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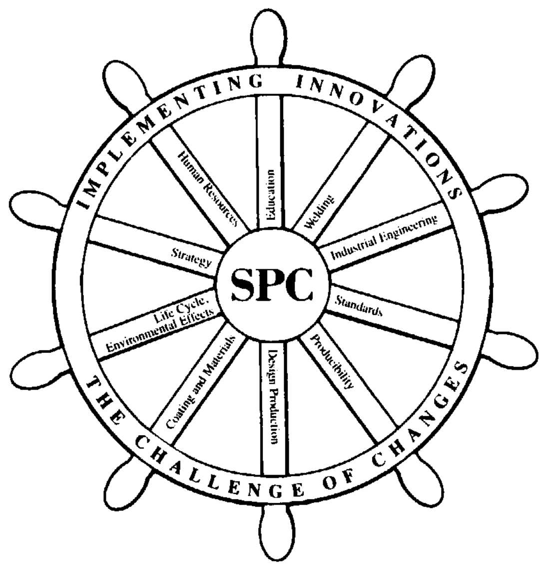

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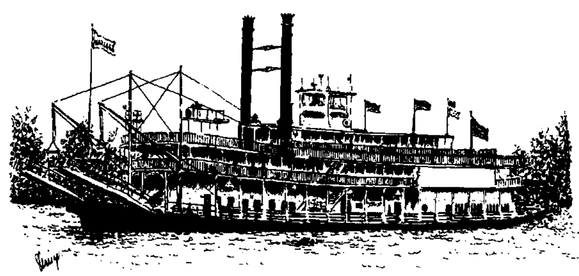

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Producibility in the Naval Ship Design Process: A Progress Report

No. 4A-1

Robert G. Keane, Jr., Life Member, and Howard Fireman, Associate Member, Naval Sea Systems Command

ABSTRACT[1]

In October 1989, A Ship Design for Producibility Workshop was held by the Naval Sea Systems Command (NAVSEA) at the David Taylor Research Center (DTRC). The purpose of the workshop was 'To develop the framework of a plan to integrate producibility concepts and processes into the NAVSEA Ship Design Process.' The major recommendations of the workshop included initiatives related to increased training of NAVSEA design engineers in modem ship production concepts, development of producibility design tools and practices for use by NAVSEA design engineers, improved cost models, implementation of produability strategies for ship design process improvements, modification to existing acquisition practices, and improved three-dimensional (3-D) digital data transfer. The workshop was one of NAVSEA's first Total Quality Leadership (TQL) initiatives and was subsequently expanded into the Ship Design, Acquisition and Construction @AC) Process Improvement Project. This paper reports on the major findings and recommendations of the workshop, the near term accomplishments since the workshop, and the long range strategic plan for continuously improving producibility in the Naval Ship Design Process.

l The views expressed herein are the opinions of the authors and not necessarily those of the Department of Defense or the Department of the Navy.

ACRONYMS

ASMS - Advanced Surface Machinery System
ATC - Affordability Through Commonality
CAD - Computer Aided Design
CDRLs - Contract Data Requirements Lists
CEFs - Critical Evaluation Factors
CONREP - Military Sealift Command Construction Representatives
C41- Command/Control/Communication/ Computers/Intelligence

DAC - Design, Acquisition and Construction
DOD - Department of Defense
DTRC - David Taylor Research Center
ECB - Executive Control Board
ESG - Executive Steering Group
FY - Fiscal Year
I-&I&E - Hull, Mechanical, and Electrical
MlT -Massachusetts Institute of Technology
MOU - Memorandum of Understanding
NAVSEA - Naval Sea Systems Command
NIDDESC - Navy-Industry Digital Data Exchange Standards Committee
NRC - National Research Council
NSRP - National Shipbuilding Research Program
PARMs - Participating Managers
PATs - Process Action Teams
PDES - Product Data Exchange Standard

PODAC - Product Oriented Design and Construction
QMBs - Quality Management Boards
RESUPSHIP - Resident Supervisor of shipbuilding
SBIR - Small Business Innovative Research
SDM - Ship Design Manager
SWATH - Small Waterplane Area Twin Hull
TQL - Total Quality Leadership
U.S. - United States
3-D - Three-Dimensional

STATEMENT OF THE PROBLEM

The U.S. Navy is not fully realizing the significant benefits which could accrue from modem shipbuilding methods. These benefits include reduced construction cost, improved quality and reduced construction time.

During the last decade, many U.S. shipbuilding yards have made major improvements in the way ships are produced, adopting zone-oriented and related modem construction techniques. Effectively implementing these shipbuilding advances has frequently required changes to the specifications, drawings and other contractual documents typical of a Navy ship contract design package. Despite the keen interest that the Navy has in producibility, the NAVSEA ship design process has not kept pace with developments in the shipbuilding industry. To more fully realize the significant benefits of modem ship construction, actions must be taken to consistently include producibility in future Navy ship designs.

INTRODUCI'ION

TheU.S. shipbuilding industry continues to be generally uncompetitive in commercial shipbuilding on a world scale. The predominant market of the leading U.S. shipbuilders today is the U.S. Navy. The reasons for and implications of this situation are of significant concern to the Navy, whose dependence on the industry is so great.

The Navy asked the National Research Council (NRC) of the National Academy of Sciences to identify promising technology developments that have the potential to improve the productivity of the U.S. shipbuilding industry. The NRC report, references (1) and (2), which was developed by the Marine Board, noted that the U.S. shipbuilding industry is in the midst of a fundamental transition. U.S. shipbuilders are introducing advanced ship production technologies such as zone-oriented methods, with resultant productivity improvements in terms of reductions in construction man-hours and schedules, and an improvement in quality.

The U.S. shipbuilding industry has drastically changed its construction process in recent years. The use of 'modular,' 'zone-oriented,' 'group technology, ' and other construction techniques have replaced the traditional 'system-oriented' approach. These changes have come about as a result of projects which analyzed the shipbuilding practices used by the highly productive Japanese shipyards. Many of these projects were funded by the National Shipbuilding Research Program (NSRP) and some were conducted by U.S. shipbuilders at their own expense. These analyses demonstrated that it was not advanced facilities or a superior work force that allowed Japan to be highly productive, but rather their rigorous planning and organization of work using good, basic industrial engineering concepts.

The NRC Marine Board emphasized that the Navy needs to take better advantage of the productivity improvements which these developments offer. One of the major recommendations in the report (1) states:

> To foster the use of zone-oriented ship construction, the Navy should:

1. develop means to apply the technology in prehminary and contract design,
2. educate its personnel on the advances being embraced by shipbuilders so that Navy practices and procedures can be adapted in support of them, and
3. work together with its shipbuilders to provide a receptive environment for the use of productivity improving technology.

ln the early stages of the Navy ship design process , NAVSEA has not generally placed strong emphasis on producibility. Mission performance, integrated logistic suppa manning and other operational requirements are considered higher priorities. Over the past five years, however, much interest and some improvements in specific programs have occurred. References (3) through (10) highlight just some of the activities in this area.

Long Range Obiective

In recognition of the problem, a NAVSEA Steering Committee was established in the Spring of 1989 under the chairmanship of the Deputy Director of the Ship Design Group. The Committee established a long range objective as:

> To integrate ship produciiility concepts and processes into the NAVSEA ship design process.

The Need for a Workshop

An early decision of the Steering Committee was to use a workshop to define the actions needed to achieve this long range objective. They held a two-day planning session in June 1989 to develop the framework for a larger group to generate a more complete set of recommendations. This process improvement is one of the first TQL initiatives of the Naval Sea Systems Command. That planning session used the diverge/converge consensus building process as described in reference (11) to reach cotiensus on the eleven top priority actions to be addressed by the workshop. Those actions were grouped into six categories which became the basis of six working groups which were established for the workshop in October 1989. The major findings and recommendations of the six working groups are described below.

Objective of the Workshop

In comparison with the long range objective, the Steering Committee defined the objective of the workshop more narrowly as:

> To develop the framework of a plan to integrate produability concepts and processes into the NAVSEA ship design process.

In order to fully address all these aspects of ship design for producibility, representatives from the Navy, shipbuilders, academia and design agents were requested to participate. The Producibility Workshop was held on 24 through 26 October 1989 at the David Taylor Research Center, Carderock, Maryland. The primary product of the workshop was an overall strategy for including producibility in the NAVSEA ship design process with an enumeration of specific actions which needed to be taken.

Workshop Definition of Producibility

Ship producibiity takes on different meanings depending on perspective and point in time during the designlacquisitionlconstruction cycle. For the purposes of the workshop, the focus was on reducing

[2] The phrase ‘early stage design’ in this paper refers to feasibility studies and preliminary/contract design.

Navy ship acquisition costs through the greater use of design features and acquisition practices which facilitate shipyard production. The following definition was adopted:

> Ship producibility refers to any concept or action that reduces the ship acquisition cost without any degradation of performance.

Ideally, a successful producibility concept will provide better integration of design and production activities, resulting in savings in production labor, material and/or construction time. Given that trade-offs among these three areas can result in a combination of pluses and minuses, the net result must still be lower acquisition cost. Performance degradation includes any facet of the ship's performance after delivery, including: mission capability; maintenance/ logistics requirements; expected service life of materials; fuel consumption; or any life cycle cost increases.

The adopted definition was not ideally suited to the purposes of all of the workshop attendees. Some believed that it did not encompass their particular concerns. However, the focus was not on definition, because the purpose of the definition was to facilitate communication, not to hinder analysis.

WORKSHOP MAJOR FINDINGS

The following summaries provide an overall thrust of both the planning session and the workshop.

The overall finding of the workshop was:

- the current early stage ship design process does not adequately address producibility, and the Navy is not fully realizing the significant cost and schedule benefits of the latest advances in ship construction technology.

There are numerous reasons for this, the most important being grouped into the following six categories.

<u>Training</u>

- NAVSEA ship designers are not sufficiently knowledgeable of the latest advances in ship construction technology to incorporate producibility features in the design.
- Existing training at NAVSEA in ship construction technology is extremely limited.

<u>Engineering Tools</u>

- There are no community-wide recognized or institutionalized producibility requirements.
- NAVSEA design policies, procedures, and standards do not routinely address design trade-offs relative to ship production efficiency and lack quantitative measures of producibility.

<u>Cost Models</u>

- The NAVSEA ship acquisition cost estimating process used in assessing the cost impacts of different design options is not adequately sensitive to producibility considerations in a ship design.
- The process infrastructure and methods required to support the integration of acquisition, design, construction and cost engineering are not clearly identified.

<u>StrateQ</u>

- There is a lack of concurrent product and process design and an inconsistent approach to addressing producibility among ship designs.

Acquisition Practices

- Acquisition strategy has a large impact on design and the design approach.

- Ship acquisition practices frequently inhibit incorporation of design changes by shipbuilders which could enhance producibility.

- There are a large number of acquisition program factors which influence the ship detail design and construction process.

3-D Digital Data Transfer

- Making 3-D digital data available to shipbuilders can result in significant reductions in costs by eliminating expenses, time and errors due to regeneration of design data. NAVSEA has only limited ability to generate, utilize and transfer this type of data.

WORKSHOP MAJOR RECOMMENDATIONS

The workshop generated a number of recommendations to improve the inclusion of producibility in Naval ship designs.

Training

- Establish extensive training programs to educate NAVSEA engineers in modem shipbuilding methods and in the application of producibility practices.

Training programs are needed to educate ship design engineers in modem ship production techniques and design features which accommodate them. These need to be thoroughly and continually updated programs, coupled with "hands-on' experience that will make producibility a familiar subject to the designers. The long term goal is to enable engineers to routinely include producibiity in their design tradeoffs.

Engineering Tools

- Determine the most important measures of produabihty to use in ship design.

- Update computer based ship design synthesis models to include producibiity features.

- Provide a Produabity Design Practices Manual with 'do's and don't's' to the NAVSEA ship design community.

Engineering tools constitute the technology base which will enable NAVSEA design engineers to identify, evaluate and select ship producibility concepts in early stage ship design. A produabihty design practices manual should be a catalog of lessons learned and feedback data from ship construction processes. Measures of producibility would enable quantification of pro ducibility concept trade-offs. Inclusion of producibility features in ship design synthesis models will facilitate the evaluation of ship impacts aeated by producibiity concepts. The substance of producibility engineering tools should be included in the producibility training discussed above.

cost Models

- Determine cost drivers and focus on high cost drivers.

- Modify the NAVSEA ship acquisition cost estimating process to reflect producibility aspects.

To accomplish these 'cost' recommendations, the process infrastructure and tools required to support the integration of acquisition, design, construction, and cost engineering must be identified. Next, cost analysis must be introduced during the earliest stages of this process. The cost and design communities should function as a team with both participants having been aoss-trained in the areas of cost estimating, construction, and design technologies. The cost models developed for this effort need to be sensitive to producibility constraints. They need to be structured to reflect the relationship of labor costs to changes in design and manufacturing technologies and facilities improvements. This should include material alternatives which have impacts on labor costs. These cost models can be developed by evaluating existing cost data, by examining shipbuilder proposals, and by requiring shipbuilders to structure return cost data to reflect construction procedures used. These models can be tailored to produability questions in specific designs. After the development of the costing models, a method should be establishedwherebyproduabilityconstraining actions can be identified and priced as trade-off analyses in specific designs.

Strategy

- Navy and industry management must commit sufficient resources to ship design for improved producibility in order to realize significant resource savings during ship construction.

Improved producibility will require the establishment of produability goals and the conduct of producibiity trade-offs in early stage design. The additional "up front" producibility work will require added design funds in order to achieve a net reduction of the total resources required to design and construct a ship. With this goal in mind, the required **resources should be** quantified.

- Modify the ship design process to maximize shipbuilders' early participation in NAVSEA ship design and to foster concurrent product and process design.

The current ship design and construction process needs to be modified so that producibility is considered throughout the process. Product design is the engineering activities required which define the ship to be constructed. Process design is the definition of the process by which the ship is to be constructed. The design of the construction process is currently delayed until atIer contract design, very late in the overall design cycle. By including process design in earlier stages, all design phases will consider how design decisions will be implemented by the shipyard. The Navy can accommodate shipbuilder production processes where they are acceptable relative to ship operational requirements. This can be accomplished by evaluating the implications of designing to fit the process before basic ship configuration features become locked-in.

- Establish a framework or methodology for making producibility decisions within the ship design process.

While different ship types and programs may require focusing on different details of producibility, a generic framework should have elements common to all ship acquisition programs. A consistent systematic procedure for considering producibility during early stage design is needed in order to institutionalize producibility as an inherent part of every Navy ship design.

Acquisition Practices

- Revise/apply contract terms and conditions to eliminate producibility constraints and make better use of contract incentives.

- Make better use of cost plus contracts for lead ship design and construction.

Some of the most significant actions which NAVSEA can take in early stage ship design to enhance produability are aimed at removing impediments to shipbuilder producibility improvements. Many of the impediments are created by the Navy being overly sensitive to certain acquisition or contractual matters. Within the legal alternatives, NAVSEA can structure ship acquisition strategies and contract structures to facilitate shipbuilder application of more producible design solutions.

The Navy can encourage shipbuilders to use efficient construction processes by including contract incentives for increased producibility.

3-D Digital Data Transfer

- Establish a phased program to develop NAVSEA capability to generate, utilize and transfer 3-D digital data models.

- Develop appropriate data transfer contractual mechanisms and electronic protocol.

The NAVSEA ship contract design process produces a set of specifications and two dimensional hard copy drawings which together define the ship that the Navy wishes to acquire. Many of the drawings are based on three dimensional databases which contain additional information not contained on the two dimensional drawings. Generating and transferring this 3-D digital data electronically to shipbuilders will avoid human error in the translation, will help eliminate expenses and time due to regeneration of databases, will reduce production rework man-hours due to interferences, and will result in other improvements in the transition from design to production.

Designers and builders use information in different manners and inherently categorize information differently. Additionally, there are problems inherent in the transfer of information electronically, as communications protocols must be established. The digital data protocols need to be established which are necessarily unique to the marine industry and support their use. Furthermore, NAVSEA must inaease its investment in acquiring the necessary engineering software and hardware, and in training its engineers to effectively use this powerful capability.

Summary

The recommendations generated in the Ship Design for Producibility Workshop are action items which need to be pursued for implementation. The workshop proceedings and recommendations address the basic elements of the Navy ship design process, including people, methods, processes and products. They are illustrated in Figure 1. Changes are needed in all of these elements in order to achieve the goal of improved ship design for producibility. Fundamental changes in the ship design and construction process will be required. A long term commitment to improving this very complex process is required of all involved Navy and industry participants.

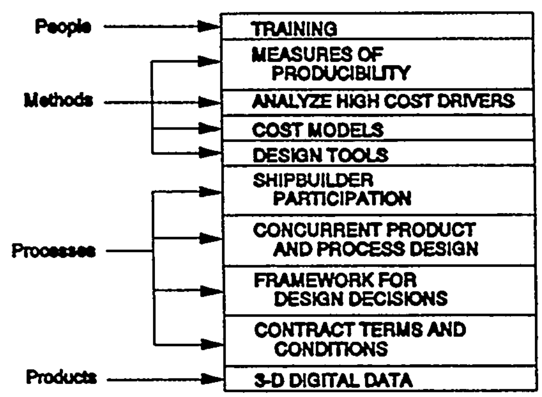


Figure 1 Design for Producibility Elements

INTEGRATING PRODUCIBILITY INTO THE SHIP DESIGN PROCESS

Like any other design process, the evolution of a ship design is a series of iterations beginning with a very broad concept and becoming more specifically defined with each iteration or stage of design. The fundamental reason for conducting the Producibility Workshop was to identify the actions which need to be taken in early stage (pre-detail) design to accommodate efficient ship construction. In order to address that purpose, it is necessary to understand:

- what is meant by the phrase 'early stage ship design,
- which elements of a ship design are "locked in" in early stage design, and
- which producibility considerations must be evaluated during early stage ship design.

This section of the paper provides an overview of the ship design process, indicates the parts of it which are referred to as 'early stage,' and describes a process for evaluating and deciding on producibility considerations during early stage design.

The description of the design process given here is brief and only sufficient to place the rest of the paper in context. The process has been described in more detail in several published works. References (12), (13), and (14) provide more detailed descriptions of the Navy ship design process.

Overview of the Navy Ship Design Process

Figures 2 and 3 illustrate the nominal phases of the Navy Ship Design Process and how they fit into the Department of Defense (DOD) Acquisition Process. Initial requirements are derived from threat assessments coupled with operational analysis. The desired ship characteristics are estimated during exploratory design performed within the Navy. The resulting operational requirements for a new ship acquisition form the starting point for the design process.

Ship design now proceeds through phases: feasibility studies, in which key characteristics of the ship are firmed up (i.e. major dimension, weights, configuration); preliminary design during which all technical areas are initially engineered; and contract design, where the final technical package (i.e. drawings and ship spetication) is developed for a contract award. These phases typically take over two years to complete and constitute what is referred to throughout this report as early stage design. The Navy generally develops its own designs, but interested shipbuilders are often involved during contract design to provide guidance on construction preferences before the specifications are finalized. Concurrent with the engineering work are the programmatic and logistics preparations. Part of this effort is incorporated into the contract, which contains numerous requirements for detail design and construction.

A Conslstent Process for Producibility Design Decisions

What is needed is a consistent decision process for integrating producibility into the many different naval ship designs. A true integration requires a new 'way of thinking,' a new attitude or culture that makes producibility an integral part of Navy ship acquisition activities.

The general approach to producibility will be the same no matter what type of ship is involved. However, the details of the analysis and the related results in a particular ship acquisition program will depend on many aspects, including: number of ships to be built, submarine or surface ship, combatant or non-combatant and degree of complexity. The competitive structure of the industry is also important. For an airaaft carrier construction program, there is only one qualified bidder; for modem submarines, two bidders; for major surface combatants not more than half a dozen; and about a dozen for small non-

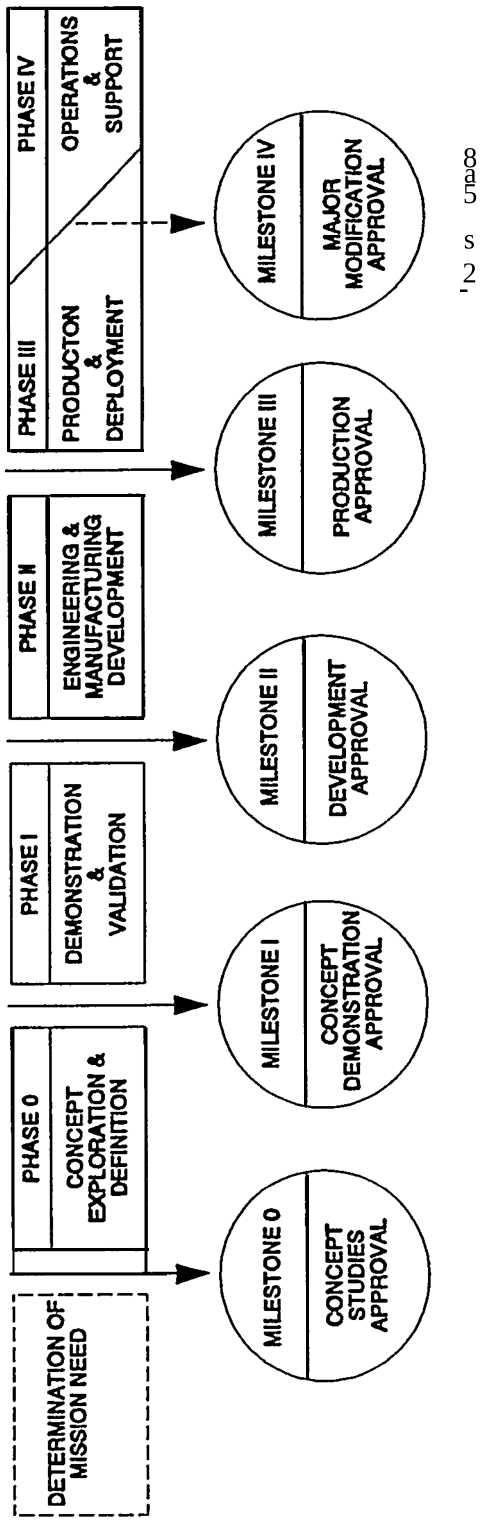


Figure 2 DOD Acquisition Process

combatants. Because of the wide range of factors involved, each acquisition program must be examined on its own merits in order to define the most appropriate producibility approach. These factors will form the basis of decision criteria to be applied in analyzing potential producibility concepts in specific ship designs. References (3), (9), and (15) describe examples of producibiity issues which have been considered during the design efforts of three specific ship acquisition programs.

A Framework for Produabilitv Desia Decisions

While different ship types and programs may require focusing on different details of producibility, a generic framework should have elements common to all ship acquisition programs. Although the Producibility Workshop definition for producibility did not allow for any degradation of performance, the process does provide a means to trade-off improved producibility against performance. A systematic plan for considering producibility in the design and construction process should cover four steps, which follow:

1. Identify potential producibility concepts.

2. Evaluate producibility concept ship impacts and estimate cost.

3. Select desirable producibility concepts.

4. Provide a lessons learned mechanism and feedback loop.

These steps are shown as an iterative evaluation model in Figure 4, which was provided by Professor Henry S. Marcus of Massachusetts Institute ofTechnology (MIT) (who was instrumental in initiating the workshop). The evaluation model presented here is generalized and simplified. The four key steps can relate to analysis of a

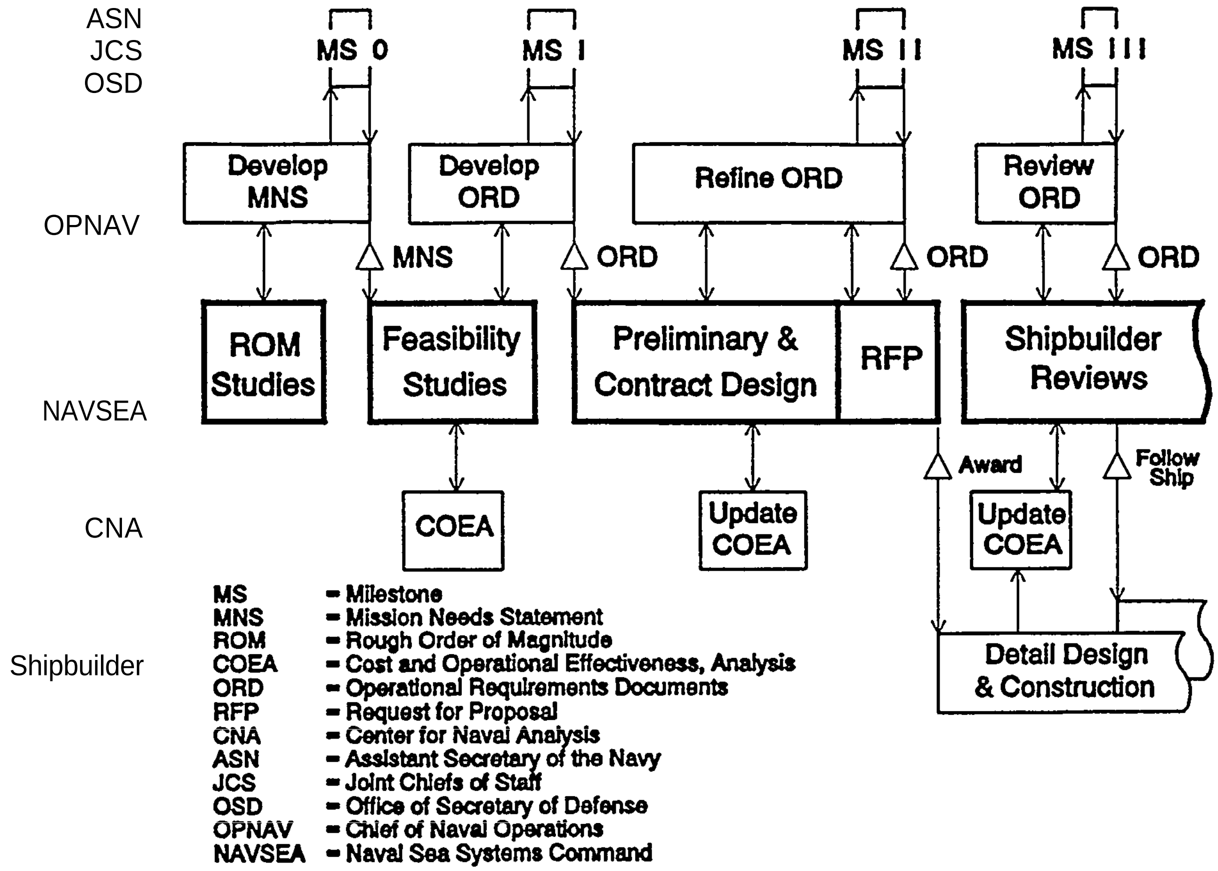


Figure 3 Overview of the Navy Ship Design Process

subsystem component or a dramatic new way of integrating design and production. The parallelograms indicate data bases, the content of which will vary with the topic under analysis. The rectangles refer to key activities (although in the interest of simplification, more than one activity may be involved in a single rectangle). The diamonds indicate key “Go/No Go” decision points.

The criteria used in this general model may also vary. The straightforward definition for produability used in the workshop demanded that a good producibility concept must reduce ship acquisition cost without any degradation of mission critical performance. A more complicated criterion might allow for trade-offs between produability and other ship design attributes. In addition, it may be desirable to use different criteria at different design phases.

The Navy has conducted producibility enhancement efforts for several ship designs. The main characteristics common to these efforts have been shipbuilder suggestion inputs and Navy review of the suggestions. Though these efforts have led to the acceptance of many beneficial ideas in Navy designs, they have not realized full potential. In most of the past Navy efforts, there was no systematic approach to review, no means of judging cost/effectiveness, and no decision criteria as a basis for selecting producibility concepts. The approach of treating producibility in an unstructured, subjective manner is inefficient, and less than fully effective.

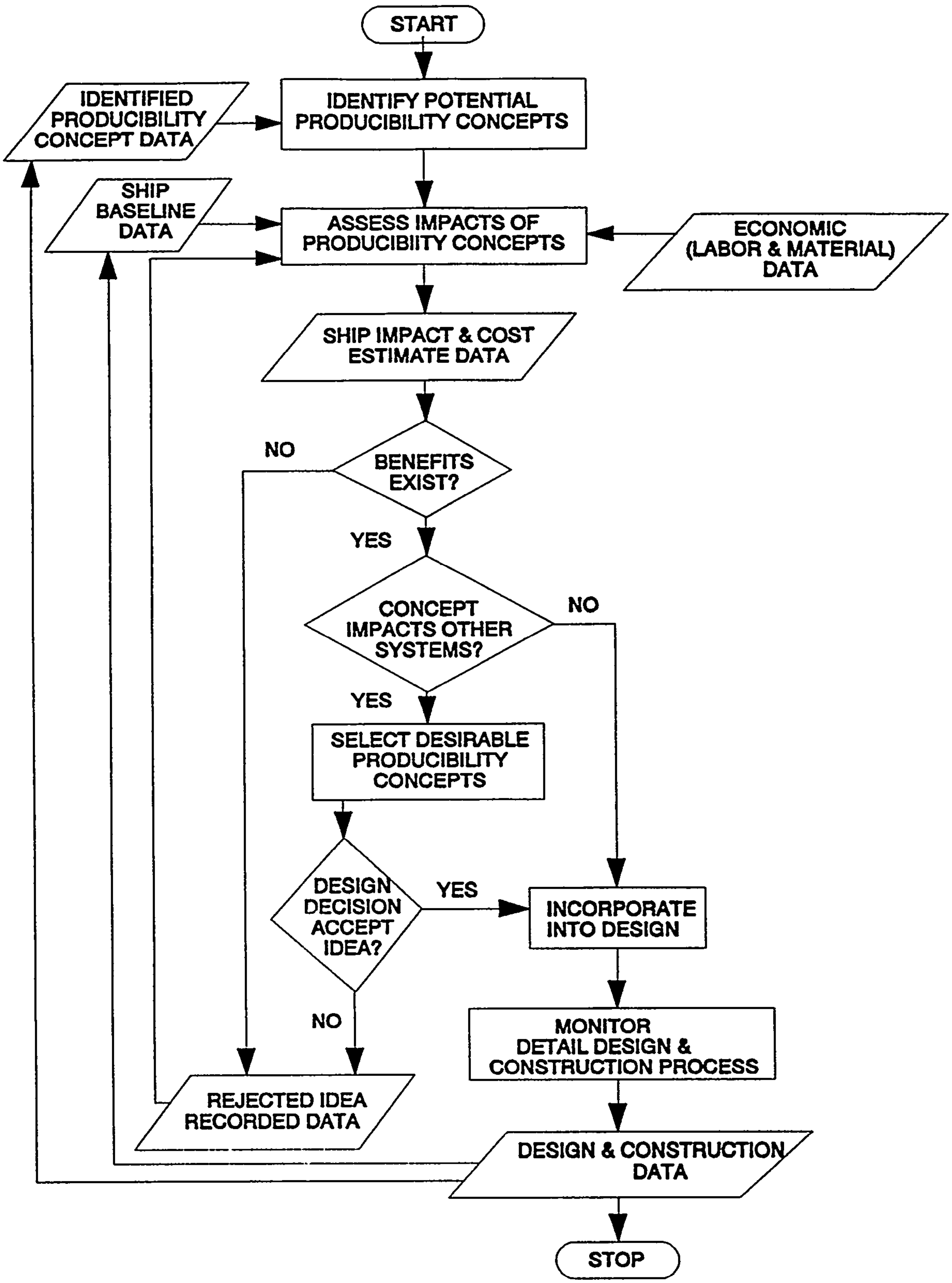


Figure 4 Framework for Producibility Design Decisions

The unstructured approach to designing for producibility lacks selection criteria, which results in inconsistencies in review and evaluation modes. In one ship design, for example, the Navy received over 4,000 shipbuilder ideas, and the review of these was unstructured. Receipt of shipbuilder comments at non-specified times complicated NAVSEA response mechanisms and the sheer numbers were an unmanageable quantity within the time allowed. The approach to collect suggestions was not exhaustive and there was no rationale for selection of suggestions for review and evaluation. The reviewers had neither the time nor a systematic means of quantifying producibility enhancement. The decision makers were provided with too little, too much or the wrong type of information necessary to make good decisions.

The shortcomings of past NAVSEA ship producibility efforts can be alleviated by developing tools to quantify costs and effectiveness of concepts and by integrating producibility efforts into the main stream of NAVSEA ship design development. There have been benefits from past NAVSEA producibility efforts. There is potential for significantly greater benefits through use of a rational, structured approach to identity, evaluate and select producibility enhancements.

NEAR TERM ACCOMPLISHMENTS

Since the October 1989 workshop progress has been made on many of the workshop major fmdings and recommendations. Significant accomplishments have occurred in training of NAVSEA ship design personnel, integrating producibility in ship design and acquisition strategies, and implementing 3-D digital data transfer. Little progress has been made in development of engineering design tools for evaluating the producibility of alternate designs, improvement in cost models that can quantitatively assess producibiity changes in design, and modiication of acquisition practices to maximize benefits of producibility. The following is a summary of progress in each of the six categories of workshop findings and recommendations.

TRAINING

Training NAVSEA ship designers in ship construction methods and producibility concepts was the top priority recommendation of the workshop and significant progress is being made in achieving this objective. Training, or more appropriately, education, has been a continuing and widening process including formal training courses offered at NAVSEA, on the job training and work assignments, and formal graduate level education under NAVSEA's long term training program. The following are a few examples of progress being made in this area:

NAVSEA Professor of Ship Production

For a number of years, NAVSEA has had a Memorandum of Understanding (MOU) with the University of Michigan. This MOU established the position of NAVSEA Professor of Ship Production, currently held by Professor Howard M. Bunch, who has developed educational and training courses for NAVSEA ship design engineers. The courses developed include:

- Advanced Ship Production,
- Design for Producibility, and
- Quality Function Deployment.

These courses have been taught by Professor Bunch under the auspices of the NAVSEA Institute and have been attended by approximately 300 NAVSEA personnel. These initial courses have emphasized basic or fundamental knowledge. As results are achieved in the development of new tools and techniques, these will be incorporated into the training. Finally, as shipbuilding technology continues to evolve, new lessons learned must feedback and be taught to the early stage ship designers.

NSRP Particination

NAVSEA commitment to NSRP has provided the opportunity for many NAVSEA engineers to participate on various NSRP panels. NAVSEA engineers are actively participating in panels SP4 (Design and Production Integration), SP-6 (Standards), SP-9 (Education). NAVSEA participation in the Executive Control Board (ECB) has been increased to include representation of NAVSEA Ship Program Managers. Inaeased participation in NSRP is offering immediate feedback and training to NAVSEA personnel. This feedback will keep NAVSEA engineers in touch with ongoing research in this area.

Shinvard On-Site Assignment of NAVSEA Ship Design Manager (SDM)

One of the many findings of the DAC Process Improvement Study was that NAVSEA should collocate the SDM at the Resident Supervisor of Shipbuilding (RESUPSHIP) Office during the Detail Design phase. The typical NAVSEA Contract Design package has a large number of contract drawings, contract guidance drawings, specification pages, project peculiar documents, study plans, etc. The transition phase from the NAVSEA Contract Design to the Shipbuilder Detail Design typically generates a significant number of questions, highlights mistakes in the contract package and general misunderstandings of the drawings and/or specifications. This transition phase is critical to the overall success of the shipbuilding program.

The T-AGOS 23 Construction program was selected as the NAVSEA prototype program for assignment of the SDM. The T-AGOS 23 has the challenge as the U.S. Navy’s largest Small Waterplane Area Twin Hull (SWATH) ship. The intent was to improve the transition from design to production by solving minor and some major design problems in real time, on-site at the RESUPSHIP in Tampa, Florida. This particular shipbuilding program is supported at RESUPSHP by Military Sealift Command Construction Representatives (MSC CONREP). The small integrated team of NAVSEA SDM, MSC CONREP, and RESUPSHIP personnel worked closely together towards achieving these objectives, that is to solve problems in a timely manner and get it right the first time. The SDM’s participation locally at RESUPSHIP offered the opportunity to have an instant NAVSEA response as anunofficial member of the RESUPSHIP staff.

The T-AGOS 23 was awarded to Tampa Shipyard on 28 March 1991. The six-month experiment at RESUPSHIP Tampa started in July 1991. The results of this prototype assignment were very encouraging. The SDM was warmly received by both RESUPSHIP and MSC CONREP. Numerous design questions were promptly answered. Several critical engineering change proposals were prepared by the SDM in the field and were quickly sent to the shipbuilder. The assignment of the SDM to the field offered the unique opportunity for all participants to better understand each other’s perspectives and provide a synergism not available dealing through the mail system or through periodic design reviews. The SDM gained “profound knowledge’ of detail design issues, errors in the contract design package, and ship producibility and vendor issues. The field office had the opportunity to better understand the rationale and logic of the contract design package and to more expeditiously get up on the learning curve of unique SWATH technology.

This assignment of the SDM to the RESUPSHIP Office is highly recommended for future shipbuilding programs. The SDM’s tour of duty should be extended for the duration of the detail design. In larger shipbuilding programs, this approach should be extended to the NAVSEA Hull Systems, Ship Machinery Systems, and Mission Systems engineers.

In summary, NAVSEA's commitment to educating and training its ship design and acquisition personnel has made good progress since the Produability Workshop. However, classroom instruction cannot take the place of on-site practical experience. Assignment of early stage ship design personnel to detail design projects at RESUPSHIP Offices is encouraged for all new ship acquisition programs.

ENGINEERING TOOLS

The Producibility Workshop recommendations pose a significant challenge to the Naval ship design and shipbuilding community. In order to produce quantifiable producibility engineering tools that can be of aid in early stage ship design, the naval shipbuilding community will have to develop databases of producibility lessons learned, producibility measures of effectiveness, decision making tools, etc. The long term goal is to integrate engineering tools that address producibility as a primary attribute into the earlier stages of the ship design process.

NAVSEA has a number of ongoing initiatives to achieve this longer term objective. Initiatives have been undertaken with the DOD Small Business Innovative Research (SBIR) program and the NSRP. Successful results from these initiatives will be the foundation of these future engineering tools.

SBlR Proiects

NAVSEA is participating in the Fiscal Year (FY) 92 DOD SBIR Program. This program strives to encourage scientific and technical innovation in areas specifically identified by DOD. Phase I of SBIR projects is to determine the scientific or technical merit and feasibility of ideas (about a l/2 man-year effort). lf Phase I proves to be feasible, DOD will consider further work in Phase II (about 4 to 10 man-years of effort).

NAVSEA has submitted five proposals into the SBIR,program in this area. As of June 1992, contracts were yet to be awarded to pursue the Phase I proposals. The NAVSEA SBIR topics include:

1. Development of Naval Ship Producibility Lessons Learned Database,
2. Shipyard Productivity Measurement,
3. Life Cycle Cost Models for Naval Ship Design,
4. Analysis of Strategic Defense Industrial Technologies, and
5. Modeling Naval Ship Construction Delays.

NSRP - SP 4 Panel Tasks

NSRP SP 4 (Design/Production Integration) has a number of ongoing initiatives that are directly related to development of future engineering tools to aid the designer in addressing producibility during the early stages of ship design. The tasks funded are:

1. Development of Producibility Evaluation Criteria for U. S. Naval Ship Design. This task was funded in the FW 90 NSRP program. The final report is in the process of being submitted for NSRP publication. This study was initiated to:

   a. identity criteria by which the producibility of a design can be evaluated based on the actual work content involved in constructing the design at a shipyard, and

   b. develop standard procedures for using those criteria in evaluating producibility of specific design proposals.

   The results of this ongoing task are presented as part of the 1992 Ship Production Symposium.

2. Development of Generic Build Strategy. This task was approved for the 1992 NSRP program. As of June 1992, the contract for this task has yet to be awarded. This task will produce a generic build strategy as well as a master construction plan to serve as a guide for early stage design and future ship construction planning.

Dynamic Decision Model

During the DAC Process Improvement Study, many process improvements were identified. While consensus was reached that each idea would have a positive effect on the overall process, there was no means to evaluate just how effective the change might be prior to implementation. Toward the end of DAC Phase I, the study team became aware of the possibility to model the whole ship design and acquisition process on a computer. This tool would allow proposed changes to the process to be evaluated as to their impact on time, cost and quality.

A dynamic decision model was chosen for process change evaluation. Such a model, based on ideas of MIT Professor Jay Forrestor, uses control system theory to describe the interactions of a process, allowing for feedback, time, cost, and quality predictions. As of June 1992, the model is in the prototyping stage and operational to a modest level of detail for the design portion of the DAC process. Near term efforts will be to calibrate the model's performance against known past ship designs and test how changes affect the DAC process.

Development of turn-key engineering tools that are quantitatively sensitive to producibility is the goal for early stage naval ship designers. NSRP and NAVSEA have barely saatched the surface in this important area.

COST MODELS

As stated above, little progress has been made in improving cost models such that they can be used to quantitatively assess producibility changes during early stages of design. The first step in improving cost models is the collection of cost data that are consistent with shipbuilding processes.

It has been proposed that NAVSEA conduct a pilot study to resolve problems associated with maintaining cost data continuity. The pilot study would address two major concerns: (1) tracking cost information from the initial budget submittal through ship delivery; and (2) identifying information which will permit NAVSEA to manage and improve internal processes using actual data from the shipbuilders and the participating managers (PARMs) responsible for government furnished equip ment.

The development of accurate cost trends is an essential ingredient to making informed decisions. This requires the capability to resolve differences between similar classes of ships which can have a significant impact on cost forecasts if not properly addressed. By standardizing shipbuilding data collection at a level which permits flexible accounting of programmatic decisions, these difficulties can be resolved.

The concept of managing and improving processes using data is the cornerstone of the Deming philosophy. To gain control of internal processes costs must be captured in an appropriate manner. NAVSEA does not currently collect data from either the shipbuilders or PARMs in a manner useful for managing internal operations, although we are fully committed to continuous process improvement.

The people within NAVSEA who must determine which data, from the vast array of information available, is needed to improve operations are the senior managers who jointly own the internal processes requiring change. Many of these senior managers are currently working on teams as members of three Quality Management Boards (QMBs), sponsored by an Executive Steering Group (ESG), working on behalf of the DAC Process Improvement Program (16). Using the tools developed to support TQL, the QMBs will be asked to identify the Critical Evaluation Factors (CEFs) they would use to measure improvement and manage internal processes.

The cost of acquiring data can be very expensive; therefore, NAVSEA must foster an attitude of not collecting data unless they have specific plans for its use. The possibility that additional information will be required from the shipbuilders and PARMs is real; however, some of the information currently being requested may not be necessary. ln these cases, steps should be taken to eliminate these data submittal requirements.

Considerable planning has been accomplished in support of this pilot study. The need for process improvement in the area of standardizing shipbuilding cost data collection has been carefully documented. The notion that maintaining continuity of cost information throughout the acquisition, managing with data, only requesting needed information, using information wisely, and taking steps to work smarter will allow NAVSEA to be more efficient and better serve its customers. These cost data collection improvements are essential to improving the ship acquisition cost estimating process and ultimately developing cost models that are sensitive to produabity considerations in ship design.

STRATEGY

In June 1991, NAVSEA published a Strategic Plan for Improving the Ship DAC Process (17). The objective of the plan as defined by the NAVSEA Chief Engineer is:

> To identify the critical actions necessary to improve the quality of future ship designs (i.e., meeting customer's requirements) to reduce ship construction costs, life cycle costs and to reduce the time required from establishment of requirements to delivery of the lead Ship.

The DAC Phase II team is working on the implementation of the major recommendations from the Strategic Plan.

Producibilitv Review Teams

NAVSEA has established a framework for making producibility decisions within the ship design process. For new ship acquisitions, Producibility Review Teams are established and are an integral part of the design process for each new design. The Producibility Review Team has multidisciplined membership. Team membership is comprised of knowledgeable and experienced representatives from NAVSEA technical, program management, and contract codes; industry produability consultants; academia; and shipbuilders. Producibility Review Teams have been established and are making producibility decisions on the DDG 51 Flight IIA and CVN 76 ship designs.

CVN 76 Ship Design

The most significant proposed producibility improvements involve modifying the build strategy and addressing long lead time contractor furnished material. Improvements to the basic build strategy must be defined before construction starts. In order to execute a build strategy that inaeases the amount of preouthtting, the critical material must be available. For this reason, the Producibility Review Team recommended that the Navy enter into an advanced planning contract with the shipbuilder to provide sufficient time for the development of a revised build strategy and for the purchase planning of long lead time material.

During contract design a significant producibility improvement effort is planned. The build strategy will be maintained, and wilI be used to evaluate design changes which wiE also be evaluated for produabity. The development of a cost model based on the production process rather than weight is being investigated to support estimating the cost savings of produabiIity improvements.

Shipbuilder Participation

NAVSEA is currently maximizing shipbuilder participation in early stage ship designs that are limited to only one or two shipbuilders capable of building the ship. These designs include the DDG 51 and the CVN 76.

Not much progress has been made on ship designs that have a high number of potential shipbuilders. Fiscal constraints during the early stages of design and/or difficulty in determining how to down select to a smaller number of potential shipbuilders are the major causes.

ACQUISITION PRACTICES

While much of the Producibility Workshop dealt with changes needed in the NAVSEA ship design process, the workshop participants also recognized that some aspects of the broader ship acquisition process can inhibit or enable producibility improvement. Some contracting approaches, acquisition strategies and construction contract clauses can act to discourage or incentivize shipbuilders to design for produability. The summary findings and recommendations of the workshop with respect to Acquisition Practices are listed in Tables I and II. Little progress has been made to date to implement these recommendations. However, a few recent initiatives have been taken to begin to address these important but difficuk improvements to the ship acquisition process.

NAVSEA Professor of Ship Aquisition

Since completion of the 1989 Producibility Workshop, NAVSEA has established a MOU with MIT. This MOU established the position of a NAVSEA Professor of Ship Acquisition, currently held by Professor Henry S. Marcus. As of June 1992, Professor Marcus has concentrated his research in the following areas:

- evaluating vendors/suppliers,
- international technical standards,
- contract Ianguage - case studies of three contracts,
- contract streamEning during emergencies (USS STARR and USS SAMUEL B. ROBERTS),
- comparison of TQL in three naval shipyards, and
- feasibility of having one shipyard subcontract to another (modeling production aspects).

Acquisition QMB

As part of the implementation phase (Phase II) of the Ship DAC Process Improvement Program, NAVSEA recently estab Iished an Acquisition QMB (16). The Acquisition QMB has oversight over two Process Action Teams (PATs) which have been chartered to implement specific recommendations from the DAC Strategic PIan (17), developed during Phase I. The DAC Phase II organization is shown in Figure 5. The Acquisition QMB PATs are determining how to implement the Phase I recommendations pertaining to the Acquisition Pro cess (PAT B-l) and the use of Product Oriented Design and Construction (PODAC - PAT D-l). The PAT B-1 objective is to modify the Preliminary and Contract Design process such that there wi.U be one continuous design process from Milestone I through contract award. PAT D-l is discussed below.

Table I Major Acquisition Process Influence Factors From Working Group 5

TYPES OF ACQUISITION APPROACHES

1. Contract terms and conditions.
2. Type of contract for ship detail design and construction.
3. Number of ships ordered.
4. Degree of participation by shipbuilder in pre-detail design.

TECHNICAL PRODUCT DEFINITION

1. Level of detail of Navy shipbuilding specifications.
2. Extent of guidance drawings.
3. Number of changes after contract award.
4. Systems based contract design.
5. Extent of use of CAD.

TECHNICAL PRODUCT REVIEW AND MONITORING

1. Government reactions to shipbuilder submittals.
2. Requirement for system oriented CDRLs.
3. Program reviews to enhance producibility.
4. Quantity of CDRL items.
5. Compatibility of Navy design and acquisition with shipbuilder zone approach.

OTHER ACQUISITION INFLUENCES

1. Extent of Navy incentives.

Table II Acquisition Process Recommendations From Working Group 5

TYPES OF ACQUISITION APPROACHES

1. Revise/apply contract terms and conditions to eIiminate producibility constraints and make better use of contract incentives.
2. Make better use of cost plus contracts for lead ship detail design and construction.
3. Maximize use of multiple ship orders.
4. Maximize early participation by shipbuilder in design; select shipyard(s) prior to contract design phase.

TECHNICAL PRODUCT DEFINITION

1. Carefully consider detail of Navy shipbuilding specifications.
2. Maximize use of guidance drawings.
3. Emphasize configuration management.
4. Use of zone design/specs vs. system design/specs.
5. Maximize use of CAD.

TECHNICAL PRODUCT REVIEW AND MONITORING

1. Improve Government responsiveness.
2. AIIow use of zone-oriented vs. system oriented CDRLs.
3. Evaluate use of program reviews to enhance produability.
4. Evaluate quantity of CDRL items.
5. Better align Navy design and acquisition with shipbuilder zone approach.

OTHER ACQUISITION INFLUENCES

1. Encourage use of modular procurement.

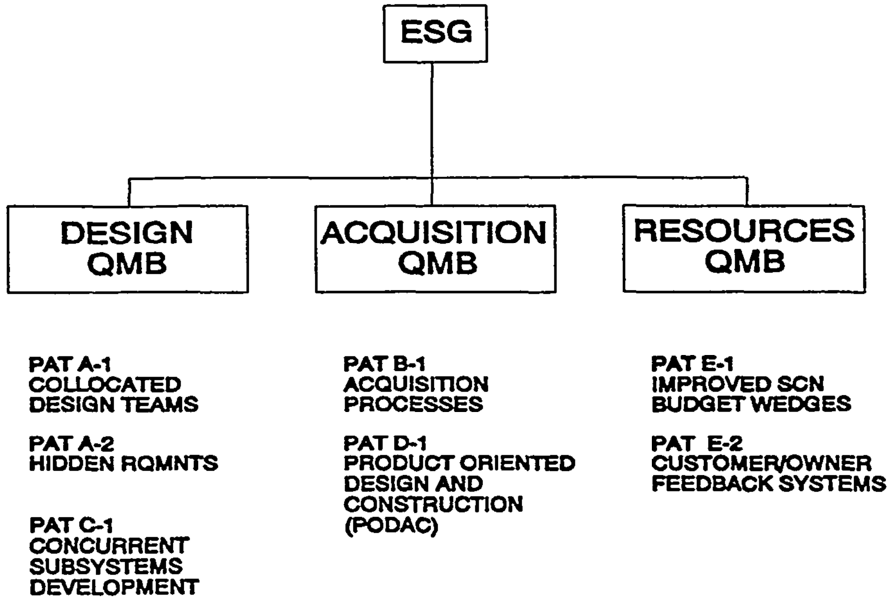


Figure 5 DAC Phase II Organization

Contract Strategies

Recent direction from the Secretary of Defense has changed acquisition practices from the 1980s. During the 1980s, the direction was to utilize firm fixed price shipbuilding contracts, even for the lead ship of a new class. The current acquisition strategy for the lead ship of a new class is to utilize cost contracts and contracts that have award fees. This decision will offer ship acquisition managers flexibility in contract development to incorporate potential producibility initiatives specific to the ship platform.

As a result of the Navy DDV study, affordability initiatives are aggressively being pursued during the DDG 51 Flight IIA Contract Design. This initiative is a cooperative effort between the Navy and the participating shipbuilders. The goal is to reduce hull, mechanical, and electrical engineering costs by $30M per ship.

3-D DIGITAL DATA TRANSFER

The naval ship design and shipbuilding community is making significant progress in the area of 3-D digital data transfer. During FY 91, NAVSEA awarded a Computer Aided Design (CAD) II contract to Intergraph Corporation. Billingsley (18) emphasized that availability of this contract to NAVSEA's early stage ship designers has the potential for 'revolutionary' improvements to the ship design process. By the end of FY 92, the principal technical codes within NAVSEA will be operating with the same CAD hardware (over 150 workstations) and software that is integrated. Training of in-house NAVSEA personnel has begun. Integration of CAD II systems to specialized ship design analysis tools has begun. This integrated approach will offer significant productivity gains in 3-D digital data transfer within NAVSEA.

Navy-Industry Digital Data Exchange Standards Committee NIDDRSQ

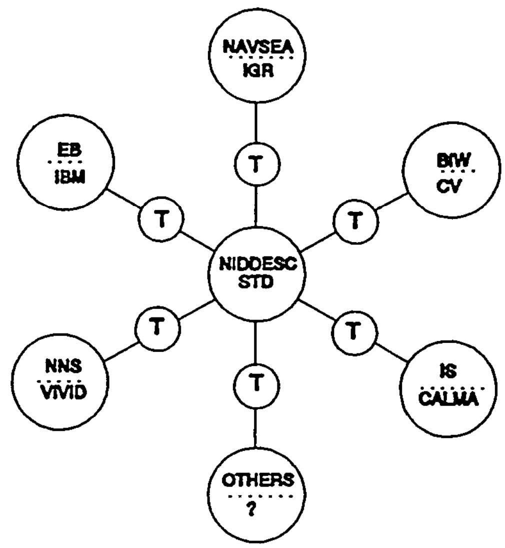
A normal contract package from NAVSEA for new construction of a ship is an impressive quantity of documentation. The transition of the design is in the form of specifications, contract drawings, contract guidance drawings, project peculiar documents, design criteria manuals, etc. This wealth of documentation requires months of detail design effort to replicate into a zone-oriented design ready for production. In 1986, a cooperative Navy-Industry organization was established to tackle a data exchange agreement.

NAVSEA and the marine industry have been working together as members of NIDDESC (19). NIDDESC members have been working on development of a product model definition. NIDDESC has developed six application protocols. These protocols are based on Product Data Exchange Standard (PDES) entities. These entities provide a content and format standard for data. The data for exchange is both graphic and non-graphic. Product model information can be easily converted into traditional drawings.

Figure 6 displays an example of the connectivity between Product Model Systems developed under the NIDDESC organization. This shipbuilding standard will greatly aid in consistent data transfer between all concerned government and contractor organizations. The intent for product models is not to support only new construction but to maintain ship design information throughout a ship's life cycle (20).

3-D ḣ+'l Data Transfer Between NAVSEA and Private Shipbuilders.

Most of the work sponsored to date by NIDDESC addresses the digital data transfer between shipyards, as is the case between the lead shipbuilder and the follow shipbuilder. However, the first critical transfer of 3-D digital data is between NAVSEA and the lead shipbuilder. NAVSEA and NSRP have recognized the critical nature of this transfer and have



IGR - Intergraph Corporation
- General Dynamics Electric Boat
E V - Bath Iron Works
- Ingalls Shlpbulldlng
FNNS - Newport News Shlpbulldlng and Dtydock
NIDDESC - Navy-Industry DIgItal Data Exohange Standards Commlttw
IBM - International Business Machines

Figure 6 Connectivity Between Product Model Systems

approved a SP-4 project entitled 3-D Digital Data Transfer to Shipyards.

The objective of this project is to identify those digital products which, if transferred to shipbuilders, would result in cost and time savings. These savings would result from the shipbuilder being able to avoid the costs and time associated with the regeneration of data and to more clearly identify to the NAVSEA ship designers the digital data required for advanced manufacturing. The identification of digital data transfer benefits to shipbuilders could result in modification of the NAVSEA contract design process to facilitate both the development and transfer of ship design information in an agreed upon digital format.

Currently, the NAVSEA contract design process produces hardcopy deliverables such as drawings for delivery to the shipbuilders. As Billingsley recently noted (18) NAVSEA is in the process of a revolutionary upgrade of its in-house CAD capability. This 'revolution' is being ignited by the purchase of over 150 CAD II engineering workstations and will eventually result in NAVSEA's contract design deliverable being a full 3-D digital data product model. The successful transfer of digital data between NAVSEA and shipbuilders requires:

- agreement on the information (data) to be transferred,
- agreed upon formats for the data, and
- contractual mechanisms to require both development and transfer.

The NSRP working in close cooperation with NIDDESC is the ideal forum for the development of such agreements. This project has significant potential benefits to the Navy and is consistent with the new goals of the NSRP; they are:

- improved manufacturing cycle efficiency,
- commitment to quality,
- expanded industry, government and academic participation in NSRP infrastructure, and
- capability of building to international standards.

Several papers on this subject will be presented during the 1992 Ship Production Symposium. NAVSEA has made significant progress on implementing the Workshop 3-D Digital Data Transfer recommendations. However, much work remains ahead to have the Navy and a majority of the marine industry standardized on the results of the NIDDESC work.

THE WAY AHEAD - LONG TERM STRATEGIC PLAN

The most significant progress since the workshop in 1989 is the increased awareness of and attention given to ship producibility by the senior military and civilian executives throughout the Naval ship design community. As described above, much progress has also been made in educating NAVSEA design engineers concerning ship producibility; establishing formal Producibility Review Teams for new ship designs as a framework for bringing NAVSEA ship designers and shipbuilders together to work as a team in evaluating and making producibility design decisions; and defining the geometry of the ship design in a full 3-D digital data model which can be readily transferred between different computer systems, and zonal versus systems definitions.

On the other hand, much work remains to be done to provide the early stage ship designers with the design methods, cost models and evaluation criteria to fully integrate produability into the NAVSEA ship design process (21). It is the authors' opinion that the fulI impact of concurrent engineering (that is, designing the construction process by which the ship will be built at the same time the ship is being designed) has not yet been realized. The potential impact on the ship DAC process is monumental, but the potential benefits in terms of reduced *time* and cost *are also monumental*. For this reason, the senior leadership of NAVSEA have personally endorsed a time-phased strategic plan for the 'Way Ahead.'

Design. Acawlhon. and Construction (DAC) Process Imorovement

The Way Ahead is built on a foundation of continuous process improvement of the DAC process and a number of pillars deriving from the DAC Strategic Principles. Two of these pillars are PODAC and Affordability Through Commonality (ATC), which are discussed below.

The DAC project has established strategic principles which provide a framework for continually improving the DAC process. These strategic principles are:

- customer focus/customer understanding,
- long range planning,
- concurrent ship and system development,
- availability of appropriate resources,
- Navy/shipbuilder/supplier partnership,
- total ship engineering,
- 'Best Known Method' build strategy,
- data continuity throughout ship life cycle,
- continuity of the ship development process,
- senior management commitment and involvement,
- fact-based management,
- process training, and
- process technology investment.

Ryan and Jons discuss each of these principles in reference (22).

PODAC

The results of the Produability Workshop and the DAC Study pointed out that more efficient ship construction processes could be used for the construction of Navy ships. As emphasized in reference (17), full implementation of PODAC is the best known method for reducing the time and cost of the ship construction process.

The major premise of product oriented ship construction is to integrate hull assembly, outfitting, and painting as early in the construction process as possiile.

PODAC is a concept for building a ship as a series of interim products, rather than system by system. Once interim products are defined, group technology principles can be applied for systematically classifying them into groups or families having design and manufacturing attributes sufficiently similar to make batch manufacturing practical. Process lanes can then be established for the efficient manufacture of similar interim products providing for efficiencies of batch manufacturing for small numbers of ships. Once process lanes are established, workers assigned to these lanes quickly become experienced in recognizing and avoiding manufacturing problems associated with those products and processes.

Additionally, the application of process control through statistical analysis of interim product accuracy can be implemented because similar interim products are being manufactured - providing a continuous feedback loop on the process.

Product-Oriented Design and Construction concentrates on optimizing the design and construction of interim products. Similar interim products coming off a dedicated process lane can be applied to naval combatants, commercial ships, drill rigs, floating or land based power generation plants, etc.

Most U.S. shipyards currently use some degree of product oriented construction. However, the level of implementation varies from shipyard to shipyard, and even between ship types in the same yard. U.S. shipyards have made significant improvements in hull fabrication and erection, and this remains the dominant activity in most shipyards. Other functions such as outfitting and painting are not being accomplished to the same degree.

Navy and shipyard management must fully agree that this is the most productive method for ship construction and commit to its implementation.

Industry and Navy must work together to develop generic or ship-specific build strategies describing how Navy ships will be built in accordance with Product Oriented logic and principles. The build strategies should be used to guide the Navy's Preliminary and Contract Design efforts. Working with industry the build strategy should be continually refined as the Navy design process continues, but when contract design is complete the build strategy should be known to all who plan to bid on construction.

PAT D-l has been chartered to develop a plan to implement the logic and principles of PODAC throughout NAVSEA and the shipbuilding industrial infrastructure. The PAT D-l plan of action is as follows:

1. In conjunction with the shipbuilding industrial infrastructure, develop a high level definition of the PODAC process.

2. Obtain a high level commitment to implement PODAC beginning in the early stages of design through delivery and life cycle support of Navy ships.

3. Develop a baseline description of the entire PODAC process including responsibilities, products and tools required at each stage of the process.

4. Identify constraints to the implementation of the PODAC process.

5. Develop incentives which would institutionalize the continuous evolution and improvement of the PODAC process.

6. Provide the expected time and cost benefits to be derived in the phased implementation of PODAC.

ATC

The ATC study team had its beginnings in discussions of the initial findings of the DAC effort and the ever-increasing affordability crisis within the country's defense industry. These discussions between senior managers within NAVSEA led to the suggestion of commonaliiv as the best hope for the future of Naval ship DAC. An interdisciplinary study team was formed in January 1992 to investigate the potential benefits of commonality, serve as a node for commonality information, and, if warranted, serve as a catalyst for highlighting the potential benefits to higher-level decision makers. Initial efforts centered on reviewing previous Navy and commercial applications of increased commonality and deciding on a level of commonality focus. A wide range from common components up to a single common ship was considered. The ATC team has chosen to focus upon the intermediate sub-system and system levels. Commonality was defined by the ATC team as:

> The use of common modules in fleet wide applications to reduce the design, construction, life cycle and infrastructure costs of Navy ships.

The ATC team's early focus has been on HhMrE systems, while acknowledging the future potential leverage and importance of Command/Control/Communication/Computers/Intelligence (c41) systems.

Three elements of commonality are advocated:

- standardize/ fewer components in modularize larger sub-assemblies,
- improve efficiency — more fabrication and testing accomplished in the more efficient shop environment, and

· reduce construction time:	rapid assembly of large subassemblies.

There are obvious tie-ins to several of the DAC PATs shown in Figure 5, in particular, PAT-C-l (Concurrent Subsystems Development) which is pursuing a design budgeting or 'turn-key' approach to installing communications equipment in new construction ships and PAT D-l with an objective of increasing PODAC of Navy ships. There is also a common thread with PAT A-l (Collocated Design Teams) as ATC is set up as a collocated design team. Many elements play in the ATC team achieving its objectives: technical, strategic planning, industry liaison, specifications and standards, and programmatics, to name just a few. Current pilot module concept design projects include an Advanced Surface Machinery System (ASMS) power module, auxiBary machinery modules and berthing modules. ATC is implementation oriented with a proactive strategy for the assemblage of resources required to accomplish a radical long-term change to the process of designing, acquiring, building and supporting Naval ships.

With the active support of senior military and civilian executives within NAVSEA, the ATC concept has been presented widely. Other senior leaders within the Navy have also committed their support. The Commander of NAVSEA recently presented a proposal to the Presidents' Club of the American Society of Naval Engineers and the Shipbuilders Council of America, and support has been very strong. The first ATC industry briefing was held in late April at DTRC. The challenge now is to convert a small study team into a larger and broader-based program implementation team with the resources to accomplish the daunting task of transitioning to an alternative process for ship DAC involving increased levels of commonality. The NSRP can play an important role in helping NAVSEA achieve the objectives of ATC. Together, NSRP and NAVSEA can form a partnership that will benefit the shipbuilding industry in becoming more competitive in the international market and thus benefit the Navy in maintaining an industrial base critical to its future.

SUMMARY

The changes facing the nation, the Navy, NAVSEA, and the U.S. shipbuilding industry in the years ahead are immense and (as recent events have shown) largely unpredictable and rapidly increasing. Most large organizations and industries adapt to change relatively slowly (and do so seemingly reluctantly).

This will no longer suffice!

In the decade of the 1990's and beyond, the ability to adjust to (and indeed to take advantage of) change will be crucial. The Navy and the shipbuilding industry together have faced such challenges before, and have done extremely well.

The initiatives described in this paper carry on this successful tradition of facing and overcoming challenges. By NAVSEA and the shipbuilding industry working together and re-examining and continuously improving our many processes from ship concept to commissioning, these initiatives will greatly assist the Navy and the shipbuilding industry in meeting and taking advantage of the rapid changes to be faced in the 1990's and in setting the direction for the 21" Century.

ACKNOWLEDGEMENTS

The authors wish to recognize several of the many people who have participated in Improving Produability in the Naval Ship Design Process. First, we would Eke to dedicate this paper to the memory of Bob Riggins, who was one of the editors of the Workshop Report and who made many contributions to naval ship design over his

35-year career. We also want to recognize Kit Ryan for his outstanding work in editing the Workshop Report. In addition, we want to further recognize the contriiutions of the Chairmen of the Working Groups from the 1989 Workshop:

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Working Group 2 - Dr. W&en Dietz (Engineering Tools)
Working Group 3 - Mr. Michael Hammes (Cost Models)
Working Group 4 - Mr. J. Christopher (Kit) Ryan (Strategy)
Working Group 5 - Mr. Michael Resner (Acquisition Practices)
Working Group 6 - Mr. Robert ComIy (3-D Digital Data Transfer)

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