OPERATIONAL ACTIVATIONS OF MARITIME SURVEILLANCE SERVICES WITHIN THE FRAMEWORK OF MARISS, NEREIDS AND SAGRES PROJECTS

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ABSTRACT

This paper presents the results obtained by GMV in the maritime surveillance operational activations conducted in a set of research projects. These activations have been actively supported by users, which feedback has been essential for better understanding their needs and the most urgent requested improvements. Different domains have been evaluated from pure theoretical and scientific background (in terms of processing algorithms) up to pure logistic issues (IT configuration issues, strategies for improving system performance and avoiding bottlenecks, parallelization and back-up procedures). In all the cases, automatizing is the key work because users need almost real time operations where the interaction of human operators is minimized. In addition, automatizing permits reducing human-derived errors and provides better error tracking procedures. In the paper, different examples will be depicted and analysed. For sake of space limitation, only the most representative ones will be selected. Feedback from users will be include and analysed as well.

1. INTRODUCTION

The European Union is facing new challenging border scenarios that demand enhanced surveillance systems. In the maritime domain, main drivers are the avoidance of loss of lives, the increasing of safe&rescue measures, the enhancement of law verification and enforcement (for custom dealing and irregular immigration) and the provision of safer corridor lanes. The monitoring of the maritime borders, especially at the Mediterranean Sea and West Africa coast, needs from Pan-European initiatives that involve more than one Member State (MS). Otherwise, the main goals would not be successfully fulfilled.

In such initiatives, data fusion is essential as currently there is no sensing device that can provide target location, identification and tracking with competitive spatial-temporal coverage. Main assets include ship / airborne surveillance, cooperative data streams (AIS, LRIT…), coastal remote sensing (Visible, IR, Thermic…) and Earth Observation (EO, SAR & Optic).

In this context, the European Commission (EC) and European Space Agency (ESA) have promoted R&D projects with the pursued goal to provide insights into a future system able to cope with maritime surveillance at European level in an integrated and efficient way. The system shall support and complement current operational practices, which are mainly conducted by short-range sensing devices plus local surveillance resources (ship and airborne). The scale is the key parameter as ideally the system should provide the same tracking and identification capabilities of local sensors at the scale of the whole European maritime border. From a technical point of view, key topics are:

- Advanced processing of cooperative means with alarm detection, route propagation and constraint-based track delineation (coastline, bathymetry, harbour…)
- Proper exploitation of EO data with extraction of reliable information. Main concerns are focused on the detection of small and non-metallic ships, the provision of enough parameters for target categorization and support for extended tracking. The detection of large and metallic ships is currently mature.
- Integration of the information derived by in-situ or local devices, such as coastal radars, ship radars or underwater sensors.
- Integration of supporting information derived from statistics and external reports that can shed light on the best way to exploit the available assets. The output is related to strategic information so that areas of interest can be isolated in a semi-automatic manner with decision support algorithms.
- Standardization of dissemination mechanisms and fully integration into user systems
- Capability to success load and performance tests that assure that system performance is independent from the processed data streams and system stress.

With this in mind, the following initiatives are relevant:

- ESA's MARISS
- EC's NEREIDS, DOLPHIN and SIMTISYS from the FP7 2010 space call
- EC's PERSEUS, SEABILLA and I2C from the FP7 2010 space call
- EC's SAGRES and LOBOS from the FP7 2012 space call.

GMV is involved in MARISS and is the Project Manager of NEREIDS and SAGRES. Thus, these projects will be the main topic of interest in this publication.

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2. PROJECT SUMMARY

MARISS is building up a network providing operational services to different MS with the current state of the art of maritime surveillance systems (EO + cooperative). The services available in the MARISS portfolio are:

- ***Critical Area Monitoring***: Characterization of all vessels within a specified area of interest. Primarily intended for open water monitoring – however can be customized for monitoring Third Party Coastal Waters including Ports/Harbours and beaches (e.g. to detect presence/absence of vessels of interest, anomalous behaviour etc) – this is described as a separate service (Third Party Coastal Waters Monitoring)
- ***Extended Tracking of Contact of Interest***:
  - Provide persistent monitoring of the behaviour of a specified vessel (or set of vessels) over a period of time
  - Provide situation awareness around a vessel in situations where the vessel master may not be cooperative (e.g. hijacking, piracy, IUU fisheries)

  This service is usually requested under strong timeliness constraints (in general when a national authority becomes aware of the fact that a specific vessel is undertaking an activity that should be monitored). In addition, the requirement for satellite based tracking usually arises from the current location of the vessel of interest outside of areas where member states have patrol assets or fixed surveillance systems, in general open ocean or coastal waters of third countries several hundred nautical miles away from European waters
- ***Area Search***: Emergency search of a given area to find particular vessel – this may be in support of Search and Rescue operation or finding vessels suspected to be engaged in clandestine activities
- ***Monitoring of Third Party Coastal Waters***: Detect and characterise activities in third party coastal areas that represent potential threats to EU member states – eg build up of persons on beach or in harbour areas, presence/absence of vessels of interest in third party ports or harbours
- ***Background Pattern of Life:*** Pattern-of-Life (POL) analysis is becoming increasingly important in today's military. It revolves around the continuous observation of behaviour patterns for a population, town, or village. From these considerations a technology based on Artificial Intelligence has been derived. It can characterise long term human activities, by analysing the background variations of a stack of satellite images of the same scenario, taken in a period of time.
- ***Statistical Analysis***: Point out statistical trends featuring cues of illegal trafficking

The ***NEREIDS*** project (https://www.nereids-fp7.eu) is conceived to provide an integrated vision of maritime policy and maritime surveillance so that the different elements of the service become useful to the different maritime domains (Illegal trafficking, illegal immigration, fisheries control...). Currently, each of the available service focuses in specific applications and provides limited capabilities when the information of interest is modified. For instance, the technological constraints differ greatly from open sea monitoring to coastal / beach tactical analysis. The idea behind NEREIDS yields on developing a system of systems that permits a complete and meaningful maritime picture and permits solving the most challenging technological drawbacks that current services have to face on. This objective is completely aligned with what promoted by the EUROSUR program: "*Awareness in the maritime domain requires monitoring the compliance of all activities, detecting with the help of surveillance and ship reporting system anomalies that may signal illegal (security threats) acts and generating intelligence that enables law enforcement authorities to stop unlawful entry into the EU area*"

In addition, GMES has been recognized (different EC communications, BORTEC study, ESRAB and ESRIF reports...) with the known limitations as a key element supporting maritime surveillance and facilitating interoperability, data sharing and the integrated approach. NEREIDS shall endorse such approach and define the specific objectives compliant with such general approach.

The main users that have shown interest are:

- Guardia Civil; EFCA; Italian Coast Guard, Portuguese GNR, Portos da Madeira, Spanish Fisheries Directorate and Spanish Customs.
- UK and Sweden users are being engaged for the last set of demonstrations campaigns.

Main NEREIDS goals are:

- To identify possible new areas (in the maritime surveillance domain) where EO can already contribute in an efficient way.
- To investigate new EO automatic processing capabilities together with data fusion techniques.
- To contribute reducing existing barriers for the users to adopt new technologies in particular in the maritime security domain.
- To define an open architecture (toolbox) that simplifies the engineering cyclic process in a simple, flexible, modular and robust basis.

- To contribute to the definition of the future maritime surveillance services within by ensuring a proper understanding of EU and national policy areas.
- To foster collaboration with other initiatives for efficient resource usage, mainly dissemination.
- To define and execute well-defined campaigns with measurable results over different areas covering multi-sectorial interests.

SAGRES (http://www.copernicus-sagres.eu/index.html) supports the pre-operational test and deployment of the high-time critical CONOPS components via the EUROSUR network. CONOPS refers to a document conceived and defined by FRONTEX, EMSA, EUSC, JRC, ESA and EC (through DG-ENTR and DG-HOME) that summarizes the set of services (and the associated technical requirements) foreseen by the user community to cover the major operational needs in the field of border surveillance. The reference scenarios are:

- Tracking vessels on the high seas with two main components:
    - Monitoring of a specific third country port.
    - Tracking the identified vessel over high seas**.**

The pre-operational services are delivered to FRONTEX via EUSC and EMSA. EUSC and EMSA will play the role of product validators and will support product delivery by generating added-value with their own technological resources. JRC is playing the role of user satisfaction validator.

The work will not start from scratch but from some pre-operational services chains (MARISS with INDALO campaign) improved with other R&D developments (FP7 space 2010 call). The principle of "use, comment, upgrade, use" applies, which will result in a cyclic development of five service versions during the timeline of the project. The resources and technological means that SAGRES will put on operation will overlap what currently existent.

SAGRES is not a tunnel vision oriented short term commercial service. It will deliver innovation at large term by an experienced, competent, proactive and complementary team. The impact on the European border guard community would be significant because SAGRES will demonstrate a new dimension of EO exploitation by merging the received data with a large and diversified list of ancillary streams. The perception of added-value will be more evident and the users will find a direct link among the activated services and the products needed in day-life missions.

3. SUMMARY OF SYSTEMS

In all the three projects, the structure of the system is quite similar. What different is the modules connected to the system to perform various operations. The following elements can be distinguished:

- Service Oriented Architecture (SOA): The system is conceived to follow a toolbox approach where a main system kernel will manage and interconnect a set of modules aimed to provide specific processing capabilities (target detection, data fusion…). From a logical point of view, the architecture can be represented by "operational nodes", situated at different locations, connected together, and allowing the actors and systems to process and exchange information (see Figure 3-1). Depending on its local resources, each contributor may have a distinct collection of operational or technical services exposed to the community as remotely accessible services. Here again only agreed partners are allowed to access one specific organization services. User management and access to the local situation data (and the associated applications and services) is managed at each organization level. Thus, each organization is free to apply its own security rules, organize user profiles in a convenient way and limit access to applications and data in the most suitable manner. The global SOA exchange bus must be able to support the different exchange patterns among the domain services spread over the network such as messages exchange and request/ response. The deployed SOA architecture is designed to be flexible enough to allow new value-added services to be integrated.
- Distributed data processing: Processing flow is based on a data distribution facility that relies on publish-subscribe services providing a data–centric interoperability means among organizations. Exchanged data are organized into Topics which are identified with a Topic name and which refer to a given data structure. Each organization can subscribe to the defined Topics and can publish information on them. The publish/subscribe paradigm also allows for a flexible subscriptions management between organizations, based on their specific interests (interest zone, exclusion areas, data attributes characteristics), thus limiting data exchanges to necessary data only. Since systems are owned by different organizations (partners), it is reasonable to envisage non-availability of certain organizations at a time when data distribution occurs.

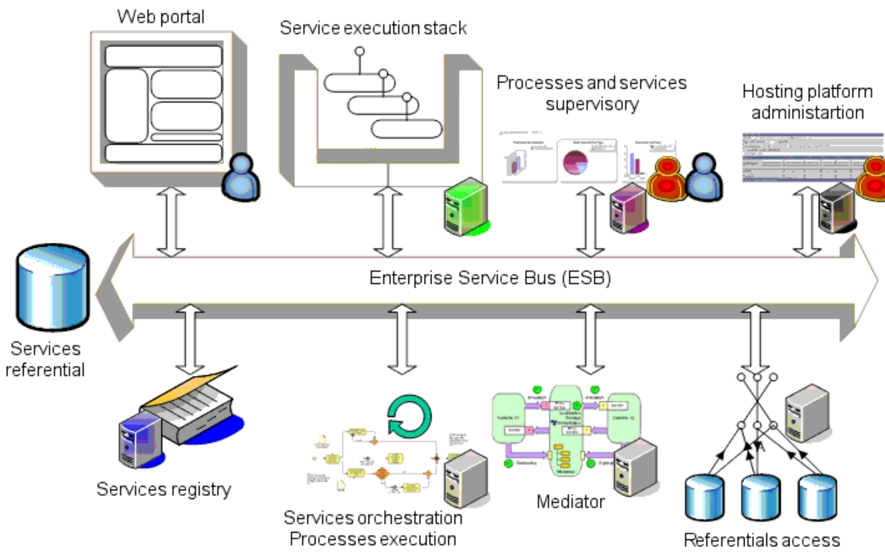

Figure 3-1: SOA architecture of NEREIDS functional view.

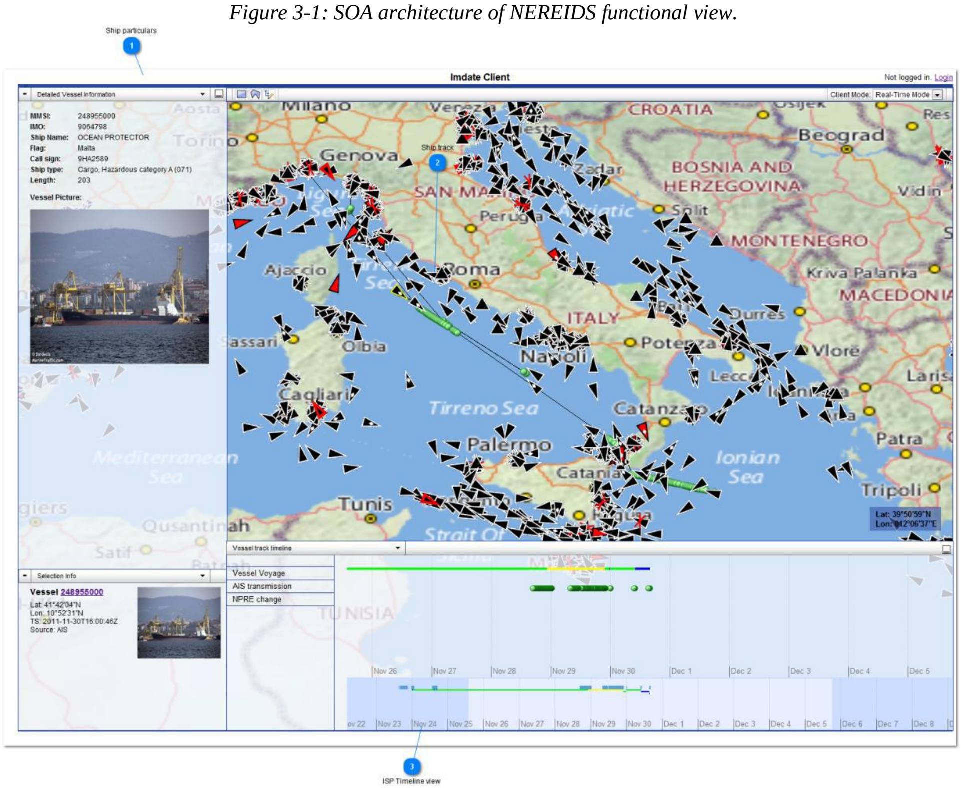

Figure 3-2: Snapshot of the HTML5 Web GL visor used in NEREIDS.

- Open-source GIS: System interface is a web-based GeoPortal following the concept of Spatial Data Infrastructure (SDI). The platform integrates several state-of-the-art technologies and components, such as web services, geospatial and thematic databases, GIS clients, graphical utilities for cross-checking, dissemination and information. The service is modular and scalable, and migrates the intensive image processing tasks at the server side. This permits an efficient resource management and better error control. From a technological point of view, a multi-tier scheme developed with portlets (JSR286-specification) and compliant with the Open Geospatial Consortium (OGC) standards is normally adopted. Main OGC standards are: Web Map Service (WMS) for map rendering, Web Feature Service (WFS) for geographic features analysis and the Catalogue Service for image catalogue. For sake of improving visualization performance, WebGL libraries complaint with HTML5 are being introduced in the clients. Besides enabling 3D capabilities over the web, WebGL also provides additional processing power, by exploiting the GPU for processing and visualisation purposes. Thanks to this, a high number and range of different ship related information can be visualized in a competitive manner. It is worth noting that WebGL treats each geometric element independently from each other so that the whole scene does not have to be refreshed when only a unique element is updated.

4. CAMPAIGNS

Different campaigns have been executed in the framework of MARISS, NEREIDS and SAGRES. Due to the sensible information managed in SAGRES, no explicit information will be disseminated. The key elements of user feedback will be only commented. The results of the campaigns will be presented in terms of maritime domains: fisheries, maritime traffic monitoring and irregular activities. Different web clients will be shown because each project uses different approaches.

4.1. Fisheries

The following figures provides two examples of key results obtained in MARISS and NEREIDS.

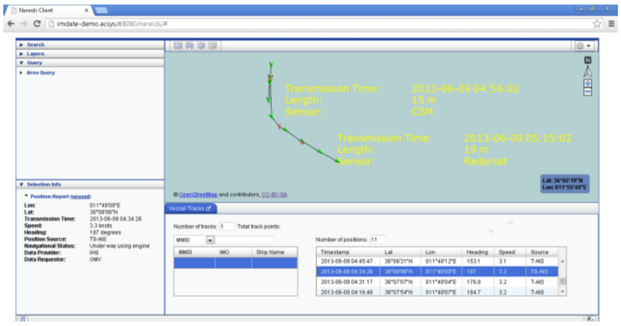

Figure 4-1: Snapshot of a fishing ship track consolidated with T-AIS with two non-cooperative (red icons) entries derived by the analysis of two SAR images acquired 25 min apart. NEREIDS project.

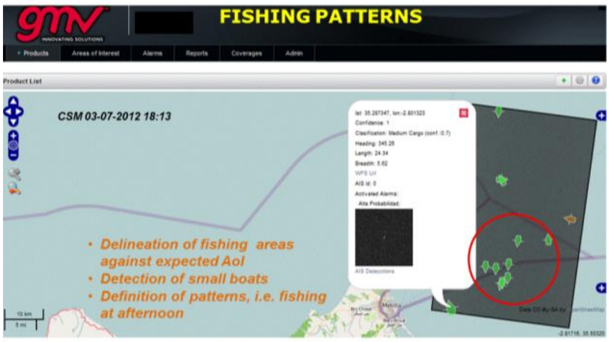

Figure 4-2: Snapshot of a maritime scenario showing the areas where fishing vessels are working. MARISS project.

Figure 4-1 is showing the powerfulness of acquiring different EO images separated with a very short time gap. This opens the door for the correlation of non-cooperative entries without the support of cooperative streams. In automatic mode, this is only possible in non-crowded areas where few ships are available. If a human operator can supervise the results, EO to EO correlation is feasible at any area provided that the successive images are acquired in less than 1 hour. This will also imply robust detection algorithms with a very low false alarm ratio.

Figure 4-2 is showing how the analysis of successive EO images over the same area along a large period of time can permit extracting patterns. Normally, this task is done with cooperative entries, but insights with non-cooperative entries is not largely available. This example has permitted the user confirm if the ships are fishing when and where expected, and to derive seasonal patterns.

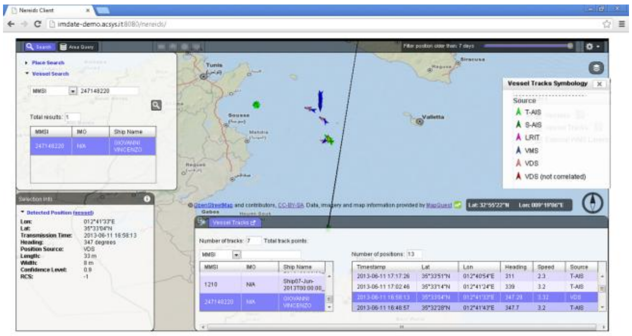

Figure 4-3: Snapshot of a maritime scenario showing the tracks of fishing vessels consolidated with VMS. NEREIDS project.

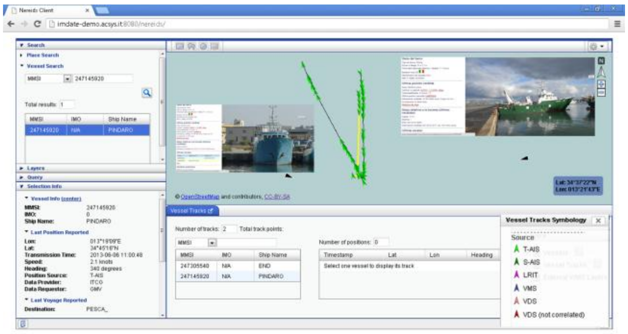

Figure 4-4: Snapshot of a maritime scenario showing the tracks of two fishing vessels labelled as potential anomaly. NEREIDS project.

Figure 4-3 is showing the tracks of fishing vessels consolidated with VMS stream. The purpose behind this example is to state the invaluable support that VMS can provide to complement integrated maritime picture. They permit increasing notably the ratio of correlation of non-cooperative entries. In NEREIDS, some approaches to permit exploiting VMS without exposing ship identity have been tested. This goes into the user credential world where specific information is filtered to specific users. According to the available layers and users, this task would not be trivial.

Figure 4-6 is showing the tracks of two fishing vessels that have been labelled as potential anomaly. Further analysis with the user (EFCA) has confirmed that such pattern is normal in fisheries. As stated by the point of contact in EFCA "*it is quite coming to fish in parallel as the ships are following the same bathymetric line (certain species can only be caught at a certain depth). The duration of about 2 hours coincides with the duration of a tow. After that (at about 11:05 Z) they both took on board the net and changed course to re-deploy the net and start fishing again*". Such example has shown another research interesting topic; the definition of fishery-adapted anomalies. Certainly, the anomalies that affect non-fishing vessels would not be considered as such in fisheries. It will be treated during the last stage of the projects.

4.2. Traffic monitoring

The following figures provides three examples of key results obtained in MARISS and NEREIDS.

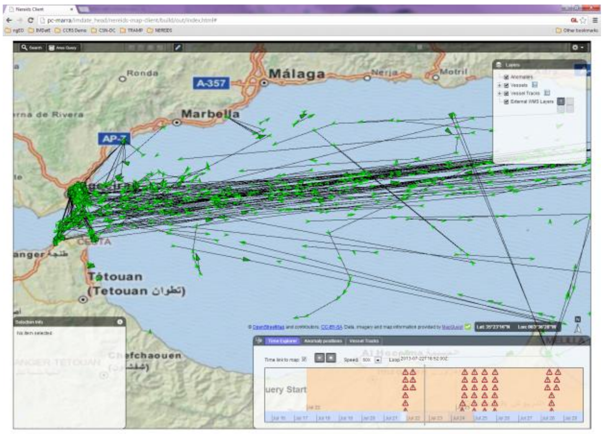

Figure 4-5: Snapshot of a maritime scenario showing a lot of tracks consolidated with T-AIS for a very dense area. Anomalies are also overlapped to highlight the tracks of interest for users. NEREIDS project.

Figure 4-5 is showing an integrated maritime picture built by merging T-AIS and non-cooperative entries derived by analysing SAR images. The client is providing some interesting features that makes the work easier for users. For instance, detected anomalies are overlapped as an independent layer so that users can only focus the attention on those ships showing patterns of interest previously pre-selected. The maritime picture at the time the anomalies were taken place can be re-played by using a time slider. This gives the user with an overall picture of the whole scene during anomaly time. Also the user can get an idea about how anomalies can interact. Other options are available as well to publish information in the clearest manner possible. Examples are the last reported layer, which shows only the last reported position for each consolidated track within the system, and the on-fly track reconstruction that generates tracks on-demand in base of user queries. Both features have appeared to be very useful for real time operations as the operator is not got confused with the large amount of data in operational campaigns.

Figure 4-6 is showing a maritime scenario where an anomalous track has been identified. This track is showing a ship cruising from port to port at the Gulf of Guinea. During the cruising, instead of going with a straight course close to the coast, the ship cruised to open seas, keep stopped for a period of 10 hours and gone back to the coast. What happened during this period is unknown even for users because no further information was available. However, the example is showing how useful this kind of integrated tools would be for users because the hard work (isolation of anomalous track) is automatically done by the system.

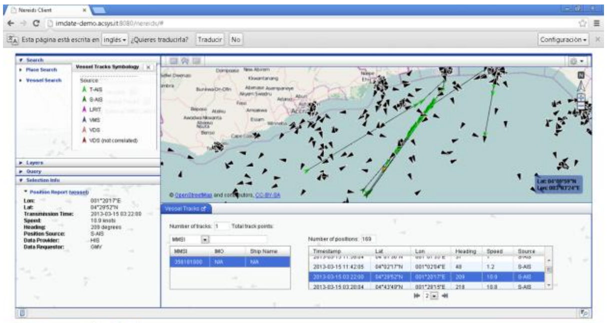

Figure 4-6: Snapshot of a maritime scenario showing an anomalous track where the ship is stopped at sea for a period of 10 hours. NEREIDS project.

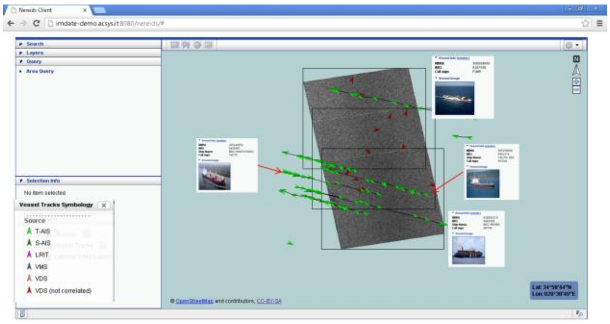

Figure 4-7: Snapshot of a maritime scenario showing some tracks of medium and large ships consolidated with T-AIS, S-AIS and non-cooperative entries (derived from SAR images). NEREIDS project.

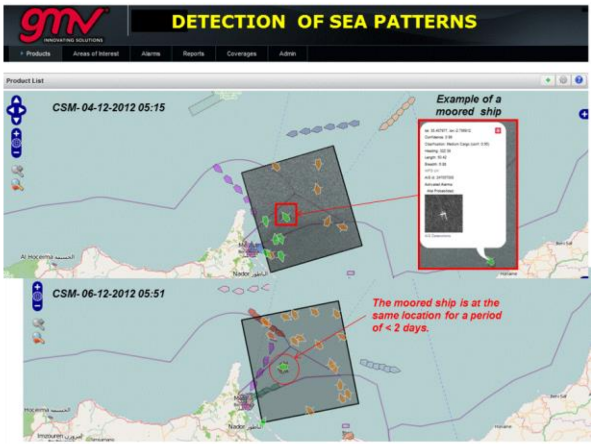

Figure 4-8: Snapshot of a maritime scenario showing sea patterns for specific ships by combining the information derived from cooperative and non-cooperative streams. MARISS project.

Figure 4-7 is showing an integrated maritime picture where some non-cooperative entries are correlated with tracks of medium and large size ships that have been consolidated with T-AIS entries. The scene also provides non-cooperative ship detection reports of small and medium size ships, which greatly complements what available with cooperative streams. Simple alarms can be derived from such scenarios that help authorities to know which kind of activity is being conducted in specific areas. In addition, such maps provide a way to discard areas for further local surveillance if EO images is showing nothing anomalous with respect to what reported by cooperative streams.

Figure 4-8 is showing an integrated maritime picture where the combined analysis of cooperative and non-cooperative streams derive specific patterns. As in the fishery case, the patterns can be linked to confirm expected behaviour or to detect anomalous ones. In this case, the analysis of successive images has permitted the confirmation that a particular ship was moored in front of a harbour area for a period of 4 days. During this time, no information about possible rendez-vous activities were reported, but this has not been discarded by users.

4.3. Irregular activities

The tasks related to monitor irregular activities are mainly focused to improve the capability to detect small non-metallic ships with high dynamics. The following figures provides three examples of key results obtained in that field in MARISS and NEREIDS.

Figure 4-9 is showing a maritime scenario where a ship with an estimated length of 8.73 m has been detected in an unusual area. The location of that ship is close to the harbour and it seems more probable to be a leisure boat.

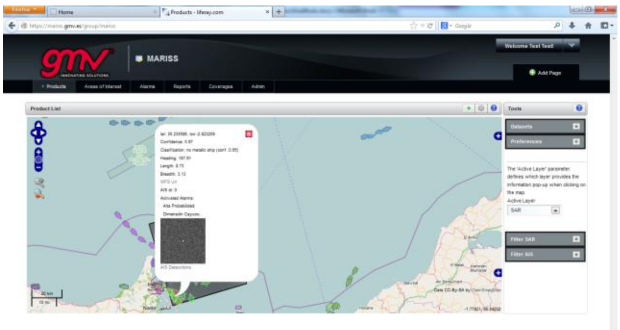

Figure 4-9: Snapshot of a maritime scenario where a ship with an estimated length of 8.73 m has been detected in a crowded area with no cooperative stream associated (T-AIS). MARISS project.

Figure 4-10 is showing a maritime scenario where a ship with an estimated length of 11.44 m has been detected in an unusual area. The location of that ship is close to the harbour and it seems to be a leisure boat.

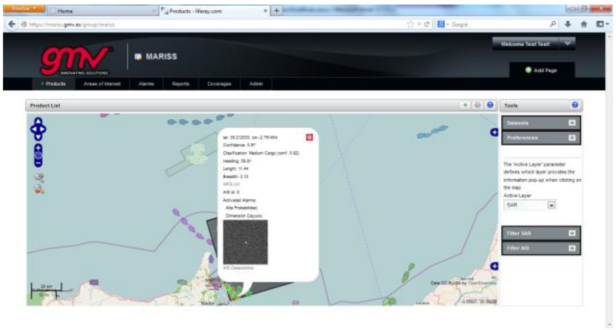

Figure 4-10: Snapshot of a maritime scenario where a ship with an estimated length of 11.44 m has been detected in a crowded area with no cooperative stream associated (T-AIS). MARISS project.

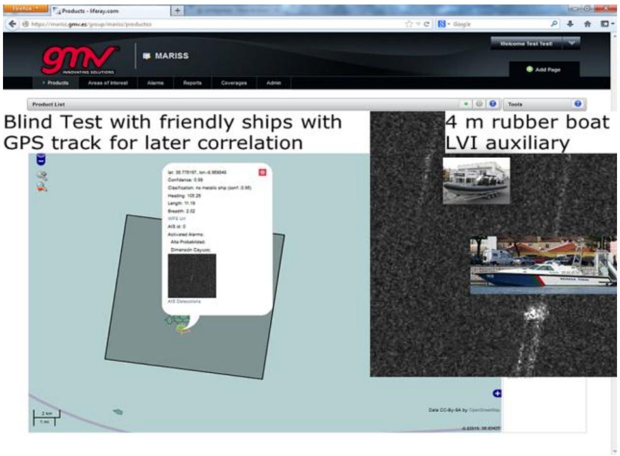

Figure 4-11: Snapshot of a maritime scenario where a friendly ship with an estimated length of 14 m has been detected, jointly with a 4 m rubber auxiliary boat. Both ships have been deployed by the user and positions were confirmed with a GPS track. NEREIDS project.

Figure 4-11 is showing a very interesting exercise where a 14 m fibber glass surveillance ship from the Portuguese GNR with a 4 m rubber auxiliary boat have been daily monitored with EO for a period of 10 days. Ship track was synchronized with the satellite pass and GPS tracks were provided by the user so that invaluable ground-truth was available. Spotlight and stripmap image modes have been used. During the time of the campaign, the ship monitoring system has successfully detected the 14 m ship in 75% of the cases. The fail cases were mainly caused by the adverse weather conditions available at the acquisition time (strong winds and current). In the spotlight images, the auxiliary boat has been successfully detected in 75 % (no chance in the 5 m stripmap images). The presented image shows an example of these cases where the blurring effects to the high dynamics associated with the targets are evident. Such effects can be compensated with autofocus algorithms that permits retrieving ship signatures with improved shape and more contrasted details. The immediate outcome of such feature is the capability to improve size estimation and target categorization, crucial for small ship monitoring.

The campaign with GNR has considered a complete success by the user. This poses a very good example of the type of collaborations that research projects can manage with users and the very competitive outcome that can be derived.

5. CONCLUSIONS

In the current paper, the main outcomes of MARISS, NEREIDS and SAGRES have been presented. Special attention has been paid to the different campaigns executed by each of them. The results / conclusions that can be derived from the joint exploitation of the different assets confirm marked technical improvements in key topics, for instance small ship detection, integrated maritime picture and target categorization. Other topics where improvements can be noted are:

- Target detection at sea with independence of observation and background conditions, and of target dynamic. Insights to the detection of small, non-metallic and fast boats with no support of cooperative data prove the reliability of this task with EO.
- Estimation of macro-scale features and target classification by only using EO data
- Advanced EO processing to diminish image artefacts and distortions (autofocus)
- Discrimination of any other target different than ships within the sea
- Target tracking by fusing cooperative and non-cooperative (EO) data
- Constraint-based track reconstruction
- Detection of anomalous behaviour to support decision making
- Environmental assessment to locate areas where the probability that certain activities of interest occur is higher
- Monitoring of specific ports and shore areas
- Complement the information provided by ship and airborne patrols
- Integration of oceanic and meteo information in the surveillance system in order to increase the range of constraints to apply when doing track reconstruction

In summary, the activities promoted by European agencies and institutions have allowed significant progress in maritime surveillance if compared with the status available five years ago. The invested money and effort has opened the door to go from the scientific and theoretical work into the pure operational one. This is one of the key milestone achieved by the projects; the development of fully-operational campaigns. However, a lot of work shall be done in the incoming two years to allow the European Commission to meet the milestone to run operational services at 2015. Intense pre-operational validation tasks are needed and are being conducted in collaboration with EMSA, EUSC and Frontex. The results will ultimately fix the level of usefulness that users perceive for EO-supported maritime surveillance.