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EDUCATION AND TRAINING

# **THE NATIONAL SHIPBUILDING RESEARCH PROGRAM**

## **1995 Ship Production Symposium**

### **Paper No. 20: The Product Model as a Central Information Source in a Ship- building Environment**

U.S. DEPARTMENT OF THE NAVY  
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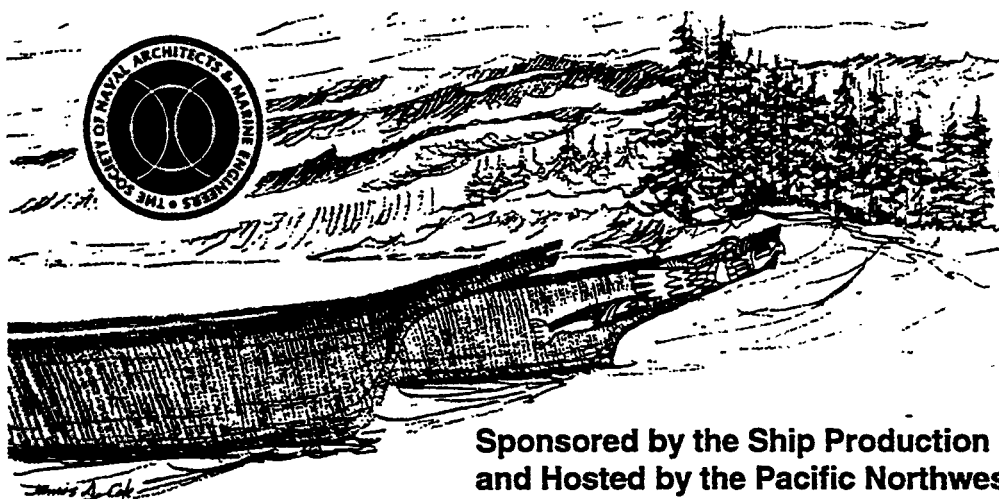
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# The Product Model as a Central Information Source in a Shipbuilding Environment

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## ABSTRACT

In a shipbuilding CAD/CAM system a product model is successively built up during the design process, with geometric as well as non-geometric information. In parallel with the design process, the model is further extended with work preparation (in some countries called production engineering) information e.g. definition of building strategy and definition of the assembly structure.

Information needed for part fabrication can be derived from the model, such as drawings, parts lists and information for numerically controlled (NC) equipment. When work preparation definitions are combined with a product model, the information needed for assembly parts lists, assembly drawings, etc. can be derived from the product model instead of being created manually.

Use of the product model concept, systems based upon it and procedures implementing it in an organization will allow a reduction of costs and an increase in productivity and competitiveness.

## INTRODUCTION

### Background

Ships and offshore structures are often built in short series or as individual made-to-order products. The high complexity of the products implies an intensive design and planning process, where many tasks have to be performed in parallel. Often, manufacture of one part of the product is going on at the same time as the detailed design of another. The need for higher efficiency and shorter delivery times means that the number of overlapping activities increases and the process becomes more and more complex. In addition to this, there are numerous design changes which are introduced very late.

A new buzz word has been introduced in some industries to describe this situation: "Concurrent Engineering." Even if the term is new, the situation is

not new to the shipbuilding industry where people have been used to working with overlapping activities for many years. The ability to work in a controlled way with overlapping activities influences the efficiency of an organization to a large extent. A key element in increasing the overlapping is the management and control of the information flow.

In most cases at a shipyard, detailed design and production are performed within the company and under direct control of shipyard management. This gives a more or less unique possibility to find efficient ways to handle information flow and to transform potential information handling problems into an information handling skill, creating a competitive advantage.

Shipbuilding has been characterized as "A process where you, from rather simple parts, assembled in a very complex way, produce highly sophisticated products: which is a good description. It is important to produce parts with enough accuracy, but the real challenge is to manage and control the design and assembly process to gain efficiency and short delivery times.

After the political changes in eastern Europe, new countries will emerge as players in the commercial shipbuilding market. Other countries, formerly concerned with building mainly navy vessels, will enter the new building business and new developing countries, especially in the far east, will enter the market as shipbuilding nations. In addition, the present major players will reinvest to maintain their position. All these changes will lead to an increased shipbuilding capacity and a very competitive market situation.

Investments are already under way in many countries in shipyard facilities and modern equipment, such as robots and robotized production lines. These investments are combined with changes in working practices as well as training of personnel to reach an optimal solution. A key element of being able to maximize the return on these new investments is to ensure that the information systems that drive them are optimized for the needs of the business and closely integrated into the new process.

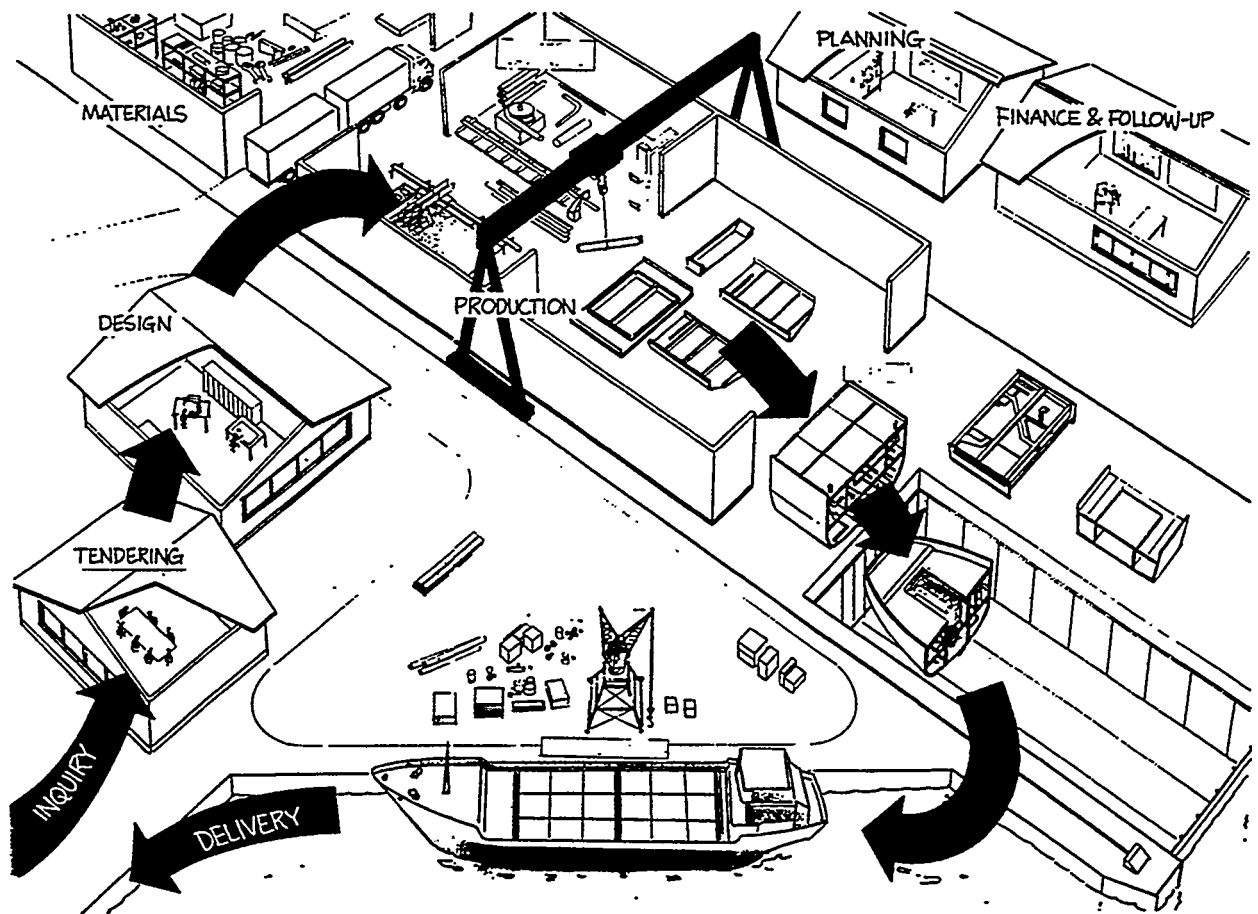


Figure 1 The Shipbuilding Business

### The Shipbuilding Business

The building of a vessel in today's world is an extremely complex business. In a simplified way, the main activities are shown in figure 1 and summarized below.

**Tendering.** Tendering is the activity where the initial design is agreed upon between the owner and the builder, together with a price and delivery time as part of the contract. The build strategy is defined. Decisions during this activity will highly influence the final cost for the contract.

**Design.** Design is the activity where initial design is further developed into a detailed design, assembly sequences are defined according to the build strategy and production information is created for production.

**Production.** In the production activity, the information created during detailed design is used to build the vessel. Production is usually divided into three major steps. The first step is parts manufacture where piece parts of different types are manufactured from raw

material. The second step is assembly where piece parts successively are put together to low level assemblies which are put together to higher level assemblies and so on until the final product is assembled. Finally in the commission stage the product undergoes tests and trials.

**Planning.** Planning is the activity where project plans are developed and monitored. Plans should be made for all activities and refer to the build strategy.

**Materials.** The materials activity supports design and production with all aspects of material control from purchasing to issuing of material from stores.

**Finance and Follow up.** In the finance and follow up activity all aspects of monitoring and control of finance, for the company and each project are handled.

**The Information Flow.** Starting with inquiry and ending with delivery, the shipbuilding business process involves a number of departments all generating and exchanging an enormous amount of information. This situation can lead to errors, duplication of work and delays when waiting for information. The net effect can be a very inefficient business.

One of the tasks of shipyard management' is to create an information flow solution specifically designed for this industry, to ensure that the organization is as efficient as possible in the shipbuilding process.

### Key Factors for Efficient Shipbuilding

There are a number of key factors which are related to information flow which have a major influence on the efficiency of ship production. These are listed below

**Design for Production.** Design for production ensures that the design can be easily produced and also reduces production manhours for the product. A well thought out build strategy describing how the vessel will be built must be developed, in parallel with early design activities, to ensure that the detailed design is best suited to the production facilities. In this way design for production can really be made to happen.

**Early Unit Breakdown** By deciding the build strategy and hence the major construction units (or assemblies) early, further design can take this into account to ensure that the units can be easily constructed through each assembly stage and that the necessary material can be ordered and marshalled to meet the building program.

**Prefabrication.** By maximizing the level of prefabrication, more work can be carried out at an earlier stage in the building process. When work can be carried out in workshop conditions as opposed to a building berth, the cost of the work is reduced.

**Preoutfitting.** By installing outfit items on hull assemblies and sub assemblies before the ship's hull is erected, the cost of outfitting can be reduced.

**Complete and Consistent Production Information.** Production information specifically created for each stage of manufacture can improve the efficiency of the operation as all necessary information is in one document and workers do not have to search for information. Consistent information along with proper accuracy control ensures that when manufactured items are joined at later stages in the building, they fit together correctly. These items can often be from different application areas, such as hull and pipe.

**NC, DNC and Robotics.** The use of numerically controlled (NC) equipment and *robots can* reduce the labor costs for items of work. It is important to be able to create the control information for these *machines* from the product model to be able to respond quickly to changes in the building program and design.

**Quality Control.** The control of quality or accuracy at each stage of production can reduce rework at later stages.

**Material Handling.** The efficient handling of material information, from initial specification through

detailed definition, purchasing, receiving, issuing and finally invoice clearance, is influenced by many departments. Shipbuilding is to a high degree an assembly process. If material handling is performed well this can have a major influence in the elapsed time and manhours for a project.

### The Challenges of Today

The challenges of today are to use systems and procedures for information handling that will lead to reduction of costs and increase in productivity. It is important to have the above key factors and special conditions in the shipbuilding industry in mind when evaluating the total information flow. To simply computerize the existing manual routines will not give as much benefit as taking the opportunity to streamline the information flow where possible, and to adapt the organization and way of working to the new tools and methods available.

The information flow traditionally consists of technical and administrative information in the form of documents, drawings, parts lists, etc. An alternative approach is the product model concept, where a database of information about the product is stored in a structured way specialized for the industry. The implementation of a product model concept is vital for the ability to optimize the key factors above.

### THE PRODUCT MODEL

The product model contains non-geometric as well as geometric information. Examples of non-geometric information are connections and dependencies between objects, such as topology, and characteristics about objects, such as material code, weight, surface treatment, energy consumption and flow capacity. It would be more proper to call the model a *product information model* to stress the difference between this information based model and a geometry or graphics based model of a product. However, since product model is the commonly used term, it is used in this paper.

When developing the layout of a complex area like an engine room there are frequent needs to analyze the arrangement in different views, to make sections and projections to verify clearances, etc. To do this with manually produced drawings is a heavy task when all sections and projections must be updated as the process goes on. For years, many shipyards have used plastic models as a tool to solve these problems, sometimes as a complement, sometimes as a substitute for manual drawings.

The product model is based on shipbuilding information objects. The content of the objects is

displayed as diagrammatical information, in a 2D drawing form or as a 3D graphics view depending on the stage of design. It is also displayed in lists and reports. All these views of information in the product model are illustrated in figure 2.

The graphical representation is only generated when it is needed, e.g. for viewing a model or creating a drawing. In this way, the graphical representation is generated as a symbolic, 2D or 3D representation, as indicated in figure 2, depending on the needs at the time of generation. The information stored in the objects is the primary information. The graphical representation (the view or the drawing) is secondary and generated by the visualization system. By handling the objects as the primary source of information, rather than the graphical information, the flow of information in the design process is streamlined.

The focus on shipbuilding information objects supports the integration of information. Each project should have a single model containing the information

for the whole project. Hence it is not necessary to link a work session to new files or drawings, or copy files to new sessions. When new model items are ready to be accessed by others, they are instantly available to all users within disciplines and across disciplines (e.g. hull and outfitting).

The building of the product model is a refining process that begins when the first product information is registered. This building process simply starts with an equipment item name and its function. This equipment object is refined during the design process. For example, when its system connections become known, they are added as well as its compartment location. Similarly, a symbol representation for use on a diagram and the 3D graphical information from a manufacturer's drawing can also be added. The principle is that once *some* information is known, it should be registered for use in later stages of design with easily refined information.

This approach also means that drawings and reports are extracted across a whole project by any selection criterion independent of how the data was created.

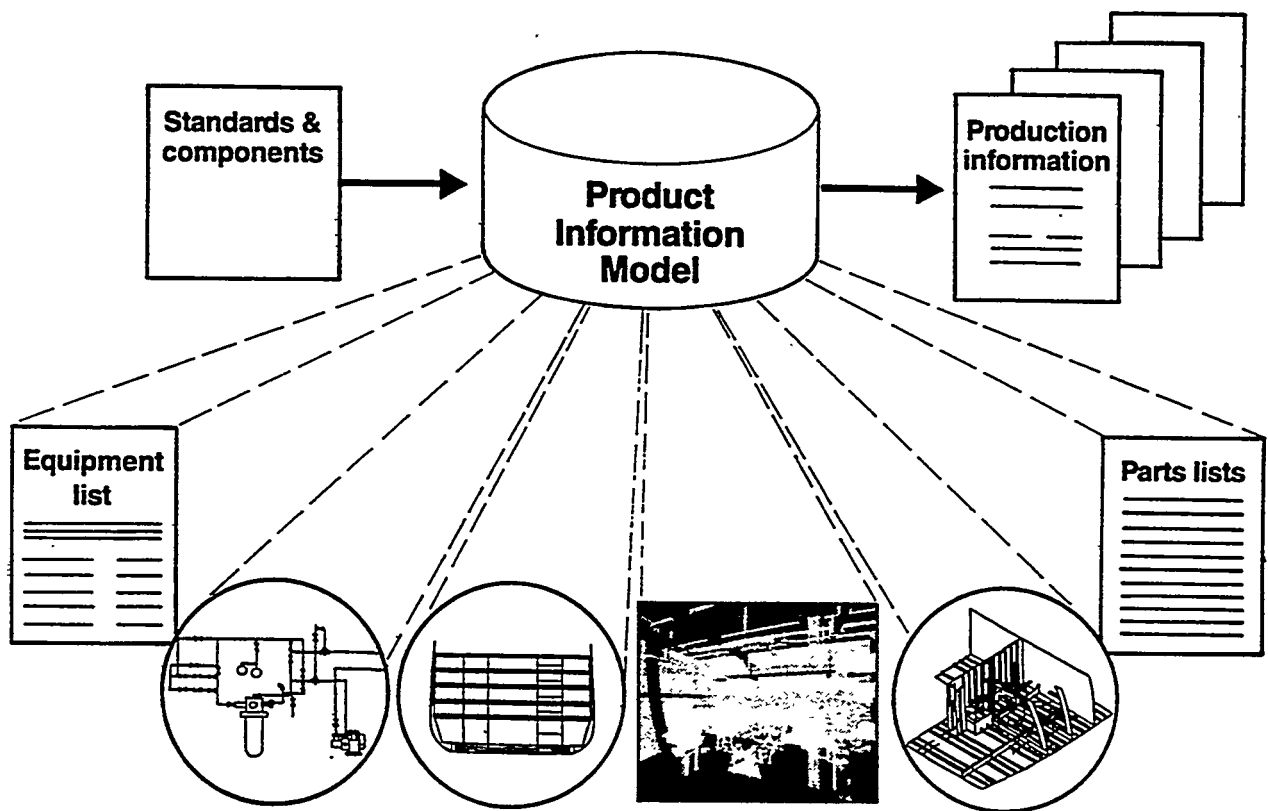


Figure 2 The Product Information Model

## THE SHIPBUILDING CAD/CAM SYSTEM

*The shipbuilding CAD/CAM system is a system designed to meet the requirements from design and production in shipyards as opposed to systems aimed for mechanical design that are generally referred to simply as CAI/CAM system. To be efficient, a shipbuilding CAD/CAM system must be based on the product model concept and address all phases in the design process in such a way that information from one stage can be used in the next*

The shipbuilding CAD/CAM system has powerful functions to define the shipbuilding objects and the relations between them in the product model. It supports designers in their work and helps them to communicate with colleagues in their own discipline and in other disciplines.

The building of a product model starts at the initial design stage, when the major components are chosen and the pipe and cable diagrams are developed. The topology of the diagram, the selection of components and the sizing are all essential to the model, even if they are presented in a 2D diagram only at that stage (see lower left part of figure 2).

During design the model is refined to a detailed level. Functions support the automatic or semi-automatic definition of e.g. stiffener endcuts and cutouts in plates. Brackets are defined by type and the system finds out the shape, internal stiffening e.t.c. depending on the environment. Cables are routed by semi-automatic functions.

A product model based system must understand what the different parts of the model really represent, and be able to interpret the rules and restrictions connected to each type of object. For example, to produce bending information for a pipe, or to check if it is at all possible to bend a certain pipe using the machine tools available in the workshop, the system must be able to distinguish pipes from other cylindrical objects that may look like pipes. Other examples would be having the ability to identify the difference between a bend and an elbow, between a prefabricated weld and an assembly weld, or investigating the surrounding structure of a pipe connection, where the system has to know which objects are pipes, stiffeners, seams, valves, etc.

The philosophy of a product model based system is that the information in the product model is the basis for the design and production process, and contains all technical product definition data. The different views, sections, projections and other information that build up the drawings are derived from the model. In this way the compatibility between different drawings is automatically secured. There is no longer a need to

restrict the number of views to evaluate a design because of the amount of drawing work. In such a system the drawings are not the primary information source.

Rules to control and check the different objects, depending on their properties, are defined. It is important to check the objects in the model directly at design time for production restrictions. Then an error is trapped at the source and not when it has created a problem in a workshop. Examples of checks are dimensional restrictions, shape restrictions (e.g. curve radius, possibility to use pipe bender), possibility to use welding equipment and interference checks.

In shipbuilding, numerical methods have been used for a long time to cut steel plates. The geometry and the marking information for all plate parts can be automatically created based on a product model.

The same process is applied to the handling of stiffeners and pipes. Information about stiffeners and pipe spools is automatically retrieved from the product model. The stiffeners are nested onto standard lengths of bar or shape material if applicable. Pipe sketches including parts lists are produced for each pipe spool. Whether a shipyard has chosen manual prefabrication or a fully automated line production, the relevant information can be retrieved from the product model.

Production information and setup information for jigs and different kinds of templates, quality control support, etc are also automatically derived from the product model.

The product model based system allows a user to automatically produce the many different types of production information needed to build a ship efficiently. Specialized production information creation programs speed up the creation of production information and provide a consistent and efficient type of information for workshops.

The quality of the information in the product model is an essential part of the total quality of the product. The product model must be included in the quality work-program in a shipbuilding company. In that process it can offer possibilities in judging the quality itself and in monitoring progress.

It is a strategic decision to use a product model and a system based on such a model. The information in the model is a common resource in a company and an important source of information in the exchange with the administrative functions of the organization.

## WORK PREPARATION

During the early phases of design the product model is looked upon as a set of systems. During the detailed design phase the model is also looked upon as

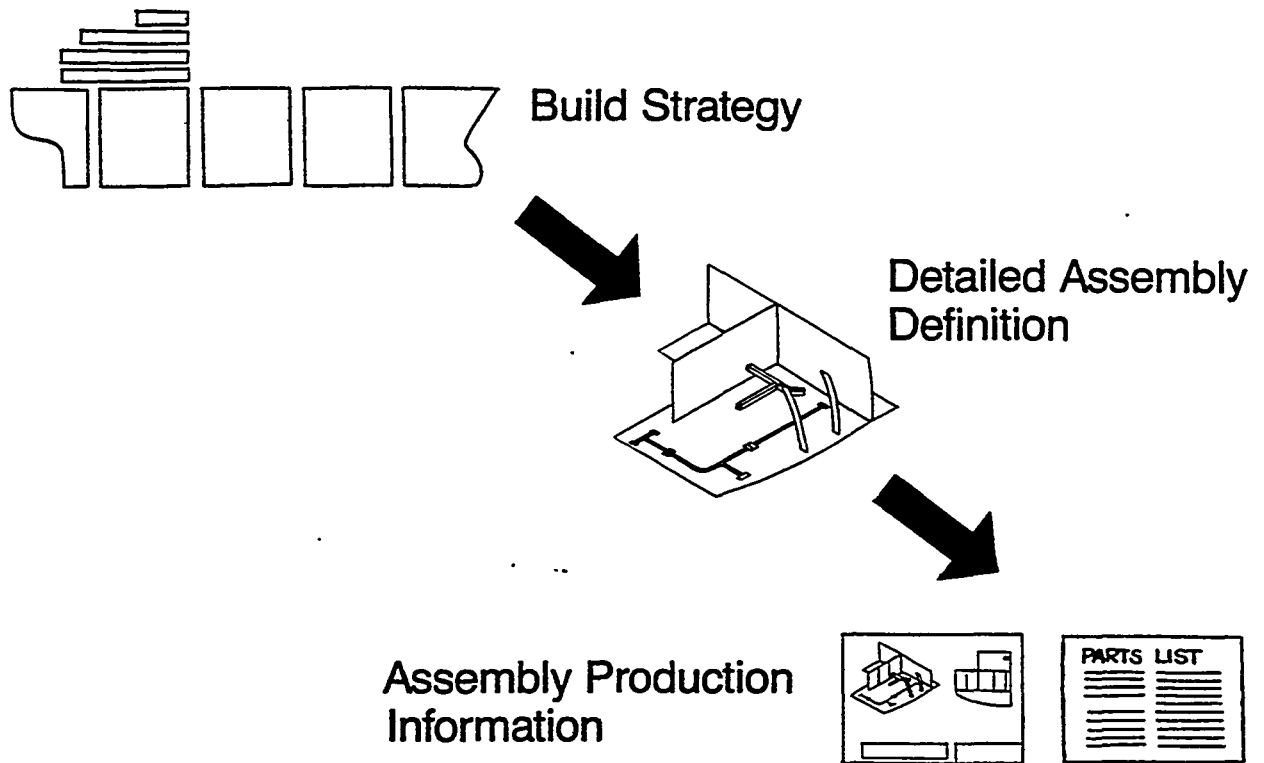


Figure 3 Work Preparation

subdivided into zones or compartments. These two views of the model are supported by the shipbuilding CAD/CAM system.

During production planning and production the product is looked upon as subdivided into a set of assemblies and assembly sequences. These definitions and this third view of the information are integrated into the product model and used by software supporting the work preparation (or production engineering). The combination of a shipbuilding CAD/CAM system and functions for work preparation forms a *shipbuilding CIM (Computer Integrated Manufacturing) system*. This approach is an efficient alternative to a traditional implementation of a Product Work Breakdown Structure.

Work preparation starts with definition of the build strategy. Later the detailed assembly definition is added. Using this information structure the assembly production information is extracted based upon information from the product model. Work preparation is illustrated in figure 3.

The build strategy is defined in parallel with initial design. It is a top-down subdivision of the product into high level assemblies as shown in figure 4.

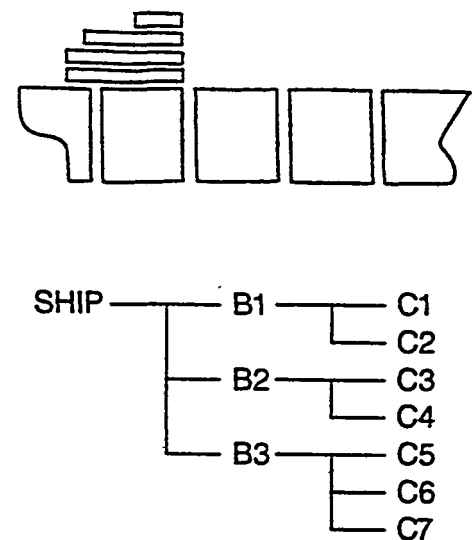


Figure 4 Build Strategy

The detailed assembly definition (see figure 5) is made bottom-up. Parts are selected to form subassemblies, which in turn are combined to next level assemblies and so on until the top-down definition in the build strategy is met. Interactive graphic methods support the definition of the detailed assembly structure. Thus, it is rather simple to select and edit the proper structure of objects for each step.

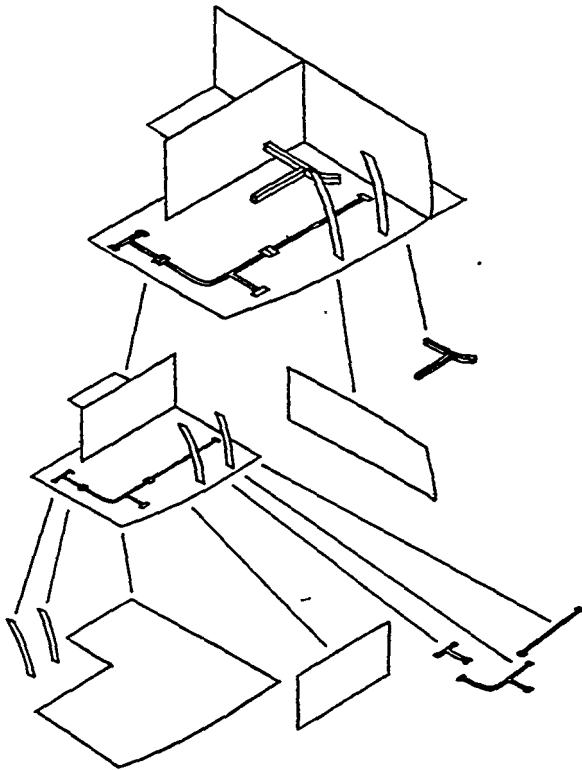


Figure 5 Detailed Assembly Definition

Traditionally, production drawings were just a refinement of the design drawings. The prefabrication information (plate part geometries, pipe spool details, e.t.c.) was obtained from these drawings which were also used for assembly purposes. Such production drawings and their parts lists usually showed the whole arrangement. Consequently the different assembly phases could not be distinguished.

When using a product model as the basis for drawing generation, it is easy to present one *set* of views from the model suitable for the designers, and another suitable for the production people.

Based on the assembly structure, drawings and parts lists are produced reflecting the assembly sequence (see figure 6). The information is produced at a late stage and is easily updated according to a change in the

design or the assembly structure.

The assembly information is packaged in a way that it contains relevant information for each stage in the process. It could be assembly of steel items, outfitting items or a combination of both, i.e. assembly of composites. All of these specialized drawings can be rather simple since they will be used for one purpose only. Detailed information is on the drawings only where it is needed. All information, from the prefabrication drawings to the last assembly drawings, is consistent since it is being produced from the information stored in the product model.

Normally, the production work is split up into workshop station sequences and/or work **operation** sequences for allocation of resources and scheduling purposes (job routing). As a further step in the use of a product model and integration with planning systems, there is a potential to create much of this information from the product model as well.

Parts lists are the fundamental source of information on material to be used. Traditionally the parts lists were produced manually during or after the drawing work. However, the designers already enter a lot of the parts list information into the product model during the design work. It saves work to extract the parts lists from the product model and then transfer the complete information to other areas, such as the materials system.

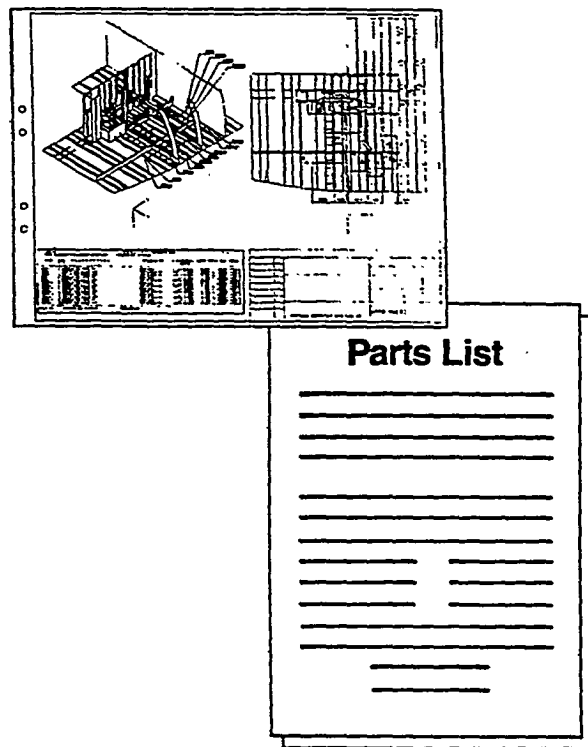


Figure 6 Assembly Production Information

## AUTOMATION

Automation of shipyard production means two things: preparing information needed for the production process automatically and making the process itself automatic.

In preparing information automatically, savings in manhours can be achieved as pointed out above. Since very little time is necessary for preparation of the information, the lead time is short which allows for late modifications of the assembly process or the design without spending extra hours on replanning and redrawing.

When burning tapes were first punched, then verified by drawing and then sent to the workshop, in most cases long before they were going to be used, there was a lead time of several days for changing a tape. Now burning information can be produced and verified by the CAM system and stored electronically together with the drawing and other necessary information. A workshop can then request the information when it is needed. The lead time for this cycle is very short.

There are different philosophies for fabrication of profiles: using shapes as raw material or building them from plate parts. Whatever method is used, the necessary information is found in the product model: the material type, cut outs, profile identification number, lengths, shapes etc. Several implementations of production lines for profiles exist today.

The information in the product model can also be used for marking. When and how marking should be performed is intimately linked to production methods and tolerance control.

Work shops, such as pipe shops, can be run as separate units within a shipyard. When the product model for a pipe exists and is approved, the information for each pipe spool can be made available for the workshop together with drawing information and information on when and where it is needed.

Normally, pipe information is released by block or assembly. Pipe shops prefer to operate by dimension. Using the product model this is not a problem.

The product model contains the following information for the pipe shop:

- pipe material,
  - pipe length,
  - bending information,
    - component information,
    - component orientation,
    - welding information,
    - surface treatment and
    - spool identification number.
- A pipe shop planner selects the information on such

attributes as dimension, quality, material availability and time for delivery to the assembly shops, and plan the work in the best possible way. Production documents are produced locally when needed. The use of this method was one important element when Kockums Shipyard, 10 years ago, reduced 3 shifts to 1 in the pipe shop!

With the knowledge of the assembly sequence, drawings and parts lists can be made automatically, at least to a great extent. It has been discussed above.

## PRODUCTION LINES AND ROBOTS

Many different types of production lines and robots exist or are part of on going development projects. All of these different types of equipment can get the necessary product information from the product model.

For example, a welding robot can get the nominal welding trace and the type of weld from the product model. The model can also provide the necessary geometry for interference control (if necessary).

It is important to find methods to define the movements of the robot based on information in the product model and on standards, patterns and macros. Otherwise the necessary information for robot movements and the simulation of it has to be defined from scratch. If so it is likely that the tool path definition and the movement control will become a bottleneck with a lot of intensive manual work involved. With a careful selection of methods and standards, the product model can be used for analysis of the context minimizing the manual interactions.

Production lines for profiles have been mentioned above. These lines are often equipped with robots for the cutting operation. Panel lines equipped with multiaxis DNC machines have been installed in several shipyards. These are used to produce panels made from plates and profiles. Cutting these panels with continuously varying bevel angle across welds is a complex problem. The information needed is extracted from the product model.

## RESEARCH

The importance of the product model concept is internationally recognized, and a lot of work has been and will be assigned to the area. STEP, meaning Standard for the Exchange of Product Model Data, is an informal name of what is expected to become an ISO (International Standardization Organization) standard. The aim of STEP is to define a neutral (vendor independent) format to exchange product models between companies or users within the same company, using different systems.

Within the area of shipbuilding, NIDDESC (Navy Industry Digital Data Exchange Standards Committee) in U.S., ESPRIT (European Strategic Programme for Research and Development in Information Technology) in Europe and others have had projects going on for many years. MARITIME (Modelling and Reuse of Information over TIME) is one of the ESPRIT projects presently working with these questions.

Projects from Europe, Japan, Korea and the U.S. working in this area were presented at ICCAS 94 (8th International Conference on Computer Applications in Shipbuilding). Interested persons are recommended to read the published proceedings (see References).

#### ADVANTAGES WITH A PRODUCT MODEL BASED SYSTEM (CONCLUSION)

In a product model based system the product model serves as the source of information for all activities. Lead time between activities can be reduced since all information released in the model will be immediately available for others involved in the process. This allows many designers to work in parallel. The approach

- supports the idea of working in zones,
- decreases the need for documentation on paper,
- decreases the amount of double work and copying and

- keeps the information consistent.

The net result is considerable savings in design time. The high quality and consistency of the production information also means that major benefits can be achieved in production. When the production information can be produced automatically, very little effort is required, once the design is made. This means that it can also be made fast which gives two benefits

- the production information can be made earlier to have an early start of production and
- the production information can be made just before being required so that late design developments and changes can be incorporated.

This means less rework and less information floating around with the risk of being out of date.

The benefits depend on many factors, but experience from shipyards shows reduced:

- time from contract to delivery of up to 30-40%,
- manhours in design and production up to 20-30% and
- cost for material.

In a paper (Bong, 1994) presented at ICCAS 94 the technical director at Daewoo Shipbuilding & Heavy Machinery Ltd., reported a reduction in the number of designers from 190 to 164 at the same time as the design period was reduced from 7.5 months to 5.5 for a VLCC ship. The reduction was a result of

implementing a product model based system.

Implementing a product model based system will also encourage the use of design and production standards.

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