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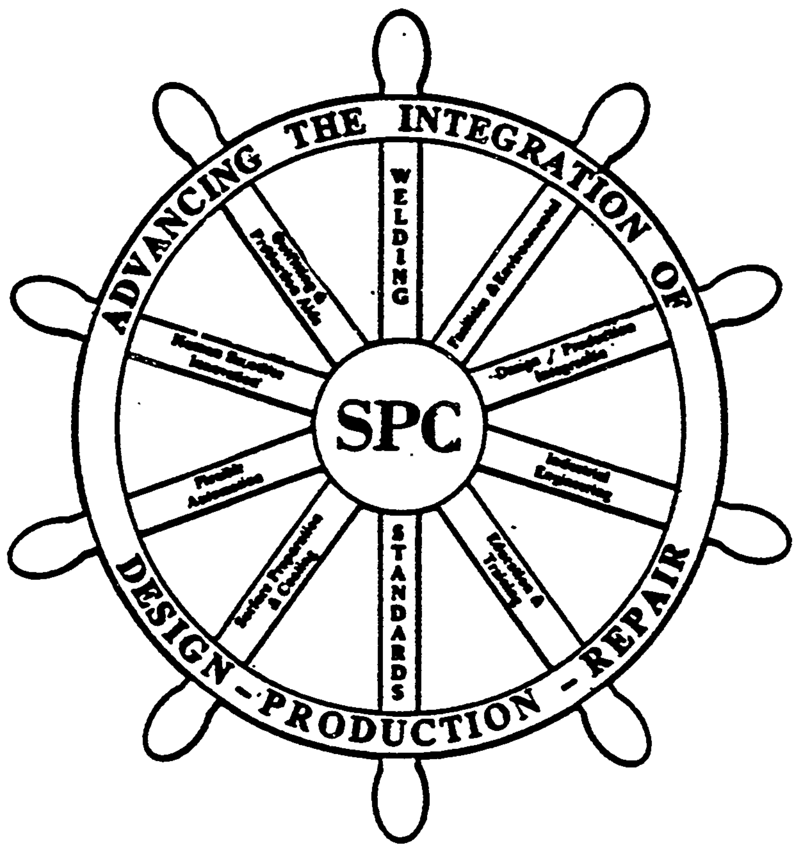

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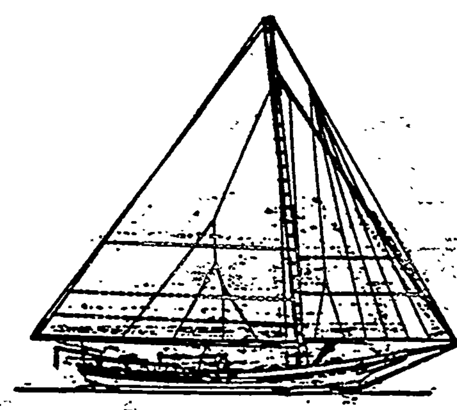

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No. 1

Computer Integration of SEAWOLF Class Submarine Life Cycle Functions

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ABSTRACT

The application of computers in acquisition and logistics support is a major requirement of future weapons systems acquisitions. Although the design of the SEAWOLF preceded most new DOD sponsored requirements, the program incorporated many initiatives that will serve as prototypes for future” acquisitions.

The SEAWOLF Program is employing computer technology to integrate the design, production and logistic support functions of the ship’s life cycle. The transportability of electronic data from the design phase to construction, and on to logistics is key to improving efficiency and more closely linking designer, shipbuilder and maintainer.

SFAWOLF is an important step in the overall effort to improve weapons system acquisition efficiency. Lessons learned by SEAWOLF will be valuable in preparing other acquisition programs to take advantage of the integration of computer data bases that can bring greater success in the execution of design, production and logistics support phases.

INTRODUCTION

The life cycle of a ship or any weapons system in general is divided into many phases. These phases extend from the first drawing that defines the ship at the highest level during conceptual design to the day when the last unit completes its final mission. One constant that has existed for centuries is the need to transfer information. In early ship construction a scale model constructed in wood may have been the only vehicle necessary to transfer the designer’s knowledge to the shipwright. The next step, and the one we are for the most part living with today, is the transfer of information from designer to constructor to operator and logistician using paper as the medium. Today, the information takes the form of drawings, specifications, maintenance plans and standards, technical publications, piece part support, allowances and a seemingly infinite number of variations. The desire to better control the life cycle functions of a ship has led to the proliferation of huge volumes of paper at each point of the process. The wasteful part of this process is the fact that we constantly recreate data that undoubtedly a person associated with some previous part of the life cycle has had at their fingertips.

The practical application of managing the data created during a ship (or any other weapons system) life cycle is an immense task. Figure 1 depicts a very high level summary of the major interfaces. There are many points of transfer and each one has its own specific requirements that must be satisfied. For example, the interface between design and construction is a particularly important one in the SEAWOLF Program today.

The shipbuilder must be provided an array of design products, the largest volume of which is drawings and associated material information. Conventionally, this point of data transfer has been strictly limited to the delivery of reproducible paper drawings. However, the ability of a program to provide that information in a data transfer medium other than paper is in today’s increasingly computer oriented environment not only an attractive option, but in the near future will be a requirement.

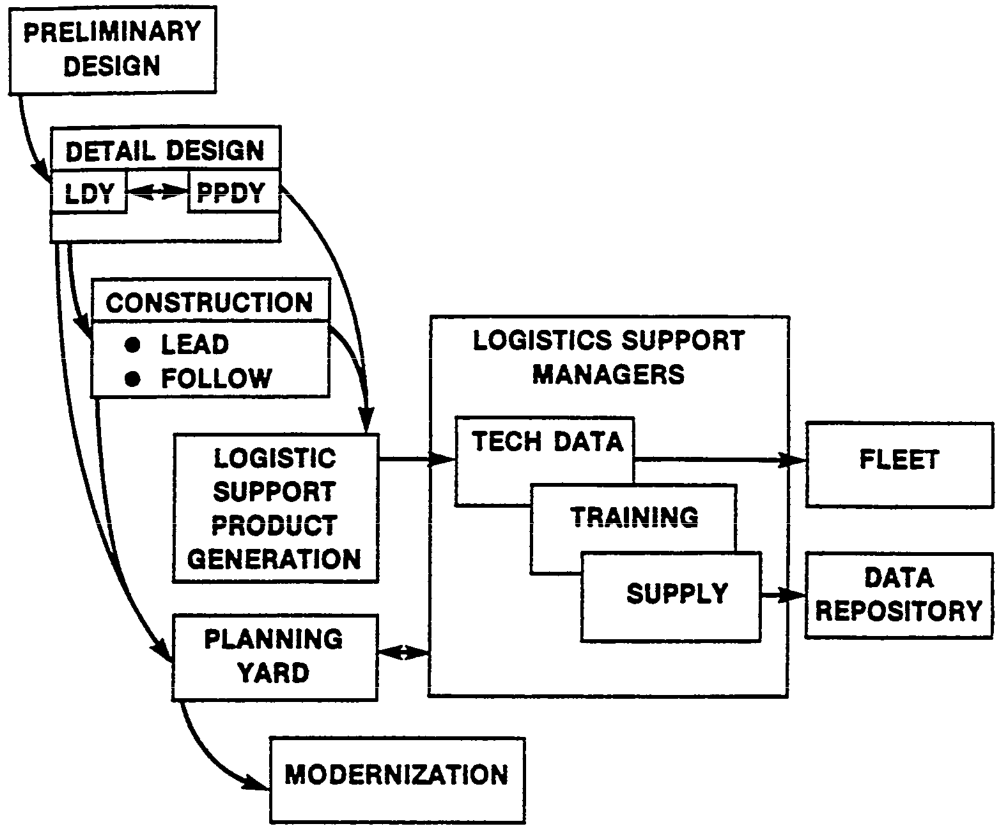

FIGURE 1. LIFE CYCLE DATA INTERFACES

Today's program manager must be expected to understand the methodology of managing data. The program manager will look at the Department of Defense specifications, the capability of potential prime contractors and mandate contractual language to implement design, construction and ILS requirements. There are many key decision points within an acquisition program concerning the vehicles by which data will be created, stored and exchanged. The most critical decisions, from the SEAWOLF experience, are the decisions made during the preliminary phases of design and implemented in the detail design contract. The detail design phase creates large amounts of data and a later change of course would in all likelihood be expensive and difficult to execute. Therefore, the topic of creating and utilizing electronic data bases in weapons system acquisition will receive increasing visibility at high level forums, such as the ship production symposium.

EARLY SEAWOLF INITIATIVES

The SEAWOLF Program preceded most DOD initiatives to improve the methods in which life cycle information is handled. Sufficient technology was available at both submarine design yards, Newport News Shipbuilding (NNS) and General Dynamics, Electric Boat Division (EB Div), to establish the contractual mandate that the EB Div/NNS design be entirely CAD based. We believe that history will support that this forward looking decision is one of the single most important milestones in the Program's history.

To support a competitive acquisition strategy, the Program's plan to go forward with a digitally based design had to deal with the difficult problem of developing the capability to transfer design products between the two submarine design yards, and eventually to a shipbuilder. The incompatibility of the design yard CAD systems left serious doubts as to whether or not the EB and NNS design data could be transferred cost effectively. There were three options explored to solve this problem: 1) direct both design yards to use the same CAD system, 2) Develop a direct translator between the two existing systems, or 3) work with a neutral format translation process, specifically the Initial Graphics Exchange Specification (IGES).

The first option would have incurred a very large expense. The second option was regarded as being too inflexible since data from a third system may not be usable and future upgrades of existing software at either design yards could necessitate revisions to the direct translator. The third option had the potential to be cost effective and flexible, however, it was recognized that large scale IGES transfers in shipbuilding had not been done before. The program selected the IGES option and accepted the task to go through the development effort necessary and make this medium of transfer an effective vehicle. In addition to the two and three dimensional graphics information that IGES would handle the need to transfer processible or "field" type text data was necessary. In 1985 the SEAWOLF Program organized data transfer working groups to bring EB Div and NNS people together and provide the framework for transferring, in most cases in parallel with the hard copy deliverable, three types of data:

- o Drawings (2D Graphics)
- o Product Model (3D Data)
- o Processible Data Elements

A working group was assigned to each of these data types with the goals of specifically defining what contract deliverables would be transferred, developing the written transfer procedures, and thoroughly testing the transfer process to validate the procedures. The charter of these working groups was to bring electronic data transfer from a goal to a reality. Additionally, the procedures developed had to be rigorous and clear for the digital product to be made a deliverable in the SEAWOLF Construction Contract.

SEAWOLF DIGITAL DATA TRANSFER WORKING GROUPS

The philosophy behind the working groups was that knowledgeable personnel from Electric Boat and Newport News, with guidance from NAVSEA, were capable of developing the tools necessary to transfer SEAWOLF data electronically. Although the management at both companies set the course, the working group's efforts for the most part were undertaken by Computer Aided Design (CAD) support engineers, for the IGES type transfer, and material specialists, in the processible text transfer. The groups met about once a month and devised their own methods of developing the products required by the detail design contract. The statement of work of the contract required the design yards to develop and refine procedures for the conversion, storage, validation, and exchange of design information (processible text, drawings and product model including piping and structural information) in digital form . In addition, as part of the Contract Data Requirements List (CDRL) the delivery of procedures was required. These procedures (see Figure 2) would become the basis of data transfer and invoked in future contracts.

1. DIGITAL DRAWING EXCHANGE

2 DATA ELEMENT DICTIONARY

3. PROCESSIBLE DATA EXCHANGE

4. STRUCTURE EXCHANGE

5. PIPING DATA EXCHANGE

6. NON.PROCESSIBLE TEXT EXCHANGE

7. DIGITAL PRODUCT DATA CONTROL

8. DIGITAL DATA TEST SET

FIGURE 2 SEAWOLF DATA EXCHANGE PROCEDURES

Drawing Transfer

The successful exchange of drawings within the SEAWOLF Program from design yard to construction yard allows the shipbuilder to have a computer usable (vector notation) drawing available. The utility of being able to work with a drawing with the same capability as if it had been created on ones own CAD system is significant. Additionally, the option to create a SEAWOLF data base at another site, such as a planning yard, is achievable.

The transfer of drawings using IGES as the vehicle is a complex process. The complexity is the result of the methods in which individual CAD vendors represent the many visual devices that convey information. Something as simple as the width (or font) of a line can create a thorny translation problem. Although IGES translators were available from each of the CAD vendors whose products were involved in SEAWOLF design, the initial attempts to transfer data resulted in drawings at the receiving site that did not resemble the original drawing. The major reasons for these drawing exchange difficulties were rooted in four areas:

- o Translator Problems
- o IGES
- o System Differences
- o User Errors

Each problem was documented and categorized by priority and method of solution. Translator problems were resolved by feeding back information to the CAD vendor who provided the translator. Both vendors involved (IBM and CV) were very receptive to the requests from the SEAWOLF Data Transfer working groups for improvements in the translator software and most problems have been solved. Recommendations to change IGES were referred to the IGES committee and the National Bureau of Standards (now National Institute of Standards and Technology). This process, although slower than working through the CAD vendors, resulted in useful changes that improved the translation process. Working with the CAD vendors and IGES had the advantage of not being a direct cost to the government. The feedback provided by the SEAWOLF working groups to the CAD vendors and the IGES committee provided a basis for a significant product improvement to the vendors translators and IGES.

In the event a solution to a problem was required prior to being addressed in the translator or IGES, an interim solution to most problems was resolved by creating "work around" software at the sending or receiving site. System differences and user errors were corrected through the institution of internal procedures within each company to provide uniform CAD products and a SEAWOLF drawing transfer procedure to govern exchanges of drawings between sites. In addition, a standard set of test cases was developed to check translator integrity when a new revision of CAD Software was introduced by either design yard. The program to improve drawing transfer has been very successful. The SEAWOLF effort has achieved a consistently accurate transfer of information with only minor problems that are well documented and easily corrected at the receiving site, as part of the drawing validation process.

Future Acquisition Programs must decide what medium is required to transfer drawings. The SEAWOLF Program chose IGES as the medium to provide computer usable drawings at various sites. Options other than IGES, i.e., raster images, can provide improved transfer, storage and retrieval capability, but without the virtue of being cAD usable. A Raster image is a series of dots that can be electronically stored to represent a 2D graphic. The advance of technology in converting Raster to vector may someday allow the Raster transfer to become the 2D transfer medium of choice.

Product Model Transfer

The transfer of product model or 3D information is an important function, particularly from the standpoint of manufacturing. The accurate 3D description of parts that comprise a ship is the entry point for advanced manufacturing systems. A hallmark of the SEAWOLF Program is the contractual requirements for both design yards to deliver piping and structural product model information to the shipbuilder.

Moving information through a manufacturing process is a complex procedure. In most cases the time to create the paper or software products that support the fabrication of each piece takes many times longer than the actual time to manufacture. The need to reduce fabrication costs has driven most shipbuilders to implement producibility enhancement programs that reduce the time and complexity of the manufacturing process. One method revolves around bringing numerical control machinery onbcard and interfacing. them with computers. A generic computer integrate manufacturing system is depicted in Figure 3. To take full advantage of a systemts potential, the maximum amount of information is transferred electronically from computer to computer through direct links. Down loading to paper at any point in the process and then recentering the data into another data base represents failure. The front end of the system is the CAD station work station that originates the designer’s description of the piece to be fabricated, whatever it may be. In the case of

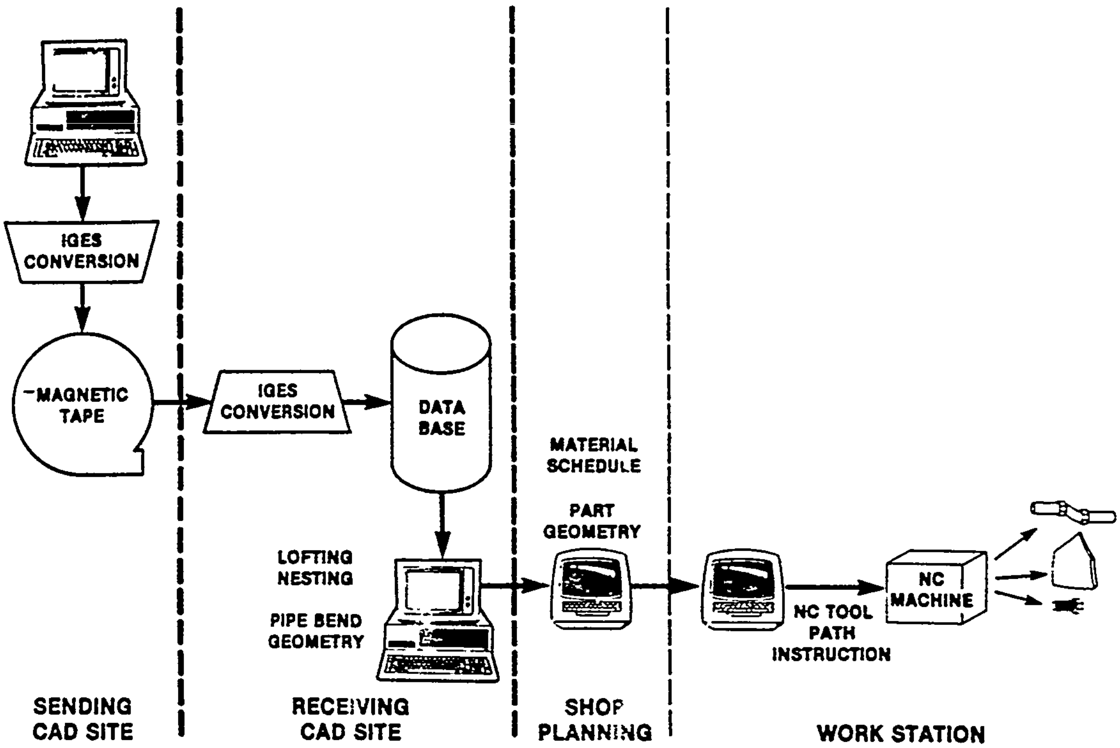

FIGURE 3. ADVANCED MANUFACTURING SYSTEM

SEAWOLF that piece may be designed at either NNS or EB. In order to electronically link the design data base to the manufacturing system of the shipbuilder, the SEAWOLF program developed and is continuing to develop the procedures to utilize IGES based transfer of product model data.

A working group, similar to the drawing transfer working group, developed a procedure to guide the process of moving structural and piping product model data from design yard to shipbuilder. In addition to the procedure development, considerable testing and resolution of problems that the testing brought out took place. The final step in the development phase has been to transfer data from designer to manufacturer and use that data to cut steel or bend pipe.

In a weapons system acquisition, the program manager must determine if the transfer of product model type information is required to support the manufacture of the system. The program should require sufficient procedure development and testing to insure that design data will fully support construction. An understanding of the manufacturing capabilities and requirements of potential manufacturers is essential to making the correct decisions. Although the up front implementation of a data transfer program as part of design is an additional design expense, in reality it is a high leveraged investment that will make the weapons system more affordable over the life cycle.

Processible Text Transfer

The text information transferred with the drawings using the IGES process is not computer usable. In other words, information such as parts data cannot be electronically pulled from the drawings to access other computer files. Although future data exchange standards (notably PDES) plan to offer this capability, at present intelligent or processible text data must be transmitted separately in a relational data base that utilizes a data element dictionary (DED). The DED is simply a definition of the data element necessary to transmit information. The data element definition is extensive. Each element requires a field name, number of characters, data code, references, description, input instructions, examples, edit/screening provisions and data structure.

AS in drawings and product model transfer, a working group was formed to develop the guidelines necessary to exchange processible text. This effort included assembling the elements of the data element dictionary and preparing the procedure to guide the actual transfer. The most difficult activity was the large quantity of elements that had to be identified and then individually defined. An example of a data element is shown in Figure 4.

FIELD NAME:

ND Matrix

NUMEER OF CHARACTERS

1 **each**

DATA CODE:

PNC129A,B,C,D, E, and F

REFERENCES

(a) Table 47, NDT Codes

DESCRIPTION:

Identifies applicable non-destructive test requirements (i.e. VT, RT, PT, UT,MT, and MN) performed on the item (DAPN).

The Codes (Y/N) in these fields relate to tests listed in Reference (a).

INPUT INSTRUCTIONS:

o **Enter the Ietter "Y" if the particular test applies to** the **item**, or enter **"N"** if not required.
"'Blank'' indicates NDT consideration not made/not applicable.
Test designation sequence:
VT RT PT UT MT and MN

EDIT/SCREENING PROVISIONS: (Performed by-)

0 Computer- Reject Code other than Y,N,or blank.

TYPE TEST	**VT**	**RT**	**PT**	**UT**	**MT**	**MN**
Applicable(Yes/No)	Y	Y	N	N	N	N

EDIT/SCREENING PROVISIONS (Performed by-)

p Computer - Reject Code other than Y,N,or blank.

DATA STRUCTURE:

A(l) each (Alphabetic)

FIGURE 4. EXAMPLE OF SEAWOLF PROCESSIBLE TEXT DATA ELEMENT

The working group further defined the categories of data to be transferred. A list of the more common data reports exchanged is shown in Figure 5. As people working in the fields of procurement, manufacturing, non-destructive testing, weight control and most notably logistics support understand the utility of the computer in their jobs; the importance of data exchange increases so that the re-input or re-creation of data received from another source is not required.

SEAWOLF: A MAJOR MILESTONE IN DATA TRANSFER

The effort of the SEAWOLF working groups have brought the state of data transfer to the point where the program is contractually supporting the transfer of production information from design yard to shipbuilder. The culmination of this effort is very much like a commencement exercise. The door has been opened and the desirability of expanding the scope of the data transfer effort is apparent. The working groups have been tasked to develop the procedures and conduct the testing to facilitate a future transfer of ventilation and electrical cabling design data. The working groups will look at transferring data that is directly available from the data base such as cable routing information and tabular listing of ventilation shapes and their dimensions. Further, the groups will explore the transfer of the 3D product model of ventilation and electrical system geometry. The end result will be similar to the structure and piping programs, as the ventilation and electrical construction drawings are issued, a parallel package of electronic data will be issued to support the manufacturing and planning operations.

Beyond the present program of providing data which represents the transfer of design information is the desire to increase the scope of the transfer to include manufacturing type information. For example, the SEAWOLF plate cutting facility takes the transferred design or "neat" part and adds information such as the bevel required for a specific welding process and any extra stock necessary for final fit up. If commonality between manufacturing sites can be reached in the methodology of preparing a design part for manufacture, then the information added by the manufacturing planner will be required only one time during the life of that part.

DATA EXCHANGE DOCUMENT

1. ENGINEERING PARTS LIST
2. LOGISTIC SUPPORT ANALYSIS CONTROL NUMBER MASTER FILE
3. STOWAGE INFORMATION
4. MACHINERY MATERIAL HISTORY
5. PREFERRED PARTS SELECTION LIST
6. SHIP'S DRAWING SCHEDULE
7. HIGH IMPACT SHOCK QUALITY DATA
8. RADIOGRAPHIC SHOOTING SKETCH DATA
9. PROCUREMENT SUMMARY INDEX
10. WEIGHTS AND MOMENTS
11. NON-DESTRUCTIVE TEST DATA

FIGURE 5. SELECTED PROCESSIBLE TEXT REPORTS SUPPORTED BY THE SEAWOLF DATA ELEMENT DICTIONARY

INTEGRATION OF DESIGN AND LOGISTICS SUPPORT

The integration of the SEAWOLF design and construction has been well documented in prior presentations. The creation of the modular build strategy, formalized by planning and sequence documents and presented in the SEAWOLF sectional construction drawings represents a major achievement in the practical application of concurrent engineering. The availability of the SEAWOLF electronic data base was key in making the transition from the system to zone design possible. The utility of the data base is also being exploited to make early inroads into the many products required for the logistics support of the ship. Design is the first phase of logistics support. As the designer creates the ship, the individual components are chosen to meet the requirements of the system. These components become the foundation of the effort required to maintain the ship in a proper condition of readiness. The design data base is the key resource from which the initialization of logistics support systems can be accomplished. The SEAWOLF logistics group, in cooperation with the design yards, is putting into place the systems to electronically extract information from the design data base and create the computer driven systems that will in turn create the products necessary to support the SEAWOLF class submarine throughout its life cycle. The systems that will fulfill this function have been integrated under the umbrella system known as SAILSS.

The creation and utilization of a computer based logistics effort represents a milestone as important in the logistics phase as the digital data transfer effort has been in the construction phase of the life cycle.

SEAWOLF AUTOMATED INTEGRATED LOGISTIC SYSTEM

Integrated Logistic Support (IIS) is a process concerned with capturing the configuration of the ship and producing and maintaining the logistic products (maintenance plans and standards, piece part support and allowances, technical manuals, etc.) that support the ship's operation. Because these products have historically been developed and maintained utilizing independent data bases, the information contained in them is often not in agreement. For example, piece part requirements can differ between the ship's allowance list, the technical manual and the repair standard. The lack of integration with the ship's logistic products results in wasted man hours and a high degree of frustration for the people performing maintenance.

To improve the efficiency and effectiveness of Integrated Logistic Support (IIS) for the SEAWOLF Class Submarine, PMS350 early in the development process sought to integrate the various ADP systems that provide this support. The historic disconnects that have existed between the various logistic products could only be corrected by integrating the systems that produce and maintain these products. This need led to the development of the SEAWOLF Automated Integrated Logistic Support System (SAILSS). SAILSS will provide an automated ILS system that will support the class during both the acquisition and operation phases.

SAILSS is being designed as a distributed data base (information resides in more than one ADP system) developed and dedicated to the logistic support of the class. The system is being designed as a composite of individual subsystems (See Figure 6), linked by common data elements, software and a telecommunication network with controls to prevent access of unauthorized individuals. NNS is the system developer and has responsibility for the design, development, testing and associated documentation of the system.

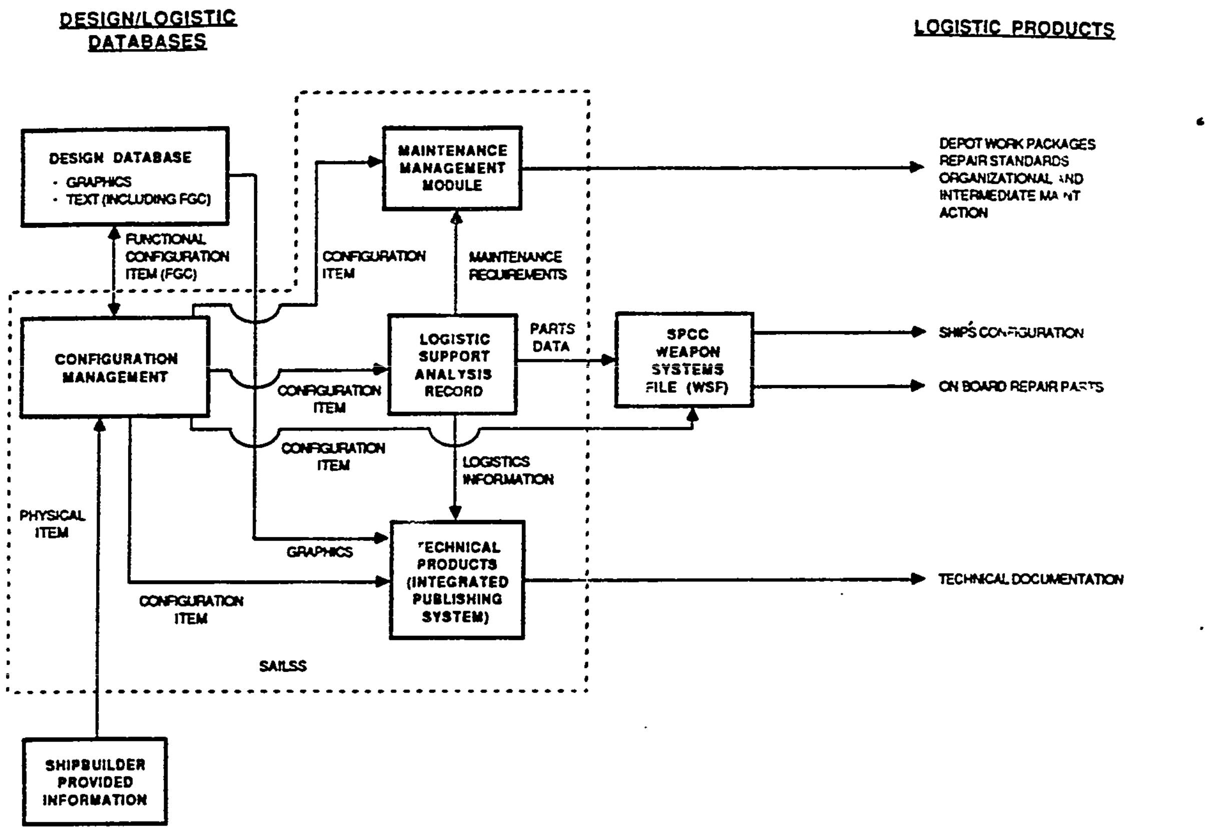

FIGURE 6. SEAWOLF AUTOMATED INTEGRATED LOGISTICS SUPPORT SYSTEM

Early in the development it became apparent that a methodology was needed that would provide commonality between the various SAILSS data bases. Additionally, since logistics is concerned with the ship's configuration, a link common to both SAILS and the design data base was required. SEAWOLF utilizes the Functional Group Code (FGC) for this linkage. The code provides an indexing system that establishes the basis for the structuring the configuration records. An example of a FGC is contained in Figure (7).

Configu ration Management Sub-system

The primary sub-system within SAILSS supports the configuration management process. The purpose of this subsystem is to capture the functional configuration (generated during the design process) and to build upon this baseline by adding the physical configuration (an item identified to a specific vendor that satisfies the function) information identified during the construction process.

The following is a very simple outline of the configuration process and how FGC is involved in the process. As systems are developed the design engineer determines that an item is required in the system to perform a specific function, e.g., pump water. These items are added to the system drawing, a file in the design data base. The system drawing is reviewed by the system engineer who assigns a FGC to the individual functional items. This information is loaded into both the design and Configuration Management data bases. The physical configuration items are later identified by the shipbuilder and electronically transferred to the corresponding FGC in the configuration management sub-system.

Currently, a prototype that electronically links SAILSS and the design data base is being developed to take advantage of the fact that the FGC, as well as other logistic related information, is in the form of processible text. During the analysis phase of this project it became apparent that information that is important to the designer may not be important to the logistician and vice versa. For example, bulkheads and other structural items are not normally considered as a configuration items by the logistician but are by the designer. Because of these differing views of the submarine, a review by the logistics engineer in the initial integration of the two systems will be required. However, once the systems are linked, the capability to compare configuration information between the two data bases will exist. This ability ensures that changes in the design are captured by the logistician.

The Configuration data base electronically provides configuration information to the various sub-systems within SAILSS, as well as external data bases. Use of these interfaces will allow sharing of data and will increase the accuracy of the data.

Logstic SUp port Analysis Sub-system

Logistic Support Analysis (LSA) is a process that documents the engineering rationale on which the maintenance concept (repair activity capability, periodicity, and technical requirements) is based and stores source data from which individual logistic products are developed. Since the LSA process utilizes a data base that is linked to other SAILS sub-systems, consistency with the analysis and other ILS products is assured.

FGC	FUNCTIONAL NOMENCLATURE
420	NAVIGATION SYSTEM
423	ELECTRONIC NAVIGATION SYSTEMS, RADIO
4231	DIRECTION FINDER SET AN/XXXX
42311	ANTENNA ASSEMBLY AS-XXXX
42312	RECEIVER-PROCESSOR R-XXXX
42313	CONTROLLER-INDICATOR C-XXXX
42314	SWITCH-MULTIPLE ROTARY
4232	NAVIGATION SYSTEM, OMEGA
42321	RECEIVER-COMPUTER

FIGURE 7. FUNCTIONAL GROUP CODE (FGC) INDEXING CONCEPT

The SEAWOLF project was the first to utilize the unified data base (UDB) software, which was developed by the Air Force, as the means to automate the LSA record (LSAR). The Naval Sea Systems Command Logistics Center (NAVSEALOG) has been designated as the custodian of this software. It is also planned that the UDB will be enhanced to include NAVSEA specific data elements not currently defined in MIL-STD-1388.

The LSAR is designed to utilize control numbers to identify the component undergoing analysis. SEAWOLF uses the FGC as the **Control** number, which will be electronically transferred to the LSAR from the Configuration Management Sub-system. This ensures all configuration items identified during the design/construction process are analyzed for logistic support requirements. Additionally, logistics support data produced by the LSA process will be distributed electronically between this system and other sub-systems of SAILS, as well as external data bases, for the actual production of logistic products.

Integrated Publishing System

The Integrated Publishing System (IPS) is a computer based system designed specifically to produce and maintain a wide variety of technical documentation. The system, which is a sub-system within SAILSS, consists of a combination of state of the art hardware and software which provides for technical matter publication and life-cycle maintenance.

IPS provides the speed and power to achieve high level of performance by replacing manual production tools and methods with computer function. The sub-system provides for the electronic tools to assist in the collection of source data, including IGES transfer of drawings from the design data base and interfaces to scanners for reading in hard copy drawings. The capability to transfer data directly from LsAR to the system will be developed. Additionally, other time consuming tasks such as page composition have also been automated. The merging of text and graphics, once a time consuming task, is now automated and the composition of a camera ready page is now a relatively simple task.

SUMMARY

There is a large body of organizations, government and industry, that are studying the concept of information transportability throughout a weapons system life cycle. The conclusions being reached, almost universally, are the free flow of data from one phase of the acquisition to another represents the greatest potential to reduce life cycle cost and improve the overall performance of the system.

However, in today's world there appears to be too much information and too little experience in structuring a long term program that utilizes the envisioned potential. Beyond the challenges of capital investment, cultural shock in the work force and the need to restructure traditional phases of acquisition, the very basic questions of "how do I structure my program and where do I go for help?" do not have clear answers. The SEAWOLF program was driven by necessity to search for the answers concerning data base structuring and utilization. The simply stated problem of "how do I transfer CAD data between NNS and EB Div" has taken a significant effort to resolve. The SEAWOLF Program has made steady progress in utilizing the design data base to improve the efficiency of the other phases of the ship's life cycle.

The Program Manager of any future weapons system acquisition will be charged with the responsibility to implement a strategy that more completely integrates ship design, construction and logistics. The only method to affordably accomplish that task is to create and utilize snared electronic data bases. The achievement of an essentially "paper less" environment that supuorts a free flow of data between life cycle phases is a significant goal that successive programs should undertake as a principal requirement. The Department of Defense has recognized the need for computer aided acquisition and logistic support systems and has formulated policy that mandates the creation of government accessible electronic data bases. The Program Manager must require, as part of the contract, the tasking to create and utilize data bases in a program tailored to support the life cycle. The lessons learned by the SEAWOLF program in this field are a major milestone in the effort to more fully realize the potential of advanced ship production techniques.

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The authors wish to express appreciation to the talented people at NAVSEA, Newport News Shipbuilding and Electric Boat Division who have labored diligently on the SEAWOLF Digital Data Transfer and Integrated Logistic Support Programs. Their efforts have helped the SEAWOLF Program achieve a milestone in technically advancing the start of shipbuilding in the United States.

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