11/10/89	01/15/90	03/02/90	03/16/90	
Actual	-	-	-	-	-	
AFFF PROPORTNR	AFPRP	-	-			
Early Sched	06/29/90	07/10/90	09/18/90	02/19/91	02/26/91	
Late Sched	11/02/90	11/13/90	01/22/91	02/19/91	05/28/91	
Current Sched	-	-	-	-	-	
Actual	-	-	-	-	-	

Figure 10. Schedule for Equipment Procurement Activities

PRINTOUT OF SYSTEM DATA TABLE DIAGRAM DATA CCNTENT
Printed on 06/12/89 at 15:03:30

SYSTEM NAME	SYMB	TYP	SHIPYARD'S DIAG NR				OWNER'S DWG NUMBER		
DURATIONS-WKS		-----DATES-----							
PH1	CLC	PH2	PH3	MNSYSCDA	DIAGADAY	MNEQADAY	MNINDADA	MNDEPADA	SYSTADAY
===	===	===	===	=====	=====	=====	=====	=====	=====
AFFF DISTRIBUTN				AF	P	-	M05D180		
2	4	8	8	03/05/91	01/08/91	09/18/90	09/18/90	06/26/90	06/26/90
AUX SW COOLING				AS	P	-	M05D180		
4	5	10	13	03/15/91	01/04/91	09/07/90	09/07/90	06/26/90	06/26/90
COMPRESSED AIR				CA	P	-	M05D12		
3	4	8	5	02/12/91	12/18/90	09/25/90	09/25/90	12/10/99	09/25/90
CHILLED WATER				CW	P	444455023-12	01234-12-333D		
2	3	10	12	03/15/91	01/04/91	11/02/90	11/02/90	12/10/99	11/02/90

Figure 11. Table Data Report - System Data Table

(b) Tabular Data Reports - The other type of report provides the contents of individual tables of the database. This type of report will be of primary interest to the Scheduling Program Manager because it allows analysis of any results which seem unusual. Figure 11 is an example. It shows the content of the rows of the System Data Table. This table contains the system diagram identifiers, the diagram numbers, the durations of the four diagram phases and the various dates which control scheduling of the drawings listed in this table. all of these data are stored in this table, even though the dates come from the results of calculations, rather than from direct entry by operators.

ANALYSIS OF RESULTS

General

Analysis of the results of the data and calculations can only be accomplished by review of the data stored in the database tables. There are a total of 12 tables in the current database, of which only five need be discussed here.

System Data Table

Durations - 9s previously noted, Figure 11 illustrates the report which shows the data stored in the System Data Table. These data include the durations of each diagram phase, in weeks, which are entered manually as initial system data.

Dates - The minimum system C-Date, listed under "MNSYSCDA", is the earliest of the Unit C-Dates of all the Units that the system is installed in. This data is obtained from the System-Unit Combination Table, a page of which

is shown in Figure 12, sorted by system and Unit C-Date. It can be verified by observation that the computer program has properly identified the earliest of the Unit C-dates for a system and stored it in the System Data Table.

The Diagram A-Date, "DIAGADAY", is the date by which the system calculations would have to be complete if the Phase Two diagram duration were to control meeting the System C-Date. This compares with date A1 in Figure 3.

The Minimum Equipment A-Date, "MNEQADAY", is the earliest of the Equipment controlled A-dates; that is, the earliest of dates A2, A3 or A4 in Figure 3. This date is obtained from the Equipment Data Table, 1s will be described later.

The Minimum Independent A-Date, "MNINDADA", is the earlier of the two preceding A-Dates. In every case shown, the Equipment A-Date is controlling.

This does not, however, mean that the hardware delivery date is the controlling date for that equipment, as will be shown by review of the contents of the Equipment Data Table.

The Minimum Dependent A-Date, "MNDEPADA", is the date by which the system calculations must be complete in order to provide necessary data to another system, so that the other system's calculations will complete on schedule. This date is calculated from the System Dependency Table, as described in the next section.

Finally, the System A-Date, "SYSTADAY", is the earlier of the two preceding dates. This is the controlling date for the system, and estab-

SYSTEM-UNIT COMBINATION TABLE DATA PRINTOUT			
Printed on 06/12/89 at 15:18:08			
SYMB	SYSTEM NAME	UNIT	UNIT C DATE
=====	=====	=====	=====
AF	AFFF DISTRIBUTN	1433	03/05/91
AF	AFFF DISTRIBUTN	1421	03/15/91
AF	AFFF DISTRIBUTN	1520	03/19/91
AF	AFFF DISTRIBUTN	1422	03/29/91
AF	AFFF DISTRIBUTN	1510	04/02/91
AF	AFFF DISTRIBUTN	1423	04/02/91
AF	AFFF DISTRIBUTN	1620	05/07/91
AF	AFFF DISTRIBUTN	2510	06/18/91
AF	AFFF DISTRIBUTN	2400	07/30/91
AS	AUX SW COOLING	1421	03/15/91
AS	AUX SW COOLING	1422	03/29/91
AS	AUX SW COOLING	1423	04/02/91

Figure 12. Table Data Report - System-Unit Combination Table

SYSTEM DEPENDENCY DATA TABLE PRINTOUT On 06/12/89 At 15:06:33									
SYSTEMS			FINISH-FINISH LAGS				PHASE 2 START		
USER	PRVDR	DRVR	USR PH1	USR CLC	PRV PH2	USR PH3	"A" DATES		
=====	=====	=====	=====	=====	=====	=====	PRPVDR'S	USER'S	
AF	SW	FM	2	4	2	2	07/24/90	06/26/90	
AS	SW	FM	1	4	2	1	07/24/90	06/26/90	
DB	SW	FM	3	5	2	2	07/24/90	06/19/90	
FM	SW	-	1	2	2	3	07/24/90	07/10/90	
PM	SW	FM	2	6	2	2	07/24/90	06/12/90	
PW	CA	-	1	1	1	1	09/25/90	09/18/90	
SF	CA	-	2	2	2	2	09/25/90	09/11/90	
SF	CA	PW	2	3	4	2	09/25/90	09/04/90	
SF	SW	FM	2	4	2	2	07/24/90	06/26/90	

Figure 13. Table Data Report - System Dependency Data Table

lishes when the system calculations must be complete. This date provides the basis for all of the scheduling programs produced by this program.

System Dependency Table

The contents of the System Dependency Table are shown in Figure 13. The only systems included in this table are those which are dependent upon services provided from another system. The dependent system is the "User" system, listed in the first column. The system which provides services is listed either in the provider column or in the "Driver" system column. When a system is shown as a driver, it means that there is a multiple dependency.

For instance, the AFFF system, AF, receives services from the Firemain, FM. But the Firemain receives services from the Main Seawater Cooling System, Sw, (at least in this pilot system). As a result, the AFFF system ultimately is dependent upon the SW system, and its scheduled completion dates will be controlled by those of the SW system's.

The Independent System A-Dates are obtained by the computer program from the System Data table and stored in the A-Date columns for the provider and user systems in this table. Then the computer program compares the data in these two columns, selects the earlier and stores it back in the System Data Table as the System A-date.

SYSTEM NAME				DURATIONS								DATES											
EQUIPMENT NAME	EQSYM	PO	NR	T	R	V	E	V	E	M	T	S	W	PD	C	DAY	CD	C	DAY	INSTL	DAY		
EQUIP A DATE				P	Q	D	L	D	D	D	R	T	P	S	PD	A	DAY	CD	A	DAY	HW	A	DAY
=====																							
AFFF DISTRIBUTN																							
AFFF HOSERACKS	AFHRK	-		3	4	5	3	6	8	2	12	1	2	3	03/05/91	03/05/91	12/30/91						
09/18/90															10/09/90	09/18/90	03/21/91						
AFFF CONC PUMP	AFPMP	-		4	4	5	4	7	9	3	26	3	3	3	03/05/91	06/18/91	12/06/91						
09/18/90															09/18/90	12/11/90	10/01/90						
AFFF PROPORTNR	AFPRP	-		2	3	5	2	4	5	1	25	2	3	3	03/05/91	06/18/91	12/06/91						
10/30/90															10/30/90	01/29/91	12/17/90						
AFFF CONC TANK	AFTNK	-		3	4	5	2	3	6	3	12	2	3	3	03/05/91	03/29/91	11/29/91						
11/02/90															11/06/90	11/02/90	02/18/91						
=====																							
AUX SW COOLING																							
A/C COMPRESSORS	ASACC	-		4	5	5	3	6	9	2	18	3	3	3	03/15/91	03/15/91	11/11/91						
09/07/90															10/05/90	09/07/90	11/08/90						
REFRIG COMPRMP	ASCPM	-		4	5	5	3	6	9	2	18	3	3	3	03/15/91	03/15/91	11/11/91						
09/14/90															10/12/90	09/14/90	11/15/90						

Figure 14 Table Data Report - Equipment Data Table

EQUIPMENT - UNIT - STAGE TABLE DATA PRINTOUT
Printed on 06/12/89 at 15:34:04

SYS	EQUIPMENT	UNIT	STAGE	INSTALLATION	UNIT	
TYP	SYMBL	NAME		DATE	"C" DATE	
===	=====	=====	=====	=====	=====	
P	AFHRK	AFFF HOSERACKS	1433	60	02/07/92	03/05/91
P	AFHRK	AFFF HOSERACKS	1421	50	12/30/91	03/15/91
P	AFHRK	AFFF HOSERACKS	1422	60	04/06/92	03/29/91
P	AFHRK	AFFF HOSERACKS	2510	50	01/17/92	06/18/91
P	AFPMP	AFFF CONC PUMP	2510	40	12/06/91	06/18/91
P	AFPRP	AFFF PROPORTNR	2510	40	12/06/91	06/18/91
P	AFTNK	AFFF CONC TANK	1422	50	02/03/92	03/29/91
P	AFTNK	AFFF CONC TANK	1423	40	11/29/91	04/02/91
P	AFTNK	AFFF CONC TANK	2510	40	12/06/91	06/18/91
P	ASACC	A/C COMPRESSORS	1421	40	11/11/91	03/15/91
P	ASACC	A/C COMPRESSORS	1422	40	11/22/91	03/29/91
P	ASACC	A/C COMPRESSORS	1423	40	11/29/91	04/02/91
P	ASCPM	REFRIG COMPRMP	1421	40	11/11/91	03/15/91

Figure 15. Table Data Report - Equipment-Unit-Stage Table

Equipment Data Table

This table is set up to store all data needed to produce the Equipment Ordering Schedule(s). As seen in Figure 14, it stores the durations for each activity in the equipment procurement process model shown in Figure 3. In addition, it stores various dates needed in the calculations carried out by the computer program.

The Equipment PD and CD C-Dates and the Hardware Installation Dates are

determined from other tables; the PD C-Date from the System-Unit Table, Figure 12, and the others from the Equipment-Unit-Stage Table, Figure 15.

The corresponding A-Dates are calculated using the durations given in the other columns of the Table. Finally, the earliest of the three A-Dates is selected as the Minimum Equipment A-Date, and stored in this Table and the System Data Table already discussed.

Observations

Equipment Data Table - Comparison of the three A-Dates for various types of equipment shows that, for the assumed construction schedule and various assumed durations used in the sample project, the Hardware A-Date was never the controlling date.

The C-Dates for both the PD and CD are often the same, but not always. The obvious explanation is that some parts of the system and some equipment of the system are to be installed in the same, earliest Unit for the system's installation. In such cases, because of the assumptions made about durations, the CD A-Date will always be earlier than that for the PD, and thus will control the POA date.

System Data Table - Analysis of the data shown in Figure 11 yields the conclusion that the Minimum Equipment Q-Date is always earlier than that related to the Diagram Phase Two effort. This is not surprising, but serves to emphasize that the time between the start of writing an equipment's Technical Specifications and the POA date is a significantly long period, and is deserving of close management.

In addition, the frequency by which the Dependent A-Date was earlier than the Independent A-Date demonstrates the importance of paying close attention to the integration of diagram calculation schedules.

CONCLUSIONS

POA Planning

The most obvious conclusion to be made from this study is that the normal practice of most shipyards, namely to schedule the POA of equipment based solely upon the need date of the hardware in the shipyard, should be changed. That approach will not provide the required vendor design data in time to efficiently support the ship design process. It is highly probable that many past problems blamed on "late drawings" were really due to inadequate equipment procurement planning, which precluded finishing the final drawings on time.

Program Applicability

Another major conclusion to be made is that the computer program developed as a Part of this study effort will provide shipyards with all of the information necessary for good, integrated scheduling of drawing development and equipment procurement.

It will identify the dates by which System Calculations must be com-

plete. Since these dates control all "downstream" activities of the design development and equipment procurement efforts, all other required dates can then be calculated.

Although not discussed previously, the program computes the required in-yard delivery date for every item of each type of equipment. This detail should be used whenever ordering multiple items of equipment, since it would minimize warehousing as well as encourage on-time partial deliveries.

The results of this study also highlight the importance of recognizing the design interrelationships of various systems, and the necessary control of design data transmission between dependent systems.

Reservations

The conclusions to be made from the results presented in this paper need to be qualified by noting certain aspects about the data used in the pilot test.

Construction Schedule - although the construction schedule data used was based on an actual shipbuilding project proposal, that schedule was relatively conservative, allowing a rather long time before start of construction. Of course, in order to obtain maximum productivity in modular shipbuilding efforts, the start of construction should be held off until the design has reached a mature state, so the schedule used is considered valid.

Size of Pilot Project - The number of systems used in the pilot project were relatively few, and included principally structure and piping systems. However, other distributed systems, such as HVAC and electrical wireways, are so similar to piping systems for purposes of this type of study that their inclusion would not change the conclusions.

The only impact on the computer program due to including more systems would be additional time for carrying out calculations. The calculation time for a complete recalculation of the existing data on a floppy disc is about thirty minutes. This time is increased by about three seconds for every additional row in any table. On the other hand, the full calculation is seldom needed. Once the initial data concerning systems, equipment and their unit-stage combinations are entered, recalculation can be limited to reflect only the specific changes made during future updates of the data. Also, with the database installed on a hard disc, the calculation time will be reduced.

Furthermore, no attempt has been made to date to optimize the computer program reported herein. Should the calculation time represent a true problem in the use of the program, a number of improvements are possible.

Finally, for the main purpose of the program, which is to generate integrated schedules for drawings and for equipment procurement, no calculations are necessary. Updates of current scheduled dates and actual completion dates, and generation of current schedules require no calculation time at all.

The reader will also have noted that many items of information such as drawing numbers, purchase order numbers, etc., are missing in many of the tables and reports. Obviously, these are items which have no effect upon scheduling. However, these fields ultimately will be mandatory, so a few were filled in to illustrate that they have been provided in the computer program.

FUTURE WORK

As in most research efforts, there are more things which can be done to further enhance the utility of the program presented herein.

One is to include other equipment related data for scheduling; specifically, ILS data. The inclusion of this data is an obvious extension, and can be accomplished with little difficulty.

A second as to make some minor modifications to the program in order to facilitate its use on a network.

This will allow data to be entered at different work sites simultaneously. It also will allow reports oriented to a specific organizations interests to be generated locally upon demand.

Third, a detailed description of the system and instructions for its use will be needed.

A proposal to accomplish the above tasks has been presented to the SP-4 Panel and tentatively approved. Hopefully these improvements will have been effected by the end of this year.

ACKNOWLEDGMENTS

The support of the members of the SP-4 Panel and, in particular the Ingalls Shipbuilding Division of Litton Industries, under whose guidance this work was accomplished, is gratefully acknowledged. The advice of a number of equipment vendors and vendor representatives was also of significant help in identifying the type of information which is crucial to a shipyard's receipt of good and timely information about equipment as well as of the hardware itself.

The conclusions and opinions expressed herein, and all of the estimates that were used for durations, etc., are the author's own, and do not necessarily reflect the conclusions of, or data from, any other source.

REFERENCE

1. "The Information Flow Requirements of the Ship Design and Procurement Processes", NSRP Report No. 0293, June 1989.

Additional copies of this report can be obtained from the
National Shipbuilding Research and Documentation Center:

<http://www.nsnet.com/docctr/>

Documentation Center
The University of Michigan
Transportation Research Institute
Marine Systems Division
2901 Baxter Road
Ann Arbor, MI 48109-2150

Phone: 734-763-2465
Fax: 734-763-4862
E-mail: Doc.Center@umich.edu