

REPORT
ON
CONCURRENT ENGINEERING
IMPLEMENTATION IN A SHIPYARD

A Project of
The National Shipbuilding Research Program

for

The Society of Naval Architects and Marine Engineers
Ship Production Committee

Industrial Engineering Panel (SP-8)

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Executive Summary

Concurrent Engineering (CE), a systematic approach to involving all affected functions in the simultaneous development of products and processes, has received wide recognition as a means of significantly improving overall operating results for manufacturing companies. When successfully applied, the CE process results in significant improvements in customer satisfaction, quality and cycle time. DOD studies and industry experience show that CE may reduce the number of design changes by 50%, reduce design to production time by 40-70%, and decrease scrap and rework by 75%.

In the belief that the benefits of CE methodologies could assist the U.S. shipbuilding industry to become internationally competitive, the NSRP awarded a contract to BIW, supported by a consultant team headed by Thomas Lamb, to study the application and implementation of CE to the U.S. shipbuilding industry. The study was awarded in July 1993 and completed in July 1995. Previous reports have described the Application Phase of the study and provided a User's Guide and Primer in Concurrent Engineering. This final report describes a pilot CE implementation conducted at BIW from December 1993 through June 1995 and an industry-wide Workshop held in Portland Maine in June 1995.

The CE pilot implementation began with the evaluation and selection of a host design/construction project in December 1993. After balancing the need for manageable size, project significance and schedule compatibility, the ARPA funded MARITECH Commercial Shipbuilding Focused Development Project involving the development of two vehicle carrier designs, was selected. Other major elements of this project included technology transfer from European and Japanese shipyards, facilities design, build strategy development and contracts/financial planning. A significant advantage of this project with respect to CE was the involvement of two major US ship owner/operators.

The implementation effort was divided into several phases: team selection, team and management training, design strategy, and design execution. Training, including the facilitation of the design strategy development, was entrusted to Mr. Bart Huthwaite of Institute for Competitive Design (ICD). ICD's specific CE methodology, including multi-disciplinary teaming, a business oriented design strategy, continuous process and product measurement etc. was used throughout the pilot implementation and proved to be adaptable to the ship design process.

The contract design of the first vehicle carrier was successfully completed in June 1995. BIW has continued to utilize CE on the second ship design of the Focused Development Project and has implemented elements of CE on several smaller design/construction projects. Although specific cost comparisons are difficult to obtain under practical shipyard conditions, the ability to rapidly iterate the design cycle, including parallel development of production, facility, and material plan, and cost estimates, is clearly a powerful force for cost reduction. With further refinement, CE will effectively support the US shipbuilding industry's drive to regain international competitiveness.

An industry-wide Workshop to disseminate the results of this NSRP project coordinated by Thomas Lamb, was attended by some 60 people from US and Canadian shipyards, equipment suppliers and academia. The program included speakers from industries in which CE has been successfully employed, team exercises in CE application, and a full report on the pilot implementation by the BIW employees directly involved. Feedback from the participants indicates that this material was well received and will assist them in establishing their own CE programs.

Acknowledgment

This project was funded by the National Shipbuilding Research Program Industrial Engineering Panel (SP-8), chaired by R. A. Wallen of Newport News Shipbuilding. The SP-8 Panel is one of the Ship Production Committee Panels of the Society of Naval Architects and Marine Engineers, which was established for the purpose of improving U.S. shipbuilding performance.

Portions of this report are adapted from a paper presented by James G. Bennett and Thomas Lamb at the 1995 Ship Production Symposium.

The success of the pilot CE implementation was accomplished through the efforts of many BIW managers and staff, as well as the full cooperation of the client ship owner, ABS, major suppliers and many others. Their participation and assistance is acknowledged with appreciation.

Mr. Bart Huthwaite of the Institute for Competitive Design provided inspiration, training and methodology without which the pilot implementation phase could not have succeeded. His support is greatly appreciated.

TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
Executive Summary	i
Acknowledgment	ii
1.0 Introduction	1
2.0 Implementation of CE at Bath Iron Works Corp.	2
2.1 Selection of a Pilot Project	2
2.2 MARITECH Focused Development Project	2
2.3 Implementation Plan	3
2.4 Team Organization	5
2.5 CE Training	5
2.6 Management Training	6
2.7 Product Delivery Strategy	6
2.8 Product Development Team Training	7
2.8.1 Analysis of Competitive Environment	7
2.8.2 Strategic Design	8
2.8.3 Innovation	9
2.8.4 Product and Process Measurement Skills	10
2.8.5 Team Organization and Decision Making	11
2.8.6 Accountability	11
2.8.7 Communications	12
2.8.8 Interpersonal Skills	12
2.8.9 Tools and Enabling Technologies	13
2.9 Results and Conclusions	13
3.0 References	14
Appendix A: CE Workshop - Implementation	

1.0 Introduction

Concurrent Engineering (CE) is a systematic approach to the simultaneous development of products and processes, involving the areas of design, manufacturing, materials, contracts, marketing, subcontractors, customers, regulators and others. It is based on removing the cultural and organizational barriers that historically have prevented these functions from working together. The CE process ensures that people reach timely, coordinated, well informed decisions concerning all critical elements of product design, manufacturing and life-cycle costs.

Concurrent Engineering has received wide recognition as a means of significantly improving overall operating results for manufacturing companies. When successfully applied, the CE process results in significant improvements in customer satisfaction, quality and cycle time. DOD studies and industry experience show that CE may reduce the number of design changes by 50%, reduce design to production time by 40-70%, and decrease scrap and rework by 75%.

In the belief that the benefits of CE methodologies could assist the U.S. shipbuilding industry to become internationally competitive, the NSRP awarded a contract to BIW, supported by a consultant team headed by Thomas Lamb, to study the application and implementation of CE to the U.S. shipbuilding industry. The objectives of the study were

1. To determine the extent of current applications of CE in shipyards, their familiarity with it and the potential benefits from its application,
2. To show how CE reduces time to design and manufacture a product while improving quality and reducing cost,
3. To produce a guide for CE application to the U.S. shipbuilding industry as a first step to actual implementation,
4. To implement CE on a specific shipyard design and construction program.

This study ran from August 1993 through July 1995 and resulted in several reports as well as an industry-wide workshop. Work by Thomas Lamb and his team generated two reports on the Application phase of the study, covering objectives 1-3 above: an applications report (ref (a)) and industry primer (ref (b)). A paper by J.G. Bennett of BIW and Thomas Lamb was presented at the 1995 Ship Production Symposium, covering both application and the early stages of an implementation pilot project at BIW (ref (c)). In June 1995, a CE Workshop was held in Portland, Maine at which the application study was reviewed and the results of this pilot implementation were described.

2.0 Implementation of CE at Bath Iron Works Corp.

As with most shipyards, elements of CE have been part of the evolving product development process at BIW for a number of years. In particular, past focus has been on involvement of shipyard planning and production engineering functions in the design process, overlapping design and production phases of product development, application of enabling technologies such as CAE/CAD/CAM, and more recently the use of teams in management of the product delivery process. In addition to the CE pilot described in this paper, a number of other ongoing projects at BIW have implemented best practices identified through CE bench-marking and technology transfer with industry leaders. The CE pilot described herein represents an intensified and focused effort to implement all of the essential elements of CE within a single project, and to thereby lay the foundation for broadened understanding and institutionalization of these practices throughout all future product development efforts.

2.1 Selection of a Pilot Project

The CE Pilot implementation began with the evaluation and selection of a pilot project in December, 1993. Numerous candidate projects were ongoing or proposed including barge mounted electrical power generating plants, lubricating oil purification modules for shore-based electric plants, a small coastal combatant ship, a MARITECH funded multiple ship design project and a major upgrade to the DDG 51 class destroyers presently under contract.

These projects were evaluated on the basis of several criteria including project size, manageability, required level of effort breadth of scope, duration, significance in relationship to other shipyard projects and affordability. The project had to be small enough to be manageable, i.e., the size of the effort had to be such that if obstacles were encountered there would be some flexibility in managing the impact on resources and other projects in the shipyard. A significant emphasis was placed on the need for shipyard control of the design and product delivery process. It was recognized that if external constraints were too rigid, either in terms of product specifications or contractual requirements, that the potential benefit of the project would be compromised. Counter-balancing the need for manageable size was the need to have the scope and nature of the project recognizable as a significant undertaking in terms of complexity, technical challenge and importance to the shipyard. It was desirable that the duration of the project be relatively short in order to produce measurable and identifiable results. The overriding constraint in all cases **was** that potential projects had to be funded and approved by senior management.

As expected, none of the candidate projects met all of the above criteria. The most difficult criteria to balance was the need for significance versus the desire for short duration. Of the significant shipbuilding projects considered, all were expected to span more than a year's time, due to the basic nature of large shipbuilding projects - size, complexity and level of effort - and the fact that contracts with specific commercial customers had yet to be developed.

A meeting was held in December, 1993, at which BIW managers met along with the NSRP Applications team to decide which of the candidate projects would become the CE pilot. As a result of this meeting, it was decided that the recently awarded MARITECH design project offered the best prospects for successful implementation. Factors which favor the selection of this project include: it is recognized as significant work for the shipyard, external constraints are manageable, risk to other ongoing projects is minimal, scope is broad involving all phases of ship design and construction, and funding had been obtained.

A key issue on which a compromise had to be reached was the probable duration and scheduled start of actual CE implementation relative to the desires of the NSRP. It had initially been desired that the pilot be complete within one year from the start of the NSRP project. In the case of the selected CE Pilot, the duration of the project would necessarily be prolonged due to the relationship between it and the larger MARITECH "focused development project" through which it is funded. The MARITECH focused development project involves not only the development of multiple ship designs but also development of

2.1 Selection of a Pilot Project (continued)

facilities modernization plans, commercial ship financing plans and technology transfer between BIW and two foreign shipyards, Kvaerner Masa Yards (KMY) and Mitsui Engineering and Shipbuilding (MES). As such, the implementation plan, schedule and duration of the CE pilot had had to adjust to fit within the framework of these other activities.

2.2 MARITECH Focused Development Project

The objective of the MARITECH focused development project at BIW is to achieve re-entry into the commercial shipbuilding market.. The last commercial ships built at BIW were delivered in 1983. Product development efforts since that time have focused almost exclusively on military combatants for the U.S. Navy. As previously alluded, the MARITECH project focuses on developing essential capabilities in all areas of the ship design and production process necessary to re-enter the commercial market. These areas include: design, construction facilities, human resources, contracts and financing.

The first step in this effort has been the definition of specific capabilities and technologies required in each of these areas. This has been approached by conducting in-depth studies of two world leading shipbuilders, Kvaerner Masa Yards (KMY) and Mitsui Engineering and Shipbuilding (MES). Several teams of individuals representing all functional areas of the company were involved in bench-marking of these two companies. A total of 45 BIW employees were involved in these exercises. The result is a very broad and thorough understanding of the work methods, procedures, technical and administrative systems management practices and productivity at all levels of these two world-class shipbuilders.

The knowledge gained through these bench-marking exercises is being applied through a team effort coordinated by a Commercial Shipbuilding project group comprised of representatives from all functional areas of the Company. Members of this team, co-located within the shipyard, are responsible for developing ship designs, shipyard facilities plans, ship construction plans, marketing plans, contract and financing arrangements, human resource and training plans.

Obviously, ship designs and construction plans have no use if they do not serve a viable market with known prospective customers. One of the principals of CE is to involve the customer directly in the development of new product design and delivery strategies. In the case of the MARITECH project, two prospective customers were identified at the outset. Both are ship operators that presently own and operate ships in the commercial vehicle transport trade. Both were approached and agreed to cooperate with BIW in developing the initial MARITECH project proposal and to participate as partners in the subsequent product development effort. The direct participation of the senior management, technical and operations staff of these potential customers in the CE process has been essential to achieving the goal of direct and ongoing customer interface throughout the product development process. In addition, marketing surveys and participation in important industry conferences and technical symposia are also means that are being used to achieve this goal of the CE effort.

2.3 Implementation Plan

The CE Pilot effort is broken down into several principal phases: Team Selection, Team Training, Management Training, Product Delivery Strategy, first (of two) Ship Designs (Figure 2.3 a). Ongoing and in parallel with this activity is the technology transfer between KMY and Mitsui previously described. The ships being designed are RoRo vehicle carriers. Each design has unique requirements in

2.3 Implementation Plan (continued)

terms of required cargo capacity, handling and stowage capabilities, deadweight tonnage, service speed and limiting drafts.

This process culminated with the completion of the first ship design in May 1995, followed by a comprehensive construction cost estimate update in early August. The process was carried out in parallel with technology transfer activities at both KMY and Mitsui. The same team will go on to develop the preliminary design of a second vehicle carrier later this year.

Design Process Flow
Including Concurrent Engineering

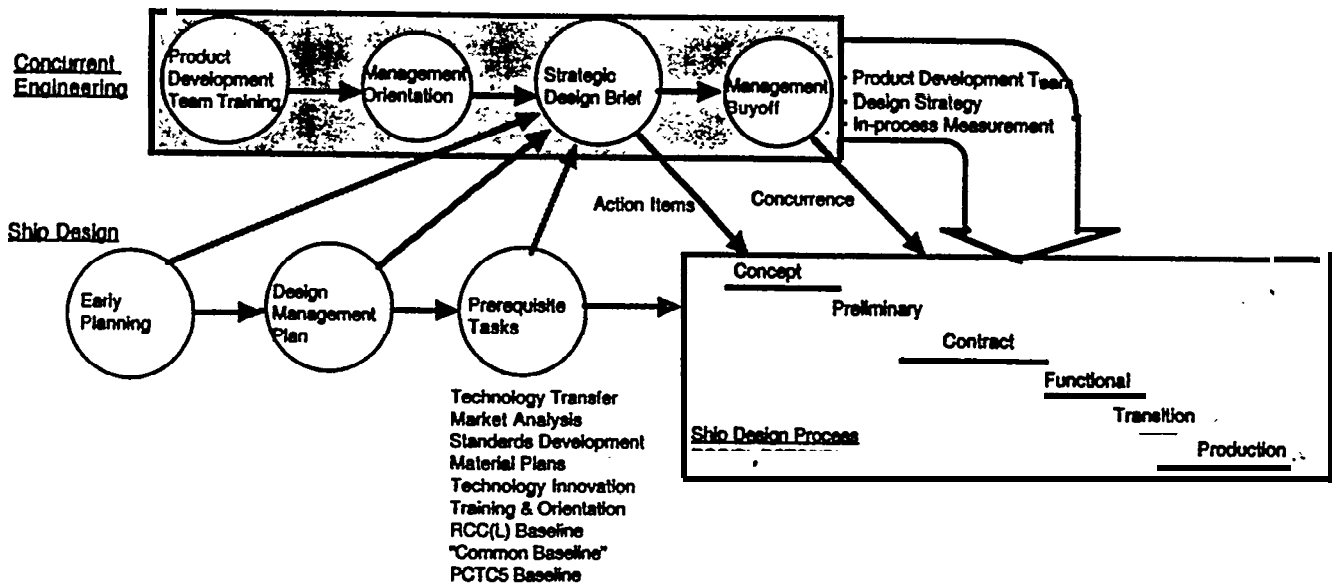


FIGURE 2.3 a

2.4 Team Organization

As discussed earlier, there is as yet no established organizational model from within the shipbuilding industry to follow in determining the composition of a shipyard CE team. Reported U.S. shipyard CE experience has focused primarily on “enabling technology” - CAD product models, distributed databases, document and work flow management systems - as opposed to CE team organization. This is also true with respect to foreign shipyards which have for the most part not adopted a formal CE approach in their product development processes, at least insofar as establishing CE team organizations distinct from the line organization.

The team was organized within the Commercial Shipbuilding Project Office (CSPO), a project organization reporting to VP Marketing. The overall team structure evolved into three entities:

The Product Development Team (PDT) functions included representatives from all affected functions as listed below. The majority of PDT members received the training described below and participated in the development of the design strategy. During the design process the PDT participated in trade-off studies and reviewed design products to ensure that the design was compatible with facilities, production processes, material availability and owner requirements. Except for those who were also part of the Core Team, PDT members remained attached to their line organization departments.

Production Facilities	Outfit Detail Design
Facilities Engineering	Structural Production
Material Procurement	Outfit Production
Estimating	Ship Owners
Structural Detail Design	Design Subcontractor

The Core (design) Team consisted of five engineers covering the disciplines listed below, who were responsible for the pre-contract design of the ship. These individuals were detached from their line functions and reported to a manager within the CSPO.

Naval Architecture	Mechanical Engineering
Structural Engineering	Electrical Engineering

Finally, the Support Team consisted of all those within the line organization who were called on for additional support by any of the above. Members of the Core Team or PDT assumed custodial responsibility for representing, interacting with and directing support team activities. Example disciplines included

Hydrodynamics	Mechanical Design
Structural Design	Weight Estimating
Outfit Design	Marketing

In addition to the team structures, a senior management sponsor and advisory council was designated to provide oversight accountability and direction to the team.

2.5 CE Training

Training of the CE team is an essential element of implementation. In BIW'S case, considerable effort had been made over the past several years to provide broad-based training in team problem solving techniques. In-house training programs include one to three day courses providing instruction in team process orientation, management leadership and specific matters relating to the ongoing transition from trade to muhi-disciplinary work teams in production. This training can provide useful background for

2.5 CE Training (continued)

participants in a CE process, however, it provides only one of several skill sets that are essential to a competitive product development team. beyond basic technical design and team problem solving skills, development of skills in the following areas is considered to be essential:

- Analysis of Competitive Environment
- Strategic Design
- Innovation
- Process and Product Measurement
- Team Dynamics Measurement
- Interpersonal Interacting

Extensive training material has been developed and is available from CERC and the Institute for Competitive Design (ICD), Rochester, Michigan, to instruct product development teams in these areas. The ICD program has been applied in the training of product development teams at over 300 companies world-wide. As one of the NSRP project tasks, BIW agreed to apply the ICD method and to evaluate its effectiveness in preparing the CE pilot team.

The agreed upon training program was planned during a visit by Mr. Bart Huthwaite of ICD to BIW in December 1993. It focused on three areas:

1. Management training
2. Product development team training, and
3. Facilitating development of a Vehicle Canier Product Delivery Strategy (the Strategic Design Brief).

2.6 Management Training

Management training began with the initial visit of Mr. Huthwaite to BIW in December 1993, in which he conducted a CE orientation briefing in conjunction with the bench-marking exercise previously described. This briefing covered the basic principals of CE and including an hour long questions and answer session in which many organizational and procedural issues were discussed. A second management training session was held on March 8, 1994. This session included members of the pilot product development team as well as Mr. Huthwaite. The product development team presented the results of the training workshop, described later, in which they had participated. Another important element of this session was an evaluation of management confidence level in the existing product development process. The intent if this exercise was to establish a baseline against which to measure the effectiveness of the CE implementation effort. This evaluation included strategic perspective, speed, cost awareness, quality and efficiency of present produce development efforts. In each of these areas, four to five specific questions relating to performance of present product development efforts were asked. Managers rated corporate performance on a simple scale of one to ten. The overall results indicated a less than satisfactory perception of the existing product development process.

2.7 Product Delivery Strategy

The development of a “product delivery strategy” within the context of a CE process is very similar to the exercise of developing a “build strategy”. The actual process involved is described below as part of CE

2.7 Product Delivery Strategy (continued)

product development team training. The result of this process is a 30-50 page document which spells out specific product attributes, metrics, action plans and responsibilities for accomplishing the development of a new product. The development of this document took place over a period of four days, from August 5-8, 1994, in which members of the product development team including ship owner's representatives and representatives from all internal BIW division participated. This process culminated in the presentation of the product delivery strategy to senior management.

Specific results of this effort will be presented at the industry-wide CE workshop planned for June, 1994, in Bath, Maine.

2.8 Product Development Team Training

Training of CE product development team, comprised of both core and support team members, was conducted by Mr. Huthwaite from January 12-15 at BIW. Between 25 and 30 BIW employees participated throughout a period of four days. The purpose of this effort was to provide thorough understanding of the fundamental skills required of product development teams, and to provide hands on experience in the application of these skills through a series of hands-on exercises. A second four-day session was held to develop, and present to management a "Strategic Design Brief" (Design Strategy) for the vehicle earner designs. In general, the format for these sessions follows a set sequence that begins with explanation of a particular technique by Mr. Huthwaite followed by discussion involving the entire group, break-up" of the group into working teams, application of technique to a sample problem, presentation of results by each team, and critique of results by the entire group. For the purposes of training the group was given the task of designing a simple mechanical device. Initially, the device chosen was one used by Mr. Huthwaite with many training groups over a long period of time. By exercising its skills in designing this simple device, the group was able to compare its results with the results of many other groups facing the same challenge. The comparisons, needless to say, were quite intriguing. The group also worked with a sample design problem representative of that which would be encountered in a typical ship design situation. The chosen example was a down-flooding device to be used in refrigerated cargo holds wherein the device would serve as an effective barrier against the pressure, temperature and humidity differences between two adjacent cargo holds as well as function reliably as a cross connection in the case of flooding.

2.8.1 Analysis of Competitive Environment

For a produce development team to be effective, it must have a clear understanding of the competitive environment in which it operates. This environment is characterized by

- Customer's needs including:
 - functional requirements;
 - price expectations;
 - performance expectations;
 - schedule demands.
- Current competitive products available under development in the marketplace.

2.8.1 Analysis of Competitive Environment (continued)

- External and internal constraints including:
 - Available capital resources;
 - Available technology,
 - Safety and environmental regulations;
 - Other legal or political restrictions.
- Internal strengths and weaknesses including:
 - Available skills and experience;
 - Shipyard tooling, facilities and capacity;
 - Proven capability in the marketplace.

By tasking the product development team to analyze the competitive environment, the entire team is driven to define and focus attention on what are the most important problems to be solved in the design process. In general, it is more important at the outset that the team by working to solve the right problems, as opposed to working to immediately solve any particular problem right.

An effective strategy employed by the BIW CE pilot team is to observe the operations of ship types similar to that which is to be designed. Direct discussions with ship operating crews, port facility operators as well as ship owners are essential to understanding the competitive environment in which the ship will operate. Comprehensive data regarding the port restrictions, usage fees, insurance fees, operating and maintenance costs, crew skill, qualifications and experience were being sought. Industry trade journals and reports of pertinent regulatory agencies have been reviewed, compiled, analyzed and condensed. A strategic goal of this effort was to consolidate a technical library of ship designs to serve as design performance benchmarks in the development of new ship designs.

To understand its own competitive strengths and weaknesses, it is necessary for a company to view itself from the outside looking in. Bench-marking of competitors is one way to gain this perspective. Considerable recent research and attention have been devoted to analyzing the general competitive strengths and weaknesses of the U.S. shipbuilding industry. This work can serve as a useful starting point in developing techniques for analyzing and quantifying its own specific strengths and weaknesses. The use of consultants to obtain a third party opinion may also be of benefit.

2.8.2 Strategic Design

The analysis of the competitive environment provides a rational basis for defining specific functional attributes of the product design. Traditionally, these attributes are described in an outline specification developed by the marketing department in conjunction with a potential customer. In a CE process, other shipyard departments are involved in this process through participation in the product development team. In the CE process, the definition of product fictional attributes is not limited to just external customer requirements, but is expanded to include the requirements of internal “customers” as well. The result is a set of requirements that reflects the company’s strengths and capabilities and that ultimately leads to achievement of the highest quality within the competitive constraints of the market.

The process of defining product attributes in a team environment is quite straightforward. The team divides into groups, the groups compose lists of attributes, the attributes are categorized evaluated against the company’s strengths, internal and external constraints, ranked in priority order and finally selected by

2.8.2 Strategic Design (continued)

the team to be either included or excluded. The objective of this effort identify the eight most important competitive attributes of the product. These eight will become the basis for future measurement of product success. One important criteria in the selection of these attributes is that each attribute must be quantifiable in terms of some measurement of the product design, e.g., cargo deadweight capacity or the number of structural parts are both measurable attributes of a ship design.

For each product attribute, three measurements or metrics are initially identified

1. The current design value;
 2. The minimum or threshold value considered to be acceptable, and
 3. The objective value or competitive goal.
- (See Appendix A, pages 102- 104).

For a complex product such as a ship, the idea that there should be only eight attributes of the design considered “most important” created a great deal of controversy within the pilot product development team. To resolve this controversy, the technique used was to broaden or categorize the definition of the eight most important competitive attributes, and to discretely specify attributes and associated measurements within each broad category. Thus, a broad category such as maintainability could be identified as a critical product attribute, but quantified in terms of several more discrete attributes such as overhaul and dry-docking interval, underway maintenance tasks, crew size, number of required spares, etc.

The essential benefit of this exercise is that it focuses the team’s attention on the attributes which are most important to the success of the product design, and provides quantifiable goals for the measurement of the design in process.

Another important outcome of this process is the definition of the “step”, “stretch” and “leap” versions of a product representing the present version, the next incremental evolution and the future long term vision of a product. The product development team should be encouraged to look beyond present constraints and/or limitations to envision how future versions of the product will evolve. In the marine industry, for example, future requirements for safety, environmental protection, automation, etc. can be expected to have significant impact on ship capabilities. The objective of developing a design strategy is not only to identify and quantify competitive attributes of the present version of a product but to identify and plan for future development and improvement of the product. The ultimate goal is to provide for such development and future upgrade of the product in the present design.

2.8.3 Innovation

The core technical skill of the product development team is its ability to innovate and develop cost effective technical alternatives to achieving strategic design goals. In world-class product development teams, this is accomplished by iteration of multiple alternative designs and rational evaluation of those designs based upon criteria that measure the total cost impact of their distinguishing attributes. It is essential that the product development team understand the total cost impact of alternative designs. This includes understanding the principals of producible designs and developing the ability to map and evaluate the process impact of alternative design solutions. In the CE process, the core team effort is initially focused on developing the technical solutions to the eight top priority competitive product attributes. In latter stages, support teams should also apply this methodology in developing detail design of subsystems and components.

2.8.3 Innovation (continued)

The principal elements of process based design include:

- Reducing numbers of parts.
- Simplifying manufacturing processes.
- Simplifying product structure/architecture.
- Identifying and eliminating hidden costs.

Part number reductions can be achieved either through the greater use of “common” or “standard” components, by parts “implosion” or simply eliminating parts. Standardization is not a subject that is new to the U.S. shipbuilding industry, however, by comparison the U.S. industry clearly has away to go in achieving the level of standardization typical of world leaders. One of the most successful strategies employed by industry leaders is the use of multi-functional materials, i.e., materials that can be substituted or applied in a variety of situations. The use of high strength steel in lieu of mild steel for the equipment foundations to avoid having to stock two different grades is a good example. Parts implosion is the technique of creating a single part to accomplish the same function as previously accomplished by a number of parts. The familiar case of using stanchions to both support grating and pipe running beneath the grating is an example of part implosion. A simple example of parts elimination would be the use of shallower deck stiffening which eliminates the needs for reinforcing collars in way of stiffener penetrations through web frames and bulkheads.

Process simplification is achieved in a number of ways including the elimination of process steps through simplification of the product design, and the reduction of variability and precision required in the manufacturing process. Examples of highly variable processes typically involved in shipbuilding include welding, compound curvature in plate forming and compound bends in pipe bending. Designs that make use of modularity or repeatability will by definition have fewer process steps than otherwise. Design for assembly is also a technique for eliminating process steps in the assembly process. This is typically exploited in shipbuilding by designing for on-block and on-unit installation.

Simplification of product architecture means reducing the variety of technologies applies in production. This is the corollary to reducing the number of process steps. The objective is to simplify part geometry, eliminate sophisticated material forming and joining technologies, high precision/low tolerance machinery, fitting, measuring and aligning. The use of poured chocks for instance is an example of a simplified product architecture for the mounting of a complex piece of equipment.

Eliminating hidden costs means identifying the various processes such as marshaling, staging, handling, tooling set-up, surface preparation and cleaning, testing, inspecting and documenting, required to enable the production of a product. The evaluation of hidden cost is often the most difficult challenge facing the product development team. The involvement of production personnel in the product development process is essential to making well informed evaluation of the indirect costs incurred on the shop floor.

2.8.4 Product and Process Measurement Skills

The total cost associated with a given design is identified and understood by thoroughly examining the process steps involved in the production of that design. Many techniques have been devised to enable such analysis, including Quality Function Deployment, ICD/FOCUS methodology, Taguchi Methods, Boothroyd Dewhurst’s Product Design for Assembly, GE/Hitachi Assemblability Evaluation Method and Lucas Engineering’s Design for Assembly.

In evaluating the total cost of alternative designs, it is essential to include not only the direct labor and material cost, but also the indirect or hidden costs. The ICD/FOCUS methodology accomplishes this through a common sense approach. The method enables the CE team to quickly and comprehensively

2.8.4 Product and Process Measurement Skills (continued)

identify the process steps involved in supply, pre-production, production, and post-production stages of the product life cycle. All significant costs contributors are identified including numbers of parts and part numbers, manufacturing technologies, process steps and indirect costs or processes. An index is calculated based on the material cost the number of parts, the number of part number (i.e. different parts), the number of pre-production and production process steps and the level of precision, variability and risk associated with the processes. This type of analysis, while time consuming, results in a rational basis for evaluating design alternatives.

A representative list of the design issues which were evaluated by the CE pilot team include:

- basic hull structural framing system and frame spacing alternatives
- structural assembly breakdown and hull block size alternatives
- hull form alternatives including flat bottom versus deadrise and faired versus knuckled bulb and skeg
- deck stiffening alternatives including bulb flats versus angle bar
- main deck girder contraction including box versus tee sections
- hoistable deck and ramp arrangement alternatives
- main engine selection and installation alternatives
- piping material alternatives
- hull paint system alternatives.

2.8.5 Team Organization and Decision Making

To ensure effective buy-in and participation of the line organizations, the BIW CE pilot team was carefully chosen to include the individuals that will carry a large portion of the responsibility for implementing the decisions made through the team process. The CE pilot team's relationship with the line organization is maintained through each organization's respective representative on the team. The team member has responsibility to inform the line organization manager of decisions affecting his area of responsibility. The line manager must concur with respect to the general functional, procedural and regulatory requirements to be met by the design. Cost and performance objectives must also be agreed upon. These requirements are defined and articulated within the "Product Delivery Strategy" alluded to earlier. The team has latitude to make decisions as long as the decision fits within the boundaries of the framework defined by the Product Delivery Strategy.

2.8.6 Accountability

The key issue with regard to empowering the CE team is the accountability of the team and interaction between the team and management. The core team must be accountable. In the present CE pilot, the collective accountability of the team is to its senior management sponsor, the VP of Engineering. Overall goals and objectives are set by an senior management advisory committee comprised of company officers and directors.

2.8.6 Accountability (continued)

The frequency upon which these groups interact is important in setting the pace for the effort of the CE team. In the present case, the pilot team meets formally with the team sponsor about once per month. The Senior Advisory Committee meets on a quarterly basis.

As alluded to earlier, each core team member is accountable to both the product development team leader and the respective line functional manager whom he/she represents. It is expected that both line managers and team leaders will have input to the team members performance evaluation.

2.8.7 Communications

One of the principal advantages sought in the formation of a product development team is improved communications and coordination of effort amongst team members. Collocation of team members is often viewed as a requisite to effective team formation and communications. BIW has thus far employed collocation as a strategy in the pilot implementation. An office facility has been provided wherein core team members are collocated. Additional space is available for the temporary use of support team members, visiting owner's representatives, subcontractors and/or suppliers.

It has been found thus far that collocation in and of itself does not assure improved communications unless accompanied by an effective team process, pro-active participation of the individuals assigned to the team and support from the line organization. Communications between the team and the line organization is just as important as is intra-team communications. There is presently a direct line of communication between each team representative and the managers of that member's respective line functional division. Meetings between team members and line members and line managers must be encouraged to be frequent and spontaneous.

2.8.8 Interpersonal Skills

To measure and assess the effectiveness of the team process, the BIW-CE pilot team has been trained in a method of team dynamics measurement. This technique is simple in concept. The team decided upon a number of measures of effectiveness including

- Technical Skill
- Decision Making Process"
- Efficiency
- Open Minded Spirit
- Leader / Team Interaction
- Communications
- Individual Involvement
- Sense of Accomplishment

The CE pilot team presently conducts its own self evaluations on the basis of these factors (see Appendix A, pages 111- 113). Team members rank team performance in several areas within each of the above categories on a scale of one to ten. The results are compiled and summarized by an individual outside the team organization to ensure objectivity and anonymity if desired. The team meets as a group to review the results and to address performance issue and decide upon corrective action.

2.8.9 Tools and Enabling Technologies

The CE pilot team has been encouraged to seek and apply tools and technologies which best suits its goals, needs, level of expertise, background and familiarity. The use of proven technology has been encouraged both within the team and on the part of BIW management. Advanced geometric modeling, and naval architecture design tools have been in use for some time and are being actively employed by the team. Thus far, the application of new technology has included advanced ship structural design optimization systems and the use of state-of-the-art statistical and computational fluid dynamics systems for performing hull form and propulsion trade-off studies. It is expected that these technologies will have a significant influence on the product development team's capability to perform a greater number of iterations on a design within a shorter period of time.

The CE pilot team has a long term objective to review, analyze and recommend new enabling technologies that can benefit future product development efforts. This objective is being pursued through the foreign shipyard bench-marking exercises and through direct contacts with suppliers. Thus far the focus has been on evaluation of integrated shipbuilding and design systems.

2.9 Results and Conclusions

The overall goal of the ship design task within the Focused Development Project was the development of a ship design which met the Owner's requirements at an internationally competitive cost and construction schedule duration, thereby leading to a ship construction contract. The use of concurrent engineering techniques supported this goal by:

- Fostering a broader understanding of the ship design process by all operational elements of the Company,

- Providing a mechanism by which production, facilities and materials issues could be resolved and a build strategy developed in parallel with the early design process,

- Maintaining a focus on both the Owner's priorities and the shipyard business strategy,

- Providing a mechanism for effective cost trade-off studies and costing support leading to greater confidence in the final cost estimate.

BIW has continued to utilize CE on the second ship design of the Focused Development Project and has implemented elements of CE on several smaller design / construction projects. Although specific cost comparisons are difficult to obtain under practical shipyard conditions, the ability to rapidly iterate the design cycle, including parallel development of production, facility, and material plan, and cost estimates, is clearly a powerful force for cost reduction. With further refinement, CE will effectively support the U.S. shipbuilding industry's drive to regain international competitiveness.

3.0 References

- (a) T. Lamb "Concurrent Engineering- Application", NSRP, January 1995
- (b) T. Lamb "Concurrent Engineering - Primer and User's Guide for Shipbuilding", NSRP, January 1995
- (c) J.G. Bemett & T. Lamb, "Concurrent Engineering Application and Implementation for U.S. Shipbuilding", 1995 Ship Production Symposium

Appendix A

CE Workshop - Implementation

BIW Implementation Introduction and Project Description

Concurrent Engineering Workshop

Bath Iron Works Corporation

Russ Hoffman

June 8, 1995

Outline

- Background
- Technology Transfer Results Related to Concurrent Engineering
- Implementation of Concurrent Engineering in the “Project
- High Points of Implementation
- Difficulties
- Conclusions

Background

- Commercial Shipbuilding Focused Development Project
- Car Carrier for Great American Lines
- Other Implementation of Concurrent Engineering at BIW

Commercial Shipbuilding Focused Development Project

- Contract awarded in the Fall of 1993 as part of the first round of ARPA awards
- Purpose is to design competitive commercial shipbuilding processes at Bath Iron Works
- Project offered an implementation vehicle for the NSRP Concurrent Engineering Project

Features of the Commercial Shipbuilding Focused Development Project

- Learning world-class processes and methods through **technology** transfer from Kvaerner Masa-Yards and Mitsui Engineering and Shipbuilding
- Designing a facility to reflect competitive international practice
- Designing ships for partners in the project, Great American Lines and American Automar
- Developing processes for competitive commercial ship Design, Estimating, Planning, Materials, and Production

Technology Transfer

- Multi-functional BIW participation in travel to Kvaerner Masa-Yards and Mitsui Engineering and Shipbuilding
- Purpose of the trips was to gain KMY and MES expertise in process and product technology
- Trips were planned to emphasize integration across BIW functions; Marketing, Estimating, Planning, Design, Materials, and Production

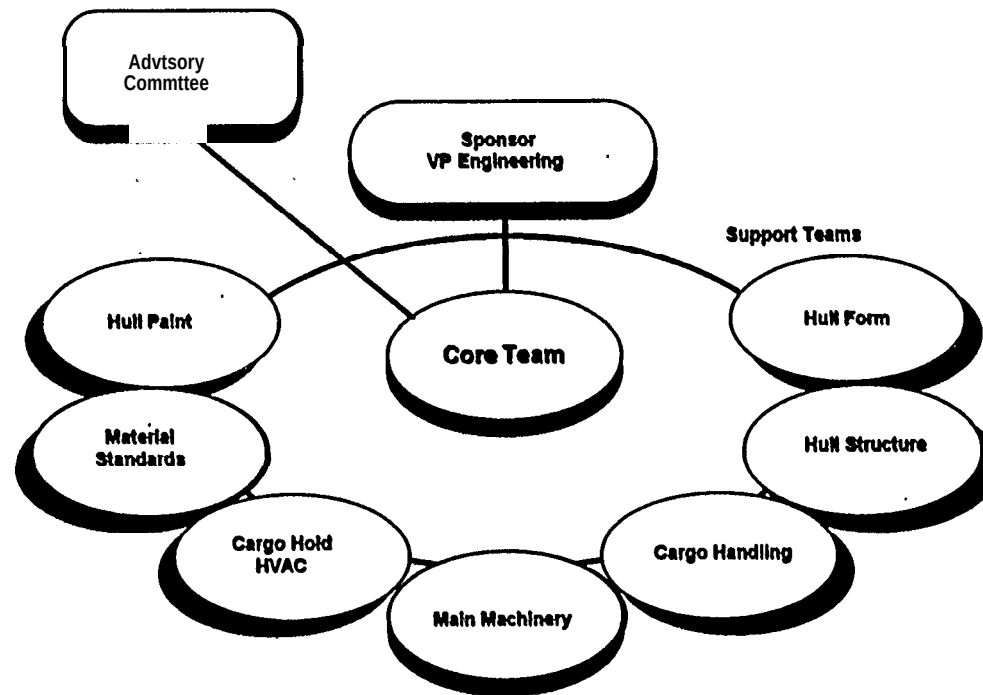
Technology Transfer Key Findings

- Small, flat, organizations relative to BIW
- Alignment of Design, Planning, Materials, Production organizations
- Significant design effort prior to contract award
- Experience maintained in a database of reference ship designs
- Design functions have broader responsibility than at BIW
- Integrated systems employed throughout the process
- Reliance on infrastructure such as standards and stock material
- Focus on least cost solutions

Implementation of Concurrent Engineering in the Project

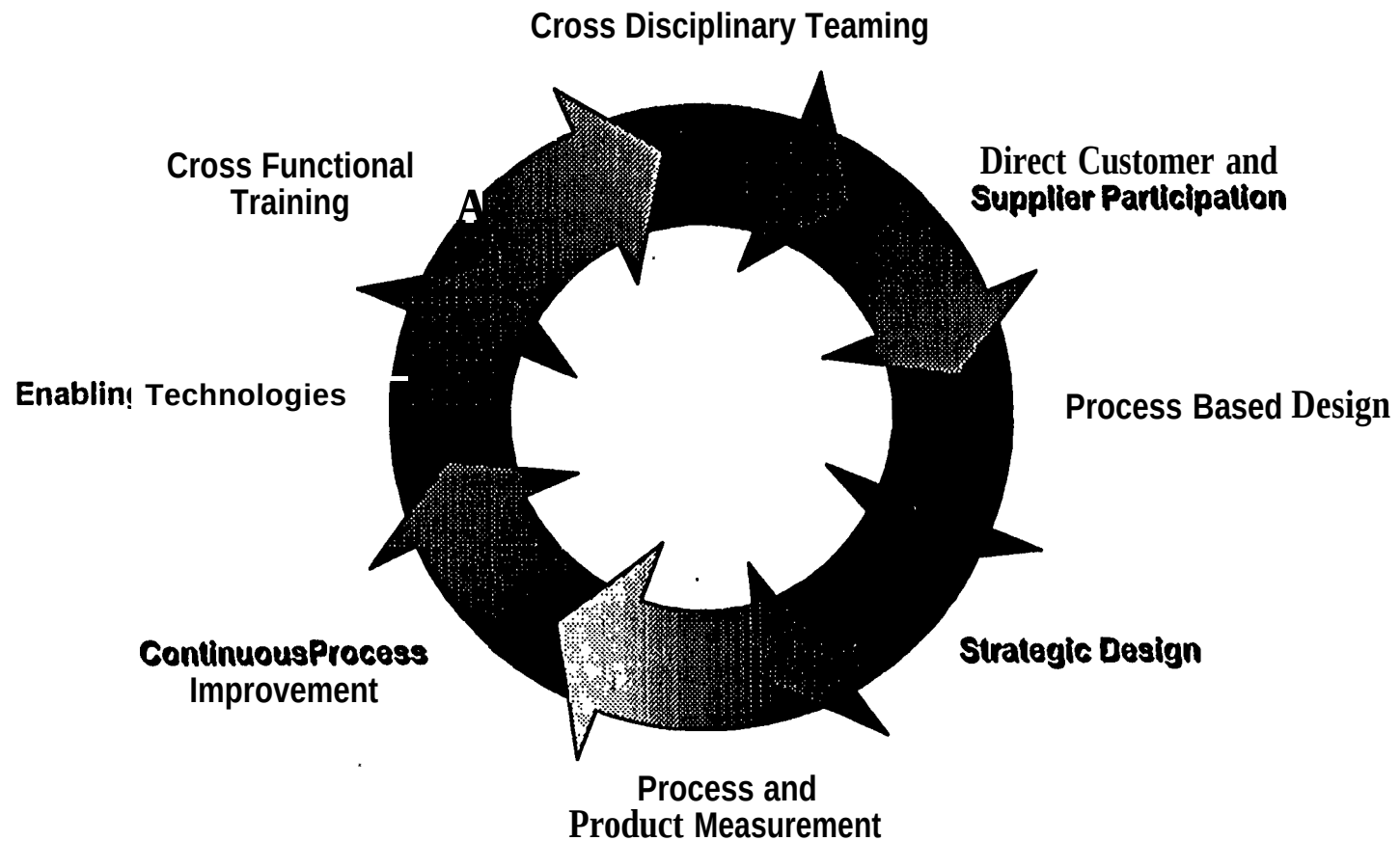
- Design Strategy Workshop
 - Strategic Design
 - Process Based
 - Product and Process Measurement
 - Team Decision Making and Problem Solving
 - Team Dynamics Measurement
 - Presentation to management
 - Accomplish Understanding
 - Ownership of the Method
 - Notice of Design Initiation
- Establishment of Product Development Team
- Product Development Team Meetings
 - Emphasis on process-based design; Planning, Materials, Production, aspects as well as Engineering
 - Identified and worked issues

PILOT TEAM ORGANIZATION



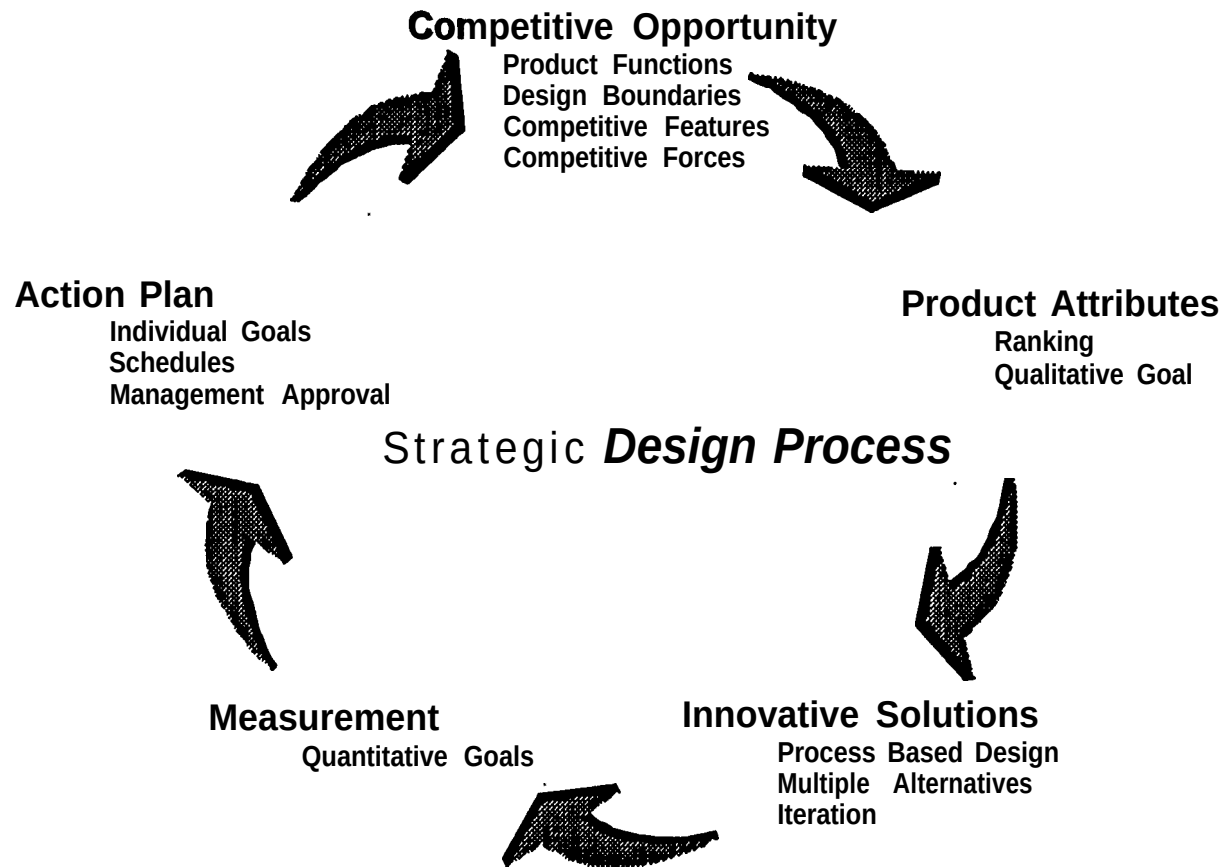
BATH IRON WORKS CORPORATION

**BATH IRON WORKS CORPORATION
CONCURRENT ENGINEERING IMPLEMENTATION**



BATH IRON WORKS CORPORATION

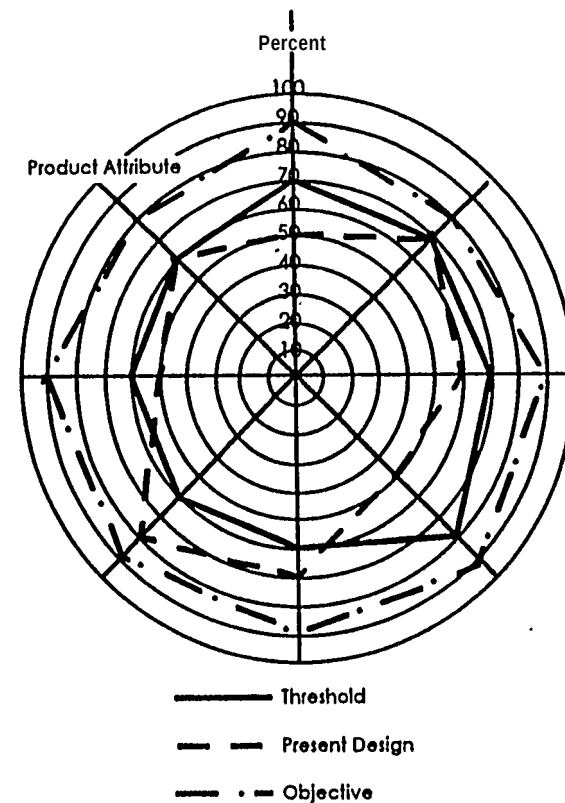
Strategic Design - Basis for Competitive Product Delivery



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Chosen Metrics for First Ship Design

- Affordability
- Performance
- Commonality
- Producibility
- Deliverability
- Risk
- Reliability
- Maintainability.



Concurrent Engineering Implementation Design Strategy Working Session - OUTLINE

•PROCESS BACKGROUND

- OPPORTUNITIES
- STRATEGY
- MEASURING PRODUCT SUCCESS
- MEASURING PROCESS PERFORMANCE
- ACTION PLAN

Concurrent Engineering Implementation Design Strategy Working Session - OPPORTUNITIES

- ENTRY POINT ON STRATEGIC DESIGN ROADMAP
- HIGHLIGHT CUSTOMER DESIRES

Concurrent Engineering Implementation Design Strategy Working Session - DESIGN STRATEGY

- IDENTIFY AND DEFINE “ILITIES”
- DEVELOP DESIGN TACTICS TO SUPPORT EACH “ILITY”

Concurrent Engineering Implementation Design Strategy Working Session - MEASURING PROCESS PERFORMANCE

TEAM EVALUATION TOOL

- TO BE COMPLETED NEXT WEEK AS A BENCHMARK AND IN 4 WEEKS TIME TO MONITOR PERFORMANCE

- Attributes MEASURED
 - TECHNICAL SKILL
 - DECISION-MAKING SKILL
 - ORGANIZATIONAL EFFICIENCY
 - OPEN-MINDED SPIRIT
 - LEADER/TEAM INTERACTION
 - COMMUNICATION
 - TECHNICAL FOCUS ON GOAL
 - INTERNAL TEAM INVOLVEMENT
 - EXTERNAL INVOLVEMENT
 - SENSE OF ACCOMPLISHMENT
 - PERSONAL SATISFACTION

Concurrent Engineering Implementation Design Strategy Working Session - ACTION PLAN

- PERSONAL ACTION PLANS
 - INDIVIDUAL TASK SHEETS
- TEAM ACTION PLANS
 - WEEKLY MEETING OF CORE TEAM
 - AT-A-GLANCE STATUS IN COMMERCIAL
SHIPBUILDING OFFICE

Benefits of Concurrent Engineering

- Cross-Functional involvement from the outset of design project
Engineers with Planners, Designers, Production, Materials
- Involvement of Owner
- Local S6 involvement through teaming agreement

Difficulties with Concurrent Engineering

- Basic Design process not understood by entire team
- Talking to one another not intuitive for engineers
- Consensus takes time
- PDT meetings not regular enough

Conclusions

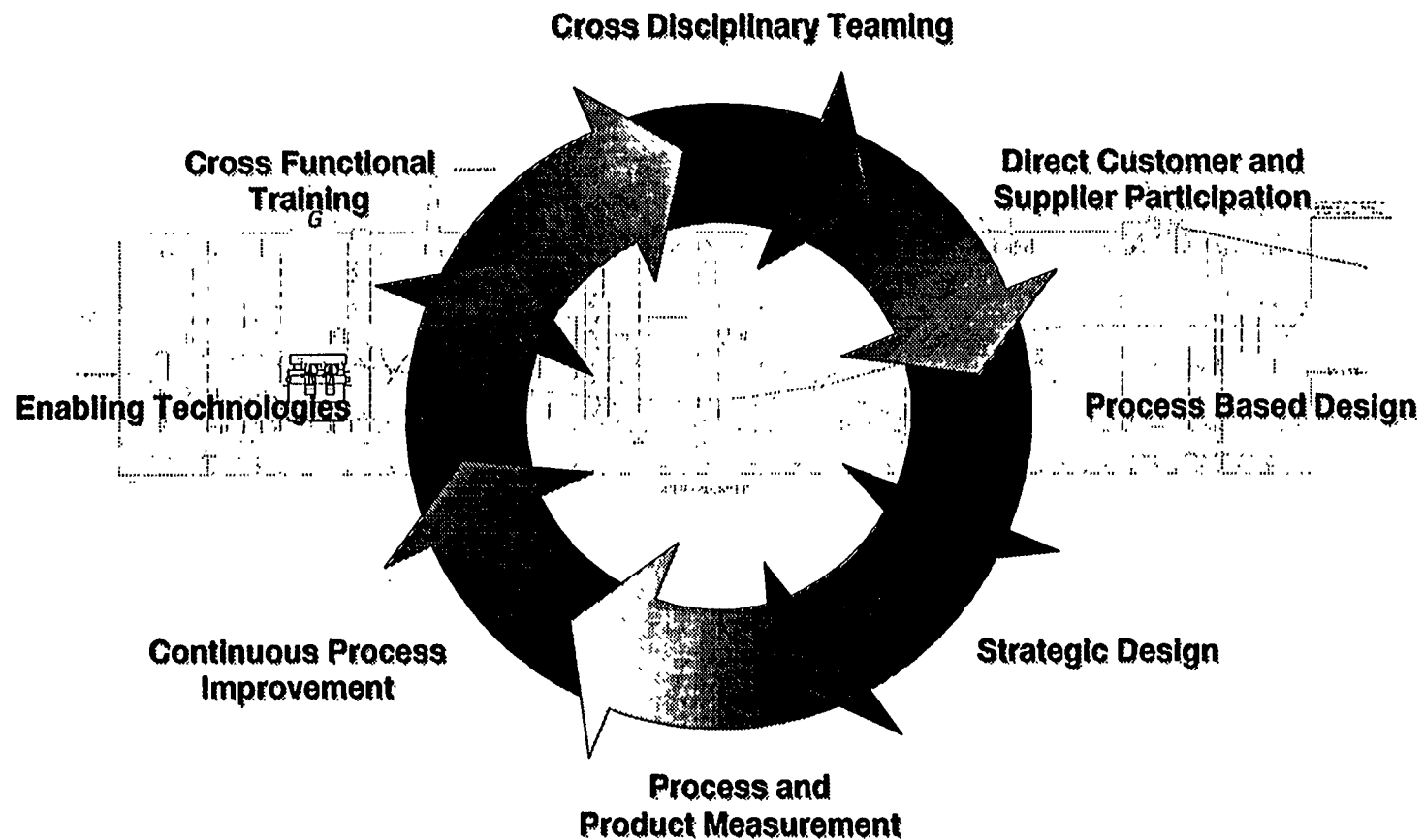
- The Future for Concurrent Engineering at BIW
 - PCTC
 - Power plant generation barge
 - Cross-functional teams developing process plans
- DDG51 Flight IIa
 - Area teams developing design

Concurrent Engineering Implementation Lessons Learned

**James G. Bennett
Sr. Naval Architect**

June 8, 1995

Elements of CE Implementation



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Naval Architectural Issues

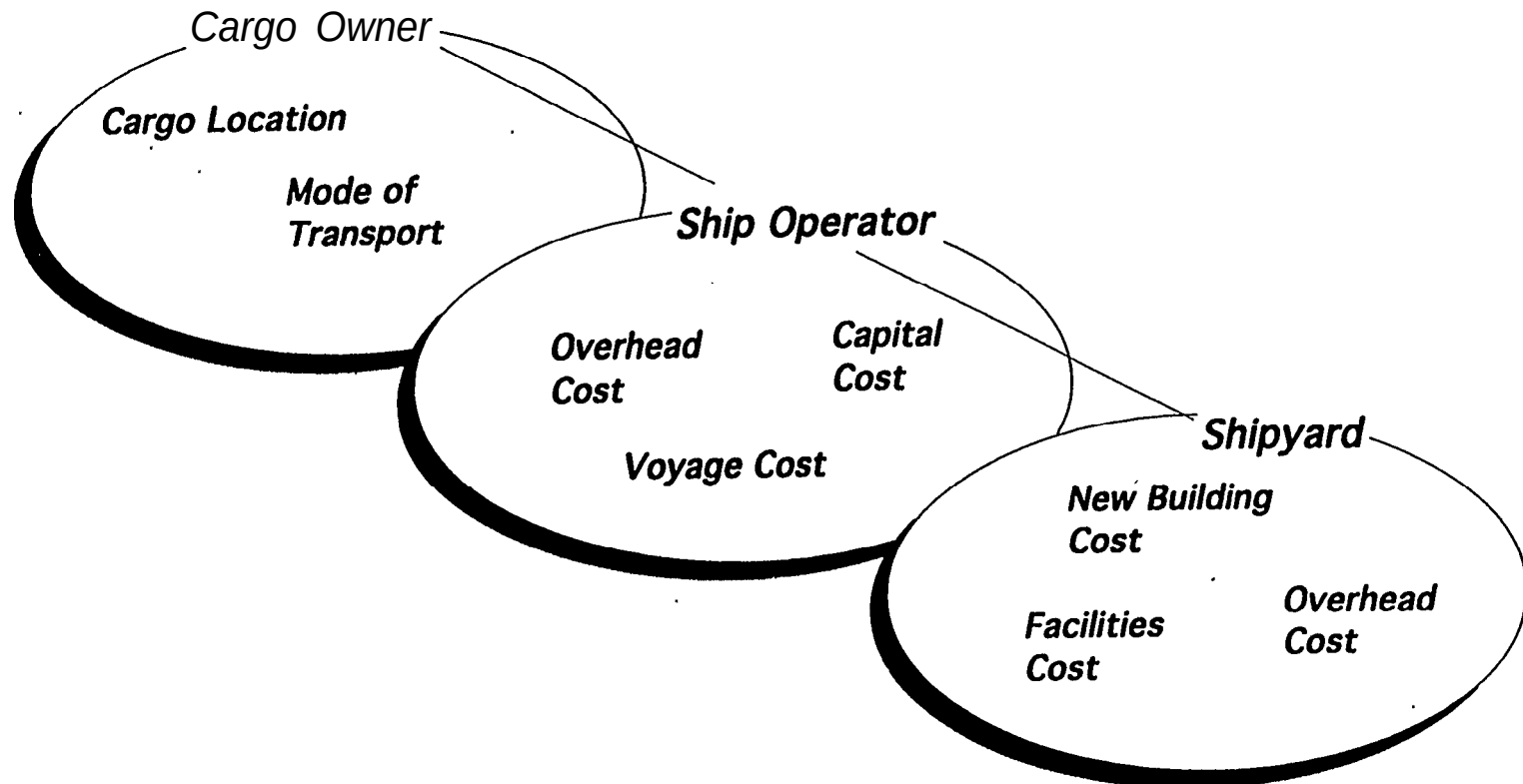
- General Arrangement
- RoRo Cargo Handling System
- Reefer System
- Hull Form
- Main Engine Selection
- Machinery Arrangement

Total Sea Transport Logistics System

- .Cargo handling is starting point of ship design process**
- .Most difficult area for US yards to establish expertise**
- .Strategic Reliance on Suppliers**
- .Tech Transfer instrumental in establishing supplier contact**

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Sea Transport Logistics Chain



RCC(D) Mission

- **Commercial RoRo**
- **Military RoRo**
- **Palletized Reefer**

RoRo Requirements - “Ilities”

- **Commercial RoRo**
 - 6000 car
 - 65% Light Truck
- **Military RoRo**
 - MIAI Tank
 - Straight & Semi Tractor-Trailer Trucks
 - HMMV'S
- **24hr in-port turn-around**
- **Simple interface to ship**
- **Self-contained/modular cargo handling systems**

RoRo CE Approach

.Customer involved from earliest stage

- Sumitomo Contract Design
- SRS Contract Design

.Thorough research of world fleet

- World Wide Fleet Statistics
- RoRo Conference in Sweden

.Numerous discussions with owner's reps

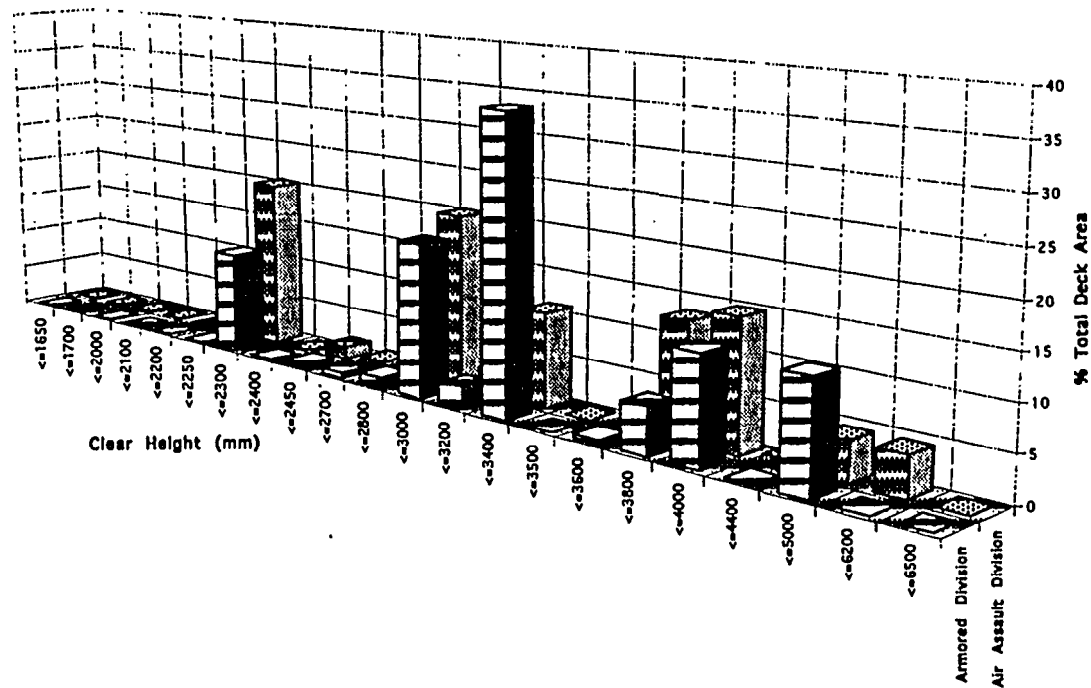
- Visits to European Ship Customer's

.Extensive visits made to ships in service

- Visits to Sunbelt Dixie
- Visits to Maersk Lines Ships in Portland

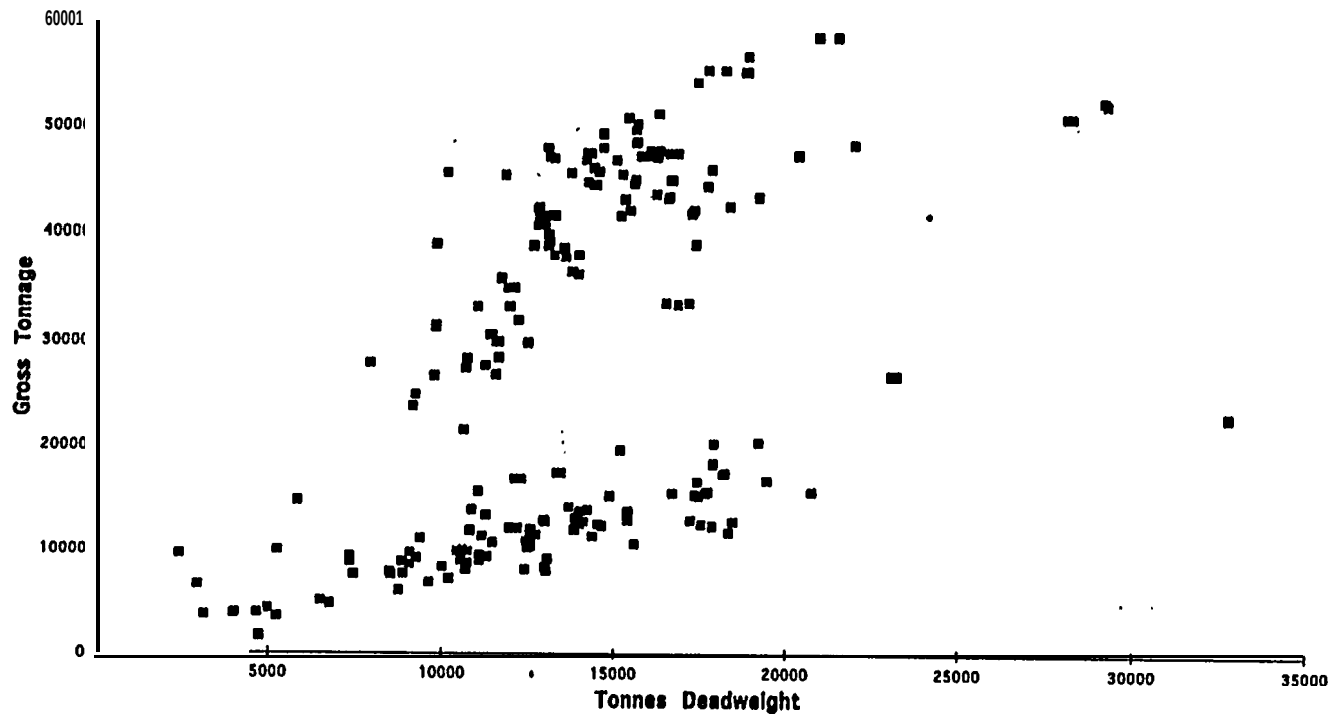
Military Vehicle Statistics

Military Deck Height Demand



RoRo Fleet Statistics

DWT Vs. GT



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RoRo CE Approach (cont'd)

- .Commercial & Military Vehicle Statistics**
- .Customer's technical representative made frequent visits to BIW**
- .Strategic relationship with cargo handling equipment suppliers**
 - Expertise in development of cargo handling systems**
 - Visit to Cargo Elevator Supplier**
- .Equipment Supplier personnel on-site at BIW**
- .In-process involvement of BIW production planning personnel**

RoRo Producibility Issues

- .Lessons Learned from States Lines RoRo**
- .Ramp/Elevator Arrangement**
- .Hoistable Deck Arrangement Vs Block Breakdown**
- .Arrangement of Vehicle Tie-Down Fittings**

Key RoRo Metrics

- .Deck Area/Height Distribution**
- .Clear Span Between Columns**
- .Vehicle Stowage Capacity**
- .Vehicle Dimensions, Axle Loads**
- .Vehicle Loading/Unloading Time**
- .Ramp/Deck Deployment Time**
- .Elevator Speed**
- .Number of RoRo Maneuvers**

Key RoRo Metrics (cont'd)

- .Number of Lift Deck Panels**
- .Number of Ramps**
- .Number of Install Parts**
- .Length/Quantity of Hydraulic Piping**
- .Number of Vehicle Tie-Down Fittings**

RoRo CE Results

- **Many iterations of ramp arrangements - optimized to suite mission requirements**
- **All military and commercial vehicle cargo objectives were achieved**
- **Minimal use of hydraulics**
- **Cargo hold arrangement and placement of elevators and ramps simplified - wing tanks, flush bulkheads**
- **Three ship concept designs - S, L ,D - and two variants - forward and aft facing stern ramp - were developed in less than 2 months**

RoRo CE Results (cont'd)

- .Block Breakdown worked concurrently with GA**
- Cross training of planners in use of CAD to visualize Block Breakdown**

Reefer Requirements - “Ilities”

- **Significant increase in reefer capacity compared with existing ships**
- **All palletized reefer handling**
- **Even distribution of cooling air**
- **Segregation and Protection of cargo**
- **Forklift stowage and battery charging**
- **Dual mission impact on RoRo handling system - gas tight ramps**
- **Low cost construction**
- **Durability and Maintainability**

Reefer CE Approach

- .Reefer system supplier brought in at very early stage**
- .Initial systems engineering received from supplier**
- .Cargo hold insulation / plenum system engineering developed by supplier**
- .Production Reps involved in supplier meetings**
- .Customer heavily involved in educating builder to nuances of Reefer trade**

Reefer CE Approach (cont'd)

- **Numerous meetings and telecommunications with customer**
- **2-Day on-site supplier visit**

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Reefer Producibility Issues

- **Reefer Plenum/Grating Arrangement**
 - Robson Vs. conventional reefer grating system
 - Transverse Vs longitudinal air flow
- **Reefer Vent Trunk Arrangement**
- **Use of reefer fans for hold ventilation**
- **Pre-Assembly of Reefer Cooling Units**
- **Clearance for Reefer Plant Installation**

Key Reefer Metrics

- .Install cost of Reefer Plant/cu ft Reefer Capacity**
- .Total Ship Cost/cu ft Reefer Capacity**
- .Quantity of Insulation**
- .Total Install Cost of Insulation**
- .Number of Reefer Plant Install Parts**
- .Number of Grating/Plenum Install Parts**

Reefer CE Results

- **Reefer plenum grating arrangement modified to incorporate higher strength grating material, reduce number of parts**
- **Cargo hold arrangement modified to suite efficient insulation process**
- **Reefer plant engineering package developed by supplier**
- **Extensive technical data exchange between suppliers and shipbuilder**

Reefer CE Results (cont'd)

- **Reefer and insulation systems engineering provided by suppliers**
- **Install cost of Reefer Plant is commercially competitive**

Hull Form Requirements - “ilities”

- **20 Kts at full load displacement**
- **20% Sea margin at 90% MCR**
- **Stability to USCG standard**
- **Maximum Producibility**

Hull Form CE Approach

- **Customer contacts established performance expectations**
- **World-wide RoRo fleet benchmark**
- **Internal review of plate bending/forming capabilities**
- **Strategic relationships with world-class hydrodynamics test facilities**
- **Visit to Hydrodynamics Laboratories**
- **Tech Transfer with KMY and MES**
- **Computational Fluid Dynamics**

Hull Form Producibility Issues

- **Complex Vs Simple Curvature**
- **Flat Surfaces**
- **Bilge Radius**
- **Deadrise**
- **Bilge Keel Arrangement**
- **Bulbous Bow**
- **Bulbous Skeg**
- **Stem and Stern Construction**
- **Rudder Installation**

Key Hull Form Metrics

- **Admiralty Coefficient**
- **Speed loss in waves**
- **Number of Shell Plates**
- **% Curved Vs Flat**
- **% Complex Vs Simple Curvature**
- **No. Furnaced Plates**

Hull Form CE Results

- **CFD analysis**
- **Improved reliability of performance prediction**
- **Reduced risk of main engine selection**
- **In-process input from Production**
- **Deadrise**
- **Shell Plate Forming Limitations**
- **Stem and stern construction**

Hull Form CE Results (cont'd)

- **Measurement of Hull Form Metrics improved confidence in hull construction estimate**
- **Maximum flat and simple curve surface geometry**

Main Propulsion Engine Requirements - “Ilities”

- **Reliability**
- **Crew skill & ability**
- **Parts availability**
- **Fuel Economy**
 - 84 T/Day for Main Engine
- **Modularity**
- **Shipyard Familiarity and Capability**
 - System Design and integration
 - Installation Technology
 - Activation

Main Propulsion Engine Requirements - “ilities” (cont’d)

.Sea Margin

- 20% at Full Load Displacement

.Overhaul Interval

.Maintainability

- Shaft Removal
- Valve Cleaning
- Piston Removal

Main Propulsion Engine Producibility Issues

- **Shipyard lifting and handling capacity**
- **Arrangement of casing and access to support late installation**
- **Number of auxiliary equipments**
- **Pre-assembly of auxiliary equipments “On-Unit”**
- **Lack of shipyard experience with slow speed diesel plants**

Main Propulsion Engine CE

- **Medium Vs Slow Speed trade-off study**
- **Early involvement of Main Engine Suppliers**
 - **On-site visits to BIW**
- **Consultation with MES**
- **Production Involvement in Suppliers Meetings**
- **Production Visits to MES**

Main Propulsion Engine CE Results

- .Slow Speed selected over medium speed**
- .Seven Cylinder engine rated at full sea margin**
- Starboard side casing arrangement Block Breakdown supports late installation**
- .Shaft removal without cutting of web frames**
- .Piston removal without special lifting fixtures**

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Summary - Overall

- .Development of international customer and supplier relations is major challenge to US yards**
- .collocation of Core Team is essential**
- .Group decision making requires considerable effort**
- .Effective in-process measurement is difficult to achieve**

Summary - Costs

- .Customer involvement requires clear business relationship and agreement to participate prior to contract**
- .Need training and clear definition of support team organization and responsibilities**
- .collocation requires commitment of facilities**
- .Standard metrics and methods needed to achieve effective in-process design measurement**

Summary - Benefits

- .Increased cost awareness of Engineers**
- .Improved cost competitiveness of RCC(D) Design**
- .Improved Communications**
- .Broader understanding of “total” ship design problem**
- .Higher confidence in design cost and performance predictions**
- .CE Approach has been adopted on all new product development efforts - Power Barge, Flight IIA DDG, High Speed Monohull**

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Structural Design- Concurrent Engineering Experience

Stephen **W** . Tarpy
Project Structural Engineer

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CE Decision Examples

- **use of bulb flat stiffeners**
- **collarless construction/threaded stiffeners**
- **elimination of box girders**
- **frame/web/pillar spacing**
- **engine casing length**

Decision Making Settings

- **Product Development Team meetings**
- **small teams assigned to specific issues**
- **meetings with owner's representative**
- **small group meetings**
- **polling and one-on-one discussion**

Early Decisions and Design Principles

- no box beams and girders
- avoid deck insert plates
- avoid use of collars
- maximum panel size
- maximum erected unit weight
- design for robotics
- built-up tees

Panel Stiffeners: Bulb Flats vs. Angles

Factors for consideration-

- **enhanced producibility**
- **improved coating performance**
- **heavier and deeper**
- **no domestic sources**

Approach-

- **small team assigned**
- **regular meetings and actions over two months**
- **data gathered by engineering, purchasing,
production and estimating**
- **estimating compiled results**

Panel Stiffeners: Bulb Flats vs. Angles

Conclusions-

- small net cost reduction**
- production preference confirmed**
- Holland profiles should be incorporated in design**
- spec to be written to allow substitution of other shapes**

Collarless Construction

- **shallow deck structure required**
- **traditional panel process dictates collars**
- **understanding of alternatives evolved with tech transfer visits**

Conclusion-

- **new panel line must efficiently accommodate threading stiffeners**

Elimination of Box Girders

Conflicting motivations-

- **closed sections are easiest design solution**
- **tees will be much more efficiently produced**

Engineering effort-

- **substantial time required for deck analysis**
- **commitment to producibility provided incentive**

Results-

- **no closed sections in the typical hull framing system**

Shell Frame Spacing

Desirable attributes-

- **maximum use of panel line capacity**
- **repeat pattern from block to block**
- **fewest parts and minimum weld length
(i.e. wide spacing)**
- **minimum weight**
- **no box girders**

Shell Frame Spacing

Study-

- 800 to 1000mm spacing considered
- webs every 3, 4, or 5 frames
- pillars every 3, or 4 webs

Results

- frames at 830mm, webs at 3.32m, pillars at 9.96
- 20 frames including 5 webs per panel (16.6m)
- efficient and useable for a range of ship lengths

Engine Casing Length

Principles-

- block breaks at multiples of panel length
- desirable to fab casing within complete panels

Open item-

- . initial design failed to recognize block break
i s s u e
- difficult to change (but will be)

Concurrent Engineering- A Planning Perspective

**Paul Laroche
Principal Planner**

BATH IRON WORKS CORPORATION

Concurrent Engineering; A Planning Perspective

- Factors influencing the Planning Process with respect to Concurrent Engineering:
 - Future Facilities Upgrades (currently in pre-permitting phase)
 - Teaming initiatives (under current contract and future anticipated)
 - Increased Block Erection Weights
 - Increase in the size of Erection Blocks
 - Increased emphasis on Accuracy Control
 - Compressed Commercial Milestones Schedule
 - Influence to the Build Strategy as a result of knowledge gained from KMY & Mitsui

Concurrent Engineering; A Planning Perspective

- Planning Products which were reviewed with Engineering, Production, Facilities and Materials Team:
 - Block Breakdown Scheme
 - Area Breakdown Scheme
 - Erection Schedule
 - Shipbuilding Policy Outline
 - Build Strategy Outline
 - Product Work Breakdown Structure (PWBS)
 - Principal Milestones
 - Outfit Packaging

Concurrent Engineering; A Planning Perspective

- Producibility Comments discussed with Engineering during the Design Process
 - Frame spacing logic to
 - >> Optimize Future Facilities (Panel Line and Assembly Areas)
 - >> Enhancing Product Repeatability
 - Orientation of Engine Room Sea Bays to avoid Block Breaks
Location of Machinery Uptake Space Bulkhead in order to completely Package the Uptake Casing
 - Simplify details around Stanchion Supports to avoid complex on-board fit-up..

Concurrent Engineering; A Planning Perspective

- Deliverables/topics jointly reviewed and agreed to
 - 830mm frame spacing
 - Simplified structure at Stanchion Cruciform
 - Repeatability of Mid Body Products
 - Machinery Space Lay-out which will yield logical Outfit packages
 - Block Breakdown which will simplify block make-up and reduce onboard welding (90 Erection Blocks, 201 sub-Blocks)
 - Area Work Breakdown which will organize work by common “Work Problem” (78 shipboard areas) (Design & Production)
 - Producible cargo hold ventilation penetration arrangement in deck structure

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Concurrent Engineering

ive

	Current Process			Past Practice		
	Review Process (Formal / Informal)	Review Participants	Purpose	Review Process (Formal / Informal)	Review Participants	Purpose
Block Breakdown	Formal, During Contract Design	Production, Design, Accuracy Control, Materials	Inform, Buy-In	Formal, During Detail Design	Design	Inform, Direct
Area Breakdown	Formal, During Contract Design	Production, Design, Accuracy Control, Materials, Production Control, MET, Master Scheduler	Inform, Buy-In	Formal During Detail Design	Design	Inform, Direct
Build Strategy	Formal, During Contract Design	Production, Design, Materials, Planning	Inform, Buy-In	Informal, piecemeal	Production	Inform
Shipbuilding Policy	Formal, During Contract Design	Production, Design, Materials, Planning	Inform, Buy-In	N / A	N / A	N / A
Erection Schedule	Informal, During Contract Design	Production, Design, Materials, Planning	Direct	Informal	Production	Direct
Outfit Package Breakdown	Informal, During Contract Design	Production, Design, Materials, Planning & Machinery Design	Inform (Buy-In later)	Formal During Detail Design	Design, Production	Buy-In
Producibility, Material Selection	Formal, During Contract Design	Production, Design, Materials, Planning	Direct	Formal During Detail Design	Design, Materials, Planning	Direct
Producibility, Production Process	Formal, During Contract Design	Production, Design, Planning	Direct	Formal During Detail Design	Design, Materials, Planning	Direct

Concurrent Engineering; A Planning Perspective

- Lessons Learned from Concurrent Engineering Process
 - Need better tools (metrics) to qualify the effectiveness of decisions made in a concurrent engineering environment
 - Need better decision making process when Producibility issues collide with issues such as Owners Desires, Specs or Naval Architecture.
 - Need to be involved early and stay involved throughout the Design Process.
 - Ability to listen, understand and compromise when necessary.
 - Anticipate and be ready to change.....often!
 - Need better tools (Hardware) across the group.
 - Experienced Team Members, once trained don't let them go !
 - Co-location is essential

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PRODUCTION PARTICIPATION WITHIN CONCURRENT ENGINEERING

PROJECT PRODUCTION REPRESENTATIVE
(OUTFITTING)

ANTHONY J. CLUKEY

JUNE 1995

Concurrent Engineering: Production's Participation

Outline

- Reasons for Participation
- Participation Considerations
- Potential Roadblocks
- Results to Date
- Daily Considerations

Concurrent Engineering; Production's Participation

Reasons For Participation

- Nobody better understands the construction process.
- Short build times.
- Reduced rework.
- Best understanding of current Labor Contracts.
- Who better appreciates facility capabilities?
- Design ownership.
- Participation equals buy-in.
- Incorporation of lessons learned.

Concurrent Engineering: Production's Participation

Participation Considerations

- Expect criticism,
- Recognize and accept that no decision is an easy decision.
- **Recognize** that no one person has all the answers.
 - Networking is essential
- Understand options, consider all aspects, and then proceed.
- Must be a team with a mission.
- Expect a feeling of satisfaction.

Concurrent Engineering; Production's Participation

Potential Participation Roadblocks

- Cultural Change
- Alienation
- Lack of “staying power”
- Participant turnover

Concurrent Engineering; Production's Participation

Participation Results to date

- A splinter group has been formed.
- This group will involve the right people at the right times.
- We've identified numerous characteristics for consideration.

Some of which are:

- durability
- required training
- unique safety issues....hazardous materials
- material pricing
- material availability

Concurrent Engineering; Production's Participation

Participation Results to date (con't)

- Currently we're brainstorming potential candidates for the group to consider.
- A few of these items are:
 - Potential use of thermoplastic pipe.
 - Potential use of “spin flange” technology.
 - Potential use of standardized electrical foundations.
 - Potential use of single bulkhead penetration pieces.

Concurrent Engineering; Production's Participation

Items for Continuous Consideration

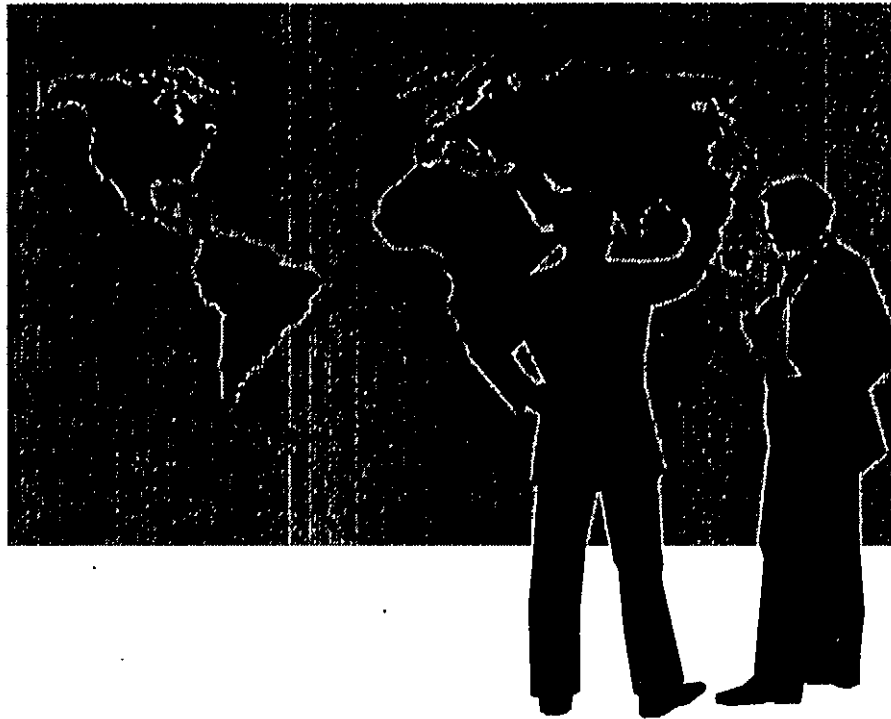
- Design with production very much in mind.
- Simple design, if you please!
 - No requirements for special tooling or jigs.
 - No requirements for special fittings.
- Pipe piece standardization.
- Maximize downhand work.
- Maximize shop work.
 - “hot work” - shop
 - “cold work” - ship

Concurrent Engineering Production's Participation

Summary

- Short build times necessitate the use of concurrent engineering.
- Expect a roller coaster ride.
- Recognize that this is your opportunity to truly influence the process.
- Take satisfaction from your participation.

BATH IRON WORKS CORPORATION INTERNATIONAL SUPPLIER DATABASE



JUNE 9,1995

BATH IRON WORKS CORPORATION

S U P P L I E R D A T A B A S E

OUTLINE

- ⇒ Introduction
- ⇒ Background
- ⇒ Database Structure
- ⇒ Database Capabilities
- ⇒ Conclusion

BATH IRON WORKS CORPORATION

SUPPLIER DATABASE

♦ **INTRODUCTION**

*"As the US. shipbuilding industry tries to enter the international commercial shipbuilding market one thing becomes increasingly clear; they must embrace an in-depth **cultural change** if they are to be successful.*

One of the primary cultural changes that must take place is a management process that facilitates communication, collaboration, and rapid decision making of all parties involved in the ship design and construction process."

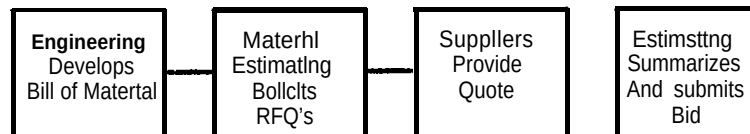
Robert Schaffran
Program Manager, MARITEC

SUPPLIER DATABASE

• BACKGROUND

The past BIW culture.... **“Parochial & Structured”**

- Direct communication with suppliers by Engineering was discouraged.
 - Purchasing Acted as a Liaison
- Design was completed with notional understanding of cost.
- Design Development & cost estimate preparation was segment



- BIW told the suppliers exactly what we wanted.
 - Detailed Purchase Specifications were developed & issued

SUPPLIER DATABASE

♦ **BACKGROUND**

⇒ The emerging BIW culture.... **“Breaking down the Walls”**

- Engineering encouraged to talk directly with suppliers.
- BIW is looking to develop relationships with key suppliers
 - Input from suppliers sought during the design phase.
 - Performance Specifications vs. Purchase Specifications
- Overall cost impacts are better understood during design phase.
 - All functional areas, including suppliers, have input during design phase.

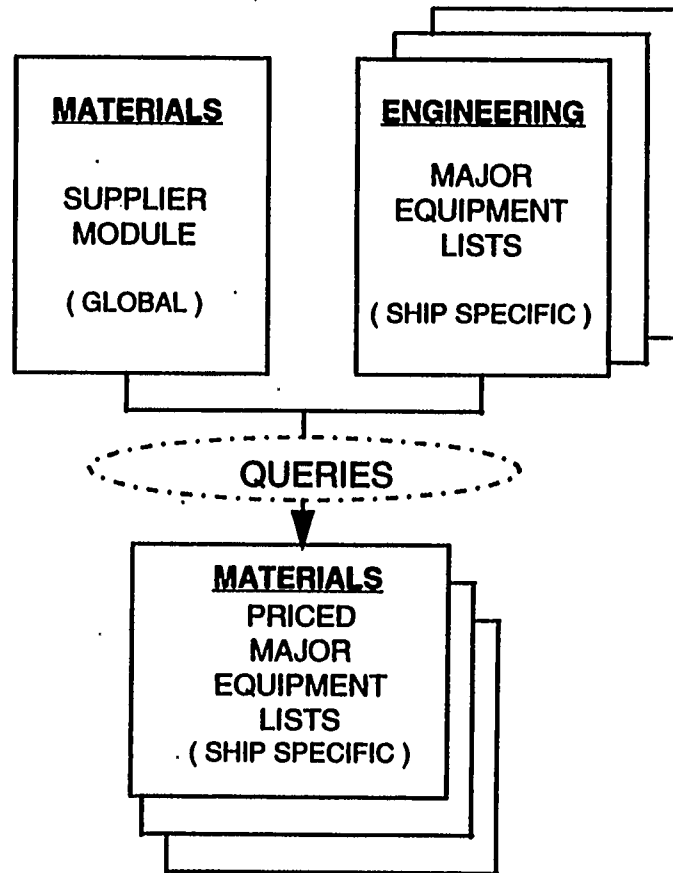
SUPPLIER DATABASE

BACKGROUND:

- ⇒ **As we embarked on this new process, it was recognized that a common repository to share the knowledge being obtained needed to be established.**
- ⇒ **The purpose of the database was defined by two high-level objectives:**
 1. **Develop a method to determine who BIW will do business with.**
 - **Familiarize Ourselves with International Commercial Suppliers**
 - **Supplier qualification process**
 - **Familiarize Foreign Markets to BIW**
 2. **Support Proposal Development Efforts**
 - **Historical Pricing records for Major Equipment.**
 - **Major Equipment Lists for various ship designs maintained in one place.**

SUPPLIER DATABASE

DATABASE STRUCTURE :



BATH IRON WORKS CORPORATION

SUPPLIER DATABASE

DATABASE STRUCTURE:

- ⇒ The Materials Division has the primary responsibility to maintain the supplier module which tracks the following:

Numeric Designation (WBS)	Equipment Description	Qualification	Status
Vendor Name	Vendor Address		
Vendor Contact & Title	Vendor Phone/Fax		

- ⇒ The Major Equipment Lists module of the database will be maintained by Engineering and will provide the following data:

Numeric Designation (WBS)	Equipment	Shipset Quantity
Descriptions	Fluid	Material
Color	Capacity	Head
Classification Society	Pressure	Pressure Drop
Temp	Heat Dissipation	Efficiency
Dry Weight	Wet Weight	Power
Dimensions	Electric	Power Factor
Voltage	Phases	AC/DC
Enclosure Type	Documentation Required	
System/Equip. Identifiers	Reservations/Comments	

SUPPLIER DATABASE

DATABASE STRUCTURE:

- ⇒ Through the use of queries, the vendor information from the supplier module will be linked to a specific ship's Master Equipment List to facilitate the RFQ process.
- ⇒ The Priced MEL module of the database will be maintained by the Materials Division and track the following information for each ship estimate completed:

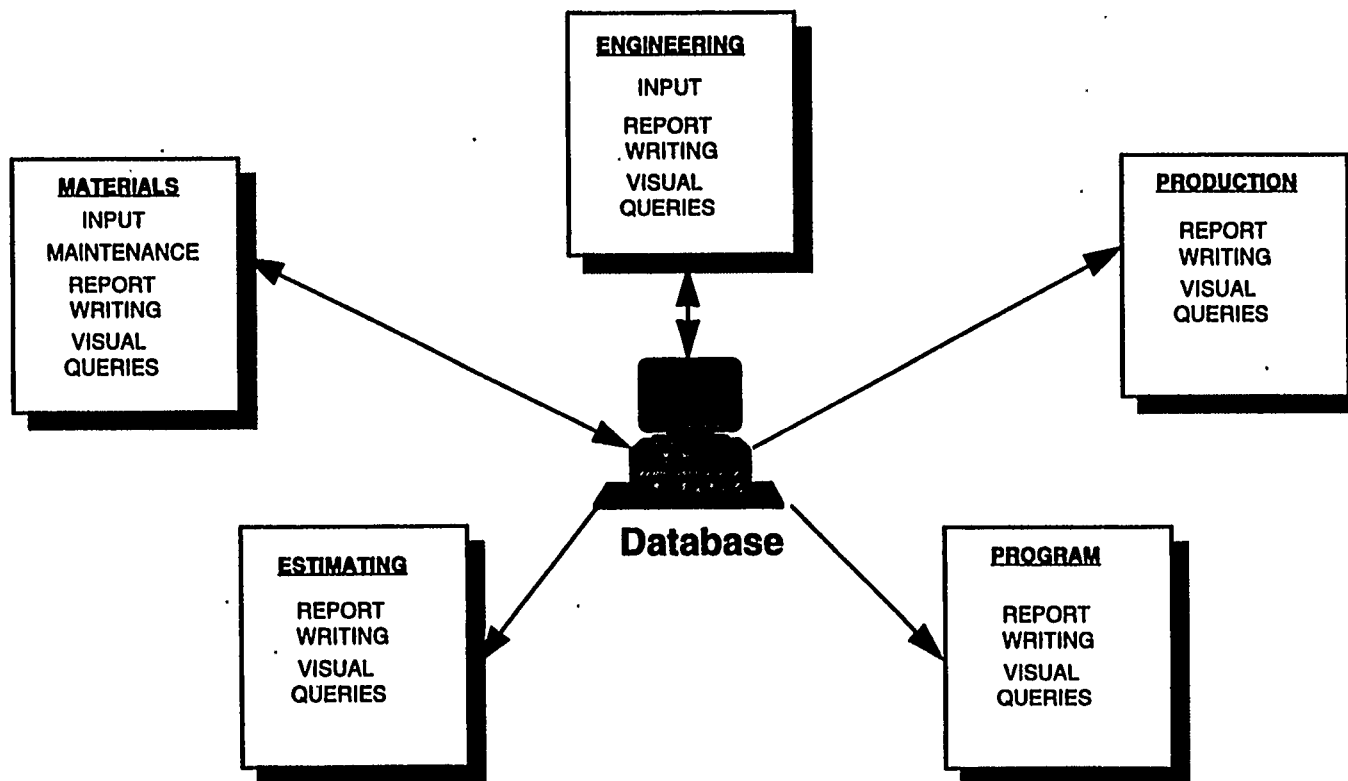
Numeric Designation (WBS)
Vendor Quoting
Lead-time
Notes/Comments

Equipment Description
Price Quoted (in \$ US)
Price Validity

BATH IRON WORKS CORPORATION

SUPPLIER DATABASE

DATABASE CAPABILITIES :



BATH IRON WORKS CORPORATION

SUPPLIER DATABASE

DATABASE CAPABILITIES:

- ⇒ User groups will be established and trained to access the information gathered within the database.
 - Ž Materials - Supplier Information, Past pricing for price analysis, etc.
 - Ž Engineering - Material Cost Information, Notional Bills of material, etc.
 - Estimating - Material cost data for high-level analysis
- ⇒ Standard reports will be developed to provide needed data.
 - Ž Makers List to support Proposal Submittals
 - Ž Mailing lists
 - Ž Notional Bills of Material for Commercial Ship designs
 - Weight reports
- ⇒ Ad Hoc reports can also be developed.
 - Supplier activity reports
 - Quote history for different equipments/materials
 - Ž Long Lead-time material reports
- ⇒ Over time, a priced bill of material will be available for various ship designs.
 - Facilitate future bill of material development.
 - Facilitate high-level indicative price estimates

BATH IRON WORKS CORPORATION

SUPPLIER DATABASE

CONCLUSION :

- ⇒ As we continue with our Commercial Shipbuilding endeavors, the database should serve as the foundation for continued improvement in both our design and estimating efforts.

CE IMPLEMENTATION

Measurement

•The “Rules” of Design Measurement

- Team develops measurement goals & tools
- Measure what's important, not what's easy to measure
- Direction is more important than precision .
- Measure in-process
- Measure often
- Measure all parameters concurrently
- Use a visual presentation of results

CE IMPLEMENTATION

Measurement

•Project Strategy

Strategic Illity

1. Affordability
2. Performabillty
3. Standardability
4. Producibility
5. Deliverabiity
6. Riskability
7. Reliabiity
8. Maintalnabiity

Definitlions

- Achieve a competitive ship price
- Meet all specified owners /regulatory requirements for performance
- Maximize the use of common parts, components, and processes
- Maximize the use of efficient BIW processes to produce the product
- Ability to get the product from concept to delivery within contractual time period.
- Design in adequate margins to achieve high probability of product project success
- Make use of proven components, simple and easy to maintain systems and proven technology coating systems
- Minimize frequency of maintenance intervals and effort required to maintain the ship in service

CE IMPLEMENTATION

Measurement

•In-process Measurement

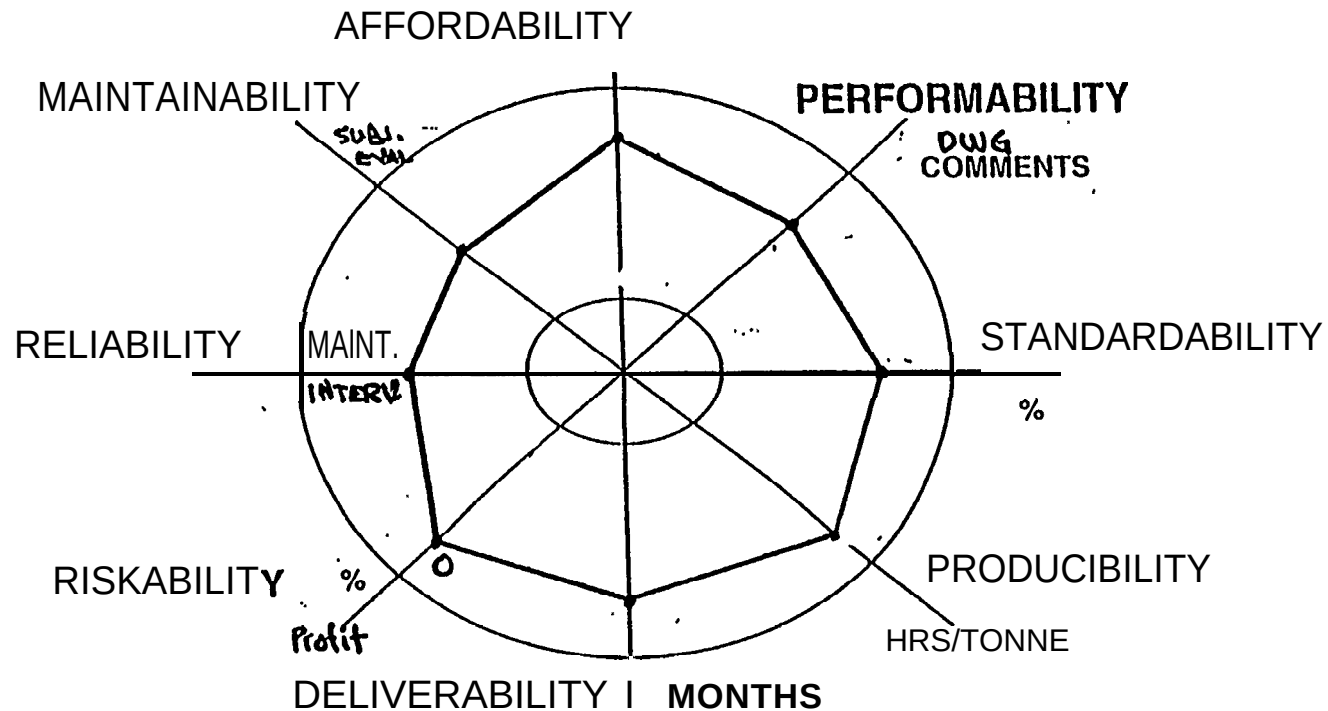
Strategic

Measurements

- | | |
|--------------------|--|
| 1. Affordability | Projected total ship cost in US\$ |
| 2. Performability | Number of comments against approval drawings |
| 3. Standardability | % Commonality of processes and catalog parts |
| 4. Produceability | Projected product labor hours. Total ship hours/ton steel weight |
| 5. Deliverability | Months to deliver finished ship |
| 6. Riskability | Projected vs. target total ship \$ cost |
| 7. Reliability | Maintenance intervals for major equipment |
| 8. Maintainability | Subjective maintenance evaluation projection by team |

CE IMPLEMENTATION Measurement

•In-process Measurement



CE IMPLEMENTATION Measurement

- **Design Measurement Experience**
 - **Problems in application**
 - » **Metric inapplicable to design phase**
 - » **Metric difficult to evaluate**
 - » **Subjective judgments (non-quantitative)**
 - » **No assigned evaluator**
 - **Example - Riskability**
 - **Example - Revised metrics for next design**

CE IMPLEMENTATION Measurement

•Riskability Analysis

- Design .
- Developmental ship systems
- Installation experience
- New production facilities

Riskability						
4/18/95/wcb						
Parameter	Description of Risk	Original Margin	Current Margin	Trend	Score	Risk Mitigation
Design						
Weight & KG	Ship has insufficient deadweight, or fails to load full cargo due to stability limitation. GUARANTEE	%				Weight control plan including margin budget through delivery
Sea Margin	Ship fails to make service speed with required engine and sea margins. GUARANTEE	20%	14%	adverse		CFD analysis, model testing, fall back to bigger engine, negotiate margin with owner
Deck Height	Ship as-built has insufficient clear cargo deck height	% or mm.				Accuracy control plan
Deck Area	Ship fails to load required number of cars and/or reefer pallets. GUARANTEE	% or m ² or # of items				Close attention to maintaining clear area during detail design and construction
Maneuvering	Large military vehicles cannot maneuver to/from assigned stowage	mm. on swept path				Close attention to maintaining clear lanes during detail design and construction
Hull surface control points ("Hard Spots")	Insufficient room for major components eg main engine, bow thruster, pallet elevators (worst case). Special structural arrangements required to accomodate these features (more likely).	mm. clearance				Close attention to these control points during functional and detail design
Developmental Ship Systems						
Pallet Elevators	Supplier inability to supply the required system (beyond the state of the art)	n/a	n/a	undefined		Close cooperation with supplier(s).
Movable Decks	Supplier inability to supply the required system (beyond the state of the art)	n/a	n/a	undefined		Close cooperation with supplier(s).
Reefer Grating	Supplier inability to supply the required system (beyond the state of the art)	n/a	n/a	undefined		Close cooperation with supplier(s).
Installation Experience						
Slow Speed Diesel	Excessive installation hours, poor component performance, schedule degradation	n/a	n/a	undefined		Strong supplier support, In-house training
Cargo Handling Systems	Excessive installation hours, poor component performance, schedule degradation	n/a	n/a	undefined		Strong supplier support, in-house training

Reefer System	Excessive installation hours, poor component performance, schedule degradation	n/a	In/a	undefined		Strong supplier support, In-house training
New Production Processes						
New Facility	Startup problems with new facility, failure of developmental production processes to perform designed					Realistic learning curve, in-house training
Commercial Standards	; Unanticipated problems in adopting new standards, costs associated with inadvertent use of Navy standards					Realistic learning curve and accuracy control plan including in-house training
Accuracy Control	Unanticipated problems in adopting MES type; accuracy control plan, failure of plan to facilitate Installation of dimension critical components such as movable decks, pallet "elevator system					Realistic learning curve
Design Tools/Processes	Slower than planned learning of new design techniques, software, processes. Failure of , software and/or processes to perform as expected.					Careful selection of tools and processes including pre-purchase testing where appropriate, realistic learning curve, in-house training *

CE IMPLEMENTATION Measurement

- **Proposed Design Metrics**
 - **Affordability**
 - **Performability**
 - **Standardability**
 - **Producibility**
 - **Deliverability**
 - **Riskability**
 - **Reliability & maintainability**
 - **Marketability**

Proposed Design Metrics - PCTC						
1/21/95/wcb/rev5/28/95						
Utility		Design Phase				
	Contract	Functional Classification	Transition	Production	Delivery	Guarantee
1. Affordability	Estimated cost	EAC	EAC	EAC	Final cost	Guarantee cost
2. Performability	Exceptions to owner's requirements, owner changes during negotiation	Owner and Classification Agency comments	Adherence to system design	Adherence to system design	Test and trial data	Voyage performance data
3. Standardability	Adherence to LSE, LOE	Adherence to detailed design & process standards	Adherence to design & process standards	Adherence to design & process standards	Final analysis of adherence to design & process standards	n/a
4. Producibility	Target hours/ton steel (or similar)	Adherence to system material budgets	Adherence to system/zone material budgets	Adherence to zone material budgets	Final hours/ton steel (or similar)	n/a
5. Deliverability	Contract delivery time	Estimated delivery date	Estimated delivery date	Estimated delivery date	Actual delivery date	n/a
6. Riskability	Establishment of realistic design margins	Adherence to margin budget	Adherence to margin budget	Adherence to margin budget	Remaining margins, extent of performance penalty	Voyage performance data
7. Reliability and maintainability	Estimated TBO and MTR of major components, life of specified coatings, drydocking interval; owner changes during negotiation; provision of adequate maintenance envelopes, pull space etc.	Estimated TBO and MTR of major systems, owner comments on R&M	Maintenance of adequate maintenance envelopes, pull space etc.	Maintenance of adequate maintenance envelopes, pull space etc.	Number of operating crew comments	Number of guarantee items
8. Marketability	Estimated % market penetration; development of marketing support package; achievement of target number of ships under contract	Confirmed market penetration	Confirmation of option ships	Confirmation of option ships	Confirmation of option ships, estimated market penetration of "stretch" and "leap" designs.	Estimated % market penetration of "stretch" and "leap" designs. Owner feedback on commercial success

CE IMPLEMENTATION

Measurement

.Team Dynamics Measurement

Technical skill

Decision making

Organizational efficiency

Open minded spirit

Leader/team interaction

Communication

Technical focus on goal

Internal team. involvement

External involvement

Sense of accomplishment

Personal satisfaction

CE IMPLEMENTATION

Measurement

• Team Dynamics Measurement Results

Item	Date		Notes
	9/94	5/95	
1. Technical skills	6.5	6.1	
2. Decision making	6/4	5/9	WBS process, perception of empowerment
3. Organizational efficiency	6.0	6.0	
4. Open minded spirit	7.2	7.7	
5. Leader/team interaction	7.1	7.9	
6. Communication	5.2	7.1	
7. Team focus on goal	5.7	6.0	
8. Internal team involvement	7.8	5.9	Perception of involvement
9. External involvement	6.3	5.2	Absence of management participation
10. Sense of accomplishment	7.5	7.2	
11. Personal satisfaction	7.5	6.2	Overwhelmed, rushed by interruptions

CE IMPLEMENTATION Measurement

- **Team Dynamics Measurement - Simplified**
 - Technical skill
 - Decision making
 - Empowerment
 - Organizational efficiency
 - Leader/team interaction
 - Open minded spirit/mutual respect
 - Involvement

CE IMPLEMENTATION Summary

- **Multi-disciplinary team**
- **Team and management training**
- **Team co-location**
- **Design strategy**
- **In-process measurement**
- **Continuous improvement**

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