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Dynamic Positioning Committee
Marine Technology Society

DYNAMIC POSITIONING CONFERENCE

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RELIABILITY SESSION

Reliability of DP Operations in Deep Waters Experiences and Results from Field Tests

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Abstract

The "Reliability of DP Operations in Deep waters" is a joint industry project aiming at increasing the operational reliability of DP operations in deep waters. The project has focused on reference systems, how to handle them and on operator support tools. Several new products and functions have been developed during the project. All new developments were tested during a ten day offshore test.

Introduction

The "Reliability of DP Operations in Deep waters" has been a joint industry project aiming at increasing the reliability of DP operations especially in deep waters. This project headed by Kongsberg Simrad, also has participants from Seatex, Shell, Statoil, Norsk Hydro, Saga, British Petroleum, DSND Offshore, the Norwegian Petroleum Directorate and the Norwegian Research Council. The project started in 1995 and has been completed by an extensive offshore test onboard the MSV Botnica of DSND Offshore in November 1998.

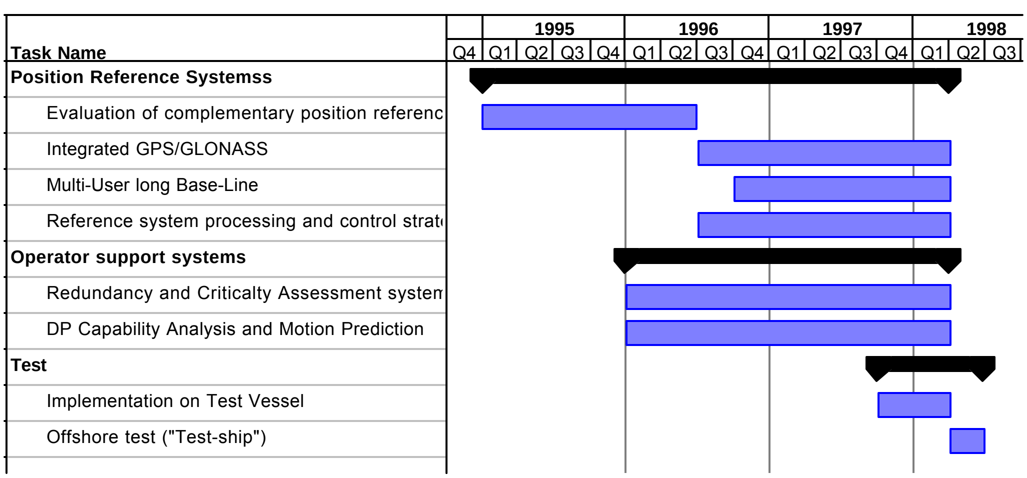
This project had a number of objectives:

- To improve overall safety when using a DP-operated vessel for drilling, sub-sea installation, well testing, well intervention and production.
- To reduce the risk of incidents that can lead to "drift-off" and "drive-off"
- To improve the performance of existing DP technology and to develop systems with acceptable reliability for operation in remote areas and in deep water.

The project has mainly focused two fields:

- Reference systems for deep water and how to handle these
- Operator support tools to give the operators of a DP vessel a better understanding of the operational conditions both with respect to vessel equipment as well as nautically.

The overall project schedule is shown in the figure below:



The industry partners contributed with the following products and functions in the offshore test:

Company	Product/ Function	Description
Seatex	DPS100	New generation differential GPS Position Reference System
	DPS200	Integrated differential GPS and GLONASS PRS utilising GPS and GLONASS satellites to complement each other.
Kongsberg Simrad	Multi-User Long Base-Line (MULBL)	Multi-user version of long base line acoustics allowing a common transponder array to serve all vessels and ROVs in an area.
	Reference System Processing/Estimator	More robust reference system processing and estimator in the DP system.
	On-line DP Capability analysis	A function to determine the most severe environmental conditions in which the vessel is able to perform its operations taking into account equipment failures according to the IMO guidelines.
	On-line Motion Prediction analysis	Simulates the motion pattern as a function of time in a drift-off situation taking into account equipment failures according to the IMO guidelines.
	Redundancy and Criticality Assessment (RCA)	Integrated online fault monitoring and criticality assessment tool which monitors and confirms that resources required for a specific mode of operation are available.

Parts of the project have been presented at the MTS DP conferences earlier. This presentation is focusing on the results and experiences gain during the offshore test period.

Prior to the actual test, all products and functions developed were implemented in the Integrated Automation System (IAS) installed onboard the MSV Botnica. The system layout of Botnica is shown in the figure below.

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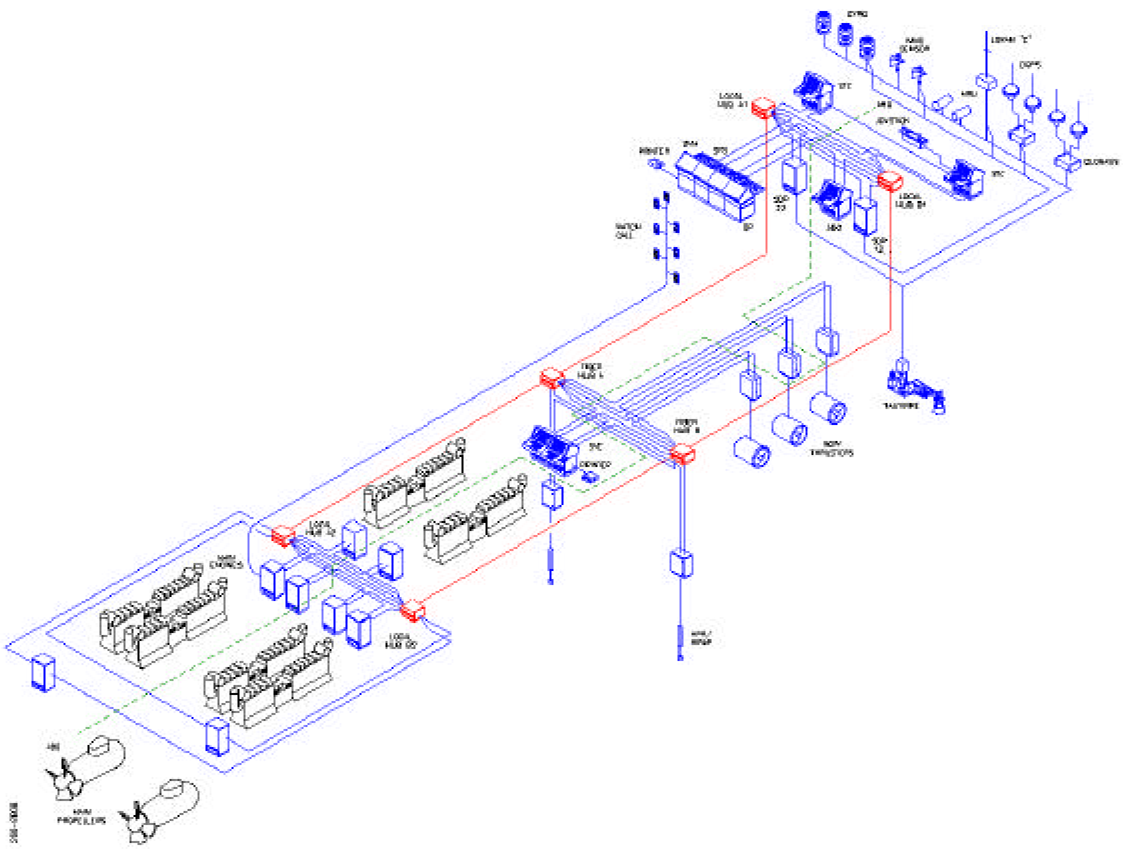

The Offshore Test

The main objective of the offshore test was to verify and demonstrate the functions developed in the project under realistic environmental conditions and in deep water.

A ten days offshore test took place in November 1998. The test team consisted of the development staff who carried out the tests and observers from the other companies. In addition an independent observer was invited to witness the tests. An appointed test master conducted the test program.

Storegga (63° 33.78'N, 005° 09.45'E) was selected as the centre of the test field. The reasons were mainly that the water depth is in excess of 1000m (1170m) and that Norsk Hydro could provide detailed seabed maps.

Every morning a meeting was held to brief the observers on the tests that were to take place in the following day(s). A briefing was performed by the person responsible for the specific function to be tested. Every evening a debriefing was held by the test responsible, presenting results from tests that had finished during that or the previous day(s). This included results from preliminary analysis of the test results.

In the following the different tests are outlined and some of the main results presented.

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Tests at Storegga

At the start of the test period, the weather was very good, with wind ranging from 0 m/s down to 12 m/s, until it increased to 45 m/s. The weather condition made it impossible to continue testing, and as the tests requiring deep water were completed, the vessel moved to Breidasundet near Alesund on the north west cost of Norway to complete the test program at that location.

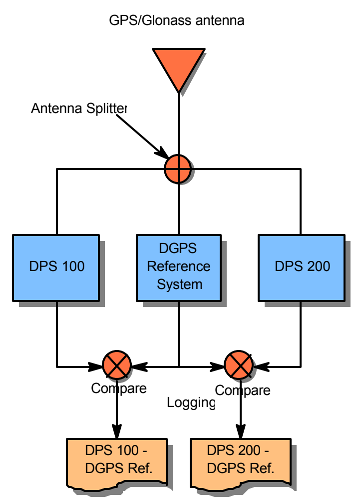
Tests at Storegga covered:

- Integrated DGPS/GLONASS
- Multi-User LBL
- Redundancy and Criticality Assessment
- Reference System Processing/Estimator (partly)
- Pre-test of On-line DP Capability Analysis

Integrated DGPS/GLONASS

The purpose of the tests was:

- To verify system performance (both static and dynamic) according to specifications during normal operation.
- To "stress" the system, simulating abnormal conditions and fault situations, then verify the performance of the system during such events to show system robustness. The events include loss of gyro sensor, loss of satellites, loss of differential signals, partial blockage of horizon and multi-path interference.



Accuracy tests were carried out by comparing with a well proven DGPS system (SeaDiff system). The accuracy of the SeaDiff system is ,however, of the same order of magnitude as the systems to be tested. Real Time Kinematic (RTK) GPS was not available. The test setup is shown in the figure to the right.

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Static accuracy

The static tests were performed while the vessel was along the quay in Stavanger, prior to the test period.

Test parameter	Design requirements	DPS 100	DPS 200
Accuracy (95% CEP)	3m	2.52 m (fixed) * 1.96 m (diff) **	2.52 m (fixed) 2.12 m (diff)
Availability	99.99%	99.990 %	99.995 %

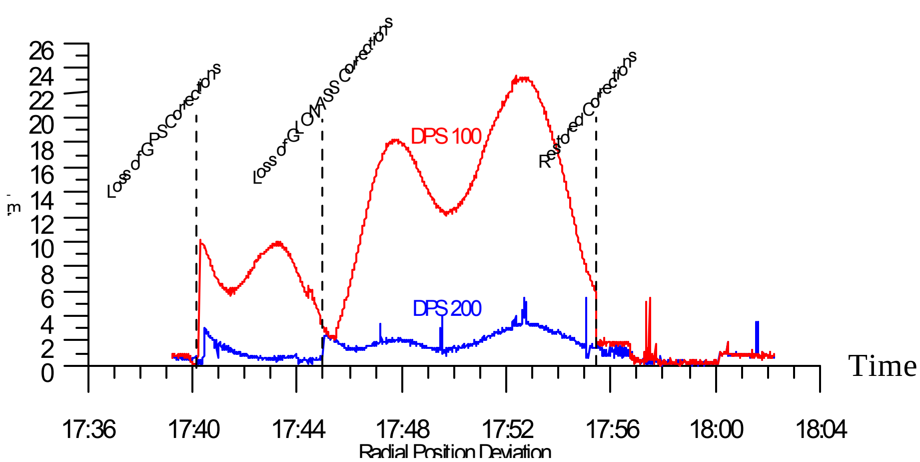
* direct readings including vessel motion
** compared to SeaDiff

Dynamic accuracy

Accuracy	DPS 100	DPS 200
95% CEP	1.21 m	1.49 m
97% CEP	1.44 m	1.71 m

Loss of correction signals

In the figure to the right, the GPS corrections were removed at 17:40. At 17:45 the GLONASS corrections are also removed. We observe that the GLONASS based measurements stays acceptable where as the GPS derived position is not usable for DP.



Conclusions

The tests showed good results, meeting all major requirements.

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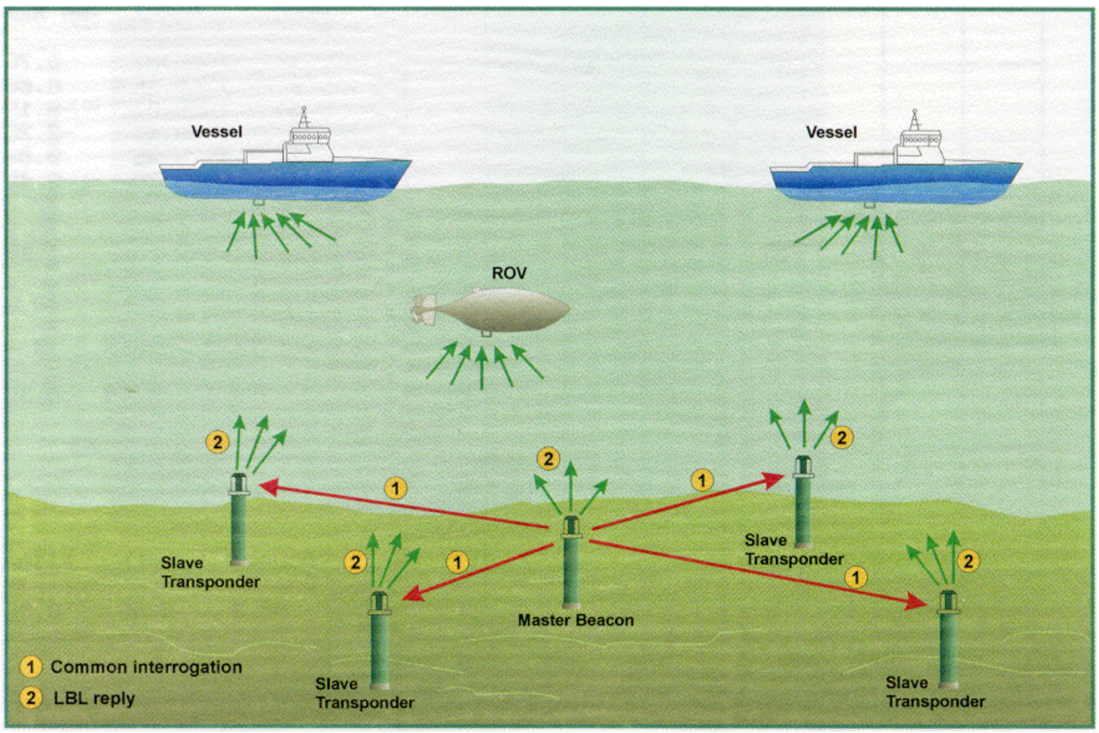
Multi-User LBL

The purpose of the test was to verify the Multi-User version of the Long Base Line position reference system. A typical MULBL setup is shown in the figure below.

In the MULBL concept the vessels are passive units. It is a master beacon (in the centre of the array) which is interrogating the other transponders. When these slave transponders are interrogated, they will reply to the surface.

The specific functions to be tested were:

- Position repeatability
- Position accuracy
- Horizontal range capability
- Influence from thrusters



Repeatability

An example of time series is shown in the figure below (including vessel motion).

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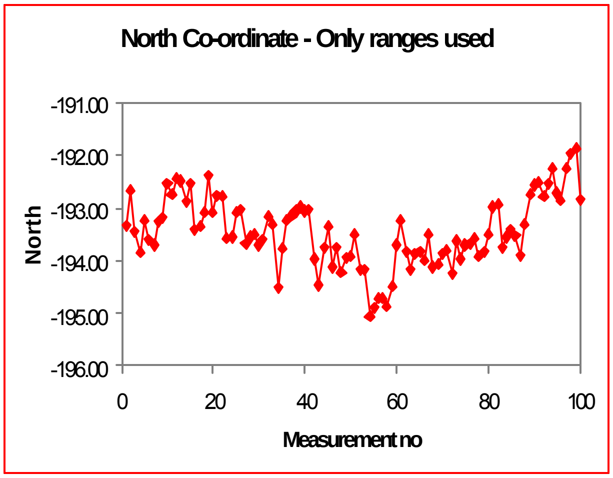

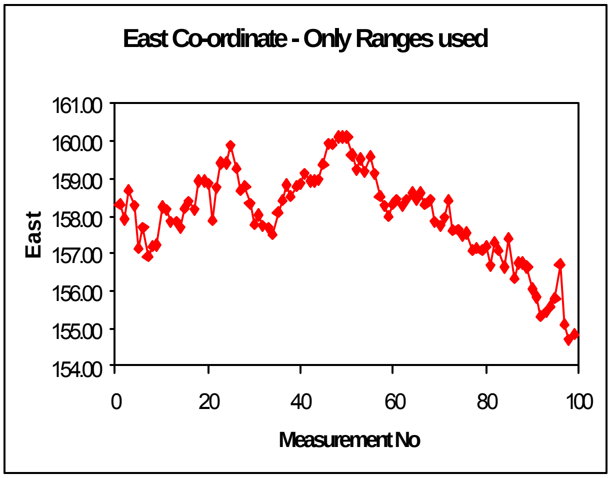

The different tests showed system accuracy of 0.5 – 1 m standard deviation.

Conclusions

The tests showed very good results, actually exceeding the requirements and expectations. The system was able to produce position updates as fast as each 1.2 sec. DP operation with MULBL as the only position reference system at update rates down to 1 update every 10 seconds worked well.

Redundancy and Criticality Assessment

The purpose of this test was to show the functionality of the Redundancy and Criticality Assessment system implemented in the Integrated Automation System onboard MSV Botnica. Some of the goals according to the original concept study were:

- To monitor the vessel's station-keeping equipment, such as thrusters, electric power generators, electric distribution systems, auxiliary machinery systems, machinery control systems, DP-system / reference systems
- To report to the DP operator if any unit required for the actual operation (being either in service or in standby mode) should become unavailable for some reason. Status of units which are not required for the present operational mode should not be reported
- To allow the operator to select the desired operational mode, and to report whether any unit required to fulfil authority requirements with respect to availability is not in the required state

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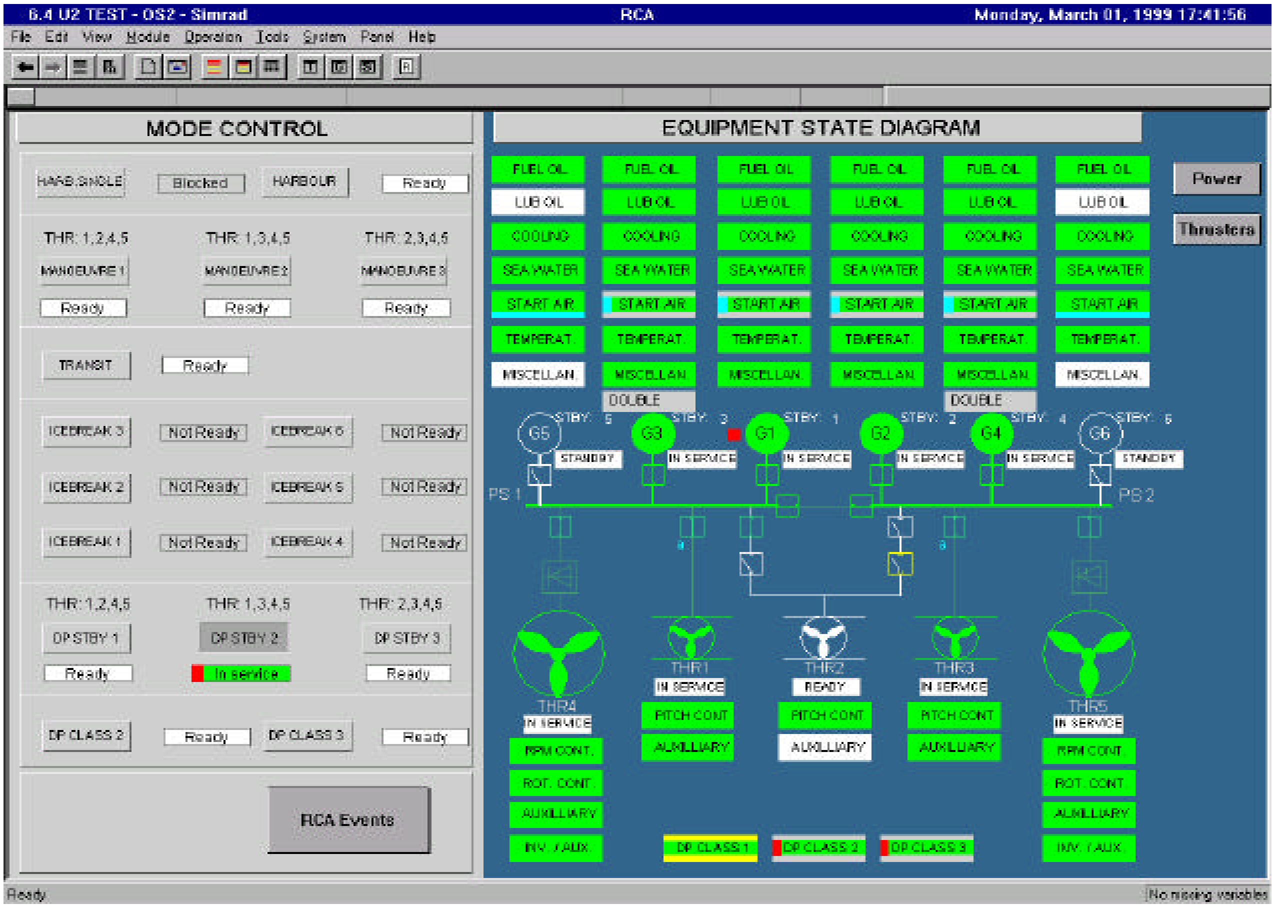

Conclusions

The goals specified in the concept study have been reached for all major and most of the detailed requirements.

Tests at Breidasundet

The weather conditions were very good for the remaining tests, with wind speed ranging from 15 m/s down to 8 m/s.

Tests at Breidasundet covered:

- Reference System Processing/Estimator (remaining tests)
- DP Capability
- Motion Prediction

Reference System Processing/Estimator

The main purpose of the tests was to verify that the **robustness of the DP control** was improved as a result of another way processing position measurements.

Specifically the designated areas for improvements were:

- Increase robustness of estimator to low update rate and noise characteristics of reference systems.
- Include possibilities to utilise quality (variance) data estimated by the reference system. The reference system is able to determine quality as a function of several factors unknown to the DP, such as. measurement geometry, differential correction age, residuals in position fix etc.
- Improve mechanisms to detect position measurements with bias and slow drift.
- Possibilities for monitoring the performance of a reference system before it is used for DP control.

The interfaces to the new or upgraded position reference systems should also be tested. These systems are: MULBL, DPS100 and DPS200.

Robustness

The concept of adaptive gains showed that the robustness is increased significantly. An example where the vessel is commanded to move 20 m ahead, then 40 m astern and finally 20 m ahead to the original position are shown in the figures below. The update period from the reference system (DPS100) was set to 5 seconds (by manipulating the DPS100). Similar tests were also carried out successfully with the new estimator concept using the MULBL with update period as high as 10 seconds.

The figures below show clearly that the "nervous" vessel behaviour using the standard estimator is not present using the new concept.

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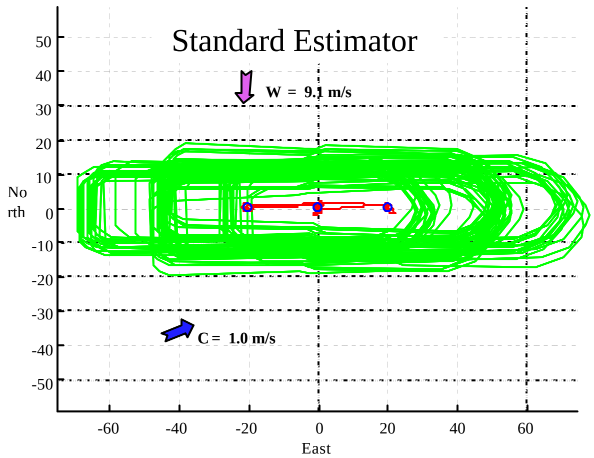
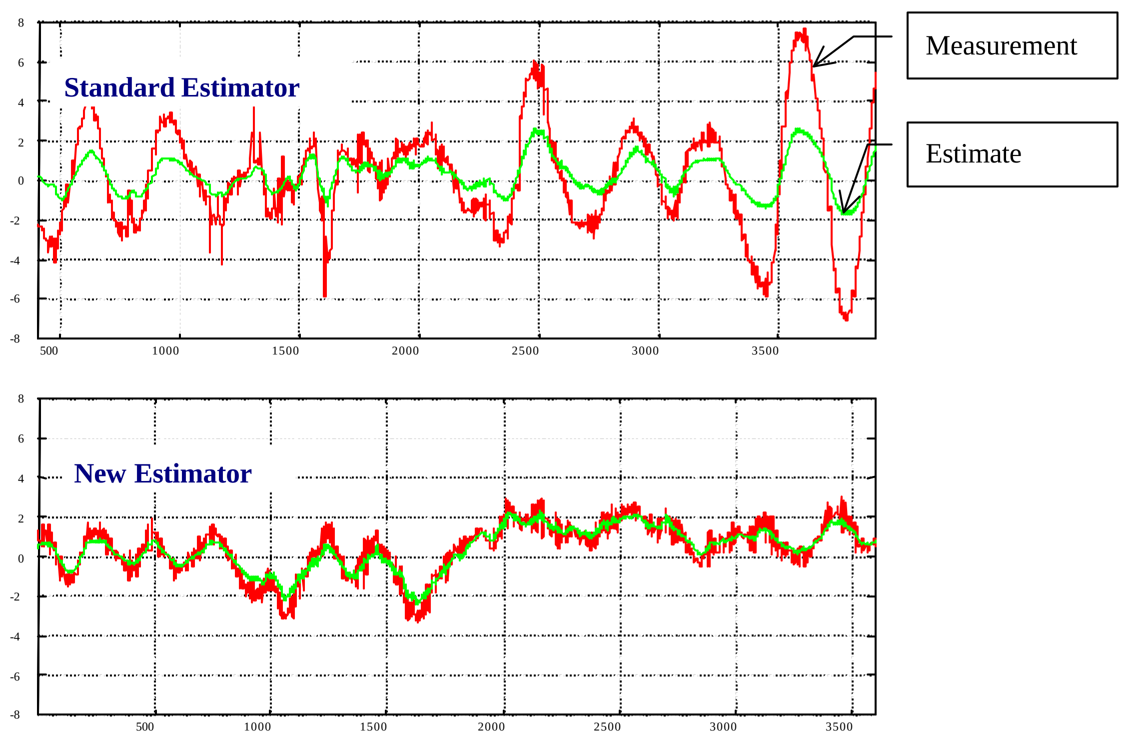
Birds View



Sideways Motion



Conclusions

A successful implementation was demonstrated for the new and improved functionality:

- Interfaces to new or upgraded position reference systems are functioning very well.

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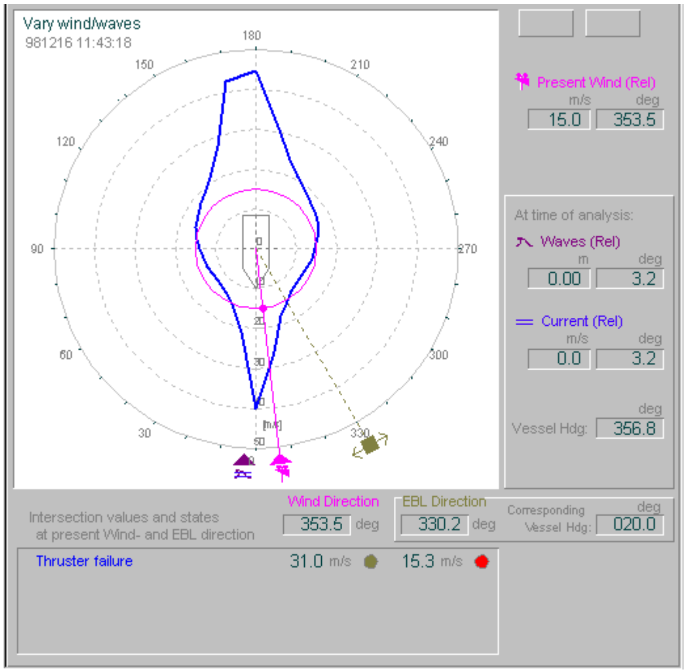
- Internally generated variance estimates and variance data from the reference system are complementary. Using both estimates in an integrated manner would constitute a more robust system than using either one or the other method.
- Bias estimation for detection of drifting reference system was implemented and demonstrated.

DP Capability

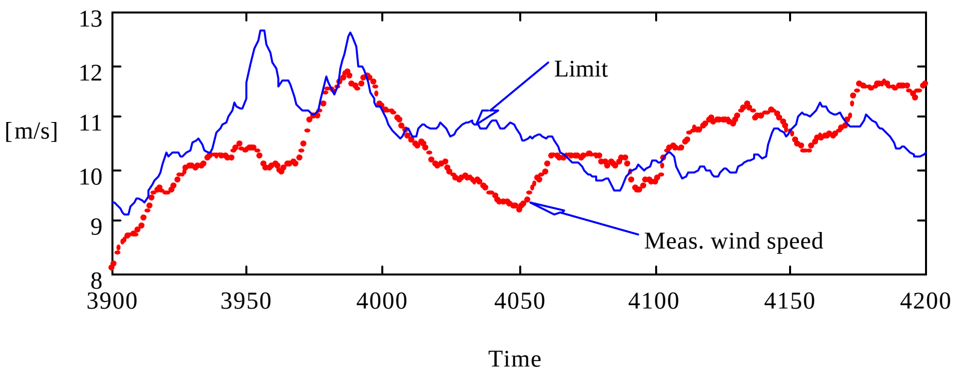
The main purpose of the tests was to investigate how accurate the DP Capability Analysis function could predict the maximum wind speed for DP operations and to investigate the variations of the predictions as a function of time and wind angle of attack. Tests were undertaken for different thruster configurations and for loss of one switch board.

Thruster failure

The capability plot is shown in the figure to the right. The magenta circle indicates the present wind speed and the magenta line its direction. The blue curve shows the limiting wind speed. When the capability curve and the circle intersects, the vessel will be on the limit of performing station keeping. This intersection is indicated by the green dotted line in the figure. When rotating the vessel to this direction, a drift off should commence.



The next figure shows what takes place when the vessel reaches this new heading.



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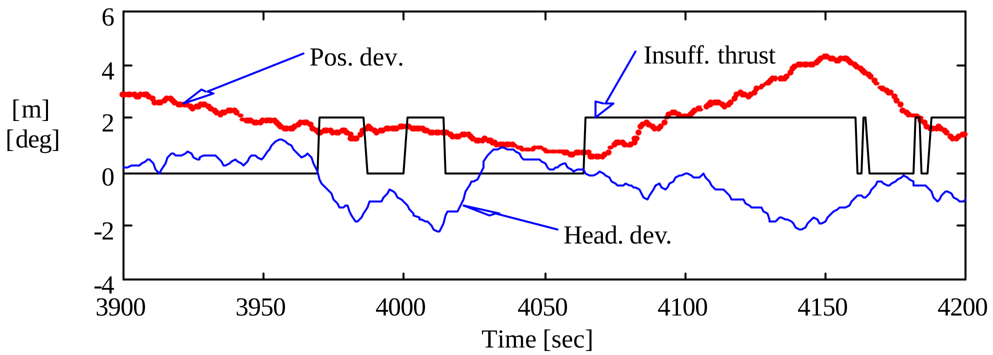


Conclusions

The following may be concluded from the tests:

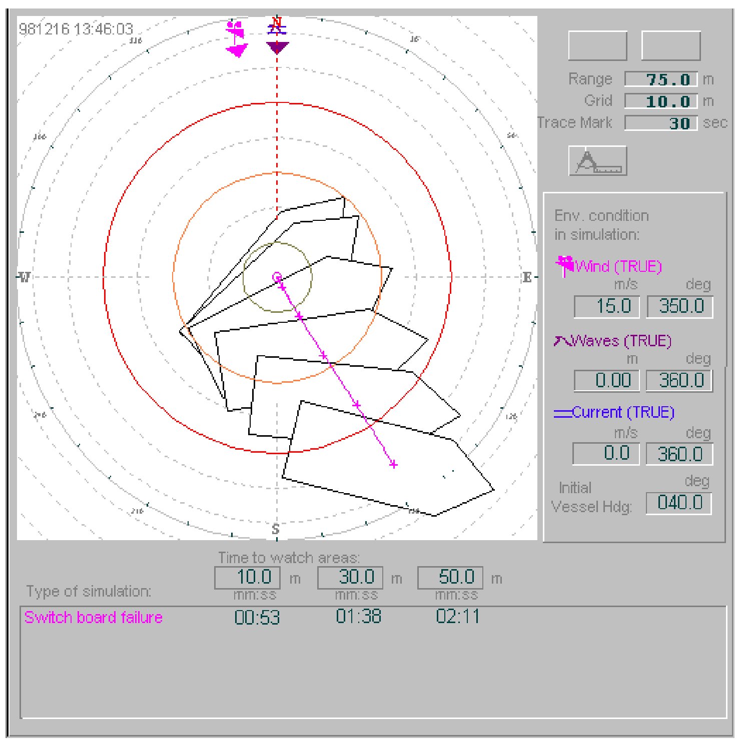
1. The function gives reliable predictions of the limiting weather conditions for DP operations.
2. The function is capable of predicting the effects of failures in thrusters and power system

Motion Prediction

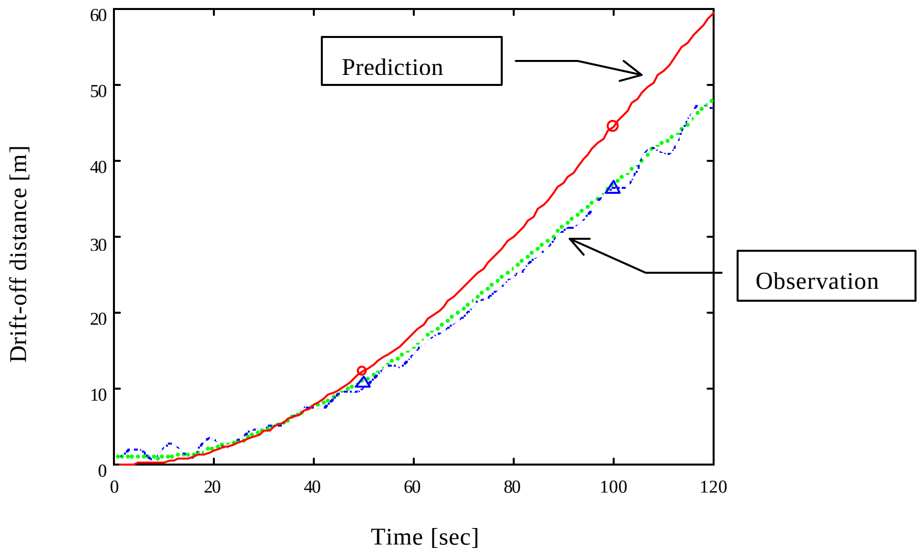
The main purpose of the tests was to investigate how well the Motion Prediction function predicts the drift-off pattern of the vessel. Drift-off tests were undertaken for a total black-out situation and for loss of one switch board.

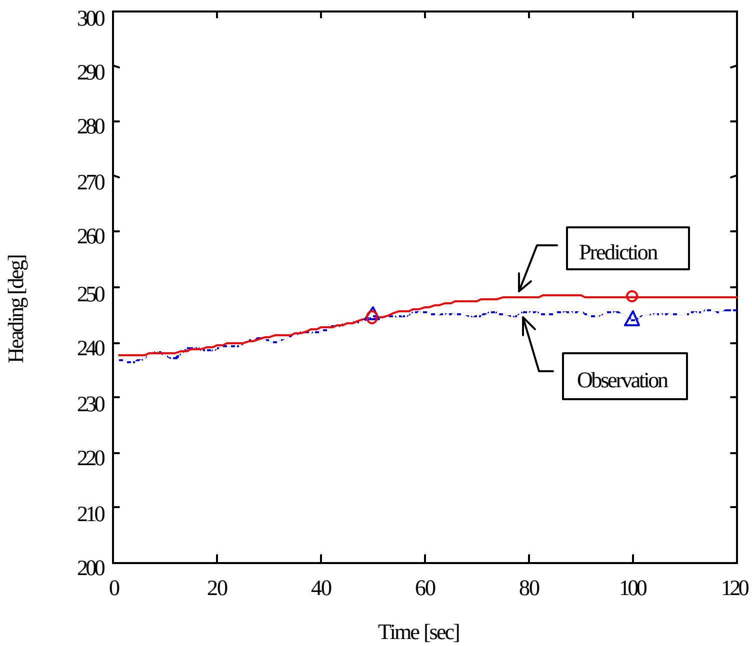
Switch board failure

An example of a Motion Prediction view is shown in the figure to the right.



The next figures show the drift-off as a function of time





Conclusions

The following may be concluded from the tests:

1. The function gives reliable predictions of the drift-off directions for different failure configurations.
2. The function gives accurate predictions of the time to reach the watch circles if the wind speed experienced during the drifting period is closely similar to the mean wind speed used in the simulations.
3. The prediction of vessel heading after failure show discrepancies for the total black-out cases. The accuracy improves considerably when the vessel has some remaining positioning capability after failure.

Summary and conclusions

The test activities of the project have been finished successfully. All products and functions have been tested according to well-prepared procedures, and the results fulfil or even exceed the requirements and expectations. The tests were performed well within the scheduled time. The qualification tests performed could not have been carried out in such a systematic way if carried out as part of ordinary sea trials or during normal operations. The experience gained during this test is extremely valuable.

This type of test campaign should be mandatory in any development project of this kind.

The vessel “Botnica” proved to be well suited for the task of performing the tests.