ENC-GNSS08

MULTI-MODAL TRACKING & TRACING SYSTEM INTEGRATING BOTH EXISTING GNSS INFRASTRUCTURE AND GALILEO CAPABILITIES

N. Lan[1], G.J. van Oosten[2], J. Andersson[3], H. Zelle[4], B. Peeters[1]
[1]*Ursa Minor Space & Navigation B.V., Delft, The Netherlands*
[2]*West Consulting B.V., Delft, The Netherlands*
[3]*Pilotfish Networks A.B., Göteborg, Sweden*
[4]*Argoss B.V., Marknesse, The Netherlands*

Abstract

With a view to exploiting the unique capabilities offered by the future Galileo constellation, our consortium has undertaken the design of a marine safety information system providing location based services to both leisure vessel users and marine rescue control centres (RCCs). Not only does the resulting demonstrator system illustrate the potential benefits of Galileo infrastructure, but the design also considers the integration of existing space-based and terrestrial infrastructure to provide an increased range of information from a number of independent systems in a single product.

More specifically, the system envisions the integration of new capabilities into an existing, commercially available product. The resulting architecture based on GNSS positioning considers and offers the following location based services: -

- value added meteorological information and forecasts
- standard marine safety information gathered from multiple sources
- two-way communication with rescue services in the case of an emergency situation, using the foreseen capability of Galileo's SAR return link message including extended available information and value added services for search and rescue
- both terrestrial and space-based communications infrastructure

The system has been designed with existing marine safety information services as a baseline such that comparison of the extended capabilities identified can in many cases be made directly with other existing and planned systems. The potential advantages of these capabilities are discussed.

The integration of different systems stems from a desire to provide user focused services. Therefore requirement analysis is driven by user needs, as is the resulting system architecture such that systems are included as necessary in providing desired top level behaviour by our multidisciplinary consortium. Complexity is inherent in the project through this need to integrate a number of independent systems, as well as products from several partners, further indicating a need for an interface-focused design process. One result of this design process has been an exploration of the challenges and solutions found in such a system of systems. These issues, and the technologies employed in their solution, are discussed.

Future work identified for the development of this demonstrator system is identified and discussed in the context of different development options. Potential in its original target market is explored with reference to this potential performance and extension of the developed infrastructure is considered for potential application to other location based services and markets.

1. Introduction

With the forthcoming Galileo constellation bringing new possibilities for location based services, our consortium has, under contract from the GSA, undertaken the design and implementation of an integrated location based system for the enhancement of marine safety. For leisure vessel users, this provides relevant marine safety information from various sources, including value added wind, wave and current forecasts, as well as demonstration of potential for synthesis of provided information to quick look situational information for coastguard users. The system also demonstrates a two-way communications link between marine vessel users and emergency services enabled by potential Galileo capabilities and the possibilities in combining Galileo capability with other infrastructure.

Our consortium includes expertise in the development of suitable web services for such a development, availability of suitable demonstrator hardware and backbone for the user system, environmental data provision and expertise in future Galileo capabilities for this integrated system design. Furthermore, part of the infrastructure is based on another demonstrator system for marine safety, implemented by some of the partners, that shares many system elements with MTTS to provide drift predictions in marine emergencies [1].

Section 2 of this work describes the context in which this system might be placed with respect to existing GNSS services, Galileo differentiators and alternative systems, as well as gauging the usefulness and attractiveness of such a system to stakeholders. With respect to these stakeholders, section 3 describes the requirements analysis and resulting system design activities performed in the definition of this solution. The envisaged MTTS architecture is described. Implementation of these requirements in the demonstration system is described in section 3, highlighting the technologies used and emphasizing the potential role of the Galileo constellation. While the demonstrator system implemented has some nice capability, potential future work that would lead to a commercial system is identified, as well as opportunities for further relevant capabilities that might be integrated in section 5. Conclusions to this work may be found in section 6.

2. Marine Safety Context

In the improvement of marine safety, important characteristics of support tools and applications include robustness, availability and accuracy. Furthermore, dissemination of safety information such as weather forecasts and location of physical hazards is key to the prevention of accidents involving maritime traffic, with the improvement of situational awareness provided by such information aiding planning and mitigation actions for both vessel operators and RCCs. In case of an emergency, however, situational awareness for the RCC is also enhanced by knowledge of the distressed vessel having the aforementioned characteristics. This work focuses on leisure vessel users rather than commercial operators where the safety system environment is more mature.

With the introduction of the Galileo constellation, the following potential advantages will become available to the implementation of marine safety services: -

- Potential for return link message in emergency situations
- Greater availability of navigation signals in combination with other systems
- Greater accuracy of the navigation signal, perhaps in combination with other systems
- Greater availability for distress signals in combination with other communication modes
- Greater availability and coverage for RCC to distressed vessel communication via new return link message capability
- Enhanced coverage enables consideration for more global services
- Greater redundancy and robustness in combination with alternative systems

Currently, vessel information, MSI and weather forecasts may be communicated through the AIS standard [2,3]. However, information is limited to that which AIS receivers can receive and transmit over the utilised

RF frequencies used, and is effectively limited to coastal waters. In addition, numerous internet services publish AIS information, as well as MSI messages collected from various sources. General weather information may also be received through such web services as well as regular radio broadcasts.

In general, devices such as EPIRBs are used for the automatic or manual broadcast of distress messages through Cospas Sarsat, along with conventional RF 2 way communications. Distress beacons are, however, limited in functionality.

Enhancement of marine safety through new technology, services and space infrastructure is currently under study in many activities, both governmental and commercial. For example, the MARNIS project under FP6 is a broad study of potential solutions for maritime navigation and information services, considering the needs of MTTS related stakeholders such as RCCs and vessel users, and includes study of maritime information services for the enhancement of marine safety [4]. One objective of this work was to harmonise marine vessel systems including those described previously.

While the forthcoming RLM capability of Galileo has many potential uses, the use of a return link message for marine distress message authentication was also considered as part of the GJU funded project, MARUSE [5], and envisaged an architecture with many similarities to that envisaged by MTTS, including the integration of this SAR functionality into a multi-functional marine user terminal. In terms of the dissemination of location-based marine safety information to leisure vessel users, the ALIS project (also funded by the GJU), envisages a service similar to the related part of the MTTS system [6].

SARIS is one example of other marine safety information systems currently in service with RCCs, where some environmental information is provided from selected sources for improvement of situational awareness. The system's main functionality is in drift prediction [11].

While using normal satellite communication capacity rather than the Galileo SAR RLM, interest in 2 way, satellite-based, ship-to-shore communications is in development in the ESA funded MeCA project [7]. This project's implementation is supplying a number of services to Canadian Coastguard vessels including email and VOIP communication, as well as secure data services.

3. MTTS: High Level Design and Architecture

A thorough requirements analysis was carried out in the conception of the MTTS architecture. This analysis was based on analysis of stakeholder requirements including direct consultation with stakeholders including several coastguard services. General need can be inferred from both this analysis and the project context described in section 2 for the following services: -

- Integrated, location based MSI from multiple sources
- Two-way comms with Galileo between leisure vessels and RCCs
- Potential value added services based on the provided information

The high level MTTS architecture displayed in Figure 1 is developed from the requirements analysis considering the use of existing space and terrestrial infrastructure such that Galileo will complement existing capability and make good use of what exists already. The data provision services, on-demand data and MSI+ service provide MSI and environmental information to both the coastguard and the leisure vessel user. Analysis service is seen as a potential added value service for the RCC, using the extensive MSI data, environmental data and individual vessel information available in MTTS to provide automated preliminary prioritisation of distress situations based on the available data. On demand data is able to provide detailed visual wind, wave and current forecasts whenever required. In a similar way, MSI+ service provides a range of location based textual safety and weather information.

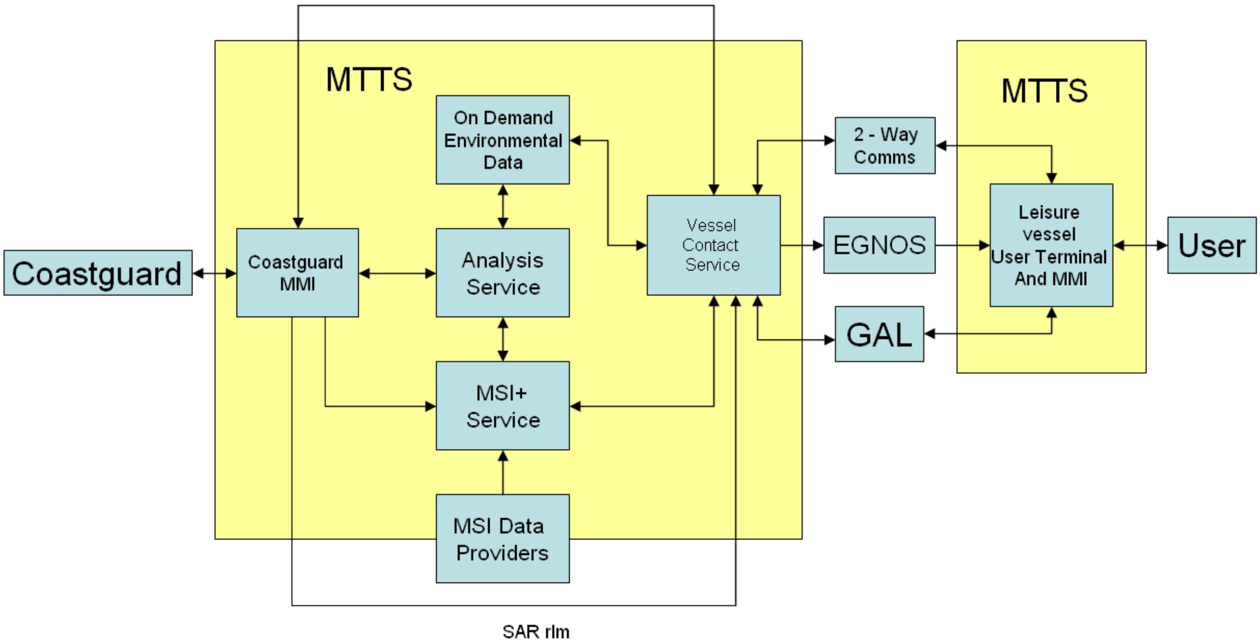

Figure 1: Envisaged system design including Galileo. MSI Data providers are present both within and external to this design in that geotagging capabilities are included in MTTS to localise textual MSI messages. On Demand Environmental Data defines graphical value added environmental data supplied to both RCC and vessel user. MSI+ Service collects and provides localised MSI gathered from multiple sources to both RCC and vessel user. Analysis Service provides value added emergency management information based on available MSI and other environmental data to the RCC. Vessel Contact Service provides the system backbone for connecting MTTS to remote vessel users through multiple communication modes. Galileo in this case provides 2 way comms between RCC and user in the absence of other 2 way comms such as GSM. In addition to distress initiation from the MTTS system, it was envisaged that a distress message from an EPIRB could be directed to the CGUI, or details of an alert may be entered manually by the RCC.

This system provides a two way interface between RCCs and users, gathers MSI data from multiple sources and makes relevant information available to the user according to their specified position, provides in addition value added environmental data that would enhance the situational awareness of vessel users and RCCs, enables efficient transfer of relevant vessel and journey details in case of an emergency, includes multiple communication modes, enhancing availability and hence robustness, and supplies value added location based data to RCCs in cases of emergencies. The details of environmental data and extra information supplied to RCCs are given in the following section.

2 way comms such as radio communications provide 2 way voice communications but are limited in range. EGNOS might be used for wider ranging broadcast of safety information but has no capability for communication to RCCs. Cospas Sarsat provides a link to RCCs with use of emergency beacons. Galileo will form part of Cospas Sarsat with its SAR payload, and can provide a return link message enabling useful 2 way communication and again will greatly increase coverage of the system. These multiple modes also improve robustness in the architecture.

In terms of marine safety, situational awareness is key for both leisure users and rescue control centres. The MTTS system links these stakeholder groups, envisioning for wide-coverage two-way emergency communication utilising the forthcoming Galileo return link message capability. This communication allows for the use of short, user-defined messages, as well as the efficient exchange of pre-defined vessel and journey related data founded on that which is available in other marine safety specifications such as AIS.

4. Demonstrator System Design and Implementation

With the architecture described in section 3, a system was designed and implemented to demonstrate the use of such a system. Since Galileo is currently under development, capacity for short RLMs was emulated through a web interface able to transmit short user defined messages and a number of predefined parameters. EGNOS capability was also unavailable for this demonstration.

Open standards and technologies were used in exchange, description and storage of system data between the remote elements implemented by the multiple consortium partners. The result was a secure network able to synthesize input from multiple sources in providing a single solution through two distinct interfaces for specific customers. With the multiple partners using differing hardware and software, an interface focused design process was essential to the success of the project. The following open standards and technologies were used to describe and store the data, and to exchange data over a (secure) network between the different subsystems developed by the consortium partners.

- Web Feature Service (WFS) for serving the alert information. The information is stored in a PostGIS data store;
- Web Map Service (WMS) for serving the map data;
- Web Services (and associated technologies WSDL and SOAP) for the communication between the subsystems
- Network Common Data Form (NetCDF) to exchange the environmental conditions and drift prediction data;
- The man-machine interfaces were created using the MapBuilder and OpenLayers toolkits, using AJAX technology for a rich and interactive user experience
- Custom software components have been developed in the Java and Perl programming languages.

The implemented physical architecture is shown in Figure 2.

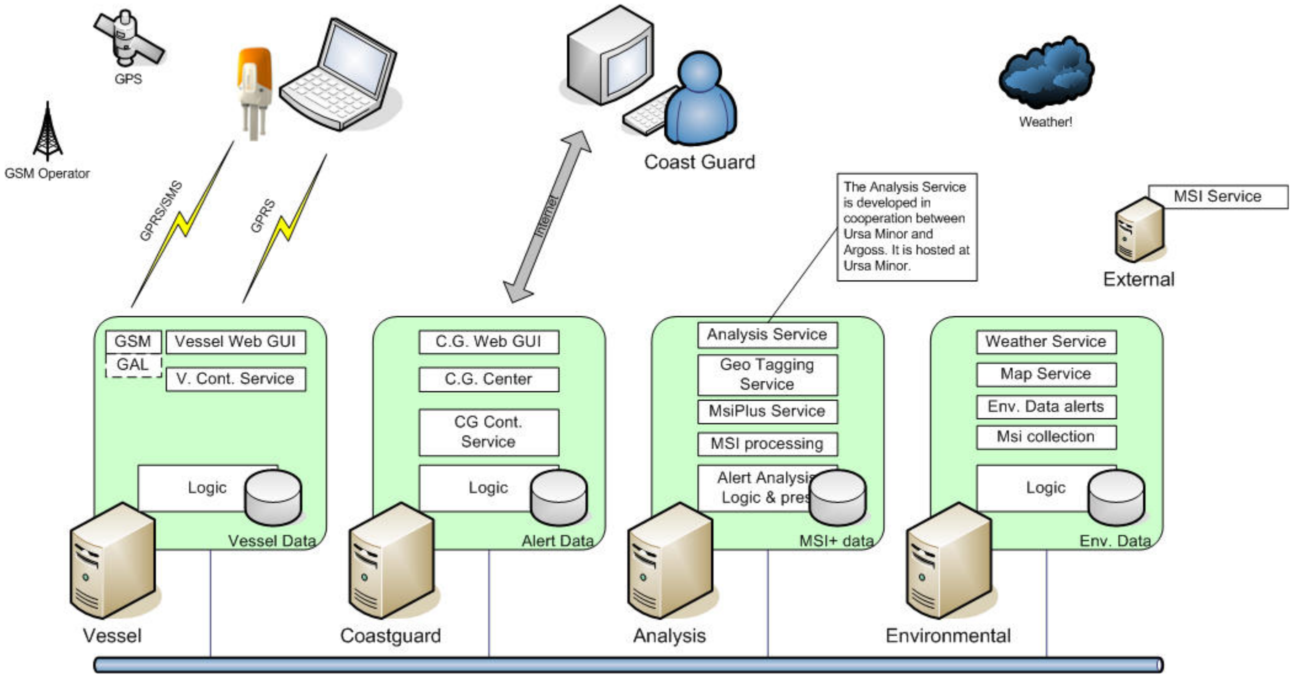

Figure 2: MTTS Demonstrator Physical Architecture. Web services are utilised to allow the running of different parts of MTTS at remote partner sites.

While more of the functionality of the envisaged system at the leisure vessel user end has the potential to be integrated into a custom user terminal, for the purposes of the demonstrator most current functionality is implemented into a web interface Leisure Vessel Graphical User Interface (LVGUI). To demonstrate integration into a marine safety hardware product, a C-POD yacht management system terminal was integrated into the system to demonstrate EPIRB-like manual distress initiation and automatic alarm triggering on submersion of the unit, shown in Figure 3 [8]. The terminal also provides the GPS location data to the system, as well as other dynamic vessel parameters. Functionality of the user interfaces is as described in Figure 4 and Figure 5.

Figure 3: C-POD yacht management system terminal

On demand data service provides graphical wind, wave and current information that are superimposed on the user map (see Figure 5). Data is generated from forecast models that are calibrated with both satellite scatterometer and local measurement data in an ongoing process of improvement. Both offshore and near shore forecasts are available globally for up to five days ahead [9].

MSI+ Service collects and distributes data in several areas. Example shipping forecasts are collected from the UK Met Office and geotagged with appropriate polygonal region areas such that vessels can be sent the information relevant to their position or course. In a commercial system, forecasts could be collected from any number of sources such as this to provide users with the forecasts they prefer. Warnings are automatically detected and flagged so that they can be highlighted in the user interface and so that the alert analysis service can upgrade an alert priority in case of an emergency in bad conditions. Plain text MSI messages in several formats may also be entered into the system through the CGUI. Text pattern recognition is used to extract the location and warnings from messages. Tabular representations of the data provided in the on demand data function are also gathered and distributed. Warning tags are generated when environmental factors exceed the preset limits. Furthermore, MSI+ service collects and distributes active alerts from the CGUI, such that users can be made aware of distressed vessels in their vicinity if necessary.

Analysis service demonstrates two possible added value services that may be provided through processing the MTTS available data described above. The first shows how localised vessel, environmental and other MSI data may be automatically assessed to provide a fast preliminary prioritisation for multiple alert situations. The service takes into account the following parameters and uses predefined rules to generate approximate priority of individual alerts.

- Type or types of distress
- Local weather conditions
- Other hazards in the local area
- Type of cargo
- Small vessel size in bad weather

The second part of analysis service emulates the use of the Galileo SAR RLM for efficient 2 way communication between an RCC and a distressed vessel in the absence of other modes of communication. Given whatever vessel data that may have been entered through the LVGUI or C-POD, the system assesses the most useful further information required by the coastguard and responds to the LVGUI causing a prompt to appear asking the user to fill in the requested information. For efficiency in an emergency situation, only the most urgent unanswered questions are asked in any given case, once these are entered and sent to the coastguard, the analysis service may be called again to request the next most relevant questions. Questions are primarily based on the type of distress encountered e.g. if a medical emergency is specified, the system would ask how many people require assistance, and other onboard contact details for two way communications, if these are not already available. Distress types used in MTTS relate to those defined by the IMO [10].

The demonstrator system can therefore perform the following functions: -

- Provide multi-source, location-based MSI and environmental data to leisure vessel users on-demand or automatically
- Emulate multi-mode, 2-way emergency communication between an RCC and a leisure vessel user

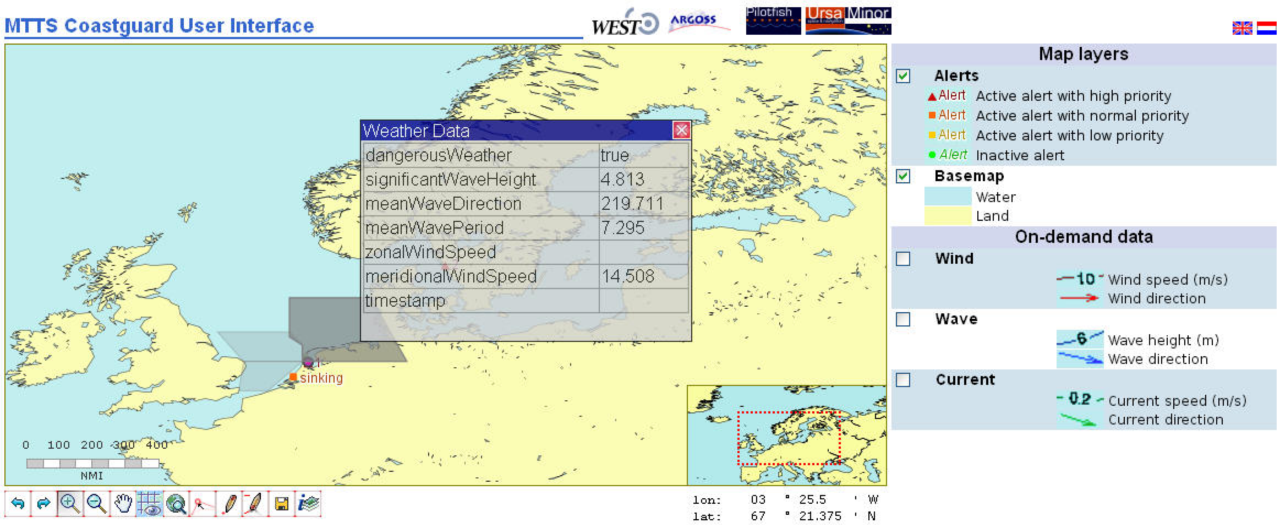

Figure 4: Part of MTTS RCC User Interface (CGUI). Web accessible MTTS interface for RCC. Interface also allows: i) viewing of individual alert information transferred through MTTS from the vessel ii) input of user defined return link message for 2 way comms iii) access to all relevant MSI data provided by MTTS iv) submission of textual MSI message to MTTS for geotagging and dissemination

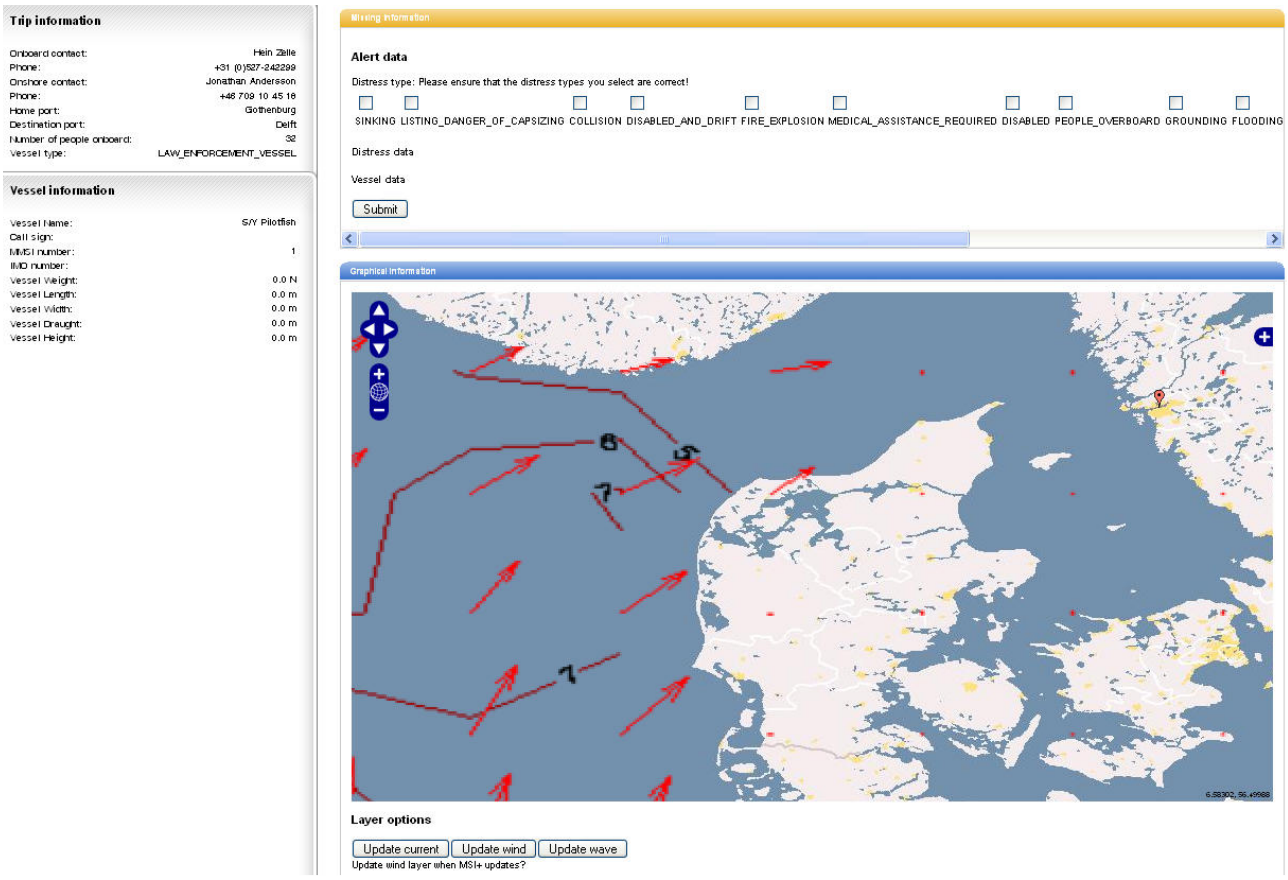

Figure 5: Part of MTTS Leisure Vessel User Interface (LVGUI). Location of user vessel is shown on map with graphical representation of local wind environment provided by MTTS. Interface also allows i) input of extensive vessel and trip information useful to RCCs in emergency situations ii) reception of position relevant MSI messages and data from multiple sources through the single MTTS service iii) input and dynamic update of distress parameters in case of an emergency iv) reception of both predefined and manual input replies from RCC in emergency situation

5. Future Work

With the use of extra capacity in Galileo services yet to be decided, the use of the envisaged system is dependent on the implementation of the required capability in the final constellation. However, it can be seen that elements of this system might be used in other such location based marine services. In any case, commercialisation of the system would require some further development work as well as additional customer consultation to refine the functionality. However, the fact that the demonstrator already includes commercially available marine hardware indicates potential for moving some portion of the system into the commercial sector as part of other systems.

There are also many options for adding functionality to the system, including the integration of a previous project of some of the consortium partners, EDD. This system shares many elements with MTTS and uses environmental data to predict the drift over time due to wind, waves and current of bodies in water [1]. While similar in function to the SARIS system referenced in section 2, EDD uses integrated environmental forecast information to make predictions, rather than manual input current information. Furthermore, the proposed added value services of the analysis service could potentially be made much more complex, considering many more available factors with available data. In an operational system, data from alert priority ratings could be useful for analysis of prioritisation of alerts given the available data.

At the time of writing, demonstrations of the system to stakeholders are planned and feedback should help to guide further work.

6. Conclusions

User focused requirements analysis and system design has led to the design of a potential system utilising forthcoming Galileo capability for the enhancement of marine safety. The relevance of the system's functions to marine safety has been discussed and related projects have been identified and discussed. A demonstrator has been implemented to show or emulate many of the functions of the system.

- Design of integrated system use of Galileo SAR RLM in an integrated system for enhancement of marine safety
- Implementation of a demonstrator system emulating the system's potential capability

This user focused design has considered the use of multiple communications modes complementary to existing marine safety systems and future Galileo capabilities. The envisaged architecture has the following capabilities.

- Integrated, location based MSI from multiple sources
- Multi-modal two-way communications including Galileo capability between leisure vessels and RCCs
- Value added information services based on the provided information for enhanced situational awareness and efficient emergency communication

A demonstration system has been implemented and tested using open standards and technologies to demonstrate and emulate the proposed architecture. Capabilities reflect the general intention of the proposed architecture and already implements potentially useful services such as: -

- Emulation of efficient 2-way emergency communication between a leisure vessel and RCC suitable for use with Galileo RLM capability
- Collection and dissemination of multi-source location-based MSI and environmental data including detailed wind, wave and current data
- Demonstration of value added information services for RCCs based on available information

Future work for development of this system both in relation to Galileo and in other contexts has been discussed, as has the potential of the system in relation to the wider marine safety system context, finding that there is potential for adoption of such an architecture to enhance marine safety.

7. References

1. Ursa Minor B.V. Environmental Distress Demonstrator (EDD), Eindverslag. EDD-FR-UMR-ARG-WST-001. 2007
2. ITU. Recommendation ITU-R M.1371-1: Technical Characteristics for a Universal Shipborne Automatic Identification System Using Time Division Multiple Access in the VHF Maritime Mobile Band. 2001.
3. IEC. Maritime navigation and radiocommunication equipment and systems. Class A shipborne equipment of the universal automatic identification system (AIS). Operational and performance requirements, methods of test and required test results. IEC 61993-2:2001. 2001
4. MarNIS Project (accessed Jan 2008), http://www.marnis.org/
5. MARUSE, *TN-20 Analysis of using the Galileo SAR RLM Service for position authentication,* MARUSE-TN20-UM-SAR-R00, GJU05/2410/CTR/MARUSE, 2006.
6. ALIS project, (accessed Jan 2008), http://www.alismarine.co.uk/

7. Telesat Canada. Marine eCommerce Applications (MeCA), Final Report. ESA Contract 17482/03. March 15, 2005.
8. Pilotfish, Manufacturers and distributors of the C-POD yacht management system (accessed Jan 2008), http://www.pilotfish.net/
9. Argoss, provider of marine environemental data (accessed Jan 2008), http://www.argoss.nl/
10. IMO. IMO Standard Marine Communication Phrases. resolution A.918(22). November 2001
11. SARIS informational website, http://www.bmtcordah.com/?/92/46/, accessed 27/3/08.

Acknowledgements

The authors would like to acknowledge the funding and support of the Galileo Supervisory Authority in relation to this work. Also, the authors would like to thank the many coast guard authorities who contributed feedback and advice on the proposed system.