Maritime Industrial IT

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ABSTRACT

In the automation industry a shift in technology related to integration of real time control and monitoring systems and transactional systems for operation management was initiated in the middle of 1990s. This shift of technology denoted as industrial information technology (Industrial IT) has been driven by the process automation industries such as pulp and paper, chemistry, oil and gas, utilities, etc. During the 1990s the use and availability of web technology as mean of communication has increased tremendously. This has enabled e-business and remote monitoring and control capabilities of equipment, systems and ships. The desire to achieve online interaction on all organisation levels from top management to operators involving both transactional business systems and real time control systems has emerged. In parallel to this several research programs related to ship operations and management have been carried out by the Norwegian maritime cluster. It is believed that the main results of these research efforts motivates further work on the development of maritime industrial IT solutions to the benefit of ship operators and vendors. This paper will give an overview of this field of research and development taking place both at research institutes and the industry.

INTRODUCTION

One of the main focus areas in the automation industry has been on connectivity ensuring physical integration of the various control systems. Today several vendors are in position to offer integrated automation systems. A few vendors are also in position to integrate the automation system to the electrical power generation and distribution systems and various process packages. Normally the integrated automation systems are proprietary. However, some attempts to establish open integration standards have been tried and are still subject to development. Communications with external devices, equipment and systems on control and operational management levels are provided by dedicated hard wiring, field buses and/or so-called gateways.

Systems for operational management such as condition monitoring and diagnostics systems, supply chain management systems, enterprise management systems, etc. have increased the possibility to improve operational performance, productivity and life cycle optimization of the assets related to operation of the installations.

Lately, the automation vendors, mainly in land-based industry sectors, have started the next step to physically and functionally integrate the real time control systems with the operational management systems, see [1]. This has been denoted as industrial IT. The introduction of industrial IT into marine applications has yet only started, and is still an area of research and development. For vendors and ship operators it is challenge to take out the potential this shift of technology gives.

This paper will address research efforts related to the application of industrial IT in the maritime industry. Physical (connectivity) and functional integration of control systems and operational management systems and technical condition of assets, systems and ships will in particular be addressed.

INTEGRATION ASPECTS

Maritime industrial IT solutions for the various marine
market segments will be dependent on type of trade and charter, vessel complexity, safety and availability requirements, size of fleet, etc. Concerning vessel automation we will in this paper focus on ships and vessels characterized as advanced and specialized with high number of input/outputs (I/O) and rather complicated operational functions. This is denoted as the high-end market; see also Fig. 13 later in the text. Examples are ships and rigs for oil and gas exploration and exploitation, passenger and cruise vessels, and so on. Typical applications in the offshore market are service vessels, drilling rigs and ships, shuttle tankers, cable and pipe layers, floating production off-loading and storage units (FPSOs), crane and heavy lift vessels, geological survey vessels and multi-purpose vessels. In Fig. 1 an illustration of an integrated automation and power plant installed on a drilling rig is shown.

System Overview

An offshore vessel as illustrated in Fig. 1 may comprise the following sub-systems:

- Power plant.
- Propulsion and thruster system.
- Equipment packages and systems for e.g. drilling, offloading, crane operations, oil and gas production.
- Automation system

We will in this paper address aspects related to the information flow between the real time systems ensuring on-line control and the management systems optimizing the operations and the business processes. This includes fleet allocation related to transport logistics, supply chain management, monitoring and diagnostics of technical condition of equipment and systems.

Power Plant

The power generation and distribution systems are divided into the following main parts:

- Power plant with prime mover and generators. Prime movers are either diesel engines or gas turbines. In the future fuel cells may also be used for certain vessel applications. Combined power plants consisting of hybrid solutions are also installed.
- Power distribution system with main switchboards, usually split in two, three or four sections.
• Voltage conditioners or filters for reducing harmonic interference.
• Transformers for feeding of alternate voltage levels.
• Low voltage switchboards and motor control centers.
• Rotating converters for frequency conversion and clean power supply.
• Uninterruptable power supply of sensitive equipment and automation systems.

As a part of enabling industrial IT solutions some vendors have installed condition monitoring and control functions locally on the power equipment and field devices as indicated in Fig. 2 with the possibility for remote monitoring and diagnostics.

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Figure 2  Automation plant.

Propulsion and Thruster System

Propulsion and thruster system involves all components and systems necessary to supply a vessel with thrust for dynamic positioning, maneuvering and transit. This includes typically of prime movers, generators, transmissions and thrusters. A ship can be equipped with several types of thrusters. Conventional ships typically have a main propulsion unit located aft. Another common type is the tunnel thruster which is a propeller inside a tunnel that goes through the hull and produces a fixed-direction transverse force. A third type is the azimuth (rotatable) thruster, which can produce thrust in any direction. While the main and the tunnel thrusters have fixed force directions, the direction of the azimuth thruster can be changed, either manually by the operator or automatically by the positioning control system. Rudders in combination with main propellers can also be used actively in the positioning system to produce transverse force acting on the stern.

In dynamic positioning systems the main objective is to control the thruster's force. However, since this resulting force cannot be measured directly, it is common to control the thruster revolution speed (RPM control), moment and power or the pitching of the propeller blades (pitch control). The servo mechanisms for the propulsion devices must be designed to give accurate and fast response. This is referred to as low-level thrust control.

Automation System

The merging of software and hardware platforms in automation systems has enabled totally integrated automation system comprising:

• Dynamic positioning (DP) systems.
• Autosailing system (including autopilot).
• Power management system for handling of generators, black-out prevention, power limitation, load sharing and load shedding. For advanced vessels more sophisticated energy management systems are used for intelligent power planning and allocation.
• Vessel automation and HVAC control systems.
• Cargo and ballast control.
• Process automation system.
• Emergency shutdown and fire and gas detection systems.
• Off-loading control system.
• Sensor and position reference systems.

In many installations redundant systems are available, and the number and types of measurements required are specified by certain class rules.

Physical integration based on standardized communication protocols ensure connectivity of devices and integration of controllers and operator stations into three network levels (Fig. 2): real time field bus network communication on low level between devices and controllers, real time control network connecting controllers and operator stations, and office plant network to various office systems and information management systems. The last level opens up for satellite communication to land offices at ship operators or vendors, see also Fig. 6.

INDUSTRIAL IT

Industrial IT is supposed to increase the integration of vessel plant data with the business management systems ensuring optimized asset management and operation of each vessel in particular and the whole fleet.
on corporate level, see Fig. 3. As cost on the vessel-to-land satellite communication is reduced (Fig. 4) and the maritime information technology architecture is improved this kind of information flow is expected to be working seamlessly in real time, as opposed today, where a limited amount of data is transferred at discrete events.

Figure 3 Industrial IT architectures.

Up to now integrated automation systems have been proprietary with a limited number of vendors. However, in the automation industry it is a trend towards openness in communication protocols and network. How this will influence on the technology solutions and responsibilities for multi-vendor integration systems is still a subject for discussion.

Figure 4 Fleet allocation and operations managed on cooperate level.

Over a decade several major research programs (Fig. 5) on ship management and information technology have been run as joint industry projects involving the Norwegian Ship Owners Association, MARINTEK, NTNU, Ship operators and vendors. In the following the three latest research programs will briefly be described.

Figure 5 Roadmap of recently research programs related to Maritime industrial IT.

SIKT
Shipping and maritime industry were in the past dependent on personnel with practical experience from the sea. In the last years shipping has become more dependent on personnel with academic education and scientific research and development. One example on this the emerging number of diesel electrical propulsion systems on the behalf of conventional mechanical driven propellers. Shipping is more and more becoming a knowledge-based industry, and competence will in the future be the main competitive advantage for this industry as well as others.

Through the R&D programme Maritime IT Operation running from 1994-1998, a fully integrated automation and navigation system was developed and tested. A computer-based system was established for more efficient onboard data acquisition, and for more efficient information flow between ship and owner office and further to external parties like suppliers and classification societies, Fig. 6. Such systems make extensive use of decision support tools for technical and commercial operation possible, as well as improved planning and monitoring of cargo operation and voyages. The future challenges will be to exploit the technology to increase the added value and business opportunities to the ship owners (increase the efficiency in management and operation, better the safety and have a more environment friendly management, and to improve the working environment). There are also challenges to make the commercial available products and systems robust and reliable.

SIKT [5] had the following principal objective:

“To improve the competitiveness of the Norwegian maritime sector by developing new technology and new forms of organisation, focusing on shipping companies’ commercial and technical operations”.

The following approach was employed to fulfil the objectives:

- From a shipping company point of view the program was about the ability to redefine business needs, formulate relevant technology requirements and deploy the technology in support of new and more efficient work processes.
- From a shipping point of view SIKT was also about future access to high-quality human resources, measured in terms of competence and capacity. In this respect, the approach was to provide a limited number of shipping companies and training institutions with research and development (R&D) that would enable them to evaluate and implement alternative schemes for the selection, evaluation, education and training of seafarers.
- From a software and system manufacturer point of view the programme was about the ability to understand the needs of shipping companies and to provide relevant products and solutions. The SIKT approach was to support a large number of product and software development projects, with priority given to projects that could document a high degree of end-user needs and involvement.

**Program Results**

The topic “The shipping company of tomorrow” resulted in a long series of fully industrialised products, some of which had originally been developed in the course of earlier programs, while the SIKT program implemented the results of the program in the working processes of participating shipping companies.

- Höegh Fleet Services (HFS) has implemented an integrated information and communication technology (ICT) structure onboard ship and ashore; this includes “Fleetmaster” and “Electronic Logbook” from Kongsberg Maritime Ship Systems (KMSS), which are currently being evaluated by the Norwegian Maritime Directorate and the IMO, as well as a system for centrally controlled vessel maintenance developed by HFS in collaboration with Xantic (Spectec) Knowledge gained from the pilot project “Höegh Monal / Höegh Morus” formed the basis for further development of a concept for centralised maintenance planning system, which has been implemented on the entire fleet. Experience from the

**Objectives and Program Execution**
test period and new industrialised ICT systems provided a platform for the integrated approach which is being implemented in the organisation.

- **Odfjell** is implementing an integrated ICT structure which is based on the development of the maintenance planning function from “STAR Information Systems” for technical condition management for vessels, and which includes an Internet-based purchasing system for maintenance spares. Experience from a test phase formed the basis for implementation of the integrated work process and development of decision-support functions for improvement of ship management, gained through a streamlined ICT solution.

- **Barber International** has launched the BASS (Barber Software Solution) Easyinfo concept, an integrated management system for document handling and quality systems. The system was based on a comprehensive analysis and structuring of the information process and the requirements of the decision makers in the organisation.

- **DNV’s Nauticus concept and software packages** have been integrated with shipping company applications by DNV and Barber Ship Management, to use information models and analytical tools to exchange data between databases, e.g. in a class society and a shipping company. The project has formed the basis of international standardisation work in EMSA (European Maritime STEP Association), and in ISO/IEC for the standardisation of the integration of Automation and Communication systems.

- **VTM Guide and VTM Administrative Products**, which deal with vessel-to-port reporting and on-board administrative functions, have been delivered to several shipping companies.

- **Active Operator Guidance (AOG)** is an integration of sensor systems and mathematical algorithms for calculating hull strength, intended to protect vessels and their cargoes from damage caused by heavy weather. The concept, to which software and consulting services have been supplied by DNV and MARINTEK, is currently being sold by MIROS.

- **Emergency Management** is a total concept that has been integrated from a series of other systems and applications and which is being industrialised by KMSS (formerly Autronica).

- **In ECDIS** (electronic charts), the development of Automatic Identification Systems (AIS) and supporting services has involved many SIKT partners including KMSS, the Norwegian Hydrographic Office, the Norwegian Meteorological Institute and Seatex; this has enormous worldwide market potential.

### SEATRALOG

Logistics as a competitive factor has become increasingly important in most branches of industry. In Fig. 7 is an example of a door-to-door (D2D) logistics chain shown. Efforts to develop new, more efficient logistic solutions are making new demands of participants at both European and global level. The competitiveness of sea-based solutions is often determined by the degree to which these improve logistic efficiency with regard to costs, service, capital inputs and environmental loads in an integrated perspective.

### Objectives

The objectives of the SEATRALOG program [4] were to offer participating shipping companies and manufacturing industry a competitive advantage through the development of better, more efficient, environmentally friendly logistic solutions, and to help to reduce environmental loads due to the transport industry in Europe by transferring transport from land to maritime routes and inland waterways.

The target groups of the program were:

- Shipping companies (coastal and deep-sea shipping companies).
- Cargo owners.
- Maritime supply industry.

### Program Results

Figure 8 shows the various project areas and projects performed in the period from 1999 to 2002. The three areas of interest were:

- Organizational and competence challenges.
- Innovative logistics.
- The transport technology of tomorrow.

### Organizational and Competence Challenges

The question raised: For the Stakeholders in the future Transport Supply Chains, how will this develop and be organized to meet the customer needs?

To address this issue we will mention experience from two of the projects that were carried out:

- ENISYS I og II – Unit cargo transport chains.
- Wallenius Wilhelmsen Lines – Global Logistics Management Concept (WWL-GLM).
ENISYS looked at the possibility for establishing a cooperation between several industrial players for joint logistics solutions for liners operation. The project involved many industry vendors and ship operators. The production sites and consumers were located at the West coast of Norway and Europe. Important motivation for the industry vendors was to reduce transport cost and lead time. The project gave in increased knowledge about organizational challenges and commercial drivers and obstacles in launching of new logistic solutions involving many partners. However, it was concluded that having so many partners involved a step-to-step approach in introducing new logistics concepts was a better approach instead of a comprehensive change as this project suggested.

The WWL-GLM project focused on structural actions needed to extend the logistics service provided by ship operators from *harbour-to-harbour* to total logistics responsibility *door-to-door* (D2D) services. The project covered all phases from concept development to testing by pilot projects. The motivation for WWL was to strengthen its market position and earnings by offering *value added services*. The experience from the project has shown that this was a successful extension of scope of supply, and the WWL-GLM project has become a benchmark for similar activities carried out by others.

Innovative Logistics Services

In addition to the two projects mentioned above a multi user logistics concept for sea transport on rivers and lakes inside Europe have been carried out. This project was named COMBILOG and focused on ro-ro transport. Here, environmental aspects in addition to cost effectiveness were highlighted as important success criteria to strengthen the competitive situation compared to alternative transport solutions, e.g. car transport.

A new tool named TurboRouter for logistics planning, decision support and fleet allocation was developed. Optimisation methods for optimal utilization of a fleet subject to various operational conditions and restrictions were developed in a library. TurboRouter has become a success and is installed at several ship operators. New versions and upgrades of TurboRouter are offered to the market.

Transport Technology of Tomorrow

Three areas were addressed partly in the SEATRALOG program and partly by related activities in Norway:
- Means of future transport carriers and systems for standard cargo units.
- Effective port terminals as a node in the logistics chain at the premises of the users.
- Tailor made ships.

In the SEATRALOG project the COMBILOG concept has shown commercial interests.

MARIKST

MARIKST [3] is an on-going research and development project funded by the Norwegian Ship Operator Association to strengthen the cooperation between Norwegian ship owners in the area of Information and Communication Technology (ICT). The main objective is through innovative use of ICT enable the Norwegian maritime cluster to strengthen their market position. The MARIKST structure is based on the traditional segregation in shipping, where one organisation deals with Ship Management, or technical operations, and another with the commercial aspect of the shipping, called Operation. The third element is where shipping companies are becoming more involved in the supply chains of the cargo owner. To cover the broad spectre of activities it is decided to build up MARIKST as a cluster of projects with a common management overhead, or program management. The three themes (Fig. 10) selected are:
- Ship Management.
- Maritime Logistics.
- MARINET (ICT infrastructure and framework).

Ship Management

The Ship Management Research Program is a selection of R&D projects aiming to improve various Ship Management related businesses areas for members of the Norwegian Ship Owners Association in cooperation with MARINTEK. Various methods and tools are already developed and utilized in other industries. These will also be tested for Ship Management.

Hence there are two important main elements that is recommended to be in focus when developing Ship Management:
- The ability to develop and improve business processes [strategy]
- The ability to utilize best practices from other industries such as work processes, ICT usage, methods and tools, and also to develop and utilize methods specific for Ship Management [organization, work processes, applications]
Sub-projects

The following sub-projects are running:

- **Performance Monitoring and ICT.** Transforming strategy into Key Performance Indicators and ensuring continuous improvements
- **Work Process Modeling and ICT.** Map current and future Work Processes and identify candidates for improvements related to ICT
- **Reliability Centered Maintenance and Monitoring of Technical Condition.**

![Figure 7 Logistics chain – door to door (D2D).](image)

![Figure 8 Main projects run in the SEATRALOG Program.](image)
Improvement of ship maintenance management is one of the operational tasks focused in particular in several studies in Norway during the last 10-15 years. Maintenance is probably the single most important factor in the upkeep of a modern society, but there are few areas where maintenance plays such a dominant role as in shipping. The maintenance cost is also a dominant part of the daily operational costs (less capital, fuel and harbor costs), approximately 50% of the daily operational costs when the manning cost related to maintenance are included. Maintenance contributes also to minimizing equipment downtime and in providing reliable ship and equipment that is safe for personnel and environment.

Here, more effective maintenance systems and management, based on available ICT and information about the technical condition of structures and equipment, is the focus point.

Condition monitoring and RCM (Reliability Centered Maintenance) are well known concepts in many industries. These concepts have now also been incorporated in ship maintenance management systems [2]. Today, ships in many trades have only very short loading and discharging periods in port. This means that maintenance that only can be performed in port including flag state and class surveys have to be carried out during these short periods to avoid downtime. To improve such a harmonization, analysis and planning methods have to be available to monitor the status of the vessel, to schedule surveys and to predict the future state of the ship based on frequent reporting and continues monitoring of technical condition for structures and equipment (Fig. 9). This concept can further be developed into a “continuous” risk analysis based on this technical condition information, and adapted to highlight risk equipment related to the different operational mode of the ship, i.e. a way to enhance safety measures.

For some years research to develop technical condition parameters for structures and equipment as a mean to obtain a proactive maintenance strategy, has been conducted within the oil and gas industry in Norway [6]. As part of the MARSIKT project, three students conducting their Master thesis in 2002 adapted this concept to ships with encouraging result. Hopefully, the...
activities can continue with the aim to establish a library of methodology and standard procedure for continues condition assessment of machinery systems and equipment onboard ships, using results from both research onboard ships and from Norwegian oil and gas offshore plants.

Maritime Logistics & ICT

The maritime logistics and ICT project is aiming to improve the knowledge and understanding of ICT systems usage in logistics processes. The main objective is to improve business through better selection and composition of ICT systems.

Figure 11  A step-by-step approach for logistics processes.

The projects step-by-step approach (Fig. 11) and main activities are as following:

- **Maritime processes and ICT**: The establishment of a process - functionality matrix will form as a basis for understanding the link between logistic processes and ICT functionality that is needed for optimal performance and efficiency. The functionality will also be used in a logistics software system survey to get an overview of the best systems available.

- **System integration and configuration**: There will be established an overview of standards for information exchange between ICT systems. Both present and future standards will be in focus.

- **Pilot studies**: In 2001 the pilot studies looked at work processes and ICT functionality in maritime logistic processes. The 2003 focus will be on how to implement and use new and better functionality.

- **Improved business and ICT project model**: The goal for the project is that all project participants will increase their knowledge and understanding on how ICT systems and "state-of-the-art" functionality can help improving the way their logistics processes are being carried out.

MARINET - Maritime Infrastructure and Solutions Framework

This project (Fig. 12) aims to leverage on the power of the Norwegian Maritime Cluster, to attract enough attention and dedication from owners, agent and ICT vendors, to set the agenda for efficient and secure utilisation of ICT in shipping to gain competitive business advantage.

Figure 12  Maritime information network.

No single player within the maritime industry is big enough to set such a standard, hence the success of the project relies on active participation from ship owners/ship management, system vendors (hardware, software, telecom, infrastructure in general), and application vendors (PMS or similar).

The conclusion so far from the MariNet pre-project workshops is that Internet is coming onboard the ships, and it will change the world from being application based to become a world supported by Internet Services. The availability and cost of Satellite Communication drive the timing of the rollout. The move to an Internet based world will influence and may even dramatically change the way ships are operated in the future by offering better decision support. The business opportunities opening up in an emerging world of Internet services are only limited to our ability to rethink our business models. This emphasise the importance of a strong Maritime Cluster able to set the agenda for a Maritime industry supporting business processes with Internet services both on shore and on board ships.

PROSPECTS FOR THE NEXT 10 YEARS

The maritime market may be characterized into low-end and high-end market segments dependent on complexity in automation and logistics and ship management, see Fig. 13. The automation complexity is defined in terms of number of input and outputs, advanced
functionality, safety requirements, etc. Similar to logistics and ship management complexity are characterized by supply chain management, size of fleet, regularity requirements, customer relations and trade, cargo handling, extension to land-based transport service, etc. Within logistics and ship transport it is a trend that traditionally low-end players expand their business to total integrated logistics chain (door-to-door services). At the same it is seen that the automation degree and the introduction of on-board software systems increase. Another example is that electrical driven thrusters, propulsion, pumps, etc. replace mechanical and hydraulic systems. This trend will put new challenges on the ship operators to adapt to the electrical driven and software controlled ship. In addition increased focus on environmental aspects will force new demands and solutions.

**Figure 13** Low-end and high-end market segments within automation and ship management.

**Conclusions**

This paper has summarized main research and development activities on ship operation management and maritime industrial IT taken place in the Norwegian maritime cluster over the last decade. It is observed that the automation vendors are approaching transactional and operational management systems from real time control and monitoring systems. New hardware and software technology including applications is enabling a closer integration between the automation industry and the operational management business. This trend is in general driven by the land-based process industries and will open up new solutions in the maritime business as well.

In the maritime market important drivers for this development are international requirement on environment and safety issues addressed by e.g. the European Commission and consolidations among customer.

**REFERENCES**


