Development of Pre-operational Services for Highly Innovative Maritime Surveillance Capabilities

Final Report Summary - DOLPHIN (Development of Pre-operational Services for Highly Innovative Maritime Surveillance Capabilities)

Executive Summary:
The DOLPHIN Collaborative Project aimed at identifying and developing new tools providing effective improvements of the state-of-the-art capabilities in Maritime Surveillance with respect to Users’ real needs, in particular through the filling of present Technological Gaps.
The identification of these Technological Gaps is made easier by the fact that, in the last decade, the DOLPHIN Consortium has developed a mature and solid experience through a number of historic and ongoing initiatives, such as LIMES, MARISS, MarCoast, EMSA CSN, in which a wide European Users community has already expressed and well identified the main gaps in the Maritime Surveillance sector.
The DOLPHIN Project has therefore benefited from the know-how of the partners who gathered Users
requests during several years and worked on developing their own Service Chains in order to reach the
required performance in terms of delivery time and product quality.

In particular, users need specific technological support, very focused on users’ missions, which the
DOLPHIN Project responded to through the development of Decision Support Modules (DSM), providing
actual, measurable and effective added values to Users’ decisions making processes. DSMs were based
on the integration of innovative Software Tools, aiming at filling specific Technological Gaps, therefore
stressing technological solutions beyond the current state-of-the-art.

Three topics, or policy areas, have been selected as being in most need of improvement:
- Border Surveillance for the control and monitoring of European maritime borders, in order to reduce the
  number of illegal immigrants entering the EU undetected, reduce the death toll of illegal immigrants and
  increase internal security of the EU by contributing to the prevention of cross-borders crimes
- Traffic Safety for the continuous monitoring of highly congested areas in order to prevent deaths, injuries
  and damages resulting from both ships collisions and environmental hazards, and to take
  countermeasures against piracy and transport of hazardous goods
- Fisheries Control for the sustainable development of fisheries, which requires better marine governance in
terms of effective jurisdiction of coastal States over their waters and a European-wide co-ordinated
approach.

In accord with the established concepts, the following S&T objectives have been defined:
- The filling of the technological gaps, through the development of Decision Support Modules
  implementing innovative solutions (i.e. software tools);
- Effective validation of the innovation developed by means of Operational Scenarios, i.e. long duration
  trials, covering all the five main Policy Areas and focusing on specific regional aspects;
- Strong involvement of Users, the main players among which are already well-known by the Consortium
  through their involvement in previous projects and which are already provided with operational services;
- Strong link with ongoing and future space and security activities, above all the MARISS Service
  Network. Attention has been paid also to the coordination with the European-wide Integrated Maritime
  Border Control System.

The main results of DOLPHIN can be outlined as follows:
- innovative algorithms for global maritime safety and security monitoring through the development of
  Software Tools for actual and focused Technological Gaps filling;
- Decision Support Module (DSMs), integrating the innovative Software Tools and validated in a
  operational scenarios.

Project Context and Objectives:
The aim of the DOLPHIN Project was to identify and develop innovative software tools providing effective
improvements of the state-of-the-art capabilities in Maritime Surveillance, by filling the current
Technological Gaps. The identification of these Technological Gaps was made easier by the fact that, over
the last decade, the DOLPHIN Consortium partners gained a mature and solid experience through past
and on-going initiatives, such as LIMES, MarCoast, MARISS, SeaBilla, EMSA CSN, in which a wide
European Users community had already expressed and well identified the main gaps in the Maritime
Surveillance sector.
The DOLPHIN Project aimed at responding to the Users’ need through the development of Decision Support Modules (DSM), providing actual, measurable and effective added values to Users’ decision making processes.

The project had been developed according to three policy areas:
- Border Surveillance for the control and monitoring of European maritime borders, in order to support competent Authorities in reducing the number of illegal immigrants entering the EU undetected, reducing the death toll of illegal immigrants by rescuing more of them at sea, and increasing the internal security of the EU by contributing to the prevention of cross-borders crimes.
- Traffic Safety for the continuous monitoring of highly congested areas in order to prevent deaths, injuries and damages resulting from both ships collisions and environmental hazards, and to take countermeasures against transport of hazardous good.
- Fisheries Control for the sustainable development of fisheries, which requires better marine governance in terms of effective jurisdiction of coastal States over their waters and a European-wide coordinated approach.

With reference to the DSMs, they consisted of the integration of a set of innovative Software Tools, providing an actual improvement with respect to the state-of-the-art. Each DSM:
- received as input satellite images and other EO and non-EO data,
- elaborated data accordingly through integrated software tools,
- integrated Software Tools outputs between the tools and with data provided by external systems.

Requirements from Users have been organized along the Policy Areas they cover and translated into Operational Requirements. Validation of the requirements has been achieved through targeted contacts with a number of selected DOLPHIN users. The Operational Scenarios have been defined with the support of the DOLPHIN User Advisory Board. In DOLPHIN, the term “Operational Scenario” indicates the operative conditions encountered during trials. Therefore, their definition refers to the description of the environment in which trials were performed. In particular, the environment was significant and representative of the complexity of the requirements and performances.

With the strong support of the Users involved in the project, validation campaigns have been conducted with the aim to test the innovative software tools and the DSMs developed in the framework of DOLPHIN. The results achieved by the DOLPHIN project aim to support users by providing them with:
- for Border Surveillance:
  - detection of small boats, extremely important for the monitoring of illegal traffic of people and goods across European maritime borders;
  - detection of wakes produced by small boats;
  - improvement in ship detection probability and ship classification;
  - improvement in speed, in size and heading of vessels;
  - improvement of multi-sensor data fusion;
  - detection of anomalous behavior, such as small boats approaching bigger vessel for rendez-vous in suspect areas;
- for Traffic Safety:
  o detection of small vessels;
  o interpolation of trajectories and route analysis;
  o detection of anomalies in collaborative data;
  o detection of suspicious vessels behaviour;
  o icebergs drifting and analysis of collision risk;

- for Fisheries Control:
  o detection of small not cooperative boats, including improved accuracy in detection of position, speed and heading;
  o detection of cages and cages towed by tugboat;
  o improved integration with AIS;
  o DOLPHIN improved vessel detection allows to highlight failures in AIS content information.

With reference to Coordination with EU initiatives, the aim was a EU wide cooperation through the pooling of resources and the sharing of activities among different MSs Organisations. It was emphasized that the DOLPHIN outcomes target EU-wide common needs in the field of Maritime Security. The tools developed and, in general terms, the DOLPHIN experiences can be exploited in different maritime sectorial areas. In particular, the possibility to enlarge the satellite imagery techniques application to the detection of small boat and in a wider context to the non-reporting vessels is considered the one of the most promising result, above all by the border control community. From this perspective, connections between DOLPHIN and other R&D Surveillance project as well as with Frontex and Member state stakeholders agencies have been developed.

With reference to dissemination activities main objectives of the DOLPHIN were:
• To publicise the scientific results of the DOLPHIN project and its benefits in relation to the relevant EU policies it addresses both to the user community as well as the general public;
• To contribute to the global Copernicus communications strategy.

The DOLPHIN project was funded under the Call “Coordination and support action (Coordinating) FP7-SPACE-2010-1.1-05” for the activity “Contributing to the “S” in GMES – Developing pre-operational service capabilities for Maritime Surveillance” in parallel with the NEREIDS and SIMTISYS projects. Therefore, in line with a request from REA, the communication team coordinated its activities with the other two projects in order to increase synergies and effectively implement a common dissemination strategy.

The achievements were evaluated at the development of the tools and their integration into the Decision Support Modules (DSM) levels:
- Software tools: this level corresponds to the achievements on the development of individual tools
- System Design (DSM Level): this level corresponds to the integration of all software tool into an integrated system
- External Systems: this level corresponds to the interfacing of the software tools or the full developed system with other systems (for instance users one)
- Operational Level: This level corresponds to the achievements related to operational constraints and requirements
- Service Design: This level corresponds to the definition of the service provided to the end user
This evaluation of assessment led the Consortium to provide the following recommendations for future R&D activities on the subject or for the operation of related services.

- Put in place European initiative on the validation ground truth following the open-data paradigm;
- Ensure the evolution of the tools and DSM developed during DOLPHIN;
- Take into account the weather and oceanic conditions in the definition of acquisition plan;
- Take into account the weather and oceanic conditions as a standard way to measure performances;
- Promote the normalisation of the external systems;
- Update the variables made available by the Marine Core Services;
- Promote the standardisation of user system;
- Involve the user in the definition, evaluation and update of maritime security services;
- Ensure the continuous service evaluation & improvement;
- Ensure the provision of Earth Observation images.

Project Results:
The DOLPHIN project aimed to:
- define and consolidate the Operational Requirements;
- define the Operational Scenarios;
- develop innovative algorithms including validation of each single software tool, according to the five identified Technological Lines for innovative solutions;
- organize and perform all the Operational Scenarios/Validation Campaigns planned in collaboration with the users;
- evaluate all the project results making an overall assessment of the project.

Requirements from Users have been organized along the Policy Areas they cover and translated into Operational Requirements at higher (DSMs) and lower (Software Tools) level. The user operational requirements for maritime services have been compiled in the three DOLPHIN surveillance domains: Border Surveillance, Traffic Safety and Fisheries Control. Most information has been collected from: the output of previous GMES projects, open source information, published institutional reports and knowledge accumulated by the DOLPHIN partners.

At Operational Scenarios level, the point was not only to merely identify real geographic areas, but also to describe the general environment in which the tests were performed, opportunely designed in order to maximise the effectiveness if their validation. In particular, the environment had to be "real-world", significant and representative of the complexity of the requirements and the expected performance levels. Trials were then performed in one or more geographic areas matching Operational Scenarios definition, taking into account the regional context, i.e. the geographical characteristics to which the policy area refers, the meteo-marine conditions, i.e. currents, winds, waves, temperature, the traffic conditions, i.e. ships densities (high/low), ships dimensions (majority of small/big ships), vessels’ equipment properties (e.g. the presence of on-board ship reporting systems).

With reference to the innovative algorithms, outputs and achievements are summarized hereinafter.

Technological Line # 1: Advanced Single Channel SAR Processing, which is exploiting the physical
mechanisms of the single-channel SAR sensors, to make Earth Observation based information more timely, accurate and reliable.

Task 1 Sub-Aperture Processing Based on RAW SAR data (Edisoft)
• DOLPHIN output: ship detector based on complex SAR images
• DOLPHIN achievement: improved capabilities in detecting small boats and medium vessels in rough sea, through a dedicated sub-aperture processing for sea clutter filtering. The filtering eases the spectral signature analysis for velocity estimation purposes. The detection rate is increased in comparison with the traditional algorithms.

Task 2 Sub-Aperture Processing Based on SLC SAR data (e-GEOS)
• DOLPHIN output: ship detector based on complex SAR images (SLC, level 1A)
• DOLPHIN achievement: improved capabilities in detecting small ships, exploiting phase information (instead of only amplitude’s one); the signal to clutter ratio is increased and higher detection performance are achieved.

Task 3 Single Channel MTI (e-GEOS)
• DOLPHIN output: ship detector with enhanced capabilities in detecting small and fast ships, based on complex SAR images (SLC, level 1A)
• DOLPHIN achievement: re-focusing functionalities in order to increase the contrast of the ship target over the sea clutter and to estimate geometrical (size, shape) and velocity parameters.

Task 4 Super-resolution filter (KSAT)
• DOLPHIN Output: Filter improving shape and structures of ships based on SLC SAR data. Output of the filter are high resolution clearer images of ships
• DOLPHIN achievements: enhancement of ship signatures and to sharp edges and structures in high resolution SAR data in order to improve the detection of small boat, close to big ships, and to better characterize the geometry of the ship.

Task 5 Passive Bistatic ISAR (UNIROMA1)
• DOLPHIN output: (1) Passive Bistatic/Multistatic-ISAR signal generator having as input the scenario parameters (characteristics of opportunity geostationary TX, RX and target) and providing as output the emulated raw signal; (2) PB-ISAR processor having as input the emulated raw signal and providing as output the focused radar image of the target ship.
• DOLPHIN achievement: general PM-ISAR focusing technique able to exploit the transmissions from different geostationary satellites (spatial diversity).

Technological Line # 2: Polarimetry and Multi-channel SAR Processing, which is exploiting multi-channel SAR sensor physics

Task 1 Polarimetric Analysis - Dual Pol (DLR)
• DOLPHIN output: ship detector with enhanced capabilities in detecting small and fast ships, using high resolution Single Look Complex Dual-Pol SAR data
• DOLPHIN achievement: Target to Clutter Ratio increased even for small target improving the detection
of small ships.

Polarimetric Analysis - Dual Pol (KSAT/FFI)
• DOLPHIN output: ship detection reports in text format, xml format and kml format as well as a user window where it is possible to follow the process
• DOLPHIN achievement: algorithm is being further developed for improved automated ship detection with polarimetric RS-2 SAR data. Confidence estimates for the ship detector improved.

Task 2 Polarimetric Analysis Full Pol (CLS)
• DOLPHIN output: Full-polarimetric SAR-based detected ships. Development of basic readers and polarimetric tools (Coherent/incoherent decompositions, Polarimetric Speckle filter)
• DOLPHIN achievement: Development of Automatic learning of the OPCE (Optimal Polarimetric Contrast Enhancement) based on the echoes data base. Detection of ships with low RCS (e.g small vessel) which cannot be detected with single-pol channel.

Task 3 Along Track Interferometry (DLR)
• DOLPHIN output: Moving and not moving ship detection reports with ATI phase analysis. Moving targets speed estimation.
• DOLPHIN achievement: Ship Speed estimation based on DRA ATI Phase.

Task 4 Dual Channel Moving Target Identification (MTI) (QinetiQ)
• DOLPHIN output: ship detector based on space-based Dual Receive Antenna (DRA) data
• DOLPHIN achievement: improved capabilities in detecting small ships, exploiting Displaced Phase Centre Antenna (DPCA) processing and Space-Time Adaptive Processing (STAP) for clutter suppression to enable detection of surface moving targets in a clutter background.

Task 5 New SAR Payload Simulator (TASI)
• DOLPHIN output: Technical deliverable.
• DOLPHIN achievement: The SW Simulator requirements are tailored to both SAR and RAR payloads for spaceborne GMTI.

Task 6 Validation Support System for Ship Detection (OW, GAUSS)
• DOLPHIN output: Targets output containing geo positions of different WaMoS II targets for specific times. Tracks output containing geo position for specific targets during the time of observation
• DOLPHIN achievement: Target detection, Target tracking based on WaMoS II X-Band radar data

Technological Line # 3: Feature Extraction and Recognition, which is directed at the extraction and recognition of specific man-made features in ocean imagery.

Task 1 Wake Detection (QinetiQ)
• DOLPHIN output: wake detections in high resolution SAR imagery data using active grid segmentation techniques
• DOLPHIN achievement: improved ship detection robustness by inferring the presence of a ship (that may not necessarily be visible as a bright echo) through its wake. Optimal performance requires ~2dB
contrast difference between the wake and sea clutter.

Task 2 Features Extraction and Recognition (Edisoft)
- DOLPHIN output: ship detector based on multilook SAR images
- DOLPHIN achievement: improved capabilities in detecting medium and big vessels in rough sea, through the Wavelet filtering. The software allows the configuration setting of the processing parameters. The filtering is complementary to traditional algorithms as pre-processing step.

Task 3.1 Vessel classification based on SAR images (FFI)
- DOLPHIN output: Vessel length estimation and classification in SAR satellite images
- DOLPHIN achievement: More detailed classification of vessels in SAR images with very high resolution (mainly in cases with low vessel speed and favourable imaging geometry)

Task 3.2 Vessel classification based on optical images (TNO)
- DOLPHIN output: Vessel length estimation and classification based on optical satellite images.
- DOLPHIN achievement: Improved vessel-wake separation and vessel length estimation (RMSE = 25.9 m); classification accuracy 89 %.

Task 4 Task 4A: SAR based vessel recognition - point 1 (SAR simulator, UNINA)
- DOLPHIN output: software tool that simulates the SAR image of a ship over the sea. The starting point is a SAR raw signal simulator for marine scenarios previously developed by UNINA and already available. The SAR simulator reproduces the scattering behavior of the ship, modelled by 3D CAD geometry, so to obtain the SAR signature of the ship as observed at different viewing angles and under different sea state conditions.
- DOLPHIN achievement: raw signals relevant to the ship and to the sea are combined in an effective, new way.

Task 4B: Ship detection based on Optical images (E-GEOS)
- DOLPHIN output: semi-automatic ship detector on optical images.
- DOLPHIN achievement: semi-automatic ship detection on optical images based on a fuzzy clustering method evolution of K-mean.

Task 5: Reduction of ship-detection false alarms due to SAR azimuth ambiguity (UNINA)
- DOLPHIN output: selective filter for the reduction of azimuth ambiguity in stripmap complex SAR images (SLC, level 1A)
- DOLPHIN achievement: the filtering procedure has been applied to very high resolution SAR sensors; a map of the potential ghosts on the sea surface can be also obtained. The proposed method can be employed in situations (PRF and antenna pattern) in which similar approaches fail, and it has a smaller computational burden.

Technological Line # 4: Multi-sensor Data Fusion, mainly for traffic safety, it is important to generate the predicted time evolution of vessel tracks using all source information for a variety of maritime tasks

Task 1.1 Multi Hypothesis Tracking of objects over time (KSAT, FFI)
• DOLPHIN output: Multi Hypothesis Tracker (MHT) providing ship tracks.
• DOLPHIN achievement: Fusion of AIS and SAR for improved tracking.

Task 1.2 Track prediction in congested coastal areas (TNO)
• DOLPHIN output: Software tool for vessel track prediction based on context information (shipping lanes, coastline).
• DOLPHIN achievement: Improved route propagation for persistent surveillance.

Task 2 Image geolocation improvement (CLS)
• DOLPHIN output: Automatic tool for estimation of space-varying registration errors based on various information metrics.
• DOLPHIN achievement: Automated SAR images (and generally EO images) geolocation improvement.

Task 3 Data fusion for forward/backward tracking with sea state information (CLS)
• DOLPHIN output: Algorithm for drift prediction (wreck, iceberg) based on drift models from metocean data.
• DOLPHIN achievement: Improved awareness of the maritime situation by forward/backward tracking of wrecks, icebergs, people.

Task 4.1 AIS Integrity software tool (FFI)
• DOLPHIN output: Software to detect and geolocate vessels that transmit invalid coordinates.
• DOLPHIN achievement: Independent verification of coordinates in AIS messages; detection and separation of vessels that reuse the MMSI of another vessel.

Task 4.2 Doppler localisation of AIS transmissions (TAS-F)
• DOLPHIN output: New AIS Integrity analysis algorithm capable of combining several AIS measures (satellite and constellations, seaborne, and terrestrial)
• DOLPHIN achievement: Test of two sets of real Satellite AIS1 data (20 minutes in March2013, 4 days in August2014), identification and taxonomy of abnormal behaviors of real data, location error parametric performance analysis thanks to synthetic Doppler

Task 5 Fusion of real-time input data from coastal cameras (SPH)
• DOLPHIN output: Software for correlation of target detection from thermal and optical coastal cameras and AIS.
• DOLPHIN achievement: Data fusion from multiple ship detection methods and AIS.

Technological Line # 5: Sea State Modelling and Algorithm Inversion, devoted to the extraction of sea state and meteorological parameters from high resolution SAR images.

Task 1 ATI and X-Band based Sea State Parameters (DLR)
• DOLPHIN output: SAR estimated 2D wind field (speed and direction). SAR estimated Sea State Parameters (Significant Wave Height, Wave traveling direction). Integration with WP230.1 combining the outputs of the ship detection tools.
• DOLPHIN achievement: high resolution wind and wave field based on X-band SAR data, coastal zone
measurements

Task 2: Software Tool for SAR image simulator of the Sea (Unina)
- **DOLPHIN output**: SAR simulator adapted to new high-resolution satellite sensors, such as TerraSAR-X and COSMO/SkyMed, and with a new input interface. The developed and implemented software tool is an updated version of the SAR raw signal simulator for marine scenarios previously developed by UNINA.
- **DOLPHIN achievement**: development and implementation of a new method to generate image speckle statistics, that is applicable to new high resolution spaceborne sensors, such as COSMO/SkyMed and TerraSAR-X, and a new user interface that renders the simulator more easily usable by non-specialised operators.

Task 3 Wind and Wave Fields Estimation from X-Band Complex (EGEOS)
- **DOLPHIN Outputs**: tool for the retrieval of sea waves and winds by exploiting complex X-band SAR data and a SAR image simulator of the wind sea.
- **DOLPHIN achievements**: Swell parameters can be retrieved far beyond the azimuthal cut off frequency (important in HR/VHR images) without resorting to a priori WAM data (forecasting model data).

Task 4 Validation Support System for Wave and Currents parameters (OWS)
- **DOLPHIN output**: Validation and extension of the existing WaMoS II High Resolution Current and water depth (HRC), so that it delivers current, water depth, ocean spectra in both space and time domain.
- **DOLPHIN achievement**: Near shore observation of highly variable current and wave fields in time and space.

With reference to the Operational Scenarios, against the eight (two X policy area) proposed validation campaigns, twelve campaigns were performed during the DOLPHIN project with a strong and valuable support of the participating Users, who were available to put boats at sea for validating the results of the software tool developed. Outputs obtained in the framework of the project can be deemed a real advance with respect to the current technology.

All the campaigns have been conducted thanks to the very active collaboration with the Users involved in the projects. In the following each campaign is listed, including the contribution of the Users per each scenario.

Campaign: Border Surveillance 1
Scope: Drugs traffic- small/fast
Area: Atlantic area between Morocco and Portugal
User: Guardia Nacional Republicana (GNR)
GNR’s contribution: rubber boat, 10 m length.

Campaign: Border Surveillance 2
Scope: Drugs traffic-big ships near small/ anomalous behaviour
Area: Azores-Portugal
User: Guardia Nacional Republicana & Mutualista Açoreana
GNR’s contribution: rubber boat, 17 m length.

Campaign: Border Surveillance 3
Scope: Illegal immigration/trafficking
Area: Libya and Lampedusa
User: Italian Coast Guard (ICG)
ICG’s contribution: Guard ship “Madre”: 25 m length, guard boat: 10 m length, rubber boat: 4.70 m length.

Campaign: Border Surveillance 4
Scope: Illegal traffic- High dynamics/data fusion
Area: North Sea and Baltic area
User: German Federal Police (Bpol), German Search & Rescue DGzRS
Bpol’s contribution: Bayreuth (66 m) vessels, control boat (5 m), rubber boat (<5 m)
DGzRS’s contribution: HERMANN MARWEDE (46 m).

Campaign: Traffic Safety 1
Scope: Early warning for crossings
Area: Bay of Biscay
User: Port of Gijon
Mean contributing: Norman Asturias commercial vessel.

Campaign: Traffic Safety 2
Scope: Early warning for grounding
Area: English Channel
User: French Maritime Affairs (FMA)
FMA’s contribution: feedback on validation results.

Campaign: Traffic Safety 3
Scope: Ice conditions
Area: North East Passage – Norway/Russia
User: Norwegian Coastal Administration (NCA)
NCA’s contribution: Coastal AIS, satellite AIS from AISSAT-1.

Campaign: Fisheries Control 1
Scope: Bluefin Tuna and Swordfish
Area: Central/Southern Med
User: Italian Coast Guard, EFCA, UNIMAR
ICG’s contribution: AIS, VMS, LRIT from ICG,
UNIMAR’s contribution: information on location of BlueFinTuna farming (Malta and Spain) and floating cages.

Campaign: Fisheries Control 2
Scope: Fisheries vessels control
Area: NAFO Campaign
User: EFCA
Campaign: Joint Scenario 1
Scope: Border/Traffic/Fisheries joint campaigns
Area: South West Approaches -Europe/English channel
User: UK Border Force
UKBFs contribution: UKBF vessels (RHIB), vessel track and in-situ observations, e.g. sea-state, weather conditions, details of other ships in the vicinity.

Campaign: Joint Scenario 2
Scope: Border/Traffic/Fisheries joint campaigns
Area: Navarea-XIX, Barents Sea, Norway
User: Norwegian Coastal Administration
NCA’s contribution: coastal AIS and satellite AIS from AISSAT-1.

Campaign: Joint Scenario 3
Scope: Border/Traffic joint campaigns
Area: Strait of Gibraltar (Border/Traffic)
User: Guardia Civil (GC)
GC’s contribution: military launch: 17 m length, vessel information from Guardia Civil in terms of ship characteristics, geographical position and velocity.

With reference to the Coordination with EU initiatives, Selex as leader of WP 630 has taken the responsibility to follow the development of the DOLPHIN activities related to the Maritime Surveillance area with a specific focus on Border Surveillance. During the second period Selex has performed the following main actions:
• Establish a suitable agreement with the Seabilla project coordinated by Selex.
• Coordinate with the MARBORSUR implementation group in the view also to create links with the I2C and Perseus projects;
• Establish suitable coordination with the other projects: Perseus and I2C.
• Support the importance of the expected DOLPHIN results/product to be included in the next Security call.

A summary of the above streamlined activities is provided as follows:
• Seabilla: DOLPHIN achievements with specific focus to those carried out by e-GEOS have been successfully incorporated into the Mediterranean Demonstration held in Rome on the 5th of November 2013. Space components have included also Elint and GMTI contribution from SIMTISYS pushing toward the end user the value of space component and strategic and tactical means for the detection of non-cooperative suspicious boats.
• Marborsur: after two initial meetings in which also the Copernicus project were invited to attend, the Marborsur coordinator decided to limit, for sake of semplicity, such meeting only to leading entities of the three surveillance projects Perseus, Seabilla and I2C. Moreover Selex has provided Marbosur panel with continuous update on the DOLPHIN development and has included the space monitoring capabilities as part of the surveillance architecture concept elaborated for the Central Mediterranean to advise and cousel Frontex about the preparation of the procurement phase of EUROSUR.
• No significant synergies have been found with Perseus and I2C; this is motivated by the presence in
those consortia of GMV which probably brought Nereids achievements.

- DOLPHIN achievements are in the position to be exploited in the Closeye project. At the very end of the DOLPHIN project, the Closeye consortia, along the industry information day held in Rome on the 3rd of December 2013 has presented the end user wish list in terms of prioritized technologies. Three groups of most wanted technologies/solutions have been addressed and UAV and the Command & Control ranked first than Satellite.
- The overall impression achieved by the WP630 is that monitoring by satellite is perceived useful for routinely practices to assess suspicious activity and it is proofed a growing interests from end users now aware of the latest DOLPHIN achievements in detection of small boat as, for example, in the DOLPHIN Lampedusa Campaign.

With reference to Communication and Dissemination activities, DOLPHIN has produced a multitude of communication material that will remain useful and distributed after the end of the project. In addition, the project dissemination activities have significantly contributed to raise awareness on the Copernicus support to Maritime Surveillance among the stakeholders already knowledgeable on Copernicus as well as among those not familiar with the topic.

The main results were:
- Preparation of DOLPHIN dedicated leaflet and website (gmes-dolphin.eu);
- Preparation of a common web entry and MMP (V1 and V2) of the DOLPHIN, NEREIDS and SIMTISYS projects;
- Presentation of the project in key events and conferences (e.g. SeaTimed, European Maritime Day 2013, ESA Living Planet 2013);
- Publication of 15 peer reviewed publications on the tools developed by the DOLPHIN project (e.g. International Journal on Remote Sensing, Ocean Dynamics);
- Publication of articles on the DOLPHIN contribution to the Copernicus support to Maritime Surveillance in public friendly media (e.g. Copernicus EC official newsletter – Copernicus Observer, Window on Copernicus, Parliament Magazine).

The activities carried out in the project will be continued under the NEREIDS project (the only Copernicus project in the area of Maritime Surveillance still ongoing).

With reference to Project assessment, it was devoted to the functional and operational assessment of the achievement of the DOLPHIN project, with respect the EU and national initiatives, in order to define a set of recommendations.

Part 1: Assessment of the developments and of the validation campaigns
- DOLPHIN output: evaluation of the adaptations of the developed tools and decision support modules (DSM) based on the results of the validation campaigns and on the functional and operational requirements collected as a first step of the project.

Part 2 : Assessment of the interfaces with other external systems and initiatives
- DOLPHIN output: picture of the EU and national initiatives related to the maritime security. Evaluation of interfaces with other maritime security R&D or operational projects.

Part 3: Achievements and recommendations
• DOLPHIN outputs: (1) identification of the major achievements of the project under the following aspects: software tools, system design, interface with external systems, operational capabilities, service design, (2) definition of recommendations for the continuation of similar R&D or pre-operational projects.

Based on the DOLPHIN experience, the Consortium provides the following recommendations for future R&D activities on the subject or for the operation of related services.
- Put in place European initiative on the validation ground truth following the open-data paradigm;
- Ensure the evolution of the tools and DSM developed during DOLPHIN;
- Take into account the weather and oceanic conditions in the definition of acquisition plan;
- Take into account the weather and oceanic conditions as a standard way to measure performances;
- Promote the normalisation of the external systems;
- Update the variables made available by the Marine Core Services;
- Promote the standardisation of user systems;
- Involve the user in the definition, evaluation and update of maritime security services;
- Ensure the continuous service evaluation & improvement;
- Ensure the provision of Earth Observation images.

Potential Impact:
The main results of DOLPHIN project are summarized as follows:
• innovative algorithms for security, safety and fisheries detection and monitoring through the development of Software Tools covering the actual gaps highlighted by the users.
• Decision Support Module (DSMs), integrating the innovative Software Tools
• Validation of the results of the software tools and the DSMs in 12 operational scenarios, where the definition of the Operational Scenarios ensured the environment was actual, significant and representative of the complexity of real requirements and performances. At Operational Scenario level, the point was not only to identify real geographic areas, but moreover to describe the general environment in which the tests were performed, opportune designed in order to maximise validation effectiveness.

The validation with the involved Users provided a direct and measurable assessment of the achievement of the DOLPHIN Scientific and Technological main objectives, in terms of:

1. involvement of new and existing users through services fully compliant to requirements:
   a. the Consortium was able to involve new users who were not fully satisfied with the current performance of satellite based maritime services (e.g. no capability to detect small boats from EO based data, no validated information on speed, size and heading)
   b. the already existing Users, as those coming from MARISS who were requiring improvements in service capability, have experimented the new capabilities developed in DOLPHIN and their operational daily activities will take advantage from these services;
2. improvement of Copernicus maritime services, thanks to the innovation brought by new developed algorithms that fill the current Technological Gaps. The Copernicus maritime services can now become compliant with performances levels and services currently required by the Agencies EMSA, Frontex and EFCA, in fact a fundamental impact is the upgrade of the Copernicus operational services, supporting the operational set-up envisaged in the “CONOPS for GMES support to EUROSUR”.
Main impacts of the DOLPHIN Project were to provide an actual and effective improvement with respect to the state of the art, through:

1) Advancement of the state-of-the-art in current detection capabilities, where assets contributing to the impact are:
   o improved detection of fast and small boats, which is a requirement expressed by all the Users. This supports the “CONOPS for GMES support to EUROSUR” and will also make the users more confident with regards to the use of satellite imagery, particularly those not being fully aware of the capabilities of new generation satellites to provide a validated support service,
   o improvement in deriving vessel/boat size, speed and heading,
   o improved detection of wakes from small boats,
   o detection of suspicious behaviour of small boats, i.e. rendez-vous,
   o improvement of ships localization accuracy; with respect to the current state a more reliable support are provided by satellite based services, even if validation campaigns demonstrated that with strong bad weather condition small boats could not be detectable;
   o improvement of ship recognition and classification; new generation satellites, providing high resolution data, together with the innovative classification techniques, enables the classification of ships not only on the basis of their dimension, but also by their type estimation and shape,
   o improvement of icebergs drift prediction and analysis of collision risk, that is very important for traffic in Arctic regions of Northern Europe,
   o interpolation of trajectories and route analysis,
   o detection of fish cages and cages towed by tugboat,
   o improved integration of space image derived information with AIS and satellite AIS data.

Validation campaigns in close cooperation with the Users allowed the project to demonstrate that the innovative software tools developed have concretely improved the state-of-the-art technologies, which is a requirement expressed by all the Users. Validation campaigns also demonstrated that the detection performance depends on meteorological conditions and highlighted the importance of detecting anomalies in collaborative data, such as failures in AIS content information.

2) Extension of current core services capabilities and uptake of products and services, where main asset contributing to the impact is:
   o implementation in the Service Providers service chains of the new algorithms and tools developed in DOLPHIN, immediately improving the capabilities to provide the Users with more performing and reliable services.

The MARISS and EMSA Operational service chains for the DOLPHIN NAFO (North Atlantic Fisheries Organisation) campaign demonstrated the usability of the new tools inside the MARISS network which already implements the EMSA formats. This allowed the new tools developed by the DOLPHIN project to be run through the MARISS Network and the project’s outputs to be ingested in the EMSA platform and delivered to EFCA for its control purposes.

3) Establishment of validated services scenarios meeting Copernicus Users’ needs, where assets contributing to the impact are:
   o Users’ assets and the DOLPHIN & MARISS Users’ network.

Users involved in MARISS were also involved in DOLPHIN, where the Users participation has been
further enlarged. With respect to the previous R&D projects, DOLPHIN represents a real step forward in the collaboration with Users, in fact relevant Authorities actively participated during the validation campaigns, putting at sea boats and vessels for allowing the project to validate the research results.

List of Websites:
www.gmes-DOLPHIN.eu/
Paola Nicolosi- DOLPHIN Project Coordinator

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