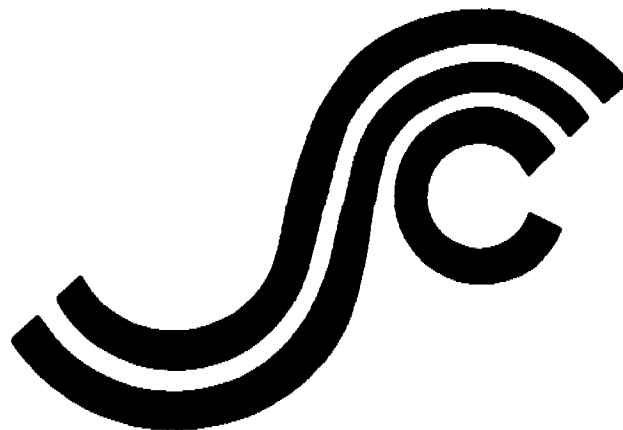


SSC-388

**SHIP STRUCTURAL INTEGRITY
INFORMATION SYSTEM
PHASE II**



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1996

SSC-388 Ship Structural Integrity Information System

Ship Structure Committee 1996

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26 April 1996

SHIP STRUCTURAL INTEGRITY INFORMATION SYSTEM

In 1992, the SSC published a report by Professor Robert Bea of the University of California, Berkeley, that introduced the need to tie together all of the failure information on the U.S. maritime fleet. A program was proposed to mirror that which is currently used in the airline and other industries. The system could be used to identify developing problems earlier and address them before they manifest themselves as a severe catastrophe.

Phase I of the project, published as SSC-380, evaluated databases currently in use by ship operators to monitor their vessels and proposed a system to address the data capture needs for design, construction, inspection, maintenance, and operations. Phase II goes further into the topic by examining the reengineering of the structural inspection, maintenance and repair process to improve the integrity and quality of operating ships' structural systems. A prototype of the system, in Microsoft Access format, will be included in the electronic version of the report, to be issued on a CD Rom library of SSC reports.

This program was conducted to provide a tool to assist the industry in management of their fleets, which would result in safer shipping and cleaner waterways. It is hoped that this program, used in conjunction with other joint government and industry initiatives, will develop into a universal, industry-driven, Ship Maintenance System.

A handwritten signature in black ink, appearing to read 'J. C. Card', written in a cursive style.

J. C. CARD
Rear Admiral, U.S. Coast Guard
Chairman, Ship Structure Committee

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Technical Report Documentation Page

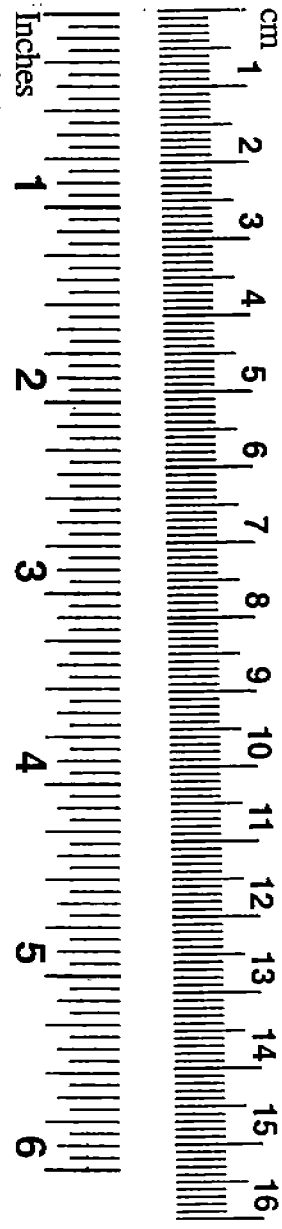
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METRIC CONVERSION CARD

Approximate Conversions to Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|----------------------------|-------------------------|---------------------------------|--------------------|-----------------|
| LENGTH | | | | |
| in | inches | 2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| AREA | | | | |
| in ² | square inches | 6.5 | square centimeters | cm ² |
| ft ² | square feet | 0.09 | square meters | m ² |
| yd ² | square yards | 0.8 | square meters | m ² |
| mi ² | square miles | 2.6 | square kilometers | km ² |
| | acres | 0.4 | hectares | ha |
| MASS (weight) | | | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | metric ton | t |
| VOLUME | | | | |
| tsp | teaspoons | 5 | milliliters | mL |
| Tbsp | tablespoons | 15 | milliliters | mL |
| in ³ | cubic inches | 16 | milliliters | mL |
| fl oz | fluid ounces | 30 | milliliters | mL |
| c | cups | 0.24 | liters | L |
| pt | pints | 0.47 | liters | L |
| qt | quarts | 0.95 | liters | L |
| gal | gallons | 3.8 | liters | L |
| ft ³ | cubic feet | 0.03 | cubic meters | m ³ |
| yd ³ | cubic yards | 0.76 | cubic meters | m ³ |
| TEMPERATURE (exact) | | | | |
| °F | degrees Fahrenheit | subtract 32, multiply by 5/9 | degrees Celsius | °C |



Approximate Conversions from Metric

| Symbol | When You Know | Multiply by | To Find | Symbol |
|----------------------|--------------------------------------|----------------------------|--------------------|-----------------|
| LENGTH | | | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| AREA | | | | |
| cm ² | square centimeters | 0.16 | square inches | in ² |
| m ² | square meters | 1.2 | square feet | ft ² |
| km ² | square kilometers | 0.4 | square miles | mi ² |
| ha | hectares (10,000 m ²) | 2.5 | acres | ac |
| MASS (weight) | | | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | metric ton (1,000 kg) | 1.1 | short tons | st |
| VOLUME | | | | |
| mL | milliliters | 0.03 | fluid ounces | fl oz |
| mL | milliliters | 0.06 | cubic inches | in ³ |
| L | liters | 2.1 | pints | pt |
| L | liters | 1.06 | quarts | qt |
| L | liters | 0.26 | gallons | gal |
| m ³ | cubic meters | 35 | cubic feet | ft ³ |
| m ³ | cubic meters | 1.3 | cubic yards | yd ³ |
| TEMPERATURE | | | | |
| °C | degrees Celsius | multiply by 9/5, add 32 | degrees Fahrenheit | °F |

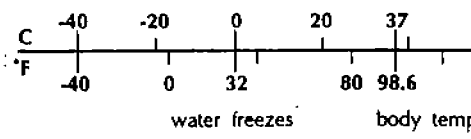


Table of Contents

| | |
|------------------------------------------------------------------|-----------|
| 1. Summary | 1 |
| 2. Introduction | 3 |
| 3. Background | 5 |
| 3.1. Marine Structural Integrity Programs | 5 |
| 3.2. SSIIS 1 | 8 |
| 3.2.1. Background - Vessel Inspection and Reporting | 8 |
| 3.2.2. Existing Database Systems | 8 |
| 3.2.3. Application Example: CAIP Report | 9 |
| 3.2.4. Recommendations from SSIIS 1 Project. | 11 |
| 3.3. Integrated Ship Design and CAD Modeling | 12 |
| 3.3.1. NIDDESC Ship Product Model | 12 |
| 3.3.2. Product orientation and systems orientation | 12 |
| 3.3.3. Integrated Ship Design | 14 |
| 3.4. Ship Operating Systems: A Case Study - Stolt Parcel Tankers | 15 |
| 3.4.1. Stolt Parcel Tankers - Background | 15 |
| 3.4.2. Process Identification | 15 |
| 3.4.3. Process Implementation | 19 |
| 4. Business Process Reengineering | 21 |
| 4.1. Background | 21 |
| 4.1.1. Innovation | 21 |
| 4.1.2. Process flows | 21 |
| 4.1.3. Process selection | 22 |
| 4.1.4. Strategy & Process Visions | 22 |
| 4.2. Enablers of process innovation | 23 |
| 4.2.1. Information Technology | 23 |
| 4.2.2. Information | 25 |
| 4.2.3. Human and Organizational Resources | 25 |
| 4.3. Existing process flow | 26 |
| 4.3.1. Identify existing activities | 26 |
| 4.3.2. Improving the Existing Process | 26 |
| 4.4. New process flow | 27 |
| 4.4.1. Envision of the new process flow | 27 |
| 4.4.2. Benchmarking | 27 |
| 4.4.3. Brainstorming | 27 |
| 4.4.4. Detailing the process vision; the solution | 28 |
| 4.4.5. Implementation and Performance | 29 |
| 4.5. Conclusions | 30 |
| 5. Information Systems | 31 |
| 5.1. Planning | 33 |
| 5.2. Analysis | 33 |
| 5.3. Design | 33 |
| 5.4. Hardware/Software Considerations | 34 |
| 5.4.1. Relational Databases and Structured Query Language (SQL) | 34 |
| 5.4.2. Client/Server Architecture | 35 |

| | |
|----------------------------------------------------------|------------|
| 6. Structural Information System - SSIIS Database | 37 |
| 6.1. Maritime Industry Strategy | 37 |
| 6.2. Maritime Industry Objectives | 37 |
| 6.2.1. U.S. Coast Guard | 38 |
| 6.2.2. Classification Societies | 38 |
| 6.2.3. Ship Operators | 38 |
| 6.3. SSIIS Objectives | 38 |
| 6.4. SSIIS - Processes and Functions | 39 |
| 6.4.1. Structural IMR | 40 |
| 6.4.2. Analysis / Design | 43 |
| 6.4.3. Fabrication / Construction | 44 |
| 6.4.4. Mechanical IMR | 44 |
| 6.4.5. Cargo Management | 44 |
| 6.4.6. On-Board Management | 44 |
| 7. Prototype Description | 45 |
| 7.1. Data Structure | 45 |
| 7.1.1. Process/Process Relationships | 45 |
| 7.1.2. Function/Function Relationships | 47 |
| 7.1.3. Function/Entity Relationships | 48 |
| 7.2. Tables | 49 |
| 7.3. Forms | 49 |
| 7.4. Reports | 51 |
| 8. Future Development | 53 |
| 8.1.1. Requirements Analysis and Benchmarking | 54 |
| 8.1.2. Data Structure | 54 |
| 8.1.3. Inspection Planning | 54 |
| 8.1.4. Inspection Activities | 55 |
| 8.1.5. Repair Planning | 55 |
| 8.1.6. Testing and Implementation | 55 |
| 9. Conclusions | 57 |
| 10. References | 59 |
| | |
| Appendix A : SSIIS Prototype Forms | A.1 |
| Appendix B : Vessel Report | B.1 |
| Appendix C : CAIP Report | C.1 |

Table of Tables

| | |
|-------------------------------------------------------------------------------------------------|----|
| Table 3.1 : MSIP information requirements | 7 |
| Table 3.2 : Stolt Software to Support Business Processes | 15 |
| Table 4.1 : Uses of information technology within a company:[Davenport, 1993 & Manganeli, 1994] | 24 |

Table of Figures

| | |
|-------------------------------------------------------------|----|
| Figure 2.1 : MSIP - Vessel Information Structure | 3 |
| Figure 4.1 : Strategies, Visions, Objectives and Attributes | 23 |
| Figure 5.1 : Reengineering and Information Engineering | 31 |
| Figure 5.2 : Development of an Information System | 32 |
| Figure 5.3 : Stages of Information System Development | 34 |
| Figure 6.1 : Ship Processes | 39 |
| Figure 6.2 : Structural IMR Information Process Flow | 40 |
| Figure 7.1 : Process / Process Relationships | 46 |
| Figure 7.2 : Function / Function Relationships | 47 |
| Figure 7.3 : Structural Function / Entity Relationship | 48 |
| Figure 7.4 : Data Entities for Structural Processes | 49 |

1. SUMMARY

Advances in information technology have resulted in better ways to use information for the management of business activities. The integration of stand-alone systems combined with improved information recording, organization and communication offers benefits for the life-cycle management of marine structures. The future offers even greater rewards as research, development and introduction of new technologies and organization changes are utilized to further improve marine safety.

This report provides a roadmap for the commercial development of modules within an information system to facilitate life-cycle management. This includes areas from ship design and construction as well as operations including inspection, maintenance and repair.

Using the guidelines developed in the Marine Structural Integrity Program (MSIP) Report [Bea, 1992] and the SSIIS Phase I Report [Schulte-Strathaus, 1994], this report outlines the development of an information system for the life cycle management of ship structures. The functions of existing ship structural management applications, including both computer and manual systems have been integrated into the prototype description of the Ship Structural Integrity Information System (SSIIS).

The role of Business Process Reengineering in the management of information is discussed as it affects the design of modules within the SSIIS project. The reengineering approach to business process design obtains maximum advantage from the implementation of information technology. The development of Information Systems, from planning and analysis to design is discussed to provide a framework for the development of the SSIIS prototype.

The development of a SSIIS prototype provides an outline of the basic data structure for the integration and development of a marine structural information system. To demonstrate the advantages of such a system the development of the prototype has focused on the management of structural survey and inspection information, and the CAIP report.

An information system must focus on business processes, support functions and activities and thus enable an organization to make accurate decisions, quickly and efficiently. The aim of the SSIIS project is to allow all stakeholders in maritime safety to improve the quality of the design and operation of ship structures through the organization of information.

It should be realized that SSIIS is only one component of a comprehensive Ship Quality Information System (SQIS) [Moore, Bea, 1995]. Other components of a SQIS address the equipment, hardware, and facilities onboard a ship; ship operations (cargo, routing, loading, unloading, supplies); ship personnel; and the organizations responsible for the ship and its operations.

It is through a SQIS that a full-scope, life-cycle ship information and communication system can be realized. A SQIS, and the business reengineering processes that provide the framework for its definition and implementation, can lead to significant reductions in work and costs. It is only when such reductions in work and costs can be delivered that the necessary resources will be devoted to develop and implement SSIIS, and ultimately, SQIS.

2. INTRODUCTION

This report documents the second phase of the Ship Structural Integrity Information System (SSIIS) project. The SSIIS project was sponsored by the U.S. Coast Guard Research & Development Center through the National Maritime Enhancement Institute of the Maritime Administration (MARAD). The project was initiated by the Department of Naval Architecture & Offshore Engineering at the University of California at Berkeley in September 1993.

The second phase of the SSIIS project had two main objectives:

- to continue development and documentation of standards for the development of a computerized Ship Structural Integrity Information System for tank ships through a review of database components and protocols.
- to continue demonstration of the application of these standards with a prototype PC based system SSIIS prototype including a CAIP reporting module.

The SSIIS project had its beginnings with the report published in 1992 by the Ship Structure Committee for the development of Marine Structural Integrity Programs (MSIP) [Bea, 1992]. The procedures were designed for commercial ships, with focus given to oil tankers and crude oil carriers. The MSIP procedure adopted a program similar to the Airframe Structural Integrity Program (ASIP) established by the U.S. Air Force and the Federal Aviation Agency.

The objective of an MSIP was to integrate the requirements of ship owners and operators, builders and regulators to obtain maximum safety and economic benefit. The keystone of the objectives was highlighted to be an information system which revolves around the life-cycle operation of marine structures. The format of such a system is represented in Figure 2.1.

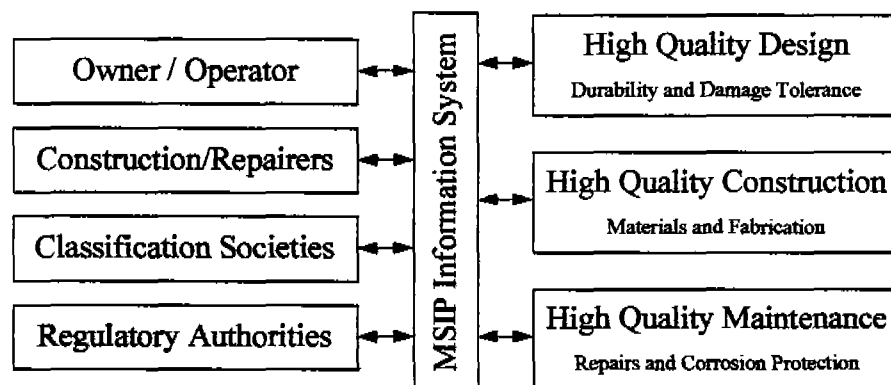


Figure 2.1 : MSIP - Vessel Information Structure

The MSIP study outlined the information requirements governing the life-cycle operation of tanker vessels. This included design, construction and operational information. The SSIIS project uses this structure as a starting point for the development of a general ship information system. The MSIP objectives and information requirements are detailed in Chapter 3.

Chapter 3 also provides a summary of the following background topics as deemed relevant to the development of a ship information system:

- The first phase of the SSIIS project, which encompassed the review of software for the management of inspection information and the CAIP reporting procedure. It was found the description of trends and causes for failures was in general, not adequately addressed in several of the CAIP reports reviewed. One of the objectives of the SSIIS project is the development of analytical tools to facilitate the documentation of failure trends.
- The NIDDESC/STEP ship product model description, which details the standard for the exchange of ship structural descriptions. This has been developed for publication as an international standard and hence provides a starting point for converting between non-graphical and graphical ship model information.
- A review of an onboard vessel maintenance system, that encompass the management of onboard ship functions and activities. This system was developed by Stolt Parcel Tankers and handles the maintenance of mechanical systems, and the requisition and purchase of both spare parts and general ship provisions.

A detailed overview of Process Innovation or Business Process Reengineering is provided in Chapter 4. Reengineering is the complete change of existing business processes with the implementation of information technology and organizational change. This chapter outlines the methodology behind reengineering and emphasizes the objectives of the SSIIS to improve the safety and provide economic benefit not only for ship owners and operators but also regulatory authorities. Reengineering provides a framework for the development of information systems to evolve a new, more efficient way of working rather than simply automating existing processes.

The concepts of Information System development are discussed in Chapter 5. This is intended to provide the guidelines and theory for the development of information systems. Topics include the stages of information system development and associated activities. This includes planning, analysis, design and construction of an information system. The techniques and concepts discussed are used in the following chapter.

Chapter 6, Structural Information System, breaks down the processes involved in the management of ship structure into functional activities. These functional activities are further broken down into information requirements and the relationships between activities described. The functional activities relate only to the management of ship structures and the information requirements that match the MSIP information guidelines.

The SSIIS database prototype is outlined in Chapter 7, this system was developed using the Microsoft database application ACCESS. The prototype is representative of the information system recommendations for the life-cycle management of ship structures and thus incorporates the reengineering ideals. The prototype reflects ideas generated to enhance safety and is not just a system to automate existing ship operation functions. Future development of the SSIIS project is detailed in Chapter 8.

Chapter 9 provides the conclusions to Phase II of the SSIIS project.

3. BACKGROUND

This chapter is given to provide a background to previous work done and identify other research pertinent to marine structural integrity.

3.1. Marine Structural Integrity Programs

The Ship Structure Committee funded a study to establish a procedure for development of Marine Structural Integrity Programs (MSIP) for commercial ships, with particular focus on tankers, [Bea, 1992]. The aim was to adopt a procedure similar to the Airframe Structural Integrity Program (ASIP) established by the U.S. Air Force and the Federal Aviation Agency.

The fundamental objective of an advanced MSIP is to improve the quality of ship structural system throughout the life-cycle of the structure, from design to construction and during operation. Quality issues related to a ship structure system include serviceability-durability, reliability and economy (initial and long-term). Quality related improvements include more efficient inspection, improved economics and safer operation and more effective maintenance.

Maximum benefit for the marine industry will be obtained only if the MSIP is focused on the life cycle of ship structures. Life-cycle ship structural integrity programs must be initiated at design phase, from the formulation of design rules, and extended throughout the construction and operational phases. The requirements of all sectors must be identified and trade-offs made to obtain compatible life-cycle orientated assessment criteria.

The MSIP as proposed should be a full-scope ship integrity program that addresses:

- structural systems (integrity, capacity and durability)
- equipment systems (navigation, propulsion, steering, piping, electrical)
- operations systems (vessel traffic control, training, licensing, re-certification)

As identified in the report and shown below, several key potential organization and technical developments need to be introduced as part of an advanced MSIP:

- Centralized archiving, evaluation and dissemination of potentially important information relating to MSIP.
- Training, testing and verifying the capabilities and performance of design, manufacturing, operations and maintenance personnel.
- Development of cooperative and intensely communicative associations among the major sectors, including regulatory, classification, owner/operator, and production and maintenance sectors with a focus on safety and durability issues, avoiding 'hidden agenda' and legal impediments to communications.
- Development and application of advanced technologies with heavy emphasis on testing and monitoring founded on sophisticated and realistic analysis.
- Development and application of a comprehensive approach to engineering for, and maintenance of structural reliability.

-
- Design of ship structures that not only address the functional and strength requirements, but also design for constructability, inspection and maintainability, with heavy emphasis given to damage tolerant design and durability design to minimize the risks of high consequence accidents and unexpected maintenance.

The MSIP has two fundamental objectives:

- to develop a desirable level of structural reliability (integrity, durability) for a newly constructed ship structure, and
- to maintain an acceptable level of structural reliability throughout the ship's life.

The purpose of the MSIP is to identify and minimize the risks of low probability-high consequence structural failures while maximizing the serviceability and durability of the ship. The most significant problems associated with ship structures are unexpected and often the result of ignoring required maintenance.

It has been identified that an industry-wide MSIP project must address the technical developments which can enable ship owners and operators, builders and regulators to realize the safety and economic benefits of more durable and reliable ship structures. MSIP technical developments should include:

- structural design plans (addressing the life-cycle phases, design criteria, damage tolerance, durability, materials and operations)
- structural analysis guidelines (addressing loadings, strength design, design for durability and damage tolerance and design for inspectability, constructability and maintenance)
- requirements for the testing of critical components to demonstrate capacity, durability and damage tolerance, and in-service monitoring to provide additional information on structure loadings and performance.

It was identified in the MSIP that the development of an industry-wide information system for archiving design and construction information, operations structural tracking and maintenance tracking was required. This would include the results of inspections, hull response monitoring, maintenance programs, records, repairs, modifications, replacements and assessments of performance. The requirements for the information system identified in the MSIP project are shown in Table 3.1.

The information requirements identified in the MSIP project form the basis of SSIIS. Rather than simply automating these information requirements, the SSIIS project examines processes associated with the management of ship structures and provides the stimulus to innovate these processes and improve the quality of ship structures in an efficient way.

The challenge of the SSIIS project is to achieve the goals established by the MSIP project and ensure they are incorporated into the information system. In summary, as identified the information system must achieve the following goals:

- be life-cycle focused, and
- address structural, equipment and operations systems

| MSIP | |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Plans Module Design Construction Operations Inspections, Monitoring, Maintenance, Repairs | Operations Module Voyages Cargoes Ballasting Procedures Cargo loading and unloading procedures Cleaning Monitoring results Accidents |
| Design Module Design Criteria Rules Materials and Fabrication Loading Analysis Stress Analysis Damage Tolerance Analysis Durability Analysis Design Development Test Program Monitoring Program Development Classification Program Design Documentation Design Drawing | Maintenance Module Cleaning Coating Repairs Cracking Repairs Steel Renewals |
| Construction Module Specifications Builder Quality Assurance and Control Procedures Quality Assurance and Control Reports Inspections Design Variances As-built Drawings | Inspection and Monitoring Module Corrosion Survey Reports Cracking Survey Reports Monitoring Program Reports |
| | Repair Module Coating Repair and Maintenance Cathodic Protection Repairs and Maintenance Fracture Repairs Steel Renewals |

Table 3.1 : MSIP information requirements

3.2. SSIIS 1

The first phase of the Ship Structural Integrity Information System (SSIIS) addressed the inspection criteria of the MSIP information requirements. As part of this project, computer programs used to record ship inspection information were reviewed. In addition the Critical Area Inspection Plans (CAIP) of six vessels were examined for their adherence to the U.S. Coast Guard requirements. Based on these findings, the format for an automated system was given.

3.2.1. Background - Vessel Inspection and Reporting

In recent years, research and development projects have focused on the development and implementation of database systems to store, manipulate and analyze the information that is gathered during the operation of commercial vessels. Much of this effort has been concentrated on oil tankers due to regulatory requirements and specific structural configurations that require periodic inspections resulting in large amounts of survey data.

Due to the disproportionately high number of fatigue cracks found in vessels operating on the Trans-Alaska Pipeline Service (TAPS) trade route, the U.S. Coast Guard requires a Critical Area Inspection Plan (CAIP) for these vessels. The CAIP for each vessel has to specify the methods used by vessel operators for the documentation and tracking of structural failures [USCG, 1991]

The CAIP report contains detailed information on the vessel's fracture history, corrosion control systems and previous repairs. In addition the CAIP requires operators to document trends in the occurrence of fatigue and corrosion incidents. The plan has to be updated yearly to include the most recent survey data for the determination of the critical areas. One of the objectives of the SSIIS project is address the requirements of the CAIP report and to develop methodologies to assist operators in the identification of failure trends.

These requirements have resulted in a large amount of data that needs to be managed. This is most easily done if the vessel and survey information is contained in a database. In addition to these regulatory reporting requirements, information systems can greatly facilitate and improve the quality of inspection, maintenance and repair operations.

The *International Association of Classification Societies (IACS)* recently published a set of rules governing the conduct of surveys for existing vessels, (*Enhanced Survey Rules for Existing Vessels*), [IACS, 1993]. The document is partly based on recommendations issued by the International Maritime Organization (IMO) and the guidance manuals for tanker inspections published by the Tanker Structure Cooperative Forum, [TSCF, 1990], [TSCF, 1986].

The IACS document requires shorter inspection intervals for uncoated ballast tanks and makes it the owner/operator's responsibility to provide detailed information related to crack and corrosion survey results, including trends and damage statistics.

3.2.2. Existing Database Systems

Partly due to the U.S. Coast Guard requirement of the implementation and maintenance of Critical Area Inspection Plans (CAIP), and also to facilitate inspection, maintenance and re-

pair (IMR) operations, information systems have been developed that store general vessel information in conjunction with survey data. Several of these systems were evaluated in order to determine the general approach, the information contents and the overall effectiveness.

Special regard was given to the method used to determine and represent failure locations (cracks and corrosion) within a vessel. The use of graphical information was analyzed to determine the relation between the cost for data input and the increase in information contents and overall usability.

Evaluated systems include the CATSIR database systems (developed by Chevron in cooperation with Oceaneering), ARCO's Hull Fracture Database (HFDB), FracTrac (developed by MCA Engineering), SID (Structural Inspection Database, developed by MIL Systems) and the Ship Information Management System (SIMS), developed as part of the Structural Maintenance Project for New & Existing Ships (SMP) project conducted at the Department of Naval Architecture & Offshore Engineering at UC Berkeley.

The purpose of the review of existing database systems was to study the different approaches taken to archive and use ship information and survey results and to document the applicability of each system for a future SSIIS.

In a different database development, a selection guide for tankers of 10,000 deadweight tons or more has been developed and is updated and published annually, [Tanker Advisory Center, 1994]. The guide is intended to aide tanker charterers, cargo owners and others involved with tankers in the selection of tankers that perform satisfactorily and pose a minimal risk of casualties.

A rating system has been developed that assigns a rating to each tanker based on a set of criteria, i.e. casualties, age, name changes, owner's total losses and oil spills, classification society, owner, flag of registry, etc..

Of particular importance is the inclusion of casualties and oil spills. Any future tanker database development has to evaluate the possible data format to identify causes for casualties and oil spills. This is particularly important to evaluate the extent of human and organizational error in tanker operations

3.2.3. Application Example: CAIP Report

In the *Navigation and Vessel Inspection Circular No. 15-91*, [USCG, 1991], issued by the U.S. Coast Guard in Oct. 1991, guidelines for the development, use and implementation of Critical Area Inspection Plans (CAIP) have been provided. The requirements of the CAIP's are intended to serve the following purposes:

- Act as a management tool that tracks the historical performance of a vessel, identify problem areas, and provides a greater focus on periodic structural examinations.
- Address the **cause** of a problem, not merely the **symptoms** which results in an increased involvement of the vessel's management in the solution of identified structural and/or maintenance problems.

-
- Assist surveyors, inspectors and the vessel's crew in ensuring that the vessel is properly inspected and maintained.

The decision to require a CAIP on a single vessel or an entire class of vessels may be based on the vessel's history, its service, or even the climatology of the trade route. Currently, a CAIP is required for all vessels on the TAPS trade route.

3.2.3.1. CAIP Performance Elements

As outlined in enclosure (2) of NVIC-15-91, [USCG, 1991], each CAIP report should contain the following elements:

- Executive Summary
- Vessel Particulars
- Historical Information - Structural failures, structural modifications
- Active Repair Areas - Structural failures, structural modifications, structural analyses, trends
- Structural Inspections - Internal, external
- Tank Coating Systems
- Critical Area Inspection Plan Update

The layout and organization of the CAIP report can be chosen based on the owner's preference. The use of diagrams and vessel plans to illustrate fractures and problem areas is highly encouraged.

3.2.3.2. Evaluation of CAIP Report Examples

Six different CAIP reports from four different operators were reviewed to determine the information content of the reports, evaluate the adherence to the list of performance elements stated in enclosure (2) of NVIC-15-91, [USCG, 1991], and to determine the effectiveness of the CAIP reports in achieving the goals that have led to the implementation of the CAIP reporting requirement.

All reviewed CAIP reports follow, in general, the list of performance elements outlined in enclosure (2) of NVIC 15-91, [USCG, 1991]. The majority of the CAIP reports did not provide sufficient information with respect to the *critical repair areas*, one of the main concerns of the CAIP requirement. The description of trends and causes for failures was also not adequately addressed.

The CAIP reports either did not include an *executive summary* or did not list the designated critical inspection areas. All reports focused on the illustration of the vessel's failure history. However, one report illustrated general trends with the help of graphical illustrations of the failure distributions.

Based on the information content and the representation style of the six CAIP reports that were reviewed, it was concluded that none of the reports completely satisfied the goals and purposes that are inherent in the CAIP requirement.

In general, most CAIP reports included additional information (survey reports, sample inspection sheets, surveying guidelines, etc.) that reduced the effectiveness CAIP reports due to the increased volume. CAIP reports are intended to be short and concise summaries of a vessel's failure history with special emphasis on critical repair areas and the effectiveness of permanent repairs and modifications.

3.2.3.3. Automated CAIP Reports

Based on the evaluation of existing CAIP reports, an improved report format was developed that could be used for the automated generation of a CAIP report based on the information contents of the SSIIS database.

3.2.4. Recommendations from SSIIS 1 Project.

Although existing database systems have powerful features that allow the management of structural inspection results and the generation of graphical summaries, they are in general not designed to incorporate all the vessel information that is related to the design, inspection, repair and operation of tankers.

The review of existing analysis applications has demonstrated the scope of vessel information necessary throughout the lifetime of a vessel and has given further indication of the benefits of a unified vessel information system.

Based on the evaluation of the CAIP reporting requirements and the definition of an improved CAIP format, it was concluded that the SSIIS database structure can be used to create an automated CAIP report generating process. For a successful implementation, however, it will be necessary to define and develop detailed representations of failure locations within a vessel. This can be done either graphically or non-graphically.

A detailed definition of the graphics format used for the representation of the structural configuration of a vessel must be developed. This includes the level of detail and the organization of the structural drawings. It has to be guaranteed that the location of defects in a structural drawing matches the location description in the database.

3.3. Integrated Ship Design and CAD Modeling

3.3.1. NIDDESC Ship Product Model

The Navy/Industry Digital Data Exchange Standards Committee (NIDDESC) addressed a product-orientated and systems orientated breakdown of the ship and its components [NIDDESC, 1993]. It is proposed that the NIDDESC standard will be a part of the Standard for the Exchange of Product Model Data (STEP) International Standard.

The components of STEP referring to the ship product model are known as STEP Application Protocols (AP's). NIDDESC has written AP's for the definition of ship structures. The Ship Structure AP's represent the several stages in the life cycle of a ship structural system from preliminary design through production design.

The STEP standard has a layered architecture in which basic core definitions are used by many industry and product specific standards, such as the NIDDESC standards.

The goal of the NIDDESC AP's is to support the exchange of product data representing the ship structural system as required by ship owners, designer and fabricators.

The structure and content of the NIDDESC ship product model are influenced by the needs of the different creators and users of information over the life-cycle of the ship. An information structure that views the ship as organized by systems, without regard for construction practice or life-cycle maintenance criteria would be unsuitable.

3.3.2. Product orientation and systems orientation

The breakdown of the NIDDESC Ship Product Model is more than a traditional systems-orientated view of the ship. The NIDDESC Ship product model is built upon the ISO/STEP standard as a foundation and central or core concepts such as topology, geometry and product structure are extended where necessary.

Concepts common to a ship's product orientation such as hull block, assembly, part, system etc. are used consistently throughout the different components of the ship product model. Application protocols are used to extend the use of STEP guidelines into more specialized areas. AP's for the ship product model are described below.

3.3.2.1. Ship product model components

The NIDDESC AP's are a broad scope representation of the ship and are divided into the following categories to facilitate future development;

- Ship Geometry,
- Ship Structure Configuration Management,
- Hull Product Structure,
- Structural Parts (Plates and Stiffeners)
- Structural Openings,

-
- Structural Connections/Joints,
 - Internal Subdivision (compartments and zones) and
 - Standard Parts.

The NIDDESC AP development focused on early stages of design and manufacturing (functional design, detail design and production engineering). Within these stages support is provided for the activities of graphic presentation, structural analysis and naval architectural analysis.

The selection of the basic modeling objects for a ship's structure was based on a fundamental approach to object role modeling. The decks, transverse bulkheads and longitudinal bulkheads are all similar in their defining characteristics. They all lie on defined surfaces and contain one or more plate parts, have stiffeners and include other features such as penetrations. To ease the modeling process these elements are represented using standard parts.

The use of standard parts allows the geometry to be defined once but used many times. It should be noted that a single shape definition cannot be used to describe ship structural elements over the life cycle of the ship. Thus multiple shape representations must be used, for example for analysis, design and inspection monitoring.

Ship Geometry

The geometric representation of a ship structure is generally used as the starting point for the ship product model, and therefore, serves as the foundation to later shipbuilding activities. The geometric model must be robust enough to handle the demands for a product model placed on it by the various applications and end users. Two areas of ship geometry are addressed by this model: the geometry necessary to describe the molded hullform of a ship, and the geometry necessary to describe the structural component up the ship.

Hull Product Structure

The ship structure must be broken down into smaller pieces so that it is of sufficient 'size' that it can be readily managed and analyzed. The hull product structure refers to the product structuring schemes represented within the ship structure AP's. It is based on the recognized need for both a functional system classification, appropriate for estimating and early stage design, as well as a product-orientated work breakdown structure, conforming to the way the ship is actually built.

Structural Parts (Plates and Stiffeners)

The fundamental concept supported by the ship product model contained in the NIDDESC AP's is all structural parts contain a life cycle description. The life-cycle of a ship commences with the first design drawings and continues through to decommissioning and salvage. In the early stages of design and construction of the vessel, one or more parts may be completely designed and manufactured.

The information about a part increases as it progresses through the life cycle. It varies with the stages of design, construction and operation. This includes design information, for exam-

ple analysis properties, then to construction as-builts and inspection records. Once the vessel is in service, data includes inspection, maintenance and repair information.

Plate parts are represented as lying along geometric planes. Stiffener parts (used to stiffen plate elements) are either rolled, extruded, built-up or otherwise fabricated structural profile shapes. Stiffeners and beams are represented by extruding a cross section along a line.

Structural Connections/Joints

The interface between structural elements is broken into connection and joint properties. The connection entity serves to capture the requirements of the interface between elements and the joint and describes the overall connection properties. The connection entity details how and where the elements are joined.

The joint entity allows for the physical description of the functional connection. The description would include such attributes as weld size, standard joint detail reference and joining procedure. Also included is the configuration management information such as joint certification.

Internal Subdivision (compartments and zones)

The first and most common subdivision is the division of a ship into compartments. A compartment is usually integral with the hull and has physical bounds formed by the decks and the bulkheads. An example of compartments are tanks or other voids which can be isolated within the ship structure.

A zone is the abstract subdivision of the ship whose boundaries may or may not align with the geometric or structural configuration of the ship. An example of a zone, is the crew living quarters.

Standard Parts

Standard parts are in common use today in various shipbuilding structural CAD systems, and their use will be supported by the STEP application protocol. Standard parts enable the re-use of accepted structural details, for ease of construction or perhaps because the detail has proven serviceability and/or durability.

3.3.3. Integrated Ship Design

The combination of graphic and non-graphic information known as product or product model data has become the basis of current CAD/CAM use by many in the U.S. Navy and marine industry. Several shipyards have developed design and production systems on the integration of traditional CAD/CAM systems with other informational databases.

The trend toward the integration of previously separate database systems for design, materials and fabrication has resulted in a need for better and more complex data exchange mechanism capable of handling this expanded information base. The NIDDESC/STEP standard provides a basis for the development of internationally accepted protocols.

3.4. Ship Operating Systems: A Case Study - Stolt Parcel Tankers

A visit was made to the ship owning division of Stolt Parcel Tankers, in Houston TX (SPTIH) during January 1995 to review the information systems currently under development there. This division is responsible for the development and implementation of Information Technology solutions for the operations of Stolt Parcel Tankers worldwide. This section outlines the information business systems under development at SPTIH.

3.4.1. Stolt Parcel Tankers - Background

Stolt Nielson S.A. provides distribution services worldwide for bulk liquids. Ocean going transportation is provided by a fleet of tankers operating to all major worldwide ports. Storage terminals are operated by the company in USA, NW Europe, Brazil and on land transportation provided by railcars and tank trucks.

Stolt Parcel Tankers operates approximately 100 parcel tankers from 1300 tons to 40,000 deadweight tons consisting of both transoceanic and coastal tankers, and barges on protected waterways.

Within SPTIH nineteen people were employed across all areas of business systems development. This includes staff for hardware and communication, design and installation, software development and support personnel. In a recent three month effort, the company was certified on a global basis to ISO 9000.

Reengineering of the existing business functions and processes was clearly evident. This included, for example, implementation of a global communications network from ship to shore, and organizational change for purchasing of ship stores.

3.4.2. Process Identification

The information system and supporting programs developed within Stolt can be broadly classified to fall under one of two business processes shown in Table 3.2. Information common to processes and programs are stored in a central database titled SWORD. Stolt is not currently developing any systems to support a structural maintenance process.

| Cargo Operations | | On-Board Management | |
|-------------------------|----------------------------------------------------------------------------------------------------------------|----------------------------|------------------------------------------------------------------------------------------------------------|
| CaBo; | Cargo booking system linked to Stolt offices worldwide | MMS; | Marine Management System; used to handle all on-board preventative maintenance, requisition and purchasing |
| STOW; | Stolt tankers operator workstation used to match cargo and tanks on-board a vessel <i>under development</i> | DOCS; | used to generate reports for cargo and personnel at ports <i>under development</i> |
| Cargomax; | Check structural strength during loading/unloading <i>under development</i> | ICMS; | Instrumentation of on-board mechanical activities (new-build ships only) <i>under development</i> |

Table 3.2 : Stolt Software to Support Business Processes

3.4.2.1. On-board Management

Three systems as shown in Table 3.2 are used to handle on-board management of the Stolt vessels. The DOCS and ICMS modules are still under development, however the MMS is operational. The MMS is used for maintaining equipment systems and thus should form part of a Marine Structural Integrity Program (MSIP). It is therefore described in detail below.

Crucial to on-board ship management is the Marine Management System (MMS). It is used to track preventive maintenance requirements, and the requisitioning and purchasing of on-board ship stores. This system is in the process of being implemented across all vessels in the Stolt Tanker Fleet, and in January 1995 the hardware and software had been installed in over half the fleet. The system has been developed and implemented in only the last 12-18 months. The software was a third party product developed to Stolt's specific needs.

The MMS allows other modules to be added which share data with the equipment database and thus enhance the capabilities of the system. These modules include:

- **Inventory Management System** - this system tracks the ship inventory and organizes spare part information for efficient inventory control. It provides a detailed database of spare part inventory information created from the current inventory records.
- **Requisition Management System** - this system helps maintain correct inventory levels and facilitates the processing of shipboard requisitions.
- **Planned Maintenance System** - this system allows the user to schedule maintenance, standardize work procedures, and record equipment histories. It provides a detailed database of equipment work procedures created from the current maintenance records.

These modules share information and work together to make up the MMS. The MMS also consolidates information which is entered on the system for efficient transmission between ship and shore. This feature allows the shore office to access information that is particular to each of the vessels.

The MMS database consists of technical, inventory and maintenance information for each piece of equipment onboard the vessel. The equipment is coded to provide a flexible scheme for organizing information and identifying specific pieces of equipment.

An external links option allows the user to temporarily suspend the operation of the MMS and to run an external software application. Example uses of the external links options include accessing a graphics program to display illustrations of equipment or a spare part; a spreadsheet program to track requisition expenses; and a program to list safety notices and additional information when performing a work procedure.

Equipment Management System.

The equipment management system is the hub of the MMS. This module organizes information about the equipment and contains:

- technical and nameplate information
- equipment quantity and location
- spare parts information
- maintenance information
- equipment history

The organization of the equipment management system allows all of the information to be kept in one central location and displayed in a logical manner. This equipment information is shared with the other MMS modules for maintaining inventory control and maintenance routines.

Inventory Management System

The inventory management system is used to organize and access the spare parts information associated with a vessel's equipment, such as availability, quantity, recommended inventory levels, storage location and pricing information. The inventory management system can be used for the following activities:

- detail spare part records
- review inventory information
- adjust inventory levels
- generate labels for the parts

The module displays information that is common to a complete class of ship, such as equipment information, description and part number in one section of the screen. Another section provides information that is unique to a particular vessel, such as quantities on order, minimum and maximum stock levels, quantities in use and storage locations.

Requisitions Management System.

The requisitions management system is used to requisition parts and services from the shore office. The requisition management system can be used to:

- check the current status of open requisitions
- requisition spare parts through the shore office
- requisition services through the shore office
- monitor the cost associated with the requisitioned parts and services

The requisition management system provides an efficient way of requisitioning those parts or consumables that are short on hand, or that are needed for upcoming maintenance or storing. It keeps track of parts and consumables ordered, dates, prices and status of pending orders.

This system helps to ensure that parts and consumables are available for maintenance and other activities, thereby streamlining work procedures and tasks. A budget tracking option is included to monitor the cost associated with the requisitioned parts, consumables and services for the different departments. The requisition can be charged against the budget for a particular department or category.

Planned Maintenance System

The planned maintenance system is used to reference work procedures and organize schedules for routine maintenance and long term jobs. It is used to plan equipment maintenance and for reviewing equipment history. The planned maintenance system can be used to:

- generate a list of upcoming or required maintenance routines
- document maintenance performed on the equipment
- track equipment running hours
- detail work procedures with maintenance information; standard maintenance procedures used throughout the Stolt fleet are stored in the system.

The work procedures screen contains detailed information for various maintenance routines, including the parts needed to perform the maintenance, the steps involved in the job and the scheduling information.

Once maintenance records are in the system, the planned maintenance system is used to generate maintenance schedules for upcoming equipment maintenance, provide a detailed reference source for procedural information and keep a record of the equipment history

Data Transmission

The MMS software exchanges information between ship and shore sites, maintaining mirror images of the database at each site. As users at each site make changes to the data, such as adding or modifying records, those changes are recorded, consolidated with other changes, and put into a transaction file

Periodically, the transaction files are sent to shore via Rydex. This transmission is received and processed by a specially designed set of programs in the SPTIH office.

3.4.2.2. Cargo Operations/Commercial

Central to Stolt's parcel tanker business is the booking of cargoes for worldwide transportation. The CaBo system has been operational for the last 5 years with ongoing modifications. The system is centered around an IBM AS400 system and all 20 sales offices worldwide are connected to the system.

Other cargo management systems are being designed to reference the same central information. The STOW system is being designed to assist the ships' master place the ordered car-

goes in the storage tanks on the vessel. Tank coatings and previous tanks contents, are one of many factors that must be considered before loading a new cargo. This system helps the ships' master plan tank contents and washing procedures after offloading.

The Cargomax system is being interfaced with the STOW system to enable ship stress calculation to be performed prior to loading. This is being implemented to ensure an efficient loading and offloading sequence and to avoid overstressing the hull structure.

3.4.3. Process Implementation

The development of the Marine Management System and implementation onboard Stolt vessels has been rapid. The implementation of the system has been facilitated by the development of a training program for ship's crews and the provision of a help desk. Management is committed to the introduction of technology and has provided the necessary support to aid the implementation.

4. BUSINESS PROCESS REENGINEERING

This section is provided to give a detailed background of reengineering which will show that the design and implementation of an information system must be undertaken after existing process flows are documented. Reengineering of existing processes is an essential part of an information system for ship structures, as it obtains maximum advantage from the introduction of an advanced Marine Structural Integrity Program (MSIP).

Technology is rapidly changing the way both information and work is managed within a business. Radical change is achieved today by many organizations through 'reengineering' of existing business processes. Key to this change is the utilization of technology to manage information and work, and the order in which work activities are organized to make efficient use of technology [Davenport, 1993; Manganelli, 1994]

Process flows are descriptions of how information and work is organized within a company. This technique details both inputs and outputs, and involves ordering work activities across time, place and company functions. Business Process Reengineering (BPR), involves taking an overall view of a system and completely re-organizing the process flow.

The background of reengineering or process innovation is outlined through a discussion of processes, business strategy, and change enablers. Steps chosen to innovate a business process are detailed. These steps include understanding the existing process flows and activities, and then by recognizing deficiencies, envisioning a new process flow through the employment of technology and organizational change.

Business process reengineering, has been used by a large number of companies to improve their performance radically. This improvement is measurable in terms of financial and quality goals, as well as customer satisfaction, for example. Process innovation involves re-designing the way a company operates. It therefore involves organizing the business in terms of processes that are used to fulfill customer requirements.

4.1. Background

4.1.1. Innovation

Business process reengineering, involves taking an overall view of a system. Reengineering goes back to fundamentals and offers a *radical* and *dramatic* change to process *efficiency* [Hammer, 1993.] Documentation of the existing process flows highlights where improvement is required and changes are implemented in the new re-engineered process. These changes are enabled through the use of technology, information and organizational re-structuring.

4.1.2. Process flows

Process flows are descriptions of how information and/or work flows within a company. A process flow diagram shows inputs and outputs, and the order of work activities across time and location. These processes describe how the business is conducted, and identifies activities where value is added to a product or service, and where further information is required.

Adopting a process orientated structure generally de-emphasizes the functional structure of the business. The structural maintenance process involves the sequential movements of in-

formation across business functions. For example, in the inspection, maintenance and repair activities of a ship; fracture information from inspections is passed to ship yards who perform repairs and the information from both the inspection and repair is eventually passed to certification and regulatory authorities.

“Process innovation demands that interfaces between functional or product units be either improved or eliminated, and that flows of information be made parallel through rapid and broad movements of information.” [Davenport (1993)]

Major processes include tasks that draw on multiple functional skills. Adopting a process flow innovation change therefore involves cross-functional change and cross-organizational change.

4.1.3. Process selection

To select a process for innovation a company must have clearly identified *all* of its functions and activities. Defining a few processes broadly is easier to maintain focus to achieve radical change. Selecting and ranking the processes for innovation depends on where the greatest benefit can be gained.

Selecting a process with many inter-functional steps will provide the most leverage for change. Therefore, the aim is to specify company processes in broad terms. Broadly defined processes provide greater opportunities, but are more difficult to understand, elucidate, and change.

The relevance of each process to the company strategy can be assessed. This defines how important any one process is to achieving company goals. This ranking of process importance provides a guide to process selection for innovation. Short term expenditure must offset medium to long term performance improvements and changes must be financially accountable. Thus the goal will be to innovate those processes that will profit the company the most.

Customers are a valuable source of information used in reviewing the processes for change. Existing process criteria can be assessed through customer interviews to determine current shortcomings. Customers can also assist in the creation of a new process vision and the identification of process objectives. Process innovations often involve not only internal but also external organizational changes. Customers and suppliers must therefore be involved in the new process vision.

4.1.4. Strategy & Process Visions

Company strategies emphasize the long term goals and directions of a company. It is with these that process innovation starts. Strategies provide the focus for the development of process change and the creation of future process visions. These *process visions* consist of measurable *objectives* and define the *attributes* for individual processes, see Figure 4.1.

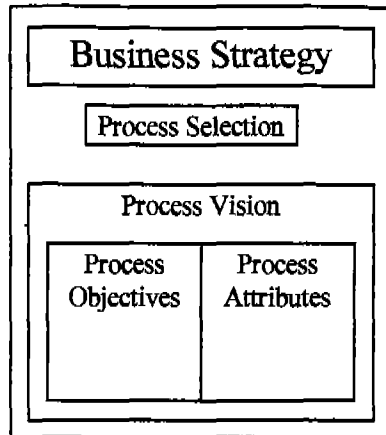


Figure 4.1 : Strategies, Visions, Objectives and Attributes

Process objectives describe the goals of the process in detail, and provide a clear definition of what the new process will achieve. It is clear that business strategy and process objectives have a common theme.

Emphasis on strategy and process objectives provides a clear statement of required achievements. For successful implementation of process innovation the motivation for change must be strong. A well defined strategy is therefore an excellent place for the establishment of process objectives.

Process attributes establish the way in which the new process will be implemented. This entails describing the information technology required (e.g. inspection recording devices) and the organizational changes (e.g. empowerment of employees) required.

4.2. Enablers of process innovation

Enablers of process innovation are mechanisms that provide the means for process change. This is achieved through extensive use of information technology as well as changes in organizational structure.

A clear distinction must be made between *information* and *information technology*. Information is manipulated or handled by information technology; information is recorded, stored, analyzed and reported by information technology.

4.2.1. Information Technology

Information Technology (IT) is a combination of the following technologies: hardware, software, communication, plus information used together to control and/or manage a process.

Information technology is used to integrate information within a process flow. One form of IT, automation which is the replacement of human-power by technology, has been used extensively by industry to increase efficiency. However, it has been introduced with a focus on improving the efficiency of explicit *functional* activities rather than improving the overall *process* flow. Automation of functional activities may only yield small benefits since technology is introduced without being integrated across the process flow.

In the past, the tendency of software development has been to support a functional view of business activities. This has resulted in programs written to support activities in a process that cannot share the same inputs and as a result data has been trapped within functional activities. With the implementation of a process view the information requirements must support the process flow.

It has been identified above that information technology and the use of information must be implemented across functional divisions to achieve innovation. Therefore, the introduction of information technology within a process must be supported by organizational changes.

Advances in communication technologies, such as the increasing use of networks, has now made integration of information technology feasible. A ship at sea can transfer vast amounts of information to and from shore quickly and easily. The use of land, cellular and satellite links has resulted in truly world wide communications making the effective electronic transfer and integration of information possible.

The impact of IT on innovation can take many forms as shown in Table 4.1

| Impact | Explanation | Examples |
|-------------------|-------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Automational | eliminating human labor from a process | manufacture : cad, computer-aided or integrated manufacturing, materials handling, robotics control : telemetry, process control, AI, feedback, command and control identify : bar codes, magnetic strips, transponders |
| informational | capturing process information for purposes of understanding | Capture and document : image, data storage, microfilm |
| sequential | changing process sequence, or enabling parallelism | share expertise : knowledge based expert systems, bulletin boards share information : data bases, external information services and networks |
| tracking | closely monitoring process status and objects | |
| analytical | improving analysis of information and decision making | analyze : simulations, correlations, trends, spreadsheets, budget, or standard vs. actual informate : telemetry, on-line access manage : decision support, management information |
| geographical | coordinating processes across distances | communicate : data communication, telephony, video, networks provide mobility : cellular telephone, laptop or handheld computers |
| integrative | coordination between task and processes | human interface : graphics, voice recognition/response, video, pen based |
| intellectual | capturing and distributing intellectual assets | |
| disintermediating | eliminating intermediaries from a process | |

Table 4.1 : Uses of information technology within a company:[Davenport, 1993 & Manganello, 1994]

4.2.2. Information

Information technology assets are managed as company capital; they are for example, included in budgets, depreciated and even allowed for in office space requirements. The concept of IT as a physical asset is easy for managers to understand. However, the information held within a company is often poorly organized. Information not held on paper but in electronic form is often not well managed even by organizations with quality certification.

The management of information is largely ignored, yet it is the information that is largely used within process innovation efforts. Information can be used in a variety of ways to increase efficiency and bring about effective process change. Examples include:

- **Process integration;** the use of information to integrate activities across time and place, and different processes.
- **Process customization;** the use of information to customize an output.

The aim in the management of IT is to develop systems which integrate information on a process level. Traditional views of software development has taken a functional approach to information requirements. Information processes are largely unstructured and moving to structured process is itself an innovation for many companies.

4.2.3. Human and Organizational Resources

Changes in organizational structure to gain maximum advantage from IT include utilization of the following:

- Team structure approach; group problem solving.
- Empowerment of individuals; using technology to supply individuals rapid access to information to solve problems immediately. Also used to compile specialist activities into manageable tasks.
- Flattened organizational structures; reduction in management levels as a result of team working and employee empowerment, cultural changes to management processes.

What typifies process innovation are the organizational changes required to yield maximum advantage from the implementation of information technology across a process. Cross-functional organizational changes are implemented from the top down within a company. These changes must be supported and executed by upper management. Consequently upper management support for reengineering is crucial for success.

Quality orientated improvements are not radical turn-arounds in the way a company conducts business. Improvements operate on a functional level where-as process innovations look beyond company functions. Innovation stresses cross-function activities and thus requires significant organization change which must be supported from the top level of management within a company.

4.3. Existing process flow

As obvious as it may appear, it is crucial to understand the existing process flow. Detailing the existing process flow encourages communication of ideas and a common understanding of current problems. An understanding of the process flow highlights possible changes by recognizing existing problems. It also stresses the magnitude of the changes required in the implementation of the new process.

4.3.1. Identify existing activities

A common problem in many companies is that of a general lack of detailed knowledge of the business processes in use [Davenport, 1993]. Alternatively, a functional view of internal departments may be known but the cross-functional relationship between them will not be well understood. Personnel often have little understanding of the role performed by other departments, let alone the detailed work activities.

The description of the process flow should identify value adding activities, waiting times and bottlenecks. Also to be detailed are customer/supplier interaction, resources used, and the use of IT in the process. Assessment of the existing IT configuration should include existing applications, databases, technologies and standards.

A description of the current process flow and identification of the existing activities can be used to:

- measure the existing process in terms of the new process objectives
- assess the existing process in terms of the new process attributes
- identify problems or shortcomings with the existing process
- identify short term improvements in the existing process
- assess existing information technology
- assess existing organizational structure

4.3.2. Improving the Existing Process

Changes can be made to processes which have not been selected for reengineering by implementing incremental improvements. These can be interim fixes until resources are allocated to design the new process. Making improvements immediately before implementing process innovation may not be worthwhile as too many changes may be required.

Incremental improvements may be recognized in processes not scheduled for innovation. These improvements should certainly be undertaken, however they may only be short-lived if innovation is planned. Organizations must be able to separate the differences between improvements and innovation.

Information systems can require considerable time to change as new software is written and checked. The adaptation of existing or the purchase of third party software which can be tailored to suit the individual application can be a solution to speed the process innovation implementation.

Changes in company organization can take considerable effort and persistence especially in larger organizations where considerable company culture has developed.

4.4. New process flow

After the company's strategies and goals are established, its processes identified, and its existing process flows documented, the next task is to change and innovate. The process activities and resources have been identified and flaws recognized; the challenge is now to design a new process flow.

4.4.1. Envision of the new process flow

The goals of the new process design are to achieve a more efficient and more productive process flow. Although individual activities may increase in complexity, the total number of activities will be reduced. The new process will perform tasks in a logical order such that work is managed effectively, and tracked easily to maintain and check progress.

With the introduction of IT, redundant steps are eliminated and parallel processing implemented to reduce bottlenecks and idle time. The use of communication technology to gather information from different areas reduces the number of work locations.

At an organizational level, jobs may be combined, support may be outsourced, and decision making brought up-front. The use of IT results in more useful information supplied to workers. This enables work on multiple tasks and quicker decision making. The use of expert systems (rule based systems) and neural networks (learnt systems) are examples of technology developed to inform humans for faster decision making.

The envisioning of a new process consists of creative teamwork and brainstorming for new ideas. Benchmarking, the comparison of work practices among other companies, is one source of new ideas. Benchmarking either competitors or companies in other industries will uncover their approaches to problem solving.

4.4.2. Benchmarking

Benchmarking is a very useful tool for process innovation. Researching what other companies have tried and their subsequent success (if any), is of enormous benefit. One idea is benchmark outside one's industry with a 'best of' company (a company that is a recognized leader in the implementation of a similar process or technology.) These companies are often detailed in business papers and journals, and may even participate in open discussion of their process innovation. Another solution commonly adopted is the use of external management consultants.

4.4.3. Brainstorming

Brainstorming in a group environment is a tried and tested method used to obtain solutions to problems. Brainstorming in teams that include the key stakeholders will assure that ideas discussed are feasible. Coming up with 'pie in the sky' ideals using far fetched technology should be encouraged as total change process change often results in innovation.

Team work will also detail the risks and benefits of process implementation with the introduction of a new process. Risks can be assessed on development and changeover times with the implementation of new technology, as well as the ability of the organization to adapt to the process changes. Organizational changes both at a structural level and at an individual employee level must be assessed.

Prototyping the new process using manual methods is useful to estimate process benefits. These benefits should be assessed against the process objectives to determine if company performance will be radically enhanced with the introduction of the new process.

4.4.4. Detailing the process vision; the solution

Once the new process vision has been identified through benchmarking and brainstorming, and the risks and benefits assessed as well as the feasibility proven, the new process vision can be detailed into a solution.

4.4.4.1. Technology & Information

During the detailing of the new process, benchmarking and review of the technical resources reveals what technologies are available for use. This includes hardware, software and networking tools to integrate and customize information.

The aim is to develop specifications for the design of technology solutions. Information management or information engineering (IE) starts with the definition of the information requirements. These requirements must be exhaustively defined through all company processes to avoid duplication of data. IE moves through the collection, analyzing and utilization of the information and data linkages.

Extensive use of information systems and/or databases is made to manage information. This allows access and updating of information by software applications written to manage and/or control a process. The specifications for these applications must be written and the user interface, often referred to as the technology/human interface, designed.

Computer aided software engineering (CASE) tools are extensively used in the IE industry to speed software development. These tools allow data linkages to be graphically established and modeled, and data analysis routines written quickly.

The challenge is to integrate effectively IT, both horizontally across business functions and vertically through management levels. Detailing information and work process flows yields an efficient order of activities across business functions. The design of technical solution details elements of IT identified in Section 4.2.1 and utilized in the new process vision.

4.4.4.2. Organizational

Designing a new organizational structure to support the new process vision revolves around the creation of a company focused on its processes. Employees work on broader defined tasks through the use of technology and are able to complete a wider range of activities inter-linked with technology. The elimination of specialized tasks requiring management levels results in the reduction of the number of required levels.

The design of organizational changes defines the new organizational layout; this consists of the definition of management/employee structure and the identification of required skills. Job descriptions should identify training requirements of existing employees and required acquisition of new skilled personnel.

4.4.5. Implementation and Performance

The transition to a new process design within a company requires considerable effort and resources. Process changes will be significant and therefore an assessment of the company's reaction to change must be undertaken. An implementation or transition plan must be drawn.

4.4.5.1. Transition plan

There are three approaches to the implementation of process change within an organization:

- Pilot; trial of a new process parallel to the existing process. Once the new process runs smoothly, the old process can be discontinued.
- Straight-out-change; discard the old process and implement the new process in an overnight change. Problems that arise in the new process may result in initial shortcomings, but they hopefully can be eliminated quickly.
- Phased; implement gradual changes over time. This reduces problems to a manageable level and avoids the numerous problems of a straight-out-change.

In any transition or implementation plan, the introduction of new technology must be accompanied by training.

An important role of management in the implementation of new processes is the communication of company's goals and the description of why changes are necessary. A responsive workforce results from open lines of communication between management and employees. Employees informed of changes, and kept aware of the transition will help the company to change as they will recognize the benefits of overall improvement.

4.4.5.2. Communication

Clear communication between management and employees are essential. From the commencement of innovation efforts, employees informed of goals and objectives will make efforts to identify required changes, and will assess the proposed changes. This feedback in the innovation process loop is essential to ensure maximum leverage from the proposed process change.

Feedback is also required after the implementation of the new process to eliminate glitches and bugs in the system. This feedback comes not only from employees but also from customers. Process innovation starts with identifying ways of improving customer satisfaction and must end with ensuring that these are achieved.

4.4.5.3. Performance measures

Customers provide the best indicator of process improvement. Company performance, as previously discussed, is ultimately determined by bottom line profit. Increased customer satisfaction and efficient process flows will increase this profit.

The assessment of process objectives and company strategy with the changed process flow will also provide a measure of innovation success.

4.5. Conclusions

What makes reengineering stand-out among business trends is the potential for *innovation*. Improvements made to the existing organizational structures are generally changes within narrowly defined functional activities. Process innovation however takes a cross-functional approach in solving problems.

Process innovation takes a system overview in the application of information technology (IT) to problem solution. The integration of information across all processes and organizational functions is only possible after the identification of the processes where information is used. Existing processes must be clearly enumerated before the development of new process flows is initiated, and IT requirements are detailed.

The use of IT in process innovation is maximized with the incorporation of organizational changes to boost process and business performance. The introduction of information management systems that do not take advantage of organizational changes to collect, analyze and utilize process information are, at best, only automational improvements of functional activities. The identification of business processes, the information used therein and the related organizational changes are therefore essential to develop a useful and effective information management tool.

5. INFORMATION SYSTEMS

Reengineering and the development of an information system have many overlapping elements. This is illustrated in Figure 5.1. The evolution of an integrated business information system from conception to implementation uses many features of business process reengineering.

The development of an information system is comprised of four phases [Mylls, 1993], very similar to that of a marine structure:-

- Planning is the why; providing the direction of the system development and determines who are the owners and users of the system.
- Analysis is the what; determining what must be accomplished, through detailing system requirements.
- Design is the how; deciding how the system operates in the organization.
- Construction is the building and testing of the system.

All four phases are related and dependent upon each other because of constantly changing requirements. Each phase cycles within itself and with other phases. Planning determines the priorities for subsequent analysis. Analysis provides the requirements for the systems to be designed. The designed systems are then Constructed. Reengineering activities are primarily involved in the planning and analysis of information system development.

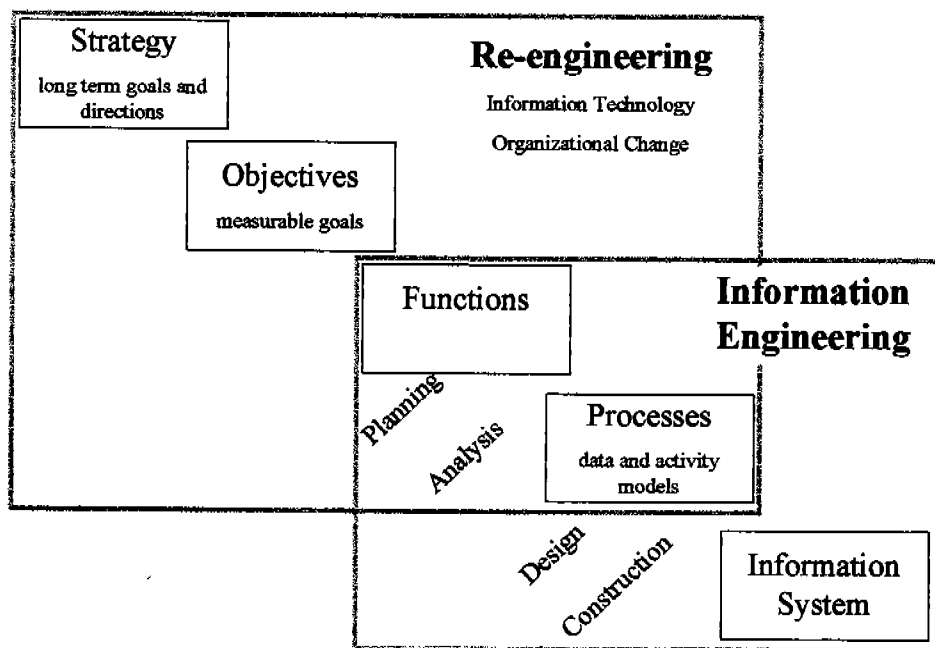


Figure 5.1 : Reengineering and Information Engineering

The creation of a business information system, evolved through each of the phases, and with a minimum number of adjustment cycles, will ensure an optimum system. This allows for in-

formation sharing between functions, that is cross-functional integration of information. Rigorous development of the system architecture will ensure the system developed matches the objectives established at the start of the project. Detailing the system development phases ensures that a business system is created to match business requirements.

Business objectives are met through the supply of correct, consistent and current information. Information engineering uses the interaction of data and business activities to formulate applications and systems to supply information.

From planning to construction, the development of four levels of information system architectures are progressively detailed, these are

- **Information Technology;** the information technology architecture is a description of the hardware, software and communication configuration. For example this may include a description of the client/server system and associated support platforms.
- **Information;** the information architecture is a result of gathering the information needs and relationships between business functions and activities.
- **Organizational;** the organizational architecture is established largely as a result of reengineering efforts. New jobs may be created when previously activities are consolidated through the use of information technology and team working.
- **Application Architecture;** the application architecture is a description of how the information system will appear to the user. This encompasses the gathering or entry of data to the reporting of analysis results.

The stages of information system design and the architecture are represented in Figure 5.2

| Architectures | | | | |
|-----------------------------------|---------------------------------------|-----------------------|---------------------------|--------------------------|
| Phases | information technology | information | application | organization |
| planning | hardware software communication | | Business Systems | |
| analysis existing processes | | | | new job roles |
| design | | procedures modules | user interface reports | restructuring |
| construction | databases | programs | user interface reports | organizational change |

Figure 5.2 : Development of an Information System

5.1. Planning

The objective of planning the development of an information system is to reflect where the enterprise is going, not where it currently is. Data must be organized to satisfy the informational needs throughout the organization, and to make the commitment to data sharing.

If the information system is developed with the ideals of reengineering, then prior to the planning phase business strategies and objectives will have been established. These are used to identify priority areas within the company and hence identify potential business systems where significant benefit can be realized.

The planning phase identifies, through benchmarking and other methods, the information technology (IT) that is available. IT, as previously discussed, consists of computer hardware, software and communication.

Planning identifies current business functions. For example they include the transportation of cargo or the inspection of vessels. Data entities are the description of information within an activity, such as the inspection records or the description of the ship geometry.

5.2. Analysis

The analysis phase of information system development details the processes used to match the company strategy and fulfill the business objectives. Detailing the processes and using business functions detailed within the planning phase, the re-engineered information flows can be developed. Identifying potential innovative changes within the organization allows for maximum benefit to be derived from the implementation of new information technology.

The analysis phase produces data and activity models and user views through prototyping. Data and activity models make use of computer aided software engineering (CASE) tools to develop the information relationships within processes, functions and associated activities. On a detailed level, data models are developed to show relationships between activities.

On a simple level the information relationships between functions and entities can be represented in a matrix format. The intersection cell defines the action the function performs on the entity type: create, read, update or delete. This is illustrated in the following chapter for the breakdown of the SSIIS information requirements.

Prototypes are effective in obtaining comments from departments and personnel who will be responsible for using the new system. These comments and ideas are carried forward into the design phase. During the analysis phase, the business system can be subdivided into separate design phase projects.

5.3. Design

In the design phase of information system development, the specifications of the modules are fully detailed. This includes defining user interfaces, that is the forms used by the user to enter data, as well as reports used to summarize the data ultimately used in the decision making process.

During this stage the role of the information system is developed. The information system can support decision making on various levels as shown in Figure 5.3. With increasing programming effort, increased support can be obtained from the system. At a simplistic level this includes general summary information providing ‘what if?’ answers. A fully developed expert system can provide decision support to the non-expert via the knowledge coded into the system.

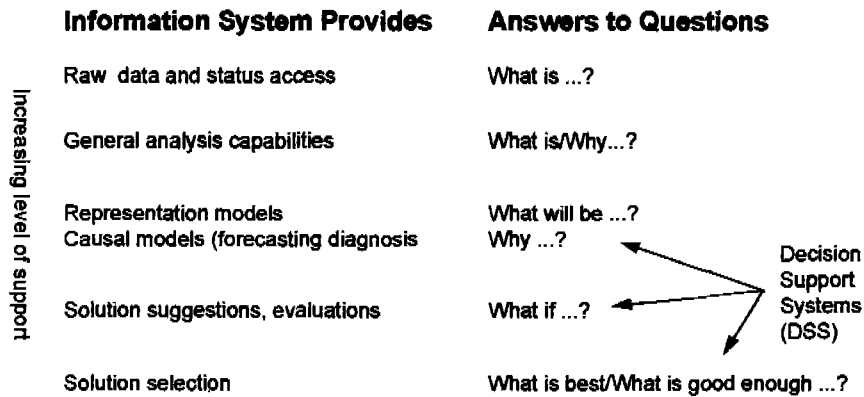


Figure 5.3 : Stages of Information System Development

5.4. Hardware/Software Considerations

The implementation of an information system must enable data to be accessed by a large number of persons over a wide range of locations. The use of relational databases and client/server system architecture are examples of software and hardware technologies that have enabled multi-user information system developments.

5.4.1. Relational Databases and Structured Query Language (SQL)

Relational databases consist of storing data in two dimensional tables. Table rows represent records of data, while table columns represent fields in the record. The column that uniquely identifies a particular fact upon which the table is based represents a unique, primary key. To eliminate data redundancy designers perform the normalization process, which aims to put all data about the primary key in the same table where the key is defined. A relational database usually consists of many tables where fields are joined by relations or links to form complex data structures.

Structured Query Language (SQL) is a default language used for data access and manipulation in relational database management system (RDBMS). SQL allows users to tell the RDBMS only what data is required, and what manipulations are to be done, but not how to perform these manipulations. SQL is the sole means of providing access to data in a relational database.

5.4.2. Client/Server Architecture

The client/server IT architecture organizes personal computers (PCs) and local area networks (LANs) from workgroup file servers to mainframes into a flexible and efficient system. It ensures that processing power is distributed to all nodes in the system and file storage remains in a central location.

The *clients* are the PCs or workstations, attached to a network and are used to access network resources. The client typically runs a graphical user interface (GUI) which accesses the resources of the *server*. The servers provide multiple clients access to shared databases, other files and communication resources.

The clients pass queries to the servers and the client performs all the user interface activities such as controlling input and output forms and reports and presentation of the data supplied back the server. Multiple clients can access the same information from the server. Tasks are split into two activities, the front-end performed by the client and back-end by the server.

Servers perform the file sharing, storage and retrieval of information, network and document management and provide gateway functions for internal and external flows of information. The client/server architecture divides an application into separate processes operating on separate machines connected over an network. An application designer determines which tasks will be performed by the client and which by the server.

The advantages of client/server architectures are as follows

- they are open systems, allowing IT managers to pick and choose hardware, software and services from various vendors.
- they can easily grow and expand and it is easy to modernize the system as requirements change.
- they are efficient, the system provides the power to get things done without monopolizing resources. End users are empowered to work locally.

“An enterprise-wide client/server architecture provides total integration of departmental and corporate information system (IS) resources. This allows applications to span the enterprise and leverage both central and end-user systems. It provides better control and security over data in a distributed environment. By implementing client/server computing as the architecture for enterprise-wide information systems, IS organizations can maximize the value of information by increasing its availability. Enterprise client/servers computing empowers organizations to re-engineer business processes, to distribute transactions to streamline operations, and to provide better and newer services to customers.” [Turban, 1995]

6. STRUCTURAL INFORMATION SYSTEM - SSIIS DATABASE

The concepts of Business Process Reengineering (BPR) and Information Systems (IS) can be used to support processes associated with the design, construction and operation of a vessel. The purpose of using BPR and IS is to provide an information process flow for ship owners, classification societies and regulatory authorities to implement together, and thus increase work efficiency for all parties across all functions and activities.

Innovation can be achieved through a number of methods used to manage and track information and work activities. As an example, consider structural inspection, maintenance and repair (IMR) activities; documentation of existing information flows from the initial inspection to shipyard repairs highlight where improvements can be made. Process attributes detail where implementation of information technology (for example, inspection recording devices) and organizational changes (empowerment of employees to make decisions on behalf of all concerned interests) will improve ship quality.

It is assumed that the changes will involve cross-functional, and cross-organization activities between the regulating authorities, classification agencies, and the ship owners and operators. The challenge is to not only document, but also detail the requirements of all parties within the process flow. The design of a ship structural information system must support the process flow concept to be of practical use.

The objective of this report is take the format for reengineering and information system development described in the previous chapters and apply them to the SSIIS project. To illustrate the potential benefits of reengineering during information system design, the Structural Inspection, Maintenance and Repair (IMR) process has been detailed in sufficient detail to enable a prototype to be built. This prototype is used to demonstrate how the integration and customization of information can be used to achieve quality improvements associated with a ship's structural system.

6.1. Maritime Industry Strategy

As identified in the MSIP study the fundamental goal of developing an information system is to improve the quality of ship systems through the life-cycle of the vessel. This includes addressing structural, equipment and operational systems. Establishment of measurable objectives along with the development of an information system provides a feedback mechanism for long-term continuous improvement.

6.2. Maritime Industry Objectives

For the maritime industry to assess and improve its performance, measurable objectives must be established. If the goal is to improve the quality of ship systems, then a initial baseline must be established upon which future assessments can be measured. The measurable objective must be across a broad spectrum of activities which will be different for agencies, operator/owners and shipyards.

Listed below are objectives which can be expanded on, after detailed consultation with the industry sectors:

6.2.1. U.S. Coast Guard

The Coast Guard, being the regulatory arm of the government, sets the overall safety requirements for the industry. Unsafe practices must be pre-empted and regulated to reduce risk. Measurable objectives for the Coast Guard primarily include a reduction in injuries and loss of life in maritime activities.

6.2.2. Classification Societies

Classification Societies being commercial entities have objectives which reflect not only the requirements of the Coast Guard but also the internal business objectives of maintaining and increasing revenue through the provision of services to the shipping community. Examples of measurable objectives for classification authorities include:

- timely incorporation and development of new rules and regulations
- accurate review and classification of planned ships
- accurate inspection of existing ship structures
- increased services to ship owners offering advice on new technologies and safety requirements

6.2.3. Ship Operators

Ship operators are responsible for maintaining profit margins between operating expenses and revenue for the transport for cargo and obtain maximize operating efficiency.

Examples of measurable objectives for ship operators include:

- reduced ship down-time
- reduced ship quality failures such as cracks and corrosion, though implementation of effective repair programs and planned maintenance programs
- optimize the short and long term costs through effective record keeping of inspection, maintenance and repair costs and operating costs

6.3. SSIIS Objectives

The development of an industry wide SSIIS project must encompass the objectives of all of the maritime community to match the maritime industry strategy of improving ship quality. The incorporation of all industry processes into SSIIS components will realize maximum benefit for all industry sectors. The goal of the SSIIS project is to show that all objectives can be matched with the development of an industry wide information system.

6.4. SSIIS - Processes and Functions

The business processes associated with owning a ship can be divided into two categories:

- **Design/Construction;** those processes associated with the analysis, design and construction of a new vessel, and
- **Operations;** those processes associated with the operation of the vessel.

Designing and building a ship can essentially be divided into two processes. The analysis/design process, which includes the specification of design criteria through feasibility, functional and detail design. The fabrication and construction process includes the incorporation of design plans and specifications into the production of the structure.

There is significant overlap between these two processes and ideally an information system would incorporate the requirements of all activities. It has only been recently that such systems have been proposed, as detailed in Chapter 2, with the current NIDDESC proposed ISO standard which incorporates design and construction activities within the development of an information system.

The responsibility of operating a ship can be divided into a number of separate processes with some overlap in certain areas. This includes cargo management, which is the booking, loading and unloading of cargo. Onboard management, including storage and procurement of ship stores and crew related activities. Finally, mechanical and structural inspection, maintenance and repair activities.

The ship operating processes are detailed in Figure 6.1 shown below. These processes can be expanded out to include specific functions and activities with the process. This, however, has only been performed for the Structural IMR process.

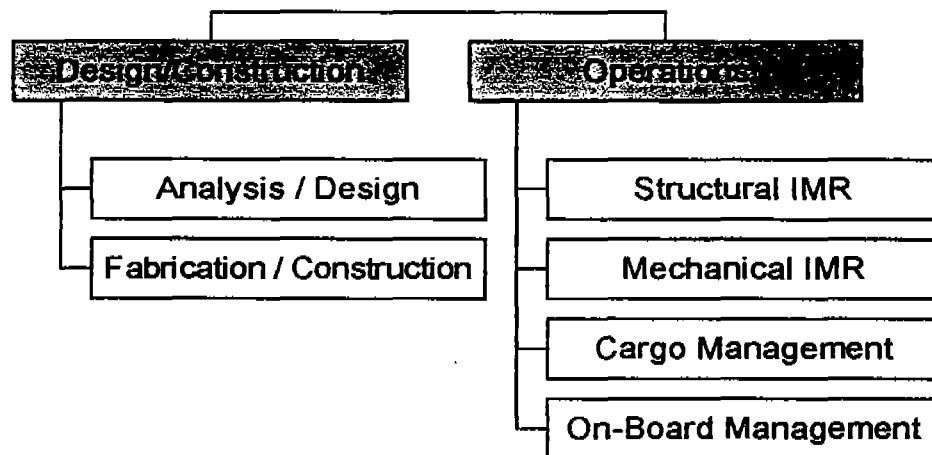


Figure 6.1 : Ship Processes

Within the SSIIS 2 project, emphasis has been given to ship structural systems, hence the main focus of this report has been on processes associated with ship structural requirements.

Overlap between structural processes such as the Analysis/Design/Construction and the Structural IMR process and the non-structural processes do exist and have been highlighted.

6.4.1. Structural IMR

The Structural IMR process revolves around the inspection, maintenance and repair of the ships structural system. This includes all potential structural quality failures such as corrosion, cracking and member/detail overstressing. It includes on-going maintenance such as tank coating and anode replacement and also the detailing of crack repairs.

The structural IMR information process flow is detailed in Figure 6.2. This figure highlights the activities associated with the IMR cycle, both as functions performed externally to the information system and as activities performed by the information system.

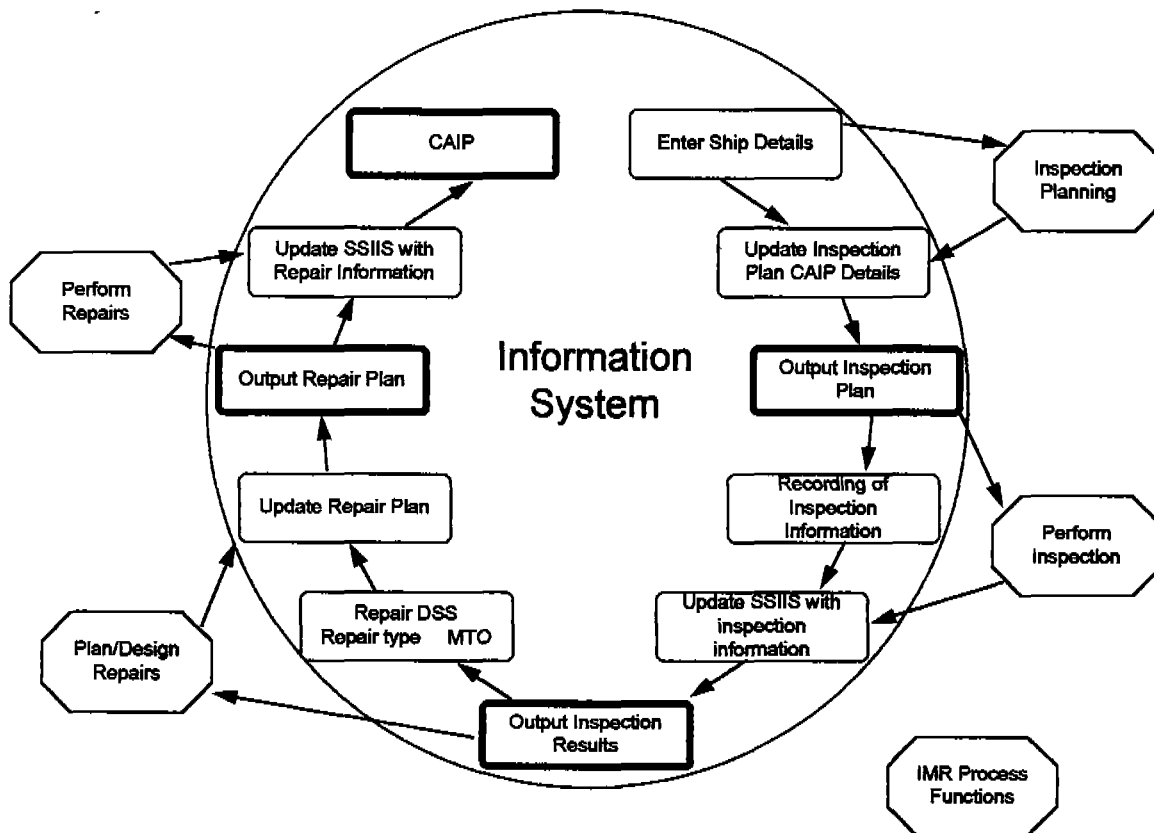


Figure 6.2 : Structural IMR Information Process Flow

The functions performed externally to the information system largely include information gathering activities or physical activities performed on the ship structure. The information system acts as the management tool to coordinate the functions and activities performed on the ship structure. The system enables the worker to perform these activities in an efficient manner by manipulating, collating and customizing the required information.

The functions performed externally to the information system are discussed, including the role performed by the information system in the Structural IMR process.

6.4.1.1. Inspection Planning

Inspection planning forms an integral component to improving the quality of ship inspections. Planning for inspection includes the selection of critical ship details (CSD). Those details that have been shown, either by analysis or experience be those with the highest failure probability.

The Structural IMR process assumes the ship structure has already been entered into the information system. This includes a full description of the tanks, frames, bulkheads and details. Inspection planning utilizes this information to develop a plan prior to the inspection to ensure critical areas are examined.

The purpose of planning an inspection is to ensure that the critical areas are included into the inspection plan and to also estimate resources and time required for the inspection. It is envisaged that in a full implementation of the SSIIS development an inspection plan is developed tank by tank, frame by frame and then detail by detail. This generates a large amount of paperwork for the inspector to handle and hence inspection recording devices should be incorporated to coordinate this information. One of the benefits of IS is the ability to customize the presentation of information for the user.

The information system should allow the user to generate the inspection plan based on different inspection techniques and conditions. From the analysis of previous inspection results for this vessel and other vessels in the same class.

The information system should allow the inspector to work through the inspection prior to entering the tank and formulate the most effective and efficient technique of examining the vessel for defects. An inspection plan is advantageous since it insures that critical regions receive attention. The inspection plan can be formulated to interface with technology used during the inspection.

Internal to the information system, the role of the information system during the inspection planning stage is to:

- maintain a record of critical areas.
- provide tools to analyze previous inspection and repair records for location of critical areas, which will facilitate the identification of new trouble areas.
- provide the means to plan an inspection, using information supplied by the user, for example inspection techniques, such as rafting or the use of platforms.
- output an inspection plan for use during the inspection as a means to record inspection results

6.4.1.2. Performing the Inspection

During the inspection a list of defects in the ship structure is gathered, this includes corrosion, cracking and other quality failures. Most ship operators use some form of tracking system to

maintain a record of failure. However, as the previous SSIIS report determined there are shortcomings in all methods used [Schulte-Strathaus, 1995]. This includes inadequate features to compare within classes and for computerized systems the lack of links between graphical and textual descriptions.

Other reports [Holzman, 1992] reviewed methods used to inspect tankers and recommendations were made regarding the use of data gathering devices. This included voice recognition devices or personal data assistants (PDAs). The inspection plan could be downloaded into the device and used to capture inspection results 'on the fly'.

Internal to the information system, the role of the information system during the inspection stage is to

- maintain a record of defects found during inspection, this includes detailed information associated with the defect such as location.
- provide a detailed report, quickly and easily from the information captured during the inspection.

This information must be able to be easily entered into the information system, this includes the use of appropriate technology to speed the input of information.

6.4.1.3. Planning and Designing Repairs

Once defects are found, the IMR cycle moves to planning and designing appropriate repairs. The repair chosen will depend on a number of factors such as, remaining vessel operational life and defect location.

This decision is largely taken on a cost/benefit analysis incorporating short and long term costs. The choice of repair technique, from simple re-welding to the replacement of steel, has significant impact on the repair costs. Thus the operator must weigh off the short-term costs against the long-term drawbacks of potential further work.

Internal to the information system, the role of the information system during the repair planning stage is to

- update the inspection findings with the associated repair
- offer the user support during the repair design phase on the best repair technique
- provide a detailed report, quickly and easily from the information captured during the inspection and repair process
- provide a means to the shipyard to provide a cost estimate for the ship repairs

6.4.1.4. Performing the Repairs

Repairs to the ship structure must be carried out according to classification society and Coast Guard requirements. Repair information must be entered against inspection failures to document the effectiveness of the repair.

Internal to the information system, the role of the information system during the repair stage is to

-
- provide the shipyard with information on repair technique and associated fabrication procedures
 - provide a means for the shipyard to schedule and complete the work efficiently

6.4.2. Analysis / Design

The Analysis/Design process traditionally creates different computer models for the analysis and then the design of a ship structure. The analysis model is typically used to ensure acceptable member stresses and is separate to the design drawings commonly produced by a computer aided drawing (CAD) application. The ship product model NIDDESC ISO standard is an attempt to enable data interchange between these different applications.

To fully integrate the analysis and design process not only must one model be used, but other information components also must be integrated into a system. This includes the creation of rule databases which directly interface with analysis and design applications and the creation of design specifications which act as templates to customize rules to suit vessel specifications.

6.4.2.1. Rules

Data structures for a rule database must be formatted to interface directly with data entities and fields associated with the ship product model. This will require linking the analysis and design ship product components to lists of rules which can be checked for compliance as the model is generated. Individual rules within the database can be linked via relationships to the originator of the rule, and the ship product model field where the rule applies.

6.4.2.2. Design Specification

The design specification details the functional requirements of the vessel, this information is used to determine the appropriate rules upon which the vessel must be assessed. This includes not only design information but also inspection and class requirements. The design specification also acts to maintain relationships between the vessel and its environmental operating criteria. It should be recognized that the specifications may change as the ship ages, the criteria for repair may be different than those for design.

6.4.2.3. Plans and Arrangements

The structural configuration can be represented by a number of methods; the traditional two dimension (2-D) drawing format, which the introduction of computer aided drafting has speeded, or the newer technology of ship product models and three dimensional (3-D) models. 3-D models can be represented in two dimensions through the definition of views.

Information systems developed to represent the ship structures must be flexible enough to enable existing ships to be simply generated without creating fully detailed product models. Significant investment in analyzing existing vessels has been made. Focus must be made to incorporate data structures in the new systems that can be uploaded with existing analysis and design information.

6.4.2.4. Analysis

The analysis function acts to calculate variables related to the configuration. This includes stresses at the structural detail level to global hydrodynamic responses. The analysis function provides the data to the ship product model based on the structural arrangement of the vessel. The analysis results can then be checked against the design specifications and rules for correct compliance.

6.4.3. Fabrication / Construction

The fabrication and construction process involves activities associated with the production of a vessel from plans and specifications to tangible reality. The process details the construction plan from cutting the steel to assembling components and modules. An integrated fabrication and construction process details the construction sequence to improve efficiency and quality of construction. It details fabrication procedures, incorporates quality records and updates the ship model created during the analysis/design process.

6.4.4. Mechanical IMR

The mechanical IMR process is very similar to the structural process, however the mechanical system maintenance is an ongoing process during the operation of the vessel. Maintenance is generally performed by the ship's crew whereas structural maintenance is performed during port calls. The system developed by Stolt Nielson is an example of a mechanical IMR process, and was covered in Section 3.4.1.

6.4.5. Cargo Management

Cargo management process includes the loading and unloading of the cargo, and in a fully developed system has provision for the booking of cargoes. This system ensures the ship is not overstressed during loading, cargoes are stored in the correct tanks and the loading and discharge operations performed in a safe manner.

6.4.6. On-Board Management

On-board management includes the management of crew operations to onboard logistics and other operational systems. Integrated systems for the vessel control allow navigation, radar and engine information to be presented in the bridge. Recent advances have included the development of ship monitoring systems to give real-time displays of vessel structural stresses along with vessel routing systems to aid reduction of ship fatigue.

7. PROTOTYPE DESCRIPTION

The SSIIS prototype is a Microsoft (MS) Access v2.0 database. Access is a MS Windows application. To run the prototype, both MS Windows and Access must be installed on a IBM compatible PC. It is suggested a minimum hardware configuration of a 486 machine with at least 8M of RAM is used. Installation instructions are on the disk supplied with the report.

The SSIIS prototype focuses on the Structural Inspection Maintenance and Repair (IMR) process as shown in Figure 6.2. However, the Structural IMR process requires information from other processes. Data generated in other processes is utilized by the Structural IMR process. As an example, the ships configuration or design information must be entered to locate where the failures are found during the inspection.

Thus the information requirements of the Structural IMR process can be detailed on three consecutively detailed levels to determine the information relationships. This consists of the

- **Process/Process Relationship:** At this level, information relationships between processes are highlighted.
- **Function/Function Relationship:** Once the processes are broken down into their individual functions, the relationships between functions can be determined.
- **Function/Entity Relationship:** This is the detailed level where the relationship between the functions and individual data entities within the function are shown. The data entities are further broken down into data fields, however to represent where individual fields are modified is too detailed for the matrix notation.

7.1. Data Structure

The data structures developed must be flexible enough to handle the introduction of new functions as the information system matures. A relational database structure is ideal for ensuring future flexibility.

7.1.1. Process/Process Relationships

Process/Process relationships highlight where information created within one process is read, updated and/or deleted within another process. This is shown in Figure 7.1 for the ship owning processes previously detailed.

For example the Structural IMR process reads and updates information created by the Analysis/Design Process and the Fabrication/Construction process. This highlights that data structures must be developed for compatibility between Analysis/Design functions and the Structural IMR functions.

One of the objectives is to ensure that the information system is life-cycle focused, such an approach to data structures will also ensure that data integrity is maintained by the system. This is important as future modules are implemented so that information is not duplicated and the system acts as a central repository for all data.

| | Process | Analysis / Design | Fabrication / Construction | Mechanical IMR | Structural IMR | Mechanical IMR | Cargo Management | On-board Management |
|----------------------------|---------|-------------------|----------------------------|----------------|----------------|----------------|------------------|---------------------|
| Process | | | | | | | | |
| Analysis / Design | | C | RU | | RU | RU | R | |
| Fabrication / Construction | | RU | C | | RU | RU | R | |
| Structural IMR | | RU | RU | | CRU | | R | |
| Mechanical IMR | | RU | RU | | | CRU | | U |
| Cargo Management | | R | R | | R | | CRU | |
| On-board Management | | | | | | U | | CRU |

Figure 7.1 : Process / Process Relationships

Note : **C** - where information is **created** by a process.

R - where information is **read** and used by a process but has been previously created by another process.

U - where existing information is **updated**.

7.1.2. Function/Function Relationships

The function/function relationship breaks down the information dependence further. This again highlights at a more detailed level where information originates and/or is used. An example is given in Figure 7.2.

| | Function | Structural IMR | Inspection Planning | Inspection Recording | Repair Design | Repair Fabrication |
|-----------------------------------|----------|----------------|---------------------|----------------------|---------------|--------------------|
| Process | | | | | | |
| Function | | | | | | |
| Analysis / Design | | RU | | | | |
| Rules | | | R | | | |
| Design Specifications | | | | | | |
| Arrangement | | | R | RU | U | U |
| Analysis | | | | | | |
| Fabrication / Construction | | | | | | |
| Cargo Management | | | | | | |
| On-board Management | | | | | | |
| Mechanical IMR | | | | | | |
| Structural IMR | | CRU | | | | |
| Inspection Planning | | | C | U | U | U |
| Inspection Recording | | | C | CU | U | U |
| Repair Planning | | | | R | C | U |
| Repair Fabrication | | | | R | C | CU |

Figure 7.2 : Function / Function Relationships

7.1.3. Function/Entity Relationships

The final step is to detail the functions into entities or collections of information. The relationship between the functions and entities is presented in Figure 7.3. With the SSIIS prototype, the entities represent a relational table with which the IMR functions read and update information. The relational tables are detailed in Appendix A.

| | Functions | Structural IMR | Inspection Planning | Inspection Recording | Repair Design | Repair Fabrication |
|------------------------------|-----------|----------------|---------------------|----------------------|---------------|--------------------|
| Entity Types | | | | | | |
| Vessel Arrangement | | RU | | | | |
| Tanks | | | R | R | R | R |
| Frames | | | R | R | R | R |
| Bulkheads | | | R | R | R | R |
| Details | | | R | U | U | U |
| CAIP Details | | | R | | | |
| Structural IMR | | | | | | |
| Description, People, Reports | | | C | U | | |
| Tank Coatings | | | | U | R | U |
| Quality Failures | | | | | | |
| Inspection results | | | | C | R | U |
| Repair work | | | | | C | U |

Figure 7.3 : Structural Function / Entity Relationship

Only the entities required in the Structural IMR process have been included in the SSIIS prototype. In future developments of SSIIS the entities required for all functions and processes can be included in such a format.

The data entities for the Structural IMR and the Analysis/Design process are shown in Figure 7.4. This demonstrates how processes can be dependent on other processes for the creation of information. The Structural IMR process is reliant upon the vessel description created in the Analysis/Design process. Failures and other defects must have a recorded position to gain maximum benefit for the integration of information into a process-orientated information system.

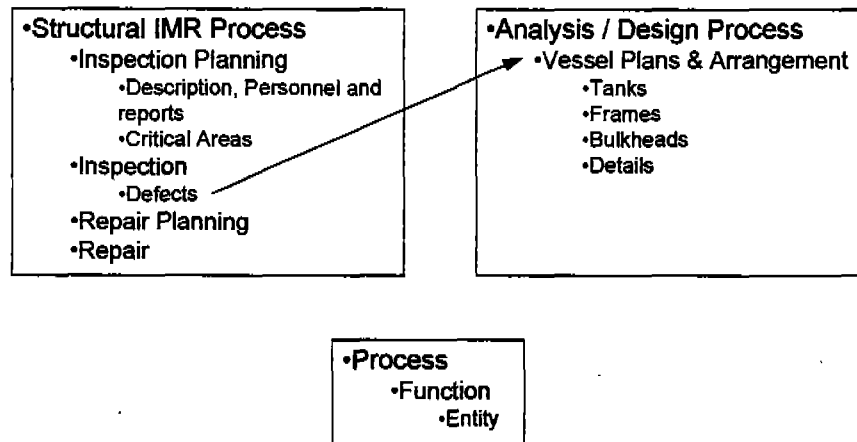


Figure 7.4 : Data Entities for Structural Processes

7.2. Tables

As the prototype is intended to demonstrate the application of an information system, the data requirements maintained in the database have been kept to a minimum. Comprehensive data structures have not been developed and the focus of the prototype has been on the information associated with the Structural IMR process. The data structures for the prototype are given in Appendix A.

The data structures have been developed to demonstrate a working version of a Structural IMR system and thus shortcomings are evident. It is anticipated that future development will detail the system further through feedback and comment from industry groups.

7.3. Forms

Once the SSIIS prototype is loaded, the opening screen as shown in Figure A.1. is presented to the user. At present, there are a selection of four further entry screens available to the user, these are

- ***Vessel Form***: This series of forms to enables the user to enter vessel configurations. The information fields that can be entered from this form and the associated subforms represents the structural configuration of the vessel. This includes details pertaining to tanks, frames and details. See Figures A.2-A.8.

-
- **Inspection Form:** This series of forms allows the user to enter vessel inspection information, including details planned for inspection, and also inspection and repair results. See Figures A.9-A.12.
 - **Companies:** This form allows the user to enter companies that can be used later for entries in the Vessels and Inspection forms. See Figure A.13.
 - **Personnel:** This is to allow the user to enter individuals who may be performing work on the vessel. See Figure A.14.

The **Vessel Form** allows the user to input the vessel arrangement and plans. For new-build ships this information is entered as part of the Analysis/Design Process. However for existing ships a simple format must be available for operators to quickly enter the ship configuration to take advantage of other SSIIS processes and functions.

At present, the SSIIS prototype uses scanned images to represent views and details, a future development could include links to CAD drawings. However the product model concept offers the best long term solution to linking graphical and textual information. The NID-DESC/STEP application protocols for a ship product model is detailed in Section 3.3.

Within the **Vessel Form** the user can input ship information in a number of categories entered in via the following subforms

- **General:** This tabbed form allows the user to enter ship specific information relating to the classification society. In the construction of a fully developed implementation of an information system, this section would be expanded to include a expanded range of ship details. See Figure A.2.
- **GA:** The form shows the vessel general arrangement, this allow the user to obtain an orientation of the vessel with respect to the tank numbers and positions. See Figure A.3.
- **Insp Schd:** This form allow the user to examine the last and next scheduled inspection due for both the classification society and Coast guard. The next owner scheduled inspection can also be entered. See Figure A.4.
- **Tanks:** allows the user to enter tank specific information. At this stage of the SSIIS development, the data requirements are limited to those required to track quality failures. In a full implementation, this would include information to be able to handle stability effects. See Figure A.5.
- **Frames:** The frames table is intended to allow the user to represent the transverse and longitudinal divisions within a ship structure. For this example transverse web frames have been included. See Figure A.6.
- **Bulkheads:** It is intended in the prototype system that the vessel tanks be entered as a collection of bulkheads. See Figure A.7.
- **Details:** The details table allows the user to enter structural details associated with the ship structure. It is intended to provide a level of detail such that an inspection can locate physical defects at a location within the detail. See Figure A.8.

The ***Inspection Form*** allows the user to input inspection and repair information. The entry boxes on these forms uses information entered from the ***Vessel Form***. Within the user can input ship information in a number of categories entered via the following subforms

- **General:** Non-specific information can be entered here relating to a description of the planned inspection, maintenance of repair activities. People associated with the activities and Reports produced as a result of the work. See Figure A.9.
- **CAIP Details:** Critical areas within the ships structure can be identified here. See Figure A.10.
- **Tank Coatings:** Maintenance to tank coatings can be entered within this subform. See Figure A.11.
- **Cracks/Corrosion:** Quality failures identified during an inspection can be entered into the database via this form. See Figure A.12.

7.4. Reports

At present, the outline for three reports has been programmed into the prototype. They are accessed via the Report Selection Form, see Figure A.15. The following reports can be accessed;

- **Vessel:** The vessel configuration can be output, this includes tanks, frames, bulk-heads and details. An example Vessel Report from the SSIIS prototype is given in Appendix B.
- **Inspection:** Inspection information can be output, this includes failure locations
- **CAIP Report:** An example CAIP report can be printed based on the information contained in the information system. This is based on the requirements outline in the SSIIS report.[Schulte-Strathaus, 1995]. An example CAIP Report from the SSIIS prototype is given in Appendix C.

8. FUTURE DEVELOPMENT

The future development of the SSIIS prototype will continue the evolution of engineering solutions for optimizing the maintenance and operation of existing ships. The SSIIS as a research development project should continue to focus on the Structural Inspection, Maintenance and Repair (IMR) Process. Areas of interface with other ship owning processes must be identified to incorporate the information links in a larger commercial development.

Future work on the SSIIS project should focus on the following areas:

- Requirements analysis of both management and the end users of SSIIS. This will identify and prioritize system requirements of all participants (USCG, classification societies and owner/operators) in the structural IMR process.
- Continue development of the data structure used to represent the ship structure for all components of the IMR process. The NIDDESC/STEP application protocols provide a starting point for future development [NIDDESC, 1993]
- Implement an inspection planning system to analyze failure trends and allow the ship inspector to interactively plan inspections to cover critical areas.
- Interface the inspection plan with the collection and storage of inspection results.
- Implement a repair decision support system interfaced to the defects recorded during an inspection. The Repair Management System (RMS) provides a starting point for this development. [Ma, Bea, 1995]
- Demonstrate the practicality of the SSIIS development and enhancements of the structural IMR process module through application to an example tank ship.
- Develop an implementation plan for commercial development once the practicality of the system has been proven.

Reengineering of ship processes, as introduced in this report, is essential to gain maximum advantage from the introduction of information technology. Reengineering the structural IMR process has the following goals:

- Improved structural quality, through the identification, inspection and repair of critical areas.
- Building of tacit knowledge, through the 'storage' and 'retrieval' of inspection and repair techniques.
- Increased accuracy of information exchange, extraction of trends and forecasting of future developments.

The fully developed SSIIS will be capable of being accessed and utilized by owners/operators, builders/repairers, regulators and classification societies. Intense cooperation will be required between these industry sectors to match different objectives. With any future SSIIS development, focus on reducing the barriers to organizational change will foster a reengineered system that can effectively be utilized by the industry.

The following recommendations are intended to be incorporated into the SSIIS structural IMR process description detailed in Chapter 6. The long term development of the SSIIS project would be on a client/server hardware and software system, the specification of such a system will depend on future project requirements.

8.1.1. Requirements Analysis and Benchmarking

The structural IMR process identified in Figure 6.2 must be enumerated and end users of the information system identified. These potential users of the information system must be interviewed to introduce the proposed reengineered process to them in order to obtain comments and identify required features, i.e. system requirements. Management must also be consulted to determine their requirements and project objectives. These requirements must be prioritized to match the project objectives and ensure the efficient development of such a system.

Performing the requirements analysis will result in an easier implementation of a future commercial development. The effort of including the end users will result in a system to which the users feel they have contributed. The resulting 'ownership' of the system by the users will encourage acceptance and contributions for further refinements. The setting up of a pilot program to demonstrate the practicality of SSIIS is important to introduce users to new technology and to gain assent of required organization changes.

A comprehensive benchmarking review of inspection techniques across all inspectors in the shipping industry and then outside industry would be useful to determine 'best practice' techniques that could be incorporated into a SSIIS development.

8.1.2. Data Structure

Overall the data structure used to represent the structural arrangement of the vessel must be improved. The prototype developed during Phase II of the SSIIS project only used scanned images to represent graphical information. The incorporation of the ship product model definitions introduced in Section 3.3.1 [NIDDESC, 1993] was beyond the scope of this project.

Incorporation of a product model definition may not be required until the commercial development of the SSIIS concept given the extensive detail that must be programmed. However for future research projects the existing methodology used in the SSIIS prototype for entry of graphical information and broad textual descriptions of the ship structure must be extended.

8.1.3. Inspection Planning

The inspection planning module can be improved through the inclusion of a failure trend analysis component and a system for planning repairs.

The analysis of failure trends and the location of critical details complements the existing manual system used to identify critical areas. At present critical areas are identified by experience often after the failure of hundreds of structural details. An analysis component would have a dual role, to identify critical areas and to track and identify repair effectiveness.

Enabling SSIIS to plan the route of an inspection survey prior to entering the tank will have significant benefits. This component would consider the methods used to gain access inside

the ship structure and build a knowledge base of how inspectors conduct surveys. This allows the tacit knowledge developed through years of field work to be codified and used by less experienced inspectors to plan their inspections.

8.1.4. Inspection Activities

Work is required to interface the inspection plan (complete with critical areas) and the recording of inspection results. This will ensure critical areas are inspected and results accurately recorded. A discussion of interfacing technology and humans during inspection is detailed in Section 6.4.2. Research work in this area is currently being conducted by the U.S. Coast Guard.

8.1.5. Repair Planning

The repair planning component of SSIIS should incorporate findings from the Repair Management System (RMS) developed for critical details during the Ship Maintenance Project (SMP) [Ma, Bea, 1995]. The use of expert system guidelines can be incorporated into the SSIIS development to give advice to engineers on how best to repair fractures and renew excessively corroded elements and plate.

The RMS provides a basis for a simplified repair analysis of critical details. This repair analysis makes use of the time to the observed cracking to define the long-term cyclic loadings required to produce the observed fracture. The analysis also makes use of stress reduction factors to define the effects of different repair alternatives in reducing (or increasing) cracking (hot spot) stresses.

The system allows a fast estimate of the expected fatigue lives associated with alternative repair strategies. This information combined with cost estimates for each of the repair strategies can then be used to make cost-life trade-off evaluations to define the repair that should be implemented for a particular class of critical ship detail.

8.1.6. Testing and Implementation

The practicality of the SSIIS development can be demonstrated through a pilot program using data from an existing vessel. The entire vessel need not be entered but a representative portion, (such as several tanks) are required. Choosing only a representative segment of the vessel and demonstrating several of the above future developments will ensure a clear set of requirements with which to continue development.

Once the SSIIS prototype is proven, commercial development can commence. A phased testing and implementation program can be designed to ensure industry acceptance of the system. This could be performed by starting with a committed owner/operator who can identify the benefits, is prepared to fund development and serve as the testing ground prior to general industry release.

Benefits of the system can be demonstrated against the baseline measurable objectives determined prior to project implementation. These measurable objectives must be identified by the industry, for example, out of service time and yearly repair costs, see Section 6.2.

9. CONCLUSIONS

This project developed the basic framework for the information system to support the Structural IMR process. The Structural IMR process includes the following functions, Inspection Planning, Inspection Activities, Repair Planning and Repair Activities. These functions share, and build on common data to complete individual activities within the function.

The role of the information system is to ensure that data is transferred between the functions and activities in an efficient manner. Reengineering and information system design principles have been used to generate the interactions and the information flow for the Structural IMR process.

The SSIIS prototype represents the start of an information system to fulfill the requirements of a comprehensive Structural Inspection, Maintenance and Repair System. At present, only the structure and future direction of the system has been detailed. Work is required to further develop the system to fully yield the benefits of an integrated information system.

Further development of the SSIIS prototype would result in improved vessel quality through

- improved inspection planning, through analysis of existing failure trends and the utilization of the information system to customize and detail the individual tank inspections.
- improved recording and reporting of vessel inspections and the central archiving of vessel failure records.
- improved repairs, using a decision support system the information system can be used to determine the best repair for a given failure based on a number of input factors.

The SSIIS prototype is used to demonstrate the application of information technology in the management of ship structures. The emphasis within this project has been on operational aspects associated with the inspection maintenance and repair of ship structural systems and it is noted that scope exists to expand the project to include other processes. There is significant investment in software addressing many of these other processes available to the industry already.

The maritime industry must continue to develop software and systems used to design and operate vessels. A focus on ship processes ensures systems are developed to integrate information across processes. This in turn guarantees decision making is based on accurate and concisely reported information.

10. REFERENCES

- Bea, R.G.; Marine Structural Integrity Programs. Technical Report SSC-365, Ship Structure Committee, 1992.
- Bea, R.G.; Evaluation of alternative Marine Structural Integrity Programs; *Marine Structures* v7 n1 1994 p77-90.
- Moore, W., Bea R.G.; Prevention Through People - Human and Organization Factors in the Quality of Ships, Draft Report to American Bureau of Shipping, New York, N.Y.; Feb. 1995.
- Schulte Strathaus, R., Bea, R.G.; Ship Structural Integrity Information System (SSIIS) Technical Report SSC-380; Ship Structure Committee, 1995.
- U.S. Coast Guard. Navigation and Vessel Inspection Circular 15-91. COMDTINST M16700.4.
- Tanker Advisory Center Inc.; *1994 Guide for the Selection of Tankers*, 1994.
- International Association of Classification Societies (IACS); Enhanced Survey Rules for Existing Vessels, Oct. 1993.
- Tanker Structure Cooperative Forum (TSCF); *Guidance Manual for the Inspection and Condition Assessment of Tanker Structures*. Witherby & Co. Ltd.; 1986 Issued by International Chamber of Shipping Oil Companies International Marine Forum.
- Tanker Structure Cooperative Forum (TSCF); *Inspection, Assessment and Experience of Older Tankers*; Oct. 1990.
- Navy Industry Digital Data Exchange Standards Committee (NIDDESC); *NIDDESC STEP Application Protocol "Ship Structure"*; The NIDDESC Working Group, 1993.
- Purchasing and Maintenance System; Shipowning Stolt Parcel Tankers, 1995.
- Hammer, M. and Champy, J.; *Reengineering the corporation: a manifesto for business revolution.*; HarperCollins Publishers Inc., 1993.
- Manganelli, R.L., Klein, M.M., *The reengineering handbook : a step by step guide to business transformation*; AMACOM, 1994.
- Various; *Beyond the basics of reengineering : a survival tactics for the '90s.*; 1994.
- Davenport, T.H., *Process Innovation : reengineering work though information technology*; Harvard Business School Press, 1993.
- Mylls, R., *Information Engineering: CASE practices and techniques*; 1993.
- Turban, E.; *Decision Support and Expert Systems: Management Support Systems*, 4th ed.; Prentice Hall, 1995
- Holzman, R.S., Advancements in Tankship Internal Structural Inspection Techniques, Report SMP-5-2, 1992
- Ma, K-t., Bea, R.G.; Fatigue Life Estimation for Repaired Ship Critical Structural Details, *Proceedings of the 14th International Offshore Mechanics and Arctic Engineering Conference*; OMAE Paper No. 95-731M, 1995

Appendix A : SSIIS PROTOTYPE FORMS

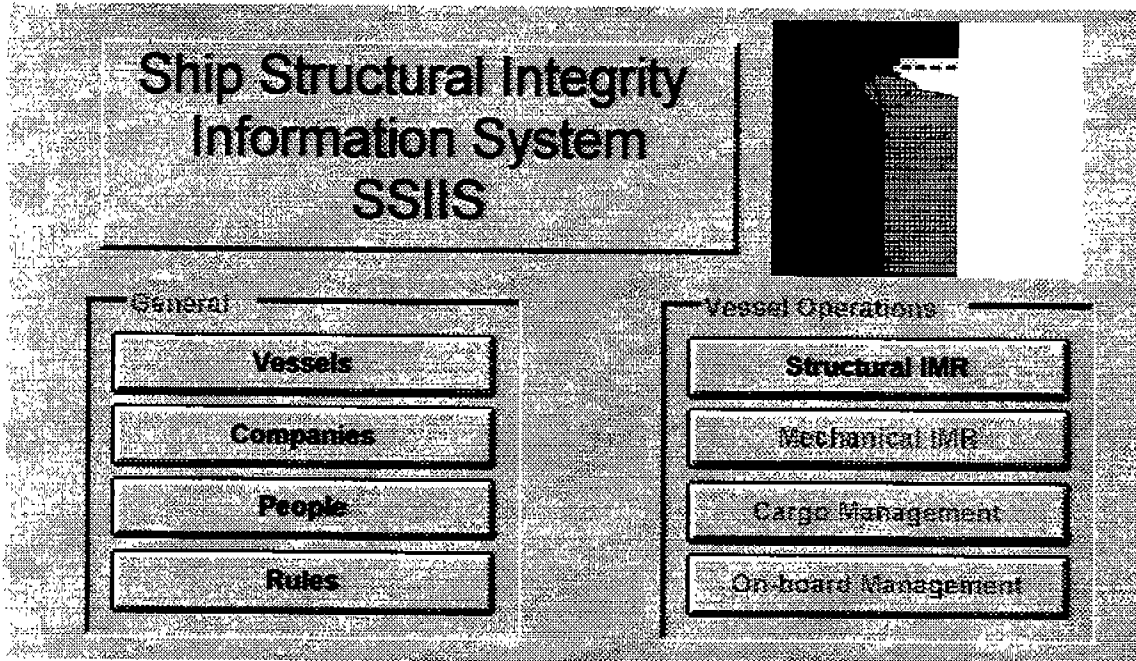





Figure A.1 : Start-up Screen

Form Vessel Search for Vessel:   

Vessel Data

id: Vessel Name: Classification Society:
 Operator: Class:

General GA Insp. Sched Tanks Frames Bulkheads Details

Classification Society: Owner:
 Class:
 Classification Society ID:
 USCG ID:
 Shipyard: Delivery:
 Hull number: DWT:

Figure A.2 : Form Vessels, Subform General

| Field | Format of Field or Relation | Comments |
|-----------------------------|--------------------------------------------|----------|
| Vessel ID | Counter | |
| Vessel Name | Text | |
| Class Relationship | Relation to List of Classes | |
| Owner Relationship | Relation to List of Companies | |
| Operator Relationship | Relation to List of Companies | |
| Classification Relationship | Relation to List of Companies | |
| Class Society id | Number | |
| USCG id | Number | |
| Shipyard Relationship | Relation to List of Companies | |
| Delivery date | Date/Time | |
| Hull number | Number | |
| DWT | Number | |
| GA Drawing | Relation to Database Vessel Drawings/Views | |

Table A.1 : Data Entities for Database Vessels

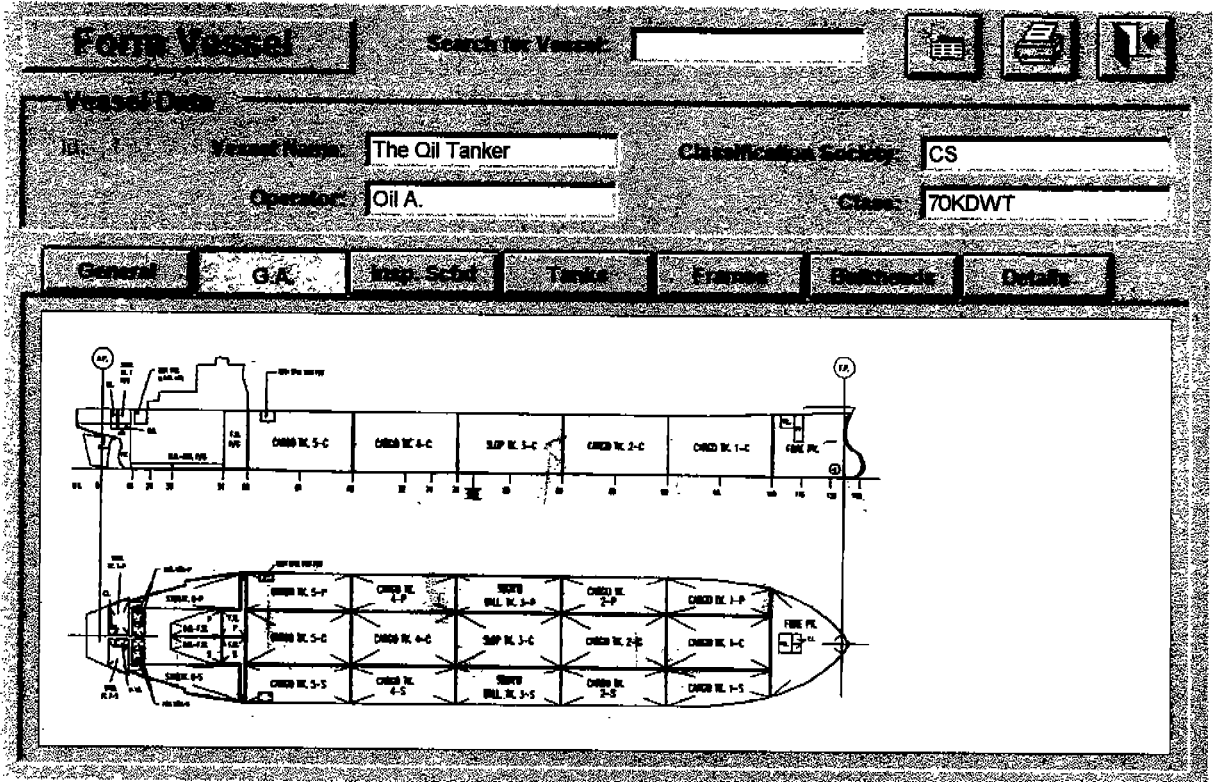


Figure A.3 : Form Vessels, Subform GA

Form Vessel Search for Vessel:

Vessel Data

ID: Vessel Name: Classification Society:
 Operator: Class:

General G.A. **Insp. Schd** Tanks Frames Deckheads Details

| | | Due | Planned | Location |
|-------------------|--------------------|----------------------|----------------------|-----------------------------------------|
| Owners Inspection | Structural | <input type="text"/> | <input type="text"/> | <input type="text" value="Richmond"/> |
| USCG | Cargo Tanks | <input type="text"/> | <input type="text"/> | <input type="text" value="Oakland"/> |
| | Annual | <input type="text"/> | <input type="text"/> | <input type="text" value="Long Beach"/> |
| Class Society | Special Survey | <input type="text"/> | <input type="text"/> | <input type="text" value="Richmond"/> |
| | Hull Survey | <input type="text"/> | <input type="text"/> | <input type="text" value="Long Beach"/> |
| | Annual Hull & Mach | <input type="text"/> | <input type="text"/> | <input type="text" value="Oakland"/> |

Figure A.4 : Form Vessels, Subform Inspection Schedule

| Field | Format of Field or Relation | Comments |
|----------------------------------------|------------------------------|----------|
| Inspection Schedule ID | Counter | |
| Vessel Reference | Relation to Database Vessels | |
| USCG cargo tanks Due | Date/Time | |
| USCG cargo tanks Planned | Date/Time | |
| USCG cargo tanks Planned Location | Relation to List of Ports | |
| USCG Annual Due | Date/Time | |
| USCG Annual Planned | Date/Time | |
| USCG Annual Planned Location | Relation to List of Ports | |
| Class Soc Spec Survey Due | Date/Time | |
| Class Soc Spec Survey Planned | Date/Time | |
| Class Soc Spec Survey Planned Location | Relation to List of Ports | |
| Class Soc Hull Survey Due | Date/Time | |
| Class Soc Hull Survey Planned | Date/Time | |
| Class Soc Hull Survey Planned Location | Relation to List of Ports | |

Table A.2 : Data Entities for Database Vessels Inspection Schedule

Form Vessel Search for Vessel:

Vessel Data

Vessel Name: Classification Society:
 Operator: Class:

General G.A. Insp. Sch. **Tanks** Frames Deckboards Details

| ID | Name | Capacity | Location | Forward frame | Aft frame |
|----|-----------|----------|----------------|---------------|------------|
| | Tank type | | Tank coating | | |
| 27 | 1P | | Port | OT Frame 1 | OT Frame 4 |
| | Cargo | 1 | Inorganic Zinc | | |
| 28 | 1C | | Centre | OT Frame 1 | OT Frame 4 |
| | Cargo | 1 | Inorganic Zinc | | |
| 29 | 1S | | Starboard | OT Frame 1 | OT Frame 4 |
| | Cargo | 1 | Inorganic Zinc | | |
| 30 | 2P | | Port | | |
| | Cargo | 1 | Inorganic Zinc | | |
| 31 | 2C | | Centre | | |
| | Cargo | 1 | Inorganic Zinc | | |
| 32 | 2S | | Starboard | | |
| | Cargo | 1 | Inorganic Zinc | | |

Figure A.5 : Form Vessels, Subform Vessel Tanks

| Field | Format of Field or Relation | Comments |
|---------------------|---------------------------------------|----------|
| Tank ID | Counter | |
| Vessel Reference | Relation to Database Vessels | |
| Tank Name | Text | |
| Tank Location | Text | |
| Capacity | Number | |
| Frame aft reference | Relation to Database Vessel Frames | |
| Frame aft reference | Relation to Database Vessel Frames | |
| Tank type | Text | |
| Tank coating | Text | |

Table A.3 : Data Entities for Database Vessels

Form Vessel Search for Vessel:

Vessel Data

Vessel Name: Classification Society:
 Operator: Class:

General G.A. Insp. Sched. Tanks **Frames** Bulkheads Details

Name:
 #1:
 Tank:

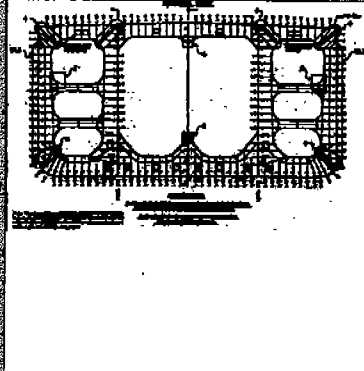


Figure A.6 : Form Vessels, Subform Frames

| Field | Format of Field or Relation | Comments |
|-------------------|-------------------------------------------|----------|
| Frame ID | Counter | |
| Vessel Reference | Relation to Database Vessels | |
| Tank Reference | Relation to Database Vessel Tanks | |
| Frame Name | Text | |
| Drawing Reference | Relation to Database Vessel Drawing/Views | |

Table A.4 : Data Entities for Database Vessel Frames

Form Vessel Search for Vessel:

Vessel Data

id: Vessel Name: Classification Society:
 Operator: Class:

General | G.A. | Insp. Sched. | Tanks | Frames | **Bulkheads** | Details

2

Name:
 Type:
 Tank:
 Frame:

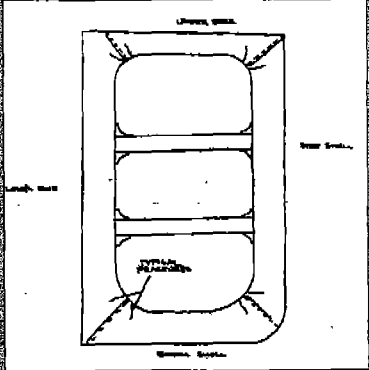


Figure A.7 : Form Vessels, Subform Bulkheads

| Field | Format of Field or Relation | Comments |
|-------------------|--------------------------------------------|----------|
| Bulkhead id | Counter | |
| Vessel reference | Relation to Database Vessels | |
| Bulkhead name | Text | |
| Bulkhead type | Text | |
| Tank reference | Relation to Database Vessel Tanks | |
| Frame reference | Relation to Database Vessel Frames | |
| Drawing Reference | Relation to Database Vessel Drawings/Views | |

Table A.5 : Data Entities for Database Vessel Bulkheads

Form Vessel Search for Vessel:

Vessel Data

Id: Vessel Name: Classification Society:
 Operator: Class:

General G.A. Imp. Schd Tanks Frames Bulkheads Details

| ID | Name | Tank | Bulkhead | Frame | Drawing |
|----|------------------------------------|------|-------------------|-------|---------|
| | Detail 1 | 1P | 1P Forward Tra | sv | |
| | Side Shell Longitudinals | | OT Frame 1 | | |
| | Detail 2 | 1P | 1P Forward Tra | sv | |
| | Bottom Longitudinals | | OT Frame 1 | | |
| | Detail 3 | 1P | 1P Longitudinal | bul | |
| | Longitudinal Bulkhead Lower Strake | | OT Frame 1 | | |
| | 11 | | | | |
| | CAIP Detail 1 | | | | |
| | | | Transverse Web Fr | | |
| | CAIP Detail 2 | | | | |

Figure A.8 : Form Vessels, Subform Details

| Field | Format of Field or Relation | Comments |
|----------------------------------|--------------------------------------------|----------------------------------------------------------|
| Detail ID | Counter | |
| Detail Name | Text | |
| Vessel Reference | Relation to Database Vessels | |
| Tank Reference | Relation to Database Vessel Tanks | |
| Bulkhead Reference | Relation to Database Vessel Bulkheads | |
| Frame Reference | Relation to Database Vessel Frames | |
| Drawing Reference | Relation to Database Vessel Drawings/Views | |
| Structural Detail Type Reference | Relation to List of Detail Types | References type of detail according to ABS Specification |

Table A.6 : Data Entities for Database Vessel Details

Inspection Database Filter for Vessel:

Vessel Data

ID: Vessel: Class: Inspection Planned
 Inspection Completed
 Repairs Planned
 Repairs Completed

Location: Date:

General | **CAIP Details** | **Tank Coatings** | **Cracks/Corrosion**

Inspection Description

| | | | |
|----|-----------------------------|--|--|
| ID | Inspection Description | | |
| | Bottom walked tank | | |
| | Class society 5 year survey | | |

Inspection Personnel

| ID | Inspection Personnel | Company | Position |
|----|----------------------|---------|-----------------------|
| 1 | Brown | Matthew | An Inspection Company |
| 2 | Bloggs | Joe | Oil A. |
| 3 | Smith | John | USCG |
| 4 | Jones | Bill | Oil A. |
| | | | Company representati |

Inspection Reports

| ID | Inspection Report | Doc Num | Title |
|----|-------------------|---------|-------|
| | USCG | | |
| | CS | ABC-555 | |

Figure A.9 : Form Inspections, Subform Inspection Description, Subform Inspection Personnel, Subform Inspection Reports

| Field | Format of Field or Relation | Comments |
|---------------------------|----------------------------------|----------|
| Inspection Description ID | Counter | |
| Inspection Reference | Relation to Database Inspections | |
| Inspection Description | Text | |
| Inspection Personnel ID | Counter | |
| Inspection Personnel | Relation to List of Personnel | |
| Inspection Reference | Relation to Database Inspections | |
| Inspection Report ID | Counter | |
| Inspection Reference | Relation to Database Inspections | |
| Inspection Report Company | Relation to List of Companies | |
| Inspection Report Title | Text | |
| Inspection Report Doc Num | Text | |

Table A.7: Data Entities for Database Inspection Description, Personnel & Reports

Inspection Database Filter for Vessel:

Vessel Data

id: Vessel: Class: Inspection Planned
 Inspection Completed
 Repair Planned
 Repair Completed

Location: date: B&W

General | **CAIP Details** | **Tank Coatings** | **Cracks/Corrosion**

Tank:

Bulkhead **Frame** **Detail**

1P Forward Transverse OT Frame 2 Detail 3

Figure A.10 : Form Inspections, Subform Inspection CAIP Details

| Field | Format of Field or Relation | Comments |
|--------------------|---------------------------------------|----------|
| Inspection CAIP Id | Counter | |
| Vessel Reference | Relation to Database Vessels | |
| Tank Reference | Relation to Database Vessel Tanks | |
| Bulkhead Reference | Relation to Database Vessel Bulkheads | |
| Frame Reference | Relation to Database Vessel Frames | |
| Detail Reference | Relation to Database Vessel Details | |
| Memo | Memo | |

Table A.8 : Data Entities for Database Inspection CAIP Details

Inspection Database Filter for Vessel:

Vessel Data

id: Vessel: Class: Inspection Planned
 Location: Date: IMR Inspection Completed
 Repairs Planned Repairs Completed

General **CAIP Details** **Tank Coatings** **Cracks/Corrosion**

| Id | Tank | Bulkhead | From Frame | To Frame | Memo |
|----|------|-----------------|---------------|------------|------|
| 1P | | 1P Forward Tra | sv OT Frame 2 | OT Frame 4 | |
| 1S | | 1P Aft Transver | e OT Frame 4 | | |
| 6P | | 1P Forward Tra | sv OT Frame 2 | | |
| 7P | | 1P Forward Tra | sv | | |

Figure A.11 : Form Inspections, Subform Inspection IMR Tank

| Field | Format of Field or Relation | Comments |
|----------------------|---------------------------------------|----------|
| Inspection Tank Id | Counter | |
| Inspection Reference | Relation to Database Inspections | |
| Tank Reference | Relation to Database Vessel Tanks | |
| Bulkhead Reference | Relation to Database Vessel Bulkheads | |
| From Frame | Relation to Database Vessel Frames | |
| To Frame | Relation to Database Vessel Frames | |
| Memo | Memo | |

Table A.9 : Data Entities for Database Inspection IMR Tanks

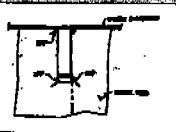
Inspection Database Filter for Vessels:

Vessel Data


id: 1 Vessel: Class: Inspection Planned
 Inspection Completed
 Repairs Planned
 Repairs Completed

location: date: IMR

General **CARP Details** **Tank Coatings** **Cracks/Corrosion**

Method: Tank:
Inspector: Bulkhead:
Planned for Inspection: Frame:
Detail: 

Repair Status:
 No Defect
 Defect Found, Repair IMR Yet Planned
 Defect Found, Repair Scheduled
 Defect Reported and Inspected

Failure Type: 
Cause:
Length/Area: sq ft

Memo:

Figure A.12 : Form Inspection, Subform Inspection IMR Details

| Field | Format of Field or Relation | Comments |
|-----------------------|------------------------------------------|----------|
| Inspection Failure Id | Counter | |
| Inspection Reference | Relation to Database Inspections | |
| Inspection Method | Text | |
| Inspector | Relation to List of Personnel | |
| Tank Reference | Relation to Database Vessel Tanks | |
| Bulkhead Reference | Relation to Database Vessel Bulkheads | |
| Frame Reference | Relation to Database Vessel Frames | |
| Detail Reference | Relation to Database Vessel Details | |
| Failure Type | Text | |
| Length/Area | Number | |
| Cause | Text | |
| Planned Inspection | Yes/No | |
| Repair Status | Text | |
| Repair Reference | Relation to Database Vessel Drawing/View | |
| Memo | Memo | |

Table A.10 : Data Entities for Database Inspection IMR Failures

Companies Search for Company: _____

Company ID: 20

Short Name: Oil A

Full Name: Oil Abroad

Street: 123 Murky Waters

City/State/Zip: Downtown CA 94720

Country: USA

Memo: _____

Company Type:

- Class. Society
- Owner
- Operator
- Shipyard
- Inspection
- USCG

Figure A.13 : Form Companies

| Field | Format of Field or Relation | Comments |
|--------------|-----------------------------|----------------------------------------------------------------------------|
| Company ID | Counter | |
| Full Name | Text | |
| Full Name | Text | |
| Short Name | Text | |
| Street | Text | |
| City | Text | |
| State | Text | |
| Zip | Text | |
| Country | Text | |
| Company Type | Text | Selection of "Class. Society; Owner; Operator; Shipyard; Inspection; USCG" |
| Memo | | |

Table A.11 : Data Entities for List of Companies

Personnel Search for Person:

Personnel ID:

Surname:

First Name:

Company:

Position:

Years Experience:

Memo:

Figure A.14 : Form Personnel

| Field | Format of Field or Relation | Comments |
|-------------------|---------------------------------|----------|
| Personnel ID | Counter | |
| Surname | Text | |
| First Name | Text | |
| Company Reference | Relation to "List of Companies" | |
| Position | Text | |
| Years Experience | Number | |
| Memo | Text | |

Table A.12 : Data Entities for List of Personnel

Vessel Details
IMR Reports
CAIP Report

Vessel For Report

All
 One The Oil Tanker

Vessel Details

General

Tanks

Fragments

Bulkheads


Details


CAIP Detail

IMR Description

All
 Inspection Planned
 Inspection Completed
 Repairs Planned
 Repairs Completed

Inspection:





Cancel

Figure A.15 : Form Report Selection

Appendix B : VESSEL REPORT

Vessel Report

The Oil Tanker

Class: 70KDWT

Owner: Best Ship
Best Ship Company
6543 Dockyard Ave
Riverfront CA 94722
USA

Operator: Oil A.
Oil Abroad
123 Murky Waters
Downtown CA 94720
USA

Classification CS
Society: Class. Society
954 Uptown St.
Ritzburg CA 94721
USA

CS id: 34232

USCG id: 2323

Shipyard: Jolly Ship Building

Delivery: 1/7/77

Hull Number: 232

DWT: 40000

The Oil Tanker

Tanks

| <u>id</u> | <u>Tank Name</u> | <u>Tank Location</u> | <u>Capacity</u> | <u>Aft Frame</u> | <u>Fwd Frame</u> | <u>Tank coating</u> |
|----------------|------------------|---------------------------------|-----------------|------------------|------------------|---------------------|
| Ballast | | | | | | |
| 33 | 3P | Port | 1 | | | Epoxy |
| 35 | 3S | Starboard | 1 | | | Epoxy |
| 45 | 5P | Port | 1 | | | Epoxy |
| 47 | 5S | Starboard | 1 | | | Epoxy |
| | | <u>Ballast Capacity:</u> | 4 | | | |
| Cargo | | | | | | |
| 28 | 1C | Centre | 1 | OT Frame 4 | OT Frame 1 | Inorganic Zinc |
| 27 | 1P | Port | 1 | OT Frame 4 | OT Frame 1 | Inorganic Zinc |
| 29 | 1S | Starboard | 1 | OT Frame 4 | OT Frame 1 | Inorganic Zinc |
| 31 | 2C | Centre | 1 | | | Inorganic Zinc |
| 30 | 2P | Port | 1 | | | Inorganic Zinc |
| 32 | 2S | Starboard | 1 | | | Inorganic Zinc |
| 34 | 3C | Centre | 1 | | | Inorganic Zinc |
| 43 | 4C | Centre | 1 | | | Inorganic Zinc |
| 42 | 4P | Port | 1 | | | Inorganic Zinc |
| 44 | 4S | Starboard | 1 | | | Inorganic Zinc |
| 46 | 5C | Centre | 1 | | | Epoxy |
| | | <u>Cargo Capacity:</u> | 11 | | | |

The Oil Tanker

Frames

| <u>Id</u> | <u>Name</u> | <u>y</u> | <u>Tank</u> | <u>Drawing:</u> |
|-----------|-----------------|----------|-------------|-----------------|
| 32 | Centreline Gird | | 0 | |
| 31 | Swash Bulkhea | | 0 | |
| 30 | Oil Tight Bulkh | | 0 | |
| 29 | Transverse We | | 0 | |
| 19 | OT Frame 1 | | 1 | 1P |
| 20 | OT Frame 2 | | 2 | 1C |
| 21 | OT Frame 3 | | 3 | 1S |
| 22 | OT Frame 4 | | 4 | |
| 23 | OT Frame 5 | | 5 | |
| 24 | OT Frame 6 | | 6 | |
| 25 | OT Frame 7 | | 7 | |
| 26 | OT Frame 8 | | 8 | |
| 27 | OT Frame 9 | | 9 | |
| 28 | OT Frame 10 | | 10 | |

The Oil Tanker

Bulkheads

| <u>Tank Id</u> | <u>Name</u> <u>Type</u> | <u>Frame</u> | <u>Drawing:</u> |
|----------------|------------------------------------------|--------------|-----------------|
| 12 | Horizontal Webs at OT Bulkhea | | |
| 11 | number 11 | | |
| 1P | | | |
| 5 | 1P Aft Transverse Bulkhead Transverse | OT Frame 4 | |
| 4 | 1P Side Shell Side Shell | | |
| 3 | 1P Longitudinal Bulkhead Longitudinal | | |
| 2 | 1P Forward Transverse Transverse | OT Frame 1 | |
| 1C | | | |
| 10 | 10 Transverse | | |
| 9 | 9 Transverse | | |
| 1S | | | |
| 8 | 8 Bottom | | |
| 7 | 7 Longitudinal | | |
| 6 | 6 Transverse | | |

Appendix C : CAIP REPORT

CAIP Report

The Oil Tanker

Class: 70KDWT

Owner: Best Ship
Best Ship Company
6543 Dockyard Ave
Riverfront CA 94722
USA

Operator: Oil A.
Oil Abroad
123 Murky Waters
Downtown CA 94720
USA

Classification CS
Society: Class. Society
954 Uptown St.
Ritzburg CA 94721
USA

CS id: 34232

USCG id: 2323

Shipyard: Jolly Ship Building

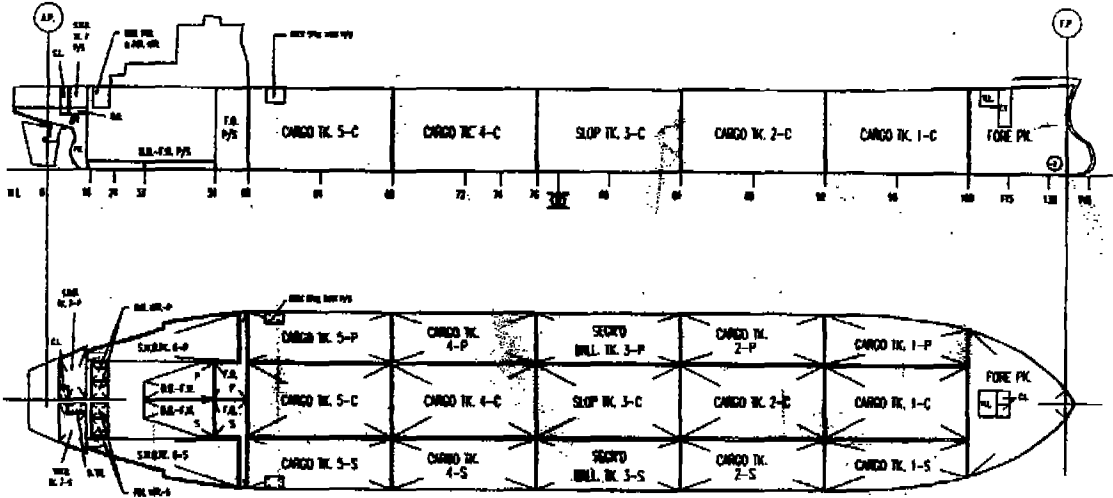
Delivery: 1/7/77

Hull Number: 232

DWT: 40000

The Oil Tanker

General Arrangement



The Oil Tanker

List of Inspections

| | | | |
|----------------------------------------|-----------------|-----------------------------|-----------------------|
| Long Beach | 12/1/95 | Inspection Planned | |
| Description | | | |
| Planned class society 5 year survey | | | |
| Under Way | 12/1/93 | Inspection Completed | |
| Description | | | |
| Crew inspection of hull | | | |
| Personnel | | | |
| Bloggs, Joe | | Oil A. | |
| Report | | | |
| Oil A. | | | ABC-556 |
| Long Beach | 12/17/90 | Repairs Completed | |
| Description | | | |
| Repairs undertaken after inspection | | | |
| Repair coating in ballast tanks | | | |
| Long Beach | 12/16/90 | Inspection Completed | |
| Description | | | |
| Bottom walked tank | | | |
| Class society 5 year survey | | | |
| Personnel | | | |
| Brown, Matthew | | Inspector | An Inspection Company |
| Bloggs, Joe | | | Oil A. |
| Smith, John | | Inspector | USCG |
| Jones, Bill | | Company representative | Oil A. |
| Report | | | |
| USCG | | | |
| CS | | | ABC-555 |
| Richmond | 12/12/85 | Repairs Completed | |
| Description | | | |
| Repaired Leak in longitudinal Bulkhead | | | |

The Oil Tanker

Summary of Failures Across Class

| <u>Class</u> | <u>Vessel</u> | <u>Location</u> | <u>Date</u> | <u>Class 1</u> | <u>Class 2</u> | <u>Class 3</u> | <u>Pitting</u> | <u>Other</u> | <u>Total</u> |
|------------------------|---------------|-----------------|-------------|----------------|----------------|----------------|----------------|--------------|--------------|
| 70KDWT | | | | | | | | | |
| The Oil Carrier | | | | | | | | | |
| | Long Beach | | 12/14/93 | 1 | 1 | | | | 2 |
| | | The Oil Carrier | | 1 | 1 | | | | 2 |
| | | | | 13% | 14% | | | | 11% |
| The Oil Tanker | | | | | | | | | |
| | Richmond | | 12/12/85 | 2 | 1 | | | | 3 |
| | Long Beach | | 12/16/90 | 3 | 3 | 1 | 1 | 2 | 10 |
| | Long Beach | | 12/17/90 | 2 | 2 | | | | 4 |
| | Long Beach | | 12/1/95 | | | | | | 0 |
| | | The Oil Tanker | | 7 | 6 | 1 | 1 | 2 | 17 |
| | | | | 88% | 86% | 100% | 100% | 100% | 89% |
| | | 70KDWT | | 8 | 7 | 1 | 1 | 2 | 19 |

The Oil Tanker

Tanks

| <u>id</u> | <u>Tank Name</u> | <u>Tank Location</u> | <u>Capacity</u> | <u>Aft Frame</u> | <u>Fwd Frame</u> | <u>Tank coating</u> |
|----------------|------------------|---------------------------------|-----------------|------------------|------------------|---------------------|
| Ballast | | | | | | |
| 33 | 3P | Port | 1 | | | Epoxy |
| 35 | 3S | Starboard | 1 | | | Epoxy |
| 45 | 5P | Port | 1 | | | Epoxy |
| 47 | 5S | Starboard | 1 | | | Epoxy |
| | | <u>Ballast Capacity:</u> | 4 | | | |
| Cargo | | | | | | |
| 28 | 1C | Centre | 1 | OT Frame 4 | OT Frame 1 | Inorganic Zinc |
| 27 | 1P | Port | 1 | OT Frame 4 | OT Frame 1 | Inorganic Zinc |
| 29 | 1S | Starboard | 1 | OT Frame 4 | OT Frame 1 | Inorganic Zinc |
| 31 | 2C | Centre | 1 | | | Inorganic Zinc |
| 30 | 2P | Port | 1 | | | Inorganic Zinc |
| 32 | 2S | Starboard | 1 | | | Inorganic Zinc |
| 34 | 3C | Centre | 1 | | | Inorganic Zinc |
| 43 | 4C | Centre | 1 | | | Inorganic Zinc |
| 42 | 4P | Port | 1 | | | Inorganic Zinc |
| 44 | 4S | Starboard | 1 | | | Inorganic Zinc |
| 46 | 5C | Centre | 1 | | | Epoxy |
| | | <u>Cargo Capacity:</u> | 11 | | | |

The Oil Tanker

Tank Coating Repairs

| <u>Tank</u> | <u>Memo</u> | <u>Bulkhead</u> | <u>From Frame</u> | <u>To Frame</u> |
|-------------|-------------|----------------------------|-------------------|-----------------|
| 1P | | | | |
| Long Beach | 12/16/90 | 1P Forward Transverse | | |
| Long Beach | 12/16/90 | 1P Forward Transverse | OT Frame 2 | |
| Long Beach | 12/16/90 | 1P Forward Transverse | OT Frame 2 | OT Frame 4 |
| 1S | | | | |
| Long Beach | 12/16/90 | 1P Aft Transverse Bulkhead | OT Frame 4 | |

The Oil Tanker

Summary of Failures By Tank

| <u>Vessel</u> | <u>Tank</u> | <u>Class 1</u> | <u>Class 2</u> | <u>Class 3</u> | <u>Pitting</u> | <u>Other</u> | <u>Total</u> |
|-----------------------|-----------------------|----------------|----------------|----------------|----------------|--------------|--------------|
| The Oil Tanker | | | | | | | |
| | 1C | | 2 | | | | 1 |
| | 1P | 4 | 2 | 1 | 1 | 1 | 2 |
| | 1S | 2 | 2 | | | | 9 |
| | 2P | 1 | | | | | 4 |
| | The Oil Tanker | 7 | 6 | 1 | 1 | 2 | 17 |

The Oil Tanker

Summary of Failures By Detail Type

| <u>Vessel</u> | <u>Detail Type</u> | <u>Class 1</u> | <u>Class 2</u> | <u>Class 3</u> | <u>Pitting</u> | <u>Other</u> | <u>Total</u> |
|-----------------------|-------------------------|----------------|----------------|----------------|----------------|--------------|--------------|
| The Oil Tanker | | | | | | | |
| | Bottom Longitudinals | 5 | 6 | 1 | 1 | 2 | 15 |
| | Longitudinal Bulkhead | 1 | | | | | 1 |
| | Side Shell Longitudinal | 1 | | | | | 1 |
| | The Oil Tanker | 7 | 6 | 1 | 1 | 2 | 17 |

The Oil Tanker

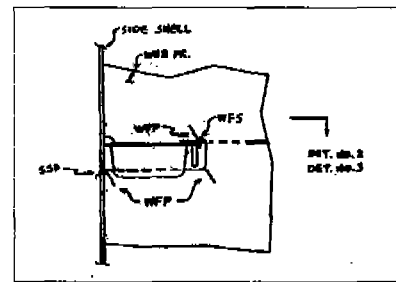
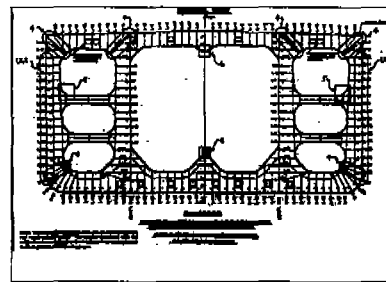
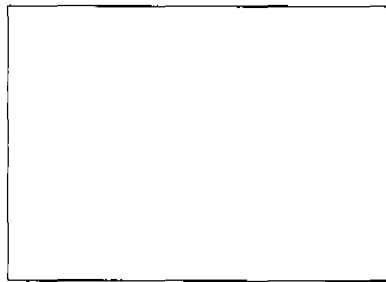
CAIP Details

Tank
Bulkhead
Frame Transverse Web Frame

Tank
Bulkhead

Frame
Transverse Web Frame

Detail
CAIP Detail 1



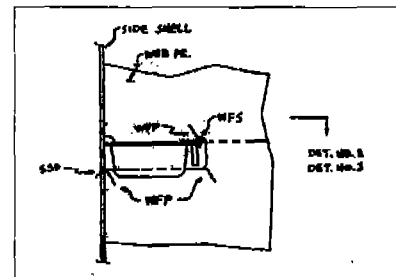
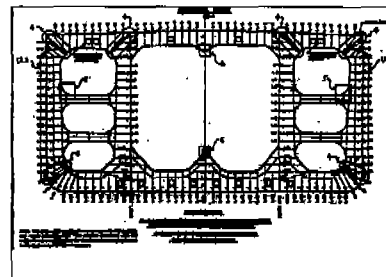
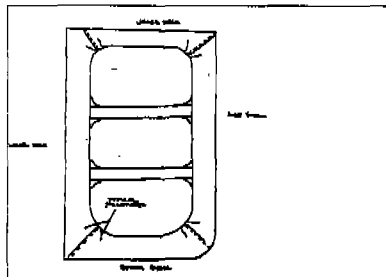
Memo

Bulkhead 1P Forward Transverse
Frame Transverse Web Frame

Tank
Bulkhead
1P Forward Transverse

Frame
Transverse Web Frame

Detail
CAIP Detail 1



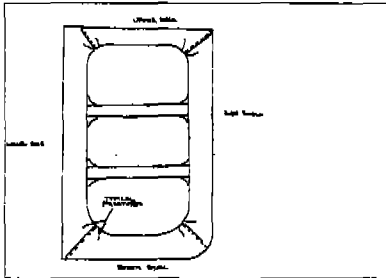
Memo

Tank 1P
Bulkhead 1P Forward Transverse
Frame OT Frame 2

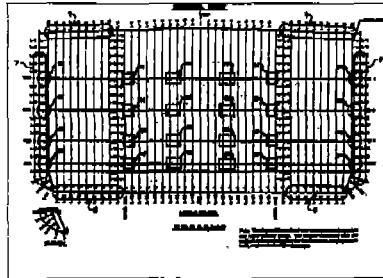
The Oil Tanker

Tank 1P

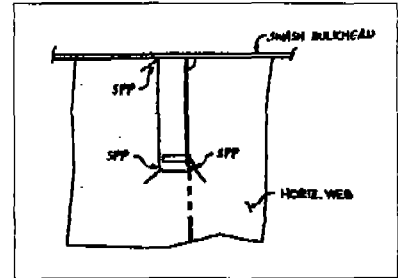
Bulkhead 1P Forward Transverse



Frame OT Frame 2



Detail Detail 3

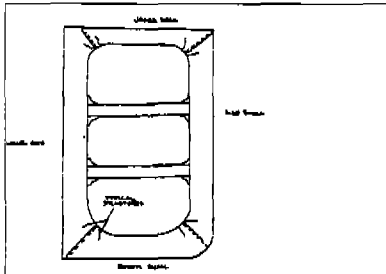


Memo

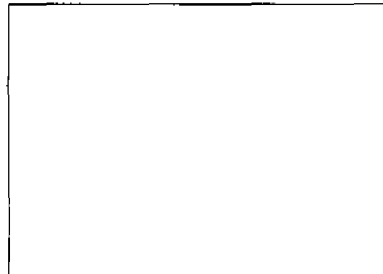
Frame OT Frame 3

Tank 1P

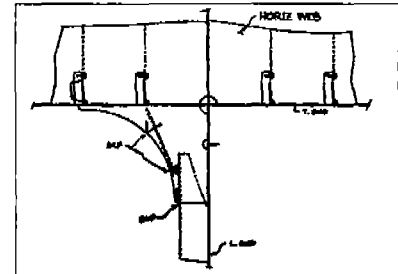
Bulkhead 1P Forward Transverse



Frame OT Frame 3



Detail Detail 2



Memo

Project Technical Committee Members

The following persons were members of the committee that represented the Ship Structure Committee to the Contractor as resident subject matter experts. As such they performed technical review of the initial proposals to select the contractor, advised the contractor in cognizant matters pertaining to the contract of which the agencies were aware, and performed technical review of the work in progress and edited the final report.

- | | |
|---------------------|------------------------------------------------------------------|
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| LCDR Rob Holzman | U.S. Coast Guard |
| Mr. Yung-kuang Chen | American Bureau of Shipping |
| Mr. Kurt Hansen | U.S. Coast Guard |
| Mr. Fred Seibold | Maritime Administration |
| Dr. Robert Sielski | National Academy of Science, Marine Board Liaison |
| CDR Steve Sharpe | U.S. Coast Guard, Executive Director Ship Structure Committee |

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Commission on Engineering and Technical Systems

National Academy of Sciences – National Research Council

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RECENT SHIP STRUCTURE COMMITTEE PUBLICATIONS

Ship Structure Committee Publications – A Special Bibliography This bibliography of SSC reports may be downloaded from the internet at: <http://www.starsoftware.com/uscg/nmc/ssc1/index.htm>

- SSC-387 Guideline for Evaluation of Finite Elements and Results R. I. Basu, K. J. Kirkhope, J. Srinivasan
- SSC-386 Ship's Maintenance Project R. Bea, E. Cramer, R. Schulte–Strauthaus, R. Mayoss, K. Gallion, K. Ma, R. Holzman, L. Demsetz 1995
- SSC-385 Hydrodynamic Impact on Displacement Ship Hulls – An Assessment of the State of the Art J. Daidola, V. Mishkevich 1995
- SSC-384 Post-Yield Strength of Icebreaking Ship Structural Members C. DesRochers, J. Crocker, R. Kumar, D. Brennan, B. Dick, S. Lantos 1995
- SSC-383 Optimum Weld–Metal Strength for High Strength Steel Structures R. Dexter and M. Ferrell 1995
- SSC-382 Reexamination of Design Criteria for Stiffened Plate Panels by D. Ghose and N. Nappi 1995
- SSC-381 Residual Strength of Damaged Marine Structures by C. Wiernicki, D. Ghose, N. Nappi 1995
- SSC-380 Ship Structural Integrity Information System by R. Schulte–Strathaus, B. Bea 1995
- SSC-379 Improved Ship Hull Structural Details Relative to Fatigue by K. Stambaugh, F. Lawrence and S. Dimitriakis 1994
- SSC-378 The Role of Human Error in Design, Construction and Reliability of Marine Structures by R. Bea 1994
- SSC-377 Hull Structural Concepts For Improved Producibility by J. Daidola, J. Parente, and W. Robinson 1994
- SSC-376 Ice Load Impact Study on the NSF R/V Nathaniel B. Palmer by J. St. John and P. Minnick 1995
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