PROJECT FINAL REPORT

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1.1. Executive Summary

Archaeologists and managers of underwater and coastal cultural heritage perform complex and totally different tasks, like investigations, monitoring, safeguarding, risk management, site documentation, site management, as well as diffusion, dissemination, enhancement, increasing public awareness etc. Due to these reasons, archaeologists and managers of underwater and coastal cultural heritage are always open to apply new innovating technologies. Experience shows that field work can't be replaced but a rather sophisticated tool that is extremely easy to use and allows saving time and budget in searching new sites and in taking care of known ones at risk is welcomed.

The ITACA (Innovation Technologies and Applications for Coastal Archaeological sites) project aimed to prove a management system for underwater archaeological sites in coastal regions. The project developed a set of applications integrated in a web-system with two main services:

- **Location & Monitoring Service** provides a tool for shape detection applied to bathymetry data that is derived from SAR or multispectral imagery. The "L&M Service" combines state-of-the-art remote sensing technologies and data with shape detection algorithms.
- **Management & Operation Service** enables the management and sharing of information regarding underwater and coastal cultural sites, by offering a WebGIS system, an abacus of archaeological shapes, a risk map tool and viewers for 2D and 3D Navigation of Archaeological Underwater Sites.

High resolution Synthetic Aperture RADAR (TerraSAR-X, Cosmo-SkyMed) and multispectral satellite data (WorldView) are combined to derive the relative bathymetry of the sea bottom. The resulting bathymetries are fused and processed using shape detection algorithms specific for archaeological items that were developed during ITACA's lifetime. Both bathymetry extraction methods are limited by suitable environmental conditions.

The availability of the aforementioned remote sensing imagery, combined with innovative processing algorithms optimized for archaeological sites, enabled the provision of a location and monitoring service for underwater archaeological sites in coastal zones. The new algorithms, the physical modelling and the computational capabilities were integrated into a WebGIS system, together with data acquired by traditional bathymetry mapping techniques (echo sounder, SONAR, underwater surveys etc.)

The ITACA system was verified and validated through an extensive on-ground (sea) campaign carried out with both cutting edge technologies (side-scan sonar, multi beam echo sounder) and traditional means (submarine exploration with professional scuba divers). Moreover, a trial service on various coastal zones was performed in order to provide a service demonstration of ITACA's services and web platform. The dissemination activities included one international workshop and a final conference with the aim to promote the developed services to the archaeological scientific community as well as the general public.

The ITACA consortium was composed by 11 stakeholders: six SMEs of which five operate in the space sector and one is specialized in the maritime sector; two research centres; one public body and one no-profit organization specialized in SMEs promotion in the space market.

1.2. Project's Context & Objectives

The transnational dimension of underwater cultural heritage, as determined by the diverse origins of ships and their cargoes, imposed the codification of measures and definition of adequate protection instruments, taking into account their particular characteristics and the specific risks to which they are exposed. Underwater archaeological sites are threatened by a series of factors such as:

- alteration of shorelines, seabed or currents, due to human activities and natural phenomena;
- the action of sediment and pollutants;
- the abuse and exploitation of natural resources.

Organizations and international institutions involved in the stages of protection, conservation and development, in recent years have used models and experiences to encourage the active participation of cultural heritage in the process of local development through the use of non-invasive technologies effectively available, positively repeatable and easy to use.

The monitoring of underwater cultural heritage is a priority for the competent Public authorities (Ministry of Cultural Heritage, Institutions and local entities) that shall assess their state of conservation and program restoration activities when required. These public bodies need cost effective, reliable and systematic means to accomplish their mission. In fact, the survey activities should not affect the underwater site more than necessary and the overarching aim is to preserve and protect a site as much and as best as possible. Furthermore, the capability of locating and monitoring archaeological items is a vital asset for the improvement of the conservation of our historic heritage in the Mediterranean area. Thus, the fulfilment of this objective shall enable the generation of extremely valuable information for both the scientific community and the public bodies in charge of heritage preservation.

The development of specific techniques, methods and tools based on the processing of Earth Observation satellite data makes possible the production of systematic survey of wide coastal areas. This information can be integrated with in-situ data providing end-users with an important management tool for underwater archaeological sites. The emphasis on the methodology and techniques to be released will encourage site managers to efficiently take decision on what solution is best to be achieved in order to reach the target objectives: deployment of non-destructive techniques and survey methods versus traditional digging and recovery of objects.

Many non-destructive techniques exist and many others are likely to be created or be adapted in order to address specific needs of archaeological research. Remote Sensing techniques have been proved very effective in archaeological research on land and they constitute a valuable tool for locating new archaeological sites or monitoring existing ones. However, very few attempts have been made to automate the detection and monitoring process. Additionally, most of the discoveries account for visual inspection of optical aerial images. This is a limiting factor as only a very small percentage of the information acquired by the sensor is used and not all in the best effective way. In fact, human perception is subjective and the result mostly depends on the background expertise and training of the operator. Moreover, remote sensing for underwater research has been limited to shallow waters as the capability of optical sensors to penetrate water strongly depends on water transparency and the use of multispectral data has been limited, up to now, by poor spatial resolution. In this context, ITACA implemented an approach that exploits a combination of innovative techniques in order to overcome the limitations of the traditional remote sensing process. The main objectives of ITACA project were:

1. The improvement of capabilities to locate and monitor underwater archaeological sites in coastal zones through the implementation and deployment of an innovative system integrating remote sensing and image processing techniques.
2. The deployment of a management and operation tool for underwater archaeological sites together with the development of a WebGIS system in order to integrate geospatial data with a 3D representation of the underwater "reconstructed site" and provide guidance to the underwater operations while complementing traditional mapping.

The above main project objectives have been subdivided into the following measurable objectives that have been traced during the project's duration:

- Develop methods and algorithms for the detection and monitoring of underwater sites from remote sensing Earth Observation datasets for the benefit of heritage preservation and archaeological community.
- Develop web-tools for 2D and 3D Navigation of Archaeological Underwater Sites targeting the information sharing as well as the management of coastal and underwater archaeological sites.
- Provide a complete validation of technologies and applications developed in the frame of the project using existing cutting-edge technologies and actual trials on submerged test sites.

In order to achieve the above identified objectives, the following main complementary activities have also been performed:

- Acquire satellite data required for verification, validation and trial services.
- Collect support data on the archaeological sites selected for verification. This included existing GIS data, maps, existing bathymetries, complemented by maps of underwater currents and prevailing winds in order to form a representative in-situ data sample.
- Define the shapes of the archaeological items to be located in close cooperation with the end users and experts in the sector.
- Set up a central processing facility for the elaboration of value added services, as well as pre-operational service delivery architecture.
- Analyse and characterize commercially viable service models for the newly identified services, as well as associated business and market analysis and strategies, which shall need to take into account the end user community guidelines.
- Dissemination of the results by means of workshop, conferences, publications and media coverage of the validation campaign.

Earth Observation data is progressively increasing in resolution and coverage, thanks to significant advances in sensors and the availability of new satellite constellations. The availability of the aforementioned remote sensing technologies combined with innovative processing techniques and software tools optimized for archaeological sites, enabled the provision of a location and monitoring service for underwater archaeological sites in coastal zones. The new algorithms, physical modelling and computational capabilities were improved and integrated with in-situ data in order to identify the most probable location of the archaeological structure of interest. The usage of the technologies that were deployed during project's activities (satellite remote sensing and WebGIS managing and operation tool) provide the institutional public bodies, historians and archaeologists with powerful tools for both the discovery of new unknown sites as well as for an increased comprehension of already excavated/known underwater wrecks and sites.

This improves their ability to identify as well as preserve archaeological remains and increases the size and complexity of datasets made available to the scholar and expert's community. Furthermore, the enhanced "virtual" visualization of the underwater sites by using ITACA tools contributes to the general growth of tourism and associated industry.

It is unlikely that all these non-destructive techniques will ever completely replace coring and excavation in archaeological research, underwater or on land. Intrusive approaches will continue to be important, but they will be much more effectively deployed if they are informed by preliminary non-destructive work. When intrusive methods are required, specific tools can help and guide the excavations minimizing the associated hazard.

1.3. Main Scientific & Technological Results

1.3.1. Overview

The ITACA project included 25 Work Packages and had duration of 31 months. Management & other activities (WP1-6) included the Project Management (WP1-2) and Dissemination and Exploitation (WP3-6) that lasted during the full timeframe of the project. In the frame of this last task, the definition of the Service Model, the market potential assessment and the preparation of the Business and Exploitation Plan took place. Specific emphasis was given to dissemination of project's results in cooperation with the End Users that organized the end user workshop and the international conference.

Specific Engineering work packages (WP7-11) were set to determine the system's requirements, define the system architecture and plan the verification and validation activities of technologies through the demonstration phase. This group of work packages also included the support activities in the field of archaeology (shape definition, map kits, risk maps). At the end of this phase, which lasted around 6 months, the implementation activities started.

In the Component Development group of Work Packages (WP12-16), the two methodologies for deriving relative bathymetry were developed independently and then fused in a consistent layer that was the input for the shape detection algorithms. Four different shape detection algorithms were developed and results combined in order to produce a detection layer. In the System Development and Integration phase (WP17-19), the WebGIS application and the System Infrastructure were developed in parallel and finally integrated with the processing chains developed in WP12-16. The final system is supported by various server and client components. The implementation phase lasted, based on Description of Work, 12 months but improvements and fine-tuning of the various components and sub-systems took place during the whole project's lifetime.

The Demonstration phase (WP20-25) was executed for 13 months at the end of the implementation work. During the last three months, analysis of the project results as well as preparation of the Final Conference took place (WP 24-25). The test campaign execution (WP21-22) was conducted in various sites selected in the Mediterranean area, Italy and Greece, where effective trials were carried out under the coordination of the expert WP leader. During the demonstration, a trial service (WP23) was executed in order to fully demonstrate the potentiality and effectiveness of ITACA services. All tasks and efforts performed during project's lifecycle were

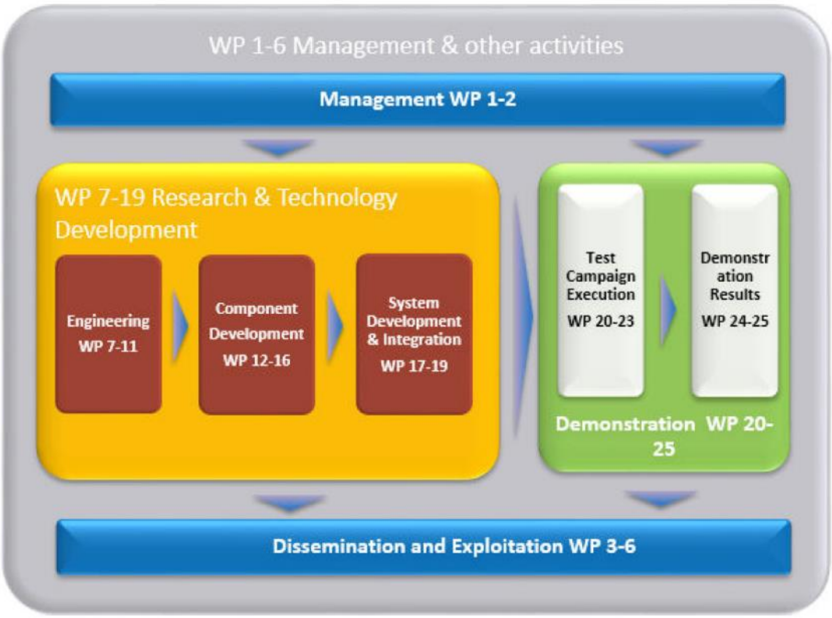

Figure 1: Work Breakdown Structure

embodied in the availability of two services:

- The **"Location and Monitoring Service"** aims at providing end users with tools that help them to search for archaeological artefacts or sites, by analysing bathymetry maps.
- The **"Management and Operation Service"** intends to offer geo-information management tools related to underwater archaeological sites.

1.3.2. Location & Monitoring Service

The ITACA Location & Monitoring Service has been developed to provide End Users a tool for searching and monitoring of several underwater cultural sites. The End User can execute a shape detection algorithm applied to the bathymetry, derived from SAR or multispectral imagery, according to the marine environmental conditions and/or to the depth of the selected site.

The shape detection process can be launched by the "Location" sub-service, choosing the base image on which the processor will search for a specific shape. On the other side, by the "Order" sub-service the End User can place an order of new bathymetry data by defining the geographic area, the time period and specifying "Bathymetry Map" as product type.

1.3.2.1. Multispectral Processing Chain for Bathymetry Extraction

The bathymetry multispectral processing chain uses raw satellite Earth Observation (EO) multispectral data as input, generates a map of bathymetry and, optionally, other parameters such as the albedo of the sea bottom or perceived quality of bathymetry. Raw data is defined as an image that has been radiometrically corrected and georeferenced by the data provider, but in which each pixel contains a digital number (DN) value, which does not directly represent any physical quantity and which is sensor and atmospheric-condition dependent. The requirements, which the multispectral images should meet in order to effectively be used in the processing chain, are the following:

- Spatial resolution: < 4m for multispectral and < 1m for panchromatic.
- More than 3 bands in the visible part of the spectrum.
- Less than 30 days revisit time.
- Georeferenced imagery delivered with metadata.
- Metadata that specify the observation geometry (view- and sun- angle).
- Clear atmospheric conditions (low cloud coverage and sun glint).

During the first phase of the processing chain (data pre-processing), the DN image is geo-rectified if required and then converted firstly to top-of-atmosphere (TOA) spectral radiance followed by a conversion to bottom-of-atmosphere (BOA) spectral reflectance. The BOA reflectance still depends on the spectral response of the sensor but the contribution of atmosphere to the signal has been minimized, leaving mainly the contribution of the BOA substrate. If the reflectance is coming from a water body, or the bottom of a water body (benthic zone), the sun glint caused by waves or observation and illumination geometry also has to be minimized. Many sensors contain a panchromatic band, which has higher spatial resolution than the multispectral band. In the pre-processing phase, the information content from the panchromatic band can be projected onto the multispectral bands, thus increasing their spatial resolution.

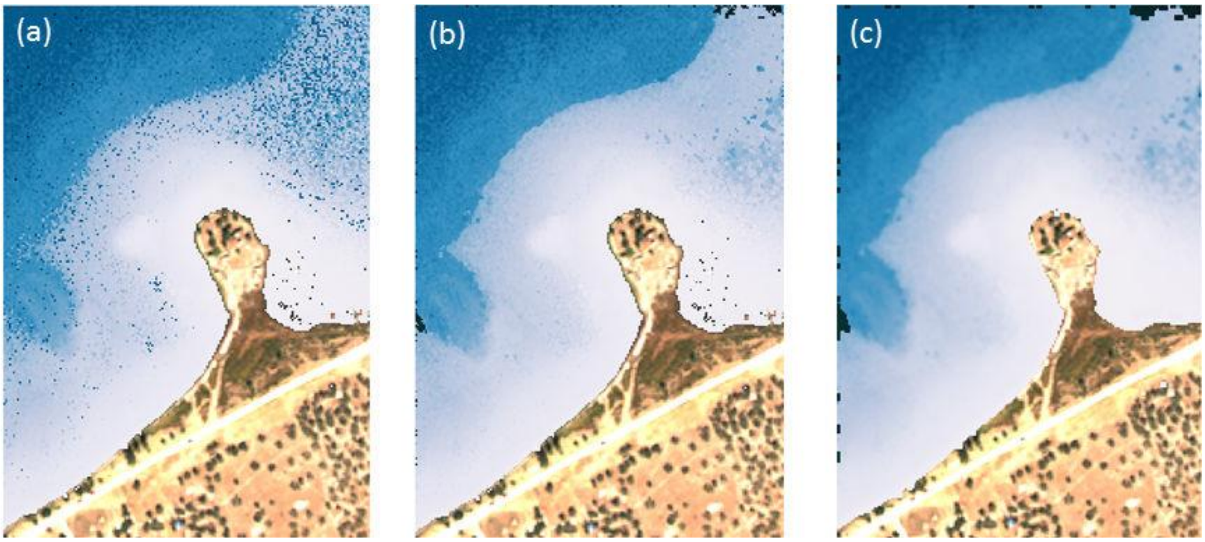

Figure 2: Example of post-processing filtering of derived bathymetry map: (a) the original map, (b) after impulse pixel removal, (c) after impulse pixel removal and binomial smoothing

The BOA reflectance of an object in different spectral bands forms the object's spectral profile. This profile can be used to determine certain physical properties of the object. In bathymetry estimation, the spectral profile can be used to parameterize properties of the water column and sea bottom and through that to estimate the bathymetry. This can be achieved using empirical models, which are trained with existing bathymetry data to establish a relationship between the spectral profile and bathymetry, or semi-analytical models that simulate the spectral profile of the water column and benthic zone by adjusting a number of physical parameters, including water depth. The final step in producing a bathymetric map is post-processing, which is applied mainly to deal with noise present in the retrieved bathymetry. This involves a number of filtering functions to fill in pixels with clearly implausible values and to produce a smooth bathymetry map.

The bathymetry map is provided at the spatial resolution of the input multispectral data, with pan-sharpening to the spatial resolution of the input panchromatic data whenever feasible. The vertical resolution (level of detail) is less than 1 m. The maximum depth of the retrieved bathymetry is not specified but it should be deep enough to perform smooth data fusion with the SAR derived bathymetry, which is around 15 – 25 m. There are three optional products that can be delivered together with the bathymetry map: sea bottom map, bathymetry quality map and true colour composite image. The feasibility of their delivery depends on the bathymetry retrieval method used (empirical or semi-analytical) and the licensing conditions of the input data. The sea bottom map and bathymetry quality map can only be delivered if the semi-analytical bathymetry retrieval method is used. The first map can be used to provide additional information to the shape detection algorithm, and the second one can be employed both during data fusion and shape detection. The true colour composite image could potentially be used as a base map for displaying to the users of the Web GIS portal.

The processing chain is implemented by a number of programming scripts. The processing scripts are written predominantly in Python programming language. They make use of numerous specialized Python libraries, such as: geospatial data abstraction library (GDAL), scientific computing library (SciPy), numerical N-dimensional array library (NumPy) satellite data atmospheric correction library (Py6S) and parallelization libraries. The scripts perform pre-processing tasks (such as atmospheric correction or denoising of input data), estimate bathymetry using the HOPE/BRUCE model and clean up the resultant bathymetry maps during post-processing. In addition, the scripts ensure efficient execution of the processing chain by taking care of data input and output and scheduling the parallel execution of the processing chain on multiple cores.

Finally, the support software is used for satellite data search and retrieval (various web browsers) and for data visualization (QGIS). The visualization capability is required to ensure quality of input and output of the various stages of the processing chain. In addition, QGIS (together with Orfeo Toolbox) is used for pan-sharpening of the input images if required.

1.3.2.2. SAR Processing Chain for Bathymetry Extraction

A processing chain, based on current method, has been developed for the estimation of bathymetry by SAR data. The chain is not completely automatic, because it includes a step where a visual inspection and comparison of the SAR image and the available reference bathymetry map is needed in order to identify the areas that are worth processing and to set configuration parameters. In the radar cross-section modulation image, the selected areas have to display features having some consistency with the underlying bathymetric profile, in accordance with the adopted physical model. In this regard, a routine has been developed that compares the gradient map computed from reference bathymetry data with the SAR image in order to highlight areas of interest; it can be useful if reference data have enough resolution and SAR features are quite marked, so that it can be considered an optional pre-processing step. The processing chain consists of data and metadata preparation (pre-processing phase), a computation step where the physical model is directly applied and a post-processing phase, which basically includes the resampling of output data in a regular coordinate grid and their encapsulation in TIFF format.

The computation of bathymetry by means of current method is possible if a specific physical phenomenon is taking place in the sea scenario during the SAR acquisition and if there are opportune conditions so that the phenomenon is detectable by SAR. This means that sea currents must be present which are varied by bottom topography and their variation must reflect on short-scale surface roughness modulation. According to literature, these conditions are generally not very frequent and are less probable in Mediterranean Sea where tidal currents are weaker than in the oceans.

Furthermore, since radar signals are proportional to spectral density energy of Bragg waves range component, bottom topography is best imaged when the current flow is in the cross-track direction and when the topographic features are aligned with the satellite flight direction. It turns out that the automatic detection of the presence of all these favourable environmental conditions in the noisy SAR amplitude image is rather difficult, so that, at least in the phase of method assessment, it has been more fruitful to make use of a visual comparison between the (despeckled) SAR image and available true bathymetry map in order to select areas where there are suitable conditions so that the algorithm can generate correctly sea bottom topography.

The implementation of the SAR bathymetry processing chain is hosted in a Linux environment and it is composed by a set of binary executables produced from C and C++ source codes. The executable "SAR_bathymetry_processing" script was designed for the execution of the pre-processing steps and the application of the bathymetric model on the input SAR image and it requires the following parameters:

- Name of the input product.
- Type of sensor (COSMO-Skymed or Terrasar-X).

- Configuration file.
- Output directory and output filename.

The configuration file has been designed for introducing parameters to the algorithm and it is organized as a tagged text file. The main parameters are tagged in the following way:

- OFFSET_ROW,OFFSET_COLUMN, SIZE_ROW and SIZE_COLUMN specify the offset and extension for the identification of the processing area.
- APPLY_DESPECKLING,HALF_WINDOW_DESPECKLING,MULTIPLIER_FACTOR_DESPECKLING and ITERATION_NUMBER_DESPECKLING specify the parameters required by the median filter for despeckling.
- APPLY_IMAGE_AVERAGE_REDUCTION,AZIMUTH_IMAGE_AVERAGE_PARAMETER and RANGE_IMAGE_AVERAGE_PARAMETER specify the parameters required by the resolution reduction routine by average.
- REFERENCE_BATHYMETRY_BEGIN, REFERENCE_BATHYMETRY_END are the tags which mark the list of files containing the reference bathymetry: the filenames must be associated to further tags describing whether the reference bathymetry has exact spatial correspondence with SAR image (EXACT_CORRESPONDENCE|NO_CORRESPONDENCE), whether the file is binary or textual (BINARY|TEXT), and in case there is no correspondence and the file is binary must be specified the file with coordinates and its dimensions.
- APPLY_MOBILE_WINDOW_AVERAGING and MOBILE_WINDOW_AVERAGING_PARAMETER specify the parameters required by the routine of mobile average routine to be applied on input SAR image.
- SELECTED_AREAS and SELECTED_AREAS_END are the tags which mark the list of the sub-areas to be processed: they are polygons identified by specifying the corners in clock-wise order.
- SEA_LAND_MASK_FILENAME indicates the sea-land mask for marking not sea pixels.
- PRODUCE_ONLY_DESPECKLED_SAR_IMAGE is the tag which stops the program before the application of the bathymetric model so that only despeckled SAR image is produced in output: it is useful for the manual step where the sub-areas to be processed have to be identified by visualization of despeckled images.

Table 1 presents the output files that the SAR bathymetry processing chain generates.

Table 1: SAR Processing Output Files

Output Files	With filename containing prefix	And suffix
the bathymetry image in the selected sub-area	bathymetry_	area_1
the available true reference bathymetry image in the selected sub-area	true_bathymetry_	area_1
the map of the estimated currents for every row in the selected sub-area	estimated_current_velocity_map_	area_1
the SAR input image in the selected sub-area; this map preserves the original resolutions even when resolution reduction has been applied in the pre-processing	input_	area_1
the despeckled SAR input image in the selected sub-area; this map has reduced resolutions if resolution reduction has been applied in the pre-processing	despeckled_input_	area_1
the bathymetry image in the selected sub-area displayed in the chosen processing area	bathymetry	-
the available true reference bathymetry image displayed in the chosen processing area; this map has reduced resolutions if resolution reduction has been applied in the pre-processing	reduced_true_bathymetry	-
the available true reference bathymetry image displayed in the chosen processing area; this map preserves the original resolutions even when resolution reduction has been applied in the pre-processing	true_bathymetry_	-
the despeckled SAR input image in the chosen processing area; this map preserves the original resolutions even when resolution reduction has been applied in the pre-processing	despeckled_input	-
the despeckled and (in case) reduced SAR input image in the chosen processing area; this map has reduced resolutions if resolution reduction has been applied in the pre-processing	reduced_input_	-
the SAR input image in the chosen processing area and in the original resolutions	input	-
the SAR input image in the chosen processing area and in the original resolutions with the application of the sea-land mask; it is optionally generated if a sea-land mask is applied in the processing chain	land_sea_corrected_input	-
the algorithm produces a text-report where the estimated sea current velocities for every processed row and the list of computed depth values compared with available ground-truth data are showed together with the relative and absolute errors	-	-

In the post-processing phase, the output maps from the SAR bathymetry algorithm are resampled in a regular reference grid (in latitude-longitude or UTM reference system) and then encapsulated in GEOTIFF format. A set of vector files computed on the bathymetry map are produced as well. These steps are performed by the bash script *referenced_images_creating.sh* that invokes a set of binary executables and requires the following parameters:

- the filenames of the maps from the SAR bathymetry algorithm,
- the dimensions of the maps,
- the reference system (latitude-longitude or UTM) of the regular grid where the maps have to be resampled.

The post-processing phase produces in output:

- a geo-tiff file for every map computed by SAR bathymetry algorithm,
- a set of shape format vector files with contour lines built on the computed bathymetry maps

The use of SAR bathymetry methods employed in the ITACA project has also been used by Stewart and others (Stewart et. al., 2016) to a different scale using of Sentinel-1 data and another geographical area (North Sea). The results have been validated against EMODnet dataset showing a very good agreement. This research has been hosted in the frame of ITACA project under the sponsorship of ALMA Sistemi and Stewart has been invited to several ITACA meetings to share their results and compare the same methodology applied by KELL in order to improve the algorithms used in the project. Final results of Stewart research has been presented in the EARSEL workshop on Cultural Heritage.

1.3.2.3. Data Fusion Module

In the case of ITACA Project, the term "Fusion" is used to identify the process that allows different bathymetry rasters, acquired with different methods and resolutions, to be merged together into one unique raster that contains "the best" of all acquired data (Figure 3). The algorithm for the data fusion assumes that the inputs are DEM raster files containing geo-referenced data, reproducing the bathymetric morphology in a regular coordinate grid. The algorithm has been developed by following these guidelines:

- One of the input bathymetry rasters is assumed as master and it drives the data fusion processing so that the output bathymetry raster will have the same extension and pixel resolution as the master one.
- The not-master data, in the fusion processing, is upgraded or downgraded to the resolution of the master, or kept unaltered, according to the resolution ratios between master and slaves images. Probably, for ITACA project purposes, the downgrade strategy will never be chosen. Here it is reported for completeness in the description of the algorithm.
- For every input image, the algorithm requires info about the confidence associated to the reported depths, i.e. the error which expresses the uncertainty range for the computed bathymetry values.
- For every input image, the algorithm can apply one of the following interpolation techniques in order to resample the bathymetry data to the common output grid: nearest neighbour interpolation, inverse distance interpolation, bilinear interpolation, cubic convolution, linear or

quadratic loess interpolation (with minimization technique or applying a smoother kernel) and Kriging interpolation with spherical variogram model.

- In case of overlapping areas, the algorithm manages the fusion processing by resampling the input bathymetry images to a common grid and then by fusing them with a weighted average, where the weights are directly proportional to the confidence or, equivalently, inversely proportional to the error.
- Optionally, a feathered output fusion bathymetry raster is produced, where an average is applied along the borders of the input images in order to smooth the discrepancies between bathymetries from different sources and to attenuate the visual negative impact.

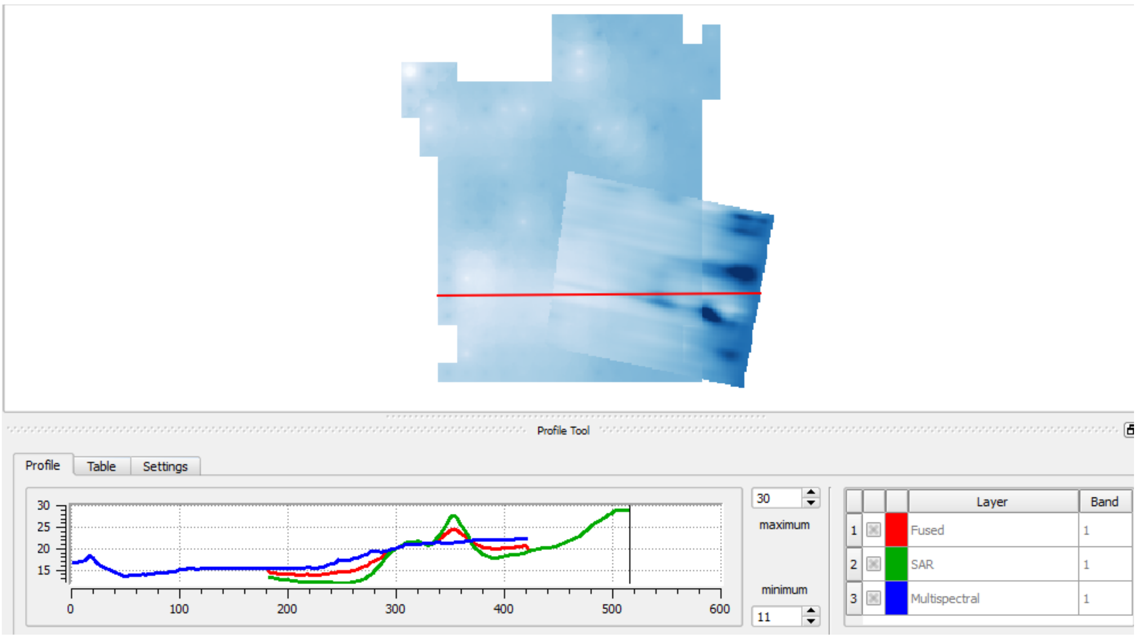

Figure 3: Result of bathymetry fusion

1.3.2.4. *Shape Detection Algorithms*

The Shape Detection is an engine of several algorithms having the scope to search a shape (a contour and/ or a combination of an edge and a colour spot) into an image. The operator selects the image, the shape to find, the proper algorithm and the minimum required level of similarity. The system provides four shape detecting algorithms: Hu's Moments, Log Polar, DoDE and Fuzzy Logic. The shape detection system returns all found shapes having a similarity level above the required value and the position in the image. Standard ESRI shapefiles can also be provided in order to allow addition and comparison of layers within a GIS software.

Results, including geo-reference position and other parameters, are stored in the ITACA system database for further processing (statistics, searches, etc.). Figure 4 shows the Shape Detection components of ITACA system. The operator, by means of ITACA service GUI, builds a specific request. The shape detection is scheduled to be executed as a batch program. The user can check the results and, if necessary, the shape detection can be re-executed with different parameters. Graphical results can be managed by means of the WebGIS system that is part of the GUI.

The Shape Detection system is a unique program including four algorithms: “Hu’s moments”, “Log Polar” and “Double Exponential”. The fourth algorithm, separately developed by FFCUL, is integrated in the Shape Detection system as an external call to a specific Java application, implementing the “Fuzzy Logic” detector.

One of the goals of ITACA project was to identify sites of archaeological interest by analysing satellite and bathymetry images of coastal regions. Here we innovated by enhancing an existing algorithm for detecting arbitrary shapes in contour images - Generalized Hough Transform (GHT). The original GHT algorithm was improved by introducing into the voting process a spatial neighbourhood concept combined with fuzzy logic, to deal with different scales of shapes and with noise, and a filling ratio to compute the completeness of detected shapes, allowing the detection of partial and complete shapes, and reducing the number of false positives.

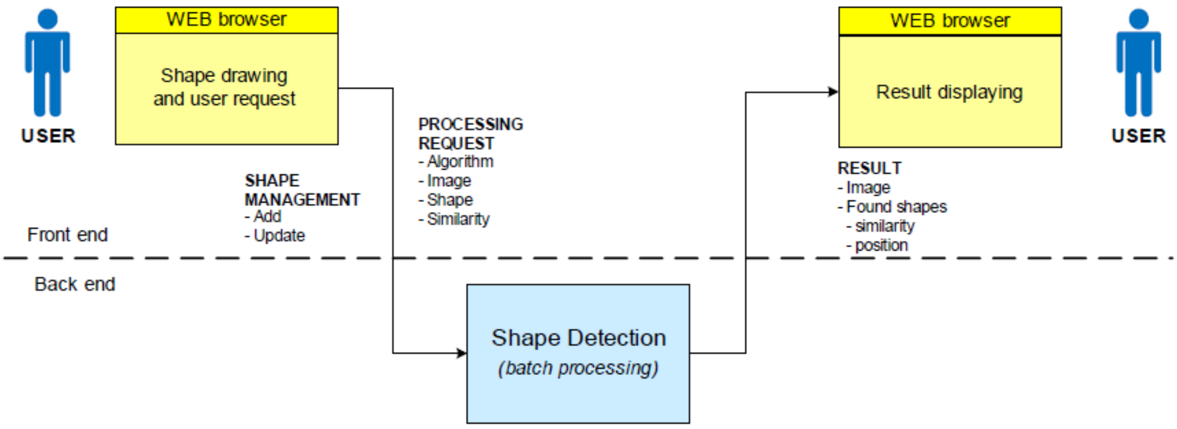

Figure 4: Shape Detection Components

Fuzzy Logic algorithm receives as input the reference contour (in SVG format), the query image and a similarity level. The algorithm starts by applying a grayscale to the query image, followed by a radius blur, and then uses the Canny edge detection algorithm to identify the edges of the image. Following that, the line fitting algorithm converts the edges to a set of points that compose each edge, to make it possible for us to work with a set of ordered points instead of having only pixels to process. The next step uses the points from the reference and the query on the shape detection module. With the reference contour points the R-Table is generated that will be used in the accumulate votes process. This process has the fuzzy logic concept applied and will help to locate the reference contour position in the query image, even in images with a lot of noise and when the object’s contours are vague. After the accumulated votes, algorithm finds the best candidates by sweeping the accumulator array to find local maxima. With the maxima coordinates, we now have information of the object location, its rotation and its scale that we output as results.

The method is invariant to rotation, scale and translation, suitable for noisy, blurred and very complex images, making it usable in real case scenarios where we want to detect objects in images with very complex backgrounds, as is the case in the ITACA project. Moreover, its flexibility in dealing with imprecise and partial shapes allows us to detect objects partially buried, arbitrarily rotated, imprecise contours of the shapes and objects that could present similar shapes. An experimental evaluation comparing our approach with the original GHT, using standard measures and the ETHZ shape dataset, showed the validity, effectiveness and superiority of our method.

1.3.3. Management & Operation Service

The Management and Operation Service has been developed to enable the management and sharing of digitized information concerning the underwater cultural sites included in the data base. The End Users can use two kind of sub-services, the "Sites" sub-service where all the digital documents are organized per site, and the "WebGIS" sub-service for visualizing the geospatial data. Furthermore, the Management and Operation Service offers a Risk Index Tool that can produce an Archaeological Occurrence Risk Map and a Risk Map for Vulnerability and Danger. Additionally, a text file is generated that contains all defined parameters together with their weight values.

1.3.3.1. ITACA Services Web-portal

The ITACA Service Web-portal is the entry point to ITACA services on the web. It is reachable at the following web address: https://services.project.itaca-fp7.eu/itaca/

The Web-portal hides the complexity of the ITACA distributed system composed of many interconnected sub-systems deployed at different locations (e.g. EO Data Processing facilities, system infrastructure and web-GIS). Moreover, it allows:

- end-users (e.g. archaeologists and underwater site managers) to access both "Location & Monitoring Service" and "Management & Operation Service" by simple-to-use human-machine interfaces;
- ITACA service administrators to manage the ITACA service itself (e.g. by the management of product types, contents, users, products generation workflow (from order to publishing into the web-GIS)).

The website provides four types of accounts with different permissions for accessing its webpages and tools: Anonymous User, Frontend User, Backend User (Content Manager) and Backend User (Product Specialist). Basically, the two Backend User accounts have different level of administrator privileges. Only Anonymous and Frontend User's functionalities will be described here because these types will be mostly used by the public.

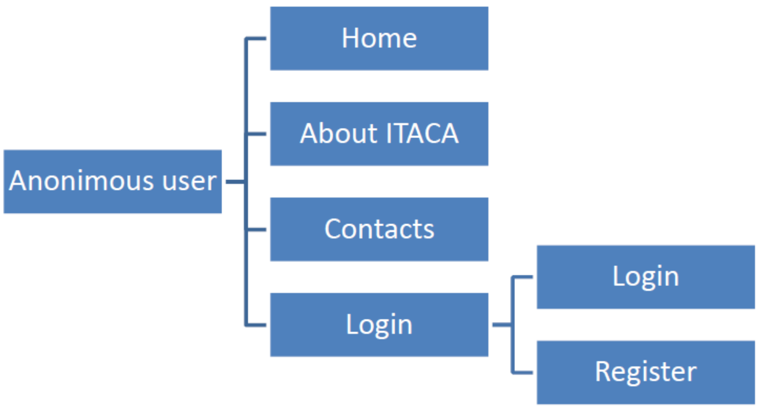

Figure 5: Anonymous User Account Permissions

Anonymous User Account

Figure 5 presents the webpages that a user, not registered in the service, can access. In more detail, "Home" webpage provides access to the "About" and "Contact" webpages as well as the "Log In" and "Register" forms. The "About" page provides generic information regarding the project while "Contacts" mentions contact information about the website administration. To sign in as an existing user, the "Login" button must be pressed and the user will be directed to the "Login" page (Figure 6) where can provide the credentials (email address and password). In case the user does not have an account, the "Register" button (Figure 7) directs the user to a webpage (Figure 8) where can create an account by filling in a form with the requested information.

Figure 6: Login Webpage

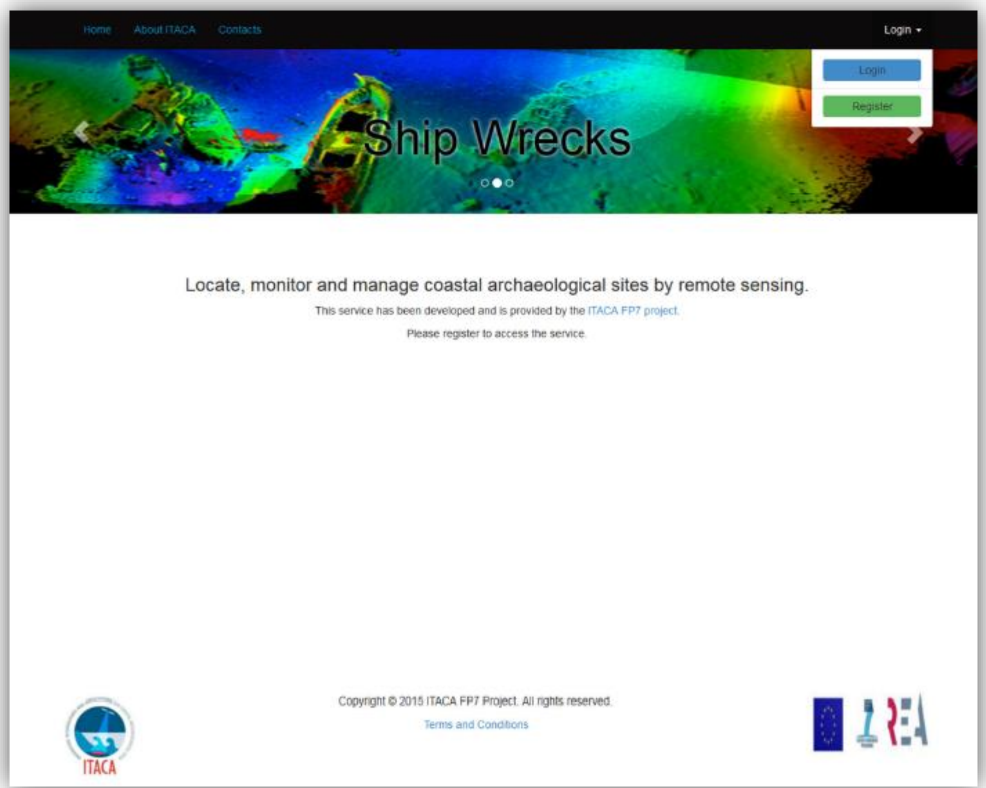

Figure 7: Login/ Register Webpage

Finally, the “Create” button must be pressed in order to complete the registration. After this step, a message is displayed that the new account has to be approved by an administrator. At the same time, an email message is sent to the valid address that was given before with further instructions.

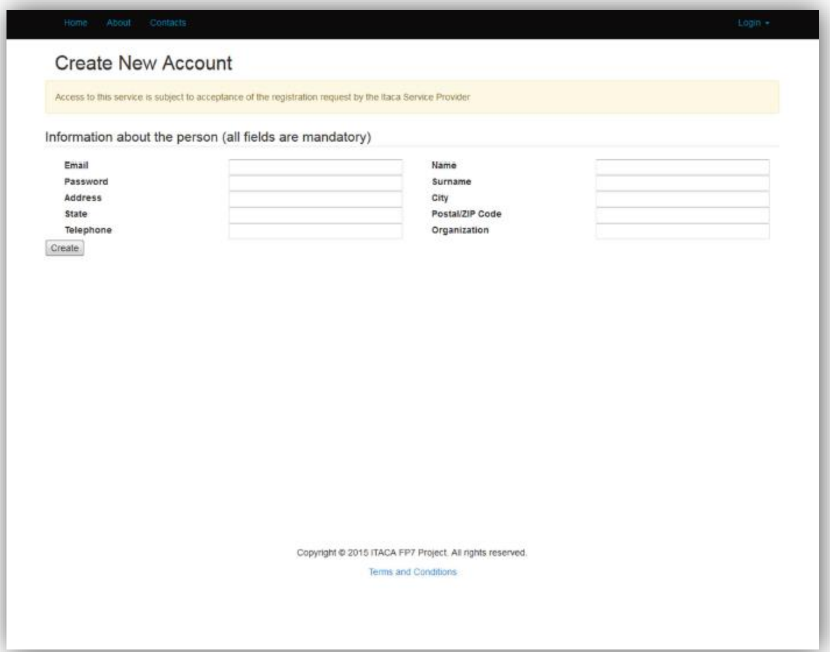

Figure 8: New Account Form

If the credentials of an existing account are forgotten, these can be erased and new ones can be submitted by clicking the “Forgot your password” link. Firstly, a new email address should be provided (Figure 9) where a message will be sent containing the instructions to reset the password. Following the link sent with the email message, a new password can be specified (Figure 9).

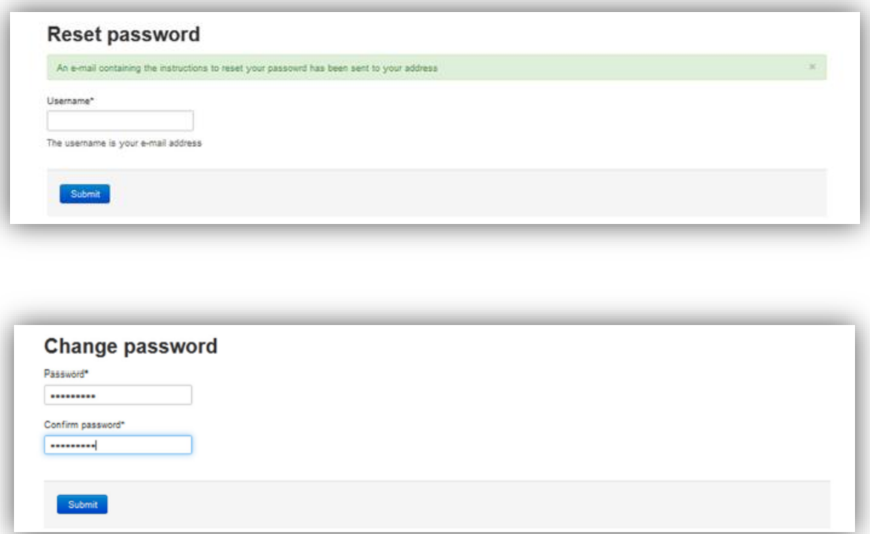

Figure 9: Change Credentials Webpages

Frontend User Account

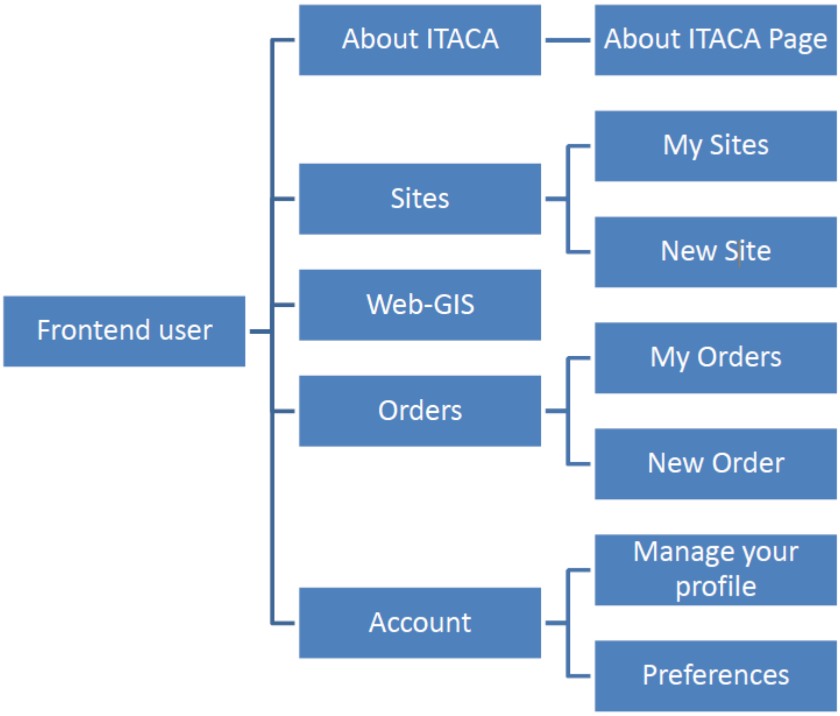

Figure 10: Frontend Account Permissions

Figure 10 displays the webpages that a Frontend user can access. In general, a user with a Frontend account have access to the following webpages:

- Sites
- WebGIS
- Orders
- Account

SITE

The "Site" webpage (Figure 11) contains all the user sites of interest. From this section, the user can add another site by providing the following information:

- Name
- Description
- Type
- Scarcity
- Variety
- Material
- Preservation State
- Maintenance Program
- Base Maps
- Researches
- Threats

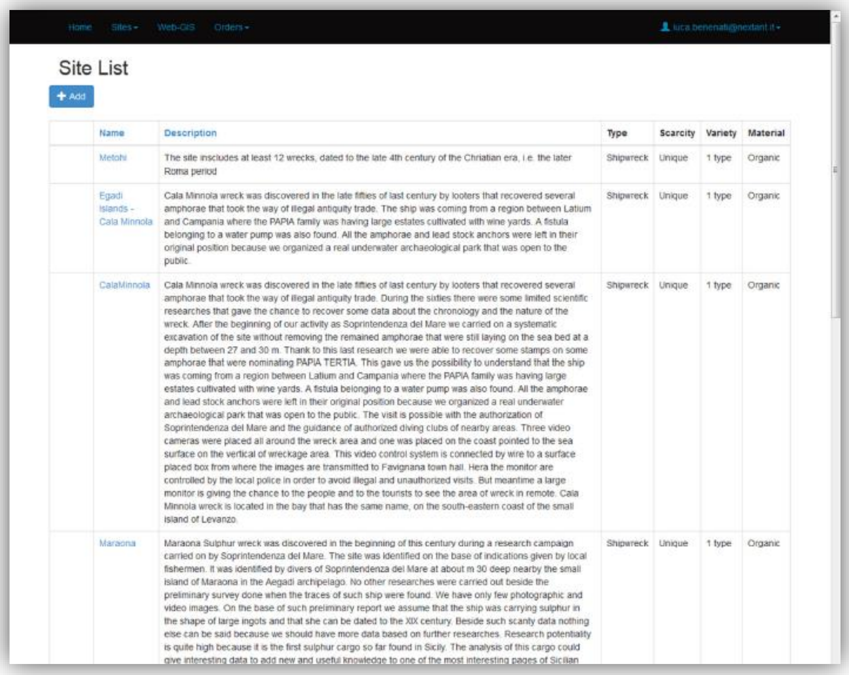

Figure 11: Site Webpage

Clicking the “Add” button, a new site can be added (Figure 13). Moreover, clicking on the name of a site, the user can obtain more information about the specific site.

The “Site Description” page (Figure 12) contains the following:

- General information about the site
- A geographic map with the geographical extension of the site
- A field for uploading PDF files and images
- The list of Surveys and Threats related to the site.

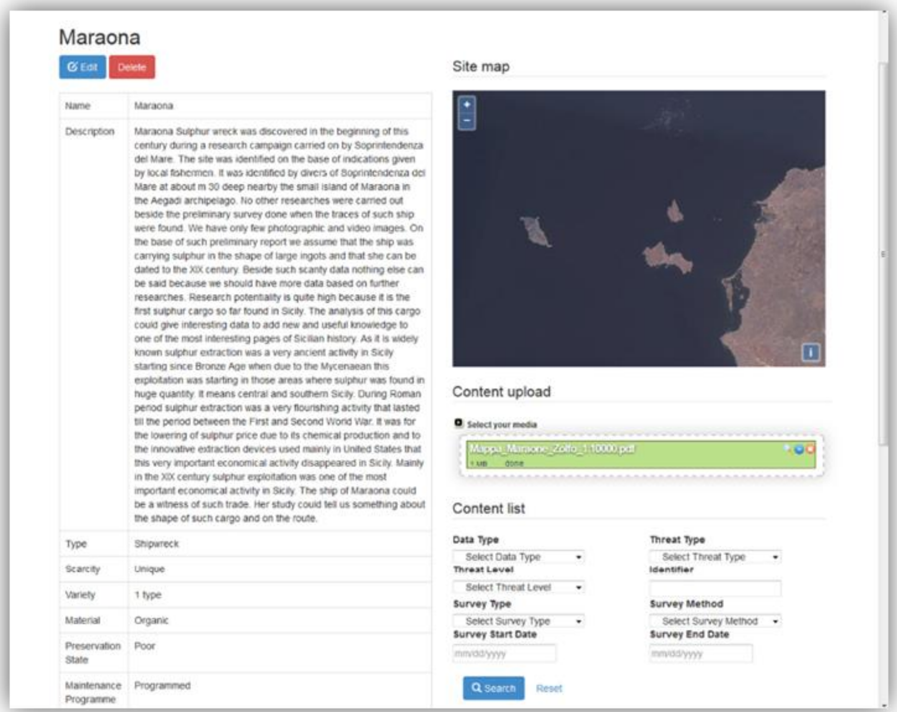

Figure 12: Site Description Webpage

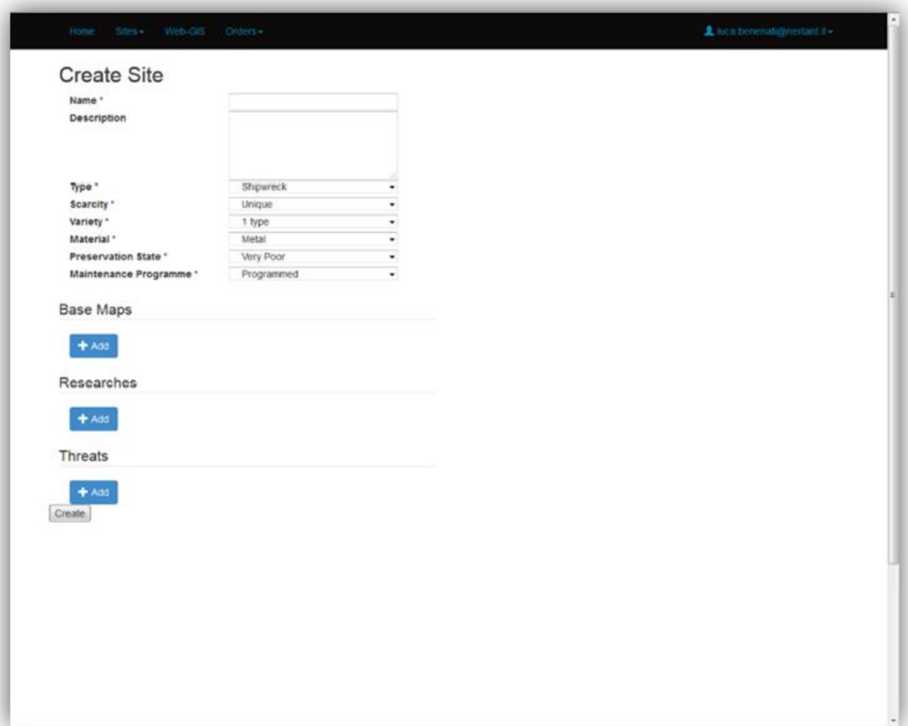

Figure 13: Create Site Webpage

Research

Clicking the "Add" button in the "Research" webpage (Figure 14), the user can add information related to a new research campaign that took place in the specific site. The form that should be filled in, contains the following fields:

- Identifier
- Description
- Type
- Method
- Method Details
- Start Date
- End Date
- Polygon

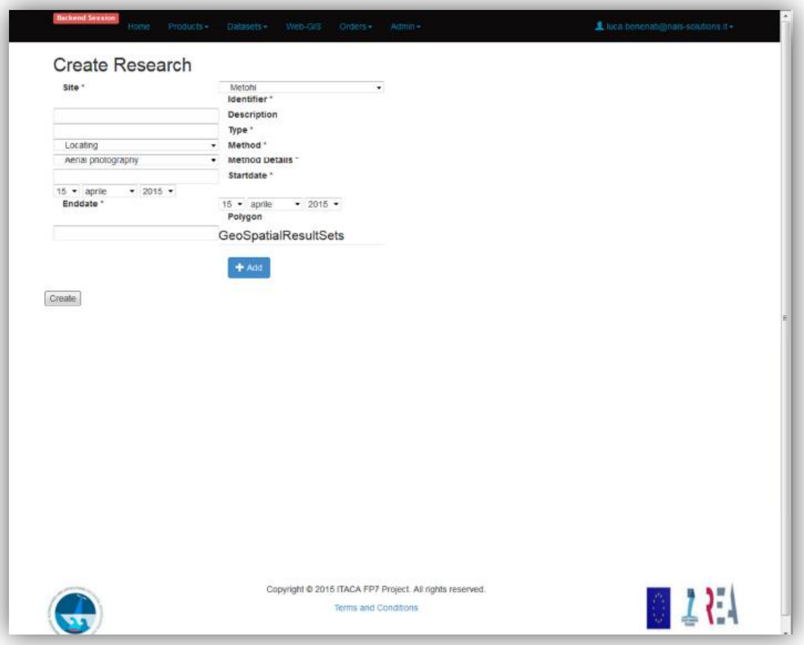

Figure 14: Create Research Webpage

Threats

A new threat related to the site can be added by clicking the "Add" button and specifying the "Threat Type" and "Level" fields (Figure 15).

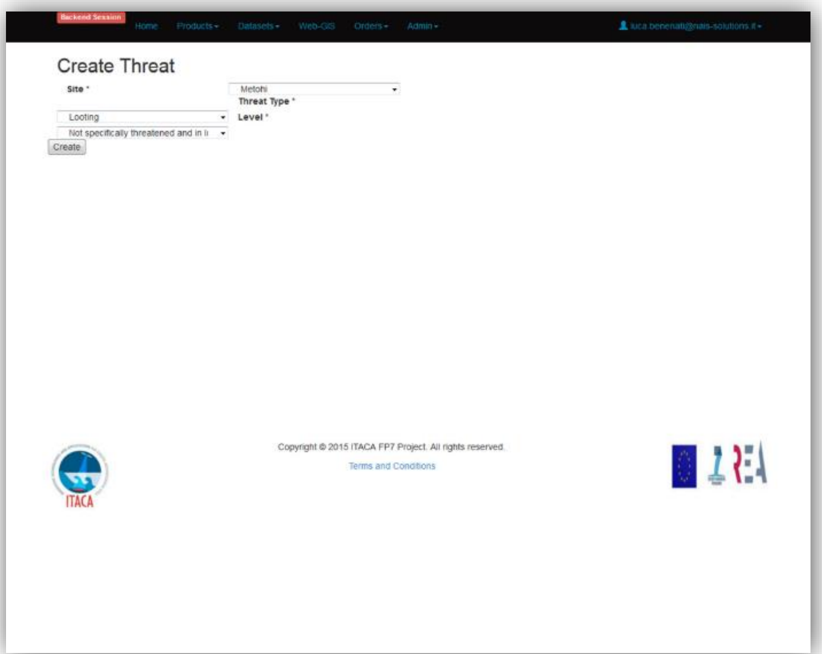

Figure 15: Create Threat Webpage

1.3.3.2. WebGIS

The ITACA WebGIS sub-system (Figure 16) is the application responsible for visualizing the geographic layers and information produced and managed in the context of the ITACA project through a geographic viewer. The WebGIS sub-system, therefore, offers a user friendly interface through which end users can see the spatial data on cartographic background and be able to inquiry them to visualize their attributes. The viewer does not require installing any plug-ins on the end-user PC, and is compatible with all major browsers on both Windows and Linux platforms. Through the WebGIS sub-system, end users can consult the map data in an interactive manner. They can zoom in, zoom out and move the map with high interaction to seek and identify areas of interest. This continuous user interaction produces, at the software level, subsequent requests from the WebGIS client to the map server. In order to increase the performance of the server and make the consultation of the data more efficient and fluid in the WebGIS sub-system development, the "Tiling maps" technique has been implemented in order to display the data. Thanks to TMS (Tile Map Service), it is possible to call up a map dividing it into multiple pieces (tiles) and rebuilding, through the various pieces, the requested map on the client side. This offers huge benefits in terms of increased performance of the map server. The access to the WebGIS client is allowed upon authentication. Once logged in, an index page is displayed, which contains the authorized site areas for the specific user. By clicking on the "WebGIS" menu item, the user accesses the WebGIS viewer.

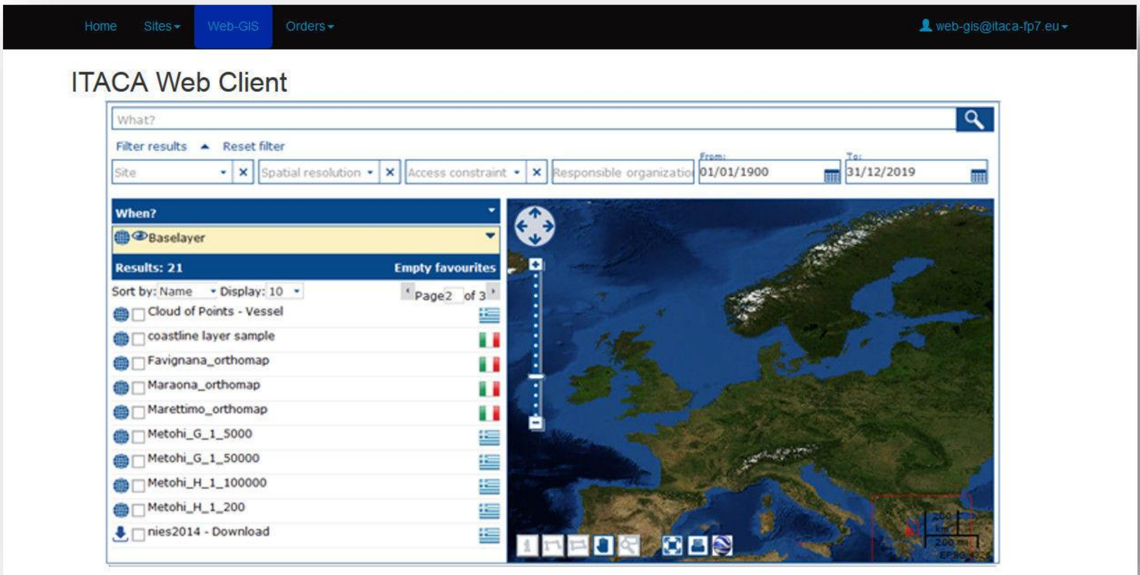

Figure 16: WebGIS GUI

The default map is displayed when the user connects to the WebGIS client and it displays the background map of the target site. A navigation bar is available over the background map which buttons activate the associated functions (Table 2). At the bottom right of the viewer panel, the coordinates of the cursor are displayed in the WGS84 system. The user can select a display scale of the maps, with the related tool. The indication of current view's scale is shown in the lower left corner of the viewer. Beside the geographic viewer, the TOC (Table of Content) panel is also displayed. The TOC (Figure 17) includes all the layers the user is enabled to display according to the given permissions. Furthermore, it allows the user to manage the display of maps and map layers. Through the TOC, the user is enabled to:

- Zoom to extent of the layer
- Turn on and off individual map layers.
- Manage the degree of map's transparency.
- Change map style provided by the layer
- View legend layer
- Order up/down among layer list
- Delete a map from the viewer.

Table 2: WebGIS Buttons Functions

Button	Description
Full Extent	Allow displaying the map at the default scale (full site area).
Pan	Allow moving on the map in Drag Drop mode.
Zoom Box	Expands the area of the map defined by the mouse drawn rectangle.
Zoom In	Expands X2 the map keeping the same centre of the map displayed. The 'Roll Forward' function will be enabled as well: it will tie to the mouse wheel roll forward the same effect generated by the Zoom In button.
Zoom Out	Reduce X2 the map keeping the same centre of the map displayed. The Roll Back function will be enabled as well: it will tie to the mouse wheel roll back the same effect generated by the Zoom Out button.
Identify (Query)	Allows querying georeferenced items visualizing their attributes within a table (e.g. type of shipwrecks, type and depth of water, status of the site).
Polyline Measure	Allows measuring distances polylines drawn on the screen. The line drawn can then be removed with the tool.
Measure	Allows measuring the perimeter and area of polygons plotted on the screen. The area traced can be then removed with the tool.
Print	Allows printing / exporting the cartographic map (e.g. generating a PDF with all the layers displayed).
Google Earth	Allow displaying (or exporting) georeferenced items visualizing them over the Google Earth application.

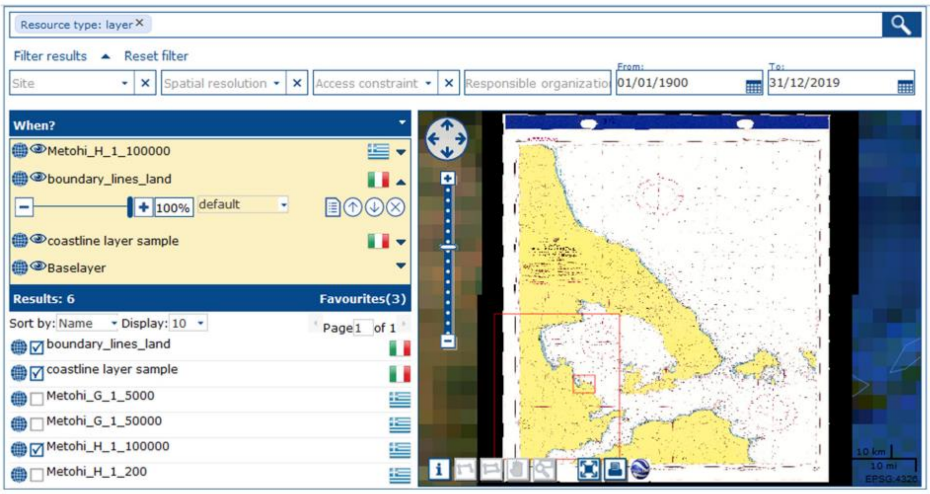

Figure 17: WebGIS Table of Contents

1.3.3.3. Risk Index Tool

A Risk Index Tool was generated in the framework of ITACA project. This tool is used for the final index calculation in a matrix environment and the production of two raster maps where all cells are coloured according to final risk indices. The indices were chosen by following the classic structure of the Environmental/ Static Structural/ Anthropic danger related to vulnerability of architectural elements. Around ten factors were initially identified and five of them were finally used for the development of the tool after the consultation of experienced ITACA partners. All indices were classified with values from 1 to 5, with value 1 assigned to the lowest vulnerability and 5 to the highest. The outcome is two raster maps, the "Archaeological Occurrence Risk Map" and the "Risk Map for Vulnerability and Danger".

For the generation of the final products, various steps are implemented that are divided in the preparation of input data for the computation of maps and the generation of final products. The tool needs vector data as input and generates two rasters as output (Figure 18), so firstly the input data must get the appropriate form in order to be ready for the generation of the outputs.

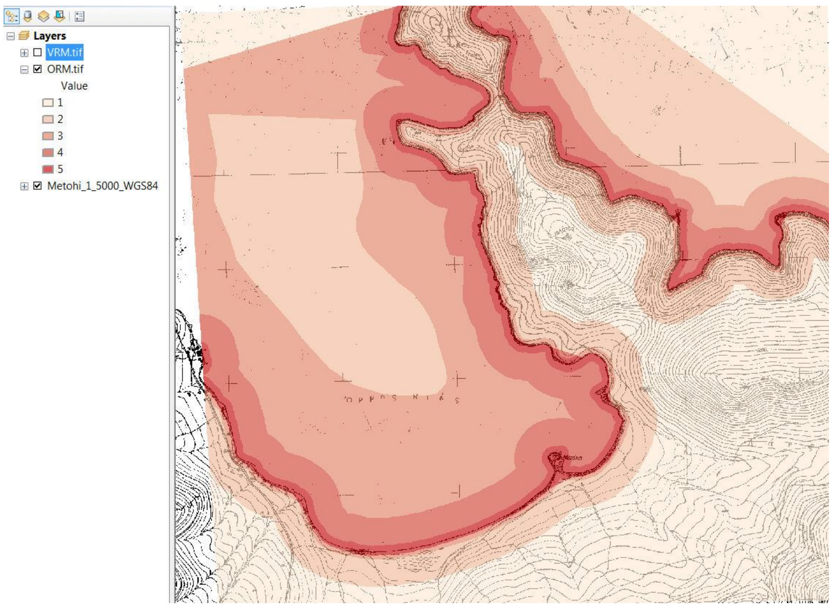

Figure 18: Product Sample

In general, the vector data (lines, polygon) is converted to raster data and classified in five classes according to their vulnerability.

In order to create a flexible and adjustable Risk Index Tool, a Python stand-alone script was developed using the ArcPy site package that provides Python access for all ArcGIS geoprocessing tools, including extensions, as well as a wide variety of useful functions and classes for working with and handling GIS data. In general, it is needed a MS-DOS window (command prompt), the Python shell or an appropriate IDE (Integrated Development Environment) software application in order to execute a Python stand-alone script. The mentioned methods can be confusing and difficult for persons that are not familiar with programming development. Therefore, the next step was the conversion of this stand-alone script to an ArcGIS tool with a graphical user interface that makes easy the use of the tool from people that have no previous experience with programming languages. It must be noted here that the tool has been updated, after end users proposed some adjustments that enhanced its functionality and effectiveness. The tool's newer version was used in the Trial Case activities.

The GUI window has six main areas. The first one, and always visible, is the area where the mandatory information must be provided. The directory of the final products (both of them or just one), the desired spatial reference of the outputs and a polygon vector that describes the area of interest must be always provided in order to execute the tool. The expandable parts provide areas that must be filled in order to compute the Occurrence Risk Map or/and the Vulnerability Risk Map. It must be noted that all parameters are optional because data for each of them might not always be available. In this case, the corresponding box can be left empty and the tool does not use this parameter in the computation of final products. In the newer version (Figure 19), end users can also specify a weight value in order to define the significance of each parameter or the accuracy/reliability of its value. Attention must be paid in the correct preparation of the input data because one small mistake can give wrong outputs or maybe result in un-executed operation. The newest version of the tool generates a text file with all parameters and weight values that have been provided by the user. This text file is automatically displayed when the geo-processing has been executed successfully.

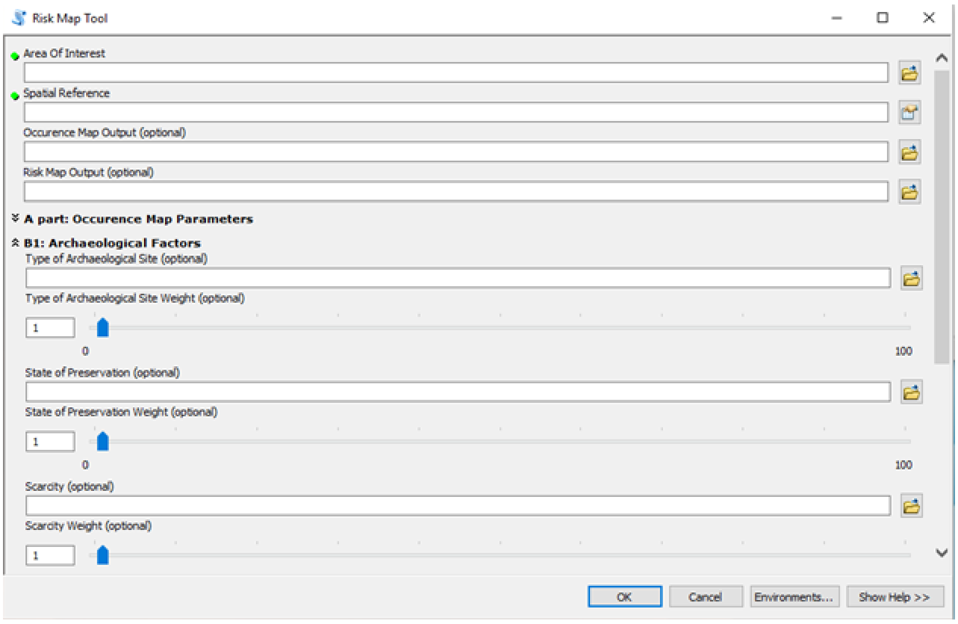

Figure 19: Risk Index Tool GUI

1.3.4. ITACA's Field Campaigns

The purpose of the Test Cases carried out in Italy and Greece was to provide information in order to verify/validate SAR data as well as multispectral/optical data and to build up the 2D/3D scenario for the WebGIS management tool that has been deployed. During the test cases, Regione Sicilia and I.EN.A.E. performed scientific and archaeological supervision interacting with CODEVINTEC that has conducted the technical survey using multi-beam echo sounder equipment. Each team member performed specific technological and field work activities providing verification and validation tools based on their technical expertise and background knowledge.

1.3.4.1. Greek Sites

The Metohi submerged settlement constituted part of the demonstration campaign for verification using existing or procured data sets and validation including real trial cases (field campaign). Following the Minutes of all previous meetings held by the ITACA's Consortium and Progress Meeting #2 in particular, it was agreed among partners that it would be beneficiary for the project to proceed with the topographical recording of the shipwrecks and their cargo (concentrations of ceramics and anchors) that have been discovered at Cape Glaros.

Field Campaign - 2014

The first ITACA field campaign was conducted by the Hellenic Institute of Marine Archaeology (IENAE) at Metohi, Bay of Nies (in the south Pagasetikos Gulf), and took place from the 1st – 15th of September 2014, following the permit issued by the Greek Ministry of Culture. Overall 19 people participated, all divers.

Trial trenches were conducted in order to better evaluate the stratigraphy and clarify the chronological occupation of the site. Since there were evident changes on the geomorphology of the site due to active wave movement, particularly on the NW part of the peninsula (at the slope and the coastline), a considerable number of archaeological remains had been uncovered and remained exposed. This is, therefore, mainly the reason why was decided to focus the archaeological work at that part of the site.

Figure 20: Late Bronze Age Remains

All finds, which were collected during the field campaign, were safely stored and transferred to Athens, where they were handed over to the Conservation Laboratory of the Greek Ephorate of Underwater Antiquities. Following the 2014 archaeological documentation, 129 finds have been recorded. The majority belongs to ceramic pots like amphorae, skyfoi, kylikes and cups but also a considerable number of sherds belong to pithoid jars. Moreover, the majority of finds (Figure 20) can be dated to the Middle Bronze Age period but there are also finds that date to the Late Bronze Age, the Roman, Byzantine and modern times, providing evidence for the continuation on the occupation pattern of the settlement. Prehistoric finds originate from north and central Greece.

The initial purpose of the topographical survey (Figure 21) at Metohi has been the representation of all archaeological finds on adequate drawing scale. It became quickly apparent that it could contribute as well in other ways to the archaeological work. So, beyond the preliminary survey and cartographic documentation of positions and format of the finds, the topographical work (almost on a yearly basis) has included:

- the re-positioning (stake out) of the finds, towards their marking before the annually scheduled archaeological work,
- the temporal monitoring of impacts from the waves on the coastal zone of the study area.

The result of these activities has been the saving of time in the process of spotting and marking the finds, the documentation of coastline's deformations during the research period, the pilot application of modern surveying techniques and finally the drawing of an up-to-date topographic plan.

Most of the archaeological finds have been recorded by using a geodetic station. During this process, the archaeologist in charge of the project has been indicating the positions and the type of every find. A diver has been placing the spike of the topographic pole to the specific point, while a member of the team was controlling the vertical plane. Upon the positioning and the vertical placing of the topographic pole, the operator of geodetic station has been recording the measurement. Meanwhile the sketch has been produced in accordance with the writing of measurements for each find.

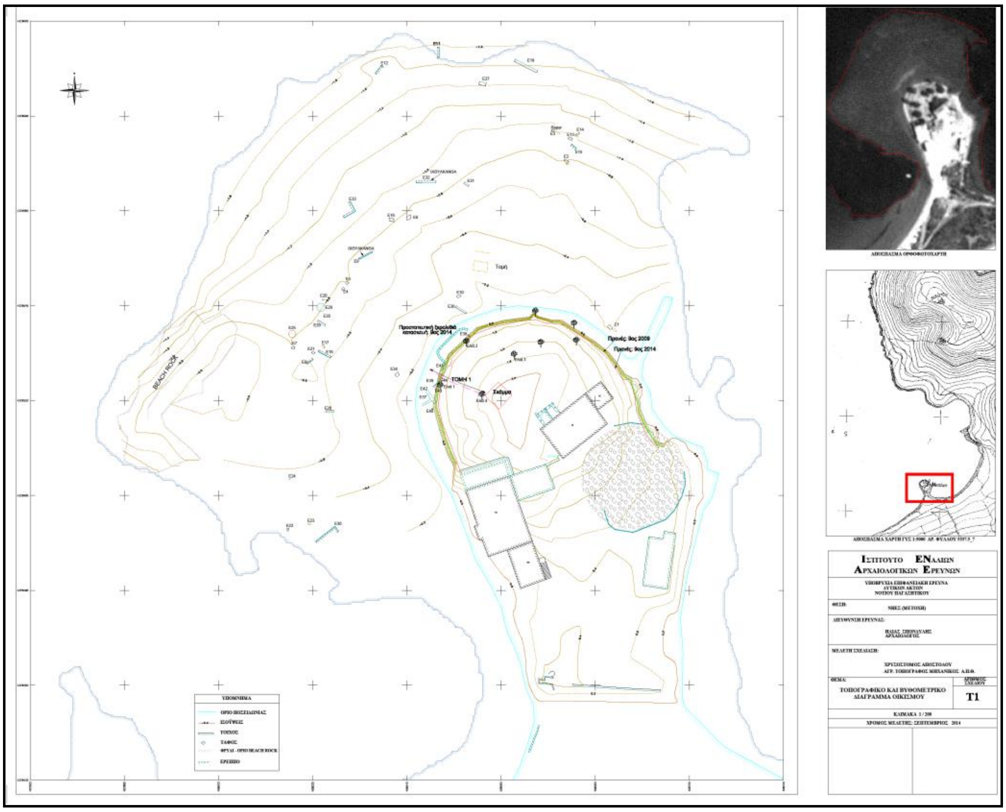

Figure 21: Topographic Plan of the Metohi submerged settlement, produced in 2014.

Field Campaign - 2015

The second field campaign lasted from the 21st of May – 21st of June. Overall 29 people participated, all divers. At this year's venture, 14 people participated on a voluntarily basis. During the course of the campaign, a diving boat and two inflatable speed boats supported the diving activities in the field.

All the correspondence with the Greek Ministry of Culture was conducted successfully in order to receive the permit for the Pagasetikos field campaign in due time. All administrative matters in relation to the campaign were dealt before the opening of the field season and all available data of Pagasetikos Gulf was distributed to Codevintec in order to conduct the Metohi test case measurements. In addition, solutions were provided on the organization and planning of the geo-physical survey (*i.e.* for the execution of the mapping campaign on boat using multi-beam echo sounder, side-scan sonar and laser scanner).

Regarding archaeological documentation, all new finds were recorded *in situ*. Photographs with orientation (North) and scale as well as measurements were taken in order to add all new finds to the topographic plan (Figure 22). All archaeological activities were photographed and filmed, both on land and underwater. Underwater finds were cleaned and photographed. Aerial photography with a *Drone Quattro Copter* was conducted successfully and has produced very detailed images of the site and its surroundings.

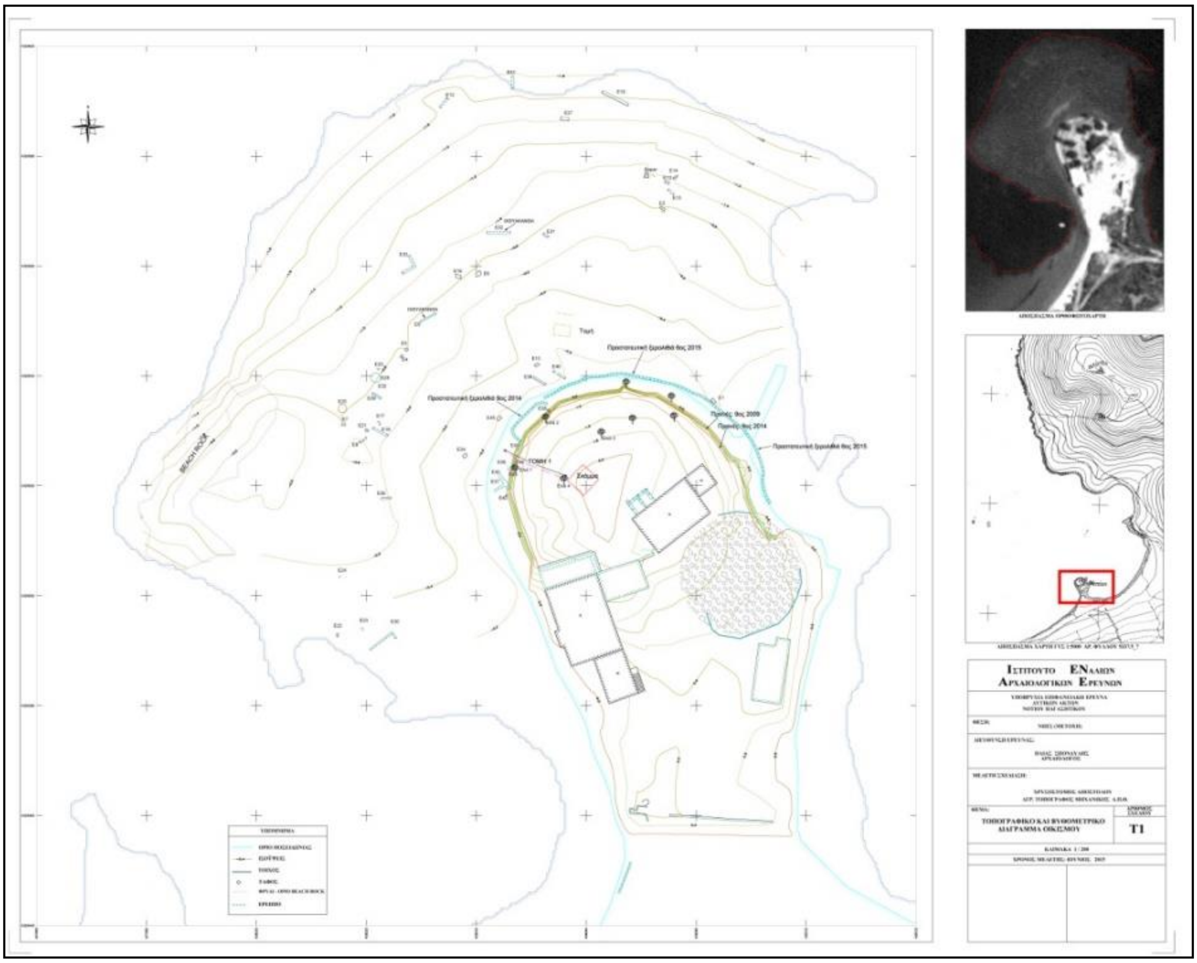

Figure 22: Topographic Plan, produced in 2015.

Figure 23: Recording Findings

Furthermore, 186 dives were conducted at Point Glaros. 122 hours were spent underwater, out of which 37h 30' were spent for decompression. From the 21 days dedicated to the Glaros' research campaign, two were missed due to bad weather conditions (on the 28/5 and 18/6) whereas one was dedicated to other actions on board the support vessel (on the 4/6) and one was dedicated to the surveying of fixed points from the site to the land. The boat was anchoring at the port of Amaliapolis around 18:30 and the work was continuing at the team's accommodation facilities, where all daily data was recorded and the next day's schedule was decided. All finds were recorded *in situ* (Figure 23). The archaeological work was photographed and filmed, both on land and underwater.

The objective of 2015 underwater survey was the detailed and accurate 3D mapping of an area that extends 400m along the northwest coast of point Glaros, covering an area of about 15000m^2, up to the depth of -30m and in some cases -36m. The aim of the surveying process was the mapping of entire area of interest and the detailed documentation of areas with a bigger concentration of finds, their geo-referencing and their virtual and graphic visualization. In order to accomplish that, three related documentation techniques were applied simultaneously: photogrammetry, geodesy and conventional architectural mapping.

Photogrammetry was chosen as the most preferable technique for the geometrically accurate and imagery-detailed 3d reconstruction of Glaros underwater site. Plans, photomosaics, single images and any other data available, collected during former archaeological survey periods, were used for the optimal organization of the photogrammetric restitution. The vast area that needed to be surveyed was not possible to be documented using photogrammetry during one survey period, while at the same time, areas with no surface finds were included into the area that had to be covered. Therefore, it was decided that two main concentrations of finds and an area of sparsely scattered finds were to be photogrammetrically surveyed and then merged into a common georeferenced map. The locations of individual finds that belong to these three concentrations were selected to be transferred to the surface with the help of buoys, so that they could be measured with a total station from the shore.

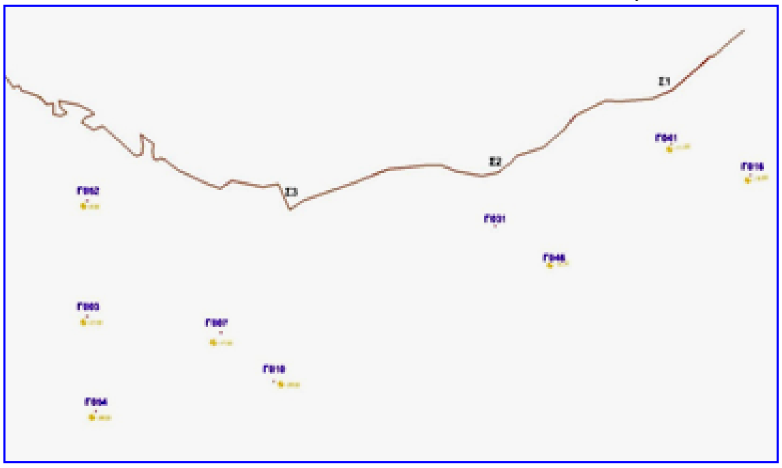

Figure 24: Selected Points that were surveyed from land

Along with the photogrammetric documentation, surveying measurements were carried out in order to geo-reference the acquired photogrammetric model of Glaros site to the National Geodetic Reference System (GGRS87) and integrate it with the coastline and land within a common map. In order to achieve it, 9 finds scattered widely around the documented area were selected to be surveyed through the use of a total station on land (Figure 24). During previous surveying periods, 3 permanent surveying points were established and measured with a GNSS instrument.

Conventional architectural mapping (Figure 25) took place through the creation of underwater sketches of selected, characteristic finds. Detailed measurements were taken on the anchors using tape measures, calipers and profilometers, along with aimed photographic documentation of finds' details with the use of scales. 3D perspective drawings of finds were also made in order to record structural details and their relation to the underwater geomorphology and other finds.

The simultaneous application of the three related documentation techniques, photogrammetry, geodesy and conventional architectural mapping resulted in a geometrically accurate and imagery-detailed 3d reconstruction of Glaros underwater site. The architectural documentation and 3d model generation of separate finds also lead to the production of detailed drawings of a large number of anchors and other finds that are important to the archaeological research of the site.

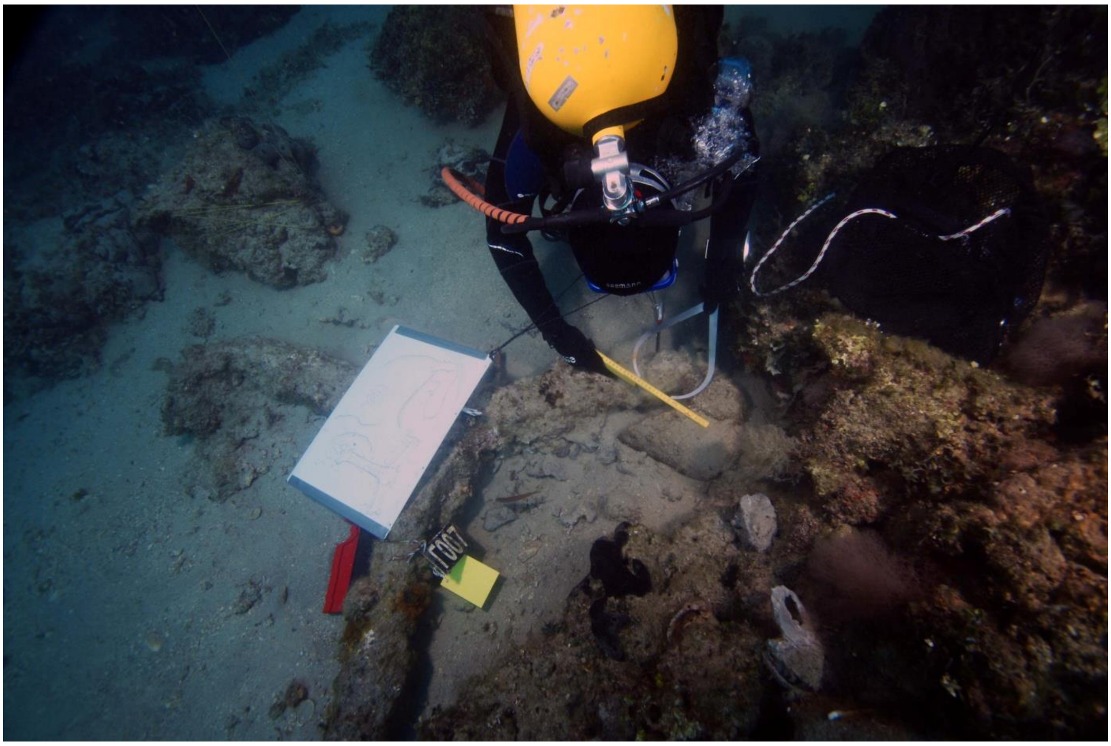

Figure 25: Diver measuring details

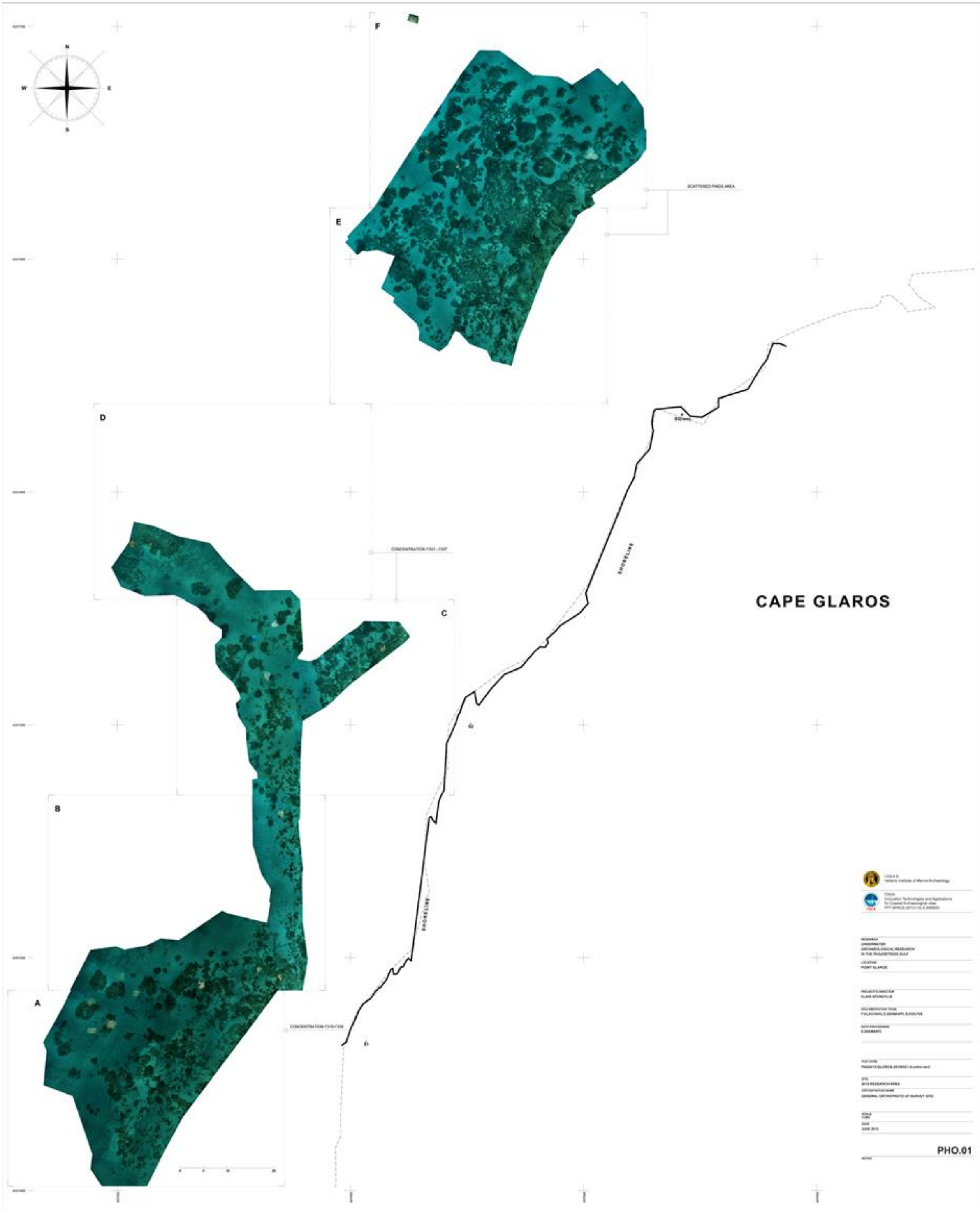

Figure 26: Site plan of Survey Area 2015 (©IENAE 2015)

A marine geoacoustic survey was carried out by the Laboratory of Marine Geology and Physical Oceanography of Patras University, in the coastal zone of Pagasitikos Gulf. The research activities were focusing on the Metochi and Glaros research sites. The survey's aim was to obtain quality marine acoustic data using a variety of systems: Multi-beam echo-sounder, Side-scan Sonar and accessories to obtain high resolution images of sea bottom; Chirp Sub-bottom profiler to investigate marine stratigraphy;

Interferometric Sonar for very shallow waters bathymetry. Wide areas were scanned (1.4 km x 1.4 km centered on the target position) to record the exact position of the targets and the bathymetry of the area. Then, scans of the target were conducted at the maximum resolution achievable. The data of the whole survey area was processed to produce a low resolution digital terrain model (DTM) (Figure 27); the two individual regions of interest - Metohi bay and cape Glaros - have been processed separately to produce higher resolution DTMs. High frequency Side-Scan Sonar data (Figure 28) was able to reveal very high resolution details of the seabed.

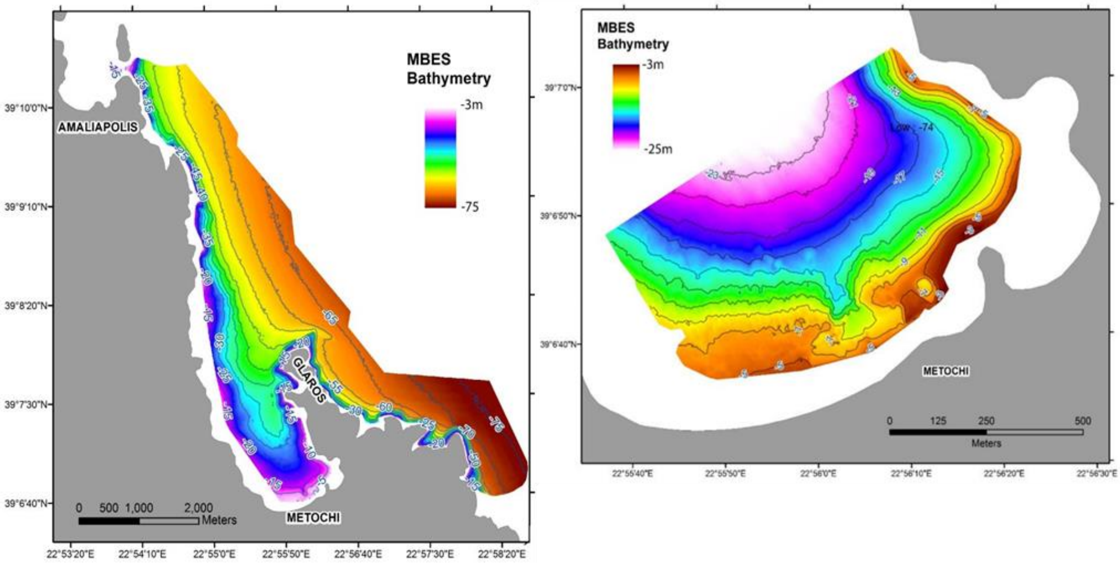

Figure 27: Low Resolution Bathymetry

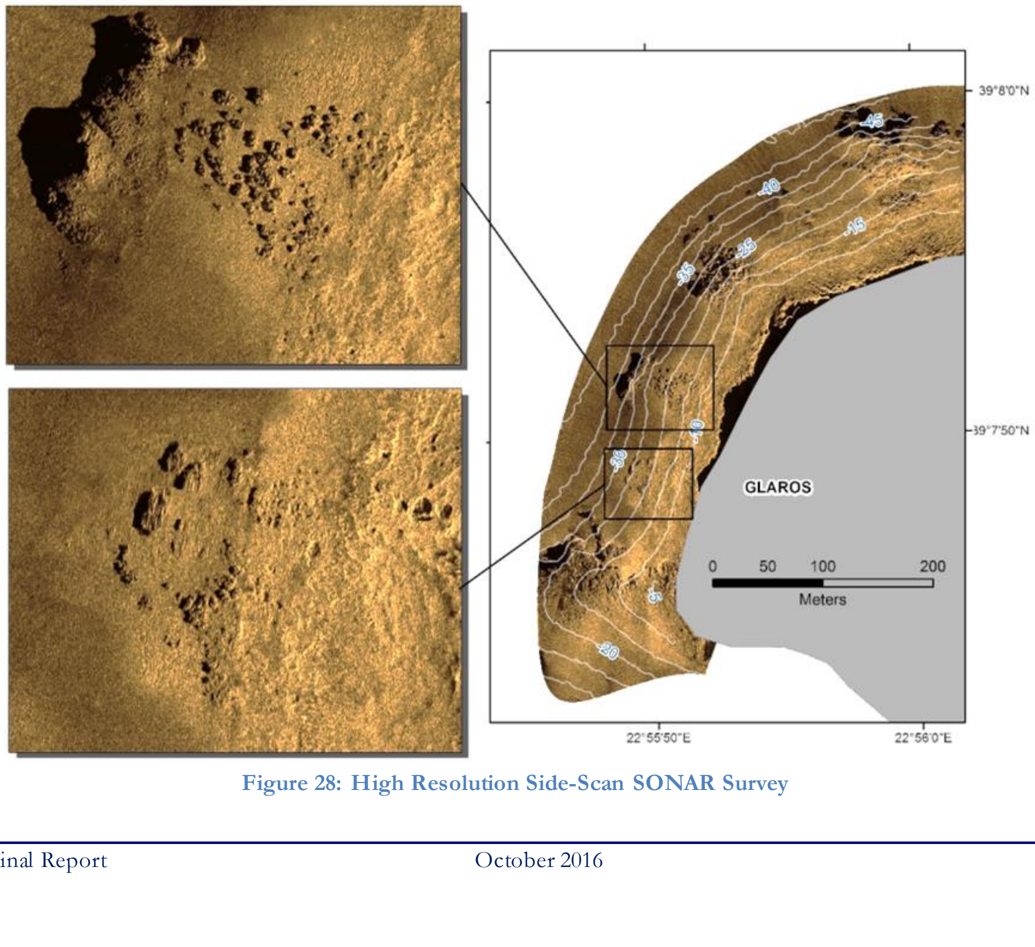

Figure 28: High Resolution Side-Scan SONAR Survey

1.3.4.2. Italian Sites

ITACA project comprised in Italy, a number of sites specifically located in the Egadi Islands area. The selected sites to conduct the test campaign were:

1. Cala Minnola (Levanzo)
2. Carmelo Lo Porto (Favignana)
3. Elphis I (Maraona)

In particular, Cala Minnola has been selected in order to test the possibility to identify the shape of an archaeological site. The other two sites are two modern shipwrecks. The partners directly involved in the test campaign were Regione Sicilia for the scuba diving data acquisition in order to produce video, photos and the 3D scenario, and CODEVINTEC for the survey campaign using multi-beam echo sounder. The test campaign focused in the achievement of two objectives:

- Data acquisition for 3D reconstruction and video production (scuba dive activity)
- Data of multi-beam survey.

For acquiring videos and photos, a Canon camera 5D Mark III has been used, in an underwater housing Easydive. Lighting sources have not been used. The 3D models visualization was performed using a Russian software called Agisoft PhotoScan. The video has been edited using the software Final Cut X. To elaborate the 3D reconstruction of the wreck Elphis I (Figure 29), 375 photos have been used with a processing time of about 24 hours. For the reconstruction of the Carmelo Lo Porto wreck into 3D (Figure 30), 351 photos have been used with a processing time of about 24 hours. For the 3D model of Cala Minnola site (Figure 31), 85 photos have been used with a processing time of about 12 hours. Using the measurements recorded during the dives, the models were rescaled in order to obtain their real dimensions. Finally, the texture was obtained from the original photos, after processing them using Adobe Photoshop, in order the 3D models to get the "real" colours.

Figure 29: Elphis I 3D Model

Figure 30: Carmelo Lo Porto 3D Model

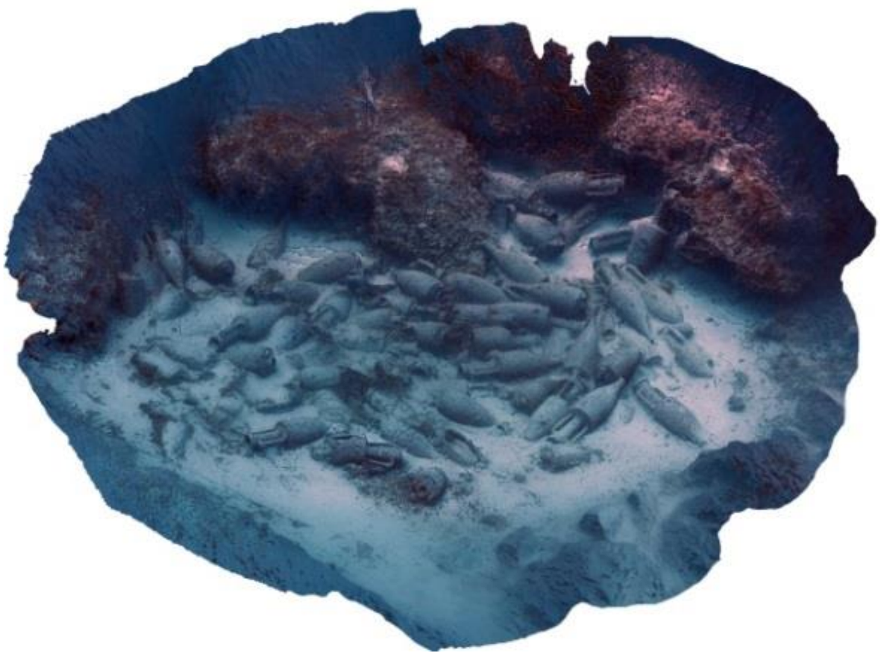

Figure 31: Cala Minnola - 3D Model

The rotatable 3D reconstructions are available in the ITACA web portal and also at the following link: http://www.regione.sicilia.it/beniculturali/archeologiasottomarina/itaca/itaca.htm

At the end of the page click on each of the three arrows with the right button of the mouse and download the pdf files. In order to visualize the 3D models, Acrobat Reader should be used.

The video is available at the following link:

https://m.youtube.com/watch?v=EQq0LR_4--o

The aim of the multi-beam survey was to determine, with a high degree of accuracy and resolution, the morphological characteristics of the wrecks and the surrounding areas.

Multi-beam is the primary technology for sea-floor mapping: unlike a traditional echo-sounder, with each acoustic ping, a multi-beam sonar system can plot the bottom depths for dozens to hundreds of points in a line perpendicular to the heading of the ship. This gives the multi-beam sonar two huge advantages: resolution is far superior, wide swath coverage dramatically reduces time and cost of surveying. In ITACA project, Codevintec used a RESON SEABAT 7125 SV2 multi-beam system (up to 512 beams, dual frequency 200-400 kHz).

Multi-beam data has to be corrected of the bias due to boat movements: precise and real-time measurements of heading (yaw), pitch, heave and roll angles are valuable output data for accurate vessel navigation, positioning and survey performance. APPLANIX POS MV inertial measurement system was used with multi-beam, enabling adherence to IHO (International Hydrographic Survey) standards.

Multi-beam systems require instrumentation for sound velocity measurement and correction at the sea-surface and throughout the water column. Without such measurements, multi-beam accuracy is jeopardized. YSI CASTAWAY-CTD is a small, rugged and technically advanced CTD, designed for profiling to depths of up to 100m.

The purpose of the hydrographic software is reading data from one or more sensors in real time, make computations with the data, display the results of the computations and simultaneously log the data. TELEDYNE RESON PDS2000 is one of the most used hydrographic software.

For a correct georeferencing of the survey, a GPS reference station was installed at the village of Favignana, on the roof of the building that houses the office of the Egadi Marine Protected Area. The complete system was comprised by LEICA SR530, receiver GPS/RTK, geodetic, dual frequency has been installed on the boat owned by the company "Teknomar" and calibrated for the determination of angular offset axes of pitch, roll and yaw by comparing data acquired on the same areas with different routes.

Cala Minnola is a well-known and reported site, therefore the research phase has not been performed. A set of lines parallel to the coast was performed (Figure 32), with a multi-beam swath angle between 50° and 70°, up to cover the entire area of the archaeological site.

In **Elphis I** area, a first phase of research of the wreck has been done with a low resolution (swath angle of the multi-beam at 130°). Once the wreck was identified, a high resolution survey was performed (multi-beam swath angle between 50 ° and 65 °), up to a total coverage of the entire area (Figure 33).

The **Carmelo lo Porto** wreck was identified quickly, thanks to the good reliability of the estimated coordinates. Once the wreck was identified a high resolution survey was performed (multi-beam swath angle between 50 ° and 65 °), up to a total coverage of the entire area (Figure 34).

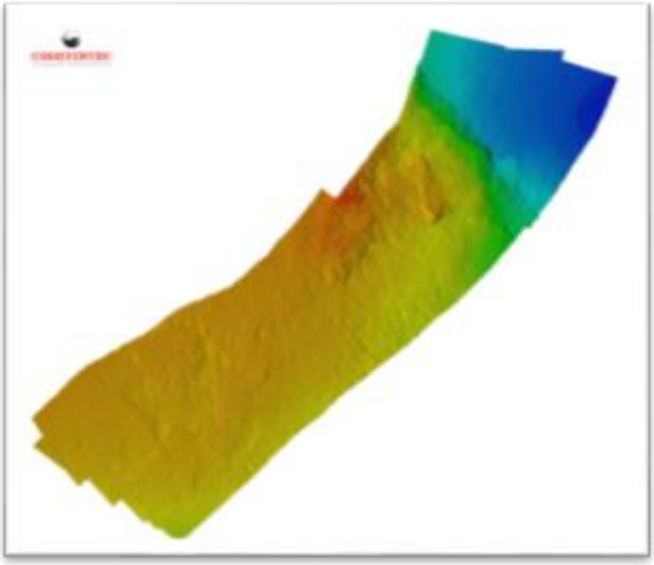

Figure 32: Cala Minnola Bathymetric Data

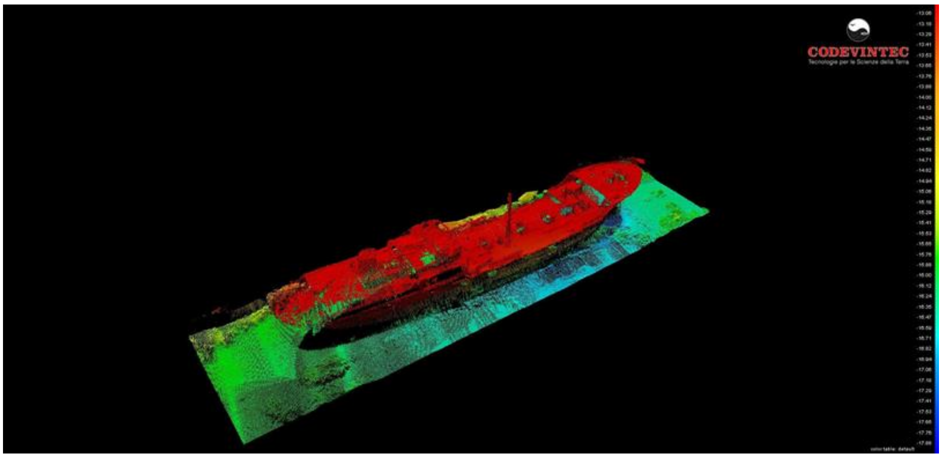

Figure 33: Elphis I Bathymetric Data

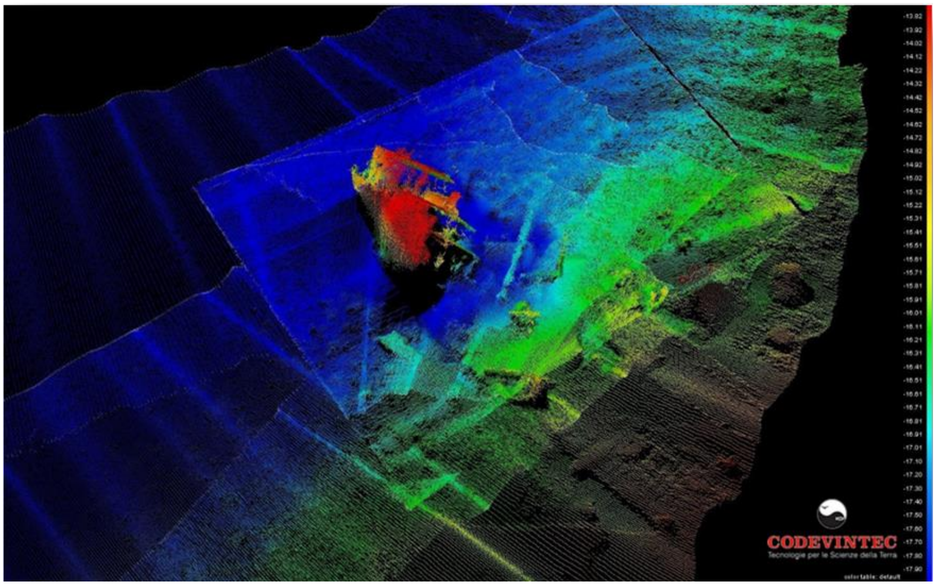

Figure 34: Carmelo Lo Porto Bathymetric Data

1.4. Potential Impact, Main Dissemination Activities & Exploitation of Results

1.4.1. Potential Impact

ITACA system materializes an appropriate tool accessible through the World Wide Web that is able to involve researchers from all over Europe and world in specific investigations without the need to transfer data or involve expensive desktop solutions. This tool enables the users to access and enrich the information related to archaeological sites in its geographical context, both in a 2D overview and in a detailed 3D view. The tool includes modules taken from the current state-of-the-art WebGIS technology, which can be further customized for specific use cases and seamless integrated into the process of information generation.

The system has different levels of authentication that allow sharing information with different types of users, from the manager to the researcher to the wide public. The system offers an interactive combination of the different data sources and project outcomes in terms of geospatial information to increase the exploitation possibilities for archaeologists.

Specifically:

- *Location & Monitoring Service*, enables searching a specific shape using a Map kit and an Abacus of shapes and permits to place new-bathymetry requests by defining the geographic area, the time period of satellite data acquisition and the type of product.
- *Management & Operation Service*, permits the generation of a new site, provide information about surveys, describe the content and threats of the site; permit editing of an existing one with its relative information and documents. Additionally, the WebGIS permits the management of geo-information related to a specific site. A functionality that is useful for safeguarding, risk management, site documentation and management.

Regarding the range of utility of the *Location and Monitoring Service* for underwater cultural heritage, two limitations emerged for shape detection: one referable to the size of objects to be identified through satellite images and the other referable to the depth. In fact only shapes larger than 10 meters can be detected and in shallow water. However, it is worth noting how current limitations in the detection of small shapes cannot be ascribed to the shape detection techniques implemented in the frame of ITACA, but mainly depend on the resolution (both horizontal and vertical) of the bathymetry images used as inputs of shape detection.

Another limitation of use is related to the bathymetry estimation using satellite-based SAR observations that require presence of strong sea currents comparable to oceanic tidal currents and winds with the correct speed for the generation of surface waves. As it is already explained in related deliverables, these conditions are not frequent in Mediterranean Sea but can be strengthened by sea surface winds. Thus, studying meteorological data could give an impression about the suitability of SAR images during a specific time period. On the other side, the system was also positively tested to detect shapes larger than 10-15 meters and partially overlapped (20%-50%).

Moreover, through the ITACA Final Conference – Satellite Remote Sensing Technology in Underwater Archaeology that was held in Athens, the ITACA Project results were disseminated to the public. This event provided the opportunity to invite end-users to:

a) communicate, through a creative discussion, their experience on the application of innovative technologies in underwater archaeology and
b) to express their overview on the project's results.

As a general impact, ITACA system provide End Users the great opportunity to detect new fields of technological support and optimise the activities in the field of research, protection and management of Underwater Cultural Heritage by offering several advantages than the services and tools already available:

- Lower costs.
- A service offered on the web by accessing a service web-portal.
- No need to install and maintain software applications on each user's computer.
- A sophisticated tool that is extremely easy to use.
- A tool with friendly interface that the users can enrich with information, documents and can be further customized and tailored for specific use cases.
- Realize collaboration and information sharing.
- Possibility to use the same tool for two purposes, sharing information between researchers and managers but also making available general information and documentation to the general public.

ITACA project demonstrated that the use of satellite images for underwater cultural heritage management is a great opportunity, that its potentiality is very high, but the road for an optimum operational use is still long, mainly due to current technical limitations in getting detailed-enough sea-bed and bathymetry maps from satellite imagery. However, it is worth noting that:

i. There are some operational scenarios where satellite imagery can be already successfully exploited. This is for instance the case of investigating and monitoring underwater archaeological sites in very shallow waters when the presence of rocks does not permit surveys by vessel-mounted traditional equipment.
ii. Most of the technologies developed in the frame of the project (e.g. shape detection algorithms, web-GIS tools, web-based sites management and operation technologies) can be also successfully exploited when combined with imagery and data coming from the use of traditional survey techniques.

On another note, a good step was reached and it could be useful to cope with nowadays situation of Underwater Cultural Heritage. Underwater activities are, in fact, becoming very common among the population. Today it is very easy to get the basilar diving knowledge. In only one week, a person can follow some lessons and get the rudimentary rules to use cans and dive up to around 20 m deep. On one side, this attention is important because contributes to increased respect and knowledge of cultural as well as natural features of sea. But on the other side, there could be a huge danger because we are in front of larger and larger amounts of potential looters of antiquities. As it was realized, it is impossible to control thousands of potential looters only with the help of marine police or coastguard. It is clearly understood that is very important to have the opportunity of monitoring these sites with the help of new technological methods and tools. ITACA is on the right path to find new ways to protect and manage such great heritage.

As everyone knows underwater activities are very costly due to technological equipment and labour high costs. So, before starting to exploit the possibility to evaluate underwater archaeological sites, the financial impact of ITACA should be considered. ITACA services can help users to find inexpensive ways to carry on projects in their field of research and domain of protection. ITACA helps in the achievement of a good balance between costs and benefits of evaluating underwater cultural heritage.

At European level, ITACA project contributed towards to the realization of less expensive and more effective solutions in the domain of marine and coastal archaeology and site conservation. In more detail, the project contributed towards the Integration and Strengthening of the European Research Area, combining a multidisciplinary and cross-thematic research, such as satellite remote sensing, image processing technologies and WebGIS with others such as in-situ mapping supporting archaeology research and site preservation.

ITACA results have their main impact on:

- The organizations directly responsible for keeping, running and maintaining the underwater cultural sites.
- The enterprises (in particular SMEs) that benefit from R&D activities.
- The European Union at large because innovations proposed by the project have been widely diffused through dissemination activities.

ITACA proposed solutions for the protection of underwater and coastal archaeological sites - including monitoring, mapping and managing of underwater and coastal archaeological sites – that have been positively welcomed by specialized actors. The innovative technology and methodology that ITACA project has developed is suitable to be applied to a variety of application domains, not only for the management of underwater and coastal archaeological sites but also for producing relevant positive economic effects on a vaster audience of SMEs acting as prime contractors or sub-contractors in several fields.

A specific aspect of ITACA has been the reinforcement of links between SMEs involved in the development of space activities (not necessarily from the space sector) and other traditional actors in the space sector. Thanks to project activities, SMEs directly involved have been fully integrated into the value added chain in a sustainable way through the provision of their core expertise.

In particular, all the participant SMEs have significantly increased their expertise, offer and positioning in the market:

- PKH by improving their offer through the development of unique management tools for underwater heritage as well as new products like the Risk Index Tool.
- KELL by developing a new service based on innovative use of remote sensing technologies with the potential to be employed in cultural heritage as well as in different markets (e.g. maritime and defence) with a substantial economic impact.
- NAIS by consolidating the market position as system integrator and provider of high value IT products and services with:
    - the development of web-based solutions for the management of Cultural Heritage sites (not only underwater) and their associated threats,
    - the development of a web-based system infrastructure for the management of spatial data and the management of satellite-based products generation work-flow that is easily portable to application domains other than the Cultural Heritage one.
- CODEVINTEC by demonstrating the advantage of using the proposed mapping technologies to a large potential market addressing the not yet explored underwater cultural heritage.
- ALMA by further improving its background expertise in image processing algorithms with a specific application potentially useful in the frame of other markets including defence.
- ANESTI by preparing the Business Plan, improved the transferability of its portfolio of competence also acting on dissemination of project's outcomes.

The high level impact of the project on SMEs is reflected also by the consortium, that is leaded by a Greek SME (PKH) and it is composed by six SMEs (PKH, KELL, ALMA, NAIS, CODEVINTEC, ANESTI), but includes research centres (I.EN.A.E., FFCUL), public bodies (REGIONE SICILIA) and non-profit research organization (GRAS, S4S). Four, up to six, SMEs have been involved in R&D, one in the demonstration only (CODEVINTEC) and one in the market analysis (ANESTI).

Regarding the specific impact on the organizations directly responsible for keeping, running and maintaining the underwater cultural sites, the use of ITACA technologies, tools and methodologies has definitely marked a substantial progress on the use of potentialities of aerial and satellite view.

It is important to remember that the impact of ITACA tools and methodologies could help the dissemination and application of best practices that are highlighted in the UNESCO convention for the protection of Underwater Cultural Heritage. The Convention is a very important step in the history of cultural heritage safeguarding because it represents an essential addition to UNESCO's standard-setting apparatus. According to the Convention, it will be possible to offer legal protection to the historical memory that exists in underwater cultural heritage, thus curtailing the growing illicit trade by looters. But to enforce such activities it is necessary to have available a frequent, precise and low-cost information concerning the underwater archaeological and historical sites.

The Convention, adopted in 2001 by UNESCO's General Conference, aims at ensuring more effective safeguarding of submerged shipwrecks and ruins. The international treaty represents the international community's response to the increased looting and destruction of underwater cultural heritage, which is becoming ever more accessible to treasure hunters. It is important to put in evidence the importance of the UNESCO Convention on the Protection of the Underwater Cultural Heritage and the need, within the framework of its international character, to put it widely into effect by recurring to bilateral or multilateral agreements. ITACA will enforce such activity in the frame of international cooperation strengthening.

To conclude, attempts like the one represented by ITACA project lead to fruitful discussions on the validation/verification of new technologies and pave the way to new applications in the archaeological discipline. ITACA has captivated a new management tool for the recording and monitoring of coastal archaeological sites that although will need to be improved in the near future, has most definitely proved that it can contribute to underwater research.

1.4.2. Dissemination Activities

The Consortium created a communication plan for the project including decisions on what information will be disseminated. Marketing tools like the website are fully operational and well used and other marketing tools like the creation of a logo, banner, poster, leaflets have all been completed. The creation of an initial awareness of the project by potential users has been stimulated and been further developed by Consortium members presenting and attending various workshops and Conferences across Europe to build on the growing approval of the project from stakeholders.

A range of dissemination activities took place throughout the lifetime of the project with the aim to increase awareness and support for building the future exploitation of ITACA outcomes; conduct early market penetration, user awareness and education and first stage contact with potential users; promote the real benefits of the proposed remote sensing and image processing technology to the stakeholders.

Key dissemination tools and activities conducted by the project are described below.

- **Conferences & Workshops.** In order to raise awareness on ITACA's project objectives, the Consortium attended a wide range of conferences and workshops across Europe and beyond. These Conferences were focused on particular areas of interest; appealing to specific target markets, rather than a general audience. This approach enabled the targeted audience to see the functions and benefits of ITACA. Workshops and seminars were even more specialised, and held on a smaller scale. REGIONE SICILIA and I.EN.A.E. were central in developing this approach by working with final end-users, underwater archaeologists and research partners across Europe, to explore the usage of ITACA outcomes into the existing methods. In the context of ITACA, one workshop and one conference were organised. The main objective of the "*End User Workshop on Coastal Archaeological Sites Management*" was the collection and analysis of user's and system's requirements for technologies to be developed during the project and the enhancement of consortium's knowledge on the topic by listening experts and end users of the worldwide marine archaeological community. ITACA's "*International Conference on Underwater Archaeology*" aimed to increase awareness and support for building ITACA Services future, by creating expectation and finding industries and organisations interested in exploiting project's results. The project was presented in 13 Workshops\ Conferences during its lifetime.
- **Published Papers.** The Consortium members promoted the ITACA project through papers, articles, promotional material and publications in specialised journals. The objective has always been to obtain greater visibility among potential user and stakeholder communities. Moreover, attention was paid to the prestige of the selected press channels, preferring the ones considered as sector opinion leaders and specialised in the archaeology fields. The press channels were either a physical journal or an online version. Overall, six papers were published, two are under review and another one is currently being prepared.
- **Press Releases & Editorials.** A key success to project dissemination was to ensure that all relevant audiences would be aware of the product and services. An important part of ITACA Dissemination Plan has been to create and use an eclectic range of official press releases for a selection of different targeted audiences. Certain general guidelines have been agreed by the Consortium in relation to press releases created. The Consortium agreed that any press release, regardless of its publication context, must outline what the system is, what its innovative functionalities and what its benefits are. It supported the idea that press releases should be in English, however translations undertaken into native languages to boost readership in local magazines would also be welcomed and written in time to overlap with related workshops and conferences. Articles, written for magazines aimed at more general audiences, have given a higher level overview of the project and used more open and accessible language, whilst pieces for the more specialised magazines have given much greater level of project detail and depth of facts. In addition, a number of selected magazines and newspapers were contacted to assure that project would have some editorials. Of course, the Consortium is not responsible for what is written in the editorials. Four press releases were communicated and six editorials were published during project's lifetime.
- **Newsletters.** The first ITACA newsletter was distributed in March 2014 and went out either in hard copy or electronic form to over 125 recipients with positive results. General attributes of the ITACA Newsletter included news and upcoming events, as well as contact information for general inquiries and information about project events such as meetings, publications and conferences. In total, seven Newsletters were released.

- **Website.** ITACA website started up in May 2014 and is available at www.itaca-fp7.eu. It is fully functional as a tool to obtain information about the ITACA Project and is an important element in the Dissemination Plan, acting as a first contact communication tool and main information resource. The website was also regularly updated in response to new and developing updates on the project and partner activities. The website also includes some media materials like reportage images and short videos from the ITACA's meetings, workshops and conferences with interviews on the contribution of each partner, general project objectives and achievement, as well as photo-shootings during the demonstration phase.
- **Leaflets.** Leaflets have been developed for conference and for EU distribution. Two leaflets were produced, one for ITACA's "*End User Workshop on Coastal Archaeological Sites Management*" and another one for ITACA's "*International Conference on Underwater Archaeology*".
- **Branded Material.** Various types of branded material was produced in occasion of various events, in which all partners or single partner participated. This material included commercial products: stickers with ITACA's logo, pen, pencils and notebooks available in Workshops and Conferences, t-shirts, kiosks advertising the end product in events relative to the ITACA's objectives. Additionally, a folder for "*International Conference on Underwater Archaeology*" and block notes sheet were also developed.
- **Posters & Banners.** Scientific posters or promotional banners have been prepared in occasion of Conferences/Congresses/Fairs/Business meetings. For dissemination purposes, two roll-up banners and one poster were created.
- **Social Network Tools.** Some social network tools (Twitter and YouTube accounts) were set in order to maximize the dissemination of the project results or to increase the awareness and the notability of the project with reference to potential End Users.
- **Exhibition Booths.** ITACA project was presented in various conferences/exhibitions in a specific booth or at partner's booth. In fact, the project had its own exhibition booth in three events.
- **Project Meetings.** During ITACA's lifetime, several project meetings took place, normally every 3 months. These meetings covered internal review and were open to external contributions. In this respect, user requirement workshop and final conference were useful to disseminate project results outside the internal audience. Eleven project meetings took place along the duration of the project.

1.4.3. Exploitation of Results

It is out of any doubt that ITACA project provide the great opportunity to detect new fields of technological support in order to optimise the activity in fields of research, protection and management of Underwater Cultural Heritage. Although the road to a complete and really optimum use of commercial satellite images in the above mentioned fields is still long, it is clear that we reached to a level of knowledge that allows us to be sure that the potentiality of this methodology is extremely high. This means that it will be absolutely necessary to continue working in this field in order to optimise what has been achieved with ITACA project. ITACA project gave us the possibility to understand that it will be possible in a near future to have a low cost activity of research, protection and management of Underwater Cultural Heritage, but also the possibility to avoid risks for human life using images instead of diving survey.

Generally speaking, ITACA system is functional and can provide reliable results in many cases but, as usually happens in ambitious projects like this one that comprise for the first time different technologies and methods, there is always room for improvement. The current situation of the system could act as a base for the integration of data coming from new sensors and development of new tools. In this way, ITACA services could be extended and broaden their application field. This aim can be accomplished by integrating new capacities to the major components of the system: multispectral and SAR processing chain, shape detection algorithms and web-platform.

SMEs participating in project consortium will try to benefit from the commercialization of the results, together with private consultancy services and support for maintenance of the system for potential market operators. This will be achieved by advertising and promoting project's services (*Location & Monitoring Service*, *Management & Operation Service*) beyond project's duration. In fact, the system could be introduced to other application fields and markets by suitable dissemination actions:

- **Coastline Market.** The Coastline market is including any customer who wants ITACA Services to be carried out over a specific area along the coastline. Demand will be generated primarily by public entities having responsibility over coastline preservation. It may also include governmental organizations, or scientists carrying out research in a specific area. Of great importance, in such group, are the private entities involved in offshore engineering projects whose impact on coastline is expected to be relevant. This commercial area therefore includes civil works companies and companies contracted by natural resources exploitation entities, like offshore wind farms industry and oil industry, to operate as service providers making appraisal of areas meant for underwater pipelines, cables and outfalls. This market is generated by the need to monitor areas indicted for these activities from the very planning stage to later stages that also involve time when works are completed and there is a need of occasional or systematic monitoring campaign. After the structure has been built, in fact there may be an opportunity for ITACA to be used in cost effective monitoring activities to control changes taking place around the structure, e.g. scouring round wind farm bases, or sandbanks shifting to expose pipelines and causing risks to the fishing industry.
- **Ports & Harbour Authorities Market.** Ports and Harbour authorities having responsibility of sea traffic and supervising sea bottom morphology, of areas they are responsible for, do fall into this market segment. Increasingly strict legal requirements to monitor sea floor, both for safe navigation and for environmental reasons, are expected to generate demand. Only the largest ports have their own in-house surveyors, with smaller ports calling in hydrographic surveyors either on a regular basis or as required. The opportunity here is to offer survey services also for detecting dangerous objects that the tide erosion or marine storms may have brought to light in the sea floor along vessels routes approaching or leaving the harbours. Only in Europe there are a total of 3024 commercial shipping ports. In addition to these, there are ports used for other activities, such as fishing and ferries.
- **Scientific Community Market.** Scientific activities may be initiated or supported by organisations such as the IOC (Intergovernmental Oceanographic Commission) or EU as well as at national level. The user system of work follows always a "project by project" basis. Whereas a project, to have scientific sense should follow a typical duration of a few years, financial endowments to UCH entities (in the generality of cases being public entities) follow a "year by year" criteria making long term planning almost impossible. However, demand generated by this market segment is expected to be relevant to ITACA in the years to come, if not for the scientific activities other than UCH, at least for the cultural heritages ones and this for the following

reasons. UNESCO has defined cultural heritage as "the entire corpus of material signs – either artistic or symbolic – handed on by the past to each culture and, therefore, to the whole mankind." Consequently, the cultural heritage sector addresses the identification, conservation and presentation of the elements that form part of the concept: cultural heritage. A large number of international and national associations, agencies, forums and organizations have been established to implement cultural policies as well as manage and promote designated cultural heritage sites.

Furthermore, the activities organised by the project and the outcomes obtained have led to new ideas for research proposals and plans to better integrate existing projects. As a result of this, contacts with potential funding organisations (European, regional and national) is being carried out to provide longer-term funding opportunities. For instance, an EU "Horizon 2020" proposal was submitted in March 2016 by some ITACA members addressing the design and development of a multi-task platform that would integrate satellite remote sensing and ground-based technologies with GIS mapping applications, diagnostic tools and long term monitoring of cultural heritage sites. Finally, ITACA Consortium will continue working on the release of new scientific publications as a continuation of the ones already published.

1.5. Contact Details

1.5.1. Website of ITACA project

Additional information regarding ITACA project as well as official documents can be found in ITACA's website:

http://www.itaca-fp7.eu/

1.5.2. Official Logo of ITACA project

A new logo was developed during the first months of the project and this is the Official ITACA Logo. It is used on both internal and external documents.

1.5.3. Contact Details of ITACA Stakeholders

No.	Beneficiary Name	Country	Point of Contact	Email address
1	PLANETEK HELLAS	Greece	Stelios Bollanos	bollanos@planetek.gr
2	KELL SRL	Italy	Antonio Salvati	asalvati@kell.it
3	NAIS S.r.l	Italy	Antonio Monteleone	antonio.monteleone@nais-solutions.it
4	DHI - GRAS	Denmark	Lars Boye Hansen	lbh@dhi-gras.com
5	I.EN.A.E.	Greece	Christos S. Agourides	ienae@otenet.gr
6	FFCUL	Portugal	Dr. Manuel J. Fonseca	mjfonseca@ciencias.ulisboa.pt
7	ANESTI LIMITED	U.K.	Eutimio Tiliacos	anesti@anesti.co.uk
8	REGIONE SICILIA	Italy	Prof. Sebastiano Tusa	sebtusa@archeosicilia.it
9	ALMA SISTEMI SAS	Italy	Alessio Di Iorio	adi@alma-sistemi.com
10	CODEVINTEC	Italy	Chiara Faccioli	Chiara.Faccioli@Codevintec.it
11	SME4SPACE VZW	Belgium	Dr. Silvia Ciccarelli	info@sme4space.org

2. Use & Dissemination of Foreground

2.1. Section A

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[2] (if available)	Is/Will open access[3] provided to this publication?
1	Exploring the utility of bathymetry maps derived with multispectral satellite observations in the context of underwater archaeology	Lars Boye Hansen	Journal of Archaeological Science	~	~	~	~	~	~	~
2	Improving the Generalized Hough Transform for detecting shapes in complex images	Dr. Manuel J. Fonseca	International Journal of Soft Computing	~	~	~	~	~	~	~

Both scientific papers are currently under evaluation.

[2] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

[3] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
1	*Congress*	*ALMA*	*Second International Conference on Remote Sensing and Geo-information of Environment RSCy2014*	*7 -10 April 2014*	*Paphos, Cyprus*	*Scientific Community Industry*	*Around 100 people*	European
2	*Workshop*	*CODEVINTEC*	*The latest technologies for Marine and Coastal Surveys.*	*9-10 October 2014*	*Rome*	*Scientific Community Industry*	*70*	National
3	*Conference*	*SME4SPACE*	*International Astronautical Conference (IAC) 2014*	*29-30 October 2014*	*Toronto (Canada)*	*Most important annual event worldwide for the scientific and industrial space community*	*Several technical panels. For the panel selected the audience was about 50 people. The conference attracts thousands of people.*	Worldwide
4	*International Symposium*	*ALMA*	*ISRE 36 (International Symposium on Remote Sensing of Environment), www.isrse36.org*	*11 – 15 May 2015*	*Berlin, Germany*	*International Symposium on Remote Sensing of Environment*	*Around 100 people*	European
5	*Conference*	*Regione Sicilia*	*ITACA project at 2015 Golden Trident and Academy Awards*	*25-27 September 2015*	*Palermo (Italy)*	*Event relevant in the archaeology sector*	*Unknown*	National
6	*Conference*	*SME4SPACE*	*International Astronautical Conference*	*12-16 October 2015*	*Jerusalem (Israel)*	*Most important annual event worldwide for*	*Several technical panels. For the panel selected the audience was about 50*	Worldwide

[4] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[5] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

			(IAC) 2015			the scientific and industrial space community	people. The conference attracts thousands of people.	
7	Conference	ALMA	V EARSEL Workshop on Cultural Heritage, Advances in Remote Sensing for Cultural Heritage. ESA/ESRIN,	12-13 November 2015	Frascati (Italy)	Earth Observation and Cultural Heritage	Unknown	European
8	Video (documentary short film)	I.EN.A.E.	The Underwater Archaeological Research in the Pagasetikos Gulf Part I&II	Part I Autumn 2015 Part II Spring 2016	website	General Public	Unknown	Worldwide
9	Conference	I.EN.A.E.	Satellite Remote Sensing Technology in Underwater Archaeology	24 June 2016	Piraeus, Greece	Scientific Community Industry	72	Worldwide
10	Conference dissemination material: folder, programme, abstracts, poster, memory stick	I.EN.A.E.	Satellite Remote Sensing Technology in Underwater Archaeology	24 June 2016	Piraeus, Greece	Scientific Community Industry	72	Worldwide
11	Fair	SME4SPACE	Toulouse Space Show	28-30 June 2016	Toulouse (France)	Space Industry	Several hundreds of people	European
12	Conference	Regione Sicilia	ARCHEOLOGIA SUBACQUEA 2.0 - V Convegno Nazionale di Archeologia Subacquea.	September 2016	Udine, Italy,	Underwater archaeology	Around 100 people	National
13	Conference	SME4SPACE	International Astronautical Conference (IAC) 2016	26-30 September 2016	Guadalajara (Mexico)	Most important annual event worldwide for the scientific and industrial space community	Several technical panels. For the panel selected the audience was about 50 people. The conference attracts thousands of people.	Worldwide
14	Scientific Forum	SME4SPACE	ISSI FORUM "Monitoring coastal zones evolution under various forcing factors using	11-12 October 2016	Bern, Switzerland	Scientific Forum annualy organized by ISSI on different topics connected to	Around 80 people	European

			space-based observing systems". Location: International Space Science Institute (ISSI)			space activities		
15	Congress	ALMA	the Sixth International Congress on Underwater Archaeology (IKUWA6)	28 November – 2 December 2016	Fremantle, Western Australia.	Scientific event on underwater archaeology	Several hundreds of people	Worldwide
16	Workshop	CODEVINTEC	The latest technologies for Marine and Coastal Surveys.	1st half 2017	Rome	Scientific Community Industry	70	National
17	Poster in Exhibition	CODEVINTEC	OMC Offshore Mediterranean Conference	March 2017	Ravenna	Scientific Community Industry	19000	International

2.2. Section B

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[6]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)

[6] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Type of Exploitable Foreground[7]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[8]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge, Commercial exploitation of R&D results	*Functional optical multi-spectral satellite based bathymetry processing chain*		*After the end of the project*	*Bathymetry product offerings*	*Coastal activities, e.g. O&G, infrastructure developments, navigation, underwater archaeology*	*2016 - onwards*		*DHI GRAS (Owner)*
Commercial exploitation of R&D results	*ICT software infrastructure for the development of web platforms and cloud-based services for the management & operation of archaeological sites*	*YES*	*31/12/2017*	*Cloud-based services for the management and documentation of Cultural Heritage sites*	*R91.0.3 - Operation of historical sites and buildings and similar visitor attractions*	*Potential Commercial use in 2018*	*N/A*	*NAIS (owner)*

Multispectral Processing Chain

The further developments of the processing chain in place prior the project will allow us to be more competitive on the commercial market for satellite based bathymetry due to improved capabilities, accuracy and volume of scale. DHI GRAS will seek commercial exploitation of the service chain through direct sales of the data products and by R&D activities (e.g. ESA, H2020 and national funding). DHI GRAS IPR might be made available to partnerships/developments of cooperative services under pre-arranged agreements stipulating the conditions for use and protection of DHI GRAS IPR (e.g. ITACA continuation as an example). The field of satellite based bathymetry is constantly evolving and continuous R&D is needed to improve the offerings and maintain the state-of-the-art position. We expect satellite based bathymetry product offerings to contribute positively to DHI GARS commercial activities and revenue and see good potentials for strong commercial afterlife following ITACA.

[19] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

[8] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

ITACA IT infrastructure and web platform

"ITACA IT infrastructure and web platform" purpose is to provide end-users belonging to the cultural heritage field, such as archaeologists, with a tool directly available on the web, for the management of geo-information related to underwater archaeological sites.

ITACA web platform allows users access to services simply by using a web browser regardless of their location or what device they use (e.g., PC, mobile phone), guaranteeing a device and location independence. It will avoid to install and maintain software applications on each user's computer. Possibility of multiple accesses are the base for the realisation of collaboration and information sharing. This sharing-information process may increase information available for a single site when multiple users access and work on the same data simultaneously.

Foreground might be exploited by beneficiary 3 (NAIS) to develop cloud-based services for the management and documentation of archaeological sites, not limited to coastal areas.

IPR exploitable measure to be taken:

1. Use of the developed "IT software infrastructure and web platform" (foreground) for the provision of services directly sold by the beneficiary 3 (NAIS)
2. Licenses to use the developed "IT software infrastructure and web platform" (foreground) against payment of royalties.

No further research is required concerning "ITACA software infrastructure and web platform", however beneficiary 3 (NAIS) intends to put in place further improvements, eventually required by end-users according to their necessities.

The potential impact of ITACA service web-portal is related to the increased collaboration and sharing of information among stakeholders involved in the management of Cultural Heritage, not limited to the Coastal Archaeological Heritage. This sharing-information process may increase information available for a single site when multiple users access and work on the same data simultaneously.

3. Societal Implications of ITACA project

A	**General Information** *(completed automatically when **Grant Agreement number** is entered.)*	
Grant Agreement Number:		**606805**
Title of Project:		**ITACA – Innovation Technologies and Applications for Coastal Archaeological sites**
Name and Title of Coordinator:		Mr Stelios Bollanos

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***No***
2. Please indicate whether your project involved any of the following issues (tick box) :	***YES***
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	

• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (e.g. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc.)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc.)?	
DUAL USE	
• Research having direct military use	No
• Research having the potential for terrorist abuse	No

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	0	1
Work package leaders	3	20
Experienced researchers (i.e. PhD holders)	6	9
PhD Students	0	2
Other	15	8

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**14**
Of which, indicate the number of men:	10

D	Gender Aspects		
5.	Did you carry out specific Gender Equality Actions under the project?	○ ◉	Yes No

6. Which of the following actions did you carry out and how effective were they?

		Not at all effective … Very effective
❑	Design and implement an equal opportunity policy	○ ○ ○ ○ ○
❑	Set targets to achieve a gender balance in the workforce	○ ○ ○ ○ ○
❑	Organise conferences and workshops on gender	○ ○ ○ ○ ○
☑	Actions to improve work-life balance	○ ○ ◉ ○ ○
○	Other:	

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

◉ No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

◉ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

◉ Yes- please specify: Web-site, newsletters, brochures, posters, short video documentaries, roll-ups, Conference folders with program and abstracts.

○ No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

○ Main discipline[9]: **1.2**

[9] Insert number from list below (Frascati Manual).

○ Associated discipline[9]: **1.1 – 6.1**		○	Associated discipline[9]: **5.4 – 1.4**

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	⦿ ○	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ⦿ No
- ○ Yes- in determining what research should be performed
- ○ Yes - in implementing the research
- ○ Yes, in communicating /disseminating / using the results of the project

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	⦿ ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ⦿ Yes- in framing the research agenda
- ⦿ Yes - in implementing the research agenda
- ⦿ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ⦿ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture		Energy		Human rights	
Audio-visual and Media		Enlargement		Information Society	
Budget		Enterprise		Institutional affairs	
Competition		**Environment**		Internal Market	
Consumers		External Relations		Justice, freedom and security	
Culture		External Trade		Public Health	
Customs		**Fisheries and Maritime Affairs**		**Regional Policy**	
Development Economic and Monetary Affairs		Food Safety		**Research and Innovation**	
Education, Training, Youth		Foreign and Security Policy		**Space**	
Employment and Social Affairs		Fraud		Taxation	
		Humanitarian aid		Transport	

13c If Yes, at which level? ⦿ Local / regional levels ⦿ National level ⦿ European level ⦿ International level	
H Use and dissemination	
14. How many Articles were published/accepted for publication in peer-reviewed journals?	**2 Articles under evaluation**
To how many of these is open access[10] provided?	**1**
How many of these are published in open access journals?	**1**
How many of these are published in open repositories?	
To how many of these is open access not provided?	**1**
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[11]: ……………	
15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	**0**

16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**0**
	Registered design	**0**
	Other	**0**

17. How many spin-off companies were created / are planned as a direct result of the project?	**0**
Indicate the approximate number of additional jobs in these companies:	

[10] Open Access is defined as free of charge access for anyone via Internet.

[11] For instance: classification for security project.

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑	Increase in employment, or	❑	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	☑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:

Indicate figure: 1

Difficult to estimate / not possible to quantify ☑

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes ⦿ No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes ⦿ No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

☑	Press Release	☑	Coverage in specialist press
❑	Media briefing	☑	Coverage in general (non-specialist) press
❑	TV coverage / report	☑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
☑	Brochures /posters / flyers	☑	Website for the general public / internet
☑	DVD /Film /Multimedia	☑	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

☑	Language of the coordinator	☑	English
☑	Other language(s)		

***Question F-10*:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]