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EDUCATION AND TRAINING

April 1997
NSRP 0532

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

1997 Ship Production Symposium

Paper No. 23: New Attack Submarine: A 21st Century Design

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

Report Documentation Page						*Form Approved OMB No. 0704-0188*
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1. REPORT DATE **APR 1997**		2. REPORT TYPE **N/A**				3. DATES COVERED **-**
4. TITLE AND SUBTITLE **The National Shipbuiliding Research Program 1997 Ship Production Symposium, Paper No. 23: New Attack Submarine: A 21st Century Design**						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 Tower 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	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**8**		

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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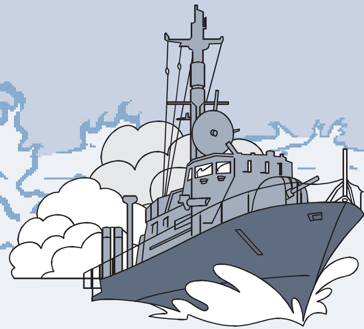

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
1997 Ship Production Symposium
April 21-23, 1997
New Orleans Hilton Hotel
New Orleans, Louisiana

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
601 Pavonia Avenue, Jersey City, NJ 07306
Tel. (201) 798-4800 Fax. (201) 798-4975
Paper presented at the 1997 Ship Production Symposium, April 21-23, 1997
New Orleans Hilton Hotel, New Orleans, Louisiana

The New Attack Submarine: A 21st Century Design

Kevin Poitras (V), Electric Boat Corporation

ABSTRACT

Nuclear submarine design for the 21st century embraces world class processes, technology, and tools. The walls which once divided engineering disciplines have been replaced by multi-functional teams. Designer and shipbuilder independence of the past is being replaced by interdependence; and the arms-length relationship with suppliers and the Navy is being replaced by cooperative, interactive teaming arrangements. The goal of everyone involved in the design of the New Attack Submarine (NSSN) is to work together to provide the most cost-effective and capable product.

In 1989, Electric Boat Corporation initiated a comprehensive review of the submarine design and construction process with the goal of reducing nuclear submarine acquisition and life cycle cost. The process was mapped for each technical discipline (electrical, structural, piping, etc.), step-by-step, and optimized around a fundamental core process to eliminate inefficient work practices. Concurrent with this internal review was an external evaluation of design and construction methods being utilized throughout a broad spectrum of U.S. and international industries. Designers and manufacturers in the aircraft, automobile, power plant equipment, reactor plant equipment, and shipbuilding industries were visited to observe their design and manufacturing processes. In addition, numerous articles and papers written on concurrent engineering were reviewed, paying particular attention to lessons learned.

These comprehensive reviews, conducted over two years, identified the best features of current industrial practice. These "best practices" were adapted and incorporated into the structure of the NSSN design process to ensure maximum producibility of the ship design. As a result, the NSSN design is being developed utilizing the basic concurrent engineering concept optimized to nuclear submarine product development. Designers, construction personnel from each major trade, and key support personnel work together on teams to produce design drawings for ship construction that consider material availability and ease of construction (producibility).

Integral to the process review was an evaluation of computer tools and software available to support the next generation of submarine design and construction. CATIA, the IBM/Dassault Digital Design System, and CATIA Data Manager (CDM), were selected as the base set of programs. These integrated tools have enabled both the production of the highest quality construction drawings, and an efficient change process, which reduces the average design change period from many days to a fraction of a day. Four key elements have been hallmarks of recent successful military and commercial programs:

- *A clearly defined program concept,*
- *Concurrent engineering,*
- *Formation and full utilization of a complete computer design database, and*
- *An organizational structure that facilitates concurrent engineering.*

PROGRAM CONCEPT DEFINITION

Concept planning for the country's next generation attack submarine began with one objective: Produce a less expensive, very capable alternative to the SEAWOLF Class submarine. The design objective of the NSSN Program is to produce a multi-mission submarine with SEAWOLF acoustic performance, the capability for efficient mission equipment modification, with acquisition cost equal to, or lower than, the cost of additional SSN 688 I's, and low life cycle cost.

As part of the shipyard and Navy concept formulation (CONFORM) efforts, numerous ship design alternatives involving significant parameter variations were studied in detail with appropriate tradeoffs considered before deciding on the baseline NSSN design characteristics. These evaluations were performed by an integrated team of designers, engineers, shipbuilders, planners, quality control experts, and cost estimators, who worked closely with the Navy in the evaluation of each alternative.

A structured evaluation process for platform integration, was used to establish design parameters. This evaluation and review of ship design alternatives is an integral part of the early design phase of every submarine program. However, the significant difference for the NSSN Program is the use of computerized solid modeling tools. Many variations of basic designs were studied in a shorter period with greater accuracy than on past submarine programs. By establishing this process, potential performance improvements have been and are continually being evaluated based on cost and overall platform capability.

The NSSN modular design will enable it to respond to changing missions, threats, systems, and resources. New technologies and components can be inserted during construction or backfit to enhance operational capabilities and reduce life cycle costs.

Concurrent Engineering

The NSSN Program is a closely integrated effort. The shipyard and the Navy worked together in a common office for several months to develop the NSSN Ship Specifications. Close communication between all parties has been achieved via concurrent engineering through the “Design Build” team process. Teams practice concurrent engineering by grouping designers, engineers, ship-builders, material personnel, planners, life-cycle support and environmental impact personnel, quality and cost personnel, equipment suppliers, representatives of Knolls Atomic Power Laboratory (KAPL), Bettis Atomic Power Laboratory, the Navy Supervisor of Shipbuilding (SUPSHIP), Groton, and other Navy representatives in an active design process. By integrating functional specialties ondesign build teams, the shipbuilder is able to tailor the design to suit the planned method of construction. At issue, design drawings suit the shipbuilder’s construction plan. This designer/shipbuilder interaction results in the most producible ship design.

All activities play a role in the development of design products. The results are:

- High quality construction deliverables and
- Fewer changes are required/due to design errors.

Problems raised by each agency are resolved during the development process rather than during construction. An integrated design involves all stakeholders up front, where it counts. Integration of Government input not only reduces the number of formal Government approvals, but also results in a reduction of the overall approval administration documents.

The NSSN concurrent engineering process is a leadership approach that empowers design build teams to develop the design products.

The teams are given authority based on program objectives to ensure that their specific products are developed in a timely, efficient, producible and high quality manner.

The NSSN concurrent engineering process has been developed in concert with design and construction labor unions. It is a working partnership in which union members are active members of design build teams. Union participation as partners in the entire concurrent engineering effort has fostered a mutual respect for the talents that are contributed. Union leadership and Corporation leadership are committed to working together as an efficient business team for the mutual benefit of the employees, the shipyard, and the Navy.

Computerized Design Database

The NSSN Program utilizes a substantial computerized design database which enables full integration of all activities. Each functional discipline has real-time access to the database so that their design efforts can be performed concurrently. Traditionally, this has been a series process with paper being transferred back and forth resulting in a step function rather than a smooth continuous design effort. In addition, without a centrally controlled database, design development occasionally proceeded with different arrangement baselines, which led to rework. With the design data available on a digital network, production can be facilitated without the need for manual or graphical hard copy transfer of data. The same data used for the design can be used to drive numerically controlled manufacturing processes from the design database without physical drawings. The database can directly control cutting torches and pipe bending machines.

The primary interface between the design build teams and the electronic design database takes place in Electronic Visualization System (EVS) rooms. There are five EVS rooms at the shipyard, and additional rooms at KAPL, Navy offices, and at key equipment suppliers' facilities. These rooms provide full multimedia presenta-tion of the design and permit interaction with it.

Close communication via video conferencing provides KAPL and the Navy an in-depth knowledge of the design and its progress, as well as fully utilizing their knowledge and contribution to achieve the best design. By using common electronic data, the need for physical models and mockups is substantially reduced. Collaboration takes place through digital data exchange and through continual design review of product model data using the electronic mockup. These data links enable the design groups to participate in model tours/reviews and conferences, thereby establishing a higher level of participation, contribution, and timely concurrence, as the design progresses.

The Design Build team members, including equipment suppliers and customer personnel, can see the details of the design at any stage of development and can interactively create, view, and modify design information. Objects can be instantaneously manipulated. Immediate feedback enables team members to identify and correct problems. Each week, electronic video conferences are conducted between the involved design parties to review the detailed design status, addressing problems that require discussion and joint resolution.

The computer database is a full service resource which contains all the information needed to support current activities such as procurement, construction drawings, automated production, logistics, electronic mockups, and downstream activities such as future repair, replacement or modification needs. As such, this database becomes both a tool for initial development of the design, for ship construction, and for its through-life support.

Organizational Structure

Successful concurrent engineering requires that an organization be structured to accommodate co-located and/or video-linked design build teams by including all appropriate functional areas. The organization structure must also convey to the design build teams the authority and responsibility for their products.

An Electric Boat Program Manager has been appointed, who has overall ship design and construction responsibility for the Program. This Program organiza-tion structure ensures a concentrated focus for the entire design and construction effort, as well as establishing a single point of contact for all Program interfaces from the beginning of design through life cycle support of the ships.

The organizational structure instituted for multi-function, co-located design build teams, eliminates independent product development in favor of truly integrated product environment development. It includes about 75 System Integration Teams, who design complete systems and structures throughout the ship. There are 15 Major Area Teams that are responsible for design of the major construction modules of the overall ship assembly. These teams provide the continuity of knowledge from design through construction and delivery.

Each design build team is held responsible for its products. This assignment of responsibility takes advantage of multi-discipline teaming, and fully utilizes discipline-specific expertise in the shipyard, in the suppliers' organizations, and in the Navy. Organizationally, these knowledgeable resources are designing the ship for efficient construction.

RESULTS

Four years into the new design and engineering process, the New Attack Submarine is taking shape at a brisk pace. What were once digital concepts on a screen are quickly becoming a validated design and detail construction deliverables. The defined program concept, concurrent engineering, use of a totally computerized design database, and a coordinated organizational structure have facilitated initiatives such as the following which have been implemented to improve design and construction performance, improve military capability and reliability, while reducing acquisition and life cycle cost. Results of this process include the following.

- A fully integrated master schedule has been developed which defines and integrates all design and construction activities from start of design through ship delivery. This schedule provides each activity the ability to review and plan the work tasks 2 - 3 years in advance.
- Shipboard systems have been simplified with a reduction in shipboard equipment.
- A fully comprehensive cost reduction program has been instituted covering design and construction processes for initial acquisition and life cycle support. Approximately 4,000 "good ideas" have been identified and evaluated by the shipyard, equipment suppliers, and customer organizations.
- Parts standardization has drastically reduced the number of different parts used. The NSSN design uses just 1/5 to 1/3 the number of unique parts used in previous designs.
- Early involvement of equipment suppliers in equipment specification development allows use of existing products and processes rather than forcing unique design and test requirements on suppliers.
- Commercial specifications rather than military specifications have been invoked where possible. For example, 90% of the fasteners used on NSSN are commercial specification.
- Environmental considerations are addressed for procurement, construction, life cycle support activities and disposal costs.

The design knowledge gained by the design build teams, the tailoring of the design for producibility, the refinement of the design developed through computer modeling, the standardization of material parts, and the initiatives taken to ensure timely material availability, will all contribute to an efficient construction process never before experienced on a U.S. nuclear submarine lead ship of a class. Integration of design and construction personnel in the design development process will greatly facilitate cost effective construction support because both functions will have participated in development of the design drawings and construction plan.

CONCLUSION

In this era of changing defense requirements, emphasis is shifting away from weapons systems designed to counter specific targets, and is moving more toward versatile systems that are effective against a broad range of threats and readily adaptable to evolving missions. Such is the case with the New Attack Submarine. As the first U.S. nuclear submarine designed to face the certain, but indistinct challenges of the next century, it must be adaptable to multiple missions and unforeseen scenarios worldwide. Its military capabilities must cover the warfare spectrum from covert surveillance and deployment of Special Forces to sudden attacks against land targets with precision missiles. And, the price to acquire and maintain that submarine must be one that the nation can afford.

The New Attack Submarine design is proceeding utilizing the four key elements found successful in other major production programs:

- A clear definition of the program concept,
- A world class concurrent engineering process,
- State-of-the-art tools, and
- An organization tailored for the New Attack
- Submarine design and construction evolution.

Working together, the Navy and Electric Boat are designing a submarine that will provide the required military capabilities while meeting cost objectives.

ACKNOWLEDGMENTS

The authors are indebted to the professional men and women of Electric Boat and the Navy who contributed to the process development and its implementation through their participation on the Design Build teams.

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