The NEANIAS project
Bathymetric mapping and processing goes cloud

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The project Novel EOSC Services for Emerging Atmosphere, Underwater & Space Challenges (NEANIAS) targets Open Science practices, finally deployed through the European Open Science (EOSC) hub. From a technological perspective, NEANIAS aims to deliver innovative thematic services that are flexible and open to accommodate the needs of communities beyond their original definition, and able to adapt to neighbouring cases, fostering reproducibility and reusability. The underwater service UW-Bat, one out of nine thematic services, utilises the open source suite MB-System to realise cloud-based bathymetry mapping and processing. The fast, uncomplicated, web-based and thus platform-independent service allows professionals and amateurs alike to easy access the world of bathymetry.

European Open Science Cloud | EOSC hub | cloud-based service | MB-System | Docker container
European Open Science Cloud | EOSC-Hub | cloudbasierter Dienst | MB-System | Docker-Container

Das Projekt Novel EOSC Services for Emerging Atmosphere, Underwater & Space Challenges (NEANIAS), das Akronym steht für altgriechisch »Junger Mann«, bewirbt die offene und freie Wissenschaft und spielt eine aktive und beispielhafte Rolle in der Umsetzung des European Open Science (EOSC)-Ökosystems. Vom technischen Standpunkt aus betrachtet zielt NEANIAS auf die Veröffentlichung von thematischen Diensten ab, die sich flexibel an die Bedürfnisse der verschiedenen Interessensgemeinschaften anpassen können. Dazu gehört die Möglichkeit zur Adaption und eine Förderung der Reproduktion und Wiederverwendbarkeit, ganz im Sinne einer nachhaltigen Verwendung. Der Unterwasser-Service UW-Bat, einer von insgesamt neun Diensten, benutzt die Open-Source-Suite MB-System, um eine cloudbasierte Prozessierung und Generierung von bathymetrischen Karten zu ermöglichen. Der schnelle, unkomplizierte, webbasierte und damit plattformunabhängige Dienst erlaubt Profis und Amateuren gleichermaßen den Zugang zur Welt der Bathymetrie.

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Introduction

The NEANIAS Project
As an EU Research and Innovation Action, NEANIAS (neanias.eu) is a project that comprehensively addresses the »Prototyping New Innovative Services« challenge set out in the »Roadmap for European Open Science Cloud« (EOSC) foreseen actions. It drives the co-design, delivery and integration into EOSC of innovative thematic and core services. While the thematic services are derived from state-of-the-art research assets and practices in three major sectors: underwater, atmospheric and space research, the core services will deliver reusable cross-sector services that are generic yet able to be further exploited and specialised both from internal NEANIAS as well as external, other parties' services. In each sector it engages a diverse set of research and business groups, practices and technologies which will design, develop and validate the services towards a qualified cloud-based solution.

The project started in November 2019 and is funded by the European Union under the Horizon 2020 research and innovation programme, via grant agreement No. 863448. Within NEANIAS, a total of ten work packages (WPs) were defined in order to fulfil the challenge. Every of the 21 partners works in several of the WPs shown in Fig. 1.

A brief overview describes the nine thematic, as well as the core services, respectively the content of WP2, 3, 4 and 6.

The thematic services
Underwater thematic services (Fig. 2)
The Bathymetry Mapping (UW-BAT) from Hydroacoustic Data service will deliver an advanced user-friendly, cloud-based version of the popular open-source software MB-System, utilised for post-processing bathymetry and seafloor backscatter.

The Seafloor Mosaicing (UW-MOS) from Optical Data service aims to provide an operational solution for large area representation (in the order of tens of thousands of images) of the, predominantly flat, seafloor also addressing visibility limitations from the underwater medium.
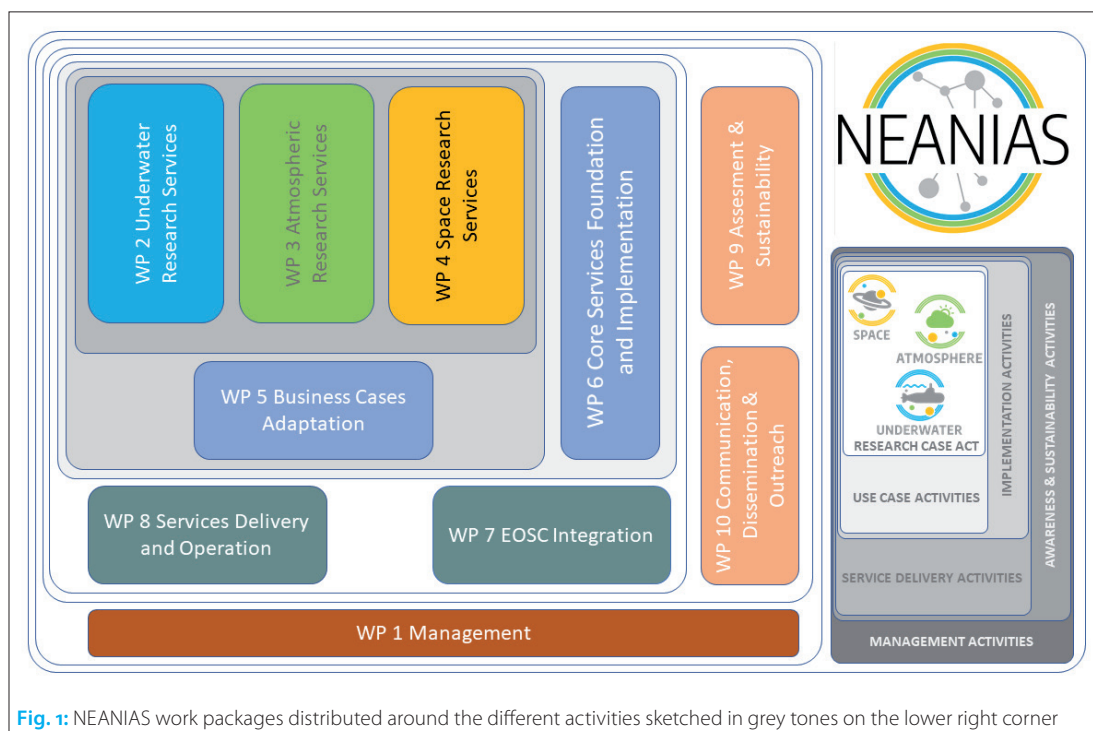
Fig. 1: NEANIAS work packages distributed around the different activities sketched in grey tones on the lower right corner

The Seabed Classification (UW-MM) from Multispectral, Multibeam Data service will deliver a user-friendly cloud-based solution integrating cutting-edge machine learning frameworks for mapping several seabed classes, validated for archaeological, geohazards, energy and other applications.

Atmospheric thematic services
The Greenhouse Gases Flux Density Monitoring service will deliver an operational workflow for estimating flux density and fluxes of gases, aerosol, energy from data obtained from specifically set meteorological stations, validated towards standardised, regularised processes.

The Atmospheric Perturbations and Components Monitoring service will perform all required analytics of atmospheric and meteorological data to estimate possible correlations of gaseous and particulate components of the atmosphere with earthquake and volcanic processes.

The Air Quality Estimation, Monitoring and Forecasting service will deliver a novel cloud-based solution providing crucial information and products to a variety of stakeholder in agriculture, urban/city authorities, health, insurance agencies and relative governmental authorities.

Space thematic services
The FAIR Data Management and Visualisation service will provide an advanced operational solution for data management and visualisation service for space FAIR data based on widespread and popular tools like VisIVO, ADN and PlanetServer.

The Map Making and Mosaicing of Multidimensional Space Images service will deliver a user-friendly cloud-based version of the already existing workflow for map making and mosaicing of multidimensional map images based on open source software such as Unimap and Montage.

The Structure Detection on Large Scape Maps with Machine Learning service will deliver a user-friendly cloud-based solution for innovative structure detection (e.g. compact/extended sources, filaments), extended the popular CAESAR/CuTEx tools with machine learning frameworks.

Core reusable services
The Open Science life cycle support service enables on one hand NEANIAS integration with EOSC hub and on the other hand also providers, services and users to publish and locate resources in need (be it data and services) as well to validate data in a machine assisted user-driven manner.

EOSC hub cloud integration service allow other NEANIAS services to integrate with other services and resource providers and consume and share storage, computation, service and data resources.

AI (artificial intelligence) service provides a reusable substrate for machine learning and other
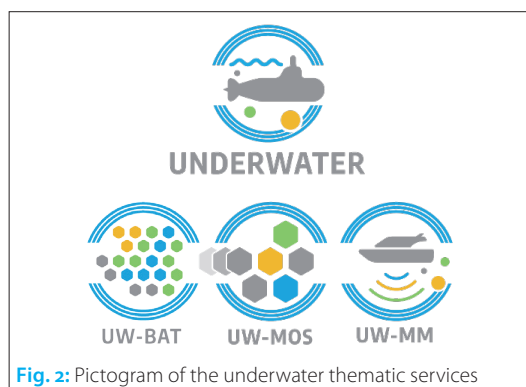

Fig. 2: Pictogram of the underwater thematic services

computational intelligence approaches that allow NEANIAS users and services to provide beyond state-of-the-art solutions to problems raised by research sector cases.

Visualisation service provides a multi-faceted solution to visualisation spanning from 2D/3D spatio-temporal data visualisation to composite 2D/3D visualisation of data of higher dimensionality and to support demanding virtual/augmented reality requirements.

This publication aims to a better understanding of how thematic cloud services in the field of marine geodesy and habitat mapping could be realised and therefore seeks the audience of the hydrographic/hydroacoustic community by focusing on the WP2 underwater service »Bathymetry Mapping« (U1). This service is mainly driven and lead by Teledyne and the University of Bremen/Marum, but with strong support from all underwater services participants regarding validation, evaluation and development towards a common user interface and connectivity between the services. The development of this U1 service would not be possible without the contribution of all the NEANIAS members who cover the fields of e.g. project management, public relation, business models, core and micro service development, and the integration of our thematic services to EOSC hub, as mentioned in Fig. 1.

The bathymetry mapping service

Knowing the depth, shape and type of the seafloor bathymetry and its hydroacoustic backscatter is fundamental for understanding geomorphology and habitats, 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.

Therefore, the aim is to provide a user-friendly service to exhibit and post-process bathymetry and seafloor backscatter data sets. Currently available software products like Teledyne Caris Hips & Sips (teledynecaris.com/en/products/hips-and-sips/), QPS Qimera/Fledermaus (qps.nl), EIVA (eiva.com), HYPACK (hypack.com), SonarWiz (chesapeaketech.com/products/sonarwiz-post-processing), Globe (Poncelet et al. 2020) or MB-System (Caress and Chayes 2017; www.mbari.org/products/research-software/mb-system) require a certain knowledge which is predominantly reserved to hydrographers or researchers in the field of hydroacoustic. The goal is to reach a broader audience of users which are interested in ocean mapping and its tools for several reasons. In the

focus are researchers and students, e.g. archaeologists, geoscientists, biologists, physicists, oceanographers as well as environmental engineers, technicians, renewable energy planners or users working in the field of underwater robotics and/or computer vision/machine learning who like to view and process recorded raw multibeam echo sounder (MBES) data. With respect to the global Seabed 2030 efforts (Mayer et al. 2018) such a service could be of particular interest.

The idea of utilising MB-System for a cloud service that enhances a wider community to create their own bathymetric maps out of raw data sets came up based on a request of the National and Kapodistrian University of Athens (NKUA) and National Technical University of Athens (NTUA). By that time, several engineers and technicians of Marum already contributed code to the open-source software. A member of Marum is currently part of the MB-System core-developer team. Due to changes at institute the lead of the project was transferred to Teledyne Reson A/S in April 2020. Since then, members of the company build the core team around this project with kind support from Marum and the MB-System team.

MB-System is running in-house at the University of Bremen and worldwide in many other institutes and universities, as a bathymetry and backscatter post-processing tool for MBES data sets. It is on a technology readiness level (TRL) 6, has been validated using different data sets from various vendors and is under constant maintenance through the open-source community.

Furthermore, MB-System is capable to realise navigation correction for AUV/ROV recorded bathymetry. This is crucial not just for bathymetry but for other acquired data sets like CTD, photos, videos. Underwater-recorded bathymetry lacks accuracy since GNSS/RTK (Global Navigation Satellite Service/Real-Time Kinematics) information cannot be used directly. Several devices are necessary to accurately steer and position underwater devices like AUV/ROV. Next to GNSS and RTK, which can only be used directly on the sea surface, USBL/LBL (Ultra Short/Long Base Line underwater positioning) and DVL (Doppler Velocity Log) and even the revolutions per minute of the vehicles propellers are taken into account when solving the algorithms for positioning by utilising 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 certain knowledge of the operating systems (Unix/Linux) and in the command line-based installation and execution of the different packages. On the other hand, utilising MB-System for bathymetric

and backscatter post-processing is a sustainable solution but as a matter of consequence when using command line, it lacks certain (UI driven) workflows and logging of what have been applied to the data. Therefore the user is obliged to document manually which commands he/she has executed. A disadvantage with respect to e.g. lineage metadata for quality standards or confidence levels with respect to the post-processing and common data quality.

User requirements and aim

The user requirements have been initially formed like »user stories« for each service. 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 on a 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 workload 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>.

For all underwater services we came across the following, common needs in Table 1.

ID	End-user	User requirement	Reason
R1	All targeted	Upload, store and possibly publish data sets 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	Visualise 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 (parametrisations)	To correct the data (e.g. image correction, photogrammetrically rectify, sound velocity correct, tide correction, etc.)
R4	All targeted	Utilise 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 (digital terrain models), backscatter mosaics, photomosaics, multifrequency-based seabed classification maps and other related products	To perform archaeological, oil and 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 data sets between users
R8	Archaeologist	To produce geospatial products/ maps with adequate precision from interdisciplinary data sets	In order to comprehend archaeological targets in data sets and fulfil archaeological survey requirements
R9	Archaeologist	To have the possibility to review the georeference of a given data set	To be able to understand the exact location of an archaeological target (such as a shipwreck) as data sets are georeferenced differently
R10	Archaeologist	To achieve very high spatial accuracy in the delivered products (e.g. to the millimetre)	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 transmissing 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 and 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

Table 1: User stories for all underwater services

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 visualise 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 serialisation processes supporting several widely used data formats. Rely on a data transfer service for storing and publishing.
R8	Medium	Medium	Provide detailed reporting and evaluation information to assess the quality of the produced results
R9	Low	Medium	Implement reoreference 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 visualisation 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

Table 2: User stories ranked and linked to a level of priority

Then the aforementioned user stories and requirements were linked with a level of priority and value based on end-user recommendations (Table 2). Also, the manner to confirm their acceptance was marked down.

Service specification

The service requirements have initially been arranged according to their type. Five distinct categories have been recognised, more specifically: storage, computing, cloud, functional and quality

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
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

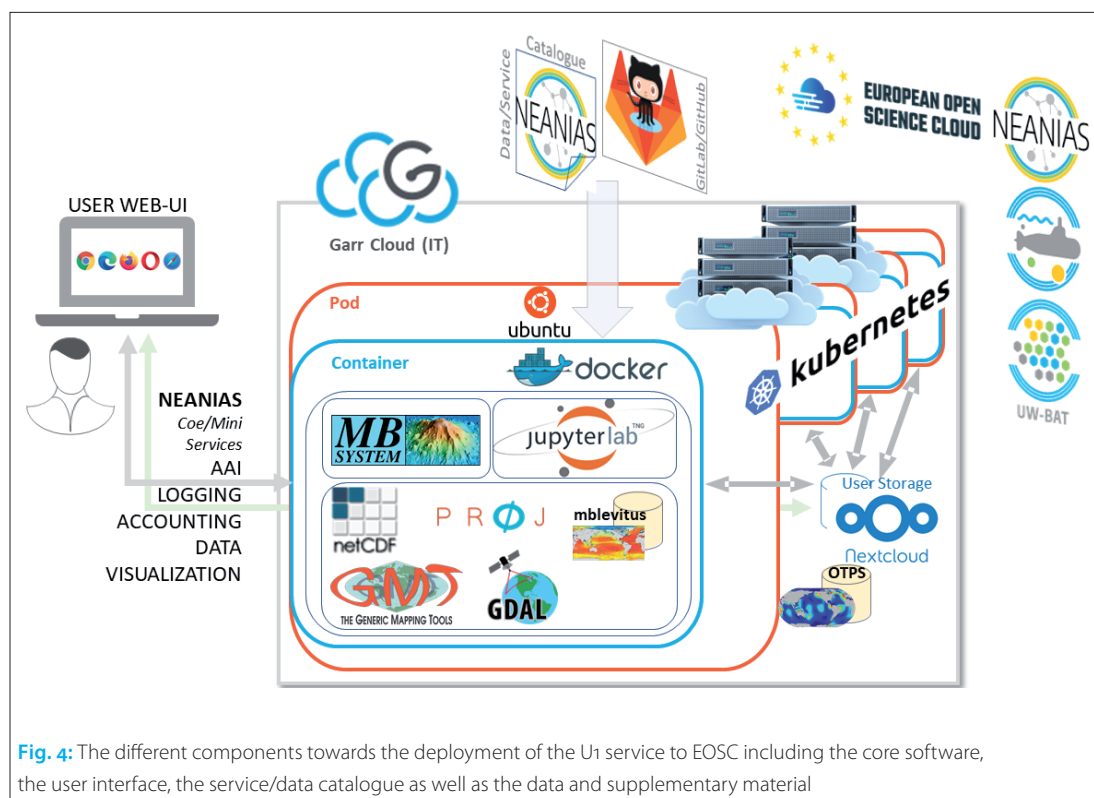**Fig. 3:** Table with service specifications, partly shown

Fig. 4: The different components towards the deployment of the U1 service to EOSC including the core software, the user interface, the service/data catalogue as well as the data and supplementary material

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.

The table in Fig. 3 exemplarily presents the specifications of the underwater services which have been defined to address the user requirements (Table 1 and Table 2). 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 have been ranked as »mandatory«, »convenient« and »optional«.

Software development plan

High flexibility, sustainability by moving fast from development towards testing and production, and accommodating for an enormous level of complexity, when utilising multiple programming languages, frameworks and architectures, are challenges when deploying a cloud service. Therefore, it seems obvious to containerise our services via Docker (docker.com) and manage the deployment on one or different nodes or virtual machines/pods with an orchestrator like Kubernetes (K8s). But a container and its orchestration are not the only thing one needs around the initial

code of the service that does the work the user requests. As according to the user requirements and service specifications several questions were raised: Who will authorise a user to use the service, allow upload and download data, provide (common) graphical user interfaces (GUI), visualise results, manage a user's workflow, enable sharing of results? And how to find the service and its documentation in the world wide web? Fig. 4 presents the different software components and modules currently utilised or developed and validated for the U1 service. This approach reflects a 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 WP 7 and 8 (Service delivery and EOSC integration). Moreover, the core and micro services development and implementation (WP 6) will foster the service usability and TRL towards 8.

The scheme shown in Fig. 4 visualises a Docker container deployed on a virtual machine in the GARR cloud. The latter is an OpenStack and Kubernetes based cloud infrastructure in Italy, built and maintained by Consortium GARR. Kubernetes is responsible for spawning one to many Docker containers (on one or several virtual machines/pods) based on one or multiple user requests. Several core and mini services will aid with respect to authorisation, logging, accounting, visualising or simply up- and download data to a Nextcloud storage connected to the Docker container. Once the container is set up, the user is able to access MB-
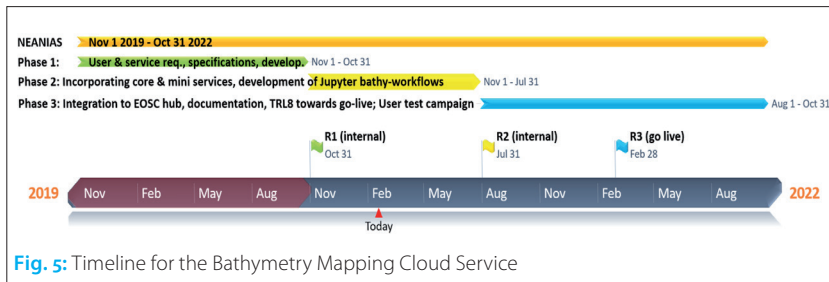
Fig. 5: Timeline for the Bathymetry Mapping Cloud Service

System through a browser-based and launched JupyterLab. All dependencies of MB-System and the Jupyter-workflow were installed previously in a Docker image. The sources are stored in GitLab/GitHub.

The expected timeline for the release of the U1 service is shown in Fig. 5.

First results and conclusions at the time

This article summarises and contextualises the NEANIAS and in particular the underwater team efforts within the first year of the project by defining the services requirements of the end-users. These requirements have been identified and assessed to set the co-design and service specifications for the software development plan on the three innovative thematic EOSC service branches that NEANIAS will implement, co-aligned to its developed core and mini services.

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 broader needs. At the same time, we also tried to address specific needs and products, through personalised use of the services, when this is possible.

The future steps are already defined by the description of the required functionality 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-user's 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 data sets 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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