NEANIAS
Novel EOSC services for Emerging Atmosphere, Underwater and Space Challenges

Deliverable Report

Deliverable: D2.1 Requirements, Specifications & Software Development Plan for Underwater Services.

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Disclaimer

NEANIAS is a Research and Innovation Action funded by European Union under Horizon 2020 research and innovation programme, via grant agreement No. 863448.

NEANIAS is a project that comprehensively addresses the 'Prototyping New Innovative Services' challenge set out in the 'Roadmap for EOSC' foreseen actions. It drives the co-design, delivery, and integration into EOSC of innovative thematic services, derived from state-of-the-art research assets and practices in three major sectors: underwater research, atmospheric research and space research. In each sector it engages a diverse set of research and business groups, practices, and technologies and will not only address its community-specific needs but will also enable the transition of the respective community to the EOSC concept and Open Science principles. NEANIAS provides its communities with plentiful resource access, collaboration instruments, and interdisciplinary research mechanisms, which will amplify and broaden each community's research and knowledge generation activities. NEANIAS delivers a rich set of services, designed to be flexible and extensible, able to accommodate the needs of communities beyond their original definition and to adapt to neighboring cases, fostering reproducibility and re-usability. NEANIAS identifies promising, cutting-edge business cases across several user communities and lays out several concrete exploitation opportunities.

The European Union (EU) was established in accordance with the Treaty on the European Union (Maastricht). There are currently 28 member states of the European Union. It is based on the European Communities and the member states' cooperation in the fields of Common Foreign and Security Policy and Justice and Home Affairs. The five main institutions of the European Union are the European Parliament, the Council of Ministers, the European Commission, the Court of Justice, and the Court of Auditors (http://europa.eu.int/).

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Abstract

The objective of this first deliverable of the Underwater Sector was to analyze the data and computational requirements collected from the Underwater user communities and related application domains, as a first step to the co-design of innovative services for an interdisciplinary international community of end-users.

After the analysis of the actual needs, the state of the art and various cases-studies from academia (underwater archaeology and marine geology), as well as the energy sector (renewable energy, oil and gas sector), a number of 14 requirements (R1-14) were defined by the service consumers. These were handed over and discussed with the core services providers. After evaluation and classification of the required functionalities, the core service providers set the service specifications in order to identify the EOSC hub service modules to support the development of the Underwater specific services U1, U2 and U3 and proceed to the first release of NEANIAS EOSC underwater services, that will be further evaluated and assessed internally and externally.

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1. Introduction

1.1. Context

In the framework of WP2, NEANIAS will deliver cloud-based services that target specific challenges of the underwater thematic sector. WP2 embrace co-design under an Agile methodology that spans all project activities, where service consumers and providers are engaged in a cycle of requirements, design, implementation/ verification, evaluation, feedback. WP2 activities are amplified by engagement and onboarding activities, ensuring the potential of sustainability from the perspective of adoption and uptake. In particular, bringing together experts and know-how from Open Science, EOSC and Research Infrastructures NEANIAS seeks not only to satisfy the needs of the underwater sector communities boarding the cloud era but also to identify and elevate opportunities that exploit the plentiful resources (data, CPU, storage, services) at reach, weaving innovative value chains and innovative ways to conduct e-science.

In such a context, the first Task of WP2 *i.e., '*T2.1 Underwater research sector user requirements, service co-design and gap analysis' has analyzed information, data and requirements collected from the Underwater-related application domains and user communities forming the first deliverable of WP2: 'D2.1 Underwater Research Services Report on requirements, Specifications & Software development Plan'.

1.2. Contents and Rationale

The scope of Deliverable D2.1 is to document the preliminary efforts undertaken within the context of T2.1 and in particular it contains requirements, specifications and software development plan for the Underwater Research Services.

In particular, to properly collect requirements, the underwater end-user communities, involved datasets and products and the current status of employed software and services are presented. A mapping of requirements to technical specifications has been performed and finally an adequate software development plan has been prepared.

1.3. Structure of the document

The document in structured in **5 main sections**.

After **Section 1** where the main objectives, rationale and structure of the deliverable are introduced, in **Section 2, *firstly***, we have identified the underwater end-user communities, by briefly describing their main needs and requirements as far as seafloor exploration and bathymetry is concerned (2.1). In a ***second step***, we proceeded in describing the User Requirements for the Underwater Services divided in the three main categories of the Underwater End-user Communities:

- firstly, from the point of view of the **underwater archaeology community** (2.1.1);
- secondly from the community of the **marine environmental scientists** and **marine geologists** (2.1.2)

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- and finally the **industrial energy sector**, representing the needs of enterprises in the domain of renewable energy, as well as oil and gas industries (2.1.3) and the robotics and computer vision domain (2.1.4). Issues of insurance and risk assessment were also assessed (2.1.5).

Each end-user community is describing current practices in their domain, as well as the requirements from underwater surveys and documentation tools for various scientific, economical and industrial objectives. Primarily, this is done in the sub-section 2.2.1 by the analysis of specific case-studies and the services used until now (Data and Products). Case-studies have been selected in order to reflect a variety of specifications needed to be taken into account when designing and implementing software development plan of NEANIAS underwater services. Their added value is that they correspond to actual recent interdisciplinary research and energy projects, that have already been accomplished in the Mediterranean and around the world. Most of the related databases are already available. However, at the end of each presentation of needs and requirements new databases provided by the NEANIAS partners are also proposed by the three main user-communities participating to the NEANIAS project: the underwater archaeologist, marine geologists and renewable energy companies. These new databases that have been produced by the partners are intended to be first tested in the NEANIAS services in order to evaluate and assess their performance.

In a ***third step*** (2.3), all communities are stating the state of art of services and software currently used that are relevant to the NEANIAS novel proposed services and in which level these could be improved for producing more precise results, achieving speed and/or efficiency in the underwater sector. Taking all the above into account, Section 2 is concluding by stating the main requirements for the novel EOSC NEANIAS underwater services summarized in 14 points (R1 to R14), formed as user stories. These requirements were then linked with a level of priority and value based on end-user recommendations.

Section 3 is focusing on the Co-design and Services specifications. Each requirement has been ranked and linked to Underwater services that is corresponding, while a specific description of the required functionalities and software specifications has been proposed.

Section 4 is dedicated on the Software development plan focused on the three services

- U1 "**Bathymetry mapping from acoustic data service implementation**",
- U2 "**Seafloor mosaicking from optical data service implementation**" and
- U3 "**Seabed classification from multispectral, multibeam data service implementation**".

For each service, a number of steps has been specified, mainly the software development effort, the pipeline processing, the user interface, the software dependencies and required libraries, and the task allocations for the software development, leading to the next step in the NEANIAS Project.

The document is concluding with the first Evaluation and the Future Steps to be followed (**Section 5**).

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2. User Requirements for the Underwater Services

2.1. Underwater End-user Communities

Knowing the depth, shape and type of the seafloor (bathymetry) is fundamental for understanding ocean circulation, tides, tsunami forecasting, fishing resources, sediment transport, bottom currents, environmental change, underwater geohazards, submerged remains of underwater cultural heritage, such as shipwrecks, artefacts and sunken cities, topography of archaeological sites, cable and pipeline routing, mineral extraction, oil and gas exploration and development, infrastructure construction and maintenance and much more.

Underwater Community	Brief Description
Archaeologists	Reconnaissance, optical documentation of underwater sites, mapping of sea-floor topography of archaeological sites, monitoring for protection (natural and anthropogenic hazards) and management, measure objects and artefacts on the site, geo-location of shipwrecks
Geologists/Biologists/Oceanographers/Environmental Scientists	Submarine geohazards, habitat mapping, marine ecosystems, marine geomorphology, seabed classification/geological maps, offshore structural geology & tectonics interpretations;
Oil & gas engineers	Pipeline planning (geomorphology), habitat mapping & marine ecosystems interactions, structural geology/tectonics (fault detection, risk assessment)
Renewable energy planners	Seabed/soil/ground classification, risk assessment (faults, geohazard potential)
Robotics	Mosaicking and 3D reconstruction of the surveyed area, global alignment of on-board navigation with image registration for improved navigation, path planning
Civil engineering	Potential of submarine geohazards, seabed classification with respect to underwater constructions.
Computer vision/ machine learning software engineers	Mosaicking and/or 3D reconstruction of the scene seen by a moving camera, mapping, annotation and/or detection and classification of underwater elements
Insurance	Risk assessment, subaquatic geohazard potential

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2.1.1. Archaeologists

More than estimated (and still triggering human imagination), a large part of our cultural heritage, is today submerged, consisting namely of ancient submerged cities, coastal areas and shipwrecks of all centuries. The 2001 UNESCO Convention on the Protection of underwater cultural heritage (UCH) promotes *in situ* conservation as the first option (https://unesdoc.unesco.org/ark:/48223/pf0000126065). Therefore, digital surveying, mapping and 3D modelling are key tools for documenting, visualizing, monitoring and assessing the preservation state of the UCH. They are also essential for raising public awareness and promoting the diffusion of information between the different scientific communities, as well as the public (Menna et al. 2018).

As a result, the archaeological community will use the three services proposed by NEANIAS:

- ***Sea-floor mosaicking (3D photogrammetry)***
- ***Seabed classification and Bathymetry***
- ***Applied interdisciplinary methodologies***

in order to better process interdisciplinary databases from 3D digital surveying and modelling techniques, with the following main objectives:

- 1. Reconnaissance. Identifying archaeological sites, such as shipwrecks, submerged cities, artefacts, etc.

- 2. Documentation. Detailed archaeological documentation recording of underwater cultural heritage (UCH) as a means for accumulated knowledge. Especially in the case of underwater or coastal excavation, the process of excavating is irreversibly destructive. Therefore, detailed documentation of every step is the essential requirement of any serious and thorough systematic scientific work.

- 3. Enhanced interpretation and analysis

- 4. Monitoring for protection and management

4a. during archaeological excavation (documenting different phases of the excavation process)

4b. in case of imminent or long-term natural or anthropogenic threat

4c. for developing preservation strategies and management policies for protection.

- 5. Dissemination for the wider public. This type of 3D documentation is used for sharing the results and facilitating dissemination strategies, such as 3D modelling, directly used in application of virtual and augmented reality, serious games etc. targeting public of all ages.

Sea-floor mosaicking (3D photogrammetry)

3D photogrammetric plans are part of the graphic representations of sites (under survey or excavation), among architectural plans and drawings, aerial (drone) and underwater photographs.

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3D photogrammetric documentation provides a benefit to the archaeological scientific community:

a- It offers a 3D representation of the site, difficult to easily comprehend in the underwater environment (Drap 2012).

b- It offers unlimited possibilities to test different hypotheses via hypothetical reconstructions (of submerged cities, harbors, ships) and modelling that should be driven by expert archaeological knowledge.

c- Facilitates dissemination strategies for the wider public (including non-divers) enabling a comprehensive view of how the ancient world may have looked like, thus raising public awareness and active engagement. Moreover, digital products are the base for Virtual and Augmented reality applications, etc. Often they are used to produce virtual tours of the modeled areas for the public, especially the non-divers, so that they gain an appreciation of the underwater cultural heritage.

Parameters of Underwater photogrammetry

Methodologically, the objective of underwater photogrammetry is to obtain a 3D geometrical modelling product from the oriented photos of the recorded sites and/or artifacts.

Underwater photogrammetry presents a series of parameters to be taken into account, in order to achieve high level of accuracy, such as the refraction of the diopter water glass and constraints of the underwater medium (turbidity of water, presence of suspended particles, etc.). Methodologically, these specific constraints force the operators to work on large scales, close to the objects (between 0.5 and 2 to 3 meters, depending on the water quality). Moreover, the photographs have to be taken with an important overlap. The key factor of this method is redundancy: each point of measured space must be seen in at least three photographs. The calibration of the cameras and their housing is also essential.

In recent years, a series of shipwrecks, amphorae cargos, underwater sites and submerged UCH monuments have been documented by advancing experimental techniques, as well as the available software to underwater community (Seinturier et al. 2004; Murai et al. 1988; Drap 2012; Drap 2012b; McCarthy-Benjamin 2014; McCathy et al. 2018; Diamanti-Vlachaki 2015; Zhukovsky et al. 2013). In some cases, archaeological remains were half-submerged, a condition that required a special treatment of the submerged and the emerged part in the photogrammetric documentation (Menna et al. 2015).

For selected case-studies in underwater archaeological research and the specific requirements underwater archaeologists are expecting from software development, see 2.2.1.

Seabed classification and Bathymetry

Archaeologists are using marine geoscience technologies and tools for the location, mapping and interpretation of submerged and coastal sites. In all cases, archaeologists are end-users of the geo-scientifc marine prospections (geological, oceanographic, biological, and

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environmental) (for the state of art and application in archaeological 3D recording and mapping - see Menna et al 2018).

- Objectives:

a. - Palaeoshoreline reconstruction- coastal palaeoenvironmental study - sea-bed topography

Landscape reconstruction, reconstruction of the relative sea-level change for different periods of times, coastline reconstruction: These are essential steps for the analysis and interpretation of submerged maritime landscapes and the study of underwater topography of submerged sites. Geological and anthropogenic factors have altered drastically past landscapes, that cannot be comprehended, if their extend and physical development is not clarified by geomorphological reconstruction (Baily et al. 2007; Bailly 2009; Flemming et al. 2014; Mahon et al. 2011; Henderson et al. 2013; Missiaen et al. 2017; Nikolakopoulos et al. 2019). Moreover, knowledge of underwater topography is essential for the understanding of the organization and distribution of archaeological sites along and in water bodies (Doneus et al. 2015).

b. - Location of targets of archaeological interest

Although the focus has been mostly on shipwrecks, targets also include submerged structures, harbor and city installations, and scattered artifacts (canons, anchors, ritual vessels etc), among others.

-Applied interdisciplinary methodologies

Multibeam and side-scan sonar surveys, Sub-bottom profiling and seabed classification

For the **location of shipwrecks**, multibeam surveys performed in a large scale are primarily used. Side-scan sonar surveys remains a cost-effective solution for mapping seabed topography in low resolution, with no precise texture rendering, covering extended sea zones. It represents the best solution for the location of shipwrecks and the mapping of large sea-floor areas. Multibeam surveys are also used for the general documentation of big shipwrecks lying in great depths, where photogrammetric techniques are too costly to be applied (Barto Arnold 1981; Penrose et al. 2005; Papatheodorou et al. 2005, 2014; 2017; Gron et al. 2015; Yamafune et al. 2017; Zhu et al. 2019; Ferentinos et al. 2020).

A sub-bottom profiler acoustic survey provides supplementary complementary data on seabed composition for contextualizing remote sensing results (Papatheodorou et al. 2005). Recent surveys have demonstrated the utility of sub-bottom profiles in distinguishing shipwreck-sized geological outcrops from potential shipwrecks (Sakellariou et al. 2007; Fakiris et al. 2016; Ferentinos et al. 2020). They also offer sections of the shipwrecks, if these are substantially covered by the sediments. Magnetometer surveys complement the aforementioned methods being efficient for the buried extension of a shipwreck (Mazotos, 4th c. BC, Cyprus- Demesticha et al. 2014) or the identification of different construction materials in the Roman harbor of Caesaria Maritima in Israel.

For the **paleoshoreline reconstruction**, a network of **sub-bottom profile lines vertical** to the shoreline is designed and performed. The results can reveal the presences of successive rocky palaeoshorelines or other features useful for the overall coastal reconstruction during the centuries (Papatheodorou et al. 2008, 2018; Geraga et al. 2015). These methods and techniques have been used effectively for the research of the prehistoric European continental self and elsewhere in the world, in order to reconstruct prehistoric landscapes and human distribution (Bailey et al. 2020; Missiaen et al. 2017; Bailey et al. 2007; Bailey 2009; Flemming et al. 2014). This research has been advanced in the framework of European projects, such as **SPLASH-COS** 2010-2013 (SUBMERGED PREHISTORIC ARCHAEOLOGY AND LANDSCAPES OF THE CONTINENTAL SHELF – COST – European Cooperation in Science and Technology), while innovative survey techniques have been addressed at **SASMAP** 2013-2016 (DEVELOPMENT OF TOOLS AND TECHNIQUES TO SURVEY, ASSESS, STABILISE, MONITOR AND PRESERVE UNDERWATER ARCHAEOLOGICAL SITES).

Finally, **airborne and underwater laser scanning systems** operating with green laser beams have also used effectively in archaeological sites (Doneus et al. 2015). Bathymetric Lidar sensors can give information on bathymetry but also on topography. They can be used for the documentation of large archaeological zones offering detailed archaeological mapping and reconnaissance.

Recently, efforts have been done at combining methodologies, essentially to integrate underwater data captured by acoustic and optical systems, i.e. to combine acoustic data and photomosaics, as was attempted in a Roman Mediterranean wreck at 800m deep (Singh et al. 2000).

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Aigina Harbour-city Project. Mission 2019. Aerial and underwater 3D photogrammetry, Total Station measurements of the ancient naval city of the 5th c. BC. A dataset to be used experimentally in the Neanias project.@ Hellenic Ministry of Culture, EUA/ Aix-Marseille Université - CCJ. Aerial Photogrammetry drone @L. Fadin, EFA 2019. Unpublished report 2019.

2.1.2. Marine Environmental Sciences and Submarine Geohazards

Despite many years of effort, less than 20 per cent of the world ocean's seafloor has been mapped. Modern **MultiBeam EchoSounders (MBES)** enable for high-resolution seabed mapping even in deep sea. Besides bathymetry (depth measurements), a seabed backscatter is retrievable which can be utilized for a remote guess in seabed classification. Accomplished by ground truth (geological and biological sampling) a bathymetric GIS analysis focusing on geomorphology, structural geology and tectonics enables a researcher to produce thematic maps. These are the basis of interpretations of marine habitats, sedimentary processes like erosion or deposition e.g. contourite deposits formed by deep water bottom currents, slope stability and pronounces submarine geohazard areas that could cause tsunami events, mass transport deposits, plate tectonic interpretations and many more.

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The knowledge of seafloor topography is crucial for the understanding of the ocean and natural processes, especially for coastal and marine spatial planning and sustainable development. Marine geohazards pose unknown risk to the nearby communities and offshore infrastructures. The major geohazards include, but are not limited to, coastal erosion, submarine landslides, earthquakes and co-seismic displacement triggering tsunamis, underwater volcanism and hydrothermal fields, gas chimneys etc. One of first steps for the geohazard assessment is to "map" these hazards and then perform detailed morphological and quantitative analyses i.e. volume calculations, usage of sophisticated algorithms to identify seabed patterns and features like depressions, gullies morphological discontinuities and possible differences through time etc. The integration of the aforementioned analyses with other kind of data such as side-scan mosaic, sediment cores and seismic data can lead to a holistic approach to risk assessment, habitat and geological mapping.

The usage of MBES revolutionized the marine surveys with respect to the quality, amount, precision of data and the ship time needed. Geohazard studies aim to identify the geological features underlying potential risk, and the objective of each study dictates the equipment used, the survey design and the acquisition parameters. In general, the usage of the MBES provides two kinds of data:

a) the bathymetric data from which delivers depth information and
b) the backscatter-intensity of the reflected signal that gives an insight of the sediment type.

Nonetheless, the processing of the data should follow a specific pipeline in order to secure the best quality of the end-products, which are the Digital Terrain Model (DTM) and the backscatter mosaic. Both are utilized for derivate or to be integrated with other datasets to quantify/model the risk.

While post-processing the data, there are many challenges to overcome, not only to meet the requirements of the International Hydrographic Organization (IHO) in case of the hydrographers use for nautical charts and navigation, but also to create a reliable end product for engineers and researchers who further analyze depending on each one's needs. This approach is focused to the latter.

Firstly, we have to verify that the software can handle and parse correctly all the information needed from data acquired through different MBES and acquisition software, since almost each vendor has developed its own, mostly binary format. This is one of the main challenges to tackle because often we need to produce a final product derived from different datasets, thus different raw file formats, at least to produce a common bathymetric grid (DTM).

One of the parameters, during the acquisition, that introduces the most significant errors in the horizontal and vertical plane is the sound speed through the water column. When processing the data it is mandatory to apply sound speed profiles obtained from different

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sensors. Besides that, a correction of the given attitude sensor offsets for e.g. roll, pitch, heave or heading might be as necessary as the correction for tide or draft.

In case of AUV/ROV recorded datasets even a correction of the georeferenced beams is commonly needed. This happens through manipulation or replacement of the navigation information. An accurate timestamp given to the data during acquisition (transmit and receive time) is a must-have to apply all the mentioned above. This is only granted by GPS or time-server synchronization.

During the editing of the data, it is important to have a variety of filters to choose since e.g. when processing data acquired from a volcanic field where topographic changes are pronounced, a slope filter would lead to undesired results. Depth filter might powerfully speed up editing while time and/or angular varying gain filters might help improving the backscatter results. Basic statistics like the standard deviation and data density for every grid cell given are essential to estimate a level of confidence.

Finally, since the DTM is needed for further geomorphological and quantitative analyses, an export to open and sustainable formats like GeoTIFF, ASCII, netCDF etc. is mandatory. One of the most widely used file formats is the Bathymetric Attributed Grid (BAG), that is designed to store and exchange bathymetric data combined with all the metadata. It has been stated that MB-System is currently not able to export BAG nor calculate/create TPU (Total Propagated Uncertainties) values. Nevertheless, both are important features for Hydrographers but not necessarily for marine research or underwater engineering.

2.1.3. Oil & Gas engineers, Renewable Energy Planners

Offshore developments, under no doubt, require high levels of reliability, flexibility, experience and project management. Most of the times, such projects require customized solutions with respect to the designing and planning phases, the pipe manufacturing and its accompanying infrastructures.

Oil and gas submarines pipelines as well as submarine transmission lines related to renewable energy require several surveys regarding the EU liabilities. Some of the studies required to be submitted are the following:

- System Screening & Optimization Study
- Overall System Hydraulics
- Onshore Route Feasibility
- Offshore Route Feasibility
- Consultation with Authorities, to identify constraints for landfalls, offshore and onshore pipeline
- Preliminary Environmental Impact Assessment Studies
- Preliminary Safety Study
- Cost and Schedule Estimating

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- Compressor Stations and Pipelines design
- Reporting & Presentation of the Studies

In the abovementioned studies, all three proposed services developed and provided by NEANIAS can be used in order to maximize the designing, planning, development and licensing processes. Marine surveys have been carried out by developers in order to improve the accuracy of the pipeline route. The equipment required for those surveys, which were separated to offshore sector, nearshore sector and on shore sector as well as to submarine lines, are included in the following[1]:

For the offshore sector:

- Multi-purpose offshore survey vessel for deployment of conventional survey equipment and AUV (Autonomous Underwater Vehicle),
- Deep water AUV with pipeline route survey payload,
- Surface and underwater positioning systems,
- Precision echo sounder,
- Multi-beam echo sounder(s): shallow and deep-water depth rated,
- Sub-bottom profilers (shallow and medium penetration),
- 2DHR seismic system,
- Piston gravity corer,
- Cone penetrometer,
- Box corer
- Vibrocorer

For the nearshore sector:

- Survey launch,
- Survey positioning system,
- Self-elevating platform,
- Multi-beam echo sounder,
- Sub-bottom profilers (shallow and medium penetration),
- Seismic refraction spread,
- Vibrocorer,
- Borehole capability

For the onshore sector (nearshore and landfall):

- Survey control,
- Topographic survey,
- Sub-surface profiling systems (resistivity and/or refraction),
- Geotechnical (borehole) drilling,

For the submarine pipelines (data required to proceed with the designing and route planning phase:

- Environmental baseline survey,
- Utility crossing survey,
- Possible data gathering in connection with archaeological sites,

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- Environmental assessment and any other feature or activity that could potentially affect the proposed pipeline,
- Advanced geohazard investigations and related laboratory testing,
- Meteocean data acquisition,
- Hydrogeology

With respect to the efforts and practices associated with the surveys, these should include topographic/bathymetric, hydrographic, high-resolution geophysical, seismic (2DHR) and geotechnical data. These data are considered crucial for the establishment of the existing topography and the seabed bathymetric surface (DTM), the determination of the sub-surface stratigraphy and shallow geology and the identification of potential hazards. In terms of sub-surface and shallow geology data, these are commonly processed through high-resolution geophysical datasets, correlated with geotechnical sampling and in-situ testing. Potential hazards referring to geological features and geotechnical phenomena, consist of various information regarding the installation and the operation of the pipeline through the projects life and thus are needed for the geohazards risk assessment of the project.

Datasets provided and analyzed by the NEANIAS novel EOSC services related to AIGAIO

With the view to developing the deliverables of NEANIAS while finalizing the desktop study of the AIGAIO project, with total wind energy capacity of 582 MW on remote and uninhabited islets of the Aegean Sea, the Cyclades and the Dodecanese complex, EUNICE as an underwater end-user in the context of NEANIAS, aims to be provided with all the essential elements for the sufficient knowledge of the seafloor geomorphology and topography, which is necessary for the cable route survey and the reassurance of the cable route security as well as for the ports' design study. Since the AIGAIO Project refers to the installation of 138 wind turbines on scattered, remote, uninhabited and non-interconnected islands, major milestone of the project is the interconnection of the already licensed RES projects on these islands through the construction of a submarine DC transmission link. The main link will be the HVDC link connecting the island of Levitha, where the main power substation of the project shall be located, with the metropolitan area of Athens, and more specifically with the Ultra High Voltage Center (400kV) of Lavrion, which will be the exact connection point. Access to accurate information and precise analysis for the seafloor and geomorphology of the Aegean Sea is crucial for the design, selection and installation of the submarine cabling and thus, for the planning of the total cost of the interconnections located in the greater area of the Aegean Sea.

Eunice, as an underwater end-user within the context of NEANIAS, aims to ultimately exploit all the essential elements for the sufficient knowledge of the seafloor geomorphology and topography provided through the developed novel EOSC services, the former of which, are necessary for the cable route survey and the reassurance of the cable route security as well as for the ports' design study. In the same time the data provided by the fieldwork regarding certain aspects during the implementation of the project will be used in order to test, enhance and improve the NEANIAS proposed EOSC services.

Marine geological surveys and provided data

The landing sites of the cables and the route of the total submarine cabling will be designed according to the sea – floor mosaicking and the geomorphology of the seafloor. A desktop

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study has already been developed, but more data regarding the seafloor mosaicking are critical for the design of the submarine cabling route, which is in need of finalization and conclusively for the study to be appropriately updated. When choosing a landing site for the transmission cable, the following characteristics are taken into consideration:

- Rocky landing site with pockets of gravel.
- The landing site is partially sheltered from wave action, remaining vulnerable to waves from the west.
- The lines of the National seashore part of the beach and the consecutive beach corridor (shoreline and coastline) have been defined according to the law.

In cable route surveys, bathymetric contours and slope gradient, which are the primary terrain attributes, are extracted from DTMs, the latter of which constituting a basic requirement for the cable route designing. A more advanced seabed analysis is performed after the completion of geophysical data collection using single and multi-beam echo sounders (SBES & MBES), side scan sonars (SSS), sediment sub-bottom profilers (SBP), seabed geotechnical and sedimentological samplings. Moreover, a detailed seabed terrain analysis and bathymetric features may then be presented in geological and geomorphological maps.

Bathymetry constitutes the main source of information on the morphology of the seafloor, which is important for the final designing of the cable route. The required data interpretation starts with the classification of the bathymetric features into flat, sloping terrain, crests, depressions and breaks of slope. Bathymetric features like ridges, depressions and channels need also to be identified directly from the bathymetry.

At this point, It should be pointed out that all data will be used in order to create thematic maps (QGIS, AutoCAD) containing information on the sailing line (navigational channel), buoys, marinas, and lock and dam structures as well as underwater hazards such as pipelines and cables. These maps will be used to redefine and therefore finalize the route design of the submarine transmission cable. Data in raster and shapefile format will be used as input files in QGIS through which they will be checked for locational and bathymetric accuracy.

MBES backscatter providing data regarding the seabed composition, will also contribute to the designing process of the cabling route. Those data, can be utilized for the seabed mapping, indicating the variability of seabed composition including sediment types, seabed features (natural and manmade), rock outcrops, etc., all based on the variations of physical impedance of the acoustic signal during the inspection of the seabed. Those data will be critical for the survey of submarine cable systems in shallow water and burial areas. Moreover, the location of wrecks and archaeological is essential to be known and taken into consideration during, when defining the submarine cable route, so that not passing through those areas is ensured.

As already mentioned, the data sets generated by the MBES will be analyzed and imported in QGIS to generate a geospatial representation of the information that will be collected.

Multiple data types will be obtained including sidescan sonar or MBES backscatter imagery, bathymetric data, sub-bottom and magnetic intensity data. The seafloor mosaicking will be used as a base map in QGIS software where it served to ground-truth and provide a visual representation of the true location of features. Furthermore, existing cable features will be revealed. These cables cannot be completely identified through the visualization as the cables are buried beneath the sediment in many instances. Nevertheless, in the locations where the cable itself is not visible in the generated imagery, the disruption of sediment associated with

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the cable routes reveals the approximate cable location. In linear surveys, as in the case of the submarine transmission cable, these data will be able to provide the exact location, detailed images and surrounding seabed to burial depths. Hence, the burial depths of the cable can be accurately defined through these data.

Furthermore, hazards such as tsunamis, fault zones and volcanoes need to be taken into consideration in the designing process of the submarine cable route. Obviously, all the above-mentioned data will be also processed through AutoCAD after the implementation of the required data manipulation and transformation. The main requirements of the underwater cable legislation and standards (ELOT) are outlined below.

Regarding the available planning tools, these include, but are not limited to, QGIS, Autocad and Google Earth.

Required data for the optimal cable and pipelines design

Furthermore, in the context of a preliminary approach concerning optimal cable and pipelines design, the following data are required:

- Location of existing and planned cables and repeaters
- Location of existing and planned pipelines
- Record of relevant cable failures' causes
- Maritime boundary delimitations
- Military exercise areas
- Dumping grounds
- Marine park boundaries
- Geoscience inputs (metocean, tectonics, volcanism)
- Bathymetric data
- Sonar imagery data
- Sub surface data
- Seabed surface features

Key uses of the data provided by the Neanias' project services, where designing the route of a transmission line takes place, are the following:

- Identify an area where the cable can be installed
- Develop a baseline of the environmental conditions
- Design a final cable route
- Specify the cable protection requirements
- Identify particular hazards along the cable route
- Identify the installation methods that can be used
- Predict performance of cable burial tools
- Contribute to modelling potential sediment transport at site
- Predict long-term changes to the seabed, such as moving sandwaves, that might need to be monitored.

Moreover, information regarding qualitative early landing site evaluation and qualitative identification of some hazards is also necessary. Finally, in the phase of the selection of the

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appropriate submarine cable installation method and vessel in order to proceed with the cable laying operation, the basic requirements are the following:

- the water depth
- the distance between sea level and the overboard chute at the CLV (Cable Laying Vessel)
- the bottom tension at the TDP (touch down point)
- the cable's weight in water and the cable's weight in air

Furthermore, regarding the feasibility study, it has to be mentioned that it will be dominated by geophysical methods which characterize the seabed, the seabed mobility and the shallow geology that describe the promoted location for cable routing. In order to proceed with this feasibility study, data referring to bathymetry, side-scan sonar survey, echo sounder survey, acoustic sub-bottom profile and magnetometer survey were used. It has to be highlighted that, geotechnical methods are normally limited to drop cores and grab samples.

In general, the cable routing survey normally includes environmental, geotechnical and geophysical data and testing such as, high resolution bathymetry, side-scan sonar, sub-bottom profiling, cone penetration testing, vibrocore and grab sampling. Also, through the development process of the pre-installation engineering of the cable/pipe, the project developer must provide the installer with data regarding specific conditions of the project, such as the seabed conditions and the depths in order to define the burial depths, the preferred approach and the specific tools and equipment in order to proceed with the laying of the cable. It is certain that, the amount and the quality of the seabed information, is crucial for the success of the cable installation. Moreover, these data will contribute to the risk analysis of the entire cable routing. MBES data are needed to proceed with the pre-ley surveys of the cable routing.

NEANIAS services can be utilized also in the phase of as-laid survey and the phase of as-built/verification survey. In the as-laid survey, some common practices in order to verify the cable's condition are, the acoustic inspection using towed sensor or a swath bathymetry system, acoustic inspection using 3D imaging sonar and inspection of the cable over the seabed. In as-built/verification survey phase, the cable has already been laid and buried. In this survey, the positioning and the burial depth of the cable consist the basic elements examined. In order to proceed with this survey, the methods that are usually applied are, the acoustic inspection of the sub-bottom profile, sub-bottom imaging and MBES surveys.

Finally, the risk management framework is a phase required in order to proceed with the development of a submarine cable/pipe. The risk assessment, according to INTERNATIONAL STANDARD ISO/FDIS 31000 ISO, is the overall process of risk identification, risk analysis and risk evaluation. Within the cable burial risk assessment, all data related to hazards, geotechnical data, geophysical data, geological data and bathymetry, are needed.

2.1.4. Robotics & Computer Vision

With cameras being one of the cheapest and more commonly mounted sensors in underwater vehicles, the use of computer vision techniques for processing the large amounts of optical

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data has been used from the early beginnings of underwater robotics. The vehicles, either remotely operated (ROVs) or autonomous (AUVs), normally gather images during the course of the underwater mission. However, the field of view of a single image is quite limited. In fact, due to the rapid attenuation of light in the media, normally the images should be taken very close to the surveyed scene in order to have decent visibility. Therefore, in order to have a general view of the surveyed area after the mission, the collected images must be composed into an overall representation that allows extracting a global view of the area, which is a process called optical mapping. Depending on the type of output map required, we find photomosaicking techniques, which result in a 2D image of the area, or 3D mosaicking/reconstruction methods, whose result is a textured triangle mesh.

Under ideal conditions, both techniques can work with images alone to provide the desired map. However, maps extracted from images alone present some limitations. On the one hand, in case of using a monocular camera, the maps are affected by an unknown scale factor. That is, the map is not metric, and while it can be used to capture the shape and structure of the surveyed site, it cannot be used to make measurements on it. On the other hand, due to the lack of a global frame, the map is not geo-referenced, which makes it difficult to compare with other maps available of the area.

Fortunately, robotic platforms are usually equipped with navigation sensors, providing hints on where the robot was at a given moment in time during the mission. This navigation information can be mixed in the optical mosaicking process in order to:

(1) Ease the mosaicking process: as it provides hints for which images should be matched together for composing the map.

(2) Improves the navigation of the vehicle: the motion computed from images is normally more accurate when close to the seafloor than the commonly used acoustic solutions for navigation (Doppler Velocity Log, Ultra Short Base Line, etc.). By mixing the image registration process with the navigation readings within a global alignment procedure (non-linear minimization of all measurements), the navigation itself is effectively improved.

(3) Provide metric and/or georeferenced maps: the metric scale of the navigation is used to infer the missing metric scale of the image-based measurements. If the navigation readings are also geo-referenced, the resulting map will also be in that global frame.

The resulting 2D or 3D maps can then be used to plan new missions (path planning), but also as a base for further inference on the data, such as detecting and segmenting instances of objects or flora/fauna of interest present in the images. In this direction, the global map can be used to manually annotate the instances of the entities a given end-user may be interested in finding. This data can then be used to train a machine learning pipeline so that the marked entities can be automatically detected in maps from different missions.

2.1.5. Insurance

With respect to the insurance scheme of a wind park project, and in this case the AIGAIO Project that will be used as the main case-study in the framework of the NEANIAS project, the insurance covers all phases of wind farm construction and operation and it can be separated into two periods: the project insurance during the construction period and the project insurance during the operation period. It is worth noting that, there is no standard insurance

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policy for a wind farm meaning that especially for the Aegean project, which is a completely novel project, the insurance policy will be a tailored mixture of many different policies to meet the project's unique requirements.

The project insurance scheme during the construction period applies to the wind turbines' equipment being installed on site location, the employer's civil liability of the project owner and the General and Professional Liability. In more detail, regarding the wind turbines, the insurance has to do with the transit physical damage coverage, effective when the transportation of the components to the installation site initiates and the time delay exposure coverage, which insures against the lost power production revenues due to Transit Delay or Construction delays. The elements that are requested in order to proceed with that insurance program are: the supply contracts; delivery, approval and commissioning schedules; the location of loading and unloading of the project's components; the specific cost and type of wind turbines that will be installed and also the expected energy production of the specific wind park, along with the current selling price of energy. Liability insurance covers the responsibility of the project owner and the subcontractors working on the construction of the project. In order to proceed with this type of insurance the elements requested are the analytical schedule for construction of the entire project, information about subcontractors and subcontractors for each subject, contract amount of each contractor/subcontractor and the Health and Safety Plan. Finally, regarding the employer's civil liability, in order to proceed with the activation of it, the requested details refer to the notification of the number of employees of the project owner working on the construction of the project.

Secondly, the project insurance during the operation period applies to the security of property and mechanical damages of the wind turbines and the insurance of civil and employer liability. Regarding the security of property and mechanical damages of the wind turbines, the requested data is about the total machinery supply and maintenance contracts, the expected monthly power output per wind turbine, a brief description of the whole project and, in large projects such as the Aegean, the insurance company will also request that an independent expert reviews both the construction and the risk assessment study. It is worth noting that the cost of such a study would be extremely high, possibly reaching around € 400,000. Last but not least, as far as the insurance of civil and employer liability is concerned the details required appear to be the same as the ones required in the insurance of the construction period.

Regarding the insurance policy for the project's power transmission system, there are several requirements that need to be met. Necessary information needed to be provided in order to proceed with the insurance are the followings:

- Routing design (ie: Design risk, natural risk, casualty exposure)
- Expected cover requirements
- Business plan
- Electrical Grid structure
- Power System Protection Design, i.e. Insulators and surge arresters (Raw material, manufacturing and workmanship risk)
- Conductors: Design, raw material, manufacturing and workmanship risk

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As far as the insurance aspects are concerned, those can be classified in three sections and can be divided in intrinsic and external factors, as it is presented below:

SECTION 1 Material Damages: Intrinsic factors

- Knowledge of the System's designer VS location
- Exposure (location, access…)
- Method of cable laying
- Specifications of main equipment
- Project Management references

SECTION 2 TPL (Third party liability): Intrinsic factors

- Routing
- location and connection points of the grid

SECTION 3 DSU (Delay in Start Up): Intrinsic factors

- Routing/ Design
- Foundations
- Project scope
- Project buffer period
- Manufacturer QA

SECTION 1 Material Damages: External factors

- Grid structure
- Location (Natural exposure)
- Project scope (substations)

SECTION 2 TPL (Third party liability): External factors

- Grid structure
- Location (access)
- Project scope (substations)

SECTION 3 DSU (Delay in Start Up): External factors

- Grid structure
- Location (access)
- Manufacturers choice (location)

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2.2. Underwater Datasets and Products

Retrieving underwater environmental information based on remote sensing technologies requires either hydroacoustic, photogrammetric or laser devices, no matter which kind of investigation is undertaken. Nevertheless, Underwater Archaeologists, Geologists, Biologists or Engineers etc., the overall aim would be the creation of diverse thematic maps, 3D models and figures out of the basic products of the underwater services, like bathymetric or multi-frequency/multispectral maps, backscatter or ortho-rectified or 3D photo-mosaics.

2.2.1. Data and Products for Archaeologists

The essential parameters for the development of the NEANIAS services for the underwater archaeological community are the following:

A. Photomosaicking: Scale, precision, accuracy

A1. Scale:

The scale of archaeological recording is completely different from the one taken into account in geological or biological prospections. Shipwrecks and structures (walls, architecture, monuments, artefacts) need to be mapped at specific mapping scales, in order to be able for archaeologists to draw precise archaeological plans that can really be useful and count as serious archaeological documentation. Otherwise, the photogrammetric model is useful as an illustrative product (a good representation respecting form and texture), but cannot be considered or used as scientific documentation.

A2. Precision

Archaeological documentation requires a higher precision, in order to allow for the structures and objects to be studied in detail. Therefore, according to the site and special conditions taken into account (turbidity of the water, etc), we can usually accept an error of millimeters for the documentation of a wreck (otherwise the original dimensions of the internal parts of the ship are distorted in the final plan), or archaeological structures with architectural details. This precision can be compromised to up to a few centimeters, if we are studying a submerged site or an anchorage in a larger scale. In any case, the precision required for the production of a scientific documentation is generally much higher than the one required for a geological survey.

A3. Accuracy

Accuracy is essential. The structures documented (and less the shipwrecks lying in deep water) need to be the accurately located in the sea-floor or the ocean. Otherwise, in a wider scale, the topographical location of the underwater archaeological features loses its real topographical relationship (i.e. during the study of a submerged city, of a harbor complex, etc). Of course, accuracy is proportional to the conditions of the photogrammetric recording (to the resolution and the scale of the photographs) and other parameters (Drap 2012).

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Paragan, Corsica 2016. Medieval wooden shipwreck. MoMArch - AMU - DRASSM, French Ministry of Culture. Photos: @Lionel Roux CCJ-CNRS, Photogrammetric processing: @Daniela Peloso, Ipso Facto.

B. Bathymetry - Seabed classification

When considering the novel NEANIAS EOSC services, the parameters required from the underwater archaeological community are the following:

When large databases of geological data are processed, algorithms and other parameters may be developed for the **location of possible targets of UCH and locations of interest**, such as shipwrecks, submerged sites, built structures, sunken artifacts, commercial routes, etc. This can be achieved by studying specific requirements that will help towards facilitating the location of certain geometries, shapes and sizes, as well as different textures and materials (ceramic amphorae, metal shipwrecks of the World Wars I and II, canons, built structures of submerged cities).

Moreover, we need very detailed processing of results from databases produced by sensors designed already for high-resolution surveys (resolution and accuracy in the order of millimeter).

Furthermore, it has to be taken into account that these targets are located as anthropogenic intrusions in natural marine environments and biological habitats (such as, sandy or silty sea-floor, *poseidonia* valleys, rocky substratum, etc.). Therefore, benthic terrain models (BTM) could be studied within an archaeological scope and be able to identify geological and anthropogenic targets of UCH. Following site formation processes of ancient shipwrecks and submerged settlements, these are always studied with their natural environment: the study can be more comprehensive and interdisciplinary, with mutual benefits for all underwater scientific communities.

Thus, databases from the oil and gas industries or renewable energy companies, that are performed in large-scale areas of the sea-floor may offer invaluable information on UCH from the quality software treatment of the results.

C. Geo-referencing system

All surveys are performed with respect to a global reference system, that is fundamental to archaeological documentation. However, geo-referencing is not always done in the same way during different marine surveys or photogrammetric recording, while not all mobile systems

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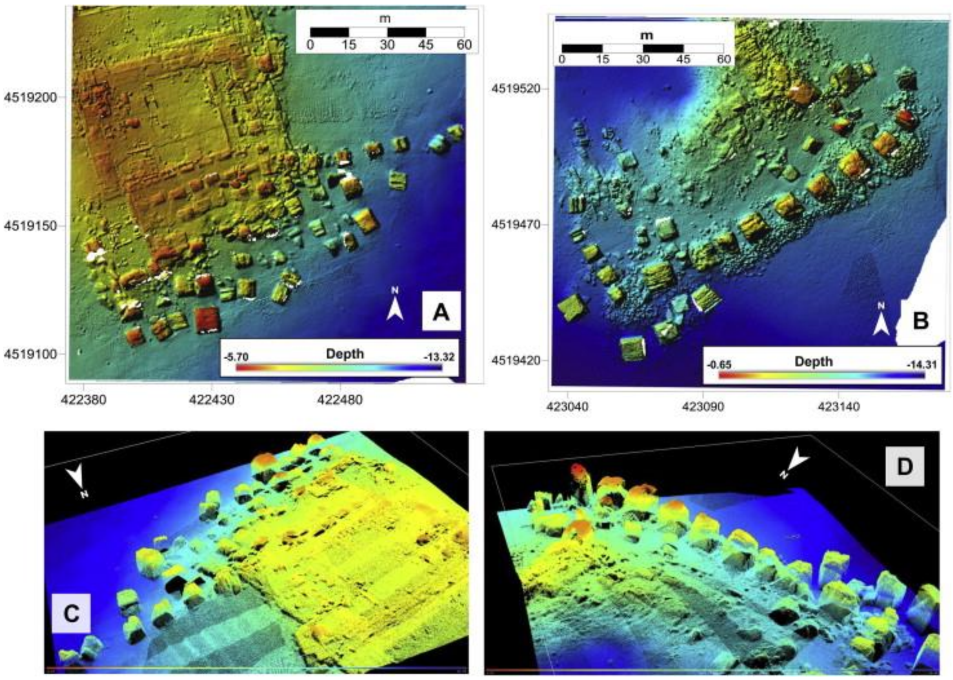
can use satellite-positioning systems. Other deep-water surveys of shipwrecks or other targets are performed in a local reference system and then geo-referenced through reference points of known coordinates (Menna et al. 2018). Therefore, it is important to consider all these parameters when dealing with the export of different information, when processing different databases in the NEANIAS services.

D. Data-storage and accessibility now and in the future

From all interdisciplinary archaeological and geological prospections, the resulting models, together with the photogrammetric georeferenced data and all the survey data, are stored in a repository database for further use and interrogation. However, these bases are not stored in a open-access database that they are not accessible to the research community. We hope that the way the services of NEANIAS will be implemented, will promote accessibility and interconnectivity between the interdisciplinary communities.

Case studies from underwater archaeology
- Submerged cities

An exemplary case of a submerged city documented and mapped with a combination of methodological tools and underwater prospection techniques is the Roman city of Baiae in Naples, sunken after the eruption of the Vesuvius and the subsequent tectonic activity during the Roman period (Bruno et al. 2015). Laser scanner reliefs of selected archaeological structures in the submerged Baiae (Petriaggi- Ayala 2015), as well as the multi-beam documentation of the submerged structures in the Puzzuoli harbor show the level of accuracy obtained for the documentation of submerged UCH (Passaro et al. 2013).



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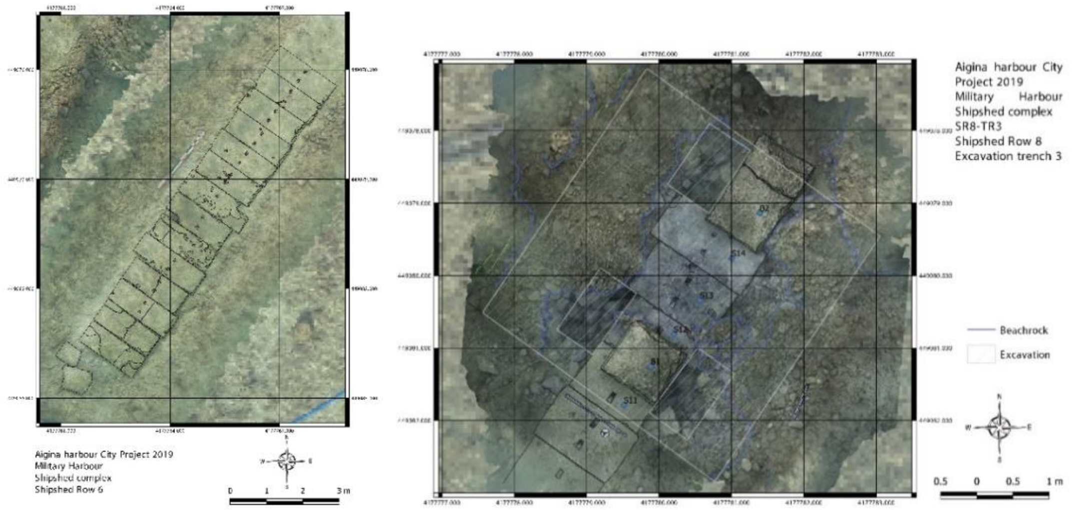
Multi-resolution morpho-bathymetric survey of submerged archaeological remains at Pozzuoli- Baika (Naples, Italy). Passaro et al. 2013.

Other successful initiatives include the 3D documentation of the prehistoric site of Pavlopetri in Greece, an extended site lying in shallow water (Henderson et al. 2013; Mahon et al. 2011).

Two datasets to be used in the framework of the NEANIAS project will be provided by the interdisciplinary survey in Aigina ancient military harbor, and from Palaia Phokaia, a submerged city in Attica, near Athens. Both submerged cities are lying in very shallow water from 0.00 to 5m depth. They are surveyed and documented by interdisciplinary teams with a combination of methods, mainly from marine geosciences and 3D underwater and aerial photogrammetry. In this case, accuracy and precision are key parameters to be achieved in the post-processing of the data; otherwise, a number of architectural details will be lost.



Aigina Harbour-city Project 2019-2023. Greece. 3D underwater photogrammetric recording used systematically to document and monitor the progress of the archaeological excavation. Above a combination of the photogrammetric documentation and Total Station measurements of the stylobates (with many architectural details) of the shipsheds of the ancient naval base of Aigina, that accommodated the fleet of triremes of the city in the 5th c. BC. DAO@J. Anbar, K. Baika.

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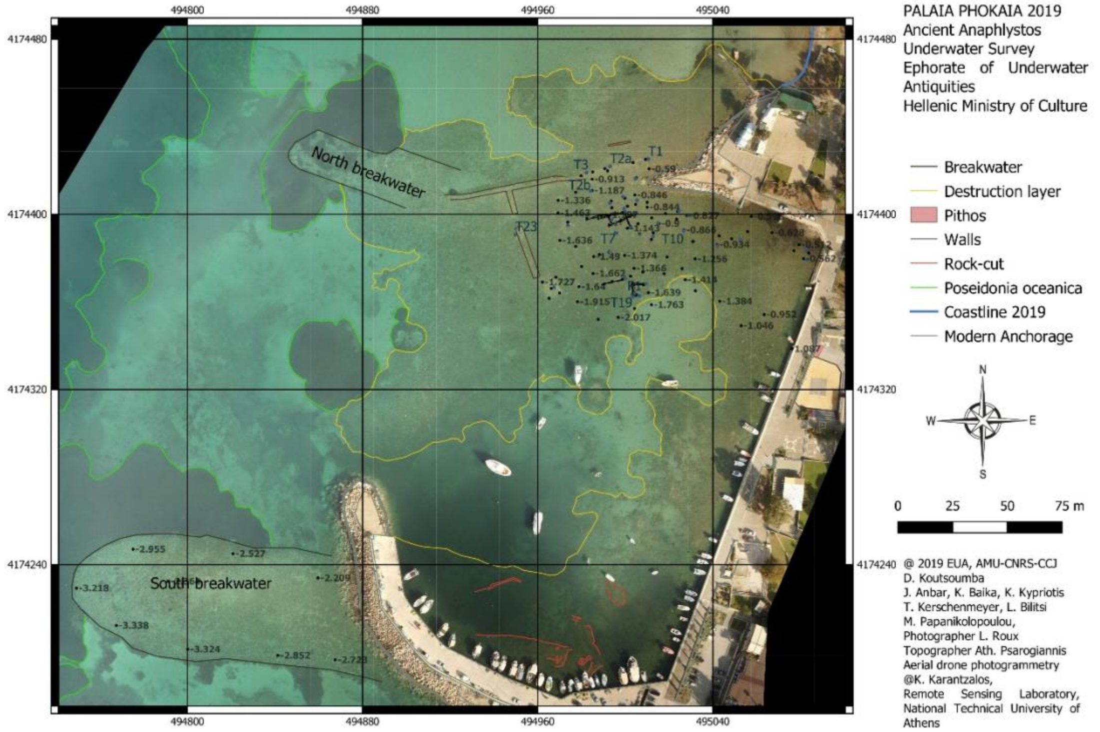

Palaia Phokaia Survey 2019. Submerged ancient city in Attica, Greece. Unpublished report 2019. Hellenic Ministry of Culture-EUA, Aix-Marseille University. Drone photogrammetry imagery: K. Karantzalos, Remote Sensing Laboratory, National Technical University of Athens, DAO@J. Anbar, K. Baika.

- Location and recording of Shipwrecks

One of the first photogrammetric recording in situ of a shipwreck was implemented on an underwater archaeological excavation of the Grand Ribaud F, a deep Etruscan shipwreck discovered in 1999 in Hyères, France. The wreck is of high archaeological interest for both its cargo and its state of conservation. Found at 90 m depth, it dates to the 6th c. BC and it contains nearly 1,500 amphorae. In this case, the study went further on. The objective was not only to measure *in situ* the archaeological artifacts, but also to obtain a theoretical model from the partially measured object, the amphora, through measured geometry and geometrical computation (Drap et al. 2001; Drap 2012). This initiative was also carried on the Phoenician Xlendi wreck in Malta (Drap et al. 2015). In both cases, this innovative research depended on a high-accuracy underwater 3D photogrammetric model, as produced by the available software.

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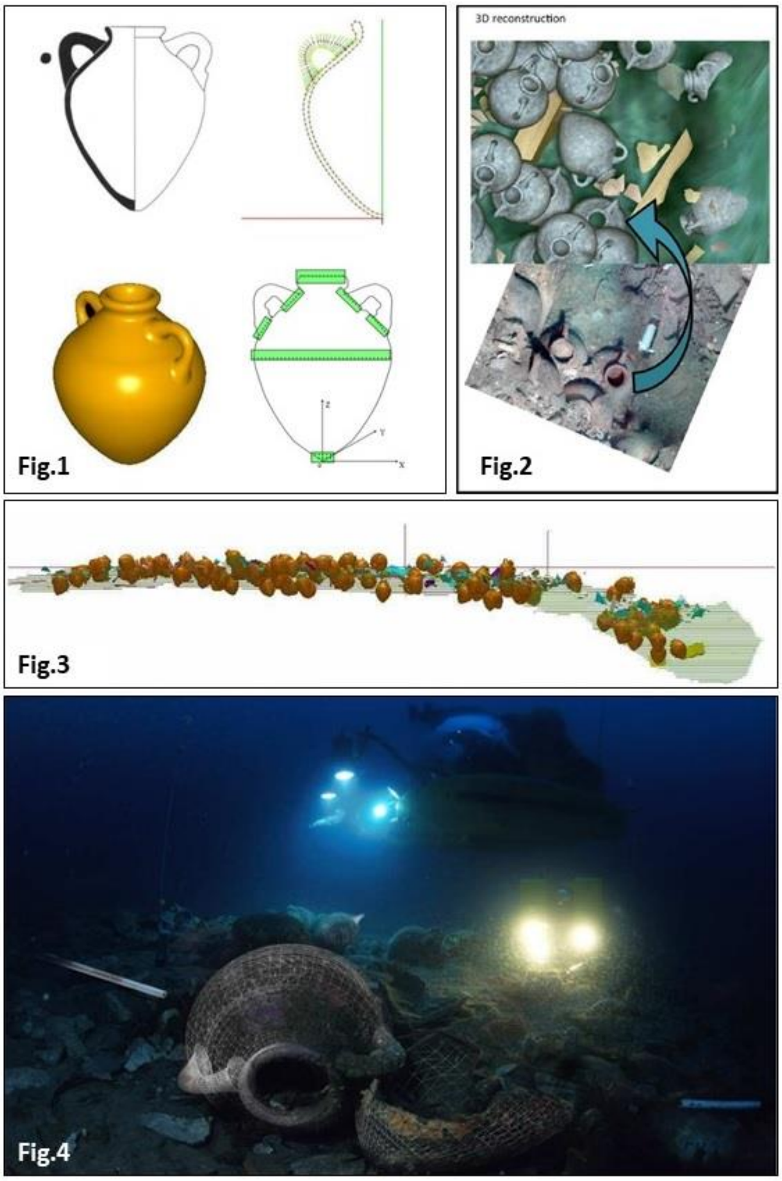

*Grand Ribaud F, a deep Etruscan shipwreck discovered in 1999 in Hyères, France, 90 m deep [Drap 2012: "**Fig. 1**. On the left, the graphical model designed until now by archaeologists. On the middle two images, a CAD interpretation of this model. On the right, the five zones where photogrammetric measurements can be taken on an amphora. **Fig. 2**. On the top, a complete virtual visualization of the site of the Grand Ribaud F wreck with all the amphorae measured. On the bottom, one of the original photographs used for the photogrammetric survey. **Fig. 3.** An east-west elevation cut of the excavation made on the Grand Ribaud F wreck visualized using MicroStation™. **Fig. 4.** The Grand Ribaud F wreck: a digital model of an amphora (Etruscan Py4) inserted into a photograph. (Original photograph from F. Bassemayousse)."].*

- Location by acoustic sensors and photogrammetric recording of a deep wreck

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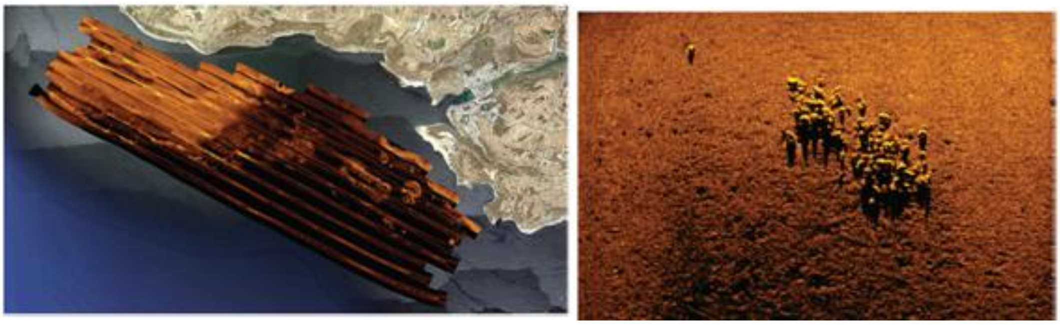
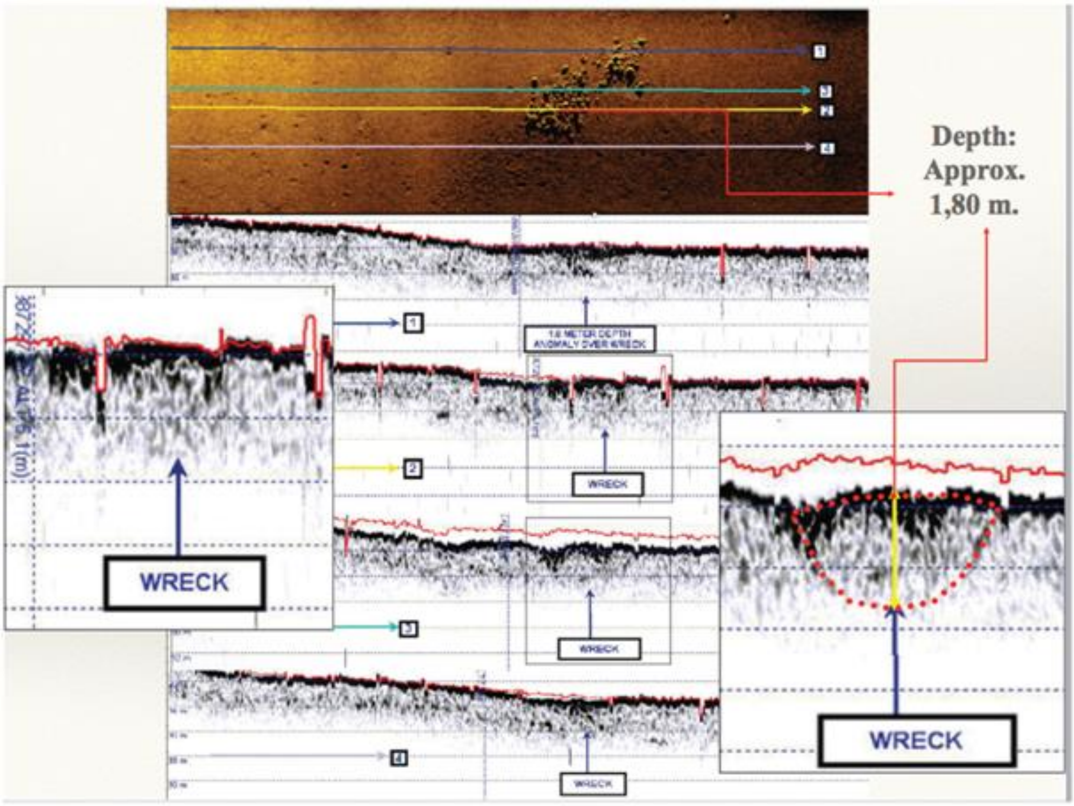
Another case-study is indeed the unique Phoenician shipwreck of Xlendi, at Gozo island off Malta, discovered in a depth of 110m and now under excavation. The wreck was located during a side-scan sonar survey, and the potential sections and form of the ship were studied by the sub-bottom profiler survey (Gabin 2014, 2015, Gabin et al. 2018), demonstrating the potential of this kind of marine geological prospections for underwater archaeological research, as well as their added value if the results offer accuracy and precision.



Xlendi wreck, Malta, phoenician wreck 110m deep. Side-scan sonar survey and archaeological target (sonar image in 500kHz) (Gabin et al. 2018, figs. 2 and 3).



Xlendi wreck Malta, Side-scan sonar and subbottom profiler survey showing sections of the shipwreck (Gabin et al. 2018, fig. 6).

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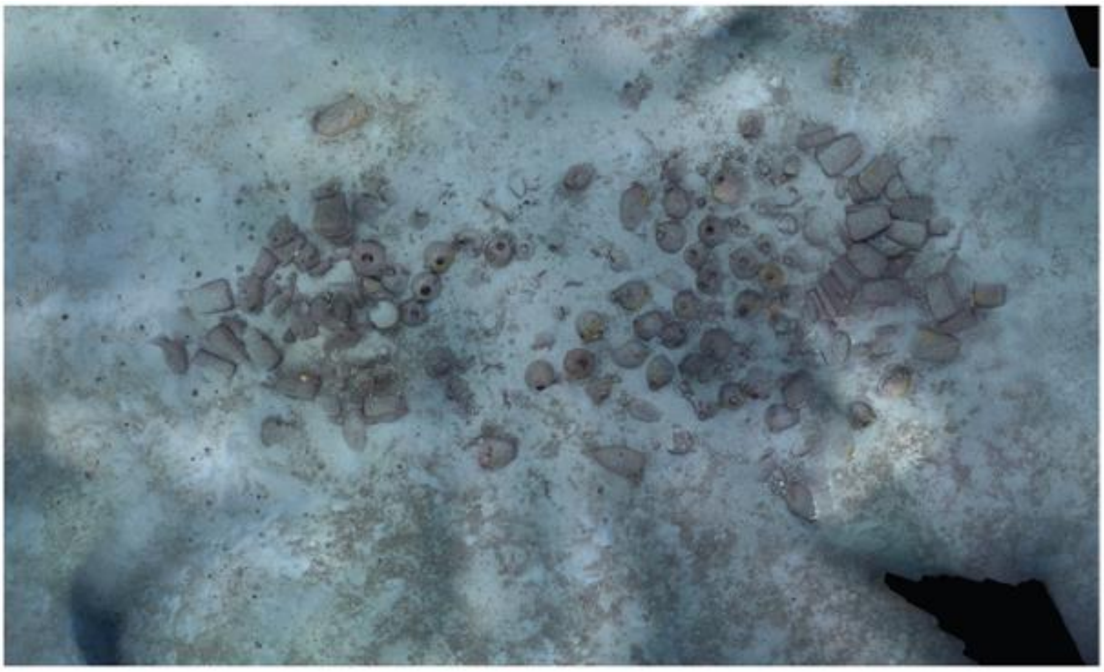

Xlendi wreck, Malta. High-resolution orthophoto from the photogrammetric documentation 2014 (Gabin et al. 2018, fig. 10).

- 3D recording of a wreck in a depth of 40m

Another example is the photogrammetric recording of the pre-excavation phase of the amphora wreck of Mazotos in Cyprus lying in 40m depth and carrying Chian amphoras of the 4th c. BC.

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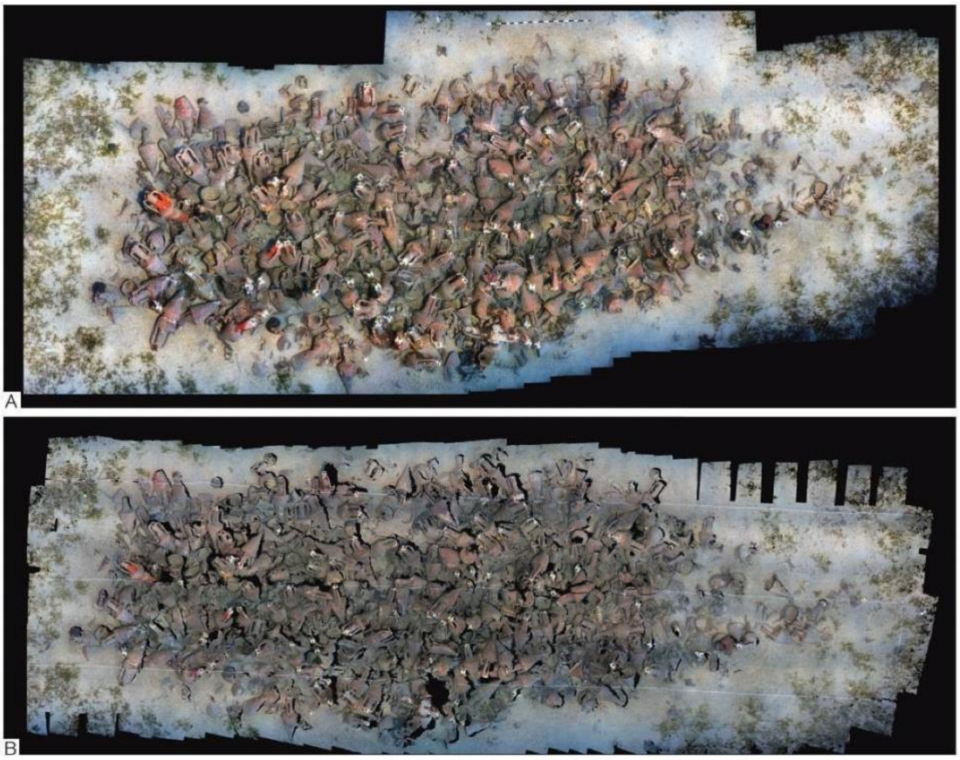

Photomosaicking of Mazotos 4th century wreck in Cyprus was documented with state-of-art photogrammetric methodology (40m deep). Demesticha et al. 2014 - Figure A: 'A photomosaic produced by photo stitching of 230 images taken in 2007 (Hartzler 2011). Although not geometrically correct, it proved an invaluable tool for communication among the team members and the production of hand sketches used in the dives. Figure B: The same set of photographs processed again in 2012 with successful results for producing an orthophotomosaic of the pre-excavation phase of the site, georeferenced in the local coordinate system'.

Other recent relevant case-studies have been published in McCarthy- Benjamin- Winton-Duivenvoorde (2018) collective volume.

2.2.2. Data and Products for Marine Environmental Scientists

Marine environmental science in general is dealing with a broad number of vendor formats from hydroacoustic devices to different underwater photo- and video-cameras. Their products are digital terrain models in various formats, backscatter and multispectral and photo-mosaics in formats like GeoTiff and at least after analysis, thematic maps produced with GIS in vector formats.

Some examples with a different focus are shown below.

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Investigations to tsunamis caused by submarine slope failures along western Great Bahama Bank led to a modelling based on bathymetric information. It revealed the potential risk for the eastern coast of Florida being hit by a tsunami (Schnyder et al (2016)).

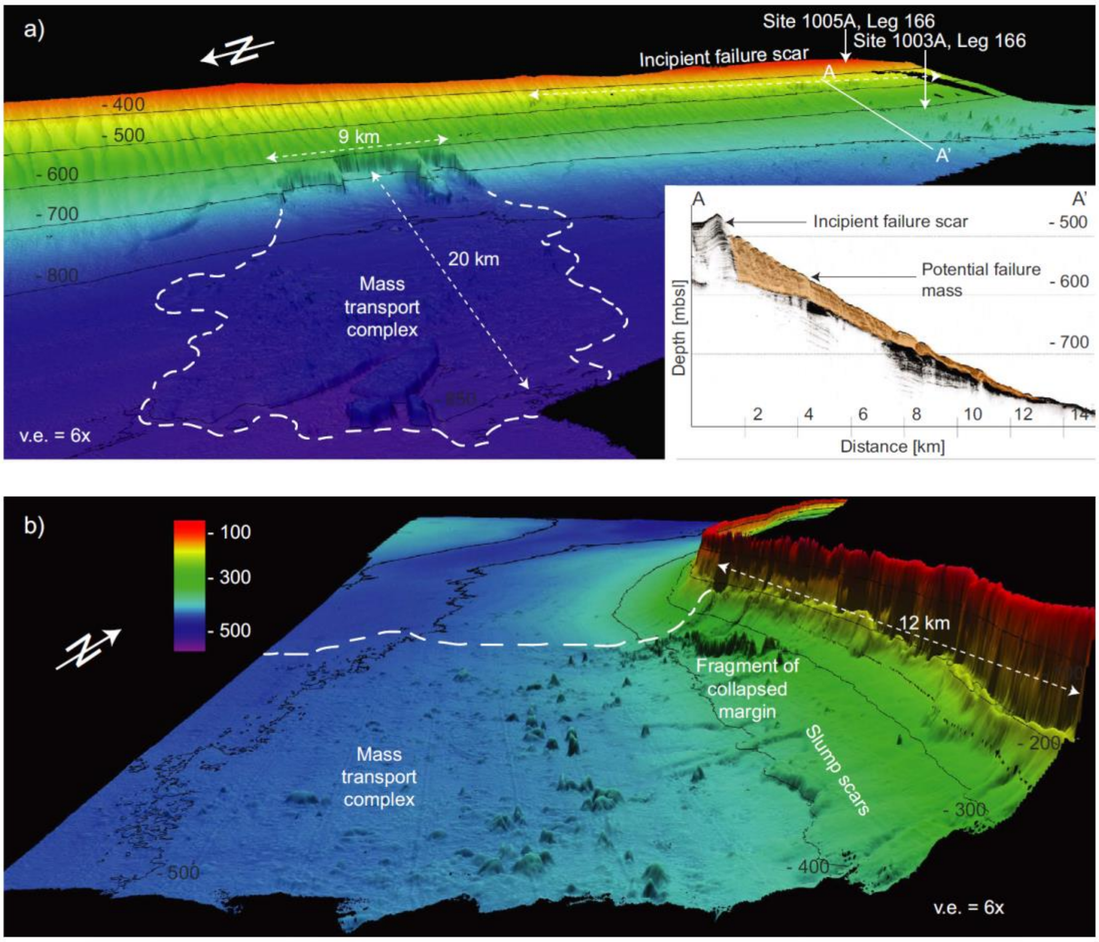

*Figure (**a**) Slope failures along western Great Bahama Bank. The scar visible on the lower slope and the associated mass transport complex in the basin. The smaller landslide was simulated using the extent of the middle part of the failure scar. The incipient failure scar (IFS), transect A-A' is also visible in the sub-bottom profile. (**b**) Margin collapse and the associated mass wasting products on the southwest corner of GBB. (The 3D bathymetry was produced using QPS Fledermaus v.7 http://www.qps.nl/display/fledermaus/. The sub-bottom profile was produced using Reflex v.6 (http://www.sandmeier-geo.de/reflexw.html).*

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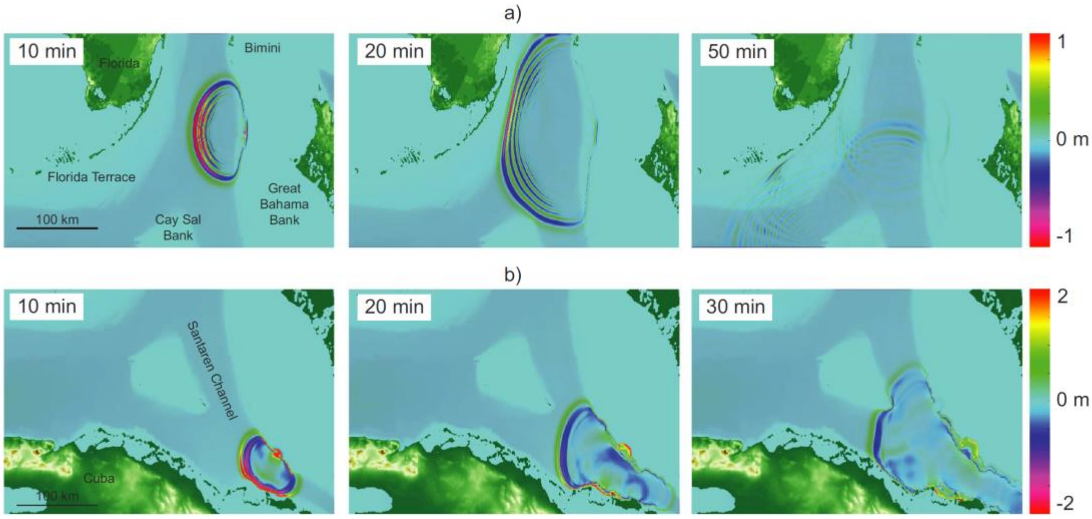

*Figure above: Tsunami wave propagation paths caused by (**a**) a submarine landslide (9 km width and ut= 20 ms−1) and (**b**) a margin collapse of southwestern GBB (12 km width and ut= 20 ms−1). (Map was created in MATLAB r2014a using GEBCO grids, http://www.gebco.net).*

The Aegean volcanic arc has been investigated along its offshore areas and several submarine volcanic outcrops have been discovered in the last 30 years of research. The basic data including swath bathymetric maps, air-gun profiles, underwater photos and samples analysis have been presented along the four main volcanic groups of the arc: (i) Paphsanias submarine volcano in the Methana group, (ii) three volcanic domes to the east of Antimilos volcano and hydrothermal activity in southeast Milos in the Milos group, (iii) three volcanic domes east of Christiana and a chain of about twenty volcanic domes and craters in the Kolumbo chain northeast of Santorini in the Santorini group and (iv) several volcanic domes and a volcanic caldera together with very deep slopes of several volcanic islands in the Nisyros group (Nomikou et al (2013). Most of the swath data from the Aegean Sea will be used in NEANIAS project.

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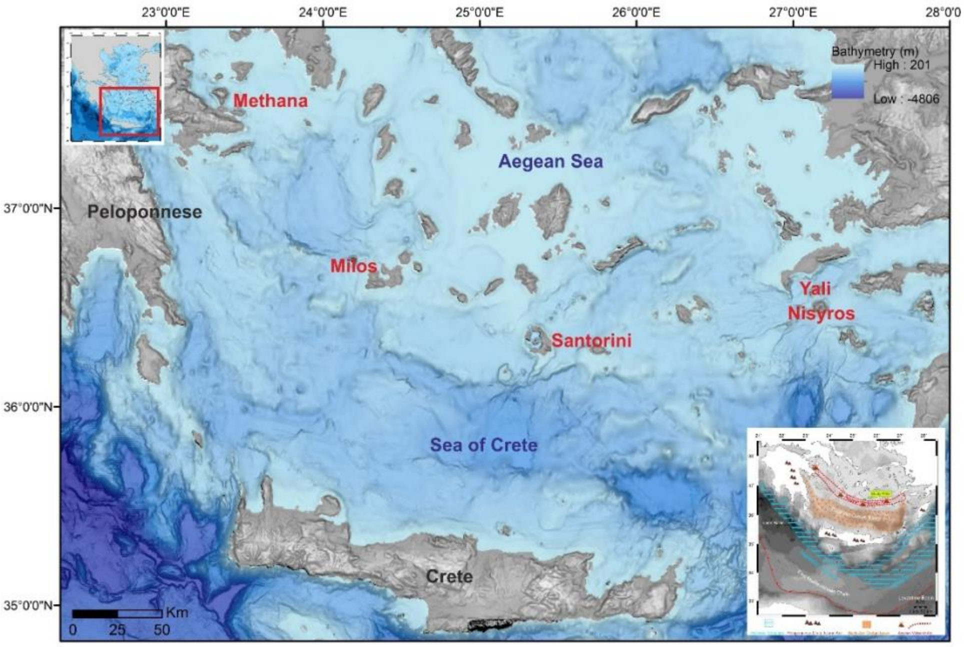

Synthetic onshore and offshore topographic map of the South Aegean Sea showing the four volcanic Groups (Nomikou et al., 2013). Inset map: The Geodynamic setting of the Hellenic Orogenic Arc.

Mud extrusion and ring-fault gas seepage – upward branching fluid discharge at a deep-sea mud volcano (Loher et al. 2018).

Mud volcanoes (MVs) are geological structures created by the extrusion of sediments, water, and volatiles (predominantly methane) from deeply-rooted plumbing systems that remain poorly understood. Two seepage domains are recognized at the Venere MV, the currently only active site in the Calabrian Arc: mud breccia extrusion from a summit, and hydrocarbon venting from peripheral sites, hosting chemosynthetic ecosystems and authigenic carbonates indicative of long-term seepage. The AUV bathymetry shown below is part of the NEANIAS test data.

Figure below: AUV-derived bathymetry (1.6 m grid) of Venere mud volcano (MV) and sampling locations. A fresh mud flow (outlined in white) originating from the W summit extends down to the caldera floor. (a) Perspective view of Venere MV (generated in QPS Fledermaus 7.3.2b; www.qps.nl). Note twin cones labeled as E + W summit, each up to 100 m high and ring faults defining a caldera up to 3 km across. Water column gas flares (red to yellow colors; extracted from hydroacoustic data) up to 260 m in height were observed at five sites, along the peripheral ring faults (Sites 1, 2, 4, 5) and near the W summit (Site 3); (b) Map-view of Venere MV (see Fig. 1for extent) with inset of the extrusion site of the fresh mudflow at the W summit (generated in ESRI ArcMap10.3.1; www.esri.com). Red stars mark the flare origins and white circles indicate sampling locations with white numbers referring to the last two Geo B-identifiers (see Table 1 and supplementary Tables S1 and S2 for full details of all stations). See

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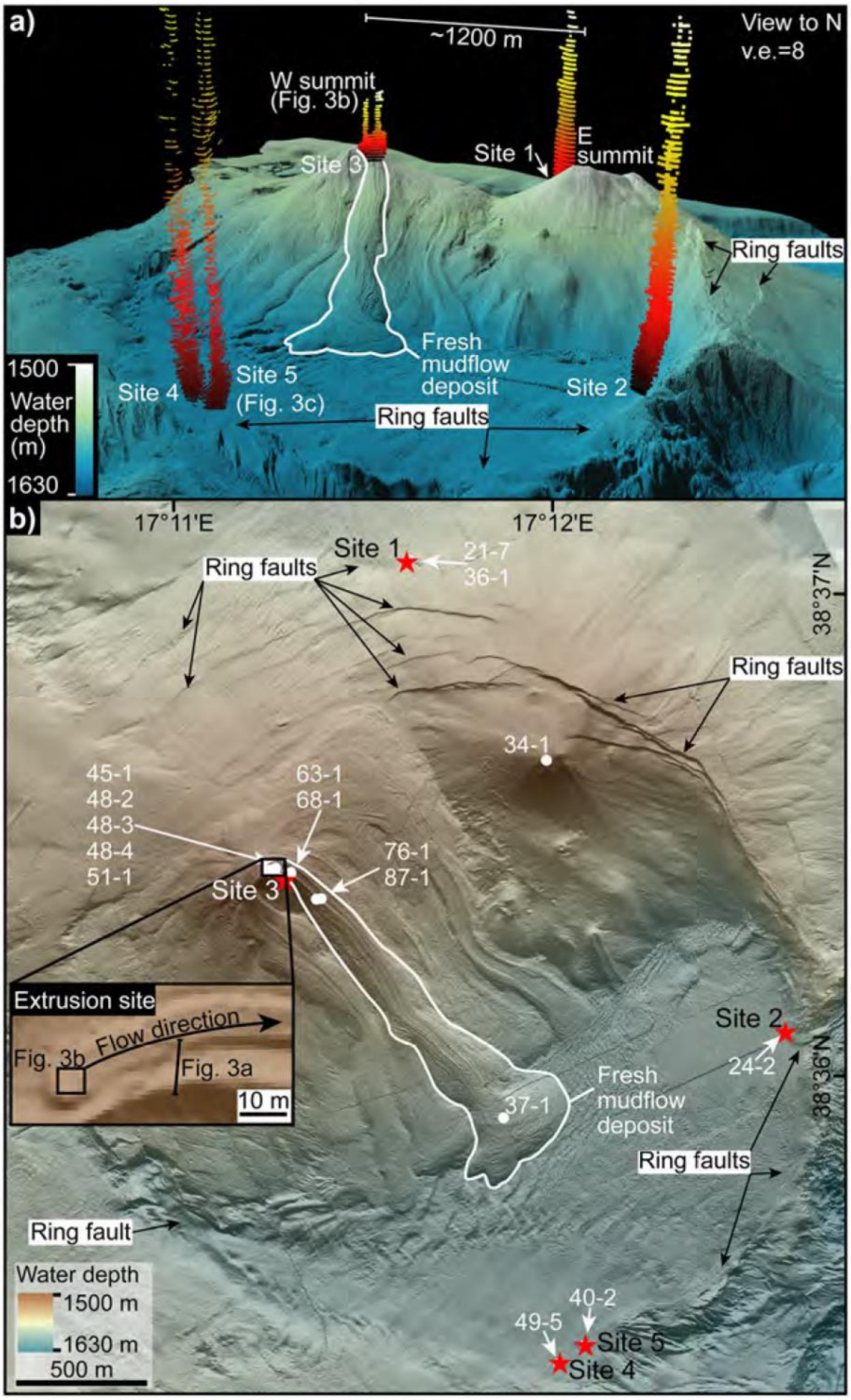
supplementary Figs S2 and S3 for bathymetry without annotations and an alternative perspective view of a) showing the heights of ring faults.



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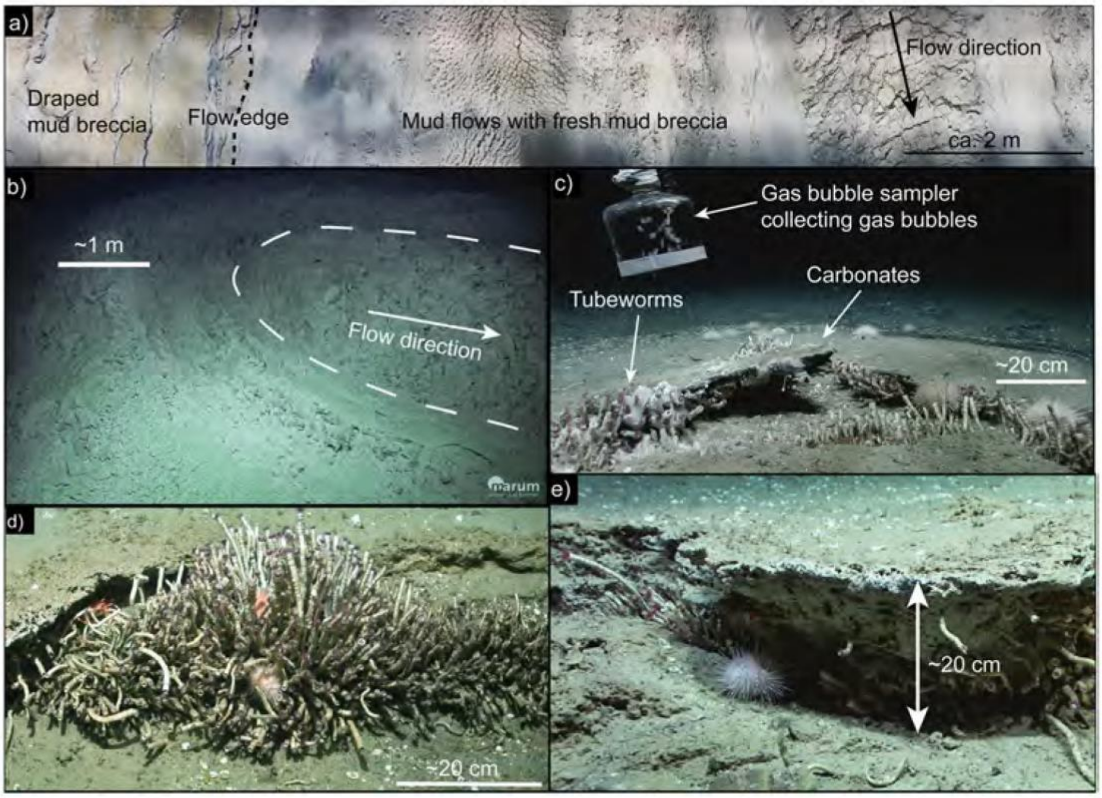

Figure above: Seafloor photographs. (a) ~10 m long transect across fresh (right) vs. older (left) mud breccia flows draped by hemipelagic sediments near the western summit (see inset of Fig. 2b for location); (b) western summit of Venere MV showing elevated extrusive center at the origin of the most recent mudflow (see inset of Fig. 2b for location); (c) authigenic carbonate crusts, cold-seep communities and sampling of gas bubbles at a peripheral seep (Site 5); (d) tubeworm colony rooting in a fracture of authigenic carbonate crust at a peripheral seep (Site 1); (e) cold-seep community and thick authigenic carbonate pavement at a peripheral seep (Site 1).

Coral Patch seamount (NE Atlantic) – a sedimentological and megafaunal reconnaissance based on video and hydroacoustic surveys (Wienberg et al (2013)).

In recent years seamounts have gained increasing interest mainly because of their possible important role as local biodiversity hotspots. For the first time a detailed hydroacoustic mapping (MBES) in conjunction with video surveys (ROV, camera sled) were performed on the Coral Patch seamount to describe the sedimentological and biological characteristics of this subelliptical ENE-WSW elongated seamount. Video observations were restricted to the southwestern summit area of Coral Patch seamount (water depth: 560–760 m). Based on these observations and ground truth an extended hydroacoustic seabed mapping was realized utilizing the benthic terrain modeler (BTM), a GIS habitat mapping tool.

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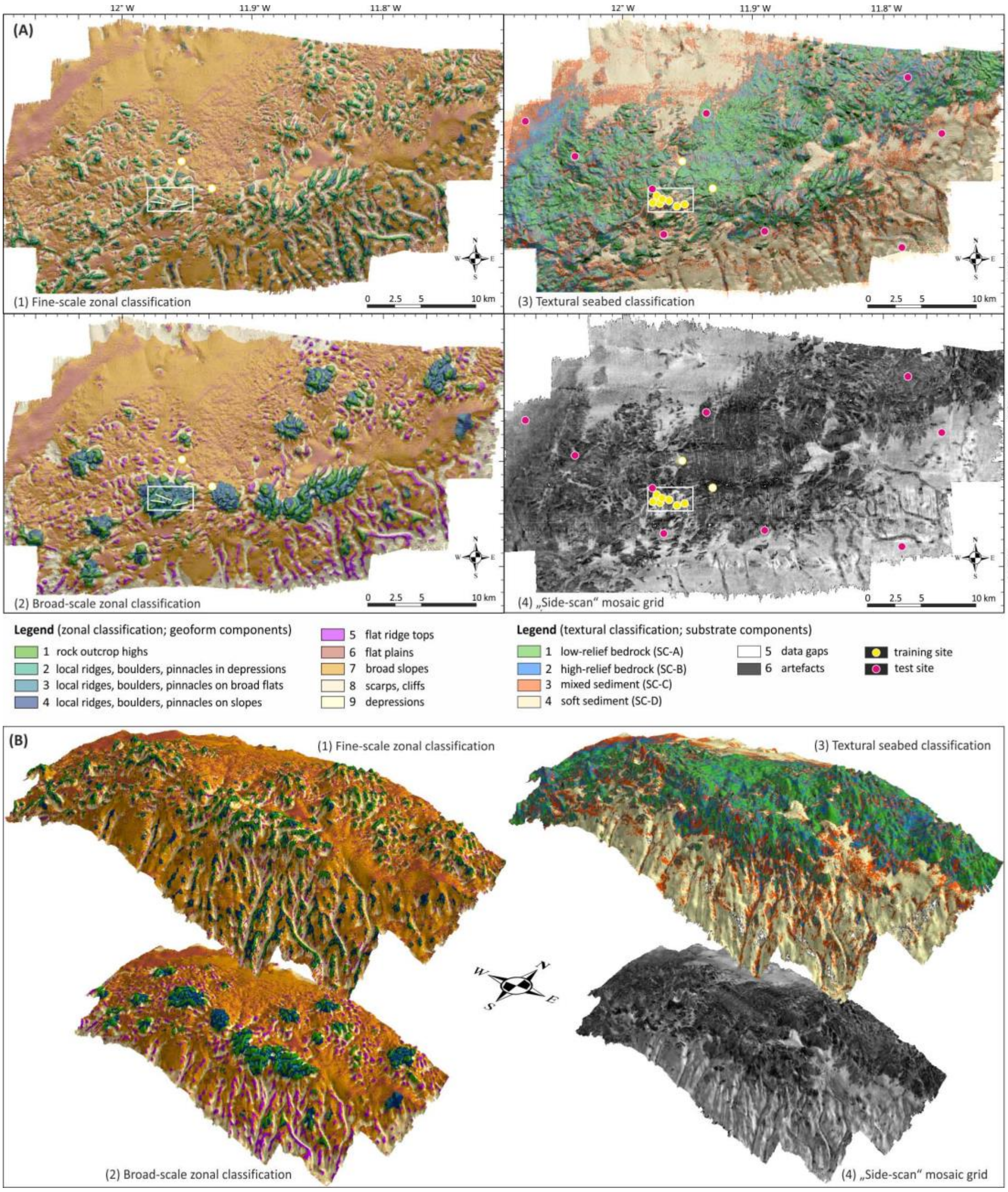

*Figure above: Hydroacoustic seabed classification maps (**A**: 2D-plots, **B**: 3D-plots) of Coral Patch seamount. (1) Fine-scale and (2) broad-scale zonal classification maps both showing the distribution of geoform components (GC) comprising e.g., flat plains, slopes, boulders and local ridges (see Table 4 for detailed description). (3) Textural classification map showing the distribution of substrate components (SC; see Table 2 for detailed description). (4) "Side-scan" mosaic grid. Inserted boxes on **(A)** indicate video-surveyed area at the southwestern top of Coral Patch seamount, white dots show position of Van Veen grab sampling, both used as ground-truthing data for textural seabed classification. The location of the training and test sites are denoted in **(A)** (3) and (4).*

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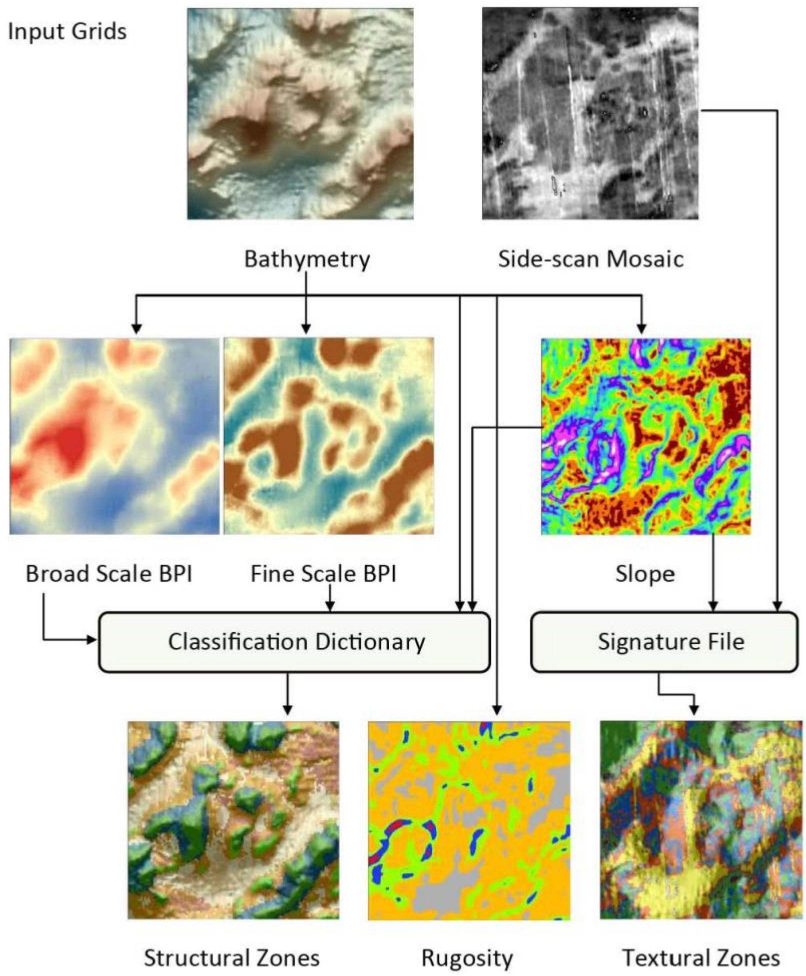

*Figure above: Flowchart of hydroacoustic seabed classification methods applied for Coral Patch seamount. The dataset used for the flowchart displays a small area at the southwestern summit. The final products (last image row) represent **(a)** topographical characteristics based on the bathymetry and derived products (BPI: Bathymetric Position Index), and **(b)** textural classes based on the "side-scan" mosaic and hillshade/slope.*

2.2.3. Data and Products for Oil & Gas engineers

The following subsection provides information on projects with submarine transmission lines and the studies required in order to proceed with the finalization of the cabling route. Those projects consist case studies regarding subsea power transmission, submarine transition cable connecting RES projects to the mainland grid, gas and oil pipelines. Most of them are included by EU in PCI (Project of Common Interest).

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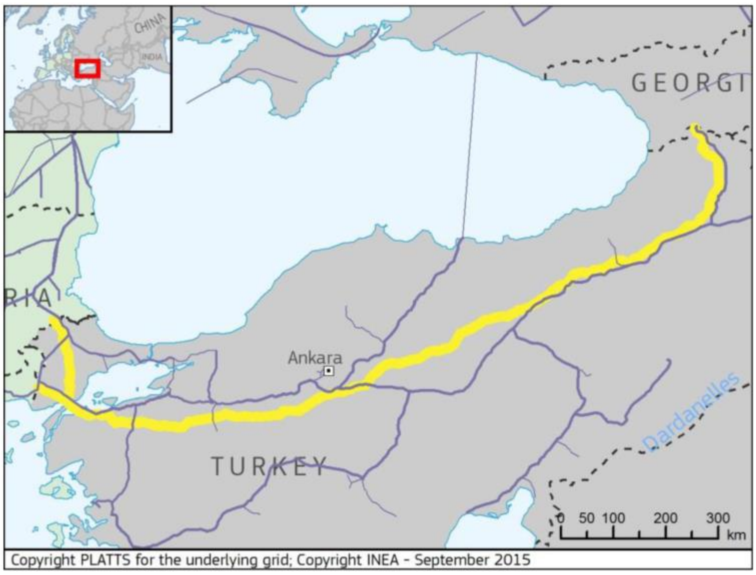
A project worth highlighting as a reference point with respect to the engineering studies required is the **TANAP SCADA** System and Crossings under Dardanelle Strait and Evros River. It is actually a gas pipeline from the EU to Turkmenistan via Turkey, Georgia, Azerbaijan and the Caspian, currently known as the combination of the "Trans Anatolia Natural Gas Pipeline" (TANAP), the "Expansion of the South-Caucasus Pipeline" (SCP-(F) X) and the "Trans-Caspian Gas Pipeline" (TCP)". The connection between the Transatlantic Gas Pipeline (TAP) and the Anatolian Natural Gas Pipeline (TANAP) has been successfully completed in 2018 with the final "golden soldering" connecting the two conductors. For the design of the project, on Greek soil, geotechnical surveys and studies were compulsory for the construction of the TAP gas pipeline. In the above-mentioned project, the geotechnical survey included 99 rotaries, sample drillings and 80 Auger drillings, with a total depth of 1810m. In addition to this, it required performing on-site testing of SPT and MAAG as well as performed laboratory tests of soil engineering and rock engineering.



TANAP SCADA System and Crossings under Dardanelle Strait and Evros River (Source:https://ec.europa.eu/inea/sites/inea/files/7.1.1-0014-tr-s-m-15_action_fiche_final_0.pdf).

The dredging at TANAP project has been completed. There is no seasonal constraint for marine construction because there is no breeding area in the sea crossing for marine fauna species. The cumulative impact assessment was performed considering some of the following data:

1. Physical environment:
    - Meteorology and climatology
    - Air Quality

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- Noise and Vibration
- Hydrogeology and groundwater quality
- Geology and Geomorphology
- Seismology
- Soil
- Visual aesthetics
- Hydrology and surface water quality
- Bottom morphology
- Physical oceanography
- Sea water
- Marine Sediments

2. Biological environment:
    - Protected areas
    - Terrestrial Flora
    - Terrestrial Fauna
    - Birds
    - Amphibians
    - Reptiles
    - Mammals
    - Invertebrates
3. Marine habitats and ecosystems
4. Marine biodiversity
5. Marine protected areas
6. Social environment
    - Cultural heritage and archaeology
    - Ecosystem services

To continue with, **EuroAsia** Interconnector is another great example of application of data in order to proceed with the marine survey of the cabling route. The EuroAsia Interconnector consists of a 500 kV DC underwater electric cable with its associated equipment for interconnecting the Cypriot, Israeli and Greek transmission networks. The first phase of the interconnector is designed to have a capacity of 1,000 MW and a total length of around 1,518 km. It needs to be mentioned that this project is also a PCI. The project has already conducted the required studies and is entering the construction phase. An external marine survey was carried out in order to determine the preferred route for the cable. Also, a bathymetric study was carried out in order to accurately determine the route of the interconnector cable along the seabed. This survey aimed to establish and evaluate the existing seabed topography and morphology and moreover, to identify potential geological features. This survey consisted of a bathymetric investigation along the proposed route and a bathymetric investigation of the

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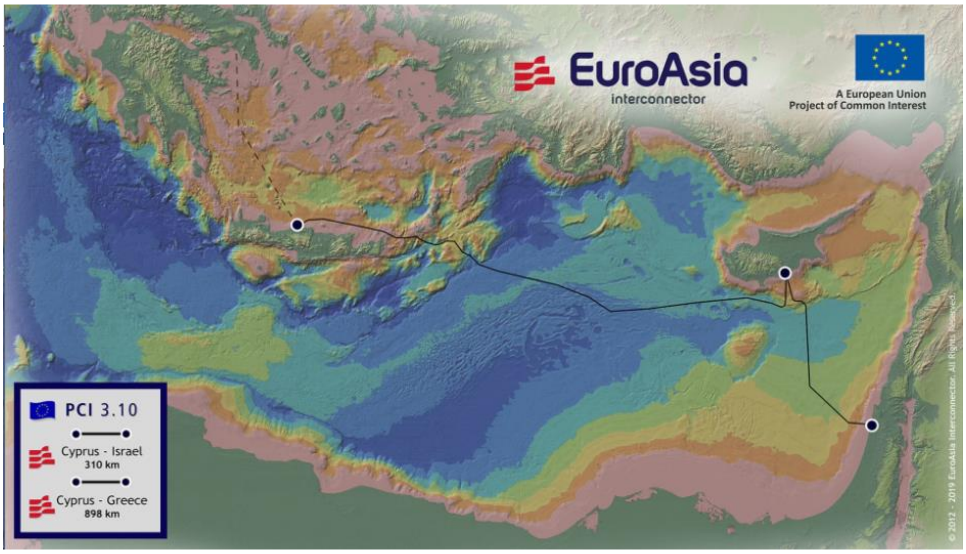
most critical areas from a bathy-morphological point of view. Further on, specific surveys were conducted such as burial assessment, so as to perform soil sampling by gravity and vibro corers and cone penetrometer test (CPT) at discrete intervals and locations determined by the geophysical results of Sub bottom profiler (SBP). Given the length for the whole survey, the extended deep water areas, the high required resolution, ROV's and possibly AUV's were needed to be employed to increase the resolution of swath bathymetry (MBES), Side scan Sonar (SSS) and SBP and on board Data processing and charting were also performed for the route design process.



EuroAsia Interconnector (Source: www.euroasia-interconnector.com).

Additionally, one more project of equal importance and worth to considerate within the framework of this current analysis, is the ***Eastern Mediterranean pipeline (EastMed pipeline)***, which is a pipeline from offshore Cyprus to Greece mainland via Crete. The length of this gas pipeline is approximately 1,900km out of which, 1,300km of offshore and 600km of onshore pipeline sections. The EastMed pipeline project received approvals from the Cypriot, Greek, and Italian Governments in 2015 and has been added in the second PCI list and considered in the Southern Gas Corridor projects. IGI Poseidon signed a Memorandum of Understanding (MoU) with Israel Natural Gas Lines (INGL) in November 2019, followed by another MoU with TMNG, a subsidiary of Israeli oil and gas engineering company Tahal Group in December 2019. The European government has added the project in the last Ten Years Development Plan (TYNDP) of the European Network Transportation System Operators of Gas (ENTSOG), which is aimed at creating a safe transmission network capable of meeting the current and future energy needs of Europe. The project includes a 200km offshore pipeline section with a

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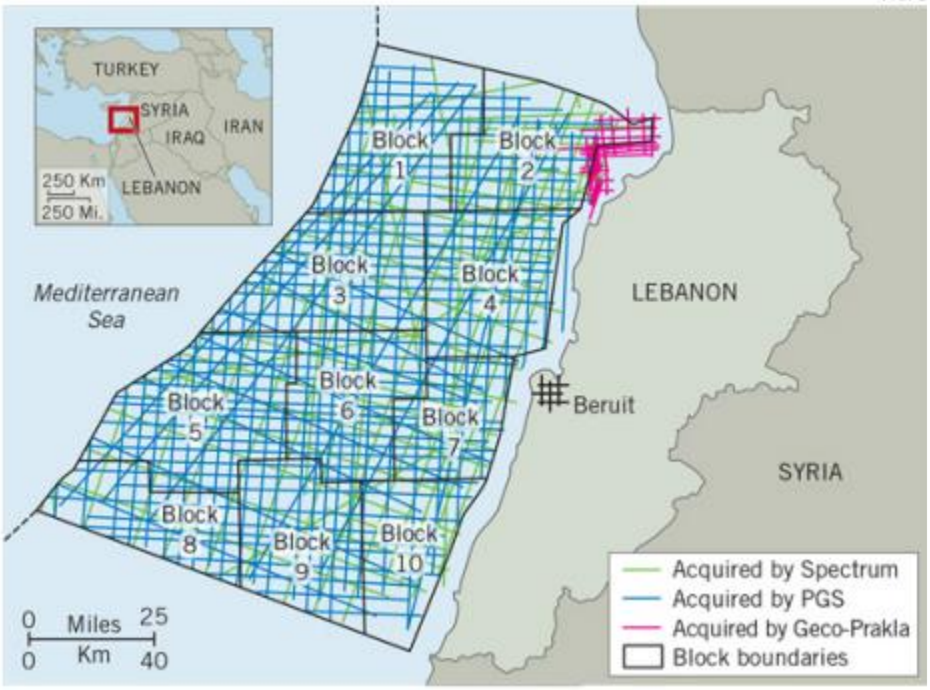
diameter of 24in that will start from the Leviathan gas field of Israel and end at Cyprus connecting the Aphrodite gas field. A 100MW compressor station will be constructed at Cyprus. A 700km offshore pipeline section with a diameter of 26in will connect the pipeline further from Cyprus to Crete Island, where a 120MW compressor station will be installed.



Offshore Seismic 2D Surveys in Lebanon – Oil & Gas Journal (Dunnahoe, 2017).

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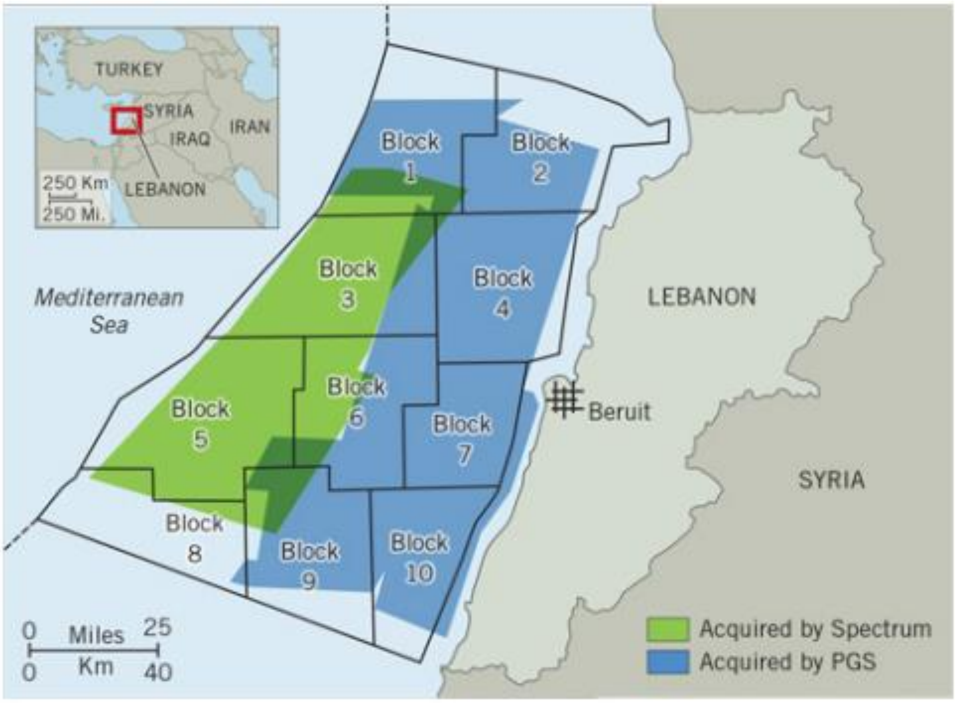

Offshore Seismic 3D Surveys in Lebanon – Oil & Gas Journal (Dunnahoe, 2017).

Eastern Mediterranean Natural Gas Pipeline, is part of PCI, therefore, pre-FEED studies were completed, in order to proceed with the project. In this context, a Technical Feasibility Studies' package, a Reconnaissance Marine Survey (RMS), as well as Economic, Financial and Competitiveness Studies were performed. The Technical Feasibility helped determining the best route together with the optimal pipeline configuration and the key technical risks, proving the technical viability and providing CAPEX and OPEX estimation. The project feasibility has been confirmed, clarifying that its configuration is well within the state of art of the available technology and proving the existence of pipelay vessels able to lay deep water pipelines. Moreover, a preliminary environmental impact assessment was successfully conducted. The RMS aimed to acquire bathymetric, geophysical and geotechnical data, contributing fundamentally to the overall assessment of the feasibility of the engineering and the installation of the marine pipeline sections. The outcomes of the RMS were integrated into the Feasibility Design that identified no showstoppers along the route and confirmed the CAPEX, estimated to be around 5.2 billion EUR for a 10 Bcm/y capacity. (https://ec.europa.eu/inea/sites/inea/files/cefpub/summary_7.3.1-0025-elcy-s-m-15_final.pdf).

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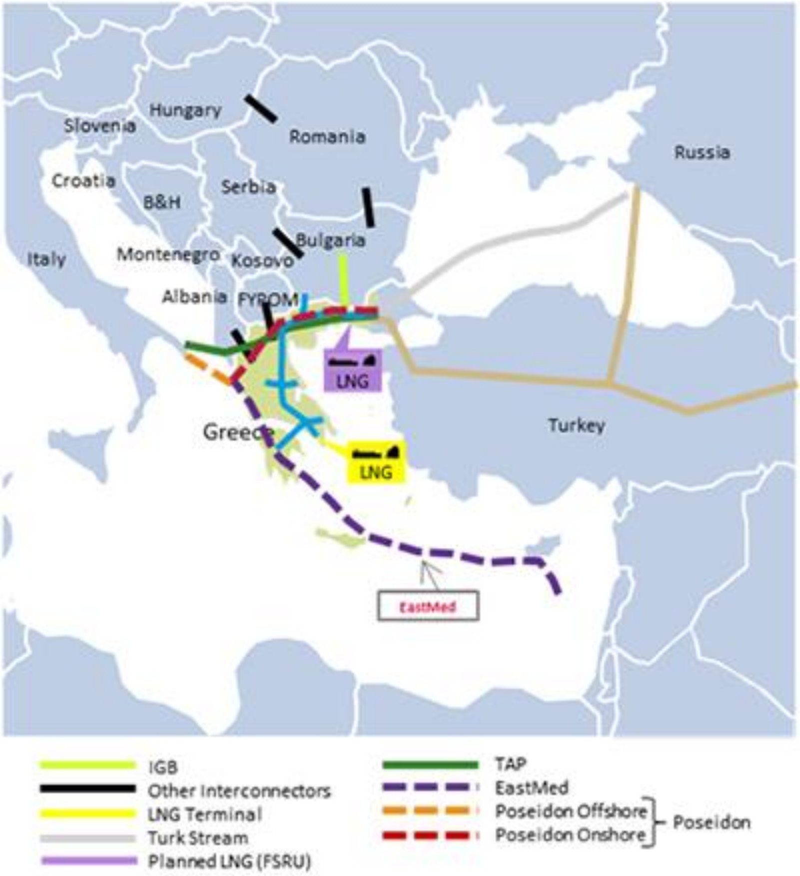

The Eastern Mediterranean Pipeline (EastMed) (Source: https://www.depa.gr/).

Furthermore, another significant example is the **Poseidon Pipeline**, which is a multi-source natural gas interconnector stretching from the Turkish-Greek border to Italy. The Poseidon Pipeline will extend for approximately 760 km on Greek territory (the onshore section) from the Turkish-Greek border in Kipi to the landfall in Florovouni and for approximately 216 km crossing the Ionian Sea up to the landfall in Italy and the receiving terminal in Otranto (the offshore section), where it will be connected to the Italian national gas transport system.[1] The Poseidon project aims to transport gas between Greece and Italy at an initial volume of 14 bcm/y (first phase) and up to 20 bcm/y on a second phase. The project includes the following phases[2]:

- Compression station in Thesprotia (120 MW)
- Onshore pipeline between the compression station and the Greek landfall
- New offshore pipeline of approximately 216 km with a capacity of up to 329.4 GWh/day between the Greek and Italian landfalls
- Onshore pipeline between the Italian landfall and the metering station in Otranto.

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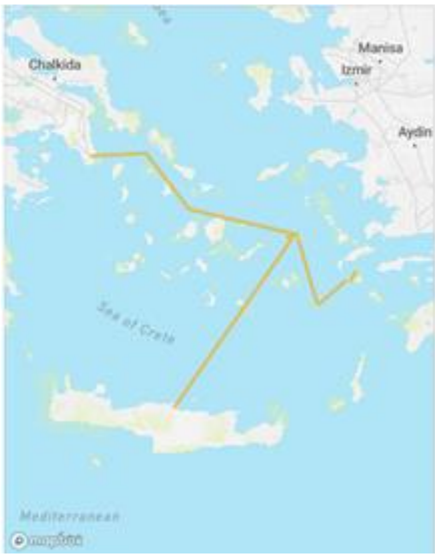
As far as the marine studies are concerned, those involve offshore and nearshore hydrographic, geophysical and geotechnical surveys. Those studies are linked with the EastMed study regarding the data required and the processing.

Regarding submarine interconnections, "**Project 293 – Southern Aegean Interconnector (SAI**)" can be highlighted due to the fact that this project refers to the construction of a submarine DC transmission link to connect the licensed RES plants at the South Aegean Sea to mainland Greece and the islands of Crete, Kos and the Dodecanese. It should be mentioned that it consists of a project considered in the reference grid. The interconnection of the AEGEAN Project has been included in the ten-year development plan of ENTSO-E as "Project 293 – Southern Aegean Interconnector (SAI)". ENTSO-E is the European Network of Transmission System Operators, representing 42 electricity transmission system operators (TSOs) from 35 countries across Europe. ENTSO-E was established by European TSOs with a mandate by the EU's Third Legislative Package for the Internal Energy Market in 2009, which aims at further liberalizing the gas and electricity markets in the EU.



Project 293 – Southern Aegean Interconnector (SAI): location and submarine interconnection system. (Source: https://tyndp.entsoe.eu/tyndp2018/projects/projects/293, http://igi-poseidon.com/en/poseidon).

Besides all, **AIGAIO** refers to submarine interconnection for renewable energy projects, as it relates to the Aegean project. This new transmission line is currently under EIA licensing process and will link the Aegean project to the mainland Greece and Crete. It will also allow the connection of non-interconnected Dodecanese island complex, the islands of Kos, Leros, Nisyros, Kalymnos and Tilos to the main grid. In this case among others, the development process of the project, requires studies as the abovementioned. Therefore, all three of the

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developed NEANIAS services are critical for the optimal development and designing of the project.

AIGAIO project's location and submarine interconnection system (source: www.eunice-group.com).

Last but not least, a further project that can be helpful as a case study, is the **Celtic Interconnector**. The Celtic Interconnector is a proposed electrical link, which if built will enable the movement of power between Ireland and France (http://www.eirgridgroup.com/). A series of joint studies into the feasibility of the interconnector have been carried out with the French TSO Réseau de Transport d'Électricité (RTE) since 2011. In 2014, a marine geophysical survey was undertaken, in which following completion of each geophysical survey, locations for geotechnical sampling were identified and an assessment was made as to the likelihood of encountering Unexploded Ordnances (UXO) during sampling based on Side Scan Sonar (SSS) and magnetometer data. Furthermore, in 2015, a geotechnical and benthic survey campaign was performed. During those surveys data referring to surficial seabed were collected. Additionally, a marine archaeological survey was conducted and geophysical and geotechnical survey data were collected over the proposed route corridors. This survey aimed to identify known and potential sites and features of archaeological interest in the cable survey corridor that might be impacted by the project. Such sites are considered critical for the cabling design because, due to their impact on the project, which dictates a subsequent limitation through the adoption of the appropriate mitigation measures.

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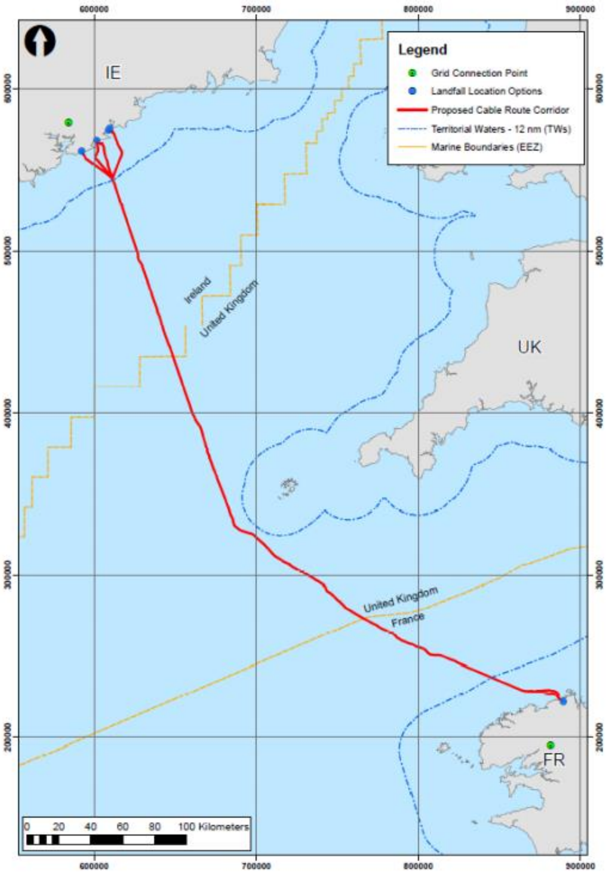

Celtic Interconnector Marine Route (Source: http://www.eirgridgroup.com/).

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2.3. Underwater Sector: Current Software and Services

State of art and Common practices

Underwater archaeology community

Most underwater archaeologists and research teams are using **Agisoft Photoscan/Metashape Professional edition® software** for the processing of the photogrammetric models. It is user-friendly, continuously updated and is offering an easy access to the students of archaeology and young researchers. Archaeological project are also low-budget and they are constrained to optimize results by collaboration with geoscientists, but also by using open access software.

In any case, Agisoft software is frequently used in order to produce orthogonal projections, sections and plans as supporting visual documentation in the framework of maritime research. However, many other different software are used for the pre- and post- processing of images and produced plans. For example, the underwater image pre-processing can be addressed from two different points of view: image restoration techniques or image enhancement methods, which do not require a priori knowledge of the environment (corrections such as non-uniform illumination, low contrast and muted colors) (Drap 2012b).

Thus, usual software includes **Abode Bridge®**, **Adobe Light-room®** and **Photoshop CS5®** to edit the color balance, the contrast, and the brightness properties of the photos. In a next step, generated 3D models of artefacts and structures and orthophotos extracted as 1:1 scaled top view photomosaics are used as the basis for drawing and tracing 2D and 3D site plans in other software, such **AutoCAD®** or **ArcGIS® or QGIS®** software, etc.

Therefore, one of the requirements from the underwater archaeology community would be to **produce a software** that could incorporate some of the above actions in order to reduce time and energy from the use of too many software for the pre- and post-processing operations.

Geologists, Oil & Gas engineers, Computer vision/machine learning engineers

Most scientists and in general R&D groups who are interested in underwater seabed classification of seafloor cover classes are using most of the times commercial software that is usually developed for land and land cover applications. These for example may include the commercial ENVIS or ERDAS Imagine software. The reason is that the aforementioned software is in most cases user-friendly and comes with a number of additional tools especially for supervised classification procedures and manual collection of training data/polygons. There are also a number of decent open source software and plugins, executing classification pipelines like the semi-automatic Classification Plugin of QGIS. It should be mentioned that currently, to the best of our knowledge, there does not exist any software developed and tailored for seabed classification based on multispectral multibeam. In particular, most seabed classification tasks are performed from R&D groups implementing custom solutions per task or dataset. An example was the recent R2Sonic Multispectral Challenge on which many researchers from different scientific domains tried to discriminate the geomorphological

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features of the seabed by using multispectral multibeam data and in order to do so they proposed different supervised classification procedures based on e.g. Gaussian Models or Support Vector Machines with linear kernels (Gaida et al. (2017), Brown et al. (2017), Buscombe & Grams (2018), Snellen et al. (2018)).

Oil & Gas engineers, Renewable Energy Planners

Planners regarding submarine transmission and pipelines are using computer-aided engineering software such as AutoCAD and GQIS for the processing of georeferenced data. AutoCAD software provides the user with plenty menu options that are useful in order to proceed with the planning phase. QGIS platform is really useful during the designing process as it allows the connection of many items and synchronized edit process of them. Using the standard QGIS interface, the user shall establish a set of demands on address points and finally provide the parameters necessary for further steps of the algorithm.

A basic condition for the proper use of the software is the quality of the data in terms of validity and accuracy of approach to their geographical location. During the abovementioned process, it is crucial that all the data are referenced in a suitable coordinate system with great precision.

In general, many other specific software may be used for the transmission design. One of those is the Electra software, which is a powerful power line CAD design software that combines design and documentation production workflows for electrical distribution design. It provides sophisticated design and analyzing tools to optimize transmission network designs in plan and profile. Moreover, the integrated use of Pls-Cadd (structure spotting) and Tower (structural analysis) software consists also a common practice. Furthermore, RSTAB (Structural Frame & Truss Analysis Software) software that is used to process data regarding the laying of the submarine cable at an intermediate water depth. A non-linear static analysis is initially conducted to build up the catenary configuration.

In general, the basic input parameters required in order to proceed with the designing of the cable route are the following:

- The water depth
- Distance from the sea level of the overboard chute at the CLV
- Geometry of the overboard chute onboard the CLV
- Bottom tension at the TDP
- Cable weight in water
- Cable weight in air
- Non-linear diagrams (reaction force N/deflection mm) for the cable–soil interaction in two directions (X, Y)
- Composite cable flexural stiffness
- Composite cable axial stiffness

U1 - Bathymetry Mapping from Acoustic Data

MB-System (Caress & Chayes, 2017) is running in-house at UBREMEN and worldwide in many other institutes and universities as a bathymetry and backscatter post-processing tool for MBES datasets. It is on a technology readiness level (TRL) 6, has been validated using different

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datasets from various vendors, and is under constant maintenance through the open source community. Furthermore, the package is capable to realize navigation correction for AUV/ROV recorded bathymetry. This is crucial not just for bathymetry but for other acquired datasets like CTD/Photos/Videos a.s.o.

Underwater-recorded bathymetry lacks of accuracy since GNSS/RTK (Global Navigation Satellite Service/Real Time Kinematics) information cannot be used directly. A number of devices is necessary to accurately steer and position underwater devices like AUV/ROV (Autonomous and Remotely working Vehicles). Next to GNSS & RTK, which can only be used directly on the sea surface, USBL/LBL and DVL (Ultra Short & Long Base Line under water positioning and Doppler Velocity Log) and even the revolutions per minute of the vehicles propellers are taken into account when solving the algorithms for positioning by utilizing Kalman filters during acquisition.

Still, the uncertainties are large unless the devices are operating very close to the seafloor and are capable to use photo/video information also for navigation decision making processes. This is rather seldom the case. Nevertheless, due to its numerous software dependencies, MB-System currently requires a deeper knowledge in the operating systems (Unix/Linux) and in the command line based installation and execution of the different packages.

Utilizing MB-System for bathymetric and backscatter post processing is a very sustainable solution but as a matter of consequence when using command line, it lacks of certain workflows and logging of what have been applied to the data. Therefor the user is obliged to document manually which commands he/she executed. A disadvantage with respect to metadata for quality standards or confidence levels.

U2 - **Seafloor Mosaicing from Optical Data**

The software for implementing U2 is currently running at in-house servers of CORONIS. The components required for this endeavor have been developed up to levels 5 (diagnostics task) and levels 6 (for the tasks of pre-processing and corrections, 2D mapping, 3D mapping). The final target for the NEANIAS project is to have it at TRL 8 at the end of the project.

Nevertheless, the current software requires a deeper knowledge on the different parameters needed to finally process the 2D photo-mosaic or the 3D representation (DTM). The challenge of the development behind this service is to make it robust to a wide range of input imaging conditions, which are representative of the intended science and commercial applications of the target user group. Making easy its use by non-experts.

U3 - Seabed Classification from Multispectral, Multibeam Data

U3 service focuses on the efficient exploitation of recent cutting-edge multibeam echosounders which go beyond the standard ones that collect backscatter at a single predefined frequency and can acquire backscatter at multiple spectral frequencies allows the acquisition of spatially and temporarily co-registered multispectral backscatter data offering capabilities for systematic and accurate mapping of the seabed. In contrast to similar R&D efforts in the proposed service different shallow and deep machine learning architectures will be further validated towards the classification of various seabed classes. An additional novelty lies in the optimization of a single classification model which will provide powerful pre-trained

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models for different sets of seabed nomenclatures. The validation process towards the targeted TRL8 will be intensive against a number of datasets (e.g., USA, Canada, Atlantic coast, Mediterranean, Santorini, Kolumbo) demonstrating in a comprehensive way the applicability and scalability of the proposed cross-cutting service on several application domains and user communities.

2.4. User Requirements for Underwater Services

The user requirements have been initially formed like ‘User Stories’. A User Story is an instrument used in Agile software development to capture a description of a software feature from an end-user perspective. The User Story describes the type of user, what they want and why. A User Story is very high level and helps to create a simplified description of a requirement. Usually a User Story provides in one sentence enough information related to the described product feature, for which the development team can conduct a reasonable work load estimation. Furthermore, the User Story is used in planning meetings to enable the development team to design and implement the product features.

A User Story typically has a predefined structure:

As a <user-type (stakeholder)>, I want to <user-requirement> so that <reason>

Id	End-User	User-requirement	Reason
R1	All targeted	Upload, store and possibly publish datasets of various formats	To process end-user data with different services and be able to store them and make them available to other users
R2	All targeted	Visualize raw data as well as resulting products and reports	For a first glance, viewing the raw/vendor data (map or mosaic etc.); inspect and evaluate the results
R3	All targeted	To (pre- or post) process the raw data and make any required calibration/ corrections (parametrizations)	To correct the data (e.g. image correction/photogrammetrically rectify/sound velocity correct/tide correction etc.)
R4	All targeted	Utilize high-computing power and ensure high-bandwidth access to the data	To solve demanding (post-)processing tasks operating on large inputs
R5	All targeted	Produce bathymetric maps, backscatter mosaics, photomosaics, multifrequency-based seabed classification maps and other related products	To perform archaeological, oil & gas, renewable energy, geological, geohazard and insurance related tasks
R6	All targeted	Document the workflow	For quality assurance, traceability, reproducibility and backlogging
R7	All targeted	Export the results in various file formats	Facilitate the exchange of datasets between users
R8	Archaeologist	To produce geospatial products/ maps with adequate precision from interdisciplinary datasets	In order to comprehend archaeological targets in datasets and fulfill archaeological survey requirements

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R9	Archaeologist	To have the possibility to review the georeference of a given dataset	To be able to understand the exact location of an archaeological target (such as a shipwreck) as datasets are georeferenced differently
R10	Archaeologist	To achieve very high spatial accuracy in the delivered products (e.g. to the millimeter)	In order for the result (mapping, 3D model) to be used as accurate archaeological documentation
R11	Archaeologist	To achieve high quality texture on the delivered products	For reconnaissance purposes: in order to be able to distinguish archaeological targets (shipwrecks from rocks, etc)
R12	Oil, Gas and Renewable Energy Engineer	Classify the seabed type	For the development of the design and installation of submerged tubes and transmission cables, the route design of the transmissioning cable and the appropriate selection of the submarine cable type
R13	Marine Geologist	Classify the seabed type and structure	To assess geohazards and study geological phenomena
R14	Robotics & Computer Vision Engineer	Plan AUV/ROV trajectories	For better AUV/ROV navigation as it is based on GPS, DVL and USBL/LBL information and often not accurate enough to be used right away for bathymetric or photogrammetric post processing

Then the aforementioned user stories/ requirements were linked with a level of priority and value based on end-user recommendations. Also, the manner to confirm their acceptance was also marked down.

Id	Priority	Value	Acceptance
R1	High	High	User Interface (UI)provides functionalities for uploading /downloading data, relying on a Data Transfer Service
R2	Medium	High	UI provides functionalities to visualize the data and the results
R3	High	High	The UI will support manual processing and apply suitable corrections to the data via graphical tools
R4	High	High	Data will be accessible from physically proximal locations and the developed algorithms will allow when required parallel processing and exploitation of any available GPGPU resources
R5	High	High	Implement thematic services that either as stand-alone or in combination produce the required final products
R6	Medium	High	Provide proper support to the logging, backlogging, auditing and accounting functionalities offered by the core services
R7	Low	Medium	Implement data serialization processes supporting several widely-used data formats. Rely on a Data Transfer Service for storing and publishing.

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R8	Medium	Medium	Provide detailed reporting and evaluation information to assess the quality of the produced results
R9	Low	Medium	Implement Georeference[1] related data inspection and quality assurance mechanisms
R10	Medium	Medium	Provide detailed reporting and evaluation information to assess the quality of the produced results
R11	Medium	Medium	Rely on interactive visualization methods/services for quality assurance
R12	High	High	The service will be able to produce the classified seabed map
R13	Medium	High	The service will be able to produce the classified sea as well as geomorphological features when appropriate
R14	Medium	Medium	The service will be able to deliver photomosaics which will aid underwater navigation tasks

1 Any valid georeferncing method will be supported, i.e. geographic or projected coordinate systems accompanied with the corresponding datum and projection method.

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3. Co-design and Service Specifications

This section presents the specifications for the underwater services in view of the requirements communicated by the users in the previous section.

The service requirements have initially been arranged according to their type. Five distinct categories have been recognized, more specifically: storage, computing, cloud, functional and quality requirements. The first two are related to the access and usage of storage and computing resources by the services. Cloud requirements rely on the features of the cloud infrastructure which will host the service while functional requirements regard specific features to be made available from the services. The quality requirements are necessary for assessing the quality of the services' results.

Another significant aspect while co-designing the specifications of the underwater services is their ranking. This ranking is based on the feasibility and the effort required to satisfy the requirement in relation to the corresponding value expressed by the users in the Tables presented in Section 2.4. Accordingly, each specification has been described as mandatory, convenient or optional. Convenient specifications are interpreted as to be offered, unless in exceptional cases due to limited effort and/or time constraints.

The following table presents the specifications of the underwater services which have been defined to address the user requirements (Section 2.4). The table presents the description of each requirement, its type and ranking according to the aspects described above, a detailed description of the specifications which have been defined for satisfying the corresponding requirement and, finally, the underwater services which should respect the specification. The specifications S01, S02, S08, S09, S10 and S11 have been ranked as “mandatory”, specifications S03, S04, S06, S12, S14 and S15 as “convenient” and specifications S05, S07 and S13 as “optional”.

Requirement			Ranking	**Specifications**		
Req #	Requirement	Type of Req(Computing / Storage / Cloud/ etc.)	Mandatory / Convenient /Optional /	Spec #	Description of the required functionalities, software specification	Addressed by the Underwater Service
R01	Upload, store and possibly publish datasets of various formats	Storage	Mandatory	S01	Interface with suitable Data Transfer NEANIAS/EOSC services for uploading / downloading data to medium / long storage locations through well-known protocols (FTP, WebDAV, etc.) and make data FAIR when applicable	U1, U2, U3
R02	Visualize raw data, resulting products and reports	Functional	Mandatory	S02	Each Underwater service implements task-specific reporting mechanisms	U1, U2, U3
		Functional	Convenient	S03	Interface with NEANIAS visualization services for visualizing raw data and results	U1, U2, U3

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R03	To (pre- or post) process the raw data and make any required calibration / corrections	Computing	Convenient	S04	Implement customizable, parametrized pipelines for pre- and post-processing the raw data	U1, U2, U3
		Computing	Optional	S05	Interface with external services for task-specific processing	U1, U2, U3
R04	Utilize high-computing power and ensure high-bandwidth access to the data	Computing	Convenient	S06	Design and develop core services based on parallel computing and/or using GPGPU infrastructure	U1, U2, U3
		Storage	Convenient	S01	Interface with a NEANIAS data storage service for transferring data to a physically proximal location for ensuring high-bandwidth access during processing	U1, U2, U3
		Cloud	Optional	S07	Interface with core NEANIAS services during service instantiation for requesting suitable computational resources	U1, U2, U3
R05	Produce bathymetric maps, backscatter mosaics, photomosaics, multifrequency-based seabed classification maps and other related products	Computing	Mandatory	S08	Produce bathymetric maps and backscatter mosaics from multibeam echosounders.	U1
		Computing	Mandatory	S09	Produce photomosaics and 3D models from underwater image datasets	U2
		Computing	Mandatory	S10	Produce multifrequency-based seabed classification maps from multi-dimensional data	U3
R06	Document the workflow	Cloud	Mandatory	S11	Underwater services implement suitable logging mechanisms and store meta-data describing the service parametrization	U1, U2, U3
		Cloud	Convenient	S12	Interface with AAI, auditing and other relevant NEANIAS services for collecting user-related information	U1, U2, U3
		Storage	Mandatory	S01	Interface with NEANIAS data transfer and other relevant services for storing and publishing logs and the workflow related meta-data	U1, U2, U3
R07	Export the results in various file formats	Functional	Optional	S13	Each service offers option to serialize the produced data in widely used file formats	U1, U2, U3
		Storage	Mandatory	S01	Interfaces with NEANIAS data transfer services for storing the output data on suitable storage locations	U1, U2, U3
R08	To produce geospatial products/ maps with adequate with precision from interdisciplinary datasets	Quality	Mandatory	S09	Produce photomosaics and 3D models from underwater image datasets	U2
		Quality	Mandatory	S02	Provide through the reporting mechanism suitable evaluation metrics for assessing the quality of the products	U1, U2, U3
R09	To have the possibility to review the geo-reference of a given dataset	Functional	Convenient	S14	Provide textual feedback in the UI summarizing geo-reference of the data	U1, U2, U3
		Quality	Convenient	S03	Interface with NEANIAS visualization services for visual feedback on the geo-reference of the data	U1, U2, U3
R10	To achieve very high spatial accuracy in the delivered products (e.g. to the millimeter)	Quality	Mandatory	S09	Produce photomosaics and 3D models from underwater image datasets	U2
		Quality	Mandatory	S02	Provide through the reporting mechanism suitable evaluation metrics for assessing the quality of the products	U1, U2, U3
R11	To achieve high quality texture on the delivered products	Quality	Mandatory	S02	Provide through the reporting mechanism suitable evaluation metrics for assessing the quality of the products	U1, U2, U3

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		Quality	Convenient	S03	Interface with NEANIAS visualization services for visually assessing the quality of the products	U1, U2, U3
R12	Classify the seabed type	Computing	Mandatory	S10	Produce multifrequency-based seabed classification maps from multi-dimensional data capturing different seabed soil types (e.g. rock, mud, sand, clay, etc.)	U3
		Functional	Convenient	S03	Interface with NEANIAS visualization services for visualizing the produced maps	U1, U2, U3
R13	Classify the seabed type and structure	Computing	Mandatory	S10	Produce multifrequency-based seabed classification maps along with any possible geomorphological information	U3
		Functional	Convenient	S03	Interface with NEANIAS visualization services for visualizing the produced maps	U1, U2, U3
R14	Plan AUV/ROV trajectories	Functional	Mandatory	S08	Produce bathymetric maps and backscatter mosaics from multibeam echosounders.	U1
		Functional	Convenient	S15	Aid the navigation of underwater agents by providing spatially accurate photomosiacs	U2

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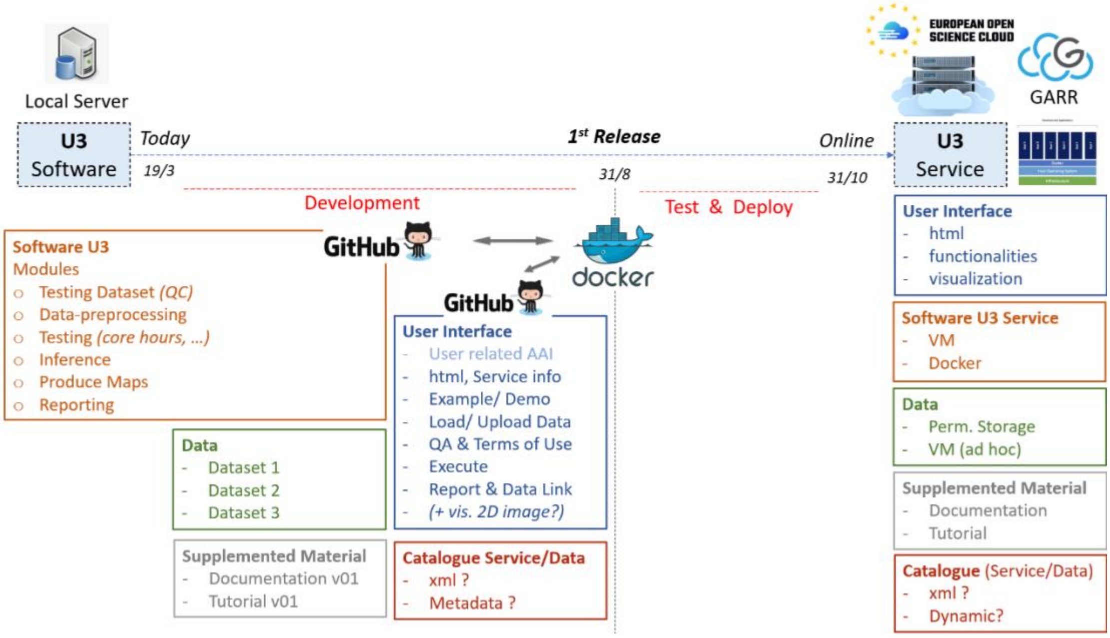
4. Software Development Plan and Guidance

The following figure presents the different software components and modules that are currently developed and validated for the U3 service but also reflects the work and similar deployment architecture of all underwater services. In general, the software and service development cycle of the underwater services will closely observe the recommendations and guidelines developed in the context of WP7 (see deliverable D7.1 for details). Moreover, regarding the aspects of service instantiation, registration to the service catalogue and integration to EOSC, the processes defined within WP6 will be followed, as described in more detail in deliverable D6.1.



The different components towards the deployment of the U3 service to EOSC including the core software, the user interface, the service/data catalogue as well as the data and supplemented material.

Moreover, the common Software Release Plan for all underwater services will adopt the following time plan:

31/8/2020 - **1st** release

31/7/2021 - **2nd**release

28/2/2022 - **3nd** release

4.1. [U1] Bathymetry mapping from acoustic data service implementation

U1 Software Development Plan and Guidance

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Software development effort	The main effort is a user-friendly version of MB-System inside a Jupyter Notebook for processing of acoustic multibeam data for it 1st release (M12). The focus will be on * creating the cloud-based infrastructure to upload data, create a secure and isolated user-space and download the result * create a workflow for the user from raw data via filtered cleaning to (pre-)processed raster data (grid) * a User Interface will be designed along with its functionalities.
Processing Pipeline, Software Inputs and Output	Pipeline: 1. Data upload and raw data view 2. Post processing, data correction 3. Creating products Inputs: Multibeam raw data Outputs: 3D grids/digital terrain models (DTM), 2D images/mosaics (from bathymetry and backscatter)
User Interface	Main functionalities required: 1. Upload data 2. Create a secure single/multi-user space for data processing 3. Have a workflow-interface that guides the user step by step through parameters and settings in order to choose filtering & other post processing options 4. (optional: allow/realize a remote GUI to edit data manually& to do navigation correction for AUV/ROV recorded bathymetry) 5. Display raw and processed data 6. Download processed data and outputs/products
Software Dependencies/ required libraries	✓ Operating System Requirement: Ubuntu 18.04 LTS or 20.04 LTS ✓ MB-System ✓ Jupyter Notebook ✓ GMT 5 ✓ Python 3 ✓ GDAL ✓ NetCDF ✓ Proj ✓ OTPS (Oregon State University Tide Prediction Software) ✓ Docker

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Software Deployment In The Cloud	UBREMEN will deliver the software in containerized form for easy deployment and re-use **Docker** open source container U1 software package plus libraries and dependencies

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4.2. [U2] Seafloor mosaicking from optical data service implementation

U2 Software Development Plan and Guidance	
Software development effort	The main effort is to create a docker image for processing optical data. The focus will be on: * creating the cloud-based infrastructure to upload data, create a secure and isolated user-space and download the result * create a workflow for the user for quality assessment, data preprocessing, mosaicking and 3D representation
Processing Pipeline, Software Inputs and Output	Pipeline: (1) Upload image set (and, optionally, camera calibration information and/or navigation data). Includes checking validity of input formats. (2) Pre-processing, individual image enhancement (3) Quality assessment (4) Pair-wise feature matching (5) Global Alignment (6A) If a 2D map is required: 6A.1. Blend images. 6A.2. Render the output image map. (6B) If a 3D map is required: 6B.1. Dense point set reconstruction. 6B.2. Surface reconstruction. 6B.3. Texture mapping. Inputs: Images, Navigation data, Camera Calibration Data Outputs:2D images/mosaics, 3D reconstructions
User Interface	Main functionalities required: 1. Upload data. 2. Create a secure single/multi-user space for data processing. 3. Interface allowing the user to set-up the parameters for each step in the processing pipeline. 4. Display raw and processed data. 5. Download processed data and outputs/products.
Software Dependencies/ required libraries	✓ Operating System Requirement: Ubuntu 18.04 LTS

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	✓ OpenCV ✓ Ceres ✓ Eigen ✓ Boost ✓ CGAL ✓ PCL ✓ OPENMVG ✓ OPENMVS
Software Deployment In The Cloud	CORONIS will deliver the software in containerized form for easy deployment and re-use via a **Docker** open source container. This docker will embed all U2 software packages, libraries and their dependencies.

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4.3. [U3] Seabed classification from multispectral, multibeam data service implementation

U3 Service - MapSEABED	
Current state	The software for implementing U3 is currently running at in-house servers of ATHENA and NKUA. Has been already validated for the datasets presented
Software development effort (next year)	The main effort will be concentrated on experiment with all collected datasets and the choice of the optimal machine learning framework for the 1st release (M12). Important effort will be allocated for data annotation. Not much effort in algorithm optimization is expected. Moreover, the User Interface will be designed along with its functionalities.
Processing Pipeline, Software Inputs and Output	Pipeline: 1) Data preprocessing 2) Training 3) Inference Inputs: Multispectral, multibeam data (a) different multibeam frequencies as separate files i.e. 2D images or (b) 3D image files, each band as a different image layer Outputs: 2D image – each pixel has a label that indicates the seafloor type/ class
User Interface	Main Functionalities required: • Data selection or upload • Visualize raw data • Select inference and class nomenclature • Visualize result/ map • Download result/ map
Software Dependencies/ required libraries	• GDAL • NumPy, SciPy • scikit-image • scikit-learn • Keras • tensorflow • Torch, PyTorch

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	• OpenCV
Software Deployment In The Cloud	ATHENA and NTUA will deliver the software in a containerized form Docker open-source container U3 software package together with libraries and other dependencies

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5. Evaluation – Conclusions – Future Steps

This deliverable summarizes and contextualizes the team effort during the last 6 months for defining the services requirements of the end-users communities for implementing the services of the underwater sector. These requirements have been identified, and assessed in order to set the co-design and service specifications for the software development plan on the three innovative EOSC services that NEANIAS will implement.

A quantity of interdisciplinary databases of case-studies of the end-users communities were collected and analyzed. The partners of NEANIAS shared discussions between the team, but also got feedback from external partners and colleagues that are using current services and potentially they will benefit of NEANIAS novel EOSC services. One of the assessments of the collected data and, in a second step, the definition of 14 requirements (R1-R14) is that a big part of the end-users communities share common needs as far as the analysis and the documentation of the seabed morphology and swath surveys is concerned. These requirements in the scientific analysis are fundamental regardless of the individual objectives of each research and underwater survey: From ocean circulation, to environmental issues and underwater geohazards to the promotion of underwater cultural heritage to cable and pipe routing and oil and gas exploration, all user-end communities share the same or equivalent requirements from the NEANIAS underwater software services.

In many aspects, this means that the NEANIAS EOSC services, currently under implementation, have the potential of being useful, if not indispensable, to a great majority of the scientific underwater community internationally, regardless of different scientific goals and approaches for specific final results and products. Underwater archaeologists, marine geologists, environmental scientists and energy developers share common requirements regarding the services to be developed, as the analysis of the user requirements revealed. Therefore, through this task we were able to reach one of the goals of our work, and demonstrate the applicability of the new cross-cutting services for diverse user-communities.

However, where some case-studies showed discrepancies in requirements, we aimed at a unified approach in order to co-design services reflecting the more broad needs. At the same time, we also tried to address specific needs and products, through personalized use of the services, when this is possible.

The future steps are already defined by the description of the required functionalities and the corresponding software development plan needed for each service, as well as the detailed allocation of tasks. The next steps continue with the work towards the first release of the services, followed by the first evaluation and assessment by the end-user community and the external advisors.

It is a great advantage that the end-users partners of NEANIAS are providing unpublished new databases, namely data from underwater archaeological research, environmental and marine surveys, as well as big development projects of the renewable energy companies. All new datasets, will provide a first valuable feedback in the first release of the NEANIAS innovative services, that is the next step of our project.

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References

1) Bailey G, Galanidou N, Peeters H, Jöns H, Mennenga M (2020) *The Archaeology of Europe's Drowned Landscapes*. Part of the Coastal Research Library book series (COASTALRL, volume 35).
2) Bailey G. N (2009) The Red Sea, Coastal Landscapes, and Hominin Dispersals. In *The Evolution of Human Populations in Arabia*. Part of the Vertebrate Palaeobiology and Palaeoanthropology. Springer, Dordrecht, Netherlands, pp: 15-37.
3) Bailey G. N et al. (2007) Coastlines, Submerged Landscapes, and Human Evolution: The Red Sea Basin and the Farasan Islands. In *The Journal of Island and Coastal Archaeology.* ISSN: 1556-4894 print / 1556-1828, DOI: 10.1080/15564890701623449, pp: 127-160.
4) Brown C and Varma H (2017) Multispectral Seafloor Classification: Applying a Multidimensional Hypercube Approach to Unsupervised Seafloor Segmentation. *R2Sonic Multispectral Backscatter Competition Entry*.
5) Buscombe D and Grams P E (2018) Probabilistic Substrate Classification with Multispectral Acoustic Backscatter: A Comparison of Discriminative and Generative Models. In *Geosciences,* 8(11), 395.
6) Caress D. W and Chayes D. N (2017) MB-System Seafloor Mapping Software, https://www.mbari.org/products/research-software/mb-system
7) Doneus M et al. (2015) Airborne Laser Bathymetry for Documentation of Submerged Archaeological Sites in Shallow Water. In *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XL-5/W5, 2015 Underwater 3D Recording and Modelling, 16–17 April 2015, Piano di Sorrento, Italy, pp: 99-107.
8) Drap P (2012) Underwater photogrammetry for archaeology. In *Carneiro Da Silva D (ed) Special applications of photogrammetry*, http://www.intechopen.com/books/special-applications-of-photogrammetry/ underwater-photogrammetry-for-archaeology. 16 Oct 2012, pp: 111–136.
9) Drap P et al. (2012b) Underwater image pre-processing for automated photogrammetry in high turbidity water. In *18th International Conference on Virtual Systems and Multimedia* Milan, Italy.
10) Drap P, Merad D, Hijazi B, Gaoua L, Nawaf MM, Saccone M, Chemisky B, Seinturier J, Sourisseau J-C, Gambin T and Castro F. (2015). Underwater photogrammetry and object modelling: a case study of Xlendi Wreck in Malta. *Sensors* **15**: 30 351–30 384.
11) Fakiris E, Papatheodorou G, Geraga M, Ferentinos G (2016) An Automatic Target Detection Algorithm for Swath Sonar Backscatter Imagery, Using Image Texture and Independent Component Analysis. In *Remote Sensing Journal*, 29 April 2016, Vol.8, pp: 373-386.
12) Ferentinos G et al. (2020) Optimal sidescan sonar and subbottom profiler surveying of ancient wrecks: The 'Fiskardo' wreck, Kefallinia Island, Ionian Sea. In *Journal of Archaeological Science* 113:105032. January 2020, DOI: 10.1016/j.jas.2019.105032, pp: 1-11.

D2.1 Requirements, Specifications & Software Development Plan for Underwater Services.D2.1 Requirements, Specifications & Software Development Plan for Underwater Services.

13) Flemming N C. et al. (2014) Land Beneath the Waves Submerged landscapes and sea level change, A joint geoscience-humanities strategy for European Continental Shelf Prehistoric Research, position Paper 21, www.marineboard.eu, v.1 October 2014.
14) Gaida T C et al. (2017) A Multispectral Bayesian Classification Method for Increased Acoustic Discrimination of Seabed Sediments using Multi-Frequency Multibeam Backscatter Data. In *Geosciences,* 8(10), 455.
15) Gambin T (2014) Side Scan Sonar and the Management of Underwater Cultural Heritage. In *Future Preparedness: Thematic and Spatial Issues for the Environment and Sustainability*, DOI: 10.13140/2.1.2672.2242, January 2014, pp: 259-270.
16) Gambin T (2015) A Phoenician shipwreck off Gozo, Malta. In *The Journal of the Archaeological Society*, Malta, ISSN 2224-8722, pp: 69-71.
17) Gambin T, Drap P, Cheminsky B, Hyttinen K, Kozak G (2018) Exploring the Phoenician shipwreck off Xlendi bay, Gozo. A report on methodologies used for the study of a deep-water site. In *Underwater Technology; The International Journal of the Society for Underwater*. November 2018, Vol. 35, No. 3, pp: 71–86.
18) Geraga F et al. (2015) The Disappearance of Helike-Classical Greece-New Remote Sensing and Geological Evidence. In *Remote Sensing Journal,* 2015, vol. 7 issue 2, pp: 1263-1278.
19) Gron O et al. (2015) Detection and mapping of shipwrecks embedded in sea-floor sediments. In *Journal of Archaeological Science*, DOI: 10.1016/j.jasrep.2015.09.005, pp: 242-251.
20) Loher M, Pape T, Marcon Y et al (2018) Mud extrusion and ring-fault gas seepage – upward branching fluid discharge at a deep-sea mud volcano. In *Scientific Reports volume*8**,** 6275 (2018). https://doi.org/10.1038/s41598-018-24689-1
21) McCarthy J. K and Benjamin J (2014) Multi-image photo-grammetry for underwater Archaeological site recording: an accessible, diver-based approach, In *Journal of Maritime Archaeology* 9: pp: 95–114.
22) McCarthy J. K, Benjamin J, Winton T, Duivenvoorde W (2018) *3D Recording and Interpretation for Maritime Archaeology*. ISSN 2211-0585 (electronic) Coastal Research Library, USA.
23) Menna F et al. (2018) Improving underwater accuracy by empirical weighting of image observations. In *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XLII-2,* 2018, Riva del Garda, Italy, pp: 699-705.
24) Missiaen T, Sakellariou D and Flemming C. N (2017) Survey Strategies and Techniques in Underwater Geoarchaeological Research: An Overview with Emphasis on Prehistoric Sites. In *Under the Sea: Archaeology and Palaeolandscapes of the Continental Shelf, Coastal Research Library 20,* DOI: 10.1007/978-3-319-53160-1_2, pp: 21-37.
25) Nikolakopoulos K. G, Sardelianos D, Fakiris E, Papatheodorou G (2019) New perspectives in coastal monitoring. In *Proceedings Volume 11156, Earth Resources and Environmental Remote Sensing/GIS Applications* X; 1115602 (2019) https://doi.org/10.1117/12.2533163. SPIE Remote Sensing, 2019, Strasbourg, France, pp: 1-11.

D2.1 Requirements, Specifications & Software Development Plan for Underwater Services.D2.1 Requirements, Specifications & Software Development Plan for Underwater Services.

26) Nomikou P, Papanikolaou D, Alexandri M, Sakellariou D, Rousakis G (2013) Submarine volcanoes along the Aegean volcanic arc. In *Tectonophysics,* vol. 597–598, pp: 123-146. https://doi.org/10.1016/j.tecto.2012.10.001
27) Papatheodorou G et al. (2014) A marine Geoarchaeological survey, Cape Sounion, Greece: preliminary results. In *Mediterranean Archaeology and Archaeometry*, Vol. 14, No 1, pp: 357-371.
28) Papatheodorou G, Geraga M and Ferentinos G (2008) The Reconstruction of Prehistoric shorelines in Dokosisland, Aegean Sea, using remote sensing Techniques. In *BAR International Series* 1746, ISBN 978 1 4073 0188 4, pp: 65-71.
29) Papatheodorou G, Geraga, M, and Ferentinos G (2005) The Navarino Naval Battle Site, Greece. An Integrated Remote-Sensing Survey and a Rational Management Approach. In *International Journal of Nautical Archaeology* 34(1), pp: 95-109.
30) Passaro S et al. (2013) Multi-resolution morpho-bathymetric survey results at the Pozzuoli–Baia underwater archaeological site (Naples, Italy). In *Journal of Archaeological Science,* vol. 40, issue 2, pp: 1268-1278.
31) Penrose J. D, Siwabessy P. J. W, Gavrilov A, Parnum I, Hamilton L. J, Bickers A, Brooke B, Ryan D. A and Kennedy P (2005) *Acoustic Techniques for Seabed Classification. CRC Coastal Zone Estuary and Waterway Management, Australia, 2005.*
32) Sakellariou D (2007) Remote sensing techniques in the search for ancient shipwrecks: How to distinguish a wreck from a rock in geophysical recordings. In *Bulletin of the Geological Society of Greece* XXXVII, pp: 1845–1856.
33) Schnyder J, Eberli G, Kirby J et al (2016) Tsunamis caused by submarine slope failures along western Great Bahama Bank. In *Scientific Reports* volume 6, Article number: 35925.https://doi.org/10.1038/srep35925
34) Seinturier J, Drap P, Durand A, Cibecchini F, Vincent N, Papini O, Grussenmeyer P (2008) Orthophoto imaging and GIS for sea bed visualization and underwater archaeology. In *HAL Id: halshs-00264017,* Prato, Italy, pp: 1-6.
35) Snellen M et al. (2019) Performance of Multibeam Echosounder Backscatter-Based Classification for Monitoring Sediment Distributions Using Multitemporal Large-Scale Ocean Data Sets. In *IEEE Journal of Oceanic Engineering*, vol. 44, no. 1, pp. 142-155.
36) Wienberg C, Wintersteller P, Beuck L, and Hebbeln D (2013) Coral Patch seamount (NE Atlantic) – a sedimentological and megafaunal reconnaissance based on video and hydroacoustic surveys. In *Biogeosciences,* vol. 10, issue 5, pp: 3421–3443. https://doi.org/10.5194/bg-10-3421-2013
37) Yamafune K, Torres R and Castro F. (2017). Multi-image photogrammetry to record and reconstruct underwater shipwreck sites. In *Journal of Archaeological Method Theory 24*, pp: 703–725.
38) Zhu B, Wang X, Chu Z, Yang Y and Shi J (2019) Active Learning for Recognition of Shipwreck Target in Side-Scan Sonar Image. In *Remote Sensing Journal 2019*, 11, 243; doi:10.3390/rs11030243, pp: 243-265.

Renewable Energy, oil and gas Projects (Links):

Priority habitat of Directive 92/43 / EEC :
https://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm

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Submarine cables and the oceans: connecting the world :https://www.unep-wcmc.org/resources-and-data/submarine-cables-and-the-oceans--connecting-the-world

International Cable Protection Committee: https://www.iscpc.org/

https://ted.europa.eu/TED/notice/udl?uri=TED:NOTICE:500453-2018:TEXT:EN:HTML&src=0

http://ec.europa.eu/energy/maps/pci_fiches/pci_7_3_3_en_2017.pdf

https://tyndp.entsoe.eu/tyndp2018/projects/projects/293

Aegean Project: http://eunice-group.com/projects/aegean-project/

Submarine Cable Map : https://www.submarinecablemap.com/

List of acronyms

Acronym	Description
PI	Principal Investigator (a researcher, an engineer, a manager…)
UCH	Underwater Cultural Heritage
AUV	Autonomous Underwater Vehicle
ROV	Remote Operated Vehicle
HVCD link	High Voltage Direct Current
MBES	Multi-Beam Echo-Sounder
MB-System	(Multi-beam) system (Software package)
DTM	Digital Terrain Model
RMS	Reconnaissance Marine Survey

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6. Appendix

From the list of End-users outside NEANIAS Consortium, a number of specialists (Mainly institutions: A1, A9, A10, A19) provided valuable feedback on the requirements of the considered Underwater Services and contributed to this deliverable. More external advisors will be consulted in the assessment of the first release of the EOSC Underwater Services.

#	Associated Entities/ Networks/ Initiatives/ User Communities
A1	Marine Geosciences Group – Institut de Physique du Globe de Paris (**IPGP**) - CNRS - France
A2	Earthquake Planning & Protection Organization (**EPPO**) - Ministry of Infrastructure and Transport - Greece
A3	Geodynamic Institute (**GI**) of National Observatory of Athens (NOA) - National Tsunami Early Warning Center (NTEWC) - Greece
A4	National Tsunami Early Warning Center (**NTEWC**) NOA – Greece
A5	Hellenic Plate Observing System (**HELPOS**) - NOA - Greece
A6	Square Kilometre Array (**SKA**) Organization - UK
A7	**GEANT** pan-European network (www.geant.org)
A8	Greek Research and Technology Network S.A. (**GRNET** S.A.) - Greece
A9	United Nations Educational, Scientific and Cultural Organization (**UNESCO**)
A10	**DRASSM** - Ministère de la Culture - France
A11	Greek Copernicus Relay Network - Space Cluster (**Si-Cluster**) Corallia - Greece
A12	United Nations - Sustainable Development Solutions Network (**UN-SDSN**) - Greece
A13	EIT **Climate-KIC** Hub Greece
A14	**LifeWatchGreece** Research Infrastructure - Greece
A15	**OpenAIRE**https://www.openaire.eu/
A16	International Lithosphere Program **(ILP)** https://www.scl-ilp.org/
A17	Democritus Research Center (**DRC**) - Greek representing for **ICOS** RI (Integrated Carbon Observation System Research Infrastructure) &**ACTRIS** (Aerosol, Clouds and Trace Gases RI)
A18	National Institute of Oceanography and Applied Geophysics (**OGS**) - Italy
A19	EDF ÉnergiesNouvelles (**EDF**) - France https://www.edf-renouvelables.com/en/

	External Advisors (EA) / Members of Extended Strategic Steering Committee (ExSSC)
1	**Dr Jorge Sanchez-Papaspiliou**, Member of the **si-Cluster** Steering Board, Chief Strategy & Financial Officer, Corallia, Greece
2	**Dr. Yan Grange**, LOFAR Software Developer, member of **Science Data Centre** at ASTRON, the Netherlands Institute for Radio Astronomy

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3	**Dr Javier Escartin**, Head of the Marine Geosciences Group, Institute de Physique du Globe de Paris - **CNRS** -France
4	**Prof. Paul D. Williams,** Professor of Atmospheric Science, University of Reading (**UoR**), UK
5	**Dr. Gergely Sipos**, Customer and Technical Outreach Manager, **EGI** / member of the EOSC-hub Engagement team
6	**Dr. Sofia Vallecorsa**, Computer Engineer, **CERN**openlab
7	**Dr. Paolo Diviacco,** Coordinator of the **OGS DIAM-PROS** unit, Vice-director of the RIMA (marine research and technologies) department of the OGS.
8	**Dr. Vicki Ferrini**, Marine Geology & Geophysics - Columbia University - USA