Project Description Case 6
Object Oriented Simulation Technology
COT/6-1-V1.0

Centre for Object Technology
The Centre for Object Technology (COT) is a three year project concerned with research, application and implementation of object technology in Danish companies. The project is financially supported by The Danish National Centre for IT-Research (CIT) and the Danish Ministry of Industry.

Participants are:
- Maersk Line, Maersk Training Centre, Bang & Olufsen, WM-data, Rambøll, Danfoss, Systematic Software Engineering, Odense Steel Shipyard, A.P. Møller, University of Aarhus, Odense University, University of Copenhagen, Danish Technological Institute and Danish Maritime Institute

The purpose of this document is to define objectives and the expected outcome of the project “Object Oriented Simulation Technology” (OOST) under the Centre for Object Technology. The document describes the expected outcome and significant expected milestones of the project and each of the participants involvement, objectives and interests in the project.

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1. Background

The Centre of Object Technology (COT) is a 3 year project concerned with research, application and implementation of object technology in Danish companies. Under the COT umbrella six individual projects are established. This project description concerns case no. 6: *Object Oriented Simulation Technology* (OOST).

The participants in OOST are:

- Odense Steel Shipyard (OSS)
- Maersk Training Centre (MTC)
- A.P. Møller (APM)
- Danish Maritime Institute (DMI)
- Danish Technological Institute (DTI)
- Odense University, The Maersk Mc-Kinney Moller Institute for Production Technology (MIP)

In this project three different cases are defined:

- Decision support system for erection sequence analysis (DSS)
- Training simulator for gantry crane operations (GCS)
- Training simulator for anchor handling (AHS)

The parties involved in the sub-cases of the three simulators are as follows:

<table>
<thead>
<tr>
<th>PARTNER</th>
<th>SIMULATOR</th>
<th>AHS</th>
<th>DSS</th>
<th>GCS</th>
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<td>MIP</td>
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2. Case Coherence

What looks as three individual problems can be solved, at least to some extent, through a common approach. APM, MTC, and OSS all have the need for some kind of a simulator, and see their particular simulator as unique. However, from the viewpoint of DMI, DTI and MIP an important aspect of the project is to develop the three simulators in an Object-Oriented (O-O) frame of reference focusing on reuse and generic features. Lessons to be learnt from the projects are among others how to identify the kind of problems where generic solutions can be applied.
The three main focus areas of COT are:

- O-O software architectures
- Computer based tools for teamwork within the O-O development project.
- Introduction of O-O methods into the development organisation

These main focus areas are described throughout this project description. The main focus areas will all be addressed in the project.

The COT project will also be used to investigate to which extend object oriented technology can contribute to improved simulator architectures. The focus is on reusable simulator components, development of application frameworks, development of design patterns for use in the construction process of sub-simulators, etc.

Due to the high complexity of modern so-called full-mission simulators, a review will be made of which tools and utilities are needed to enhance quality and productivity in object oriented simulator development. It is intended to enhance the use of object oriented technology beyond the specific cases, namely for development of simulators in general, for planning of simulator courses, and in connection with the data models used in the simulation.

The areas of development common to two or more sub-cases, and therefore defined as areas of focus, in the OOST cases are:

- Simulator architectures
- Visual systems
- Virtual instruments
- Mathematical/physical problem solving frameworks

In the OOST these four common topics will be treated outside of the sub-cases and special focus with relation to the COT focus areas will be put on appropriate common topics.

3. Industrial Viewpoint

In the following, each of the industrial partners describes their objective, involvement and interest in the project.

3.1 OSS

As part of shipbuilding, the design of a unique ship that offers the optimal benefit from a functional viewpoint to the ship owner is an important part. However, in order to offer the ship at an attractive price, the design needs to support an effective and economical production. Besides a producable design, co-ordination between design, production engineering, and production is crucial. In this context production engineering is in focus.

At Odense Steel Shipyard Ltd (OSS) production engineering is concentrated around the assembly network. This network contains information on how and in what chunks of steel the ship should be assembled to match the facilities of the shipyard. The network...
describes the ship from the lowest level of parts (atomic) such as plates and profiles up to major assemblies such as grandblock weighing up to 1,000 tons (up to 20,000 elements). Grandblocks are the assembly parts that are erected in the dry dock at the shipyard to build the actual ship.

The assembly network is conceived as part of the building strategy at the shipyard and it is the place where major parts of the production related information such as paint, lift, and weld specifications, is attached. A simplified and incomplete assembly network is illustrated below:

![Assembly Network Diagram]

**Figure 1 Example of an assembly network**

The actual specification of the assembly network is an activity that is initiated very early in the design process with the determination of the top-levels in the assembly network tree (grandblocks and blocks). At this stage in the design process very limited information, such as main dimensions, general arrangement, etc. is available. The process of extending the network is hereafter continued. The network is extended throughout the design process as more and more information about the design becomes available. At the time of production start, a final assembly network is issued, however, it is modified several times in the case of a larger series of ships.

As mentioned above, grandblocks are the major steel and outfitting assemblies that eventually are erected in the dry dock to form the ship. All grandblocks are basically erected in the dry dock with the 1000 tons gantry crane. This makes the crane the key facility in the dock area. A sketch of the dock and gantry crane is illustrated below.
The scheduling of the gantry crane is primarily documented in the erection sequence diagram (also referred to as erection sequence schedule) for grandblocks, see figure below. This diagram contains information on when a particular grandblock should be erected in the dry dock (represented by boxes in the figures) and the relations and constraints between grandblocks to be erected (illustrated by the lines between each box). Constraints could for instance be the fact that there has to be three days between the erection of two blocks to secure time for installation of outfitting items.

Besides the actual erection of grandblocks in dry dock, a variety of activities take place in the dock area. Among other things, block assembling, block turning in a sandbox, block outfitting, block moving, lifting gear shift on the crane, etc. Together with the dry dock activities, all these activities have one common denominator; they are all carried out in the dry dock area. This makes the dry dock area one of the most complex working areas at OSS, especially because time, area, and logistics in general are critical parameters.
At present no complete schedule covering all activities going on in the dry dock area exists. As mentioned above, the erection sequence schedule reveals some aspects and there are several different schedules and plans illustrating the rest of the activities. This makes a “global” evaluation of all activities in this area very complicated, almost impossible.

An evaluation should be done with respect to several production related issues such as:

- workloads in preceding production centres
- optimisation of working area in the dry dock area
- minimised lifting gear shifts
- optimisation of transport
- optimisation of scaffolding and support
- limits of facilities in the dock area
- structural related issues (strength, topology, etc.)

Many of these issues are related to the spatial geometry of both the dry dock area and the blocks. However, today very little information is available on 3D geometry, and no environment offers the possibility to view the ship geometry together with facilities.

A dimension of the OSS design strategy is to be able to build up a product model containing (principally) 100% steel and outfitting geometry within the very first design stages, or at least faster than today. The intention is not so much to get better information (higher quality) but it is more a question about more information and more information in the CAD/CAM systems at OSS (higher quantity). This should open up for better production related decisions to be made. Once this information is available simulation tools can be used for evaluation and optimisation on the above mentioned criteria.

A tool to support the evaluation process of erection sequences and all major activities being carried out in the dry dock area, for example through simulation, is conceived as an technology to be benefited from.

Odense Steel Shipyards Ltd expects that the present project provide a tool to simulate the activities of the gantry crane and other activities being carried out in the dry dock area. The simulation should be carried out with respect to a pre-defined erection sequence and a schedule of all other major activities while considering the realistic conditions which surround the operations in this area. A simulation tool should serve one primary purpose:

*ease the evaluation of schedules and plans for all major activities being carried out in the dry dock area through the simulation of facilities and entities (blocks) from the product model at OSS*

As it was mentioned earlier in this document the three industrial partners are facing different problems which, however, should be solved with a common approach. Besides the technical benefits described above, OSS has an interest in learning how to identify
problems which potentially can be solve through a common approach and furthermore learn the methods lying behind the approaches.

3.2 APM

Today A.P. Møller owns and operates a modern fleet of more than 30 anchor handling vessels. The vessels will be chartered to oil companies, construction companies, and rig operators where the vessels among other things assists with anchor handling, towing, and construction work. The development within these vessels has been in progress at an extremely rapid pace in order to meet the increasing demands. Previous high-powered vessels that were equipped with 8,400 BHK propelling machinery and 125 tons anchor handling have now been exchanged with vessels equipped with a 20,500 BHK propelling machinery and a 500 tons anchor handling winch.

The requirements to the vessels’ performance have been increased too. A few hours stop in the operation can result in considerable losses for the parties involved.

In recent years a great effort has been made to reduce accidents and today a low level has been reached. However, further reductions are required and in order to fulfil these, other means have to be used. "Learning by doing” on board in an anchor handling vessel alone will not be accepted in the future. The major part of this process has to be done ashore where you without risks for the crew, the vessel, and the equipment can test all possible solutions. Here the anchor handling simulator will become a very important tool.

3.2.1 Background

The vessel performance is constantly observed in order to be able to assist quickly and effectively. Optimum performance is crucial in order to be considered as “Customers First Choice”, which is one of the cornerstones in A.P. Møller’s strategy plan. In order to fulfil this, there are several important conditions that have to be met:

3.2.1.1 The Vessel's Crew

The theoretical background

During anchor handling two officers are always on the bridge, one officer for the operation of the vessel and one officer for the operation of the anchor handling equipment. Both deck and engine officers operate the anchor handling equipment.

The theoretical background for the officers who operate on the bridge can be divided into:

- Navigators/engineers
- Experienced/inexperienced

In the present education system for engineers and navigators, the education in anchor handling vessels and their equipment is limited.
By experienced officers distinction is made between officers with experience from anchor handling vessels and officers with experience from other vessels, for instance container and tank vessels. The category mentioned last must in this connection be considered as inexperienced.

With the exception of officers with experience from anchor handling vessels, there is a requirement for a theoretical education of the remaining officers before signing on.

The practical experience

Practical experience is important during all conditions especially in connection with anchor handling, where the right to regret an action seldom is given. The practical learning takes today solely place by “learning by doing”, which sometimes is an expensive and ineffective method.

There can be several reasons for this, of which the most important are:

- The vessel’s management is reluctant to give inexperienced officers the responsibility for the operation of especially the anchor handling equipment on the bridge. This may be due to unfortunate experiences and/or unpredictable consequences in case of errors.
- Senior officers with experience from other vessels hand over the operation to other more experienced officers, which seems rather natural at the beginning. Unfortunately this learning period sometimes gets unacceptably long.
- The surroundings on the bridge in an anchor handling operation surprise most people. Intensive communication between the parties involved combined with acoustics - and visual signals constitute an important stress factor.
- In more seldom cases the officers turn out to be unfit for the job in question. This matter is unfortunately often identified in connection with an accident.

The composition of the crew

The “chemistry” among the officers is also an important factor for a “second to none” operation. Serious co-operation problems have a tendency to blush up in connection with these operations, for instance, when performance problems are reported from the charterer or when an accident has happened.

3.2.1.2 The Vessel’s Technical Condition

One of the conditions that is required for a vessel to operate optimally is that the vessel itself and its equipment fulfil the requirements of the class, the authorities, and especially the Owner.
3.2.1.3 Foresight

The fast development within the offshore industry means that adjustment to the market is important in order to keep a leading position. It is not unusual that extensive modifications are made with few years’ interval to meet new requirements from the charterer.

In connection with finalising contracts for new vessels it is also important that the operator especially has thought of future jobs and that the new vessels are able to solve these in a satisfactory way.

3.2.2 Conclusion

With an anchor handling simulator officers are able to achieve their experience without risk for the crew, the vessel or the equipment.

A.P. Møller is convinced that an anchor handling simulator will be a most useful tool in order to keep and improve the vessels’ safe operation and keep A.P. Møller’s strategy to be “Customers First Choice”.

3.3 MTC

3.3.1 Important training

Training is an important part of everyone’s job, and crane operators are no exception. The problem of how to instruct and prepare crane operator without endangering millions of dollars worth of commodities can be solved by a crane simulator.

Crane simulation is a significant development in crane operations training. Using simulation technology, even experienced crane operators can be trained to enhance their skills.

The C Class container feeder with the container gantry crane is shown in figure 4.

3.3.2 Objective

Operating the simulator is like operating a real crane. The operator sits in the cabin, manipulates controls, senses movements, hears operating sounds and views the operating environment as he would in a real crane.

The simulator enables trainees to receive hands-on experience, overcome the fear of heights, get a feel for how the controls function, and operate the equipment efficiently without trying up any terminal gear. The ability to place operators in emergency situations is unique to simulation, and hence the only way to actively contain the costs associated with many types of accidents.
Safety procedures, equipment checks can be stressed until they become second nature. Another major advantage of crane simulation training is the virtual elimination of safety risks.

A crane simulator will reduce substantially the training hours and risks associated to the present “on-the-job” training method. The simulator system will also produce skilled crane operators within a relatively short period of time. The ultimate effect will be the creation of more capacity through the provision of faster and safer handling operation.

3.3.3 Examples to training scenarios

- Co-ordination and manipulation of controls
- Dual Operations – Hoisting/lowering
- Dual cycle operations
- Handling of 20’ containers in 40’ cells
- Arresting swing
- Positioning spreader
- Picking/placing containers
- Handling hatch covers
- Handling unbalanced loads
- Handling containers under strong wind conditions
- Electronic load control for sway, positioning and skew control

3.3.3.1 Crane automation systems

Dealing with operational problems such as:

- Failure of twistlocks
- Jammed container corner castings
- Failure of indicator lights and flippers

3.3.3.2 Failure to unlock container from Chassis

Teamwork:

- To develop skills and insight to enable improved team performance and delivery through effective teamwork

3.3.4 Crane training centre

Simulator training for crane operators becomes more widely known and accepted in the maritime and industrial communities.

MTC aims to create highly skilled crane operators and a crane training centre to meet both the short term and long term demand for crane operator training in the Ports industry, on board vessels and others such as those in the off-shore section.
4. GTS Viewpoint

4.1 DMI

4.1.1 Motivation and Objectives

The COT project will ensure and extend the competence and qualifications in the area of services in relation to development and operation of industrial simulators. The competence is sought extended in aspects concerning technical issues of simulators, simulator training aspects, simulator operational aspects as well as in the area of software development with a special focus on object oriented development strategies.

The identified areas of focus of ensuring and extending the competence at DMI are:

- Simulation architectures - High Level Architecture
- Visual simulator system
- Virtual instruments
- Mathematical/physical problem modelling

Beside these main objectives competence on training programmes development is an expected outcome of the present project.

4.1.2 Simulation Technology

Recently the American Department of Defence (DoD) has launched an initiative to develop a common standard for interconnecting simulator systems, reuse of simulator systems reuse, simulation data and on operation of simulations, i.e. on simulation architecture. The standard, denoted HLA (High Level Architecture) is being standardised as an IEEE standard. HLA is based on developed object oriented methods and the standard enables the use of distributed network computing. HLA uses object orientation in the way it is set up, controlled, and in the way quality control is ensured for simulators. HLA supports dynamically joining and exiting of simulator systems from a joint simulation and supports definition and management of data objects in large simulator systems. The overall structure of HLA is generic in the way that the interaction with a sub-simulator is based on definition of data and interaction of the sub-simulator. HLA ensures a generic and flexible development of sub-simulators by requiring that all sub-simulators provide specific functionality. One of the goals with the HLA standard is to focus on the positive contributions object orientation has in form of, e.g., reusability on a large scale. DMI intends to investigate and use HLA for the development of parts of the simulators.
4.1.3 Visual Systems

An important part of a simulator is the visual system that brings one type of realism to the training in a simulator. The advances in visual systems is developing very rapidly based on the advances in computer hardware and in software technologies. With the rapid market development of Virtual Reality and computer games the market of visual system development is expanding as well. DMI has to ensure and expand its competence on this area for being able to be considered as a market leading simulator developer.

4.1.4 Virtual Instruments

Full-mission simulators of today are mostly based on computer simulated behaviour based on the trainees input through hardware consoles, buttons, driving wheels etc. and display of status on real hardware consoles, meters, etc. Simulators based on real hardware operator consoles, real ship bridges with real radars etc. are very costly. The cost decreased and the flexibility can be highly increased by using so-called virtual instruments, instruments based on computer generated display technologies.

DMI has earlier developed frameworks and toolboxes for the development of virtual instruments. It is the objective to expand the competence on this field for being able to increase the effectiveness of developing virtual instruments.

4.1.5 Mathematical Modelling

The mathematical modelling of a physical problem is probably the most important part of a simulator. The mathematical model is dependent on the type of the simulator and the physical problem and on the training objectives. The ability of modelling the important behaviour realistically is of outmost importance. The realistic modelling secures that the training objectives can be met and that training avoids negative training effects, i.e. training of behaviour not present in real environment.

For realistic modelling of physical problems within ship and manoeuvring simulation DMI has a strong competence dating from the present and decades back in time. With new developed mathematical, numerical and software methods it is of importance that DMI strengthens this competence by further refinement and extensions to other areas of the simulation domain.

4.2 DTI

4.2.1 Motivation and Objectives

Object technology can support many different aspects of software development and interleaves therefor with many different development disciplines such as: requirements specification, analysis, design, programming, testing, project management, reuse etc. As with any new technology the uptake of object technology is not easy. The mindset of the
software developer or manager must be changed from traditional waterfall and procedural thinking in order to use object technology efficiently. These two aspects: many development disciplines involved and the requirement to change developers way of thinking makes it a challenging task to implement object technology efficiently in a company.

DTI will in this project investigate an incremental introduction approach to object technology with DMI in the role of the company introducing object technology.

4.2.2 Incremental Introduction of Object Technology

Incremental introduction of object technology requires the close co-ordination between a software development project (SDP) and an object technology introduction project (OTIP). As the SDP advances in a number of incremental steps the OTIP will introduce a number of new object techniques in each step. Evaluation of the effect of previous OTIP steps and planning of future steps based on company needs is an integral part of the incremental process.

Details of the OTIP at DMI can be found in COT/6-5.

5. Researchers Viewpoint

5.1 MIP

5.1.1 Motivation and Objectives

The research activities will focus on software architecture. The focus will be on both notation and process aspects of architecture, less on tool support in relation to these aspects. The architecture of software is still not well enough understood. This claim is clearly supported by the standards of the descriptions of the design phase in available software development methodologies. The lack of both notation and method during design is obvious, whereas the analysis and the implementation phases are much better off. The situation is very problematic for two reasons, (1) for complex systems it is not possible to come up with the right design, and (2) the change to reuse of design instead of reuse of code can not be put into practice.

Some architectural support exists however. Some examples include patterns, application frameworks, and architectural styles. We see these as promising examples of architectural abstractions that can support the design of software. As different technologies the scope and objectives of these approaches are different. A fundamental problem is to express the architecture explicitly in the software design rather than just implicitly. This allows necessary exposure of the interaction and cooperation structure during design as well as in reuse of design.

5.1.2 Approach and Plan
The approach, that is planned to make the architecture more explicitly represented during design, is partly to supply additions to the process aspect of the development methodologies, and partly to introduce notational constructs as supplements to languages and diagrammatic notations.

The work will be based on object-oriented simulation systems as our application domain. We see the existence of large systems, the evolution of these systems, professional software development teams, and realistic applications as essential elements in our research in software.

5.1.3 Promotion and Results

The results of the research activities include a general, broad promotion of architectural technologies for design of software architectures. The promotion to the involved companies and institutions involves interaction with DMI and DTI and with dedicated persons from the companies. The focus of the promotion will be on advanced use of, and new approaches for the integration of, architectural technologies in software development and evolution.

The form of the results include material for tutorials on the technologies, and research reports from the experiments with (revised method additions for) the technologies. Based on these practical results we develop theoretical contributions on the notation aspect by proposing notational constructs for explicit expression of architecture. These results are integrated parts of two Ph.D. theses. The theses will be subject for communication and discussion late in the project.

An abstract, logical model of the simulation domain is developed based on the experience from the experiments. The model includes descriptions of the problem domain and the usage domain.

We complement the model to form a possible software architecture for the application domain, but only existing architecture technology is used. The model is refined and implemented partially as an application framework in an object-oriented programming language. The purpose of the implementation is to explore the usability of the theoretical results, and to serve as a means for communicating the essential organisation of frameworks in general and for the simulation domain in particular.
6. Project plan

The project was initiated January 1, 1998 and has a duration of three years, hence it has an expected end at the end of December 2000. The overall project plan of the OOST case is outlined below.

<table>
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<th>Year</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
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Table 1: Project overview