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ACCSEAS Final Report

Review of ACCSEAS Solutions through tests and demonstrations

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Lead Author	Reviewer	Approved for Release
Name: Mads Bentzen Billesø	**Name:** Transnational Project Co-ordination Group	**Name:** Project Steering Committee
Job Title: WP6/7 Contributor	**Job Title:** N/A	**Job Title:** N/A
Partner: DMA	**Partner:** All	**Partner:** All
Signature: pp Alwyn I. Williams	**Signature: pp Alwyn I. Williams**	**Signature: pp Alwyn I. Williams**

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Executive Summary

This document describes the test scenarios, test bed infrastructure and test results from the ACCSEAS project. The document is structured in accordance with IALA Guideline on reporting results from test beds. It gives the reader an understanding of the technical aspects of the tests, and allows them to appreciate the feedback that was received from the users of the solutions. The tests cover both real and simulated environments, each presenting different challenges to testing the services. The scenarios are designed to be as realistic as possible, whilst appreciating that the solutions present an innovative means of communication between the mariner and the shore or other ships.

In the vast majority of cases, the feedback from the users were very good and encouraging. This is a direct result of feedback early on in the project to ensure that the usability and efficiency of the solutions were maximised as much as possible.

By ensuring that the mariner and shore-based authorities get reliable information, the decision making can be more certain and less likely to cause collision and grounding. Reliance on unreliable information, whether deliberate or not, can only cause an increase in the risk to the vessels and the environment. The solutions, demonstrated in ACCSEAS to real users of the North Sea Region, has the real potential to minimise the informational errors and increase confidence, safety and efficiency leading to improved accessibility in the North Sea Region.

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Lead Author	Mads Bentzen Billesø
Lead Author's Contact Information	Søfartsstyrelsen / Danish Maritime Authority Maritime Analysis, Technology and Business Development (MAF), e-Navigation Telephone: +45 9137 6329 E-mail: MCB@dma.dk
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Contents

1 Introduction

ACCSEAS was a 3-year project supporting improved maritime access to the North Sea Region through minimising navigational risk. With European transport policy providing a shift to seaborne transport, using Short Sea Shipping to avoid road bottle necks to the movement of goods, services and people, efficient and effective marine navigation services have never been more important.

By looking to harmonise maritime information and how it is exchanged and by offering training provision to support real-world implementation, ACCSEAS have worked to ensure that e-Navigation provision in the North Sea contributes a beneficial and lasting impact on the resilience of the Region's critical infrastructure in terms of safety, security, economic growth and environmental protection.

ACCSEAS have built on the findings of previous and current related regional projects and focused on co-operation in key areas of technology and infrastructure services that underpin maritime navigation and safety – looking to further enhance them.

The Project have:

- identified key areas of shipping congestion and limitation of access to ports;
- defined solutions by prototyping and demonstrating success in an e-Navigation test-bed at North Sea regional level.

The project have followed the guidance and regulatory framework of the EU, the International Maritime Organisation (IMO) and the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), ACCSEAS have looked to prove the success of new e-Navigation concepts by producing four key types of results and outputs:

1. A PRACTICAL TEST-BED implementing real equipment and infrastructure in the form of e-Navigation prototypes and complementary simulations to test these;

2. A DATABASE OF INFORMATION demonstrating the effectiveness of the prototypes – primarily in the form of baseline information – concerning vessel routes in the North Sea Region and coverage maps of the geographical extent of e-Navigation services for the prototypes. (This information will be stored in an ACCSEAS Geographical Information System – GIS);

3. SYSTEMS ENGINEERING DOCUMENTATION covering the problems and possible solutions for maritime access issues in the North Sea Region, how the e-Navigation prototypes and simulations were developed to address these, and an assessment of best practices involved in establishing e-Navigation regional solutions;

4. ANALYSIS OF THE LESSONS LEARNED, ADVICE on the TRAINING MODULES for PRACTICAL E-NAVIGATION solutions.

These outputs have and hopefully continue to inform policy development and influence the creation of any necessary institutional structures and regulatory instruments needed to deliver future e-Navigation Aids to Navigation services.

Approved and part-funded by EU's INTERREG IVB North Sea Region Programme as a transnational project, key navigation authorities and maritime administrations supporting ACCSEAS have come together to deliver the project from Denmark, Germany, Sweden, Norway, the Netherlands and the United Kingdom.

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2 Background to the Test Bed

This section provides an overview of the test bed in terms of the solutions being considered and who will be testing them. The solutions are those summarised and described in the ACCSEAS Baseline and Priorities Report.

2.1 IMO e-Navigation Gap Analysis

IMO has identified a number of solutions as part of their e-navigation strategy implementation plan. The solutions are:

- S1: Improved, harmonized and user-friendly bridge design
- S2: Means for standardized and automated reporting
- S3: Improved reliability, resilience and integrity of bridge equipment and navigation information
- S4: Integration and presentation of available information in graphical displays received via communication equipment
- S9: Improved Communication of VTS Service Portfolio

The Services/solutions being identified and developed in the ACCSEAS project generally fits all the different solutions except S1. However, these solutions are only described at a very high level of abstraction, thus in order to match the services/solutions more accurately, it is better to look at the Gap analysis made by the IMO e-navigation correspondence group as a step towards the e-navigation strategy implementation plan.

Table 1 matches the IMO identified gaps (from IMO Report NAV58/14) with the services/solutions identified in the ACCEAS project.

Table 1 - Linking of ACCSEAS solutions to the IMO identified gaps to be filled by e-Navigation.

IMO gap ID	IMO description	ACCSEAS service/solution
111-Gte01	Lack of harmonized data formats for the transfer of information received via communication equipment (e.g., Maritime Safety Information, MSI) to the navigational systems for presentation.	MSI/NM(T&P) Exchange of intended route Route suggestion No-Go Area FAL reporting Vessel Operations Coordination Tool (VOCT) IVEF information exchange
111-Gte02	There are no standardized data formats established for ship reporting.	FAL reporting
111-Gte05	Lack of technical solutions for processing, filtering of information exchanged via communication equipment.	Filtering functionality in: MSI/NM(T&P) Exchange of intended route
111-Gre01	Lack of international standards for navigation data formats.	No-Go area

	Lack of real-time environmental information (current, tide, weather) received automatically. Lack of international standards for navigation data formats and water level and current information as well as a standard for dates.	
112-Gte01	Lack of effective and harmonized means for assessment of the accuracy and plausibility of indicated information. Lack of effective ways to indicate levels of reliability.	Resilient PNT
112-Gop01	Lack of assessments to quantify reliability parameters (e.g., specific assessment of electronic position fixing systems).	Resilient PNT
113-Gte02	Lack of timely delivery of ENCs and updates via internet. Lack of real-time tidal data, AIS data and ENC updates.	No-Go Area
120-Gte03	Lack of systems for source and channel management for communication equipment. Lack of seamless and communication mean dependent protocol for exchanging navigation information between ships Insufficient techniques and procedures for exchange of data between ship shore and on board.	The Maritime Cloud
132-Gte01	Insufficient reliability of position fixing systems.	Resilient PNT
134-Gte04	Lack in presentation of manoeuvring information/data(engine-room telegraphs) on navigational display.	Dynamic predictor
	Upon receiving real-time Maritime Safety Information (MSI) and other navigational warning/broadcasts relevant for the vessel's navigation, there is no appropriate and suitable interfacing technique that could allow these data/information to be available (visible) in real-time to the mariner. Lack of technical solutions for processing, routing, and filtering of information received via communication equipment to enable transfer of the information to navigational systems. Lack of technical solutions for presenting communication information/Maritime Safety Information (MSI) on navigational displays. Lack of presentation of warning broadcasts on navigation displays.	Primarily MSI/NM(T&P) and The Maritime Cloud

	Insufficient means for sorting and display of Maritime Safety Information (MSI) such as NAVTEX, SafetyNET. Lack of user-selectable and task oriented presentation of information received via communication equipment (including MSI) on navigational systems. Insufficient network of storage, sharing and distribution of MSI. Unless having prior subscription, the current system does not allow for Maritime Safety Information (MSI) and other navigational warnings/broadcast, etc., to be received in real-time mode and be integrated with the navigation display. Unavailability of information in real-time with possible presentation on the navigational display to support bridge operation. Lack of integrated secondary screen option for digital publications and MSI. Lack of interface messages between sender and receiver for monitoring of local/coastal warning broadcasts/watching GMDSS system (NAVTEX, NAVAREA message).	
140-Gt01	With the exception of Polling, current system does not provide provision for automatic ship reporting.	FAL reporting
140-Gte02	Lack of automated and standardized ship reporting function.	FAL reporting
140-Gte04	Insufficient means for ship reporting.	FAL reporting
211-Gte01	Lack of a common maritime information/data structure harmonizing the policies for the security and use of data. Insufficient identification of harmonization needs for standards, formats and protocols. Lack of protocols, formats and data structure that enable shore based authorities to exchange information with other authorized shore based users. No standardized format for data exchange between VTS centres and other e-Navigation stakeholders.	The Maritime Cloud
220-Gtr01	Lack of international guidance on security of data and its sharing	The Maritime Cloud
235-Gte01	Insufficient delivery and presentation of maritime information that shore based authorities are required to provide to ships.	IVEF information exchange

	There are no standard data formats for on board capture and presentation that cover the entire scope of information provided by a VTS	
310-Gte01	Lack of mechanisms to provide SAR (RCC) function with the full range of relevant e-navigation information in digital format. Hardware: Resources and capability available for infrastructure can be lacking and therefore tools needed for accessing digital data may not be available. Lack of data in digital format.	Vessels Operations Coordination Tool
320-Gte01	Lack of an automated data network connecting all stakeholders in SAR intervention, including improved communication between RCC and shore-, land-, sea- and air-based entities. Lack of access to the details of all relevant on-board communication and capabilities for SAR authorities. Limited resources for communication infrastructure in SAR operation	Vessels Operation Coordination Tool and The Maritime Cloud

2.2 Additional Gap Analysis relating to Resilient PNT

Table 2 provides additional gap analysis carried out in ACCSEAS, based on the identified categories in the IMO gap analysis, relating specifically to Resilient Positioning, Navigation and Timing (PNT).

Table 2 - Gap Analysis relating to Resilient PNT.

User Field and Category	Gap	Notes on Solution
Shipboard/Information/Data Management/Improved Reliability and Indication/Technical	Lack of effective and harmonized means for assessment of the accuracy and plausibility of indicated information	The development of a Resilient PNT integrity equation to calculate an estimated Horizontal Protection Level (HPL)
Shipboard/Information/Data Management/Improved Reliability and Indication/Technical	Interoperability of systems and sensors is not realized	A Multi-Source Receiver was produced which demonstrates the interoperability of sources of PNT.
Shipboard/Information/Data Management/Improved Reliability and Indication/Technical	Lack of self-checking functionality of the electronic equipment.	The development of a Resilient PNT integrity equation to calculate an estimated Horizontal Protection Level (HPL). The demonstration of alerts to the mariner upon failure of a source of PNT to

		produce a plausible output
Shipboard/Information/Data Management/Improved Reliability and Indication/Technical	Insufficient reliability of position fixing systems	A Multi-Source Receiver was produced which demonstrates seamless and automatic provision of Resilient PNT, the monitoring of the performance of each source independently of another, and reporting on the navigation solution quality.
Shipboard/Information/Data Management/Improved Reliability and Indication/Operational	Lack of assessments to quantify reliability parameters (e.g. specific assessment of electronic position fixing systems).	The development of a Resilient PNT integrity equation to calculate an estimated Horizontal Protection Level (HPL)
Shore-based/Traffic/Traffic Monitoring/Technical	Lack of procedures that enable shore based authorities to monitor quality of navigation systems on board as well as quality of information and effectiveness of communication	The navigation solution accuracy estimate provided by the on-board HPL computation, in addition to alerts pertaining to change of PNT source may be transmitted to shore side users through the Maritime Cloud.

2.3 User Groups involved in the testing

All services have been tested with both shipboard and shore-based users; Search and Rescue Authorities, Vessel Traffic Services, National Coordinators, Hydrographic Offices and other stakeholders, to secure relevant feedback and maintain a holistic approach important for the continued development of e-Navigation.

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3 Implemented Prototype Solutions

This section provides more details the prototype solutions used in the test bed.

3.1 Overview

The following services and solutions have been implemented in the ACCSEAS project. They are all summarised in the ACCSEAS Baseline and Priorities Report, available from the ACCSEAS website.

- Maritime Service Portfolios (MSPs) for the NSR (NSR-MSPs)
- Route Topology Model (RTM)
- **"Maritime Cloud" as an underlying technical framework solution**
- **Innovative Architecture for Ship Positioning comprising both Multi Source Positioning Service and infrastructure to provide Resilient PNT (such as R-Mode and eLoran)**
- **Maritime Safety Information/Notices to Mariners (MSI/NM)**
- **No-Go-Area Service**
- **Tactical Route Suggestion Service (shore-ship)**
- **Tactical Exchange of Intended Route (ship-ship and ship-shore)**
- **Vessel Operation Coordination Tool (VOCT)**
- **Dynamic Predictor (for tug boat operations)**
- **Augmented Reality / Head-Up-Displays (HUDs)**
- Automated FAL Reporting
- **Harmonized Data Exchange - Employing the Inter-VTS Exchange Format (IVEF)**
- Real Time Vessel Traffic Pattern Analysis and Warning Functionality for VTS

Those solutions highlighted in bold are services that were tested during the demonstrations and tests of the ACCSEAS project. In the sections below, more details on their implementation is given.

3.1.1 "Maritime Cloud" as an underlying technical framework solution

The description of the test bed infrastructure for this service is given in the Service Description document on the Maritime Cloud available on the ACCSEAS website.

3.1.2 Innovative Architecture for Ship Positioning comprising both Multi Source Positioning Service and infrastructure to provide Resilient PNT (such as R-Mode and eLoran)

The resilient PNT solutions within ACCSEAS aim to provide dependable navigation solutions at all times, even under GNSS interference and jamming conditions, through the use of complementary backup navigation systems that are independent of GNSS. The Multi Source Positioning Service (MSPS) is a critical service that assures the appropriate use of positioning and its associated uncertainties for the portrayal and reporting of the vessel's navigation solution and for applications within other services on board and ashore. A full description of the MSPS is available in the Service Description document available on the ACCSEAS website.

The ACCSEAS test-bed implementation includes both shore-side and ship-side hardware and software components.

During the project, three different systems were investigated for their potential to provide a backup PNT source for GPS (the primary PNT source used by the mariner), they were:

1. Radar absolute positioning
2. R-Mode (MF IALA Radiobeacon based and VHF AIS based)
3. eLoran

A radar absolute positioning trial was performed off the east coast of the UK in July 2013, and a technical report is available [PNT2].

A complete Feasibility Study of R-Mode is available from the ACCSEAS website. The project also conducted a live trial of R-Mode (see below).

At the present time only eLoran is capable of providing a full position solution, independent of GPS (or any other GNSS) with sufficient accuracy to meet the IMO requirement for Port Approach. It was therefore decided that this system would form the backup source employed in the trials.

The project developed an ACCSEAS Multi-Source PNT receiver. The architecture of this receiver was modelled on that proposed at the IMO; see Figure 1. It can also be considered as an early prototype of a receiver that would meet new multi-system receiver performance standards currently being developed within the IMO NCSR2 committee.

This receiver was employed and demonstrated aboard the P&O ferry Pride of Hull during trials and demonstrations of several of the ACCSEAS developed e-Navigation services.

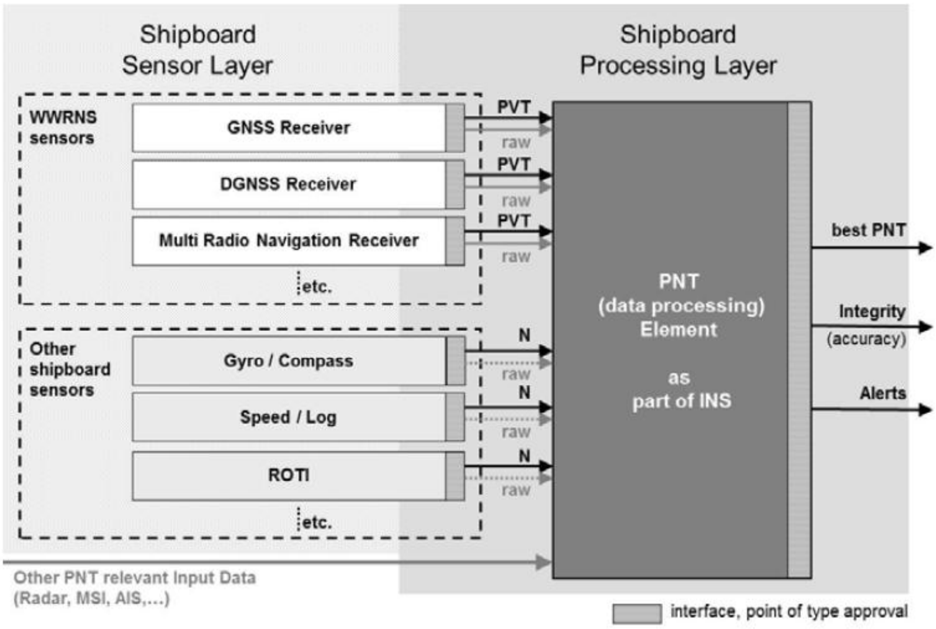

Figure 1 - Resilient PNT architecture as defined by the IMO.

3.1.2.1 eLoran Shore-side Infrastructure

For the tests a temporary and prototype differential-Loran reference station was installed in the Port of Rotterdam, and an eLoran ASF survey was performed within the coverage area of Rotterdam VTS.

The Humber Estuary, on the UK east coast, is served by a UK owned Initial Operational Capability (IOC) level differential-Loran Reference Station, capable of disseminating differential corrections valid for distance from 30 to 50km from the port.

The driver for eLoran performance in the maritime sector is position accuracy during Port Approach phase navigation, which according to the IMO requires a positioning accuracy of 10m (95%). In order to meet this requirement three vital components are needed for maritime eLoran:

1. A grid of Additional Secondary Factors (ASF) - covering each approach channel and harbour area

2. A Differential-Loran Service - with a reference station covering each approach and harbour area
3. A Loran Data Channel – broadcast as part of the core eLoran signal, to communicate differential-Loran corrections and integrity messages to the user

These components, and other eLoran technical background, are described in more detail in Annex A.

3.1.2.2 Ship-side Equipment

A receiver designed to implement the MSPS operational service was developed and is referred to as the ACCSEAS Multi-source Receiver. A total of 12 such receivers were procured for the project, the majority of which will form part of the legacy of ACCSEAS

Referring to Figure 2, the MSPS receiver consists of a DGPS receiver module, an eLoran receiver module and a computer module, along with the necessary power supply unit. The unit is mains powered.

The aim is for each receiver module to operate independently and for their respective outputs to be provided to the computer module where the ACCSEAS resilient PNT algorithms will process and analyse them and identify the “best” solution to be output to the mariner.

In order to test the performance and also to enable the test vessel to quickly return to its normal configuration, each receiver module output is also provided directly to a port on the outer case of the unit; these can also be accessed by Ethernet LAN.

The computer uses the Windows 7™ Operating System and also hosts software to control the various receiver modules. The ACCSEAS algorithms will be provided by the project partners on receipt of the unit and will be tested independently.

This is the first time that a maritime multi-source receiver has been developed and produced for use aboard vessels. As such there are no IMO minimum performance standards or IEC test specifications. ACCSEAS took an opportunity to influence and recommend an approach to the standardisation of this new type of receiver. As such, project partners have been actively supporting the development of multi-system receiver performance standards within the IMO NCSR committee along with the initial development of potential IEC test specifications within RTCM Special Committee 131. It is expected that the IEC will not begin the development of test specifications until the performance standards are approved by the IMO, both of which are expected after ACCSEAS has finished.

The heart of the MSPS functionality is built into the Matlab™ Resilient PNT Software Data Processor Module. This performs several functions, and is the key innovation in the implementation of the MSPS. The functions include the following:

- Computes a position solution based on TOA measurements from eLoran receivers, as required (also R-Mode as a future expansion)
- Stores and applies propagation data corrections (e.g. eLoran ASFs)
- Applies differential correction data to the pseudorange measurements of terrestrial PNT services
- Computes and maintains the Horizontal Protection Levels (HPL) for complementary PNT services and the primary GPS service
- Detects incidents of GPS interference and jamming, and monitors the interference level
- Potentially can be used to analyse the data output from an eRadar for the integrity assurance of absolute radar positioning
- Automatically and seamlessly switches the main PNT output of the service to the best available backup source given the prevailing interference/jamming conditions

- Generates alarms for the purposes of notifying the mariner and shore-based stakeholders

One of the most important offerings that this receiver provides is a measure of the operating PNT source's positioning error. This is achieved through the output of a Horizontal Protection Level (HPL) value. The HPL could be transmitted to the VTS centre for staff there to correlate across multiple approaching vessel and determine whether issues with a navigation system are local to the vessel or more regional in nature. More detailed information concerning this and the other data output from the multi-source receiver can be found in the MSPS service description available on the ACCSEAS website.

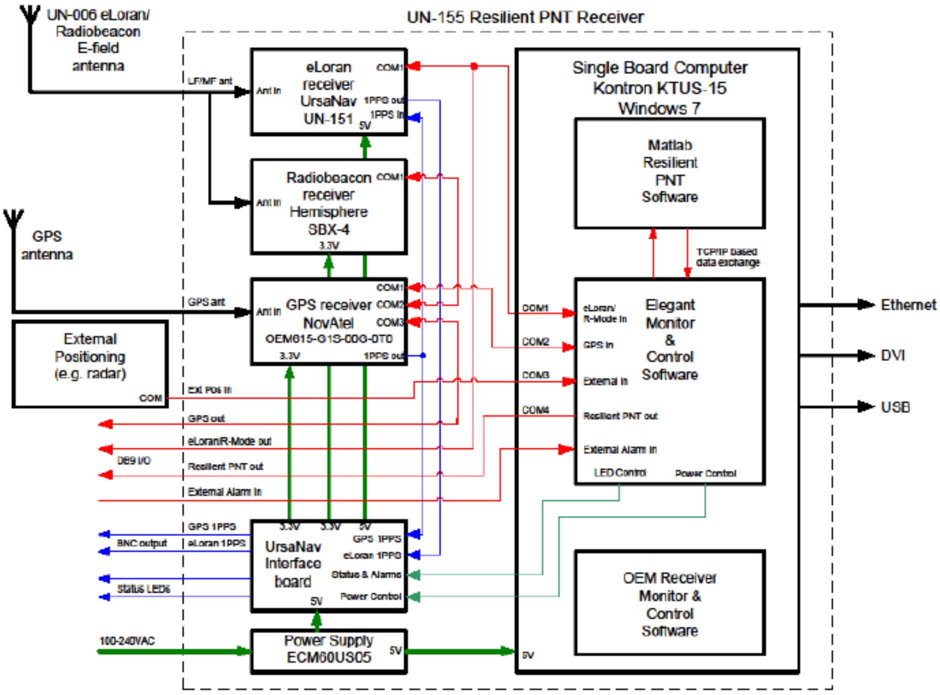

Figure 2 - Block diagram of the ACCSEAS Multi-Source Receiver.

3.1.2.3 DGNSS R-Mode Trials

High precision positioning in the maritime domain is now the norm since the introduction of Global Navigation Satellite Systems (GNSS). Unfortunately, it is well known that as low power, satellite-based systems, GNSS are vulnerable to interference (both naturally occurring and manmade); hence, the development of an alternative backup system is recommended. A variety of technological solutions to this backup requirement are possible; in the radio frequency (RF) domain we have the so-called "Signals of OPportunity" (SoOP) approach. This report considers several SoOP solutions to provide a Ranging Mode (R Mode) Position Navigation and Timing (PNT) alternative to GNSS. This work is being done in support of the EU INTERREG IVb North Sea Region Programme project ACCSEAS (Accessibility for Shipping, Efficiency Advantages and Sustainability), which is a 3-year project supporting improved maritime access to the North Sea Region through minimising navigational risk.

The R-Mode Test Bed using MF DGNSS transmission is only chartered through early 2015; this limits what can be included as part of the test bed. However, even a limited test can serve as a proof-of-concept and provide a basis for further work. The following is what the authors believe is something that can be accomplished within the timeframe of the ACCSEAS Test Bed and still be meaningful as an R-Mode field trial:

- Install a single R-Mode transmitter at one site.
- Build and install a fixed R-Mode receiver to act as a monitor site.

The installation of the mentioned system components enables the following tests:

- usability of standard MF transmitter and antenna setup for R-Mode operation
- proof of R-Mode concept using MF transmissions from IALA radio beacons
- co-existence of R-Mode signals and DGPS-transmission within one channel
- achievable accuracy figures (range and timing) in the test area
- mutual influence of R-Mode and DGNSS signal.

3.1.3 Maritime Safety Information/Notice to Mariners Service

The description of the test bed infrastructure for this service is given in the Service Description document on the Maritime Safety Information/Notice to Mariners Service available on the ACCSEAS website.

3.1.4 No-Go Area Service

Summary of this service is available in the ACCSEAS Baseline and Priorities Report available from the ACCSEAS website.

3.1.5 Tactical Route Suggestion Service

The description of the test bed infrastructure for this service is given in the Service Description document on the Tactical Route Suggestion Service available on the ACCSEAS website.

3.1.6 Exchange of Intended Route Service

The description of the test bed infrastructure for this service is given in the Service Description document on the Exchange of Intended Route Service available on the ACCSEAS website.

3.1.7 Vessel Operations Co-ordination Tool (VOCT)

The description of the test bed infrastructure for this service is given in the Service Description document on the Vessel Operations Co-ordination Tool available on the ACCSEAS website.

3.1.8 Dynamic Predictor (for tug operations)

Summary of this service is available in the ACCSEAS Baseline and Priorities Report available from the ACCSEAS website.

3.1.9 Augmented Reality / Head-Up Display

Mariners are traditionally focussed on visual recognition and identification of targets. The Collision Regulations are based as well on visual recognition of a target and its relative course and speed. Therefore the strategy and action of the Watch Officer to avoid collision is well trained and, apart from low visibility situations, is always based on visual observation and the Watch Officer's experience.

Although much effort is taken to minimize the risk of collision, accidents still happen. Accident investigation shows that human error plays by far the most important role in the cause of accidents. Once the Watch Officer is distracted from his task of watch keeping he will no longer effectively react according to the Collision Regulations.

Although ARPA/AIS can generate an audible alarm as collision Warning, Mariners who are distracted from their task will have difficulty to identify the dangerous target and cannot timely act in order to avoid collision in the little time between the alarm and the critical CPA.

On the other hand, until today there are no commonly agreed thresholds for CPA and TCPA limits to trigger the warnings. Moreover, the provided algorithm to trigger those warnings is insufficient in a way that the thresholds apply to all situations while the OOW applies different criteria for different encounter situations.

Augmented Reality can act as an Expert Support system. By superposing a virtual image on the outside world the reality is enhanced by visual clues. As illustrated in Figure 3, the direction of a dangerous target is directly visual, thus induces an immediate focus of the WO in the appropriate direction.

Figure 3 - Indication of dangerous target projected as a red box on the bridge window.

Figure 4 - Display of Suggested Route and a No-Go Area on the HUD.

As illustrated, these clues can represent dangerous targets, however, in the E-navigation domain the functionality need not be limited to collision avoidance alone. The ACCSEAS project in which this Augmented Reality study is embedded, has developed a prototype portfolio of services and solutions for mariners and related traffic management professionals. Amongst these services are 'No-Go Area Service'' and 'Tactical Route Exchange and Route Suggestion service', to name just two. Both these services can provide crucial safety related dynamic input to the navigator.

When this information is presented to the mariner through a Head Up Display (HUD) showing visual clues in their georeferenced direction on top of the real world objects, the effectivity of the information processing will be enhanced, thus speeding up the process of decision making and consequential safe manoeuvring. An example is shown in Figure 4 where the red projected box points to a critical target, and a red projected fence shows the area to be avoided and a route suggestion is shown by the projection of green 'runway' lighting. This projected information is corrected for the ship's attitude and motion and also takes into account the position of the observer in order to avoid parallax errors.

In the ACCSEAS project a testbed is set up to do a proof of concept in an existing ships bridge simulator operated by the Maritiem Instituut Willem Barentsz at Terschelling.

3.1.10 Harmonized Data Exchange - Inter-VTS Exchange Service (IVEF)

The IVEF pilot test bed was setup as well on the shore side as on one ship. At the shore side the present infrastructure was used with some expansion. Connected in such a way that the operational system could not be influenced at all. A secure internet access was granted for the ship to a separate section at the Coastguard system.

On the ship side cables, screens, software and connections had to be made to make everything possible. Special attention was made to the internet connection and the switching over between mobile network and satellite. Figure 5 shows the physical implemented test bed infrastructure for this IVEF test.

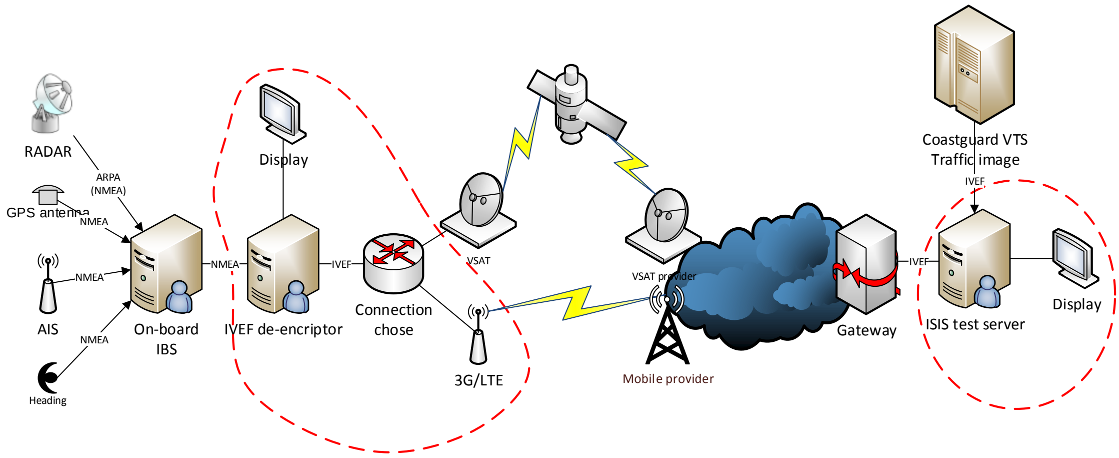

Figure 5 - Implemented sections of the IVEF test bed.

The main hardware components (already present, within red line are new/extra) are

- Sensors (radar, AIS, GPS and heading)
- The on-board IBS system
- A converter RS322 (IBS NMEA) data to TCP/IP (not shown);
- A device for converting and fusing sensor data from the IBS to IVEF;
- A screen to present the Harmonised VTS picture
- A router determine the preferred connection and to limit the throughput;
- A mobile 3G/LTE (mobile) data unit;
- A VSAT infrastructure;
- An HITT ISIS server. This server merges the KWC traffic image with the received on-board traffic image and send it back to the ship.

To realise an internet connection that would reduce costs and not interfere with the primary tasks, a combined connection type was introduced with bandwidth management. (See figure 4) This solution makes use of mobile network when available and the VSAT connection when outside of the mobile networks. Also, when operation on the VSAT communication bandwidth was maximised to 200Kbit not to disturb primary systems on-board.

To detect, switch and apply bandwidth management an extra router was placed with these features. The router was configured switching from mobile network to (on-board) VSAT and back, mainly to use the mobile network from speed and costs. All the equipment on-board is using the ITU, IEC and NMEA appropriate standards.

Just equipment would not be able to realise the pilot environment. Therefore already standard software modules were used. Next to this some extra modules had to be developed to enable the pilot. Figure 6 provides a logical overview of the software components used.

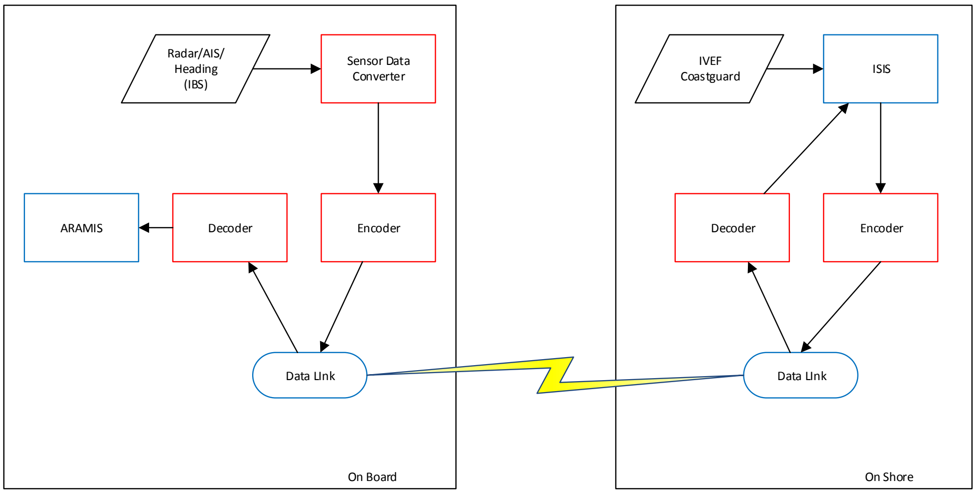

Figure 6- Test system software components.

The main software components (Blue are off-the-shelf, Red is development/modified) are:

- A converter from the sensor data in IBS data format to IVEF;
- An encoder/decoder from IVEF to compress data and link format also vice versa. For efficiency reasons, the data link format will not be the IVEF xml text format. It will be compressed;
- An ARAMIS display on the ship;

An HITT ISIS server. This server merges the KWC traffic image with the received on-board traffic image.

Using mostly standard products for realising the pilot system together with the on-board Integrated Bridge System resulted in a faster realisation of the pilot system. The other option was a ship without a suitable IBS. This would have resulted to develop more modules to accomplish the same result. For this two other vessels where inspected if they would be suitable for the pilot. They had the right sensors on board to use an off-the-shelf product, but was not suitable for this first test in case of traceability.

For operating the pilot in most cases standard procedures could be used. Only for radar tracking on the ship this had to be enabled/disabled on the IBS.

More detailed information on the IVEF is available in the Service Description document on the IVEF service available on the ACCSEAS website.

4 Test bed Methodology

In this section, we describe the methodology of testing the services in more detail, including the scenarios that were used by the participants of the tests.

4.1 Methodology Overview

The Intended and Suggested routes services as well as the No-Go Area service has been tested in a full mission bridge simulator using a Usability Testing methodology (e.g. www.usability.gov). Usability testing is a method based on the Human-Cantered Design philosophy (Norman, 1986). Usability is defined as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use." (ISO 9241-210). The important points to remember is to use the "specified users", in this case navigators and VTS operators. Further, to use "specified tasks". In this case the scenarios used in the simulator tests were developed together with, and based on real world scenarios from the areas in question. Apart from the scenarios in the wind mill park, as this did not yet exist.

4.1.1 Qualitative focus

Technical services can effectively be tested using quantitative methods. However when testing new innovative services that involves new work methods for humans, the task becomes more problematic. Purely quantitative tests could give evidence of increased safety and effectiveness, but would demand an unrealistically large number of participants to reach significance, given the complexity and time full mission bridge simulations take. One also has to keep in mind that if the new methods are not accepted by the operators the expected results is not likely to happen. Therefore qualitative methods have been chosen for the early stage of these tested services. One of the surveys questions was the one of "professional acceptance" where participants, after having tested the service, was asked to rate their "professional acceptance" on a scale from 0 to 5. Focus was also on qualitative techniques like think aloud and debriefing in a focus group. Apart from probing the acceptance of the service many good ideas for development of the service was also derived. The results were then analysed into a four level framework of conceptual, procedural, functional and HMI comments.

4.1.2 Reliability

The reliability of the tests were high as the simulators used (Transas 5000) to a large extent can simulate real world environment and uses physical ship models to simulate interaction between vessel and the environment including wave, wind and current. Also the use of local participants increased the reliability in the sense that it increased the probability that they would act according to what they would normally do and any shortcomings of the simulator environment could be filled in by their experience.

4.1.3 Validity

The validity was, however, limited because of the small number of participants. Also the ethical homogeneity of the participants limits the validity. What can be said about the generalizability of the test results is that they were well received by the communities we tested them on, however, many more similar tests in other parts of the world needs to be done before we may draw any global conclusions.

However, the tests done so far, including a ship test in South Korea, indicates good correlation between the qualitative results of different simulations and tests.

4.2 Summary of Test Scenarios

In cooperation with ABP Humber Estuary Services, a number of scenarios relevant for the ACCSEAS testing were developed. Not all of the scenarios were used in the actual tests and simulations.

SCENARIO 1 – Routing in the outer traffic separation schemes.

SCENARIO 2 – Congestion at Grimsby and emergency routing.

SCENARIO 3 – Congestion at Immingham and emergency routing.

SCENARIO 4 – Contravention scenario

SCENARIO 5 – Vessel leaving Deep Water Anchorage

SCENARIO 6 – Navigation in windfarms

SCENARIO 7 – Exchange of intended routes, vessels not following their intentions

SCENARIO 8 – VOCT scenario

(SDC = Sunk Dredged Channel, FHC = Foul Holme Channel)

4.3 Live Tests - Humber Port

The scenarios used during the live tests in Humber were developed in accordance with routine arrivals of the P&O Pride of Hull ferry. In the trials, both crew on board the ferry and Humber VTS participated, requesting Maritime Safety Information and Tidal Information from shore servers and effectively exchanging route information between vessel and VTS.

For testing, the e-Navigation Prototype Display (EPD) with basic ECDIS/VTS functionality AND the e-navigation services, were developed. All communication between EPD's and between EPD's and shore servers was obtained utilizing the Maritime Cloud.

4.3.1 Scenarios Carried Out

4.3.1.1 Scenario 1 – Routing in the outer traffic separation schemes

Objective: Test the route suggestion service.

Pride of Hull has planned a route along the green arrow shown in Figure 7. Maritime Safety Information / Notices to Mariners (T&P) (oil clean-up operations) makes it necessary to change route and follow the red arrow instead (Figure 8)

Humber VTS and Pride of Hull communicate on VHF and Humber VTS sends a route suggestion, Pride of Hull accepts and follow new route.

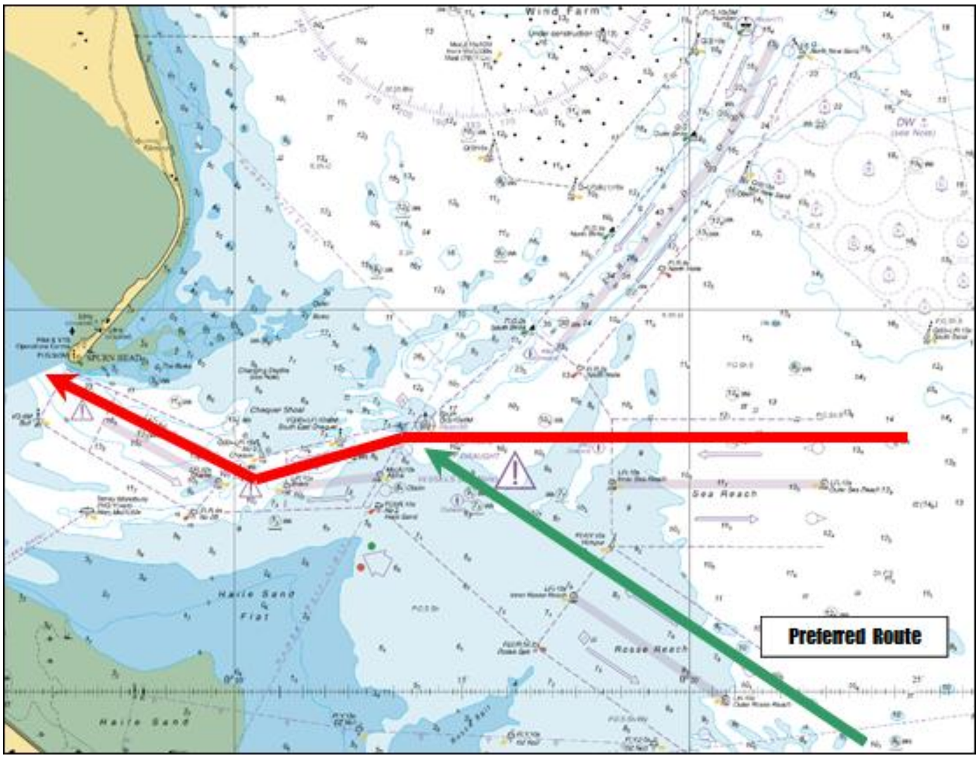

Figure 7 - Planned and suggested routes of ferry into Humber Port during Scenario 1.

TEST UK NAV WARN 008/14
NORTH SEA - HUMBER APPROACH
ROSSE REACH APPROACH CHANNEL CLOSED FOR
NAVIGATION DUE TO OIL POLLUTION
CLEANING OPERATIONS BETWEEN 53-32.0N
000-18.0E AND 53-32.0N 000-24.0E AND
53-27.0N 000-24.0E AND 53-27.0N
000-18.0E BY 'CLEANER1' CALLSIGN OXFI
AND 4 SMALLER VESSELS. GUARD VESSELS IN
THE AREA LISTENING VHF CH 16 AND CH 72.
MARINERS REQUESTED TO KEEP WELL CLEAR

Figure 8 - MSI for Scenario 1.

4.3.1.2 Scenario 2 - Congestion at Grimsby and emergency routing

Objective: Test of Route suggestion and No-Go area service – VTS sends suggested route to vessel with explanation.

The scenario was planned to be changed the other way around but due to traffic, Pride of Hull had to sail through Bull Channel – scenario adjusted accordingly.

Vessel again on an inward passage approaching Spurn Head, planned to follow the green arrow but encounters a large vessel outbound in SDC.

Humber VTS sends route suggestion to Pride of Hull suggesting to change route and follow red arrow instead.

Pride of Hull checks tide using the No-Go area service, finds there is sufficient Under Keel Clearance (UKC) and accepts route suggestion.

It was during this scenario that the Multi-Source Positioning Service was tested by the removal of the GPS signal through the disconnection of the GPS antenna from the rear of the Multi-Source Receiver Unit.

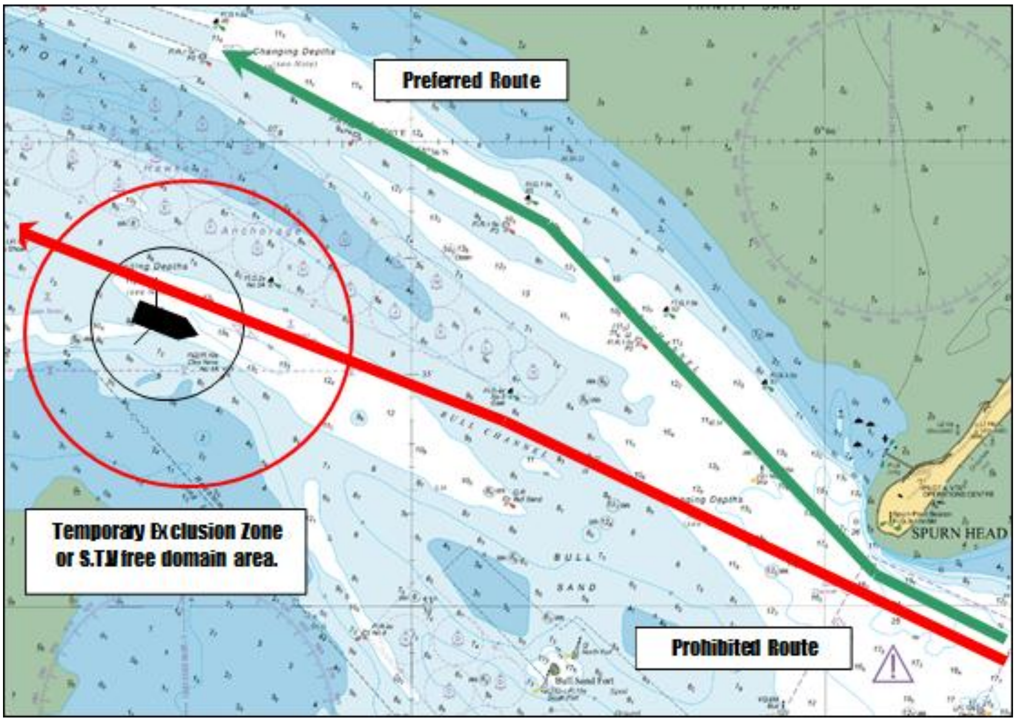

Figure 9 – Planned and prohibited routes in Scenario 2.

4.3.1.3 Scenario 3 – Congestion at Immingham and emergency routing

Objective: Test of No-Go area service and Route suggestion

Pride of Hull now inwards for King George Dock in Hull approaching Immingham one of the busiest areas within the Humber district. Several VLS (Very Large Ship) movements are due to take place ahead of the vessel which could result in the development of dangerous traffic situations and densities. The channel at the IOT (Immingham Oil terminal) is narrow and tides cross the jetty making navigation difficult. To avoid delays to the ferry or allowing the possible development of a close quarter's situation, the VTS operator recommends the use of the "Foul Holme Channel" (FHC). This channel is narrow and shallower than the main channel however, with sufficient tidal height and UKC (Under Keel Clearance) requirements satisfied this will be the safer and more efficient option for vessel routing. (Dynamic No-Go Areas).

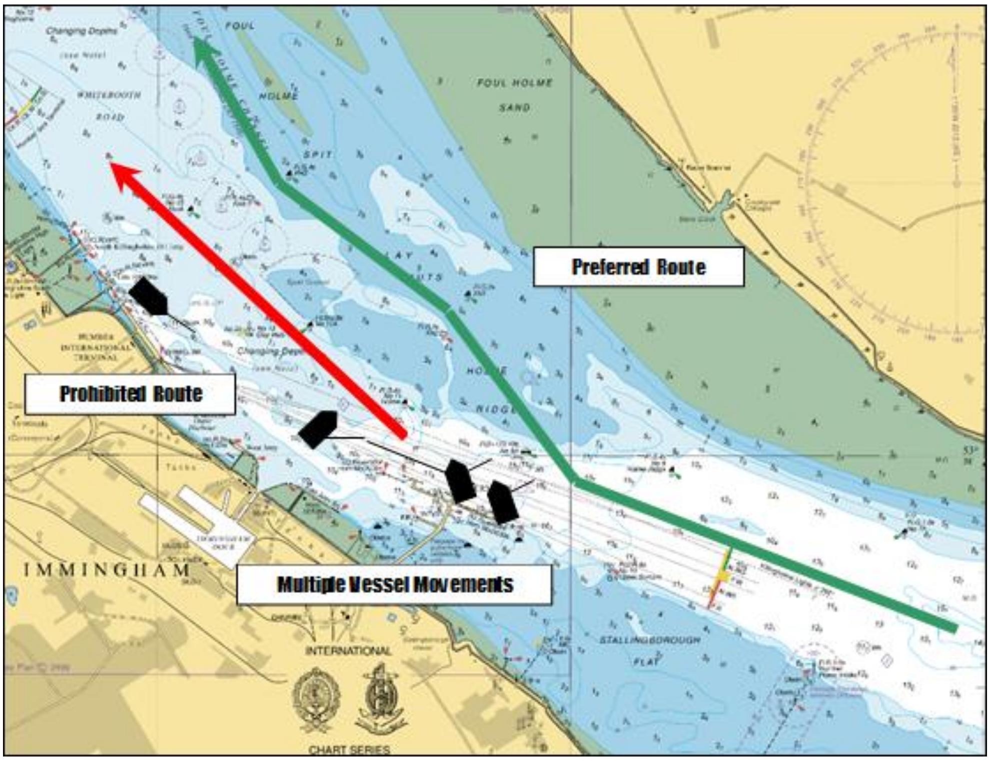

Figure 10 - Planned and prohibited routes in Scenario 3.

4.3.2 Multi-Source Positioning Service – Implementing Resilient PNT

The multi-source positioning service was demonstrated during the Pride of Hull's approach to the Humber Estuary during Scenario 2 (See above).

Figure 11 and Figure 12 show the equipment installation aboard the P&O ferry Pride of Hull.

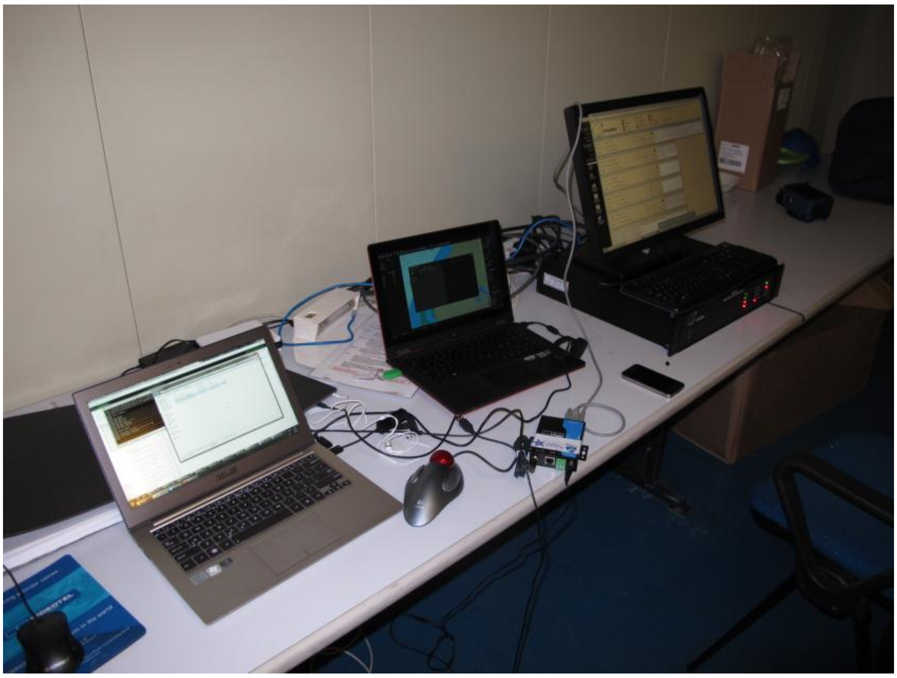

Figure 11 - EPD and Multi-Source Receiver installed in the equipment room at the rear of the bridge of the Pride of Hull. The receiver can be seen in the top right of the photograph.

Figure 12 - GPS (right) and combined eLoran/DGPS radiobeacon antenna (left) installed on the Pride of Hull.

The receiver unit contains a PC upon which various software components are installed. Figure 13 shows manufacturer supplied control software provided with the receiver upon purchase. This software, called ELEGANT connects the various receiver modules (DGPS, GPS, eLoran etc.) to the serial and TCP ports to and from which data is sent and received.

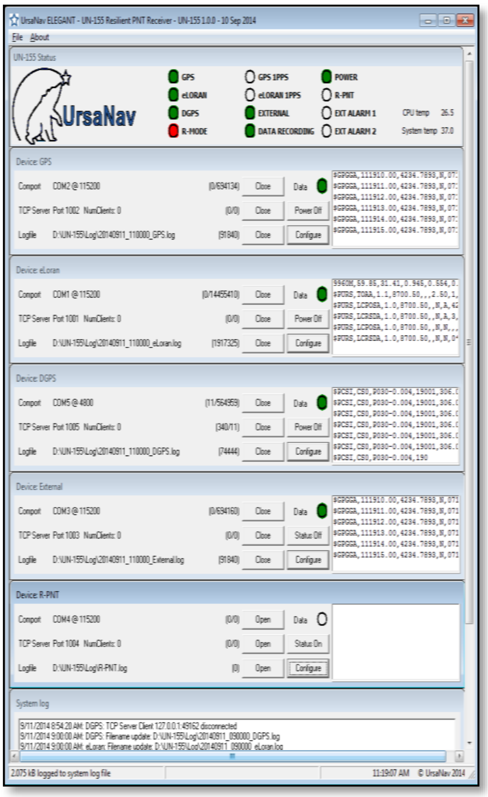

Figure 13 - Graphical User Interface (GUI) for receiver module communications setup.

In addition to this manufacturer supplied software module, ACCSEAS developed bespoke software written in Matlab™ and compiled for standalone operation. An early version of which included a GUI and is shown in Figure 14. This version was used during the ACCSEAS resilient PNT demonstrations in 2013. The software analyses the GPS data and seamlessly switch to the backup PNT source should problems occur with GPS. The later version as used in the Humber trials did not have a GUI.

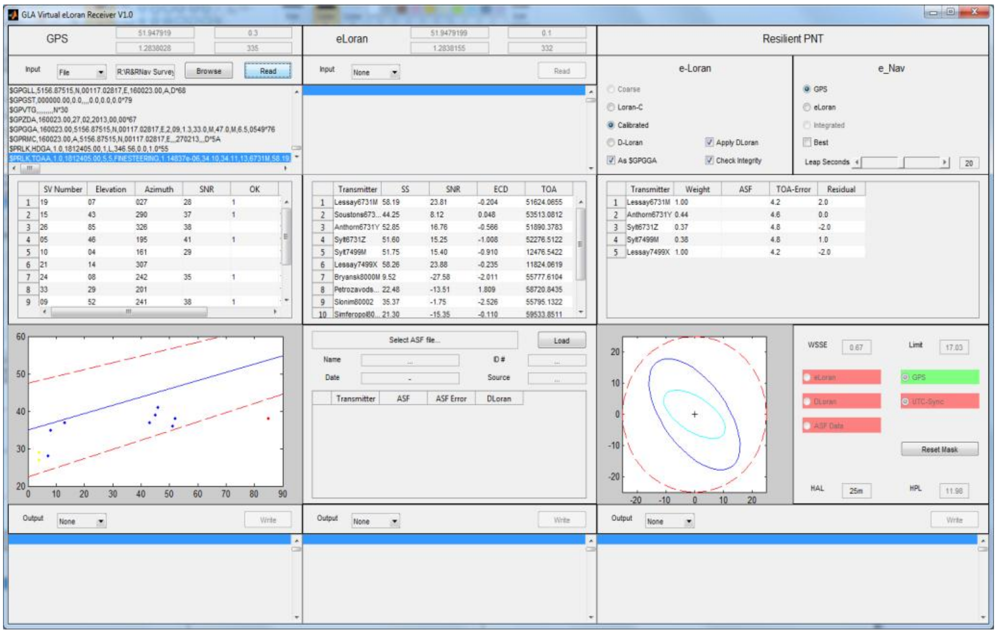

Figure 14 - An early version of the Resilient PNT Data Processing software. Recent versions forego the GUI.

Figure 15 illustrates a screenshot of the EPD, the advanced chart display software used to access the various e-navigation services. The data panel on the right hand side of the screen shows pertinent PNT information, including position, speed-over-ground, course-over-ground and heading. On the lower right is the "Resilient PNT" information panel.

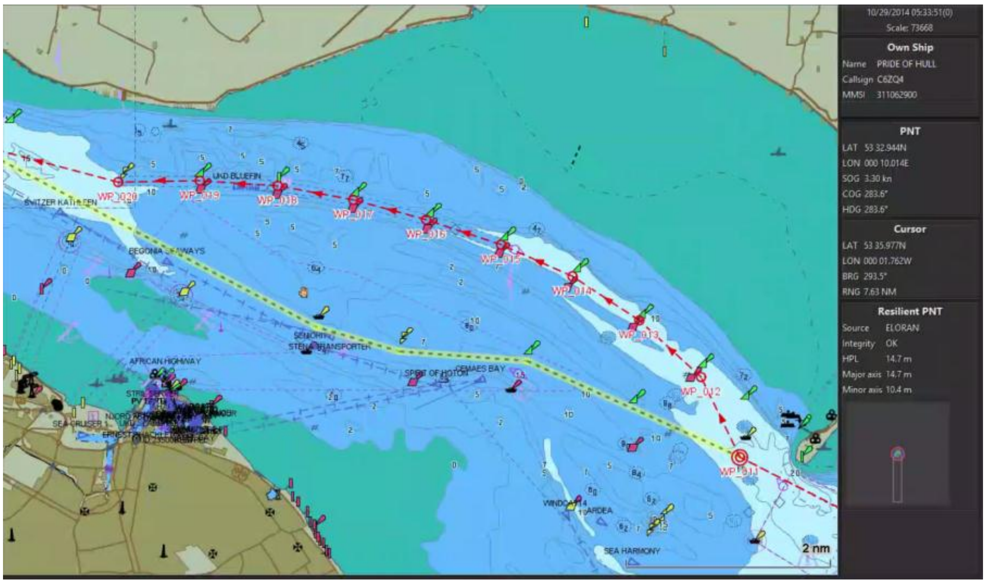

Figure 15 - EPD display panel showing PNT and Resilient PNT information on the data panel on the Right Hand Side.

Figure 16 - Resilient PNT data panel showing GPS as the source of PNT.

A close up of this panel is shown in Figure 16. On it can be seen information concerning the currently employed source of PNT, in this case GPS. The integrity indicator shows that the system is operating correctly and producing results within the desired accuracy bound. The HPL is the Horizontal Protection Level – a measure of the positioning error estimated at the 99.999% confidence level. The HPL is also used to derive a positioning error ellipse, which has components along the major and minor axes. At the bottom of the panel can be seen a line drawing of the vessel with the error ellipse overlaid. The error ellipse is rotated, in real-time, with respect to the direction in which the vessel is pointing. This allows the mariner to determine the along track and cross track error in position. This positioning geometry is important to consider when employing terrestrial radionavigation systems with limited numbers of transmitters compared to satellite navigation where positioning ellipses are likely to be more circular due to the greater number of "transmitters" available.

During the Humber Trials the EPD drew its positioning input from the ACCSEAS Multi Source Receiver. In normal operation the receiver output the primary positioning source, GPS. Upon approach to the Humber Estuary during Scenario 2 of the Humber Trials the GPS antenna was unplugged from the back of the Multi-Source Receiver to simulate an outage. Figure 17shows a screen capture illustrating the moment GPS was removed. The EPD provided an alert informing the mariner of the change. Figure 18 shows the change to the Resilient PNT data panel. The source now indicates that eLoran is currently being employed for positioning. The HPL has increased, indicating to the mariner that at that time and location the eLoran system offers a lower positioning accuracy compared to differential-GPS at the 99.999% confidence level (equivalent to an integrity risk value of 10^{-5}).

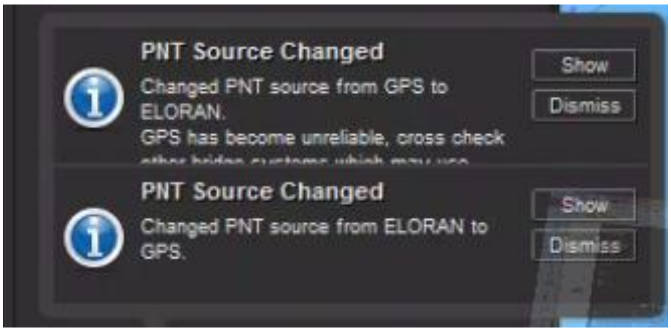

Figure 17 - Alert generated by the EPD to warn the mariner about a change in PNT source.

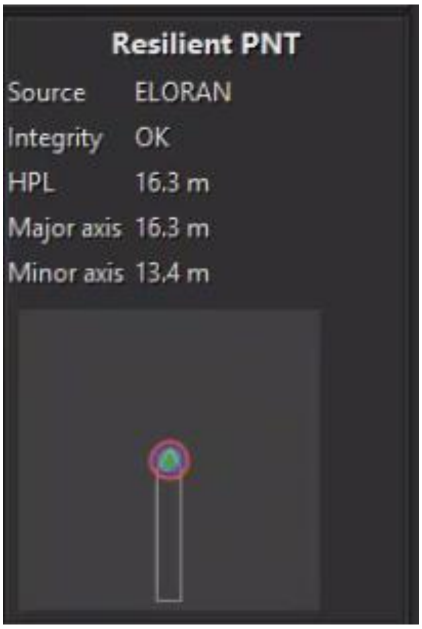

Figure 18 - Resilient PNT data panel showing eLoran as the source of PNT.

4.4 Live Tests - Den Helder

In June 2014, tests of the VOCT service was conducted off Den Helder in cooperation with Netherlands Coastguard.

4.4.1 Scenario 8 – VOCT Scenario

Scenario details:

Ship Name: ABRI

Call Sign: PH4424

Yacht Abri, vessel VHF radio does not work and it is just within the reach of the GSM network.

They have lost a person a board 3 hours ago in the position 52-53N 004-34E

Male, 25 years, condition is good, red sailing suit with lifejacket

A SAR dummy was placed in the search area by other vessel before starting the scenario.

1. The SAR operator receives call.
2. SAR operator contacts vessel on VHF and inform them of the incident with preliminary information.
3. The SAR vessel will leave and sail towards initial position provided.
4. At the same time SAR operator will calculate drift and possible position of searched object, find suitable SAR units and create search areas/patterns (using VOCT program and computer).
5. Search areas/patterns are send to vessels
6. Vessel receives search pattern and starts the search.
7. The dummy is located and rescued

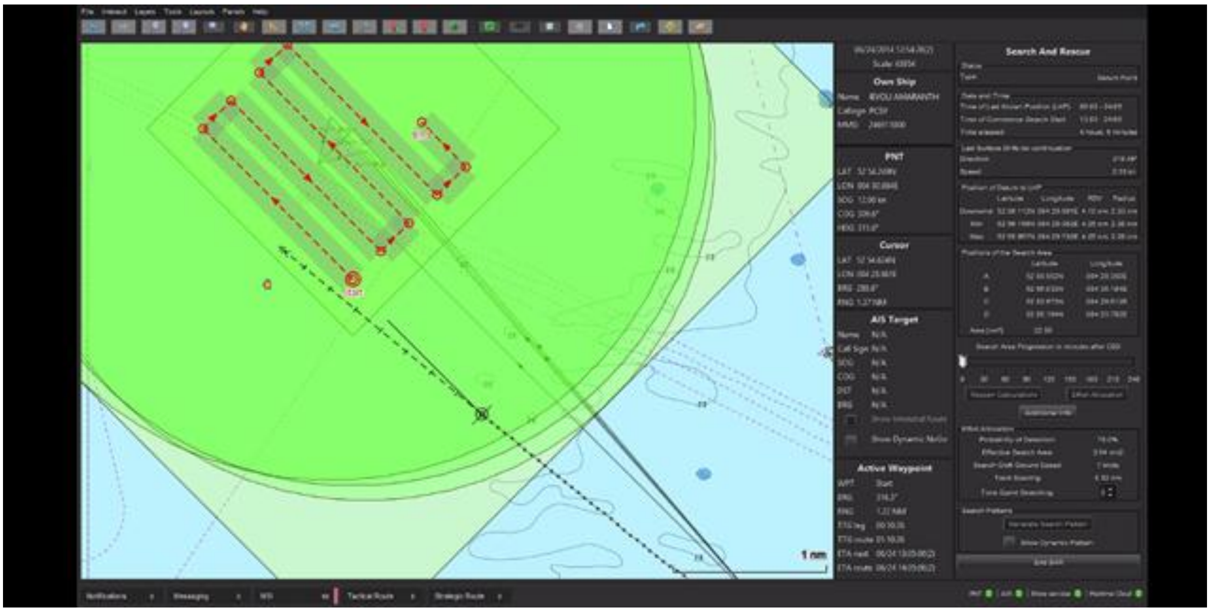

Figure 19 - EPD-Ship with search area and search pattern used in Scenario 8.

4.4.2 Test bed Participants

Role during tests	**Experience/*education***	**Age/*gender***
Operator JRCC	Watch officer/SAR Mission Coordinator, 6 years *Navy*	38 *Female*
Vessel, Captain	Tugboat/offshore, 37 years No SAR exercises or operations in career *Nautical College, basic SAR education*	53 *Male*
Vessel, Chief Officer	Tugboat/offshore, 33 years Few SAR exercises or operations in career *Nautical College, basic SAR education*	50 *Male*
Shore – focus group interview	Lifeboat skipper Coast Guard Watch Officer VTS Operator *Navy*	44 *Male*
Shore – focus group interview	Lifeboat skipper *Mate*	44 *Male*

4.5 Live Tests – Inter-VTS Exchange Format

Tests involving the Dutch VTS service was used to demonstrate the feasibility of using the Inter-VTS Exchange Format for communicating ship radar information from ship to shore. The purpose is to show that it might be possible to extend the coverage of the radar system to increase spatial awareness of those monitoring the sea-space. This should ensure that any advice is given with an even greater understanding of the traffic situation. Figure 20 shows the possible advantage of the technology. The tests will aim to show that a hidden target can be seen by the VTS centre, even though it is outside the normal coverage of the shore-based radar stations.

Figure 20 – Current radar coverage (left) and possible radar coverage (right).

4.6 Live Tests - DGNSS R-Mode

An R-Mode transmitter was installed at the location of Ijmuiden which provides a usable range for R-Mode tests of about 100 km (Figure 21).

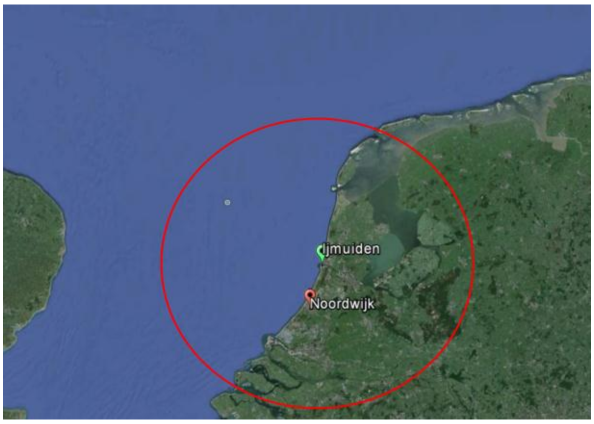

Figure 21 - Ijmuiden site with 100km range ring in red.

For the transmission of the R-Mode signals, a typical MF transmitter and MF transmitting antenna is used (Figure 22).

Figure 22 - MF Transmitter (left) and MF antenna (right) used in the test.

Based on the 3 different solutions evaluated in the feasibility study the R-Mode transmitter provides 3 signals:

- One standard MSK signal
- Two CW signals

Figure 23 – R-Mode Modulator (left) and Rubidium clock (right) used in the test.

For this purpose an R-Mode modulator was developed (Figure 23) which enable the transmission of standard RTCM messages used for the DGNSS service and two independent CW signals which can be adjusted concerning frequency and output level. Furthermore the transmission of the ranging signals need a reference timing coming from an rubidium clock.

Figure 6 show an example of a typical test signal prepared for transmission from the R-Mode site in Ijmuiden with the MSK at the centre frequency and the two CW's shifted ± 250 Hz from the centre frequency.

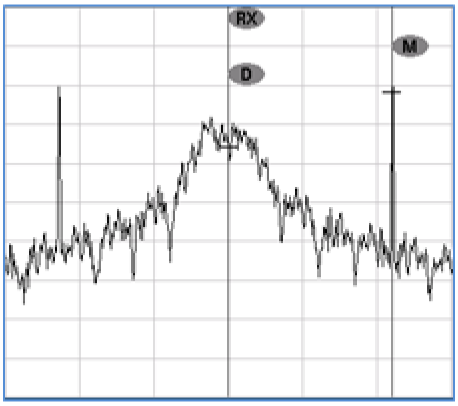

Figure 24 - Frequency spectrum of the test signal.

4.6.1 R-Mode Receiver

The R-Mode receiver needs to have the capability of measuring the pseudorange from the R-Mode transmitter. Further the R-mode receiver should demodulate the MSK signal and decode the RTCM messages. This data on pseudoranges were logged along with position and time for later analysis. For the R-Mode test bed a prototype R-Mode receiver was developed (Figure 7) consisting of an H-field antenna, a band filter with attenuator and a PC with ADC board and a MATLAB software. The receiver together with a rubidium clock was installed on a lighthouse tower in Noordwijk. The distance to Ijmuiden is about 25 km.

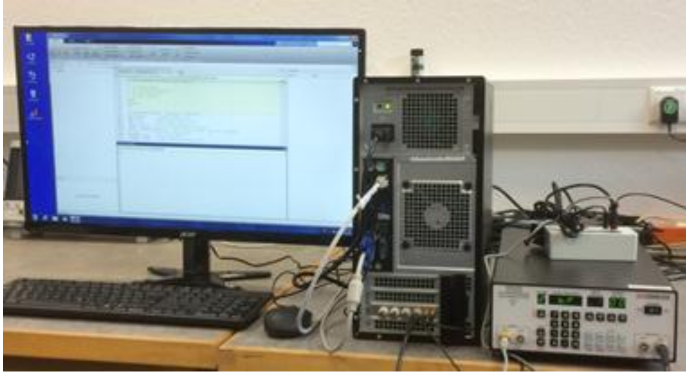

Figure 25 - R-Mode receiver at Lighthouse in Noordwijk.

4.7 Simulation Tests – Flensburg University of Applied Sciences

Below is a summary of the tests carried out at the Flensburg University of Applied Sciences in September 2014. For more detailed technical information on the tests, please refer to Annex B, and for more information on the scenarios of the tests, please refer to Annex C.

4.7.1 Scenarios Carried Out

4.7.1.1 Scenario 5 – Vessel leaving deep water anchorage

The oil tanker "Cape Mathilde" is leaving the outer anchorage of River Humber proceeding to the pilot boarding area. During the departure of the anchorage "Cape Mathilde" receives a Tactical Route Suggestion through the e-Navigation prototype Display (EPD) from Humber VTS, caused in strong currents.

4.7.1.2 Scenario 6 – Navigation in Windfarms

Three Own Ships "Yasmine" (YA), "Pride of Hull" (PoH) and "Tenacity" (TC) are sailing in the area around the brand new windfarms of East Anglia. They are following their intended routes as planned. The attention will be on the "Tactical Exchange of Intended Routes (ship-ship)" to avoid close areas within a river-like sailing area.

4.7.1.3 Scenario 7 - Exchange of intended routes, vessels not following their intentions

Three Own Ships "Yasmine" (YA), "Pride of Hull" (PoH) and "Tenacity" (TC) are sailing in the area around the brand new windfarms of East Anglia. They are following their intended routes as planned. The attention will be on the transmitted intended routes of other vessels to avoid close areas within a river-like sailing area. During the scenario some ships will not follow their intended route as broadcasted within EPD.

4.7.2 Test bed Participants

A total of 18 participants took part in the simulator study; 6 professional bridge officers (four 2nd mates, two Chiefmates), 6 professional experienced mariners (German pilots from brotherhood Kiel Canal II) and 6 students of nautical sciences, 6th to 8th semester, participated in the simulations. The nationality of one participant was Argentina and for the other 17, it was Germany. One of the bridge officers was female; all other participants were male. The range of age was 22-55. Mean age of the bridge officers was 30 years. They had a seagoing praxis from 4-6 years. Mean age of the pilots was 47 years. All pilots had more than 6 years' experience as a bridge officer and at least eight years practical experience as a pilot. Mean age of the students was 25 years. They all had seagoing practice of at least two years.

Each bridge was manned with a pilot, one bridge officer and a student, which would be realistic considering that the situations were approach to Humber pilot station and navigating in windfarms with reduced visibility and heavy traffic.

The VTS-station in scenario 5 was simulated by an instructor with three years seagoing praxis.

After each simulation run of a scenario, a group interview was conducted in the debriefing session that followed, which was of an average of 45 minutes in length. Group interviews in the form of debriefing sessions comprised approximately 450 minutes in total. The exercises explored the e-navigation functionalities in the developed test bed area of wind farms off East Anglia.

4.8 Simulations Tests – Chalmers University of Technology, Gothenburg

Below is a summary of the tests carried out at Chalmers University of Technology in September/October 2014.

4.8.1 Scenarios Carried Out

A total of 5 scenarios were carried out during this demonstration:

- Scenario 1 – Routing in the outer traffic separation schemes.
- Scenario 2 – Congestion at Grimsby and emergency routing.
- Scenario 3 – Congestion at Immingham and emergency routing.
- Scenario 4 – Contravention scenario
- Scenario 5 – Vessel leaving Deep Water Anchorage

More detailed information on the tests are available in Annex D.

4.8.2 Test bed Participants

11 professional British, Swedish and Danish bridge officers, harbour masters, pilots and VTS operators with experience from traffic in the Humber area was used for the test. All the participants were male from age 32 to 58, with a mean age of 47 years. They all had a sea time ranging from 12 to 30 years, mean 22 years.

Each bridge was manned with two bridge officers, which would be realistic considering that the situation was approach to port and constrained waters with heavy traffic.

The Spurn Head simulated VTS was manned with two VTS operators from the actual VTS centre. The VTS operators was available from the whole test except on Friday when a Gothenburg VTS operator took over the chair (after having worked together with the Humber operators on Thursday).

Full details available in Table 3.

Table 3 – Participants in the simulation tests at Chalmers University of Technology.

	Subject ID	140930-1	140930-2	140930-3	140930-4	140930-5	140930-6	141002-1	141002-2	141002-3	141002-4	141002-5
Age		55	52	41	40	32	44	58	43	52	57	47
Gender		M	M	M	M	M	M	M	M	M	M	M
Nationality		UK	Swe	UK	UK	Swe	Dk	Swe	Swe	Swe	Swe	Swe
Profession		Assistant	Pilot	Deputy Ha	Pilot	Pilot	Pilot	Pilot	Pilot	Pilot	Master	VTSO
Start as Deck Cadet			1982									
Start as Deck Officer			1986		1990	2006	1994		1995		1981	
Start as VTSO		1996										2005
Start as Pilot			1998	2002	2001	2013	2002	1996	2008	1997		
Current position		VTS Watcl	Pilot	Deputy Ha	Pilot	Pilot	Pilot	Pilot	Pilot	Pilot	Captain	VTSO
What type(s) of license(s) do you hold and which year did you acquire it (them)? Answer by filling in the year(s) (e.g. 1994) in each field(s).	Leisure crafts											
	OOW Unlim					2006			1995			
	Chief Mate Unlim		1987			2007						
	Master Unlim	X	1989	2004	2002	2010	1994		2003		X	
	VTSO	X										2005
	VTS Superv.	X										
	Pilot Cert		1998	2002	2002	2013	2002	1996	2009	1997	X	
	Other											
What type of vessel(s) do you usually operate? Several alternatives are possible! Answer by encircling the appropriate number(s) on the column to the right.	Leisure craft					X						
	RIB					X						
	Fishing vessel											
	Rescue vessel											
	Pilot Boat											
	Tug boat											
	Offshore Supply vessel								X			
	HSC								X			
	Tanker		X			X			X			
	Reefer								X			
	Dry Bulk					X			X			
	Ro-ro / Ro-Pax		X			X			X			
	Passenger vessel								X			
	Several of the above (I am a Pilot)		X		X	X	X	X	X	X	X	
	Other											
Time as Deck Cadet		4		3	3		2	3				8
Time as OOW				8	6	4	4	14	3	5	10	11
Time as Chief Mate			11		2	2	1	4	10	5	5	6,1
Time as Master						2	2		1	1	20	
Time as Pilot			16	5	12	1,5	13	18	5	16		
Sea time during past year (days)			170		160		165		10		100	
Sea time in total			28		24	12	26	20	25	16	30	19
Time as VTSO		4	5							6		8
Time as VTS Superv.		14										
Simulator experience - shiphandling		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes
Simulator experience - VTS		Yes	Yes	No	No	No	No	Yes	No			Yes
Other Comments		Teaches VTS and uses sim as lecturer					Simulation trainer at Force					

4.9 Simulation Tests – SSPA (Dynamic Predictor)

SSPA carried out tests of their Dynamic Predictor in their own bridge simulator.

Tests in bridge simulator focused on the operational service. For the tests, SSPA SeaMan Simulator was used. The setup used the 330 degrees bridge. In the consoles, the main chart was the Ship EPD developed by DMA, the second chart display shoved the chart in the open source software Open CPN. The third display show the ships conning display, including rudder, speeds, engine rpm, wind speed and direction. The radar was not used in the tests of the predictor operational service.

4.9.1 Tests performed

1. As todays operation. No dynamic or simple predictor used. Normal weather conditions.
2. Dynamic predictor without any external input.
3. Dynamic predictor with true external forces from tug.
4. Dynamic predictor with disturbed external forced from tug.
5. Use of a simple predictor using speed and accelerations only. Exchange of predicted position.

Arrivals and departures was tested.

The ship used was Coral Energy in loaded condition.

Table 4 - Details of the Coral Energy vessel used in the simulation.

LOA	154.95	m
LPP	146.67	m
Beam	22.70	m
° Draught loaded (LNG)	7.35/7.35	m
Draught ballast	5.69/4.69	m
Dead weight	8710	ton
LNG	15600	m3
Main engine	7800	kW
Service speed	15.8	knots
Max speed	18.7	knots
Propulsion	Controllable pitch propeller (119 rpm, 5.4 m)	
Bow thruster	850	kW (out of order)
Rudder	Conventional semi-spade	with max rudder angle 45

To force extensive use of the tug the bow thruster was disabled.

The port of Gothenburg quay 518 is the port of destination or departure (see Figure 26).

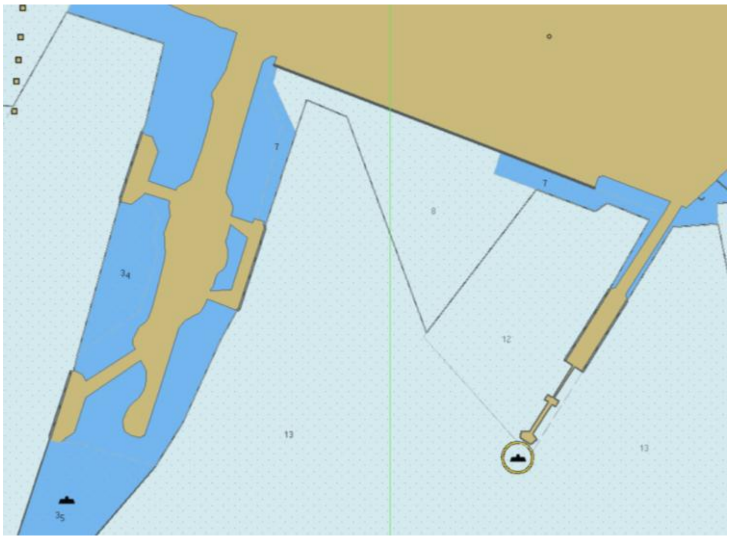

Figure 26 - Quay used for the Dynamic Predictor scenario.

A 50 ton bollard pull ASD tug was available, operated by the simulator operator (see Figure 27).

Figure 27 - Tug and vessel during the simulation.

A SW gusty wind of 10m/s is present in all simulations.

For arrival a starting speed of 5 knots is used, the starting position is in the fairway some hundred meters west of the harbour (see Figure 28).

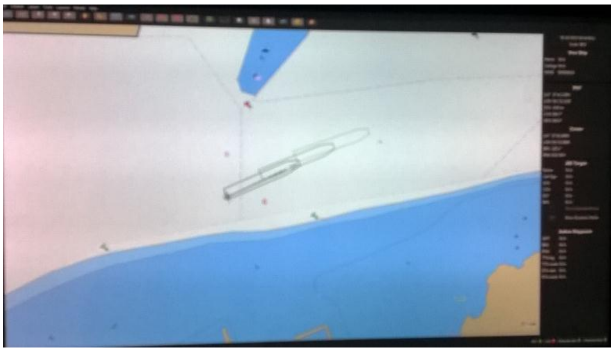

Figure 28 - Starting positions for the vessels.

Departure position is alongside quay 518, with no other ship in the harbour (see Figure 29).

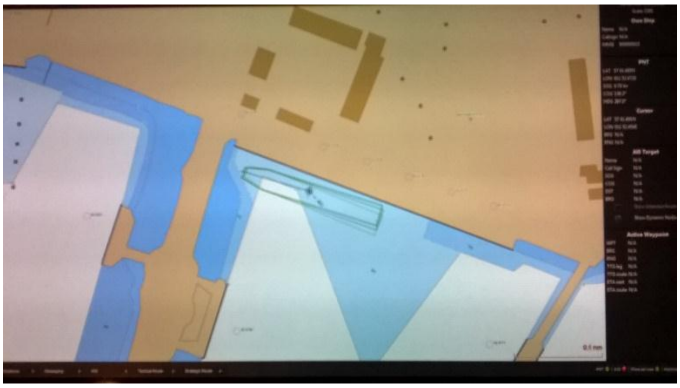

Figure 29 - Departure position when alongside the quay.

4.10 Simulation Tests – Augmented Reality

The functional layout of the proposed system is shown in Figure 30.

The Initial aim was to use one or more transparent monitors for portraying the augmentation information configured as a cocoon in front of the Watch Officer’s conning position. The company LG offered a 47inch 47WX50ML monitor based on transflective technology which promised a solution for both transparency and full colour projection. The alternative of projecting information on the existing bridge window was shortly discussed and left behind because reflection of an image on clear glass which is both clear and visible from multiple direction is only possible with a certain amount of opaqueness of the glass. This was considered unacceptable because a clear outside view is compulsory.

Eventually it turned out that the industry was not ready for large scale production of transparent 'see-through' monitors, so an alternative was found in using augmented reality goggles instead (see Figure 31).

This goggle comprises of two lenses with approximately 70 percent transparency and a SVGA projector on the remaining 30 percent of the lens. This effectively means that a synthetic image can be shown overlaid on the outside view. Augmentation by means of a tracking device provides the view direction of the wearer in three axes. This view direction is fed back to the MNARS system where it is used to calculate the relative projected position of the target, thus resulting in a co-location of the real target and its projected synthetic information in any view direction of the wearer.

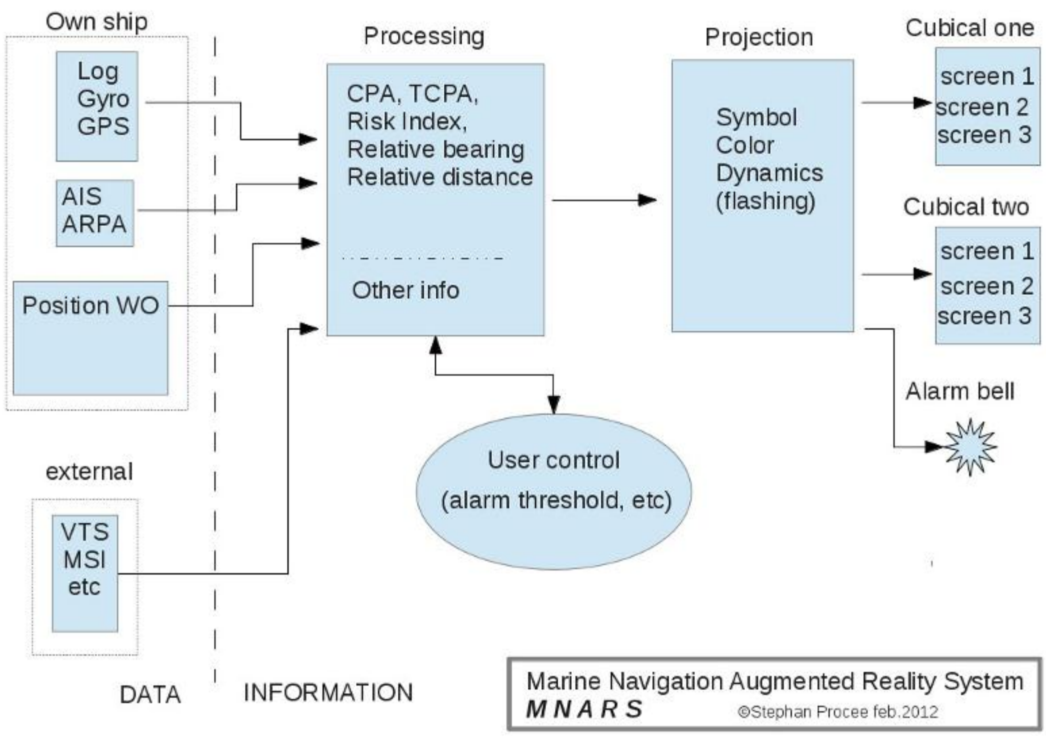

Figure 30 - Functional diagram of the MNARS "Augmented Reality System".

Figure 31 - AR Goggle in laboratory use.

As the projected ACCSEAS services were in the development phase initial focus was put on collision avoidance. So the proof of concept was aimed at portraying AIS targets in the right perspective in the augmented reality goggle.

An application was written to parse AIS messages from the coded AIVDM format to ASCII readable text and select relevant information from it like the target's time, position, course and speed. From the time, position course and speed of the own ship the relative movement of the target can be calculated on the basis of the transmitted AIS information. Thus providing a calculated CPA and TCPA of the target and a relative position, i.e. direction and distance, to the Watch Officer. This information is projected in the augmented reality goggle initially as a marker and text. Further development aims at a classed colour coding of the marker on the basis of alarm level. Alarm levels can be classified based on CPA and TPA and the sector, relative direction and distance, in which the target is located.

The test bed comprised of a Norcontrol ships bridge simulator with an own ship and an area with targets transmitting AIS messages. The stream of AIS messages is read through a COM port by the laptop on which the Augmented Reality application is running. Filtering is done to overcome the discontinuity in time of transmitted AIS messages because all targets send their messages in different time slots and in different rates depending on their status, speed and turn rate.

The goggle's position and direction of view is measured by a 'Tracker'. This device consists of a system of magnetic transducers and sensors. The sensors are mounted in an overhead box. Experience learned that this system of magnetic direction sensing was not ideal in a configuration of a relatively high metallic ceiling in combination with a magnetic rich environment. Another conclusion from practical use was that the speed of the tracker follow up cannot be too high. When moving one's head even the slightest time lagging of the tracking system leads to a sluggish follow up of the synthetic projection of the target resulting in a loss of correlation between target and synthetic information.

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5 Test bed Results

This section provides details on the results of the testing as detailed in the previous section. It is mainly based on the responses from those that participated in the tests and demonstrations.

5.1 Live Tests – Humber Port

Results from the Humber Port tests have been integrated into the conclusions section of this report.

These tests were recorded on video, and the results can be watched on the ACCSEAS website or on YouTube.

5.2 Live Tests – Den Helder

The VOCT concept was tested live off Den Helder, Netherlands with participation of Netherlands Coast Guard Joint Rescue Coordination Centre (JRCC) and a Coast Guard vessel.

A dummy was dropped off the coast before initiation of scenario. Drift, Search areas and search patterns were then calculated at JRCC and sent via the Maritime Cloud to the Coastguard vessel for direct presentation on EPD. When information was received on board, vessel was tracked for SAR unit management, and additional search information was shared between participants via the shared log functionality.

Both the build in calculation module (IAMSAR calculation) and import from the drift calculation system normally used by JRCC was tested.

The participants were a mix of experienced SAR Mission Coordinators/experienced SAR professionals and ship’s crew with background as Master Mariners but without dedicated SAR training.

The VOCT concept was very well received by all participants.

On the shore side (JRCC) the possibility to transfer information digitally and graphically to SRU’s were emphasized together with the shared log functionality. Communication is a huge and time consuming task in SAR operations today. Important information may be lost or forgotten when exchanged via voice. Information exchanged via the shared log is stored and may be extracted for later reference and the use of text messages and digital transfer will at the same time ensure that the information sent/stored is the same as received.

The basic calculation functionality based on the IAMSAR Manual may not be sufficient, so the import/export from other drift calculation systems will be very important or communication capabilities based on a standardized exchange format may be part of such systems in the future.

On ship side the crew not normally involved in SAR operations were very positive towards the VOCT concept. Especially when not involved in SAR operations or exercises often, the calculation and management may be time consuming and difficult. Graphic display and sharing of information may improve search results and reduce workload on ships crew during a SAR operation, also moving focus from communication to the important task of lookout.

All ship side participants expressed concerns on the size of text and numbers used on the screen which were hard to read. Text and numbers need to be bigger.

All participants had hopes that the VOCT concept would be developed further and result in future systems with VOCT-like capabilities.

5.3 Live Tests – Inter-VTS Exchange Format

During the tests of the IVEF involved persons on board of the Coastguard vessels and at the Coastguard centre were very enthusiastic about the usefulness of the information. Some of their reactions were foreseen but others came when the project progressed.

Because the data presented was fused with other information for the user it was not easy to determine the difference. For example, a AIS target seen by the shore system with their sensors and later fused with the radar information would still be the same on the screen unless the AIS has a different position than the radar.

Users on ship and shore side gave the following comments:

Ship side:

1. The functionality gave the possibility to see further than their own sensors could detect. Therefor they could locate ships earlier what gave them more time to plan;
2. They had the same picture as on shore as on the ship what gave no information gap between ship and shore side. This resulted in less (miss)communication;
3. Drifting buoys or other drifting material without AIS could be identified and transferred to the shore side
4. Vessels without AIS (like pleasure crafts) coming into the area were detected earlier in the area where shore based radar images are available;
5. Extra data not present on the ship added on the shore side became available on the ship.

Shore side:

1. Smaller targets further away from the shore infrastructure could be tracked due to the higher accuracy of the information from the on-board radar systems;
2. AIS targets with transmission problems could in some cases not be received by the shore system due to distance to the closest base station. These were received by the ships AIS mobile station and then transferred to the shore side;
3. Targets only detected by one of the shore infrastructures sensors could be verified by the sensors on-board of the ship.

5.4 Live Tests – DGNSS R-Mode

After the setup of the R-Mode equipment in Ijmuiden and Noordwijk a first measurement campaign was performed over two days (07-08 February 2015). The recorded data were analysed with respect to signal to noise ratio and the accuracy of the range accuracy phase measured from the phase determination of the two CW signals and the beat frequency of both signals to solve the ambiguity. Results taken from the trial are shown in Annex E.

The results show that the accuracy of the ranging signal at 25km is better than 5m for the majority of the time. This is highly encouraging for a prototype system.

5.5 Simulation Tests – Flensburg University of Applied Sciences

Tactical Route Suggestion and exchange of intended routes
The following results are the categorized list of feedback from the Flensburg simulation trials and from the observations and the input received from participants during and after the trials during the debriefing sessions.

5.5.1 General Feedback

It was concluded that there were indeed clear benefits of the concept of the novel candidate solutions of the display and exchange of intended route and shore based route suggestion.

It was believed that due to the unfamiliarity with the EPD, it appeared to be a tool for a well manned warship and added to the work load of the bridge team by designating one person to the particular piece of equipment.

Overall the candidate solutions were received positively by the participants in Flensburg.

5.5.2 Feedback on the EPD

Participants felt that training would help them overcome unfamiliarity with the EPD.

Technical comments were made to the DMA team with respect to the improvements in the EPD.

The information should be integrated with the ECDIS and even provided on the ARPA radar which can display the route of the acquired target and hide if required.

5.5.3 Feedback on display of intended route

The improvements included the link to the real speed of the vessel to add value, instead of the CPA between vessels when they would be on that particular route. In this respect the orange, yellow and neon crossing lines were critiqued as causing clutter and information overload.

Confusion occurred when past tracks of vessels who have passed before cluttered the screen and it was difficult to identify the track belonged to which vessel.

Colour change was suggested to indicate a new ship whose route had previously not been displayed or for one who has altered route.

Intelligent filtering systems were suggested.

5.5.4 Shore based route suggestion

It was suggested that the participants will query the route provided by the shore and may reject it outright, if it is not accompanied by a suitable reason or justification for the route segment being sent from ashore. The reasons would serve as explanations for the shore-based action.

The message box of the route sent from shore and certain boxes that remain on screen, while querying had the potential to block the view of the officer from the information, he/she would like to look at.

This candidate solution has created new ways of working and communicating as the shore based VTS can query if the vessel has not displayed its intended route or if it has displayed, then why is it deviating from the route.

5.6 Simulations Tests – Chalmers University of Technology, Gothenburg

The results from the simulations have been derived from data gathered using video protocol, discussions during de-briefs following the completion of each of the five scenarios, and two questionnaires focusing on demographics and professional acceptance respectively.

The results from the video protocol and discussions have been categorised in four levels: conceptual, procedural, functional and HMI (Human-Machine Interface). Quotes presented below have been taken from the video protocol.

5.6.1 Conceptual level

All the participants agreed that the tested services were valuable. “I might not have said so three days ago, but now having used it: Yes, the concept is very good, provided the data that is displayed is correct.” Another participant concluded that “after having used the system for six hours I find it annoying not being able to see ships intentions.” (The participant was referring to the fact that some of the target vessels did intentionally not send out Intended routes.)

The conceptual level was categorised in five sub-categories: Training, Cluttering, Turning off transmission intended routes, Use in approaches and open sea, and Trust.

With regard to Training one of the primary concerns of several participants was the availability of correct data and that users need training to understand strengths and weaknesses of such data. There is also a noticeable difference on training levels among navigators on different types of cargo carriers, where normally the best trained navigators with regard to system use, are those serving on-board tankers, as these are heavily vetted by the oil companies. This is often noticeable from a voyage planning point of view, where tankers normally have every detailed plans going all the way into berth, whereas other types of vessels tend to have less worked through plans.

As for Cluttering, it was generally felt among the participants that the current system design, where the user is able to interrogate single vessels for their intended rout, is better than displaying all vessels' intended routes at the same time, which would most likely clutter the display, depending on traffic situation.

Turning off transmission intended routes was something which was discussed from the outsets that if a vessel needed to deviate from its intended route there would be a way of turning off or even automatically turn off the availability of planned rout information to other vessels. One of the participants reflected on this saying "Yes, having no data is better than having the wrong data" to which there was a general agreement among those other participants However, the participants were also in agreement that for minor deviations from the intended route, like overtaking, or giving extra space in a meeting situation, it would not be necessary to stop sending, or changing the intended route, as the participants felt it would be obvious why the deviation was made. There was also an agreement that the Intended route service should not be used as a collision avoidance tool in close quarters situations.

It was felt that, when looking at the various uses of the presented concept solutions in approaches contra open sea, the Intended Route Service was found to be more important for use in the open sea rather than in approaches. The reason for the latter is primarily based on the fact that there were already risk mitigation options available in approaches, such as pilots and VTS. An example of open sea use would be areas with junctions

As for the last of the sub-categories, Trust, one of the participants said, to which there were general agreement among others, on a question that "I will not trust 100 percent, but it is helpful", reflecting over information transmitted to him in the form of Intended route and also making a comparison to his daily use of AIS information.

5.6.2 Planned speed vs. current speed

There was a major discussion on how to use planned speed versus current speed and one of the participants argued that "you always want to go a little bit faster to make sure that you can make your ETS, a Rush to wait. You will burn a little bit more fuel, but it costs more to let the stevedores, the lorries, etcetera wait." Following this reasoning, the planned speed would not necessarily be acceptable or even used by the navigators, hence the system should use current speed as its basis for calculation.

5.6.2.1 Pre-checked Alternative routes

The question of use of alternative routes, as used on many occasions when navigators are preparing voyage plans, and how this would be reflected by the Intended rout service was brought up in discussions by participants. It was generally thought that both the primary route as well as the alternative would be prepared as of today, including being checked for UKC, etc., but that only the primary route should be available as the one being displayed to other vessels upon request.

5.6.3 Procedural level

Discussions on the Procedural level focused primarily on the question on workload, both from a navigators' point of view as well as from a VTS perspective.

It was the generally envisaged by the participants that once the usability of the concept had been improved to a more mature and implementation ready level, the workload of the navigator would in fact remain the same as in today's navigational situation. However, as one of the participants put forward, "the workload re-mains the same, but the system will increase the quality of decision making". The current system, based on the EPD test platform, required the navigators to split up on the bridge while navigating; one being the navigator, the other handling the new system functionality. This was, however, envisaged to be changed with future version of the tested system.

From a pilot point of view it was deemed the Intended route service may in fact reduce workload as cooperation with the bridge team would become easier, knowing that both the bridge team and the pilot will have the same information available to them with regard to other vessels intentions. An example, given by one pilot, was that he spent a lot of time while piloting, explaining to captains and watch officers alike the intentions of other vessels in the area. Such, of the time consuming, discussions would be highly reduced, leaving more time for focusing on the actual navigation.

From a VTS perspective, it was envisaged that the Intended route service would increase the quality of service, yet also increase the workload for VTS Operators, especially in areas providing Traffic Organisation Service (TOS).

5.6.4 Functional level

A suggestion which came up during discussions was that the ECDIS could include a guard zone aft of the own vessel, which could make the intended route of overtaking vessels visible.

Also, it was also suggested that the Intended rout service should include a warning functionality, indicating if a vessel in vicinity changed its intended route, since it may be difficult to monitor such changes when navigating the own ship.

5.6.5 HMI level

5.6.5.1 Intuitive use

The question of usability of the system was discussed and it was agreed by all participants that it is high importance that not only one or two of the navigators on-board understand and know how to operate the system, but that the system design is such that it is easily understood and operated by all navigators.

5.6.5.2 Cluttering

Some of the participants involved in the first two days of trials reacted on the cluttering of information, as it was thought to distinguish between different types of information on the displays. With the assistance of the system programmers, some graphical changes were made to the display of information and by the end of the second day, the participants found interacting with the system and extracting information easier and clearer. Among other things colours displaying various information were changed, primarily increasing the contrast between colours, but also using circles for indicating a highlighted vessel. "The green colour of the intended routes makes them difficult to see; especially if you got more than one. Maybe you could use different colours; you need to be able to separate one vessel from another."

It was also found to be difficult to see the information on overtaking vessels at some points, as the own vessel's track may hide the intended rout of an overtaking vessel. A suggestion was that routes be transparent as not to hide other routes, depth soundings, etc.

There was also some discussion on the resolution of text on displays based on comments from several of the participants “When you get to our age you cannot see such small print”.

5.6.6 Survey

The participants were asked to summarize their impressions about the service in a professional acceptance survey, which included three questions. Only 9 of the 11 participants for the two days answered the survey as 2 participants had left early during one of the days.

1. What is your opinion about the tested In-tended routes concept? All the 9 answering participants answered “Good” or “Very good”. No-one answered “I don’t know”, “Bad” or “Very Bad”.
2. Do you think a similar Intended routes concept will become reality in the future? On this question all 9 participants answered “probably” or “most probably”. No one answered “I don’t know”, “probably not” or “most probably not”.
3. What is your professional opinion about the system tested? On this question the participants were asked to rank their acceptance on a scale between 0 and 5 where 0 was “Totally unacceptable”, 1 was “Not very acceptable”, 2 was “Neither for, nor against”, 3 was “Acceptable”, 4 was “Very acceptable” and 5 was “Extremely acceptable”. The mean acceptance score from the 9 answering participants was 3.7, somewhere between “Acceptable” and “Very acceptable”.

The gathered answers were set in relation to the data gathered with the demographic questionnaire. The results indicate that there were no differences in acceptance of the tested "route suggestion" functionality between participants of different age, nor previous experiences as navigators/pilots/VTS Operators. Set in relation to this, it was strongly indicated during discussions, that the high acceptance of the route suggestion functionality was based on the VTS Operators bridging the introduction of the new functionality to the navigators using VHF communication

5.7 Simulation Tests – SSPA (Dynamic Predictor)

In Table 5, time from start of simulation to first touch of the quay is shown. Table 6 shows the transverse speed the time step before first touch of the quay, Fat value being the landing value.

Table 5 - Time for simulation to finish using different predictors.

Predictor type	First simulation		Second Simulation	
	Time (min)	order	Time (min)	order
No predictor	13	5	15.4	1
Simple predictor	11.7	2		
Dynamic Predictor without tug force	15	4	11.4	2
Dynamic predictor with disturbed tug force	12.1	3	13	3
Dynamic predictor with true tug force	17.8	1	10.7	4

Table 6 – Transverse speed with different uses of predictors.

Predictor type	**First simulation**		**Second Simulation**	
	Fore	Aft	Fore	Aft
No predictor	**0.2046**	0.0166	**0.1216**	0.1355
Simple predictor	**0.0422**	0.3099		
Dynamic Predictor without tug force	**0.0988**	0.3708	**0.0829**	0.3721
Dynamic predictor with disturbed tug force	0.1038	**0.2266**	**0.1493**	0.0330
Dynamic predictor with true tug force	-0.0014	**0.1253**	**0.3034**	-0.0602

5.8 Simulation Tests – Augmented Reality

One of the results is the demonstration of the tracker and AIS superimposed image on the augmented reality goggle. The first test was done in the ACCSEAS project group where a log file of AIS messages was projected in the goggle where the observer was located in a classroom without simulator targets present (see Figure 32). The meaning of this demonstration was to show the feasibility of the goggle and its intended use to the ACCSEAS expert group. It was agreed that the augmented reality has enormous potential for practically every domain. In the navigation domain, where visual reconnaissance is still considered dominant, it certainly has the potential of increasing situational awareness.

Further findings are that training is needed to get accustomed to the overlay of a dynamic image over the real outside view. Personal observation learned that focusing on the dynamic virtual image is not very difficult when the real background is kept steady, i.e. not moving one's head. However, focus was immediately shifted to the background when this background got dynamic e.g. by moving one's head in another direction. Training methods to learn how to deal with observing two images, or two layers of information, at the same time have to be developed.

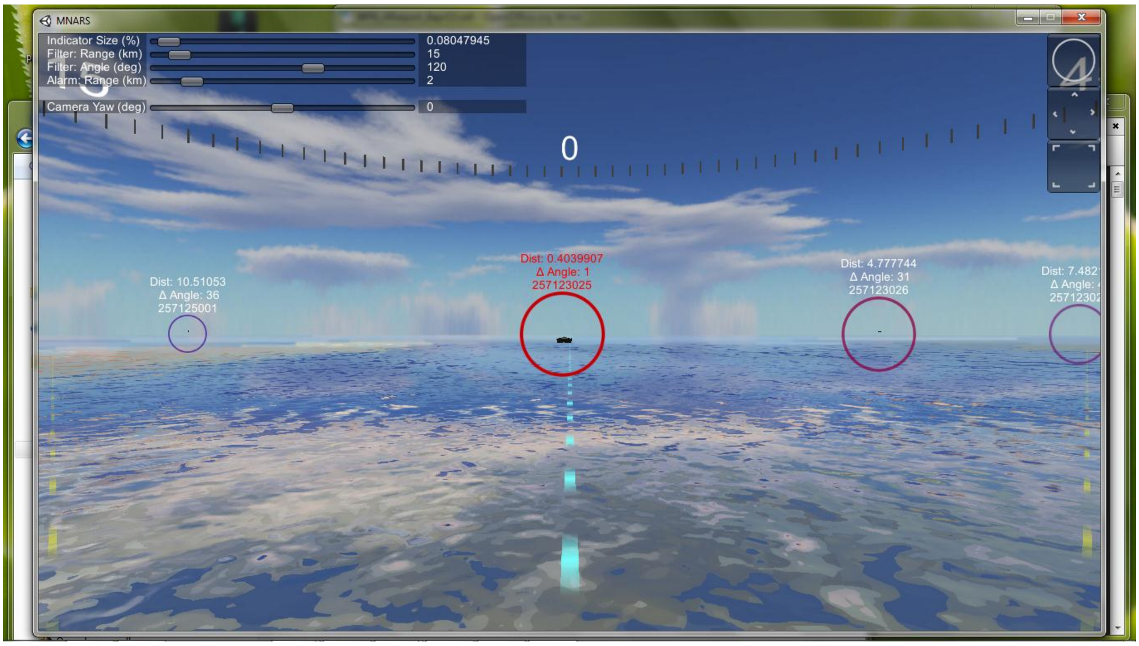

Figure 32 - Demonstration of AIS log file in the MNARS system.

6 Conclusions and Recommendations

6.1 ACCSEAS Solutions Conclusions

6.1.1 Innovative Architecture for Ship Positioning comprising both Multi Source Positioning Service and infrastructure to provide Resilient PNT (such as R-Mode and eLoran)

The ACCSEAS project has successfully demonstrated, in two separate trials, the efficacy of Resilient PNT using multiple sources of positioning information. During the first demonstration, performed aboard the THV Galatea in February 2013, a GPS jammer was employed to explore the scenario of a vessel approaching a land based source of intentional interference [PNT4]. During the live Humber Trials it was not possible to employ a live GPS jammer owing to the nature of the vessel – an operational ferry on a routine trip from Rotterdam to Hull. In this latter trial GPS failure was simulated by unplugging the GPS antenna cable from the Multi-Source Receiver. The switch from GPS to eLoran was instantaneous, with the vessel's position on the EPD was maintained accurately.

6.1.1.1 Conclusions and Lessons Learnt

The Multi-Source Positioning Service as developed under the ACCSEAS project has demonstrated the steps towards meeting the pertinent gaps outlined in the IMO's e navigation Gap Analysis; these are described in Table 2.

The Multi-Source Receiver used aboard the Pride of Hull operated extremely well. The transition from GPS to eLoran was seamless, rapid and automatic.

The development of the Multi-Source Receiver has helped inform international receiver standardisation and performance requirements.

6.1.1.2 Future Work

Collaborative Navigation

With "Collaborative Navigation" the aim would be to take advantage of the availability of the Maritime Cloud to share radionavigation system calibration data (for example eLoran ASFs) with shore-side databases and other vessels. The ACCSEAS Multi-Source Receiver contains all the necessary components to make propagation data measurements that are vital to the functioning of terrestrial radionavigation systems. This data may be collected during normal operations of the receiver installed aboard vessels going about their business. Data collected may be automatically "dumped" to a central repository, collated, processed and then disseminated as updates to existing databases, perhaps on scheduled monthly or quarterly updates.

It may also be possible to share calibration data between vessels as they pass one another; one into and one out of a region of leg of the RTM.

Remote Alerting

Remotely transmitting PNT status flags and HPL values to shore-side users, for example VTS. This could provide VTS an opportunity to identify GPS outages and their locality determined by the number and location of vessels affected by the outage. This would allow the VTS to develop MSI messages in a timely fashion for dissemination to the wider maritime community.

Expansion with ARIADNA Functionality

The inclusion of aspects of the EU Framework 7 project ARIADNA could be performed under a future ACCSEAS 2 programme of work, including expanding the use of the HPL computation to affect the "volume" of the vessel.

6.1.1.3 DGNSS R-Mode

Future work about R-Mode is required in the following topics:

1. R-Mode using MF transmissions from IALA radio beacons
   a. measuring the influence of sky wave and other environmental variations
   b. measuring the influence of transmitter and receiver setup
   c. assessment of various R-Mode solutions (based on R-Mode feasibility study)
   d. Equipment of at least two further MF-radio beacons with R-Mode setup to perform real positioning tests
   e. Further develop the existing R-Mode receiver to perform position calculations
   f. Further develop the existing R-Mode receiver towards a user friendly receiver
2. Enlarge the test bed to include transmissions from AIS shore infrastructure
3. Further develop the R-Mode receiver to use AIS transmissions
4. Test the combined solution

6.1.2 Maritime Safety Information/Notice to Mariners Service

The following is a categorized list of feedback from the MSI/NM (T&P) focus group/workshop, and from input received from participants during the user test and after the workshop.

6.1.2.1 General Feedback

- It was concluded that there were indeed clear benefits of a combined MSI-NM model/system to the mariner/end user
- A pending task is to flesh out the work process for editors, such as quality assurance.
- In general, there is a need to harmonize naming conventions between MSI and NM messages, and harmonize base data such as areas and categories.
- There is a clear need for compatibility with existing systems, such as NAVTEX, for the foreseeable future.
- Before using the MSI-NM system operationally, it needs lots of UI tweaks and polishing, plus better robustness and browser compatibility.

6.1.2.2 Feedback on the combined MSI-NM model

- Participants were generally in favour of the global identifier format and sequence numbering scheme adopted by the MSI-NM system, but it was concluded that more investigation was needed. Will e.g. omitting week numbers from NM's have unforeseen consequences?
- Participants were generally in favour of the time model adopted by the MSI-NM system, but the need for an issue-date field was raised. This would be particularly useful for SafetyNET-promulgated MSI messages, since they must be republished every 42 days. This also calls for an alert mechanism prior to the re-publishing deadline.
- Participants were generally in favour of sharing and harmonising the hierarchical category and area base data between MSI and NM, as adopted by the MSI-NM system.
- As an aside, it was discussed if areas could be left out of the model altogether, since messages are assigned geographical locations. However, the conclusion was that a textual area description is still an important part of a message presentation.
- For NM messages in particular, there may be a need to be able to assign multiple areas to a message.
- It was concluded that a priority (routine, important, vital) should not be part of an MSI-NM message – it is left to the client (ship) to prioritise the messages. Note, however, that the NAVTEX publication of a message still carries a priority.

6.1.2.3 Message Viewing

- It was proposed to have the option to show MSI and NM messages in separate layers and to consider making the icons more distinguishable.
- In map view mode, message information should be displayed via mouse-over tooltips.
- It was proposed to facilitate integration with real-time information, e.g. by linking messages to the contractor working on the issue that the message pertains to.

6.1.2.4 Message editing

- Participants called for better AtoN integration, such as a rich text editor tool for inserting AtoN pictograms in description field.
- It was concluded that there was a massive need for simplifying the creation of MSI messages. The vast majority of MSI messages are written in a completely standardized way that is tied to the category/hazard of the message; this also ensures that the messages adhere to the strict NAVTEX standards and guidelines. After the user test was completed, the MSI-NM System has been extended with an extensive template system to address exactly this point.
- Additional simplifications were requested, such as removing/hiding editor fields not considered relevant to MSI messages when editing such ones?

6.1.2.5 Message Management:

- It was agreed that, once published, a message should not be editable. If changes are required, the original message must be cancelled and a new one issued.
- There seemed to be a need for a more fine-grained quality control of messages before they are published, e.g. by enforcing a verification and a proof-reading workflow.

6.1.2.6 EPD integration

- It should be investigated how to present messages with no geographical information on graphical clients such as ECDIS, and ensure that they are read by the OOW.
- It was debated if the OOW should be allowed to delete MSI-NM messages, and how to ensure that the next OOW see all relevant messages. This could possibly be handled by requiring all new OOW's to start their watch by reloading all MSI-NM messages.

6.1.3 Tactical Route Suggestion and Exchange of Intended Routes Services

6.1.3.1 Conclusions from Flensburg Simulations

The ACCSEAS candidate solutions of the display of intended route and shore based route suggestion were well received. The technical aspects were found wanting as the technical integration of the candidate solutions in EPD were not the finalized products but rather the prototypes which were being tested and therefore the participants also focused a lot on the technicalities, which impacted their perception of reliability.

Conclusions and Lessons Learnt

As one main conclusion a recommendation is with respect to developing and finalizing the candidate solutions and their execution in the EPD shall be realized in such a way that technical glitches do not mar the experience of the participants. With respect to smooth introduction of the candidate solution familiarization training should be provided to end-users. The following conclusions and recommendations have been derived from the trials. There is training foreseen for equipment where the candidate solutions are to be integrated themselves. Tactical route suggestion and exchange of intended routes will be integrated in on-board systems like the ECDIS.

Related integrated training shall include information and practice on how to use the functionality in the specific interfaces, navigate the interface and e.g. create, substitute, modify or delete waypoints and routes for transmission. The critical point with respect to training was the limitation of the functionality of display of intended route. The limitations should be included in the training and communicate that bridge teams need to keep in mind that the information displayed on their screens revealed the Closest Point of Approach (CPA) between routes and not between actual targets. The information displayed reveals the distance between vessels when they are on that particular route. Caveats and limitations of the functionality were considered essential with respect to training to avoid overreliance. Training in intelligent filtering to avoid cluttering the screens was also considered essential by the seafarers.

Future Work

Adaptable user interface

From analysis of the simulation trials and the focus group discussions further research into individually adaptable human-machine interfaces for the different purposes of the end-users is suggested.

Exchange of route information involves not only navigators on-board but also VTS operators ashore as well as pilots e.g. planning embarkation manoeuvres. While the involved pilots and navigators overall gave positive feedback with respect to how the functionalities have been implemented there were discussion on situation specific configuration requirements that should be researched in more detail to define functions for optimal adaptation to situation-specific needs of individual operators.

Development of dedicated CBT modules

To support smooth introduction of new functionalities and in order to realize the complete benefits of enhanced e-Navigation based services it is obvious that there should be also Computer Based Training (CBT) modules from the manufacturer providing training to support familiarization especially on the integration of the functionality, its use and limitations. Such CBT units should be further complemented by in-house training regimes of companies and should be integrated into training courses like that on ECDIS, which would do away with the need for any additional training.

Simulation training to immerse the trainees in scenarios which highlight the value of the information and support provided by the new candidate solutions, would add further value to the training programme.

6.1.3.2 Conclusions from Gothenburg Simulations

- The Intended route service was considered a valuable concept.
- Intended routes should be displayed on a need to know basis, being able to customize and not to clutter the screen.
- The green, dashed representation was considered OK if the route of a particular vessel was highlighted on rollover to make its track more salient. The routes should also be transparent not to hide important information.
- Use current speed to calculate the next 8 waypoints used for the intended route service (unless one of the waypoints is the final destination or otherwise designated as “critical”, e.g. arrival at a lock).
- The results indicate that the "route suggestion" functionality served as a graphical means of supporting voice communication between navigator and VTS Operator. It was also indicated that this is considered valuable by both navigators and VTSOs and that both groups expect to see this kind of feature in future operational use.
- The results further indicate that the use of the “route suggestion” functionality could reduce the risk of miscommunication between VTSOs and navigators and that the

functionality could assist in increasing the shared situational awareness between VTSOs and navigators sailing in a VTS-area.

6.1.4 Dynamic Predictor (for tug operations)

The pilot manoeuvring the ship thinks the predictor is useful and helps the manoeuvre, but he did not use the predictor very much the last minute before landing on the quay, transverse speeds was more interesting in the latest part. He thinks the situation awareness and communication between the master and the pilot will improve with a dynamic predictor. Earlier in the project, some tug masters gave input on what they think about seeing the ships dynamic predictor. The conclusion is from these interviews that the situation awareness is improved by getting indication of rate of turn and how the ship moves.

None of the measured parameters gives a clear indication that the dynamic predictor with tug forces included make the manoeuvre more safe or more efficient. Maybe the time between first and second simulation indicate the predictor assist in learning the ships behaviour.

6.1.4.1 Safety margins

Taking a closer look on the track plots (Figure 33) indicate some simulations with very small safety margins. These four simulations all have different predictors, simple, disturbed, none or regular.

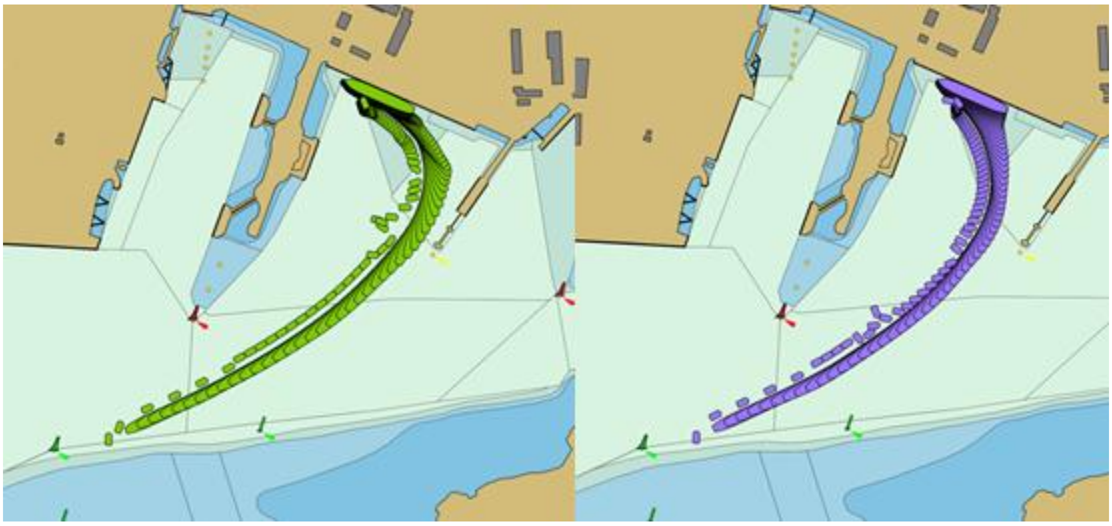

Figure 33 - Arrival with small margins (left) and with larger margins (right).

One comment from the Pilot was that the predictor might be more useful on a large vessel, like a VLCC.

6.1.4.2 Departures

A few departures was also tested (see Figure 34). The time evaluation criteria for time is from the tug is pulling 20% or more to a point is passed on the way out of the harbour.

The departure time is between 8.4 and 9.9 minutes and no correlation can be found between the predictor types. The pilot does not feel the predictor is a helpful tool for departures.

Figure 34 - Departure during Dynamic Predictor testing.

6.1.4.3 Discussion on the method

Using one full day give too few simulations to get any significance. Learning effects is most clear between the first and second simulation. The pilot was well familiar with the dynamic predictor having used it in the simulator earlier. A much more extensive test schedule will be needed to identify if any significant difference is to be found.

6.1.5 Augmented Reality / Head-Up Displays

The application has two functions, one is to alert the mariner by means of an audible signal together with a visual clue pointing towards the dangerous target through the Head-up Display, and the other is a display of operational information. Operational information can be considered in the widest sense. It is certainly not limited to collision avoidance.

As outlined in the ACCSEAS prototype description, anti-grounding and Marine Safety information are equally important. The effective management of safety critical information is a key factor in safe navigation. Depending on the situation this sometimes leads to an information overload for the watch officer in which he is just limited assisted by the integrated bridge systems presently on board. Moreover, the high number of alarm signals generated by each individual system on a modern ships bridge might even contribute to the state of information overload. Thus, helping the mariner in his decision making on the basis of relevant and validated operational information should be one of the key elements to enhance safety. Augmented Reality aims at increasing situational awareness by showing visual clues in the real world direction, i.e. Head-up, and acts as an information filter and expert support decision system.

The selection and validation of available information is traditionally done by the human on the bridge. Although this task will stay there as long as humans operate ships, it can be foreseen that an increase in the amount of available information, as already shown today by the introduction of multiple ways of communication (e.g. satellite and AIS), leads to a harder task of managing information than before.

Thus any support in effective information management must be investigated. The role of Augmented Reality can be important in this regard. Validating information is done by the WO more effective when the information is filtered and portrayed in geographical referenced direction. The quality of system (re-)generated information is effectively checked by visualizing the information as overlay on the visual outside real world, thus enhancing the integrity of the system as a whole and increase the user appreciation if the functionality of the system.

As already pointed out, a functional alarm algorithm is of paramount importance for user acceptance. Users confronted with either false alarms or lack of alarms lose their faith in the system completely. Setting the alarm threshold too wide, in order to have more time to react, is considered disadvantageous because it might generate unwanted alarms. It also happens that alarms are switched off because of the numerous false alarms.

The present testing is aimed to check the technical feasibility of an AR application, i.e. a proof of concept in the simulated environment. Secondarily testing is needed to investigate what the 'human factors' implication is for the watch keeper. It will be very interesting for example to find out whether WO's tend to feel themselves protected by a 'last resort' alarm as described and act accordingly or whether it has no affect at all. At the Maritime Simulator Training Centre (MSTC), situated near the Maritiem Instituut Willem Barentsz at Terschelling, each year over 1000 students and licensed mariners are trained, so a great number of test persons with a wide variety of experience can be found for testing.

The ACCSEAS prototype e-Navigation services such as Route Exchange and grounding alarm (No-Go area) are foreseen to be projected as an overlay on ECDIS. However, the functionality of AR might increase the effectiveness or the acceptance of these services. This should be tested in a simulated Ships Bridge environment.

Development is ongoing, a selection of topics that need to be addressed in relation to Augmented Reality and e-Navigation are:

- Input sensors, what is the relation of the navigation sensors in use to the accuracy of the calculated CPA/TCPA and the reliability of alarm
- Decisions on alarm threshold and target classification.
- exchange alarm threshold with other ships/VTS
- Display unit, is there a user acceptance to wear goggles during watch, will alternative monitors be developed as time and foreseen use progresses
- Multiple users on the bridge, what about the use of Augmented Reality when a bridge team consisting of Captain, Pilot, Watch Officer and Cadet is working on a difficult high-traffic landfall during limited visibility.

Augmented reality has great potential as man machine interface in the navigation domain. However this is unknown territory in a great many aspects. Much work and testing needs to be done to evaluate this innovative concept in the broad field of human factors and the technical aspects mentioned

6.1.6 Harmonized Data Exchange - Inter-VTS Exchange Service (IVEF)

The IVEF pilot gave several issues/lessons learned that can be concluded in the following advice.

6.1.6.1 Organisational

1. Find the right contacts on all sides (make a stakeholder map) whom are interested and motivated to help;
2. Make an inventory of possible problems the parties could encounter. Like:
    a. Operational;
    b. Legal;
    c. Organisation;
    d. Political;
    e. Goals;
    f. Technical.

3. Explain the importance of sharing data for their process but also explain the possible problems and project them on their goals and problems it would fix;
4. Make clear that "Cloud" thinking (sharing data instead of collecting it on your own) will fulfil the user need better, faster and cheaper;
5. Make clear that possible future budgets cuts will emphasize the need for sharing and collecting data because there is not enough money to realize your own system.

6.1.6.2 Technical

1. The Maritime Cloud could in the future solve problems with sharing data to all stakeholders. For making use of the Maritime Cloud some issues should be solved:
    a. Legal matters for privacy and responsibility matters;
    b. Fusing process where should that be done;
    c. Rights whom can see which data.
2. Technical connection through the IVEF protocol is a good solution in cooperation with the Maritime Cloud. Most functionality is incorporated in the protocol. Secure connections and compression if the data is not incorporated. This was done intentionally because these are evolved more rapidly than the IVEF.
3. Sensor data from and to systems should be more standardized and should be held mandatory by official bodies like IMO, IHO and ITU.

The results from the tests will be analysed and discussed with the users on both sides if this functionality would be worth having. If this is the fact a business case will be made to implement in on more vessels.

6.2 ACCSEAS and S-100

S-100 has been devised by IHO as the new framework for marine data-related product specifications and has been adopted by IMO for the development of e-navigation. It has also been an aim to evolve S-100 into a standard that can be used generally for maritime specifications, not just for ENC/GML/ECDIS-targeted specifications.

As part of the ACCSEAS project, the project has looked at creating a combined model for MSI and NM T&P. A result of this has been a proposed standardized MSI-NM interchange format and guidelines for the portrayal of MSI and NM in navigational clients. ACCSEAS has furthermore aimed at specifying the combined MSI-NM model in terms of an S-100 specification.

However, the scope of a combined MSI-NM model is much broader than displaying these messages on an ECDIS. At its core, MSI-NM has a standardized XML model (XSD), which can be transformed to formats such as JSON, MSDL (Maritime Service Description Language), GML, and so forth. The result may be displayed on an ECDIS, but may equally be displayed on websites, in mobile apps, sent by e-mail, etc.

The resulting MSI-NM S-100 specification follows the S-100 guidelines in terms of specification structure and chapters, feature catalogue, application schema, etc. However, features and attributes have not been registered with IHO, and data has not been tied to the various ISO-19100 standards.

Indeed, the work with MSI and NM has proven that the present S-100 framework not to be very suitable for the development of the combined MSI-NM model. For a work-in-progress proposal, such as the MSI-NM model, it was concluded that it would be prohibitively expensive (in terms of money, time and skills) to create a fully compliant S-100 model at this stage.

6.3 Impact of Solutions on Accessibility to the NSR

The ACCSEAS project started by looking at the challenges to maritime accessibility in the North Sea Region. In particular, the impact of increasing traffic density and larger ships in reduced sea-space was considered and explored. As a result of this work, the solutions detailed earlier in this report were proposed in the ACCSEAS Baseline and Priorities Report, first published end of 2013. Now in its third edition, it covers the IMO's work on the Sustainable Maritime Transport System and the Strategic Implementation Plan (SIP) for the e-Navigation concept that underpins all the solutions in ACCSEAS.

As shown in the previous chapters, each solution has been able to demonstrate its ability to improve spatial awareness or information integrity for both the mariner and shore-based authorities.

6.3.1 Improved Spatial Awareness

Improving the spatial awareness of the mariner and shore-based authorities will allow those users to get a better understanding of the current situation around them. The Baseline and Priorities Report highlighted the potential issue of increased traffic in tighter shipping lanes created by windfarms, particularly in the southern North Sea. There will be an increased reliance on ship systems to navigating through these areas to ensure that the risk of collision and grounding remain low.

Through demonstrating e-Navigation services such as the Tactical Route Exchange, No-go Areas and the Augmented Reality Head-up Display, ACCSEAS has shown that solutions can be developed that will allow users either to receive information they cannot yet get or is more difficult to obtain. This information will enable the mariner, and shore-based authorities, to understand their immediate and near future environment in a more clear and intuitive way. The demonstrations have shown that users are enthusiastic about the improved view of the environment that the ACCSEAS solutions provide.

By improving the spatial awareness, the users of the Region will gain a better understanding of how to traverse the Region with more confidence, efficiency and safety. This can only serve to gradually increase accessibility in the North Sea Region.

6.3.2 Improved Information Integrity

Information integrity is crucial in informing all uses of the situation in the maritime space. It underpins the acceptance and ultimate success of e-Navigation as an emerging driver for improved safety and efficiency. It is therefore unsurprising that a number of the solutions demonstrated in ACCSEAS have the aim of ensuring that the information presented to both the mariner and shore-based authorities is accurate and delivered in a timely manner.

Good examples of such services are Resilient PNT (improved integrity of positioning and navigation information), MSI/NM (improved and more reliable maritime safety information delivery), Vessel Operations Co-ordination Tool (faster and more reliable delivery of search and rescue information) and Inter-VTS Exchange Format (improved shore-based visualisation of the sea-space).

The impact that improved information integrity has on accessibility is very clear. By ensuring that the mariner and shore-based authorities get reliable information, the decision making can be more certain and less likely to cause collision and grounding. Reliance on unreliable information, whether deliberate or not, can only cause an increase in the risk to the vessels and the environment. The solutions, demonstrated in ACCSEAS to real users of the North Sea Region, has the real potential to minimise the informational errors and increase confidence, safety and efficiency in the North Sea Region.

6.3.3 Impact on Training

The ACCSEAS project has demonstrated solutions that will have an impact on accessibility to the North Sea Region and its ports. The solutions would be of limited value if the users were not suitably trained on the using the services to maximum benefit. The Training Needs Analysis and the Use of Simulators in e-Navigation Training and Demonstrations Reports highlight the need for robust training of users in the new technology and its application in navigating the seas. It is here that the training and research institutes play a critical role in covering the human factor of e-Navigation services and solutions.

Without this, the solutions developed in the ACCSEAS project will not achieve the intended outcome of improving accessibility in the North Sea Region, and even has the possibility of causing collisions or grounding due to misunderstanding or too little training on the systems. As e-Navigation solutions develop, including the ones demonstrated in ACCSEAS, it is imperative that training and the human factor is a key aspect at all stages of implementation to ensure that maximum benefit, including improved maritime accessibility, is realised.

ACCSEAS has gone a long way to investigate the human factor of e-Navigation technology, and has proposed further work to ensure that as the concept evolves, the training evolves alongside it. This will give e-Navigation the best opportunity to provide the maritime users of the North Sea Region, and beyond, much needed tools to tackle the challenges of the future.

Annex A eLoran Technical Background

The driver for eLoran performance in the maritime sector is position accuracy during Port Approach phase navigation, which according to the IMO requires a positioning accuracy of 10m (95%). In order to meet this requirement three vital components are needed for maritime eLoran:

1. A grid of Additional Secondary Factors (ASF) - covering each approach channel and harbour area
2. A Differential-Loran Service - with a reference station covering each approach and harbour area
3. A Loran Data Channel – to communicate differential-Loran corrections and integrity messages to the user

The GLAs intend to install maritime eLoran around the UK and Ireland in two phases:

1. Initial Operational Capability – eLoran at 7 major port approaches on the east coast of the UK by July 2013; Dover, Sheerness, Harwich/Felixstowe, Middlesbrough, Humber, Leith and Aberdeen.
2. Full Operational Capability – eLoran covering all major ports in the United Kingdom and Ireland by 2019.

By way of an introduction we now briefly outline these components.

A.1 Additional Secondary Factors (ASF)

eLoran receivers calculate their position by measuring how long it takes the system's 100kHz ground-wave radio signals to reach them over the surface of the earth from the transmitters. The measured propagation times are called 'pseudoranges'. eLoran receivers measure the pseudoranges of a number of signals from transmitters placed around the coverage area. The typical range of an eLoran transmitter is up to 1500km or so, so eLoran is a wide area, regional system.

Figure A.1 shows an example of some lines of position (circles) with the transmitters at Sylt (Germany), Anthorn (United Kingdom) and Lessay (France) at the centres. The reception of signals from three stations is sufficient to compute a position.

The receiver measures these time delays and, by assuming a value for the propagation speed of the signal, the position relative to the transmitters can be computed. The speed of a ground-wave radio signal depends on the electrical conductivity of the surface over which it travels. For example, it travels slowest over ice, deserts and mountains, a little more quickly over good farming land and quickest of all over sea-water.

eLoran receivers compute their position in two stages. Firstly, they assume that the entire earth's surface is covered in sea-water and they therefore employ a sea-water propagation model for the speed of propagation. This model is based on a set of standard parameters suggested by the United States Coast Guard, and it models propagation over sea-water in earth's atmosphere very accurately. eLoran receivers assume the signals propagate over sea-water because they cannot possibly know about the land along each of the propagation paths.

Figure A.1 - Example of circular positioning using Anthorn, Lessay and Sylt.

In the second stage, the delays due to land paths are taken into account by adding them to the pseudorange measurements. These delays are called Additional Secondary Factor delays, or ASFs for short. Their values are expressed as microseconds of delay, and are typically supplied to users as a database built into their receivers. ASFs are the dominant propagation phenomenon affecting the accuracy of positioning and navigation with eLoran.

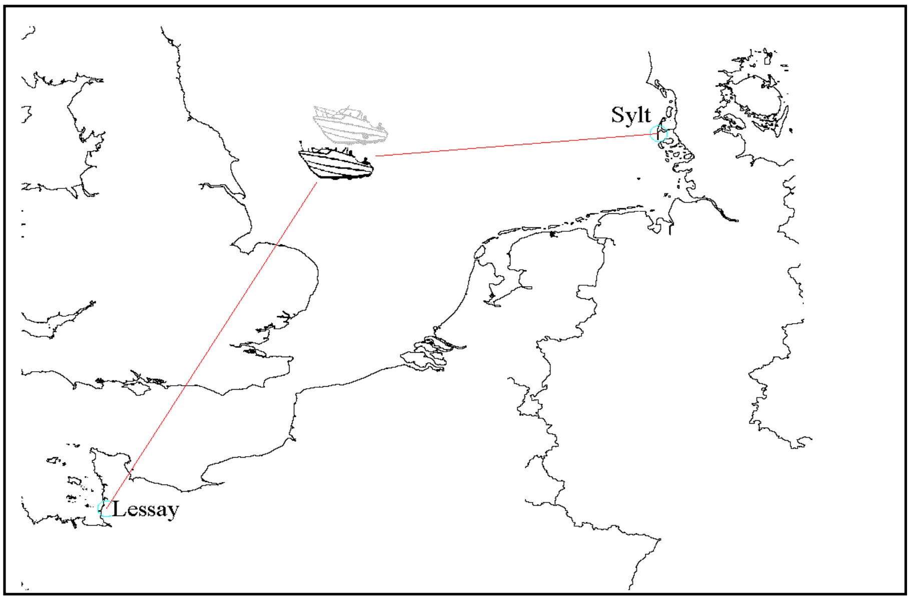

Figure A.2 – ASF due to Lessay results in a position offset if it is not taken into account.

If ASFs are not taken into account they appear as a bias, or offset, in the measured pseudorange of an eLoran signal. Figure A.2 illustrates this; the position of the vessel determined by the eLoran receiver is offset from its true position because of the land in the propagation path from the eLoran transmitter at Lessay.

The simplest, and most accurate, way to map ASFs is by measuring them using a survey vessel. The true position (the ground-truth) is typically determined using differential-GPS, which has a horizontal accuracy of 1m or so. If the ground-truth position is compared to the position given by an eLoran receiver with a sea-water only propagation model, the position offset would be due to ASF.

A.2 Measuring ASFs

The GLAs have electronic equipment that is capable of measuring ASFs, a photograph of which is shown in Figure A.3. An ASF Measurement System consists of an eLoran receiver, a GPS receiver, custom electronics and a PC in one convenient 19inch rack mountable unit. In addition, the GLAs have developed sophisticated real-time surveying and processing software, which runs on this system and is used to process and validate the ASF data collected.

Figure A.3 – ASF Measurement System.

A.3 Differential Loran

In the previous section we outlined what ASFs are, why they are needed and how we can measure them. ASFs are typically measured once and for all, on a particular day of the year, fixed, published and then stored inside a mariner's receiver. The magnitude of the ASF delay depends on the electrical conductivity of the earth's surface over which the eLoran signals propagate. If the value of the conductivity changes during the period of time between when the original data was measured and the time that it is used by the mariner the actual ASF value will change compared to what is stored in the receiver. ASF variations can occur in the short-term due to rainfall somewhere along the propagation path, or in the long term due to background seasonal changes, snow, ice etc.

We need to be able to compensate for these changes, and we do so using differential-Loran. This is exactly the same principle as differential-GPS, where corrections to propagation variations and transmitter variations are compensated for by using reference stations at precisely known locations, together with a data channel (radiobeacons) to transmit the corrections in real time to the mariner. An just like DGPS, differential-Loran also compensates for changes due to transmitter timing variations and changes in pressure and temperature of the earth's atmosphere, in addition to ASF. See Figure A.4.

A differential-Loran reference station has a very similar structure to the ASF Measurement System shown in Figure A.3. A reference station unit is installed at a location close to the area of operation of vessels and its receive antenna location is precisely surveyed. The station's own location, the locations of the eLoran transmitters, an accurate sea-water propagation model and the nominal ASFs along each of the propagation paths between itself and the eLoran transmitters are all held in an internal database within the reference station. Knowing these values the station is able to compute the discrepancies between what the station expects the pseudorange to be, and the actual measured pseudoranges of the eLoran signals. As mentioned, the discrepancies include the following effects:

- Transmitter timing errors
- Variations in ASF
- Variations in atmospheric propagation delay

These components are summed to form pseudorange corrections (PRCs). The corrections are transmitted to the user of the differential service using the Loran Data Channel (LDC). The LDC is a data modulation of the eLoran signal itself; at the moment this is a standardised technique called Eurofix [1]. Alternative, higher bandwidth LDCs have also been proposed. There will typically be one correction for each eLoran station at regular intervals, for example, once every two minutes.

In order to get the corrections onto the LDC, the reference station is permanently connected an Internet based Virtual Private Network (VPN) to allow it to communicate with one or more eLoran transmitters. Calculated PRCs are sent over this VPN to an eLoran transmitter's LDC Local System Controller ready for transmission to the mariner.

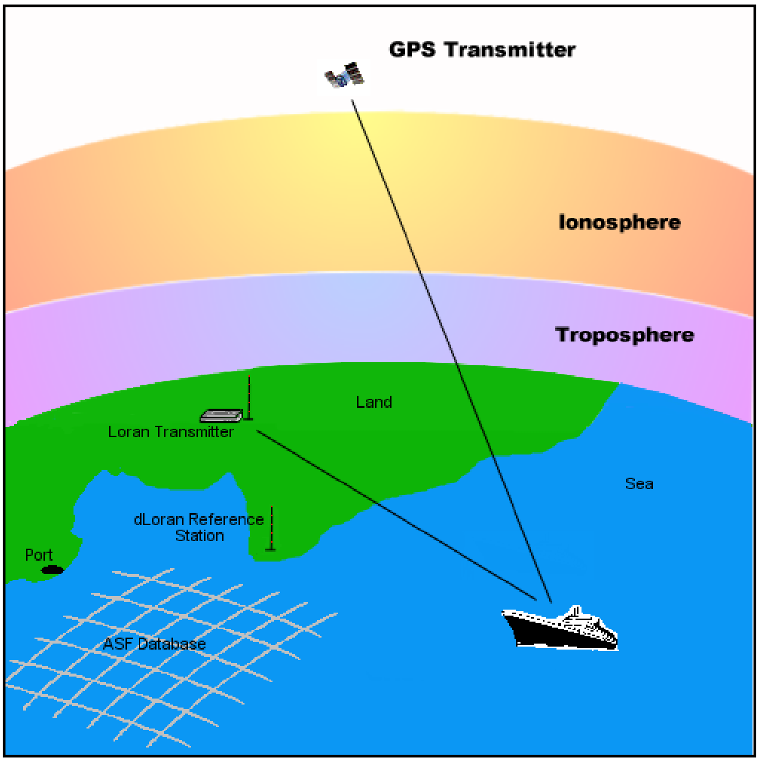

Figure A.4 – DLoran system using an ASF database and a reference station.

The variations at the mariner's vessel are assumed to be the same as those at the reference station, which is close by. At the present time "close by" is assumed to mean within 30km.

This is of course an idealised situation, and in reality there will be a degree of spatial decorrelation between the corrections generated at the location of the reference station and the corrections applicable at the location of the user's vessel. This phenomenon arises because the propagation paths between the eLoran transmitters and the reference station are different to the propagation paths between the eLoran transmitters and the mariner

(Figure A.5). In addition to pseudorange corrections, the Reference Station protects system integrity and is able to provide a timely warning to the users in case the differential-Loran system operates out of specification.

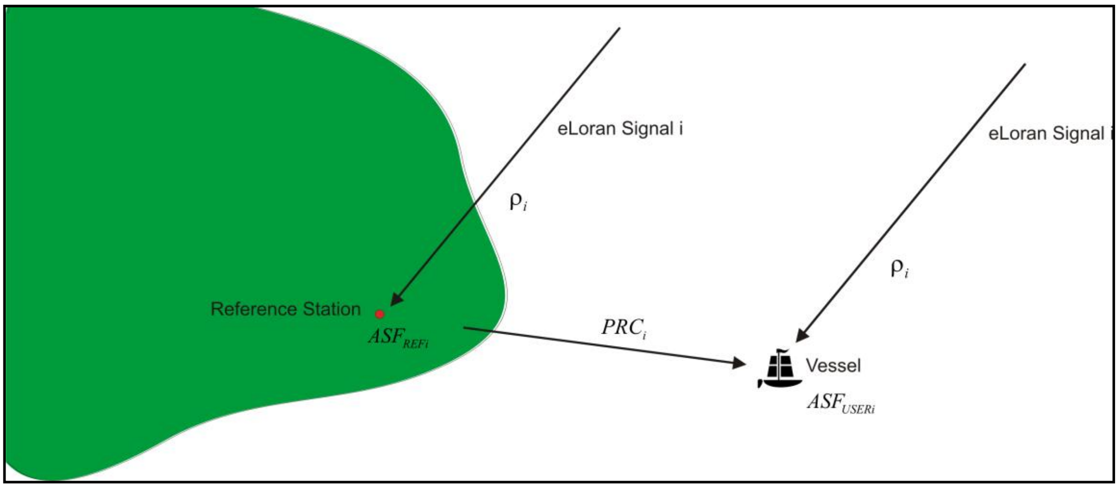

Figure A.5 – Principle of operation of differential-Loran.

Once the differential corrections become available, the mariner's receiver computes its final eLoran position like this:

1. Compute sea-water only position
2. Lookup ASF value in table using computed latitude and longitude
3. Receive latest PRCs from LDC
4. Apply ASFs to pseudoranges
5. Apply PRCs to ASF corrected pseudoranges
6. Compute position

A.4 Installation Requirements

ASF surveys and differential-Loran provision requires hardware to be installed both aboard a survey vessel and ashore.

A.4.1 ASF Measurement System

A temporary install of equipment is required for ASF survey purposes. The equipment is mains powered, and requires a normal computer mouse, keyboard and computer monitor to be attached. Three antennas are required: an eLoran antenna, a GPS antenna and a DGPS radiobeacon receiver antenna. Cable ingress will be required into the cabin of the vessel.

A.4.2 Differential Reference Station

A permanent location for a differential-Loran reference station is required. The reference station is mains powered, and takes up a small desk footprint being a 19 inch rack mountable unit. The reference station requires connections to three eLoran receiver antennas, which should be mounted on the roof of the building in an area of low interference and noise. The three antennas provide eLoran signals for, respectively, the reference station, an integrity monitor and a hot-swappable redundant standby receiver. An uninterruptible power supply will also be required for the reference station unit in addition to a connection to the Internet via ADSL.

A.4.3 References

[1] Offermans, G., 'The Technical Implementation of Eurofix', Reelektronika BV, Document number: Reel-ID-2007-01, Issue 1.1, 9 February 2007

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Annex B Technical Details of the Simulator Preparations

B.1 Introduction

This annex is about the preparation of Transas Bridge Simulation Systems for integration of nautical services developed within ACCSEAS at the maritime centre of the Flensburg University of Applied Sciences (Flensburg UoAS), Germany.

The architecture of IBS as described in the ACCSEAS e-Navigation Architecture Report makes every multifunctional navigational station independent from other stations and their status of availability. In the simulator NMEA sensor data can be transmitted via Ethernet LAN TCP-packages or serial ports as RS232 or RS422.

B.2 Upgrade of mobile Ship Handling Simulator

The mobile bridge simulator was designed 2011/12 by Arne Pluhar, a nautical student from Flensburg UoAS, for representations, education and research. The requirements of modern navigational services, the complexity of virtual test bed areas and the continuously proceeding technical development made it necessary to upgrade the existing hardware to a high-end and representative mobile bridge simulator.

B.2.1 Status before upgrade of Ship Handling Simulator

The mobile simulator contained 3 computer systems with 2 LCD-Displays. The functions were as follows:

BR8_VIS computer system based on Windows 7 x86-architecture connected to 46” LCD in the mode of operation as visualisation channel.

BR8_NTPro computer system based on Windows 7 x64-architecture connected to 19” LCD in the mode of operation as Server, Instructor and Conning Display.

BR8_MFDHost computer system based on Windows 7 x-64-architecture without LCD in the mode of operation as Model-PC

Hardware information:

BR8_VIS-C

Intel P4 520 2,8 GHz; NVIDIA GeForce GTX 560; HewlettPackard 0984h; 1,5 GB DDR 166 MHz Value; Samsung HDD 40GB 4200rpm

INSTR4_NTPro

Intel Core 2 Duo 6400 2,13 GHz; OnBoard Graphic – Intel Q965; HewlettPackard 0A58h; 2 GB DDR2 333 MHz Value; WesternDigital HDD 80GB 5400rpm

BR8_MFD-Host

Intel Core 2 Duo 6300 1,86GHz; NVIDIA GeForce 8800 Ultra; HewlettPackard 0A58h; 2 GB DDR2 333 MHz Value; WesternDigital HDD 80GB 5400rpm

B.2.2 Status after upgrading Ship Handling Simulator

The computer names moved as follows:

BR8_VIS ⇨ MOB_VIS

BR8_NTPro ⇨ MOB_NTPro

BR8_MFDHost ⇨ MOB_ACCSEAS_MFD

MBR_VIS computer system based on Windows 7 x86-architecture connected to 46” LCD in the mode of operation as visualisation channel.

MBR_NTPro computer system based on Windows 7 x86-architecture connected to 19" LCD in the mode of operation as Server, Instructor and Conning Display.

MBR_MFD computer system based on Windows 7 x-86-architecture connected to 19" LCD in the mode of operation as Model-PC and MFD-Host.

Hardware information:

MOB_VIS

Intel® Core™ i7-4820K; 2x ASUS GTX650 TI-DC2O-1GD5; MSI X79A-GD45 Plus; Mushkin DIMM 8 GB DDR3-2133; 1x Samsung 840 EVO 2,5" 120 GB, IPv4 Adress: 192.168.0.103, IPv4 Subnet Mask: 255.255.255.0, IPv4 Default Gateway: 192.168.0.100

MOB_NTPro

Intel® Core™ i7-4820K; 1x ASUS GeForce GT 630; MSI X79A-GD45 Plus; Mushkin DIMM 16 GB DDR3-2133; 1x Samsung 840 EVO 2,5" 120 GB, IPv4 Adress: 192.168.0.101, IPv4 Subnet Mask: 255.255.255.0, IPv4 Default Gateway: 192.168.0.100

MOB_MFD_ACCSEAS

Intel® Core™ i7-4820K; 1x ASUS GeForce GT 630; MSI X79A-GD45 Plus; Mushkin DIMM 8 GB DDR3-2133; 1x Samsung 840 EVO 2,5" 120 GB, IPv4 Adress: 192.168.0.102, IPv4 Subnet Mask: 255.255.255.0, IPv4 Default Gateway: 192.168.0.100

B.2.3 Additional Hardware

In order to demonstrate e-Navigation services most effective and prestigious it is necessary to set up additional hardware in terms of computer systems.

Therefore additional hardware is used as follows:

EPD & PNT

Lenovo ThinkCentre M93z; Intel Core i3-4130 Processor (3MB Cache, 3.40GHz); Intel HD Graphics 4000; 4GBx1 PC3-12800 DDR3 SoDIMM; 500GB 7200rpm SATA, IPv4 Adress: 192.168.0.105 (EPD) / 192.168.0.104 (PNT), IPv4 Subnet Mask: 255.255.255.0, IPv4 Default Gateway: 192.168.0.100

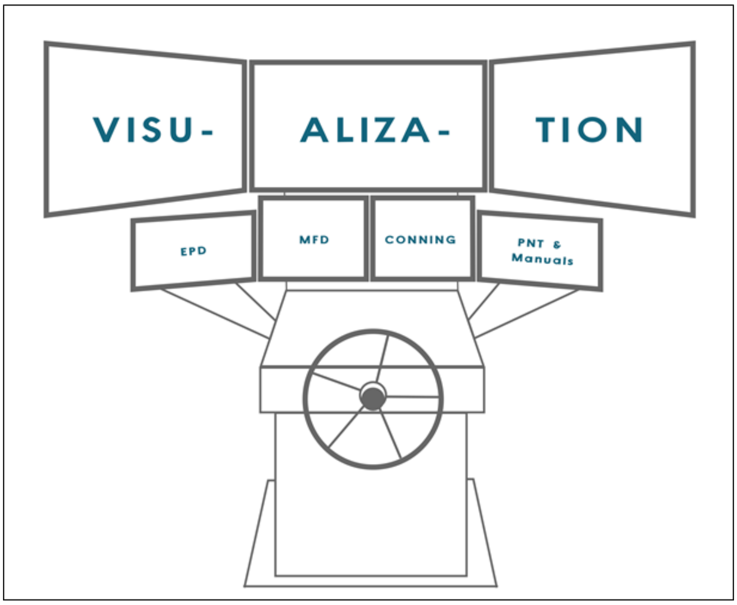

Figure B.1 - Mobile Ship Handling Simulator - Flensburg University of Applied Sciences.

Figure B.1 shows up 32" 24/7 monitors to get a most realistic scene with the mobile Ship Handling Simulator. In combination with 2 ThinkCentre-Stations "PNT" and "EPD" left- and right-handed, the maximum of demonstration possibilities are close to be achieved.

B.3 Required Auxiliary Software

This section describes the needs of software to manage exchanged NMEA data between the different stations.

B.3.1 Virtual Serial Port Driver

The exchange of NMEA data out of Transas Navi-Trainer Professional via specific software tasks requires several virtual serial ports. To provide and manage virtual serial ports numerous software solutions can be used. To be contrary to standard TCP Server solutions, VSPD allows multiple connections to their TCP server connection type.

Flensburg UoAS installed a software solution by Eterlogic called Virtual Serial Ports Emulator. The installation is short and simple to configure. A Multi-Station license is necessary for bridge simulation, depending on number of bridges and equipment.

B.3.2 PNT Noise Simulator

PNT Noise simulator was installed on computer system 'PNT'. The positioning data sent from NTPro will come into the PNT Software through virtual serial COM-port. The output of the PNT software is a serial COM-Port, too.

B.3.3 EPD

EPD Software by DMA was installed on computer system 'EPD'. Same S-57 ENC Charts are used than in Simulation Test-bed area development. All sensors were configured according to configuration details. The input and output data were transferred through serial COM-ports.

B.4 Transas Bridge Simulation – Technical Integration

Integration of ACCSEAS services into Transas Simulation System was realized through external devices, e.g. personal computers, raspberry pi, etc.. For communication between the external devices and the simulator itself, general interfaces were used, as serial ports, TCP packages via network LAN or maritime standard ports, e.g. pilot plugs or Transas specific NMEA tasks.

Tests, configuration and integration were done on Transas NaviTrainer Professional (NTPro) v5.25.5800.112780. Lower Versions of NaviTrainer Professional may not support sending NMEA strings with described configurations.

B.4.1 Bridge Simulation – Configuration

Transas simulation system is able to send all supported NMEA strings via TCP as mentioned. Which strings are supported could be looked up in the Transas list. Generally the MFD (MultiFunctionalDisplay) has to work as a standalone system, without integration of the MFD task in the router of NTPro running on the server or server-like PC.

B.4.1.1 Eterlogic Virtual Serial Ports Emulator – Configuration

The following grid shows up the port pairs and their configuration within Eterlogic Virtual Serial Ports Emulator. The optional emulation of baud rate is not necessary.

EPD

COM10 ⇔ COM11	Pair	// AIS to EPD
COM12 ⇔ COM13	Pair	// GPS to EPD
TCP COM13 ⇨ {IP-Adress-of-PNT}:5555	TCP-Client	// GPS from PNT

PNT

COM10 ⇔ COM11	Pair	// GPS to PNT
COM12 ⇔ COM13	Pair	// PNT to TCP-Server
TCP COM13 : 5555	TCP-Server	// TCP-Server to MFD/EPD

MFD

COM10 ⇔ COM11	Pair	// AIS to MFD
COM12 ⇔ COM13	Pair	// GPS to MFD
COM14 ⇔ COM15	Pair	// Sensors to MFD
TCP COM13 ⇨ {IP-Adress-of-PNT}:5555	TCP-Client	// GPS from PNT

B.4.1.2 Transas MFD Software – Configuration

The sensors of Transas Multi-Functional Display were configured as follows. The settings can be done at Transas MFD System Configuration located in the home folder of the software at the specific workstation.

Sensor	Port	baudrate	description
POS1	COM15	4800	GPS1
POS2	COM15	4800	GPS2
POS3	COM12	4800	PNT / jammed GPS
LOG1	COM15	4800	STW
GYRO1	COM15	4800	Gyro-Compass
MAGN	COM15	4800	Magnetic Compass
WIND	COM15	4800	Wind Speed & Direction
AIS	COM11	4800	AIS
SOUNDER1	COM15	4800	Depth

B.4.1.3 e-Navigation Prototype Display – Configuration

The basis of full running EPD-solutions is a virtual Maritime Cloud running on a virtual machine or the direct connection to the Maritime Cloud using internet access at the EPD workstations. For each simulated ship target an own instance of EPD has to run on an additional workstation. There were 3 different input sensors configured:

- GPS source (correct GPS source)
- PNT Source (potential jammed positioning source)
- AIS source (correct AIS source)

B.4.1.4 PNT – Noise Generator v3 - Configuration

The setup.ini within the folder of PNT Noise Generator was configured as follows:

“Input Serial COM11 BaudRate 4800

Output Serial COM12 BaudRate 4800

Write_Output = true

HAL 50”

The use of this software tool was not successful, caused in wrong output strings within the software.

B.4.1.5 Transas NTPro Configuration

The integration of developments and tasks of the ACCSEAS project required a copy of the standard bridge configuration setup. The following tasks were added(+)/deleted(-) to each bridge:

+ NMEA task	COM11	EPD	// AIS to EPD
+ NMEA task	COM14	MFD	// Sensors to MFD
- MFD interface			

B.4.1.6 Bridge Simulation - Operational

The same configuration can be multiplied on numerous bridges. It is useful to create a matrix with all ports and IP addresses in use. In addition to the normal instructor side handling of running scenarios, it was necessary to have a second instructor handling the ship targets EPD's and a third instructor observing the EPD's on the bridges and handling the EPD-shore.

B.5 Conclusions and Recommendations

The integration of developed potential solutions was not successful in beginning. It was not documented how to implement external equipment by the simulation system manufacturer. The first step to integrate and exchange additional data only through TCP ports or UDP ports did not work properly and had a bad integrity all time tested. May it is caused in the software integrated TCP/UDP tools. The realization of the exchange of data and interaction through serial cables was classified as not future-oriented and to confusing.

After many tests, the best and at least well working solution was the creation of virtual Serial COM-ports and transferring the data through TCP servers & clients. The key was to create a data collection of all ports, TCP clients & servers, workstations and software in- and outputs to get a proper configuration. Tests were done with at least 3 bridges interconnected and 28 clients of EPD within one running scenario. In future projects it is highly recommended to spend more resources into the development and tests of interfaces and finally the integration into simulation systems.

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Annex C Simulation Details of Tests at Flensburg University of Applied Sciences

C.1 Scenario 5 - Vessel leaving Deep Water Anchorage

Exercise title	Tactical Route Suggestion Service (shore-ship) – Vessel leaving deep water anchorage
Exercise No.	05
Sea area	InterregACCSEAS_HumberRiver2
Exercise time	1100 LT 08.08.2022
Paper charts	none
Duration	~ 40 min
Participants	3 Person per bridge (Captain, 1st Officer, 2nd Officer)

The oil tanker "Cape Mathilde" is leaving the outer anchorage of River Humber proceeding to the pilot boarding area. During the departure of the anchorage "Cape Mathilde" receives a Tactical Route Suggestion through the e-Navigation prototype Display (EPD) from Humber VTS, caused in strong currents.

- Decision making about when and what speed (manoeuvre)
- Overview about complex situation of vessel distribution
- Awareness of tidal streams and currents
- Communication with Humber VTS & Humber Pilot
- Using functionalities of EPD, esp. observing routes, receiving and acknowledging Tactical Route Suggestion.

Main Instructor:	Leading the scenario
2nd Instructor:	VHF handling, simulating target ships
3rd Instructor:	Operating EPD's
1st Supervision:	-- Bridge 1
2nd Supervision:	-- Bridge 2
3rd Supervision:	-- Bridge 3
4th Supervision:	-- Preparing evaluation, instructing assistants

C.1.1 Vessel Data

OS 1	Oil tanker "Cape Mathilde"
	LOA: 242.8 m Breadth: 32.3 m Depth: 9.5 m
	Outer Anchorage River Humber
Initial SOG	"Cape Mathilde" 5.5 kts, Full Maneuvering, COG 005°
Equipment	All navigational equipment fully operative, AUTOPILOT: active (all ships)

C.1.2 Environmental Conditions

Visibility	6 - 8.00 nm
Tide state	Mean tide, goes out
True Wind	19 kts, 005° steady

Current	~ 1.0 kts, tidal cond.
Sea state	2 m, 350° decreasing
Weather	Mostly cloudy, light rain

C.1.3 Exercise Timeline

Time	Instructor`s actions & messages	Participants expected actions
-15	All engaged simulator bridges & bridge teams are briefed acc. mission and weather. Bridges are manned with “full” crew.	Preparing routes
+02	Current warning from Humber VTS	Acclimatization with scenario
+06	Humber Pilot: Pilot on arrival. Portside. 2 m, 4 kn STW boarding speed.	Vessels are calling Humber Pilot with ETA & Status
+08	Instructor sending Suggested Route from EPD shore to EPD ship.	Receiving route from Humber VTS, considering which route to follow.
+12	If no reaction: VTS Humber calling “Cape Mathilde” about their intention and route planning.	Answering on VHF and on EPD.
+15	Instructors observing particularly due to tidal conditions. Pilot on arrival	
~ +25	“Cape Mathilde” crossing route of “Fure West” & “ARK Germania” // depends on their own speed	
+34		Close to pilot boarding
+35	END of scenario	

C.2 Scenario 6 – Navigation in windfarms

Exercise title	Tactical Exchange of Intended Route (ship-ship) – Navigation in windfarms
Exercise No.	06
Sea area	InterregACCSEAS_EastAnglia
Exercise time	1100 LT 08.08.2022
Paper charts	none
Duration	~ 40 min
Participants	3 Person per bridge (Captain, 1st Officer, 2nd Officer)

Three Own Ships “Yasmine” (YA), “Pride of Hull” (PoH) and “Tenacity” (TC) are sailing in the area around the brand new windfarms of East Anglia. They are following their intended routes as planned. The attention will be on the “Tactical Exchange of Intended Routes (ship-ship)” to avoid close areas within a river-like sailing area. General navigation and bridge procedures:

- Decision making about when and what speed (manoeuvre)

- Overview about complex situation of vessel distribution
- Awareness of tidal streams and currents
- Using functionalities of EPD, esp. observing routes, receiving and acknowledging intended routes of other vessels.

Main Instructor:	Leading the scenario
2nd Instructor:	VHF handling, simulating target ships
3rd Instructor:	Operating EPD’s
1st Supervision:	-- Bridge 1
2nd Supervision:	-- Bridge 2
3rd Supervision:	-- Bridge 3
4th Supervision:	-- Preparing evaluation, instructing assistants

C.2.1 Vessel Data

OS 1	CarCarrier	“Yasmine”	
	Flag:	Luxembourg	
	Callsign:	LXYE	
	LOA: 199 m	Breadth: 32.2 m	Depth: 8.6 m
	Eastbound:	between EastAnglia 1 & 2	
OS 2	PassengerCarFerry	“Pride of Hull”	
	Flag:	UK	
	Callsign:	C6ZQ4	
	LOA: 145 m	Breadth: 25.2 m	Depth: 5.3 m
	Westbound:	south of EastAnglia 3	
OS 3	BulkCarrier	“Tenacity”,	
	Flag:	Marshall Islands	
	Callsign:	V7BR5	
	LOA: 320 m	Breadth: 53 m	Depth: 18.9 m
	Northbound:	east of EastAnglia 1	
Initial SOG	“Yasmine” 20.7 kts, Full Sea, COG 124°		
	“Pride of Hull” 19.4 kts, Full Sea, COG 295°		
	“Tenacity” 14.5 kts, Full Sea, COG 000°		
Equipment	All navigational equipment fully operative, AUTOPILOT: active (all ships)		

C.2.2 Environmental Conditions

Visibility	6 - 8.00 nm
Tide state	Mean tide, goes in
True Wind	13 kts, 030° steady
Current	~ 1-2 kts, 000° to 035°

Sea state 1-1.5 m, 350° decreasing

Weather Mostly cloudy, light rain

C.2.3 Exercise Mission and Timeline

POC: “Yasmine”: → Rotterdam (NL); “Pride of Hull”: → Hull (UK);

“Tenacity”: → Wilhelmshaven(GER)

Prepare routes on ECDIS and e-Navigation Prototype Display (EPD). Precede your planned routes. Observe and check exchanged intended Routes of other vessels taking part in your area. Keep your route always up to date and active within EPD.

Route information:

Own Ship “Yasmine” - Crew will prepare

Own Ship “Tenacity” - Crew will prepare

Own Ship “Pride of Hull” - Crew will prepare

Target Ships:

“APL Mexico City” – EPD Route necessary

“ARK Germania” – EPD Route necessary

“MRC Hatice Ana” – EPD Route necessary

“Cielo Di New York” – EPD Route necessary

“Scott Vemture” – EPD Route necessary

“Wilforce” – EPD Route necessary

“Gaasterland” – EPD Route necessary

“Genje” – EPD Route necessary

“Stena Forerunner” – EPD Route necessary

“MSC Filippa” – EPD Route necessary

“Port Stanley” – EPD Route necessary

“Seafrance Nord” – EPD Route necessary

“Anna Maersk” – EPD Route necessary

“Graceful” – EPD Route necessary

“Wilson Finnjord” – EPD Route necessary

“Discovery” – EPD Route necessary

“Carolina” – EPD Route necessary

“Transpulp” – EPD Route necessary

All other AIS data will be provided by the simulation system.

Time	Instructor`s actions & messages	Participants expected actions
-15	All engaged simulator bridges & bridge teams are briefed acc. mission and weather. Bridges are manned with “full” crew.	Preparing routes

+00	Start of scenario - Attention to scenario. Observe and manoeuvring of target ships !	
+1	PoH – Bow Crossing “MRC Hatice Ana” – 800 m	Intended Route: ON LoA: 88.8 m Breadth: 16.5 m Depth: 5.7 m, Displ.: 5325 t
+13	PoH – Overtaking “Cielo Di New York”	Intended Route: ON LoA: 235 m Breadth: 42 m Depth: 25 m Displ.: 120750 t
+18	TC – Crossing “Carolina”	Intended Route: ON LoA: 82.5 m Breadth: 12.5 m Depth: 3.6 m, Displ.: 2812 t
+18	YA – Crossing “Stena Forerunner”	Intended Route: ON LoA: 182.6 m Breadth: 25.5 m Depth: 6.5 m, Displ.: 21104 t
+20	PoH – Overtaking “Scot Venture”	Intended Route: ON LoA: 82.5 m Breadth: 11.4 m Depth: 3.5 m, Displ.: 2740 t
+20	TC – Crossing “APL Mexico City”	Intended Route: ON LoA: 316 m Breadth: 45 m Depth: 13.6 m, Displ.: 111626 t
+21	YA – Crossing “Genje”	Intended Route: ON LoA: 182.9 m Breadth: 40 m Depth: 13 m, Displ.: 77966 t
+22	YA – Crossing/Overtaking “Gaasterland”	Intended Route: ON LoA: 122 m Breadth: 20.3 m Depth: 8.5 m, Displ.: 11600 t
+24	PoH – Crossing “Wildforce”	Intended Route: ON LoA: 297.5 m Breadth: 45.8 m Depth: 10.8 m, Displ.: 108959 t
+28	YA – Crossing “ARK Germania”	Intended Route: ON LoA: 188.6 m Breadth: 29.4 m Depth: 8 m, Displ.: 25598 t
+30	TC – Overtaken “ARK Germania”	Intended Route: ON LoA: 188.6 m 29.4 m Depth: 8 m, Displ.: 25598 t
+30	YA – Crossing TC TC – Crossing YA	Intended Route: ON

+31	PoH – Crossing "Seafrance Nord"	Intended Route: ON LoA: 112.3 m Breadth: 19.1 m Depth: 3.9 m, Displ.: 3100 t
+35	PoH – Crossing "Anna Maersk"	Intended Route: ON LoA: 347 m Breadth: 42.8 m Depth: 14 m, Displ.: 132540 t
+40	End of Scenario	

C.3 Scenario 7 – Tactical Exchange of Intended Routes, vessels not following their intentions

Exercise title	Tactical Exchange of Intended Route – Navigation in Windfarms – Initiation of GPS Jamming
Exercise No.	07
Sea area	InterregACCSEAS_EastAnglia
Exercise time	1100 LT 08.08.2022
Paper charts	none
Duration	~ 40 min
Participants	3 Person per bridge (Captain, 1st Officer, 2nd Officer)

Three Own Ships "Yasmine" (YA), "Pride of Hull" (PoH) and "Tenacity" (TC) are sailing in the area around the brand new windfarms of East Anglia. They are following their intended routes as planned. The attention will be on the transmitted intended routes of other vessels to avoid close areas within a river-like sailing area. During the scenario some ships will not follow their intended route as broadcasted within EPD.

- Decision making about when and what speed (maneuver)
- Overview about complex situation of vessel distribution
- Awareness of tidal streams and currents
- Using functionalities of EPD, esp. observing routes, receiving and acknowledging intended route.

Main Instructor:	Leading the scenario
2nd Instructor:	VHF handling, simulating other vessels
3rd Instructor:	Operating EPD's
1st Supervision:	-- Bridge 1
2nd Supervision:	-- Bridge 2
3rd Supervision:	-- Bridge 3
4th Supervision:	-- Preparing evaluation, instructing assistants

C.3.1 Vessel Data

OS 1	CarCarrier	"Yasmine"	
	Flag:	Luxembourg	
	Callsign:	LXYE	
	LOA: 199 m	Breadth: 32.2 m	Depth: 8.6 m
OS 2	PassengerCarFerry	"Pride of Hull"	
	Flag:	UK	
	Callsign:	C6ZQ4	

	LOA: 145 m	Breadth: 25.2 m	Depth: 5.3 m
OS 3	Containership	“ContainerShip VII”	
	Flag:	Germany	
	Callsign:	DEHZ	
	LOA: 320 m	Breadth: 53 m	Depth: 18.9 m

Initial SOG
“Yasmine” 20.7 kts, Full Sea, COG 124°
“Pride of Hull” 19.4 kts, Full Sea, COG 295°
“ContainerShip VII” 16.3 kts, Full Sea, COG 000°

Equipment: All navigational equipment fully operative, AUTOPILOT: active (all ships)

C.3.2 Environmental conditions

Visibility	6 - 8.00 nm
Tide state	Mean tide, goes in
True Wind	24.1 kts, 005° steady
Current	~ 1-2 kts, 000° to 035°
Sea state	1-1.5 m, 350° decreasing
Weather	Mostly cloudy, light rain

C.3.3 Exercise Mission and Timeline

POC: “Yasmine”: → Rotterdam (NL); “Pride of Hull”: → Hull (UK);
“Tenacity”: → Wilhelmshaven (GER).
Prepare routes on ECDIS and e-Navigation Prototype Display (EPD). Precede your planned Routes. Observe and check exchanged intended routes of other vessels taking part in your area. Keep your route always up to date and active within EPD.

Route information:
Own Ship “Yasmine” - Crew will prepare
Own Ship “Containerships VII” - Crew will prepare
Own Ship “Pride of Hull” - Crew will prepare
Target Ships:
“COSCO Portugal” – EPD Route necessary
“Hrossey” – EPD Route necessary
“Gaasterland” – EPD Route necessary
“Hai Soon 2” – EPD Route necessary
“Anna Maersk” – EPD Route necessary
“Isa” – EPD Route necessary
“Sasa” – EPD Route necessary
“Genje” – EPD Route necessary

All other AIS data will be provided by the simulation system.

Time	Instructor`s actions & messages	Participants expected actions
-15	All engaged simulator bridges & bridge teams are briefed acc. mission and weather. Bridges are manned with “full” crew.	Preparing routes
+1	PoH – Overtaken “Cosco Portugal”	Intended Route: ON LoA: 299 m Breadth: 37.1 m

		Depth: 13m, Displ.: 86900 t
+3	C7 – Overtaking “Sonia”	Intended Route: ON LoA: 128.2 m Breadth: 16.7 m Depth: 3.6 m, Displ.: 6198 t
+6	YA – Overtaking “Gaasterland”	Intended Route: ON LoA: 122 m Breadth: 20.3 m Depth: 8.5 m, Displ.: 11600 t
+6	YA – Crossing “Hai Soon 2”	IntendedRoute: ON LoA: 242.8 m Breadth: 32.2 m Depth: 12.5 m, Displ.: 77100 t
+7	C7 – Crossing Sailing Ship “Apex Twin”	Intended Route: ON LoA: <20 m Breadth:<5 m Depth:<3 m, Displ.: <20 t
+8	C7 – Overtaking “Front Page”	Intended Route: ON LoA: 89.5 m Breadth: 13.2 m Depth: 2.8 m, Displ.: 2000 t
+9	PoH – Crossing “Carlo Magno”	Intended Route: ON LoA:93.5 m Breadth: 22 m Depth: 6.5 m, Displ.: 8800 t
+12	“Cosco Portugal” starts turning stb off her intended route, going north	
+14	C7 – Crossing “Blue Aries”	Intended Route: ON LoA: 18.9 m Breadth: 5.7 m Depth: 1 m, Displ.: 30.6 t
+15	YA – Crossing “Isa”	Intended Route: ON LoA: 88.8 m Breadth: 16.5 m Depth: 5.7 m, Displ.: 5325 t
+16	“Genje” starts turning stb off her intended route, going east.	
+16	“Cosco Portugal” adjusted her intended route and broadcast it	
+16	YA – “Crossing Sasa”	Intended Route: ON LoA: 140 m Breadth: 16.6 m Depth: 3.7 m, Displ.: 6716 t
+17	C7 – “Crossing Hrossey”	Intended Route: ON LoA:125 m Breadth: 19.5 m Depth: 5.3m, Displ.: 7100 t
+18	“Genje” adjusted her intended route and broadcast it	
+18	YA – Crossing “Genje”	Intended Route: ON LoA: 182.9 m Breadth: 40 m Depth: 13 m, Displ.: 77966 t

+23	YA – Crossing "Carlo Magno"	Intended Route: ON LoA: 93.5 m Breadth: 22 m Depth: 6.5 m, Displ.: 8800 t
+24	C7 – Crossing "Prosperus"	Intended Route: ON LoA: 222.6 m Breadth: 22.9 m Depth: 7.9 m, Displ.: 37330 t
+24	PoH – Crossing "Jubilee"	Intended Route: ON LoA: 169 m Breadth: 27.2 m Depth: 9.5 m, Displ.: 24080 t
+25	PoH – Crossing "Sonia"	Intended Route: ON LoA: 128.2 m Breadth: 16.7 m Depth: 3.6 m, Displ.: 6198 t
+27	C7 – Crossing "Anna Maersk"	Intended Route: ON LoA: 347 m Breadth: 42.8 m Depth: 14 m, Displ.: 132540 t
+30	PNT Noise Jamming switched on	
+34	PNT Noise Jamming switched off	
+40	END of scenario	

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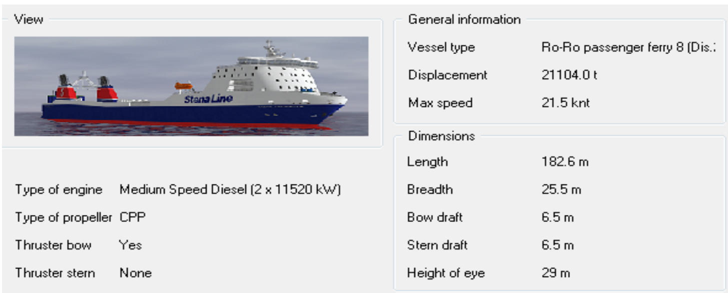
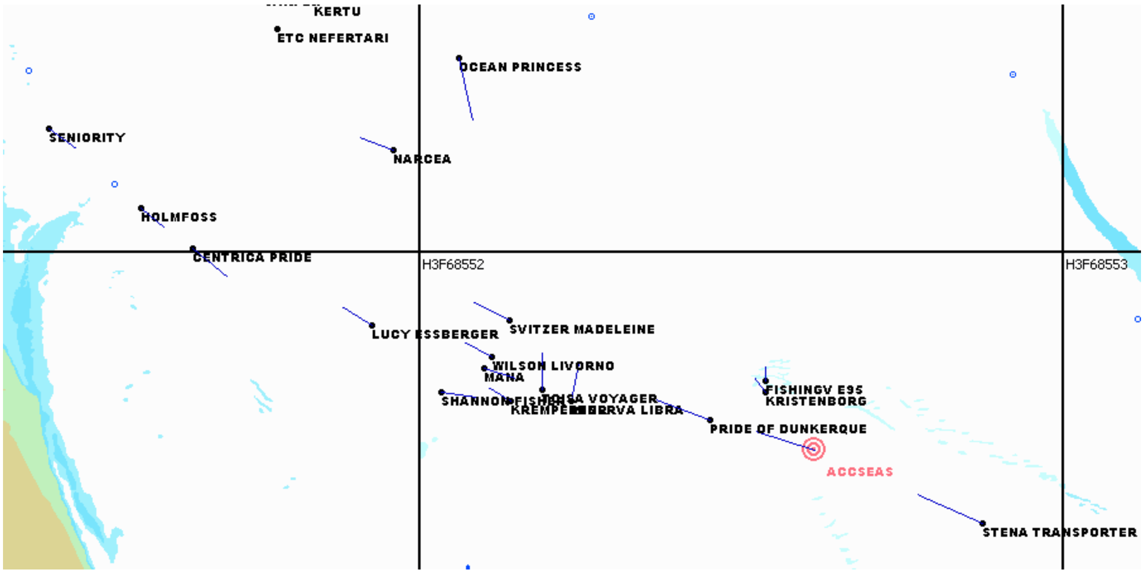
Annex D Simulation Details of Tests at Chalmers University of Technology

D.1 Scenario 1 - Routing in the outer traffic separation schemes

No.1	**Exercise description**		**Acronym of Exercise**
Exercise Title	Rough Weather Routing in the Outer TSS		
Exercise No.	**1**		
Sea Area	ACCSEAS		
Exercise time	0600 UTC 27-08-2014	**Paper charts**	BA 107, 109
Vessel data			
OS Vessel type	 Name: ACCSEAS Call sign: ACCSEAS		
Initial SOG	18 kts, Full Manoeuvring or Full Sea	**Initial COG**	290°
Equipment	All navigational equipment fully operative, EPD used as ECDIS and primary mean		
Environmental conditions			
Start Position	Passed East Dudgeon Shoals		
Visibility	6 nm	**Tide state**	Rising tide
True Wind	25.0 kts, 000° (can be increased)	**Current**	~ 1 kts, 180°
Sea state	3.5 m, 000° swell 2 m 180°	**Weather**	cloudy
Special precautions	-		

Mission			
Vessel bound for Hull			
1	**Exercise Plan**		**Acronym of Exercise**
Exercise Title	Rough Weather Routing in the Outer TSS		
Exercise No.	**1**		
Sea Area	ACCSEAS		
Exercise time		**Paper chart**	BA 109,1188
Duration	~ 30 min allocated		
Bridge Team			
Participants	2 Persons per Bridge		
Exercise storyboard			

Time	**Instructor`s actions & messages**	**Participants expected actions**
	All engaged simulator bridges & bridge teams are briefed acc. mission and weather. Bridges are manned with “full” crew.	Preparing Routes
	Overview traffic in the area (6 min vectors), no imminent risk of collision	



+5		ACCSEAS initiates contact with VTS and eventually establishes new route

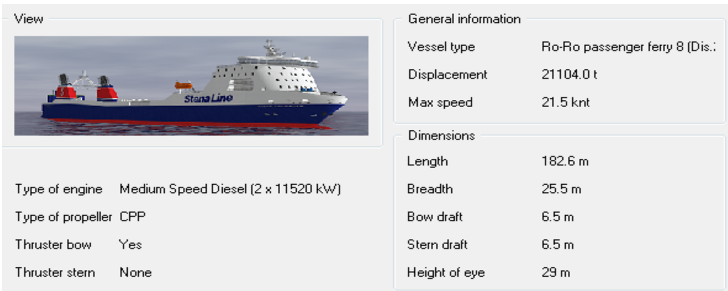
Main Objectives

	Reference	Conducted
Test of Route suggestion – VTS sent suggested route to vessel with explanation.		

Additional Instructor Information

Adjustments and Background Info	Reference	Conducted
ACCSEAS arriving from Rotterdam to the Humber with strong northerly gales producing large swells. The usual inward route taken by the ferry is the eastern “Sea Reach” TSS. With high beam swells and a large windage rolling could be reduced and safety to cargo and passengers improved by taking the south eastern route “Rosse Reach” TSS, providing the under keel clearance from dynamic tidal heights are acceptable. (Dynamic No Go Areas).		

D.2 Scenario 2 – Congestion at Grimsby

<table>
<tr><th>No.2</th><th colspan="3">Exercise description</th><th>Acronym of Exercise</th></tr>
<tr><td>Exercise Title</td><td colspan="4">Congestion at Grimsby</td></tr>
<tr><td>Exercise No.</td><td colspan="4">2</td></tr>
<tr><td>Sea Area</td><td colspan="4">ACCSEAS</td></tr>
<tr><td>Exercise time</td><td>1300 UTC 24-06-2014</td><td>Paper charts</td><td colspan="2">BA 109,1188</td></tr>
<tr><td colspan="5">Vessel data</td></tr>
<tr><td>OS Vessel type</td><td colspan="4">

Name: ACCSEAS
Call sign: ACCSEAS</td></tr>
<tr><td>Initial SOG</td><td>18 kts, Full Manoeuvring or Full Sea</td><td>Initial COG</td><td colspan="2">270°</td></tr>
<tr><td>Equipment</td><td colspan="4">All navigational equipment fully operative, EPD used as ECDIS and primary mean</td></tr>
<tr><td colspan="5">Environmental conditions</td></tr>
<tr><td>Start Position</td><td colspan="4">About to enter Sea Reach TSS</td></tr>
<tr><td>Visibility</td><td>6 nm</td><td>Tide state</td><td colspan="2">Rising tide</td></tr>
<tr><td>True Wind</td><td>10.0 kts, 225°</td><td>Current</td><td colspan="2">~ 2 kts, various</td></tr>
<tr><td>Sea state</td><td>0.4 m, 225°</td><td>Weather</td><td colspan="2">Light cloudy</td></tr>
<tr><td>Special precautions</td><td colspan="4">-</td></tr>
<tr><td colspan="5">Mission</td></tr>
<tr><td colspan="5">Vessel bound for Hull</td></tr>
</table>

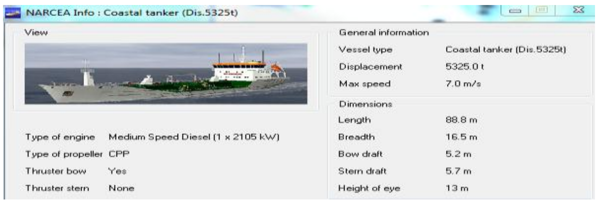
2	**Exercise Plan**		**Acronym of Exercise**
Exercise Title	Congestion at Grimsby		
Exercise No.	**2**		
Sea Area	ACCSEAS		
Exercise time		**Paper chart**	BA 109,1188
Duration	~ 60 min allocated		

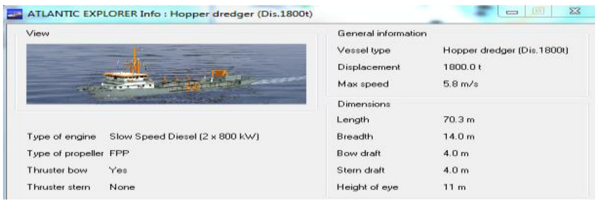
Bridge Team

Participants	2 Persons per Bridge

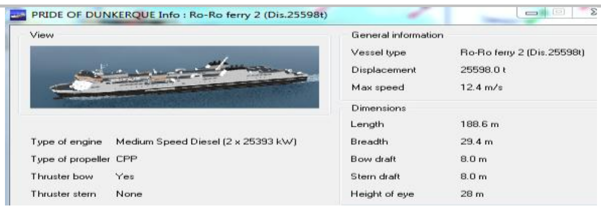
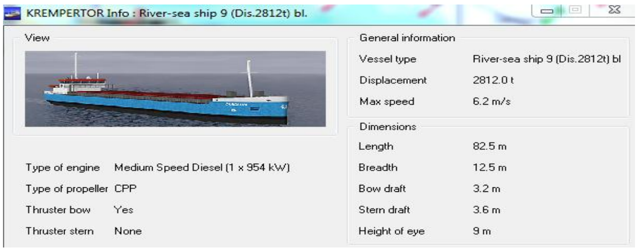
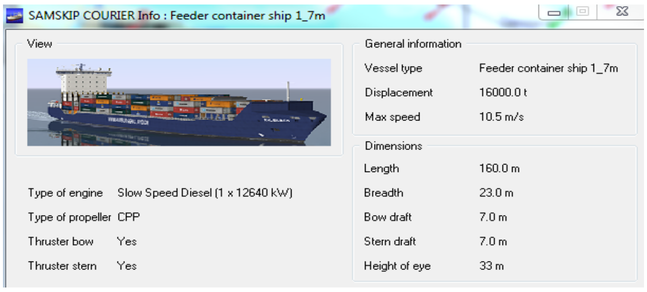
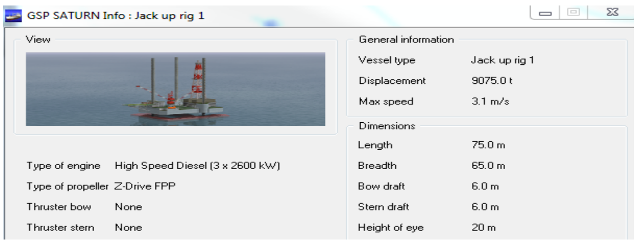
Exercise storyboard

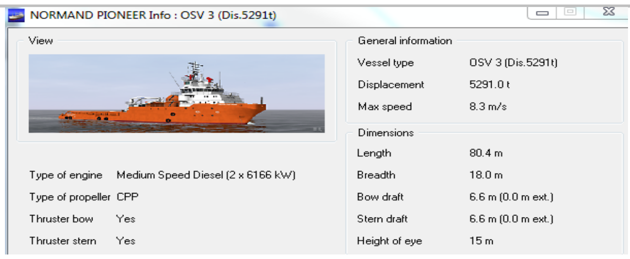
<table>
<tr><th>Time</th><th>Instructor`s actions & messages</th><th>Participants expected actions</th></tr>
<tr><td></td><td>All engaged simulator bridges & bridge teams are briefed acc. mission and weather. Bridges are manned with “full” crew.</td><td>Preparing Routes</td></tr>
<tr><td>+3</td><td></td><td>“ACCSEAS” entering TSS and reports VHF 14</td></tr>
<tr><td></td><td>VTS reports traffic to “ACCSEAS”:

“Narcea” inbound from New Sand Hole
“Atlantic Explorer” at HLF bound NSH
“Grande Roma” outbound taking Sea Reach
</td><td>




</td></tr>
</table>

	• "Pride of Dunkerque" outbound via Sea Reach	
+6	"CPO Norway" reports passing Spurn Head using SDC	
+16	"Krempertor" reports passing Clee Ness ch 14	
+21		"ACCSEAS" reports passing Spurn Lt FI
+22	"Samskip Courier" Clee Ness	
+23	"ACCSEAS" is called by VTS abt TEZ South Shoal Special Transport Vessel (STV) consists of jack up rig "GSP SATURN" towed by "OLIMPIC ELECTRA" and escorted by "NORMAND PIONEER"	

		
	Route taking SDC is proposed by VTS and sent to “ACCSEAS”	“ACCSEAS” validates route and agrees
+35?	Route exchange completed	Depending on ACCSEAS speed

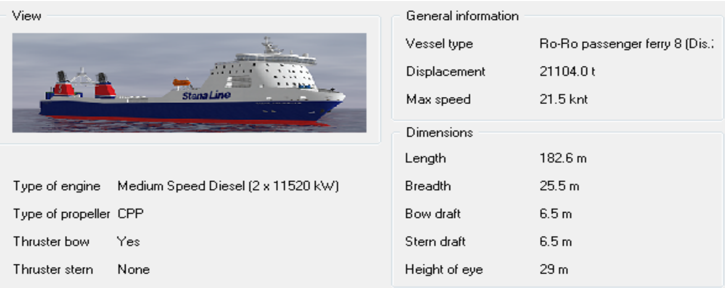
Main Objectives

	Reference	Conducted
Test of Route suggestion – VTS sent suggested route to vessel with explanation.		

Additional Instructor Information

Adjustments and Background Info	Reference	Conducted
ACCSEAS on an inward passage approaching Spurn Head encounters an emergency situation where a special transport vessel requiring a large free domain is approaching the “Cleeness Area” outward. (GSP SATURN). The situation would require active promotion of the use of the SDC to the ferry by the VTS operator. Operational safety would dictate the use of the SDC. The deep channel would present no issue for under keel clearance however, the channel would need to be clear of outward traffic for this scenario to be possible.		

D.3 Scenario 3 – Congestion at Immingham

<table>
<tr><th>No.3</th><th colspan="3">Exercise description</th><th>Acronym of Exercise</th></tr>
<tr><td>Exercise Title</td><td colspan="4">Congestion at Immingham</td></tr>
<tr><td>Exercise No.</td><td colspan="4">3</td></tr>
<tr><td>Sea Area</td><td colspan="4">ACCSEAS</td></tr>
<tr><td>Exercise time</td><td colspan="2">0700 UTC 29-06-2014</td><td>Paper charts</td><td>BA 109,1188</td></tr>
<tr><td colspan="5">Vessel data</td></tr>
<tr><td>OS Vessel type</td><td colspan="4">

Name: ACCSEAS
Call sign: ACCSEAS</td></tr>
<tr><td>Initial SOG</td><td colspan="2">14 kts</td><td>Initial COG</td><td>270°</td></tr>
<tr><td>Equipment</td><td colspan="4">All navigational equipment fully operative, EPD used as ECDIS and primary mean</td></tr>
<tr><td colspan="5">Environmental conditions</td></tr>
<tr><td>Start Position</td><td colspan="4">In-bound SDC approaching buoys 9</td></tr>
<tr><td>Visibility</td><td colspan="2">6 nm</td><td>Tide state</td><td>Rising tide</td></tr>
<tr><td>True Wind</td><td colspan="2">10.0 kts, 180°</td><td>Current</td><td>~ 1 kts, inbound</td></tr>
<tr><td>Sea state</td><td colspan="2">0.3 m, 180°</td><td>Weather</td><td>cloudy</td></tr>
<tr><td>Special precautions</td><td colspan="4">-</td></tr>
<tr><td colspan="5">Mission</td></tr>
<tr><td colspan="5">Vessel bound for Hull</td></tr>
</table>

3	Exercise Plan		Acronym of Exercise
Exercise Title	Congestion at Immingham		
Exercise No.	**3**		
Sea Area	ACCSEAS		
Exercise time		**Paper chart**	BA 109,1188
Duration	~ 60 min allocated		

Bridge Team

Participants	2 Persons per bridge

Exercise storyboard

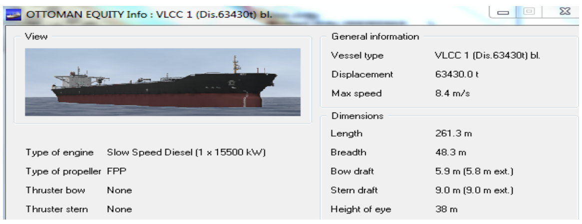
<table>
<tr><th>Time</th><th>Instructor`s actions & messages</th><th>Participants expected actions</th></tr>
<tr><td></td><td>All engaged simulator bridges & bridge teams are briefed acc. mission and weather. Bridges are manned with “full” crew.</td><td>Preparing Routes</td></tr>
<tr><td>+1</td><td></td><td>“ACCSEAS” reports to VTS on passing P5</td></tr>
<tr><td>+5</td><td>STENA TRANSPORTER calls VTS ch14

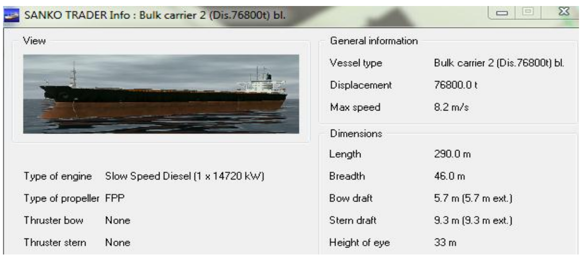
That she has left Nordic Terminal and will pass locks on “level”

VTS reports back on traffic situation:

OTTOMAN EQUITY at IOT preparing to sail, 4 tugs assisting

SANKO TRADER at Immingham BT</td><td>



</td></tr>
</table>

	preparing to sail, 3 tugs ACCSEAS in SDC	
+10	VTS briefs "ACCSEAS" on the Very Large Ship movements off Immingham: • OTTOMAN EQUITY leaving IOT • STENA TRANSPORTER leaving the locks • SANKO TRADER about to leave Immingham Bulk Terminal And recommends using FHC	
+12?		Possibly asks for route and no go area
+20		Passing Sunk Spit
+25?		Changes route to FHC

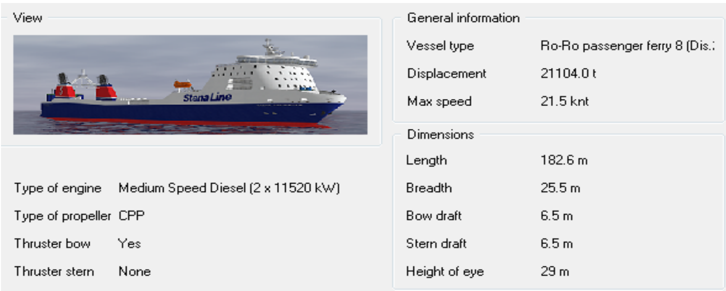
Main Objectives

	Reference	Conducted
Test of No-Go area service and Route suggestion		

Additional Instructor Information

Adjustments and Background Info	Reference	Conducted
ACCSEAS inwards for King George Dock in Hull approaching Immingham one of the busiest areas within the Humber district. Several VLS (Very Large Ship) movements are due to take place ahead of the vessel which could result in the development of dangerous traffic situations and densities. The channel at the IOT (Immingham Oil terminal) is narrow and tides cross the jetty making navigation difficult. To avoid delays to the ferry or allowing the possible development of a close quarter's situation, the VTS operator recommends the use of the "Foul Holme Channel" (FHC). This channel is narrow and shallower than the main channel however, with sufficient tidal height and UKC (Under Keel Clearance) requirements satisfied this will be the safer and more efficient option for vessel routing. (Dynamic No Go Areas).		

D.4 Scenario 4 – Contravention in TSS off Spurn

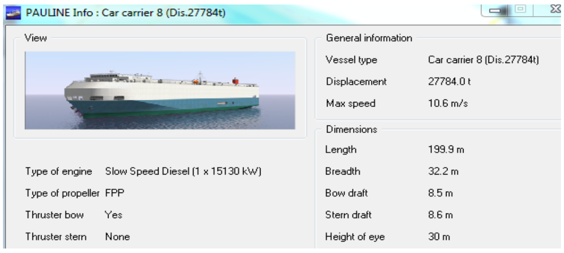
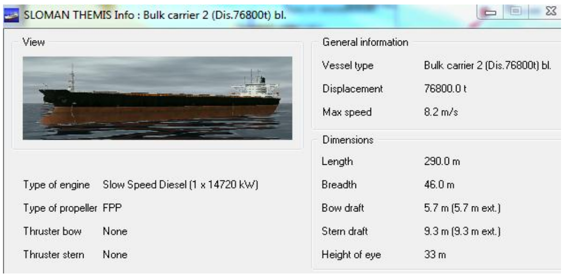
No.4	**Exercise description**		**Acronym of Exercise**
Exercise Title	Contravention in TSS off Spurn		
Exercise No.	**4**		
Sea Area	ACCSEAS		
Exercise time	1300 UTC 19-07-2014	**Paper charts**	BA 109,1188
Vessel data			
OS Vessel type	 Name: ACCSEAS Call sign: ACCSEAS		
Initial SOG	21 kts	**Initial COG**	270°
Equipment	All navigational equipment fully operative, EPD used as ECDIS and primary mean		
Environmental conditions			
Start Position	In-bound Outer Sea Reach		
Visibility	4 nm	**Tide state**	Falling tide
True Wind	10.0 kts, 225°	**Current**	~ 2 kts, outbound
Sea state	0.4 m, 225°	**Weather**	cloudy
Special precautions	-		
Mission			
Vessel bound for Hull			

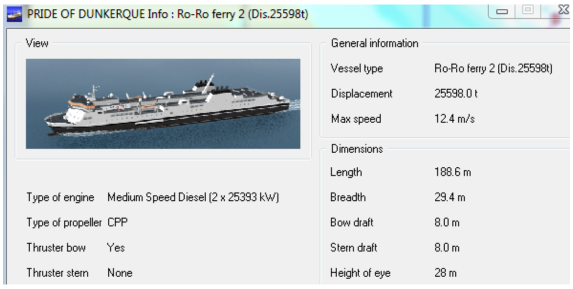
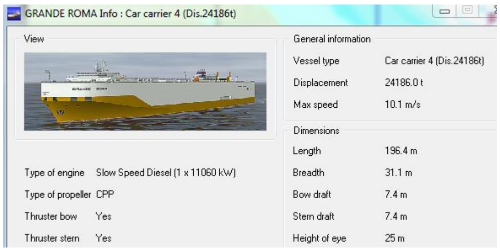
4	Exercise Plan		Acronym of Exercise
Exercise Title	Contravention in TSS off Spurn		
Exercise No.	**4**		
Sea Area	ACCSEAS		
Exercise time		**Paper chart**	BA 109,1188
Duration	~ 60 min		

Bridge Team

Participants	2 Persons per bridge

Exercise storyboard

Time	Instructor`s actions & messages	Participants expected actions
	All engaged simulator bridges & bridge teams are briefed acc. mission and weather. Bridges are manned with "full" crew.	Preparing Routes
+3	PAULINE reports Clee Ness out, ch14	
+5	SORMOVSKIY 44 reports Spurn Lt Fl in, ch14 Instructor to adjust speed to interfere with ACCSEAS (overtaking situation when meeting SLOMAN THEMIS)	
+8	SLOMAN THEMIS reports P5 SDC will go against TSS, ch14 Instructor to adjust speed as to meet ACCSEAS after Spurn Hd	

+11	PRIDE OF DUNKERQUE reports Spurn Lt Fl in, ch14	
+17	GRANDE ROMA reports Clee Ness out, ch14	
		+20 ACCSEAS reports Spurn Lt Fl ch14, possibly reduces speed
+25	Possible discussion between PRIDE OF DUNKERQUE and SLOMAN THEMIS, POD will pass ahead	
		+30 or possibly before Route exchange SLOMAN THEMIS or with VTS

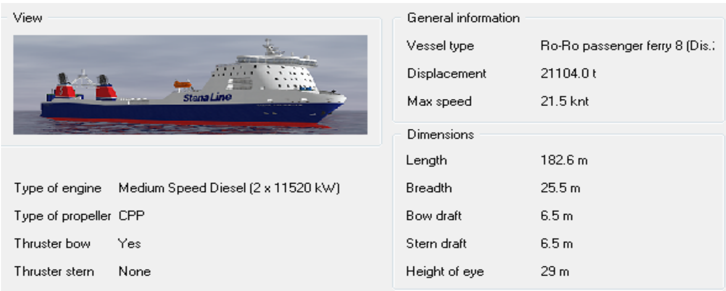
Main Objectives

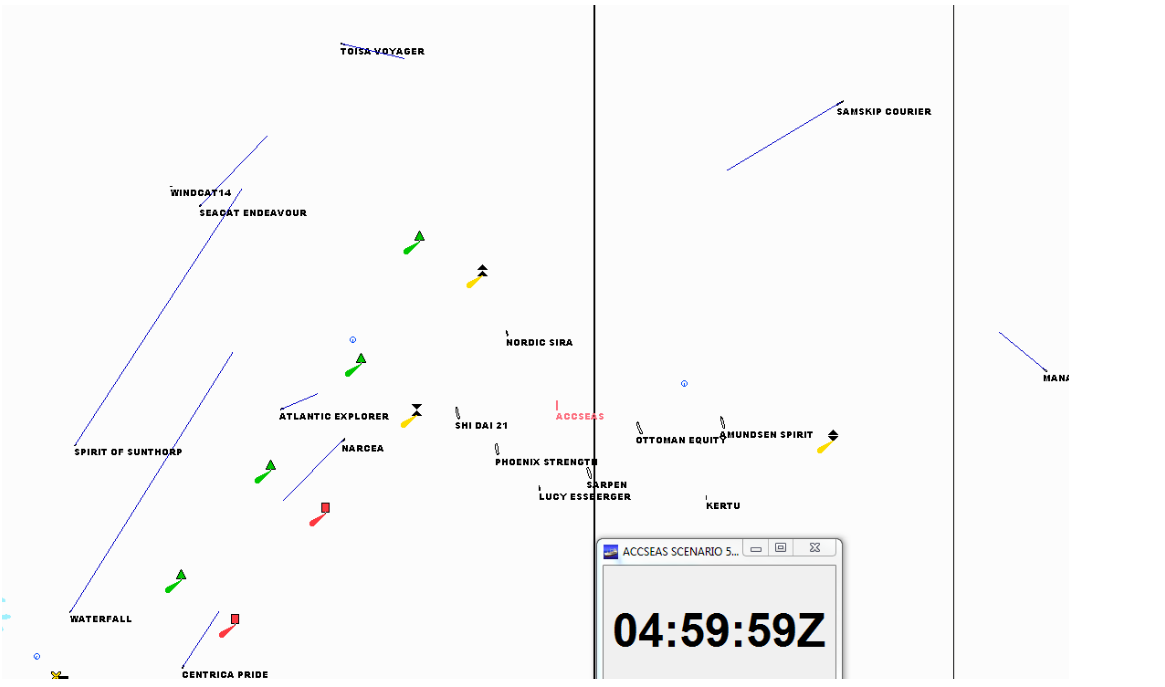
Knowledge, understanding and proficiency	**Reference**	**Conducted**
Route suggestion, No-go area for Outbound vessel and VTS, Intended routes		

Additional Instructor Information

Adjustments and Background Info	**Reference**	**Conducted**
Large vessel is outbound and other vessels inbound. To allow sufficient UKC for the outbound deep draught vessel it is directed to the northern side of the inbound lane where depths are bigger (route suggestion from shore). Inbound vessels are requested to use the southern side of the inbound lane to give space to the outbound vessel (route suggestion from shore)		

D.5 Scenario 5 – Leaving Deep Water Anchorage

No.5	**Exercise description**		**Acronym of Exercise**
Exercise Title	Leaving Deep Water Anchorage B		
Exercise No.	**5**		
Sea Area	ACCSEAS		
Exercise time	0500 UTC 28-08-2014	**Paper charts**	BA 107, 109
Vessel data			
OS Vessel type	 Name: ACCSEAS Call sign: ACCSEAS		
Initial SOG	0 kts, at anchor	**Initial COG**	n/a
Equipment	All navigational equipment fully operative, EPD used as ECDIS and primary mean		
Environmental conditions			
Start Position	Anchorage B		
Visibility	10 nm	**Tide state**	Rising tide
True Wind	5.0 kts, 000° (can be increased)	**Current**	~ 2 kts, 180° (may be increased)
Sea state	0.4 m, 000°	**Weather**	clear
Special precautions	-		
Mission			
Vessel bound for Hull by New Sand Hole			

<table>
<tr><td>5</td><td colspan="3">Exercise Plan</td><td>Acronym of Exercise</td></tr>
<tr><td>Exercise Title</td><td colspan="4">Leaving Deep Water Anchorage B</td></tr>
<tr><td>Exercise No.</td><td colspan="4">5</td></tr>
<tr><td>Sea Area</td><td colspan="4">ACCSEAS</td></tr>
<tr><td>Exercise time</td><td colspan="2"></td><td>Paper chart</td><td>BA 109,1188</td></tr>
<tr><td>Duration</td><td colspan="4">~ 30 min allocated</td></tr>
<tr><td colspan="5">Bridge Team</td></tr>
<tr><td>Participants</td><td colspan="4">2 Persons per Bridge</td></tr>
<tr><td colspan="5">Exercise storyboard</td></tr>
<tr><td>Time</td><td colspan="2">Instructor`s actions & messages</td><td colspan="2">Participants expected actions</td></tr>
<tr><td></td><td colspan="2">All engaged simulator bridges & bridge teams are briefed acc. mission and weather. Bridges are manned with “full” crew.</td><td colspan="2">Preparing Routes</td></tr>
<tr><td>+0</td><td colspan="2">Overview traffic in the area (6 min vectors), no imminent risk of collision</td><td colspan="2"></td></tr>
<tr><td></td><td colspan="4">
</td></tr>
</table>

+2		Calls VTS Humber abt heaving anchor
		Starts heaving anchor
+5	VTS Humber warns for strong currents and sends a route suggestion	

Main Objectives

	Reference	Conducted
Test of Route suggestion – VTS sent suggested route to vessel with explanation.		

Additional Instructor Information

Adjustments and Background Info	Reference	Conducted
A vessel is leaving Deep Water Anchorage A or B. Strong southbound current sometimes causes problems for vessels bringing them very close to the North New Sand N-cardinal light buoy. Humber VTS sends route suggestion to vessel that takes into account the current and brings the vessel well clear of buoy.		

Annex E DGNSS R-Mode Detailed Results

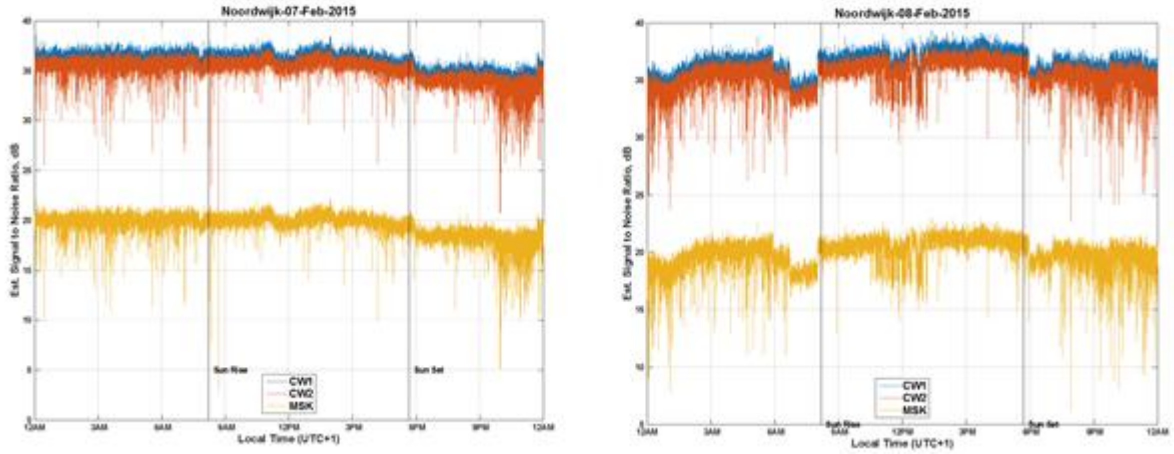


Figure E.1 – Signal-to-Noise Ratio of the MSK, CW1 and CW2 signals over time.

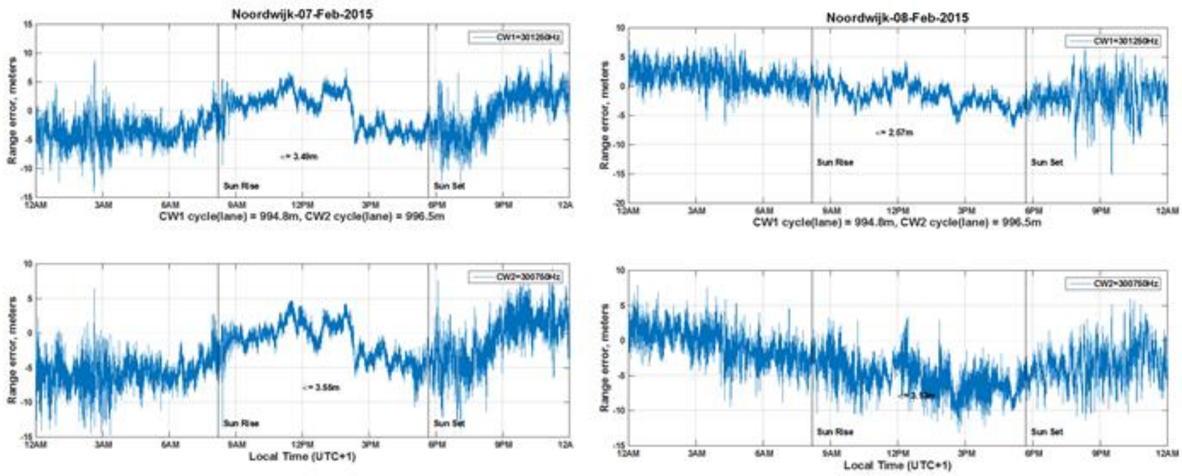


Figure E.2 - R-Mode Range Error of CW1 and CW2 over time.

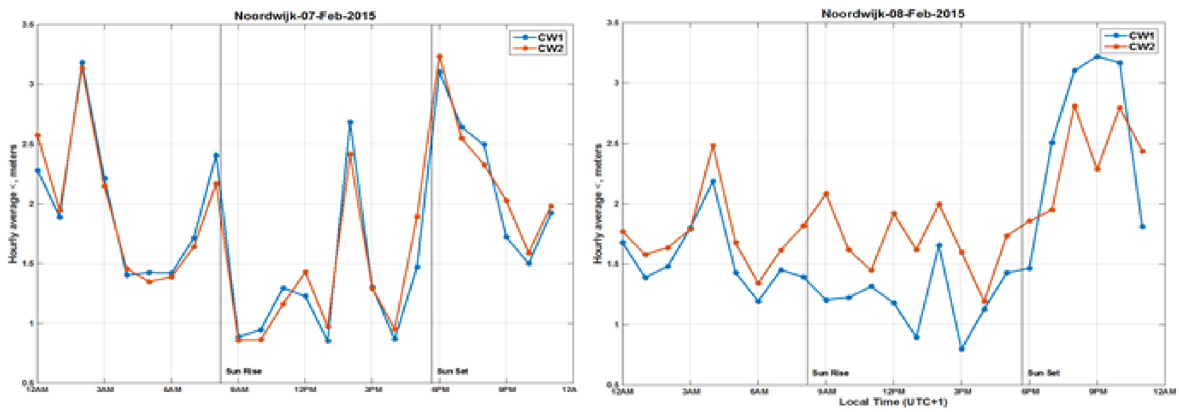
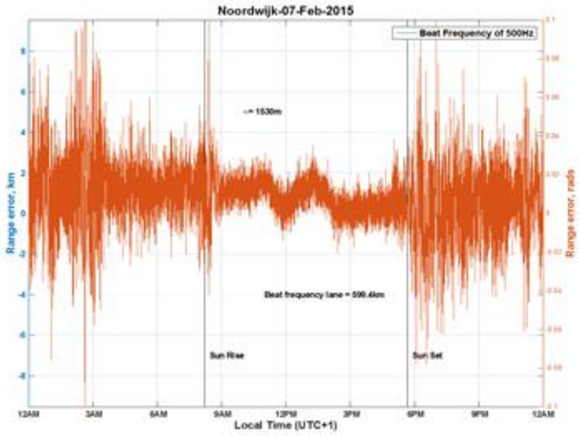


Figure E.3 - R-Mode Range error of CW1 and CW2 as hourly average over time.



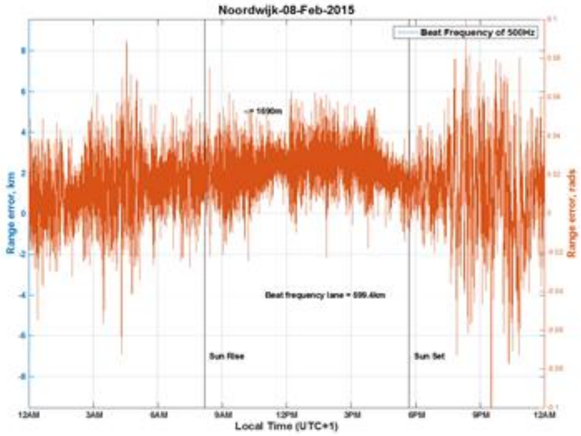


Figure E.4 - R-Mode Range Error of beat frequency as hourly average over time.