FR1: PROJECT FINAL REPORT
SAGRES

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Code: SAGRES_FR
Version: 1.0
Date: 15-01-2015
Internal code: GMV 20195/15 V1/15

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DOCUMENT STATUS SHEET

Version	Date	Pages	Changes
1.0	15-01-2015		First published version

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1. INTRODUCTION

1.1. PURPOSE

This document provides the final report of the SAGRES project by describing the main outcomes and key achievements. The results pre-operationally confirm that the high-time critical CONOPS services are reliable in a border surveillance scenario and can support the operational missions of users. In addition, they provide important insights about how generic maritime monitoring and surveillance services can be improved at any domain. The document has a brief summary of the project history that reviews the evolution done during the last 2 years from the initial framework up to the final activation campaigns close to the end. During this time, user feedback has been essential to assess the proper evolution of the project and to stress the main topics of interest. The summary of final project recommendations fixes a potential starting point for further studies at both practical and R&D level. They show that Earth Observation (EO)-based services can notably support users in any operational maritime mission.

1.2. SCOPE

SAGRES will support 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 the Directorate General) that summarizes the set of services (and the associated technical requirements) foreseen by the user community to cover a set of 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 will be delivered to FRONTEX via EUSC and EMSA as presented in Figure 1-1. EUSC and EMSA will play the role of product validators and will support product delivery and the generation of added-value by using their own human and technological resources.

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. A scrupulous alignment with the technological means available in EMSA, EUSC and FRONTEX will be followed.

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. Main topics to improve are:

- No proper exploitation of the multi-source approach.
- Insufficient amount of data to test a integrated maritime picture over large coverage.
- Limited responsiveness and delivery time.
- Limited involved actors with limited time to follow maritime surveillance and monitoring initiatives.

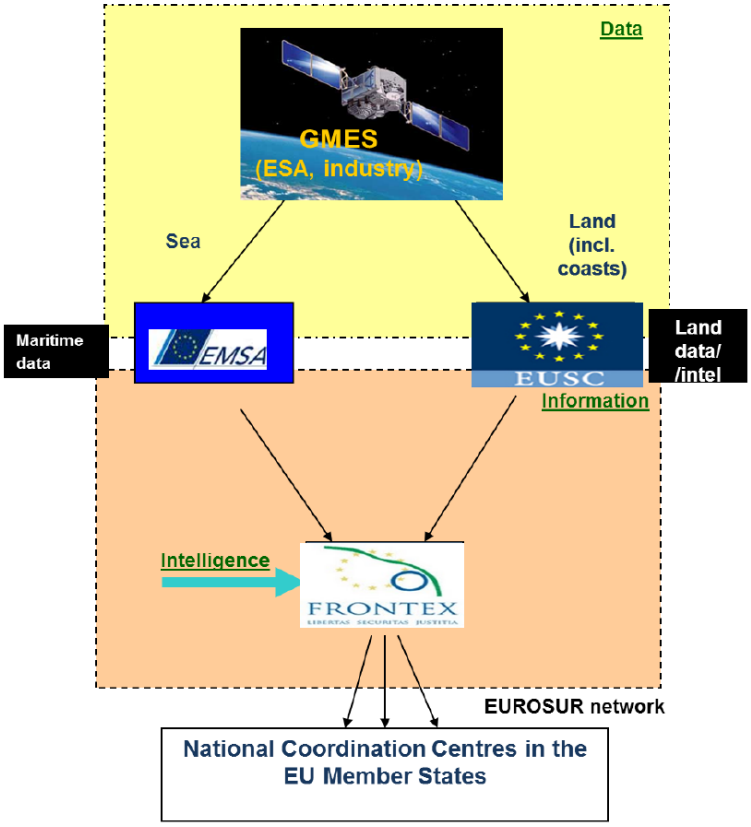


Figure 1-1: Role of the different involved agencies

The document focuses on the following topics:

- Final report by providing the main achievements of the project

1.3. DEFINITIONS AND ACRONYMS

1.3.1. DEFINITIONS

Concepts and terms used in this document and needing a definition are included in the following table:

Table 1-1 Definitions

Concept / Term	Definition
Input Data	The data arriving to a particular module
Output Data	The data that results after applying the algorithms contained in a module
Activation	The process of executing the complete SAGRES chain by activating the needed phases
Execution	The process of executing a single module
Phase	The main high-level division applied to SAGRES modules in base of the main functionality that they have been designed to.

1.3.2. ACRONYMS

Acronyms used in this document and needing a definition are included in the following table:

Table 1-2 Acronyms

Acronym	Definition
CISE	Common Information Sharing Environment

Acronym	Definition
DB	Data base
EEZ	Exclusive Economic Zone
EMSA	European Maritime Safety Agency
EO	Earth Observation
EUROSUR	European Border Surveillance Net
DWH	Data Ware House
IMDatE	Integrated Maritime Data Environment
JRC	Joint Research Centre
LRIT	Long-Range Identification and Tracking
MCS	Maritime Core Service
MSA	Maritime Surveillance Awareness
MSSIS	Maritime Safety and Security Information System
REA	Research Executive Agency
SAR	Synthetic Aperture Radar
SOA	Service Oriented Architecture
VDS	Vessel Detection System
VMS	Vessel Monitoring System
WFS	Web Feature Service
WMS	Web Map Service
WP	Work Package

2. REFERENCES

2.1. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Grant Agreement or approved by the Approval Authority. They are referenced in this document in the form [AD.X]:

Table 2-1 Applicable Documents

Ref.	Title	Code	Version	Date
[AD.1]	SAGRES Project Management Plan			

2.2. REFERENCE DOCUMENTS

The following documents, although not part of this document, amplify or clarify its contents. Reference documents are those not applicable and referenced within this document. They are referenced in this document in the form [RD.X]:

Table 2-2 Reference Documents

Ref.	Title	Code	Version	Date

3. PROJECT SUMMARY

3.1. SAGRES BACKGROUND

The SAGRES project has ended at 31-12-2014 after two years of intense and fruitful work. The implication of all the partners has permitted an optimum collaboration that produced excellent results. Some of them provide a clear break-through with respect to the current state-of-the-art, which applicability into real-life operational procedures has proven to be feasible. The most remarkable result is the **success case** that was achieved in one activation executed during September 2014 in the Alboran Sea where EO-based products notably contributed to locate a boat with distress immigrants on-board and the engines out-of-order. From a technical point of view, the performance of key algorithms that overcome classic drawbacks has been assessed as well. Examples are methods capable to detect small targets (length < 5-10 m) and/or to categorize ships by processing single-channel EO images, new multi-source data fusion approaches, the definition of complex anomalies, the propagation of consolidated tracks into the future or the automating of data ordering.

SAGRES was conceived to pre-operationally test the high-time critical CONOPS services that different European agencies have formerly defined to integrate EO-based reports into the operational procedures of border surveillance users. For such purpose, the project biased more into the practical than the theoretical domain. Actually, one project driver was to exploit the experience that was gathered from previous initiatives (FP7 projects, ESA-funded projects…) and to integrate the state-of-the-art technological and technical solutions into a unique chain. Minor developments have been foreseen and the approach to reuse whatever available (methods, algorithms, resources, infrastructure…) has been followed along project lifetime. In this framework, SAGRES promoted a close interaction with the user and stakeholder community, especially EC with some DGs, EMSA, SatCen, Frontex and the twin project LOBOS. A fluent communication channel was crystallized in terms of bimonthly User Advisory Board (UAB) meetings, which permitted reviewing project evolution and planning the following activities with the aim to achieve an efficient resource management. The user community has also played a key validator role by stressing which technological and technical solutions are more suited for the pursued goals. **Key overall objectives** were:

- Reliable, cost-effective and efficient Pre-Operational catalogue of Services with Near-Real-Time performance
- Integration with EUROSUR, a benefit generator to Europe's border security, in synergy with other initiatives; support to post-project continuous service in EUROSUR step 6 and beyond.
- Flexibility in front the incorporation of new technologies or operation beyond European areas (e.g. piracy areas)
- Effective and recognizable added-value to European Users at national level.
- Educational effort to promote the usage of EO-based services into European Users.
- Integration with other European systems and projects, such as LOBOS and initiatives from the security call.
- Generate value from products available in GMES DAP and establish EO as a primary data source in the field.
- Integrate all the experience and know-how generated in past initiatives, especially former FP7 projects.

The SAGRES goals were pursued by executing a complete activation campaign plan in base of the recommendations set up by Frontex and the associated National Coordination Centres (NCC). The service chain is similar to the one that was presented and tested in the NEREIDS project. It is based on the **system of systems** concept and the so-called Service Oriented Architecture (SOA) architecture, which allows geographically distributed processing modules to be connected to a centralized kernel. Besides management and security issues, the kernel keeps logistic functionalities, such as the ingestion of input data and added-value products, the storage of data entries and report publication. The processing modules provide the system with the algorithms that permit retrieving the parameters of interest from the incoming data. If one fails the overall chain is not at risk. Different

module versions can be tested at the same time without affecting overall system runtime. The system was implemented under operational time delivery constraints so that the processes were optimized in view of fully automating. The key element for such competitive performance is the multi-user multi-purpose DB architecture that permits different modules to modify the available data at the same time.

At the end of project lifetime and according to EC feedback, **SAGRES has achieved all the proposed objectives**. In some specific tasks, performance is beyond expectations, especially in what regards:

- The coordination of a diversified partner and stakeholder community
- The shift of scientifically used minds into fully operational procedures
- The amount of covered topics either technological or technical (new processing algorithms)
- The amount of demonstration campaigns with an active user enrolment and operational requirement constraints
- The dissemination effort with a joint collaboration with LOBOS
- The achievement of the master goal to assess EO potential capability to support operational missions with a success case

System interoperability is another remarkable feature as the SAGRES system can transparently and automatically work with other operational systems, such as the IMDATE managed by EMSA. In addition, SAGRES has adopted the same system architecture and templates than the ones in the operational world. Users are already familiar with them so that system interaction is straightforward and training demands, minimum.

3.1.1. AREAS FOR INVESTIGATION

Achieved objectives that deserved further attention are:

- Target detection by automatically processing SAR imagery with improved capabilities on locating small targets (comparable with the available resolution) and on estimating macro-scale features (length, width, heading and speed)
- Target detection and categorization by processing optical imagery with fully automatic algorithms. Up to now, semi-automatic approaches are only available
- Advanced fusion approaches able to deal with multi-sensor data, including sensors on-board in-situ platforms
- Complex anomaly detection by taking the maritime domain under analysis into account and by combining simple anomaly behaviours
- Propagation of vessel routes for traffic picture compilation and analysis in case of sensor measurements lack
- Advanced DB structure that complement the multi-user multi-purpose approach with automatic back-up procedures; performance shall be kept stable with independence of the number of entries ingested at the same time and the amount of stored information
- Real time Graphical User Interface (GUI) that permitted an integrated vision of the maritime scene under processing with an accuracy and realism close to the real life. SAGRES has not tested this topic due to the access to ImDATe that EMSA granted Frontex with. Even though such kind of GUIs are complete, they are still excessively generic and integration into internal user systems is not straightforward.
- New data ordering and tasking mechanisms that permit reducing the responsiveness time; this is especially interesting in high-time critical scenarios
- New missions and orbital concepts with the aim to reduce the sampling time and periodicity; the goal is to increase the number of available images with different observation conditions

3.1.2. THE EUROPEAN FRAMEWORK

The SAGRES effort has been done in **alignment with current European initiatives and policies**. Examples are the Integrated Maritime Policy (IMP), The European External Action (EEA), the Common Information Sharing Environment (CISE) or the EUROSUR (European Border Surveillance) network. In addition, EMSA, SatCen and Frontex have signed a set of Service Level Agreements (SLA) to frame the inter-agency collaboration from an operational point of view. They specify which and how information shall be exchanged, the procedures for joint exploitation of certain services and the available budget. In parallel, EC has updated the services framed within the security domain of Copernicus to the operational status. This ends the R&D phase by making added-value services available to end-users in an effort to serve society with the revenues that former research and pre-operational test works have generated. For such purpose, a set of Delegation Agreements (DAs) have been signed with some European agencies. Specifically, EMSA has accepted the management of the maritime services, while Frontex the border surveillance ones. All the maritime service demands within border surveillance will be managed by EMSA and trespassed to Frontex within the context of the proper SLA. The support to European External Actions will be managed by SatCen. The associated legal figure is not clear right now.

All the economic activities and human beings at sea shall attain to the maritime policies, which aim to harmonize the activities conduced on the maritime domain. The legal framework specify the domains where EO-based maritime surveillance services can contribute the most, for instance law verification and the provision of safety measures at sea. The awareness of European authorities to manage the European waters under an integrated approach that balance the economic growth with the citizens' security and environment protection has been notably increased in the last years. Among others, this is confirmed by the recent initiatives promoted through R&D programs (for instance, FP7 and H2020) and the issue of the Maritime Spatial Planning directive. Such management should be done by avoiding potential conflicts among Member States (MS).

SAGRES has been executed with a total alignment to a list of requirements that have been defined in base of the restrictions imposed by the applicable policies, user needs and the CONOPS services. The definition of such requirements has been dynamic along project lifetime as the signature of the EMSA-SatCen-Frontex SLAs experimented some delay and they were ready once the project started**. It is worth noting that the outcomes of SAGRES have contributed to refine the clauses of those SLAs and to base the redaction of DAs**. Certainly, SAGRES has supported the redaction of the "*Technical specification for the common application of surveillance tools at EU level in the context of EUROSUR by using imaging satellites and ship reporting systems*" document, which is the main technical document supporting DAs. Actually, this document aims to identify which of the formerly conceived CONOPS services can be operationally exploited. **SAGRES has complemented this input by providing an updated CONOPS service portfolio that accurately describe the operational implementation of such services with technological and technical details**.

3.2. END USER ENGAGEMENT

The relationship with users have been intense and fruitful. This has permitted conceiving complex campaigns that implied the coordinated exploitation of different data streams that were acquired from diverse data providers. In addition, users provided the project with specific datasets not available in the pure commercial net, which notably complemented the overall maritime picture. During the campaigns, user feedback was continuous and excellent. It was oriented to give advice about potential areas and/or targets of interest, to explain complex behaviours observed in the platform, to identify specific topics of interest and to detect the main deficiencies of the proposed algorithms. Most of them were handled by adopting a cyclic engineering process, which could be perfectly implemented thanks to the modular architecture of the system. The overall result was a competent system that can be aligned, in what regards performance, with other operational systems currently managed by users and/or European agencies.

At the end of the project, it can be stated that the collaboration with users has been very satisfactory for both sides. On the one hand, users were benefitted from a real and operational test benchmark with which they assessed the performance of the CONOPS services and evaluated whether they would be included in the operational chains. On the other hand, project partners had access to a large range

of data for testing new concepts and algorithms within a controlled environment that would be difficult to reach outside the project umbrella. The main user of SAGRES is Frontex that manages the border surveillance and pre-frontier pictures across Europe. Although they are in close contact with all the NCCs of each MS, there are some where cooperation has been more intense due to the location of hot spots. Examples are Spain, Italy or Greece, which NCCs collaborate in the execution of the campaigns at the Central-West Mediterranean basin.

3.2.1. ETHIC SCREENING

SAGRES confirms that has violated no ethic rule regarding the usage of confidential information and/or the identification of human beings and the monitoring of its privacy sphere. The analysis of 3rd country areas has been done by detecting and locating complex targets, but without identifying them. During the negotiation phase, the ethic review panel stated that SAGRES didn't need the supervision of an external ethic auditor. Thus, the special clause 15 of the Grant Agreement doesn't apply as the research conducted in SAGRES didn't require the written confirmation of favourable opinion of the relevant ethics committee. The reasons are exposed following:

- SAGRES only managed publicly available information. The information derived from the analysis of EO imagery aimed to locate complex targets, but do not to identify them. Cooperative reports provide ship ID information, but this is not considered confidential information.
- Frontex and SatCen filtered the sensitive intelligence-based information out from the SAGRES scope. SAGRES operated a monitoring service under a civil-based approach with no military usage.
- SAGRES did not manage a database with sensitive information. The unique information that SAGRES has stored corresponds to:
    - The processed EO imagery
    - The ship detection reports derived from EO image processing
    - The image analysis reports derived from EO image processing
    - The cooperative data entries providing tracking information of ships

  Socio-economic factors or private information of citizens have never been managed and/or acquired
- The visualization and SW supporting tools (including FTP server) have been secured with IP-based firewall-protected access plus credentials. No user and password has been transferred into the same email
- All the partners are committed to avoid disseminating any kind of project- related information to third parties without the authorized approval of Frontex. If not, legal actions can be started against. In addition, Frontex have supervised all the press releases / notes that the project has generated. Scientific publications have been very few and, when found mandatory, they have been supervised by Frontex

3.3. THE SAGRES CAMPAIGNS

Along project lifetime, **eight service activations** have been carried out.

- July 2013 at the Nador coastline (Morocco) to monitor the departure of ships at beach areas
- October 2013 at the Algerian and Lybia coastline to monitor the departure of ships at beach areas and the identification of potential activities of interest
- April 2014 at the Greece-Turkey border to monitor potential immigration ships in journey to Europe. Ship tracking and anomaly were also activated
- May 2014 at the Aegean Sea to monitor potential immigration ships in journey to Europe. Ship tracking and anomaly were also activated

- June 2014 at the Poland-Ukraine border to support in-field experiments by providing image interpretation analysis of complex targets and moving vehicles
- September 2014 at the Strait of Gibraltar, Melilla and Ceuta basin to monitor potential immigration ships in journey to Europe. Ship tracking and anomaly were also activated as well as image interpretation analysis of specific shore areas looking for specific activities of interest
- September 2014 at the Alboran Sea to monitor potential immigration ships in journey to Europe. This was initially conceived as a cooperative blind experiment with a surveillance asset of Guardia Civil. An emergency Search&Rescue call permitted using the ordered data in a fully operational mission. The detection reports allowed authorities to rapidly locate the target and save the lives of the on-board human beings
- October 2014 at the Açores and Madeira basin to monitor potential drug dealing ships in journey to Europe. The ships were only monitored and tracked by using EO images. The historic intelligence and ship detection reports were used to update the potential new situation of the ship and to order new set of images in base of that information

The exercises were executed with a **notable logistic effort**. First of all, the acquisition of cooperative data was done through different data providers in order to perform a kind of test benchmark among them. The associated data quality was evaluated against a set of metrics. The results show that fusing the cooperative data that were delivered by different providers is not straightforward. Among the detected phenomena, time shift would be the worst one. This prevents the tracks to be smooth and follow a straight and realistic line. On the contrary, a continuous forward and backward effect is observed emulating the shape of a saw. Some algorithms that were developed in the NEREIDS project have been adopted to compensate such aberrations. The last campaigns have been executed with the combined T-AIS and S-AIS link delivered by exactEarth through the SAGRES partner Hisdesat. The observed performance fitted campaign expectations.

The acquisition of satellite imagery has been benefited by the **GEST agreement between ESA and EC** for which SAGRES was assigned with a specific quota within the Data Ware House (DWH). The interaction with the GEST team has been constant, intense and very useful. Training with users permitted evolving data acquisition plans and the associated orders into a more efficient and straightforward way. The amount of data assigned to SAGRES has not been sufficient to cover all the project needs and the budget entry to support data provision was activated. Different sensors and acquisition modes were tested and the findings showed that no asset is performing better than the rest as advantages and limitations are detected for each of them. Actually, the combination of the available assets in a kind of multi-sensor constellation would be the predominant trend into the future as this would permit reducing revisiting time. However, the procedure needs from updates in order to improve delivery and responsiveness time, and to increase the flexibility on demanding different acquisition modes and processing levels.

The acquisition of in-situ and ground-truth information has been only possible in the Alboran Sea campaign at September 2014 were local surveillance means confirmed the delivered detection reports.

All the campaigns were designed and executed **under near-real time delivery constraint**, even though this was not possible in some cases due to limitations in data delivery. Main bottleneck was at EO image provider as the delivery of imagery to service providers lasted in mean value 2-3 hours from acquisition time. On the contrary, 15-20 min were normally needed by service providers to deliver the final reports to Frontex after image reception at their facilities. SAGRES worked with both SAR and optic rush images, which had an impact over the total amount of images available in the quota.

The activations were included in a cyclic engineering process for which the feedback gathered in one campaign served to fix the major developments that would be tested in the incoming ones. This provided the user with a closer vision about the advantages / limitations of the tested technologies, mainly EO imagery. In addition, this increased the perception about the usefulness of EO data in ship monitoring and surveillance. The link that has established between the scientific and operational world can be considered a big success of the project.

3.4. KEY SAGRES RESULTS

The results of the campaigns have proven that **EO technology can notably support operational border surveillance missions that involve the deployment of certain air- and ship-borne assets. In addition, the reliability of the CONOPS services, which are further described with the new portfolio, has been assessed as well. All the services present potential capability to be exploited in an operational scenario**.

All the results were validated against a pre-defined validation plan that took specific metrics into account. These metrics permitted quantifying the performance of the modules and the reliability of the proposed algorithms, i.e. the capability to improve current performance. Topics that were quantified are

- Responsiveness, processing and delivery time
- Geo-location accuracy
- The capability to detect small, non-metallic and dynamic targets
- Length, width and heading accuracy
- The capability to categorize ships with diverse acquisition modes
- The capability to detect ship anomalies
- The capability to analyse EO data in base of a specific procedure

From a theoretical point of view, one of the main contributions of SAGRES is the development of a complete environment assessment service suite with an own user interface. The service quantifies the reliability to find useful information in EO imagery in base of the service to execute, weather forecast information and sensor characteristics. The goal yields on maximizing the efficiency of image resource management by increasing the success rate of integrating image into operational assets. The user can easily interact with the system and can check raster versions of the tabular data that are used in the assessment. This service was designed and implemented as a response of one CONOPS service, but the offered capabilities overpassed the expectations.

SAGRES has also provided insights into the improvement of the algorithms that aim to detect small non-metallic targets into EO imagery. Data fusion has not been a key battle horse as the available fusion modules are advanced enough to handle the requirements of the CONOPS services. More work was demanded in the definition and detection of anomalies, especially in terms of tuning the thresholds in base of the scenario recommendations. SAGRES has investigated the potential capability of automating data ordering through specific web-based interfaces. The results are promising and a first draft system was built to test the concept with Airbus DS. Other innovation actions were related to investigate the operational exploitation of new challenging SAR acquisition modes and new route propagation procedures, which estimates the potential short-term route of a ship in base of the current navigation conditions, transportation corridors and weather forecasts. This will be very useful for data planning as the chances to detect targets of interest would increase.

In an effort to validate the EO-based ship detection algorithms adopted in SAGRES, **a test benchmark that compared the performance of the modules available at EMSA and GMV was executed**. The benchmark has been executed for a set of images proprietary of EMSA that were processed by the EMSA's and GMV's VDS services. The results have been compared against the available ground-truth (eye-based inspection or AIS) and performance has been assessed by defining some metrics based on quantitative parameters, such as the probability of detectability, length accuracy or geo-location accuracy. The results show that the GMV system performs better than the one available at EMSA. However, further tests with more accurate ground-truth (large sets of AIS data projected to the image acquisition time) shall be run before providing definitive conclusions.

From a practical point of view, it is worth noting that the first activations were not aligned with the expected performance due to inefficient processing procedures and limitations on the delivery channel. After the October 2013 activations, Frontex and SAGRES agreed on developing a new service portfolio based upon the CONOPS one that adapts to the new scenarios that Frontex has to handle and the new technological means available. The result was a more efficient service chain based on the architecture adopted in NEREIDS, which has shown to be very competitive in what regards processing and delivery

time, the report format and delivery channel, and the amount of information that can be handled. The image analysis procedure has been updated as well thanks to the feedback received from LOBOS. Actually, the partners in duty of such service are the same in both projects.

Among all the campaigns, **the success case achieved in the 09-2014 activation, which was executed from 16-09-2014 to 17-09-2014, deserves the maximum attention**. The campaign was initially conceived as a blind experiment where an in-situ ship shall be located within a SAR image with no a priori information about the true location (the ship course is synchronized within the satellite overpass). Thus, data planning was done at 15-09-2014. At 16-09-2014T1200, the ship involved in the experiment received a Search and Rescue call for looking and rescuing 38 in-distress immigrants on-board a rubber 7 m long boat with the engines out of order. The area of the experiment felt within the operational search zone, which covered approximately 50.000 km2.

The reserved image, a RADARSAT2 Ultra-Fine image with 3 m of resolution with an estimated acquisition time of 20140916T1812[1], was processed in less than 3 h from the acquisition time. The ship detection report pointed out the presence of a potential target of interest cruising to the North. The report was immediately passed to Frontex, who passed away to the Spanish Authorities. The coordinates of the detection were used to delimitate the search zone and this permitted the location of the boat on the morning of 17.09 14,5 NM far away from the position reported by the satellite image.

Figure 3-1: Snapshot for the image RST20140916T1812 associated with the success case.

[1] The image was planned at 15-09-2014

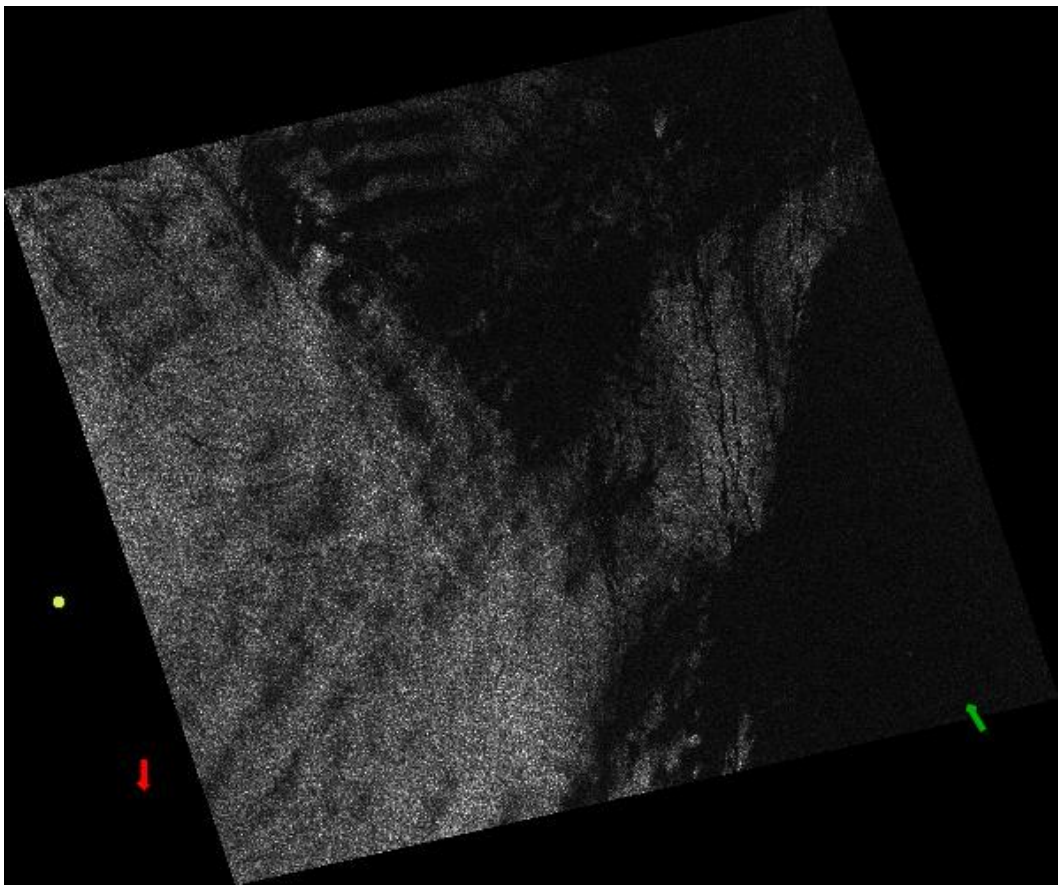


Figure 3-2: Detail of the image show in Figure 3-1.

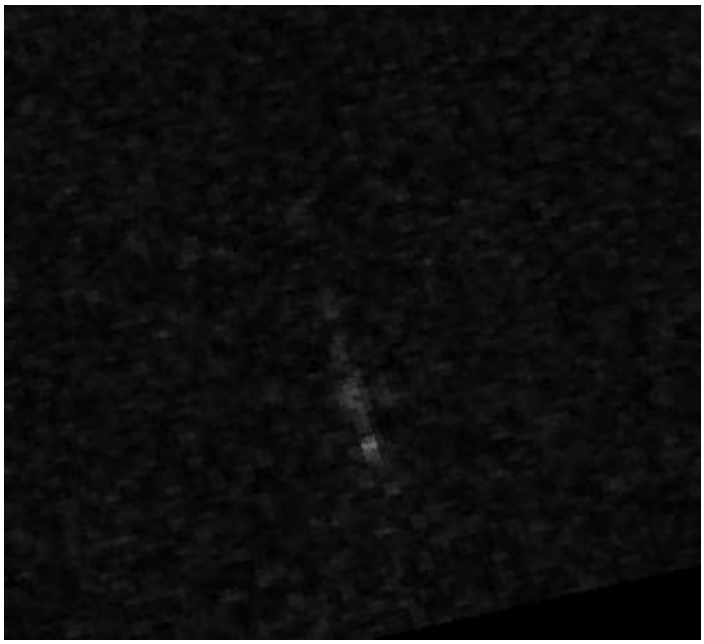


Figure 3-3: Detail of the target detected in Figure 3-2.

The contribution of SAGRES has been essential as the EO-based ship detection permitted reducing the initial huge area and this eased the search mission. This success case shows how EO technology can support high time critical maritime surveillance and how this technology can be used to save lives at sea. But this detection is subjected to the following issues:

- The weather conditions were not good with moderate wind blowing to the west at 4 m/s
- Wind and surface currents cause the aberrations and distortions observed in the image. They cause some false alarms that were manually filtered out.
- The ship was detected in an area of very low wind, which caused a very low level of background noise. This permitted increasing the dynamic range between the reflectivity of the target and the sea that eased the detection process
- The correlation of the detected ship with the confirmed position by the in-situ patrolling mean is good by taking into account the lapse time between the two reports (more than 12 hours) and the weather conditions. The target moved with no control to the west pushed away by the surface currents.
- The target reflectivity is moderate even though being a rubber boat. The reason is that the engines were located outside the sea (as observed in the picture below).

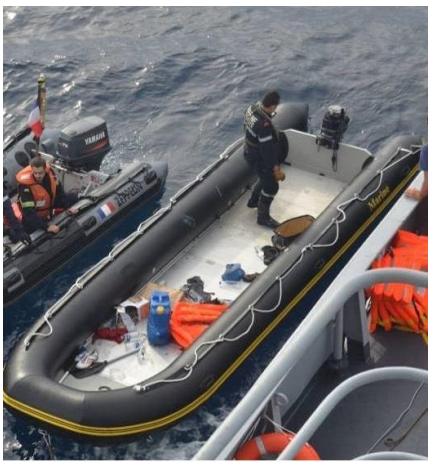


Figure 3-4: Picture of the ship detected in Figure 3-3.

3.5. OUTREACH AND DISSEMINATION

All the results achieved in SAGRES were **disseminated** under the supervision of Frontex as sensitive information was managed and the publication of confidential information was forbidden. Thus, the reports delivered by the services have not been disseminated outside the project community as well as any information that would permit the location of the activation scenarios and the characterization of the targets of interest. The number of scientific publications is low as well as the attendance to international symposiums.

SAGRES shared dissemination tasks with counterpart LOBOS project, as the background and motivation of both projects is the same. As a result, a joint dissemination plan for the two sister projects SAGRES & LOBOS has been prepared and produced in a relevant deliverable.

In this respect, both projects were presented at the European Day for Border Guards (ED4BG) at May 2014, an annual event organised by Frontex, that presents Europe's border-guard community with an opportunity to share experiences and best practice.

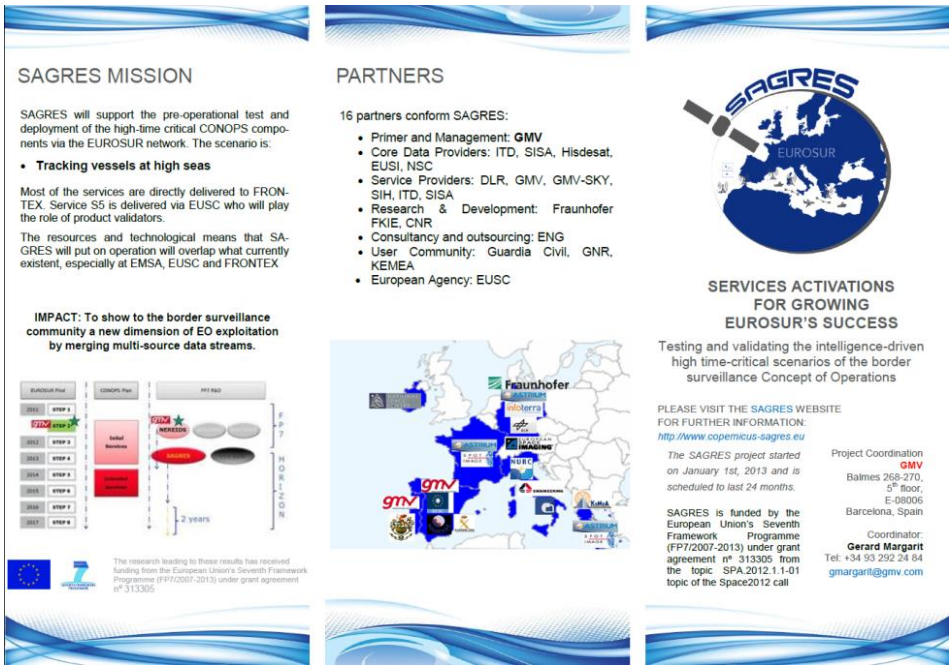
Furthermore, a joint service portfolio, consisting of a set of service components which in some cases are directly traceable to the CONOPS, and in others, are based on combinations of requirements that were originally defined within the CONOPS, was produced for the 2 sister projects.

Table 3-1: Dissemination events.

Tasks	Comments
Project website	Operating at http://www.copernicus-sagres.eu
Joint Dissemination Plan with LOBOS Project	Description of joint dissemination activities for both projects
Attendance to European Day for Border Guards 2013	05-2013, Warsaw: GMV attended.
Attendance to the Bridges project event	01-2014, REA: GMV attended.
Attendance to European Day for Border Guards 2014	05-2014, Warsaw: GMV and Terraspatium attended. Booth and presentation by GMV and Terraspatium.
Presentation during the *"European Symposium on Border Surveillance and SaR operations technology*" dissemination event, made a reference to a success case in a SAGRES activation done in Sep.16, 2014 at the Alborán Sea.	11-2014, Crete, Greece: Presentation by KEMEA
Final Flyer	Tryptic brochure describing the results of the project
Service portfolio	Joint document from LOBOS and SAGRES. It defines the pre-operational service specifications, as demonstrated at the completion of the last phase of evolution in each project.

SAGRES has contributed to the following publications:

- Copernicus MS Working group → details about the lessons learnt
- Perseus March newsletter
- European Symposium on Border Surveillance and Search and Rescue Operations Technology
- 24th United Nations/International Astronautical Federation Workshop on "Space Technology for Socio-Economic Benefits" → attendance of DLR with *Near Real Time Applications for Maritime Situation Awareness using Synthetic Aperture Radar in Open Ocean Areas*
- IEEE International Geooscience and Remote Sensing Symposium 2014 → attendance of FKIE with *Semi-Automatic Extraction of Ship Lanes and Movement Corridors From AIS Data*



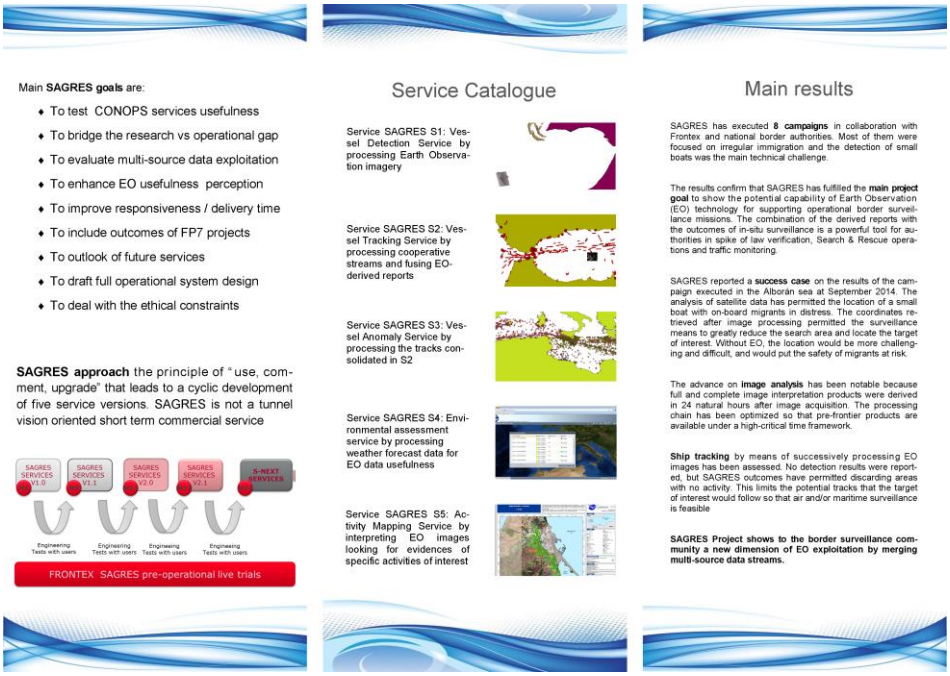


Figure 3-5: SAGRES flyer.

Figure 3-6: SAGRES Web page.

Figure 3-7: SAGRES – LOBOS Service Portfolio.

3.5.1. IMPACT

The impact of SAGRES outcomes would complement the implementation calendar of EUROSUR as shown below. The experience of former FP7 initiatives is used to build the basis of SAGRES and to reach the operational level design, after which fully operational exploitation of services can be handled. The commercial dimension of the SAGRES consortium provides a realistic exploitation roadmap

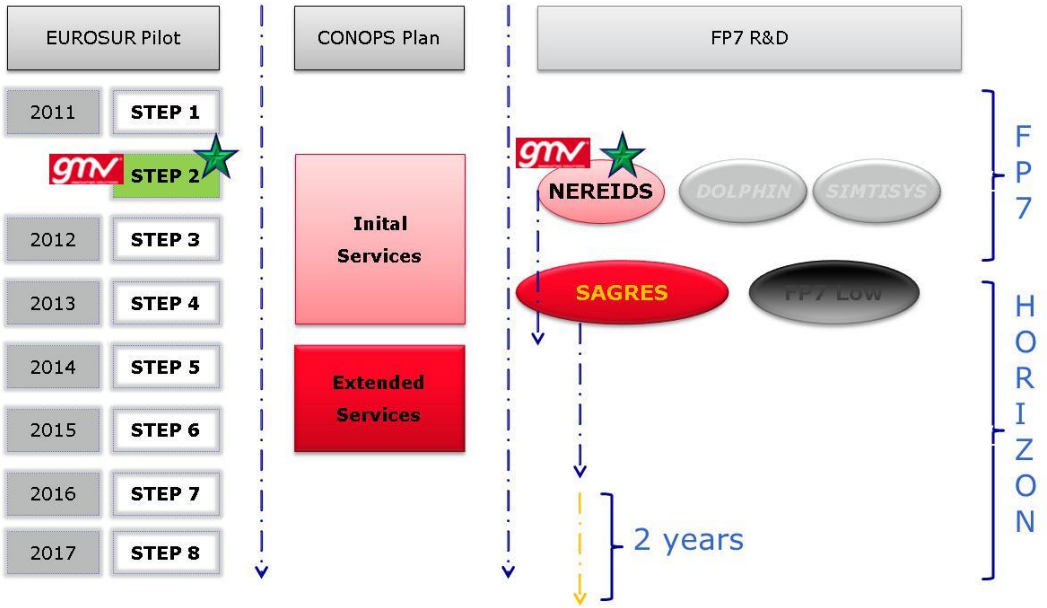


Figure 3-8: Impact of SAGRES results in the EUROSUR implementation plan.

3.6. SAGRES RECOMMENDATIONS

3.6.1. TECHNICAL RECOMMENDATIONS

In view of the results obtained by SAGRES, the following technical recommendations arise:

- Extend the **EMSA-GMV test benchmark** to other service providers with a more complete set in terms of the number of images and the associated AIS sets. Each image shall have an AIS set as ground-truth
- Work intensively on developing algorithms that support **ship tracking by exclusively using EO**-based ship detection reports. This means delineation of potential areas of interest by using current track information and the adoption of route propagation routes
- Integrate ancillary data to ease the ship detection process by discarding elements of no interest
- Fine tune categorization methods to adapt to very particular categories
- Integrate into the operational chains algorithms that compensate the **aberrations and defocusing** that would affect the signatures of targets in EO imagery (especially applies for SAR images). This degrades the capability to estimate target dimensions
- Devote efforts to permit the **estimation of the target speed** by others methods rather than the comparison of the target location with other static reference, such as the wake or the AIS track. New ideas in SAR images propose the exploitation of the Doppler information in the raw data
- A better **integration between data fusion and route propagation** is certainly a future field of research. The adoption of route propagation to cover the significant gaps that VDS contacts would have with the potential tracks that they would correlate with. This becomes even more crucial in case of sparse data.
- Integration of new type of **context information** in the Route Propagation Module, such as bathymetric data, meteorological information and traffic density maps
- Diversification of route propagation strategies according to the type of vessel. The definition of corridors or areas of transit for specific vessel types could broaden the prediction module capabilities
- Anomaly detection will be improved by adding more information such as vessel type and other information from vessel databases (e.g. EMSA databases)
- Propose new visor features, such as the integration of **real-time video** or any other ground based sensor. The static reference shall as complete as possible, and shall include the references available at user premises
- **Automate data ordering** in base of the specifications within an activation order. The process shall be transparent to non-expert users, which would only be informed about the evolution of the ordering.
- Improve the procedures at ground station in order to **speed responsiveness and delivery time up**
- Follow the evolution of **new platform concepts and/or new sensors** that would permit improving some requirements, such time sampling and revisiting time.

From a technological point of view, the platform has considered mature enough to base the design of a potential **Copernicus maritime service**. Recommendations are:

- The service shall deal with the largest range of sensors
    - Cooperative reporting systems
    - Ground-based and/or coastal sensors (radar, IR, thermal, video…) with limited coverage but continuous surveillance.
    - Airborne-based sensors with extended coverage but limited surveillance capability

- Satellite-based sensors with very large coverage but reduced surveillance capability

- The system will be integrated into a Coordination Centre (CC) that builds an integrated maritime picture with other ancillary and intelligence information
  - The communication links would be exploited through communication satellites with adequate encryption levels
  - All the assets can be interconnected among themselves
  - Standards should apply in what regards data format
- More than one CC, which can cover specific regions, would be interconnected to build extended maritime pictures and/or to increase the strategic information
  - A kind of EUROSUR network with different user profiles and different levels for accessing information would be defined
  - Each CC shall assure the enough material and human resources so that CC performance is within the requirements by a Service Level Agreement (SLA)
  - Each CC would have the own validation plan and the own resources to validate system performance
- The service will operate by means of a centralized kernel that triggers the data and service catalogue. It shall be interoperable with other systems (standard format) and will only account for modules managing data ingestion, storage and publication, and system administration. Processing modules will be geographically distributed
- Licensing is important and data shall be filtered in terms of user rights
- A service portfolio shall be defined. As minimum, the following services should be available:
  - Ship detection with estimation of macro-scale features
  - Ship tracking by combining Ship detection and cooperative entries
  - Anomaly analysis
  - Route propagation
  - Pre-frontier Image analysis
- A unique entry point for users shall be available. The associated GUI shall permit sending service activations and visualizing the reports in the most complete and efficient way
- Even though automating is essential and would be achieved in almost all the procedures, the presence of a human operator is needed to at least confirm all the decisions made by the system. Otherwise, resources would not be efficiently exploited and/or they would not be properly tuned to user needs
- A tentative system design is attached below. Although it is not mature, it would be a guideline for future works. Open-source technologies are recommended whenever possible

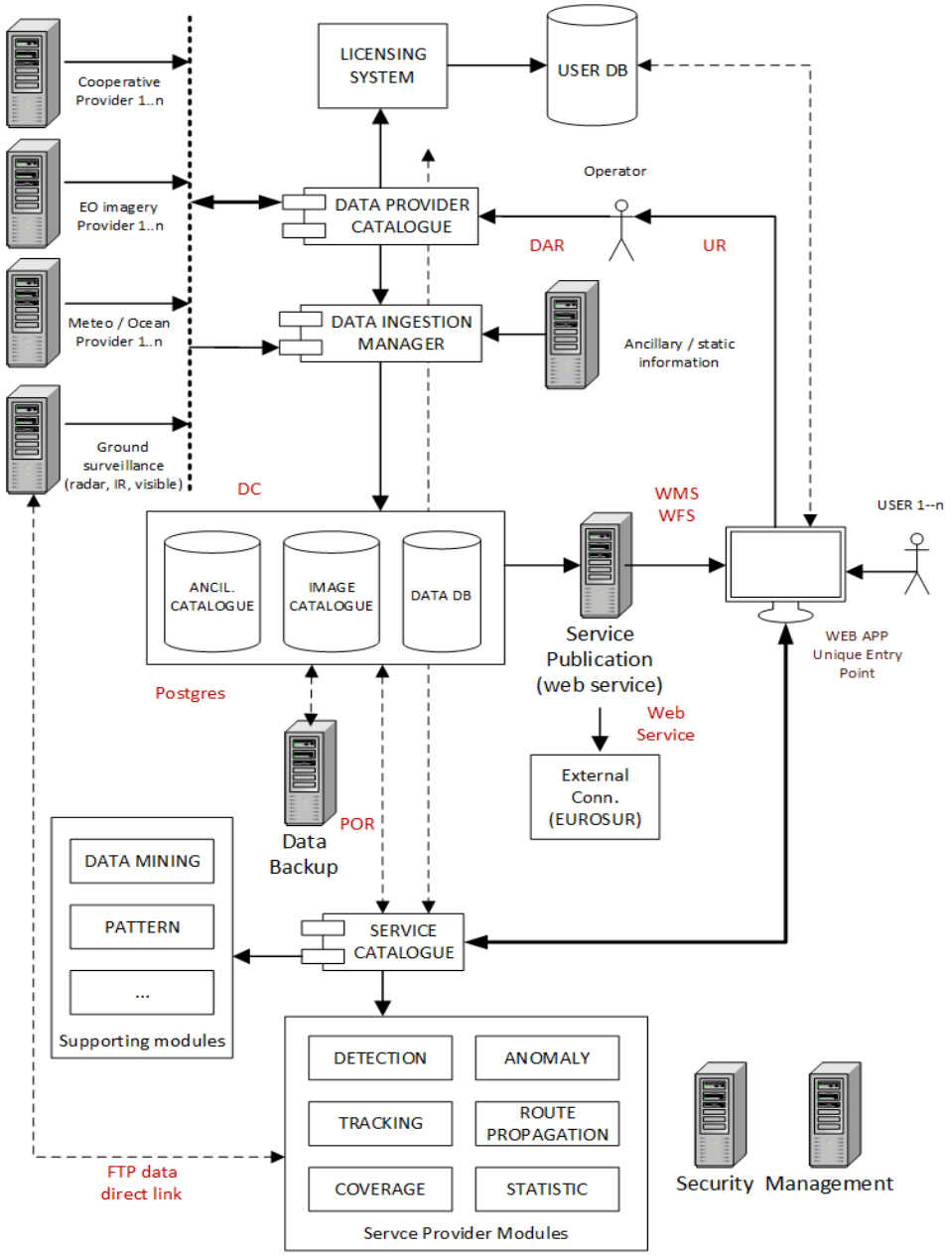


Figure 3-9: Tentative design for the system managing the maritime core service.

From a service point of view, the following is recommended:

- **24/7** service operation is mandatory with **dedicated IT resources** (communication…) that assure total availability in rush-mode scenarios
- It is recommended that the acquisition and production points are geographically located at the same point or linked by a dedicated high speed communication link that minimize the delays caused by data transfer
- **A SLA shall be agreed with all the data and service providers** that feed the system with data and/or elaborated reports. The SLAs shall specify the conditions in which the data/services are delivered, the technical requirements that shall be met and the penalization that will be applied in case of no compliancy
- Bottlenecks shall be avoided specially when delivering focused imagery to service providers

- **Educational efforts** by doing trainings, seminars and similar shall be invested so that the end users are aware of the potentialities and limitations of EO imagery. This will avoid confusions about the expectations of what the services can deliver and can provide detailed information regarding key parameters, such as responsiveness and/or delivery time
- The system shall provide a standardized publication channel, which should be based on web services (WFS, WMS…), and the user shall adapt to it. The inverse way is not recommended as otherwise the system would be forced to deal with a large range of different publication formats
- Specific **training for data ordering** is recommended in order to allow the users to better know how to manage the available data quota
- The **integration of ancillary data** shall be a key milestone as this would permit improving the final reports. The generation of procedures that can automate the acquisition of those data sets shall be defined
- Two main **operational procedures** are foreseen:
    - Punctual monitoring of a specific location in front of an emergency situation
    - Periodic monitoring over a hot spot area where notable activity is detected in past surveillance. This would imply the delineation of the hot spot areas in base of the intelligence information of users in order to better tuning the acquisition plan. Periodic monitoring can be used to discard specific areas by periodically reporting no activity.

3.6.2. POLICY RECOMMENDATIONS

From a **policy** point of view, the following recommendations apply:

(1) There is a clear need for **integrating** all the available information in a common surveillance system which the different agencies can access. Integration of National Maritime Surveillance Systems is a long running on-going process at MS level (e.g. IT, FR) for Maritime Situational Awareness purposes and at EU level, in support of the implementation of EU sectorial policies (e.g. EDA, EFCA, EMSA, FRONTEX, EUSC, etc.). SAGRES can contribute with its modular architecture to support **CISE** and **EUROSUR** as one of the available solutions in the effective integration of all data sources in future MSA systems.

(2) SAGRES was not perceived to propose new **standards**. Instead in the framework of the project, the consortium reviewed the use of standards on current and past initiatives and based on user requirements adopted the most relevant, matching with the objectives of the project.
Further innovation on the technical standards and enterprise services area is required. This, however, can only be achieved through a higher-level implementation project or initiatives. The contribution of the upcoming EU CISE2020 project is expected to be of major importance since the definition of standards is a key task for establishing **CISE**.

(3) Since 2008, the European Commission has programmed, under the 7th Framework Programme for Research and Development (**FP7 - COPERNICUS**), a dozen projects (amounting to 100 million Euros) in order to develop, integrate and demonstrate technical solutions for maritime border surveillance and in particular the urgent need for detection and tracking of small vessels.
Frontex would then gradually implement these solutions as a permanent service in the framework of **EUROSUR**. A wide **dissemination** of the outputs of SAGRES can contribute to this implementation.

(4) **Support to the decision making** and operators is available in SAGRES and a big effort was done to support the verification of specific policies. In this sense, the different users agree on the fact that the maritime surveillance awareness is improved by adding the processing of satellite imagery. However, some improvements are needed, as the delivery time shall be compatible with the **operational** missions. This is a general issue using satellite imagery and future developments of the systems will improve their efficiency.

(5) **Inter-application**: a surveillance system shall not only take into account those products related to the main task. For instance, security applications (ship tracking) shall consider products derived from the environmental maritime area (water quality, winds, currents…) or from external disciplines such weather forecast or socio-economic factors. Being modular, the SAGRES platform is easily extendable to cover various needs for other derived applications. Again, the proposed platform can support initiatives already mentioned as CISE, EUROSUR, etc. due its characteristics.

(6) **R&D**: as mentioned before, during the project much relevant solutions have been addressed. We would like to highlight the Performance Measures and Effectiveness, which provide the possibility to evaluate quantitatively data fusion algorithms. Also, this can be used to do not generate some false expectations on user that sometimes are quite high.

(7) Avoid the **overlapping** of different initiatives in the field of maritime surveillance that may have an impact national and European level – and transform them instead on complementary actions

3.6.3. ROADMAP

The graphic below depicts the domains managed by SAGRES and how they interact together in order to permit the delivery of fully operational Copernicus services.

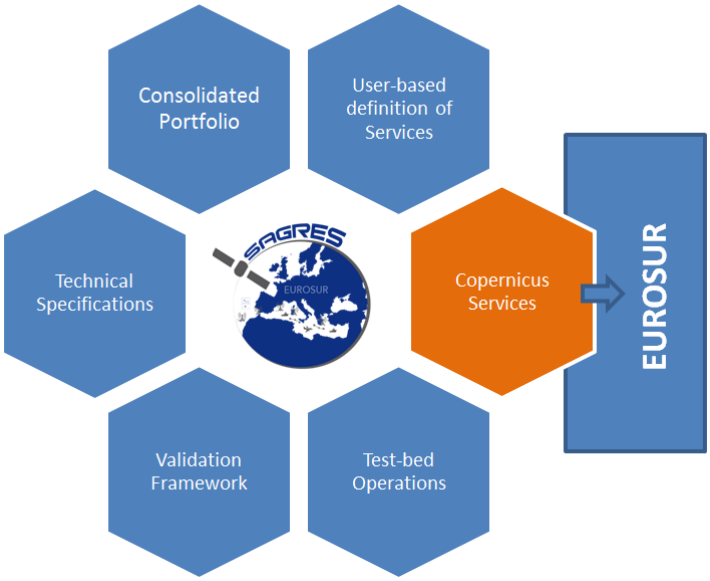


Figure 3-10. SAGRES: where we are (blue hexagons) and where we want to be (orange hexagon).

However, there are some pending steps to be done in order to reach a fully operational capability. They mainly rely on improving the access to imagery and data sources, and on making the cost affordable for user resources. Although the current technical / technological solutions are partially efficient and

mature, a room for improvement exists. Topics of interest are the time sampling, the probability of detection for targets with length < 10 m and time responsiveness and delivery. In this context, the following roadmap steps are foreseen:

- **Identification of the current systems** that can cope with the consolidated requirements issued by SAGRES. The work that EMSA is carrying out through ImDATe will serve as guideline. However, some national users have raised out the necessity to have further control over the system, the data sources and the interface options. Right now, the EMSA's ImDATe is perceived as a black box with limited flexibility to adapt to specific requirements. The demand to be closer to the data providers and to directly receive the raw data for in-house processing is not covered yet. If the demand of new systems and/or add-on in current services is large, it shall be addressed by properly defining the design and implementation requirements
- Evaluation of the **potential data providers** and analysis of the technical / technological deficiencies that would have in terms of time responsiveness and delivery. Important items are the capability to urgently program a satellite at an affordable cost, capability to deliver focused imagery in less than 30 min from image acquisition, flexibility to program at any site and any time, and availability of a good ground-station constellation that permits keeping responsiveness and delivery times with independence of the observation mode (satellite pass…). The evaluation of the potential service providers would be mandatory as well in order to get a complete picture of the potential market. Analysis of legal issues shall be conducted as well.
- Evaluation of the **potential new missions** that can complement what is currently available in the field of maritime monitoring. As one of the main current drawbacks is time sampling and revisiting time, the concept of constellation of micro-satellites would take more importance. The evaluation should go a step further and propose new missions with innovative concepts on the space and ground segment. Topics of interest would be new orbits beyond the classical polar ones (such as equatorial), mobile ground segment boarded on trucks, VHR wide swath acquisition modes or VHR geostationary satellites. A critical analysis of the sensing devices shall also be done. Certainly, maritime monitoring would benefit by using other sensors rather than SAR and optic, for instance InfraRed or thermal devices that permit locating ships by detecting the hot cells caused by engines. But technological capabilities shall be improved (especially in terms of the spatial resolution at low orbit altitudes) and this shall be addressed by complementary R+D programs
- Identification of all the **ancillary data** that can support the ship monitoring process based on processing satellite imagery. This includes references to static elements (buoys, fish farms, oil platforms…), land references (road net to find potential arrival / departure points…) or socio-economic indicators (migration fluxes…). The process shall be complemented with an in-depth analysis of legal and ethical issues so that their exploitation will not break any fundamental right of citizens. Insights into the technical solutions needed to acquire all the demanded data in an automatic and fancy way shall be analysed as well.
- Analysis of statistic and historic reports to delineate potential **hot spots** with which data ordering can be eased. This would permit exploiting a periodic operational mode that would increase the success chances to detect targets of interest that would not be visible by other surveillance means. The identification of hot spots shall be done in collaboration with national authorities and European bodies. The training sessions aimed to describe the limitations of satellite imagery and to point out the strong points can be used here to delineate the areas of interest as a function of the unitary coverage of a single image
- **Agreements at national and/or European level with data providers** to make unitary data cost affordable for the national users within the maritime domain. Right now, the unique initiative in that sense is the one managed by EMSA within the framework contract of CleanSeaNet that establishes the provision of ship monitoring services to the Member States. But this initiative is restricted to the EMSA umbrella and does not have the specific and punctual necessities of users into account. As commented above, users are increasing the know-how about EO technology and they are more conscious about the benefits of controlling all the processing chain from raw data acquisition to the final added-value service delivery. This does not mean that users are discarding EMSA's ImDATe, but they would like to have a

complementary and back-up system that can be switched on for those scenarios that ImDATe can not afford or respond. If this trend is confirmed, the demands of EO data will trespass the EMSA domain and would come from a larger potential customer community. Competitive agreements with data providers and national and/or public authorities would permit covering this market opportunity and would fuel EO imagery up as a mass consumption item. Another advantage would yield on the increased number of service providers that would be needed to cover the market demand. This would increase the direct competition and would benefit the technical and technological evolution of the services up to a levels that are not currently foreseen

- **Amendments on the current law for avoiding a kind of monopolism**. The few number of data and service providers would be a temptation for agreeing prices higher than the ones that a normal market situation would fix. The law should avoid such situations that go against the interest of all the actors and user community in maritime monitoring. In addition, the law shall permit flexibility on joint cooperation between different data and service providers. As happens in the mobile phone domain, different operators can use the logistics and infrastructure of an unique owner in order to diversify the supply of the services that reach end users. This poses benefits to the customers in terms of unitary prices and available features as the diversification of services in direct competition forces further R+D works in order to offer more advanced capabilities at an affordable price. A similar schema would be adopted in the maritime domain in the sense that different service providers can directly work with the ground stations of specific data providers. This would have two main application options: 1) service providers operate directly on data provider facilities; 2) data provider rent their facilities so that the service provider has a total control over satellite programming, data downloading and data focusing. The law shall specify the conditions of such agreement so that data providers do not loose competitiveness. The balance between competitiveness and monopolism is critical and the overall community benefit will be the main driver. The users that shall benefit from such agreements will be national / public / police / military authorities.
- **Intense training with users** that covers all the technical and technological aspects of EO-based maritime surveillance. Topics of key concern are the process and limitations of data ordering, the limitations of target detection and the recommendations for data delivery

3.6.4. COST-BENEFIT STUDY

The cost benefit analysis is a key perspective when trying to define SAGRES project not as a short term commercial service, but as a long term program offering innovation, merges in data management and added value in day- life missions. Moreover, under the general situation of economic crisis worldwide, all savings for national / international budgets are welcome.

The economic benefits of EO-based services would come from reducing current operational costs and maximizing the added value. The new services shall increase the chance of saving lives (as shown in the success case of the Alboran Sea) so that the basis of a commercial competitive product at worldwide level is putted on place. This would permit the industry to obtain a turnover for the R&D investment done in the past.

The cost-benefit study developed in SAGRES demonstrates with a real activation case (occurred in September, 2014) that when remote sensing is applicable (given its level of maturity), it can bring savings to the traditional maritime surveillance operations of up to 57% for regular operations.

The economical approach based exclusively in terms of present costs vs. estimation of SAGRES costs shows as well an economic benefit of the program. This occurs even in a pre-operational phase, and not taking into account additional savings that will be possible when the project becomes a commercial solution or technological synergies obtained through the interaction between all partners and data provision long term contracts.

Beyond the economic indicators, the ultimate benefit of the SAGRES project is the improvement of the security of human beings at sea. The last events relating to migrant activity occurring in Lampedusa or Ceuta and Melilla demonstrate it is necessary the reinforcement of existing capabilities and improvement of their effectiveness using Space technologies as cost-beneficial catalyst instrument. Law verification in border surveillance is important as well and this permit having a control of all activities conducted at the sea. This benefits citizens in a better life quality as the environment is preserved, the natural resources are sustainably exploited and a competitive market is opened.

4. EXECUTIVE SUMMARY

SAGRES has successfully fulfilled all the overall and technical goals specified at the beginning of the project. The outcomes are very promising to be integrated into an operational ship monitoring system that combines cooperative and non-cooperative data. **EO technology has been assessed as a potential contributor in border surveillance missions** at strategic, tactical and operational level. The **CONOPS** services have been pre-operationally tested and the results are gathered in a **new service portfolio** that specify the technological and technical details for their operational implementation

The concept of 'system of systems' adopted in the system architecture is recommended to be used as a potential design for the Copernicus core maritime service. Note that the system chain is not only a simple integrator of external reports (like ImDATe), but permits the direct interaction of the external processing modules with the system resources. This is what is called a multi-purpose multi-data approach. Performance was close to the one reached by current operational services, which the system can transparently communicate with (IMDATE from EMSA). Certainly, standardization and integration have been key design drivers.

Among all the results, the most remarkable one is the **success case** achieved in one activation executed during September 2014 in the Alboran Sea where EO-based products notably contributed to locate a boat with distress immigrants on-board and the engines out-of-order. From a technical point of view, the performance of key algorithms that overcome classic drawbacks has been assessed as well. Examples are methods capable to detect small targets (length < 5-10 m) and/or to categorize ships by processing single-cha nnel Earth Observation (EO) images, new multi-source data fusion approaches, the definition of complex anomalies, the propagation of consolidated tracks into the future, the development of an environment assessment service or the automating of data ordering

Oceans deserve to be safe and protected. The advanced knowledge managed in SAGRES is a step forward towards this vital goal.

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