D2.2 – Service Architecture and Technical Specifications report

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Document History

Version	Date	Author(s)	Description
1.0	2025-05-31	RISC	Submitted version
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Table of Contents

Acronyms

Acronym	Explanation
API	Application Programming Interface
CIAM	Customers Identity and Authentication Management
DMP	Data Management Plan
EC	European Commission
EO	Earth Observation
GIS	Geographic Information System
HTTPS	Hypertext Transfer Protocol Secure
OGC	Open Geospatial Consortium
REST	Representational State Transfer
WP	Work Package

List of Figures

List of Tables

Executive summary

Deliverable D2.2 of the UNICORN project defines the initial service architecture and technical specifications supporting Copernicus-based applications for disaster resilience across Europe. Addressing the rising impact of natural hazards like floods, wildfires, and geohazards, the report outlines a dual architectural strategy: a user-centric web portal offering streamlined access to hazard services, and a modular micro-services platform enabling flexible, secure, and scalable partner integration. Guided by user requirements and partner capabilities, the architecture ensures interoperability, scalability, and sustainability while respecting intellectual property and business models. It establishes the technical foundation for integrating partner services, enhancing emergency preparedness and response, and fostering long-term innovation and commercial uptake. This deliverable serves as a critical reference for implementing UNICORN's resilient, user-oriented hazard management ecosystem.

1 Scope of the document

The UNICORN project addresses the escalating frequency and severity of climate-driven natural hazards in Europe, such as wildfires, floods, and geohazards, by developing advanced Copernicus-based applications to enhance disaster preparedness, response, and recovery. Deliverable D2.2 outlines the initial service architecture and technical specifications, defining a collaborative, interoperable, and scalable framework to integrate partner services and data, as part of Task 2.2. The presented holistic architecture supports the project's goal of improving resilience for local authorities, industries, and citizens while fostering innovation and commercial sustainability for partners.

This architecture deliverable outlines a dual strategy that describes a user-friendly web portal and a modular micro-services platform. This approach ensures flexibility, scalability, and interoperability while enabling partner autonomy in service development and delivery. The web portal serves as the primary interface, providing streamlined access to partner-specific services: flood, wildfire and lava hazards. The micro-services platform forms the operational backbone, enabling flexible integration of partner services through industry standard components.

The design process was guided by user and partner needs assessment. The resulting architecture is highly adaptable to diverse operational contexts and supports both emergency responders and data providers through a cohesive, secure, and extensible system.

This deliverable sets the foundation for the integration of the UNICORN partner services, ensuring that they are technically robust, user-oriented, and aligned with the project's strategic goals of improving access to Copernicus-derived data products and fostering innovation in disaster risk management. Implementation refinements will address outstanding technical and business issues to ensure alignment with user needs and project objectives. This deliverable will be used as a foundational reference for partners.

1.1 Applicable documents

Table 1: Applicable documents

ID	Title	Version	Date
[AD. 1]	Grant Agreement incl. Description of Action	1.0	23/09/2024
[AD. 2]	Consortium Agreement	1.0	01/10/2024

1.2 Reference documents

Table 2: Reference documents

ID	Title	Version	Date
[RD.1]	D1.4 GDPR, Gender Balance and Ethical Issues Management	1.0	12/03/2025
[RD.2]	D1.5 Data Management Plan	1.0	31/03/2025
[RD.3]	D2.2 Service Architecture and Technical Specifications report	1.0	31/05/2025

2 Introduction

2.1 UNICORN Project Overview

Human-induced climate change is increasing the frequency and intensity of extreme weather events, leading to severe environmental, social, and economic impacts. Vulnerable communities and systems face the greatest risks, with rising losses from wildfires, floods, and other disasters. Over the past two decades, Europe has experienced over 1,700 natural disasters, primarily floods and storms, causing significant fatalities and financial losses. In 2021 alone, extreme weather events resulted in nearly 300 deaths and economic damages exceeding USD 58 billion[1]. The Mediterranean region, identified as a climate change hotspot, faces heightened risks due to its arid climate and susceptibility to extreme events.

UNICORN's primary objective is to provide businesses and policymakers with Copernicus-based applications. This aims to enhance the preparedness of local authorities, citizens, and industries for more frequent extreme events and geohazards. Additionally, it seeks to improve prediction, fostering better resilience to climate change. The ultimate goal is to enhance local emergency management and facilitate short-term recovery processes. To do so, a series of tools for early warning, forecasting, and monitoring of hazards will be developed. UNICORN will showcase the impact of these applications across four use cases through an end-user validation method towards building a resilient European landscape.

UNICORN will build on and expand existing, well-established solutions by enhancing their capabilities and integrating their datasets using state-of-the-art technologies around Earth Observation. The project concept builds on the European Commission's resources from previous work, investments, and initiatives (e.g., SAFERS, MedEWSa, FIRE-RES). It focuses on developing an interoperable and flexible system infrastructure (e.g., Open Data repositories, EU Data Hubs, Copernicus Data Space Ecosystem (CDSE), INSPIRE-Open Gov national-based portals), fostering both new research and operational services. UNICORN will drive innovative and responsive services tailored to the needs of different stakeholders, extreme events, and geographic regions, preparing for improved resilience, local emergency management, and short-term recovery.

2.2 Purpose of the Document

This report describes the initial UNICORN Service Architecture with associated technical requirements and is the main deliverable for Task 2.2. It begins to define the services integration strategy taking into account the project partner's business interests balanced by the research and sustainability requirements to benefit the broader research community. The presented architecture outlines strategies and protocols to enable the UNICORN project to deliver a secure, interoperable, and user-friendly platform for project partners and stakeholders that guarantees partner Intellectual Property (IP) is protected. This document serves as a reference for project partners to help define the framework for collecting, processing, managing, and distributing project data and services.

2.3 Structure of the Document

This UNICORN deliverable is structured in the following manner:

- Section 1 – presents the scope of the document.
- Section 2 – the introduction and description of the project.
- Section 3 – a description of the UNICORN services and architectural goals.
- Section 4 – the UNICORN architecture.
- Section 5 – the conclusions.

[1] https://www.munichre.com/en/risks/natural-disasters/floods.html

3 UNICORN Services

The UNICORN's concept builds on resources from previous work, investments and initiatives and is working towards developing an interoperable and flexible system infrastructure that can balance the requirements linked to integrating bleeding edge research but also develop operational services/applications that can sustain themselves well beyond the project. The following Copernicus-based applications are to be further advanced and expanded to deliver improved natural hazard information to the relevant stakeholders:

- Flood forecasting integrating Copernicus data and weather forecast fusion
- Copernicus-based wildfire early detection, mapping and nowcasting
- High-resolution fire danger forecasting
- Lava flow emergency management tool based on Copernicus data merged with numerical modelling

These downstream applications will be fine-tuned by involving relevant stakeholders and users which will drive UNICORN innovations and responsive services by tailoring to the needs of different (i) types of stakeholders, (ii) extreme events and hazards preparing for a better resilience to climate change, local emergency management and short-term recovery and (iii) areas, regions, and countries. This is fuelled by the use cases which are expected to validate the improved Copernicus-base services in a variety of conditions.

The present T2.2 task aims to look at the factors defining and linking the different Copernicus-based UNICORN services and commercial products to deliver a robust user experience and provide the appropriate hazard information for improved decision making. The scope of this task will address partner technology investments, needs for service development and evolutions, IP, and business models. It should be noted that UNICORN focuses on developing the technological improvements of the partner Copernicus-based services and the service architecture should not impede those goals. Therefore, the proposed architecture will be used to promote the different services and demonstrate service capabilities to maximise future commercial uptake.

In this sense, the following sections will describe the current UNICORN technologies, integrated Copernicus services and expected commercial products in the context of the use cases and business strategy. The following overview will identify existing data and services including a brief service description, the technical parameters for service implementation, and current business targets. Note that the system architecture and platform architecture implementations may be updated throughout the project as UNICORN services system advancements are made.

3.1 UNICORN Services User Requirements

The UNICORN D2.1 [RD.1] provides valuable analysis into the user requirements of the different user profiles and their responsibilities which need to be taken into account in the architecture analysis. A significant number of respondents shared feedback that highlighted the fact that their hazard information was being provided through at least two different platforms or systems to service their operational needs. This highlights the fact that operational natural hazard systems should be able to ingest and deliver a variety of information that is not always available through a single channel.

Mandatory operational system requirements associated to wanted UNICORN system or service requirements included the following:

- High Availability (24/7)
- Compatibility
- Transparency
- Interoperability
- Stability – long term use

- Data management and process optimisation
- Non-availability notification
- User friendly user interface
- Reporting and Downloading services.

To support users in their daily tasks in routine monitoring of natural hazards and disaster events management, the operational features of UNICORN services and products should try to align with user requirements to increase the potential of adoption and utilisation. The user requirements analysis also emphasized the fact that operational needs are primarily tied to the users' disaster management responsibilities rather than the hazard itself. Providing access to services and products via a web portal was considered optimal with most respondents confirming this requirement. On the topic of operational service modes, the users engaged in natural hazard and disaster management, e.g. monitoring, prevention, and emergency response, preferred continuous service availability, whereas the citizen, professional, and industry profiles favoured an "on-demand" service model.

A valuable insight emerging from D2.1 and the questionnaire responses is that users seek systematic and comprehensive access to information. Their goal is to avoid the burdensome processes currently required—such as subscriptions, formulating event-specific requests, retrieving and integrating data, and making necessary adjustments—to access information from existing services and platforms. Their preference would be to focus on the efficient management of emergency events.

The following summarized list of user requests from D2.1 highlights the identified key user needs:

- Continuous data supply.
- Access to large-scale products that support disaster management planning before and during emergencies at the local level.
- Frequent updates (daily to sub-daily) to enable timely adjustments and optimization of emergency response plans.
- Meteorological data, including temperature, humidity, wind speed and direction, and precipitation, requested across all event types.
- Forecast and early warning data with a lead time of at least two days before a potential disaster event.

These user needs and requirements are used to drive the architecture development. Within the context of the UNICORN services, the architecture will also have to take into account current partner solutions that have already been implemented and will continued to be developed/improved during the project. This not only affects the business and customer strategic drivers but will also affect the inter-partner collaboration needed to deliver successful project outcomes.

3.2 Architectural Goals and Guiding Design Principles

The overarching goal of the UNICORN architecture is to deliver a collaborative, service-oriented platform to support disaster management by enabling seamless integration of services from multiple partners. The collaborative nature of the project, involving multiple partners across different regions and sectors requires the architecture design to support interoperability, scalability, and agility. At the same time, intellectual property, including background IP, and business development play a key role in supporting SME partners beyond the project. Therefore, the architecture should be designed to not only align with user requirements but also operational efficiency to bolster service uptake and partner business development. Consequently, the chosen design aims to simplify UNICORN deployment to focus on partner services technology development within a shared ecosystem.

The following architectural goals were identified as drivers for the UNICORN architecture:

1. Interoperability – This goal tries to ensure seamless integration of services developed by diverse partners, facilitating communication and data exchange across heterogeneous systems. Support coordinated disaster management efforts, ensuring compatibility across heterogeneous systems.
2. Scalability – This goal focuses on system capacity to handle high demand during crises, with robust fault tolerance and minimal downtime to ensure continuous operation for critical response teams. Resources should be able to scale dynamically both up or down based on demand, ensuring optimal performance and cost-efficiency.
3. Security and Compliance – This goal considers those most vulnerable during crisis and therefore the architecture must implement robust security measures and data privacy protocols to protect sensitive information across all services and platforms. Furthermore, ensuring adherence to relevant regulations such as the GDPR during emergencies is a must.
4. Modularity – This goal relates to adopting a modular architecture that allows individual components or services to be developed, tested, and deployed independently, promoting reusability and maintainability. By creating a loosely coupled architecture, partners can deploy services independently and reduce complexity.
5. Accessibility – This goal tries to maximise access to UNICORN products and services through a web-based portal to meet the needs of disaster management professionals who require continuous operational access and citizens/industry users for on-demand access.

The following UNICORN design principles were identified to guide the development of co-operative services:

- A Service-Oriented Architecture (SOA) to be able to structure the system as a collection of loosely coupled services, each encapsulating specific business functionalities and to enhance flexibility and reusability.
- Taking advantage of the microservices paradigm to be able to decompose applications into smaller, independent services that can be developed and scaled individually, improving fault isolation and deployment speed.
- Use of standardized communication protocols to take advantage of industry protocols such as RESTful APIs and JSON to ensure consistent and efficient communication between services developed by different partners.
- Moving forward with a platform-agnostic design so that developed services are not tied to specific platforms or technologies and allowing for broader compatibility and easier integration overall.
- Include automated monitoring and management capabilities that provide system monitoring, logging, and management of services to promptly detect and address issues to ensure high availability and reliability.

Beyond the UNICORN project, important implementation considerations will be linked to maintaining of the web portal and services governance. During the project lifetime, the primary interfaces for accessing partner services has been established, however this should be extended through partner agreements formulated and established before the project end. Furthermore, clear services governance will need to be established through service level agreements (SLA) that provide details regarding services management, software versioning policies, services updates and maintenance, and services access to maintain compatibility beyond the project and support business development.

By adhering to these goals and principles, the UNICORN project ensures a robust, collaborative, and user-focused architecture that empowers partners to deliver critical services for disaster management effectively. The next sections will present the main UNICORN architecture components adopted to deliver on the above-described architecture goals and principles.

4 UNICORN System Overview

As described above, there are specific user and partner requirements driving the UNICORN system design and therefore it was necessary to adopt a dual strategy to reduce the implementation risks related to services integration provided by multiple partners. The dual strategy leverages a web portal and a modular microservices platform to address the diverse needs of project partners and stakeholder. The web portal serves as the primary interface, offering universal access to UNICORN services whereas the microservices platform provides a multi-hazard service ecosystem enabling partners to contribute independent, interoperable services that ensure scalability, resilience, and flexibility to promote and demonstrate their products and services.

The UNICORN web portal serves as the primary interface for end-users offering streamlined access to partner services. It promotes the UNICORN multi-hazard services and enables different users to directly access partner solutions increasing exposure to new customers and helping lower the entry barrier.

Complementing the UNICORN web portal is the microservices-based backend platform, which provides the functional backbone for the UNICORN ecosystem. This platform supports a flexible, service-oriented architecture where individual capabilities including security enforcement, service discovery and continuous integration, are encapsulated through independent partner services. This modularity provides service scalability, supports individual partner development cycles, and facilitates integration of third-party and/or partner-developed components.

Together, these two separate elements help achieve the UNICORN architecture goals and enables collaborative services development, deployment across multiple UNICORN partner service providers, and tailor to the evolving user and business needs.

Specifically, the presented UNICORN system addresses the following technical and business constraints:

Business strategy and competition – the project partners' wants and needs are diverse based on their organisational structure, user/customer base, hazard service, and expected developments. As presented in the DMP [RD.2], the sharing of information is not uniform across partners because of business strategy and services ownership. This impacts the openness not only between partners but also to potential competition. Therefore, security is paramount for business strategy but sharing of information is at the heart of Copernicus so promoting this is important. The UNICORN web portal addresses the need to promote the multi-hazard services without compromising SME business developments. This also provides partners a runway to develop strategic partnerships which can be scaled through the UNICORN micro-services platform.

Demonstrating the UNICORN solution – the UNICORN platform will be used to showcase the hazard use cases and services developments. This solution builds technical bridges between the service partners with the potential for future services sharing through venture agreements. The SMEs are keen to not only technically improve their services but also build lasting business partnerships. The platform architecture addresses this need technically by providing industry standard infrastructure and business constraints by integrating enterprise security.

Research and Development – Each technical partner goal is to improve their Copernicus based offering through research and development, but they also need to make their current offering available. The web-portal addresses the need to advertise UNICORN services as they are currently available and accessible whereas the UNICORN platform provides options for technical advancements to reach the expected TRL at the end of the project of at least 7-8 for the developed Copernicus based services.

Partner cross-fertilization – Both the UNICORN web-portal and the platform will help partners promote each other's services and work together to shape their services. This enables technical discussions related to not only the hazard service developments but also exposing the services to customers and sharing of data. This encourages

broadening of business and technical solutions which ultimately help improve the UNICORN solution and reduce siloed and fragmented solutions that are not in-line with user requirements.

In the following section, the two primary components of the UNICORN architecture are presented.

4.1 The UNICORN Web Portal

The first component of the UNICORN architecture is the user-friendly web portal which serves as a landing page to the available partner services and will be implemented first. The web portal serves as a central gateway for end users and partners to interact with the hazard services and shared data offered through the UNICORN project. It is designed to provide a simple interface to showcase partner-specific services. The following figure presents an overview of the web portal architecture (Figure 1).

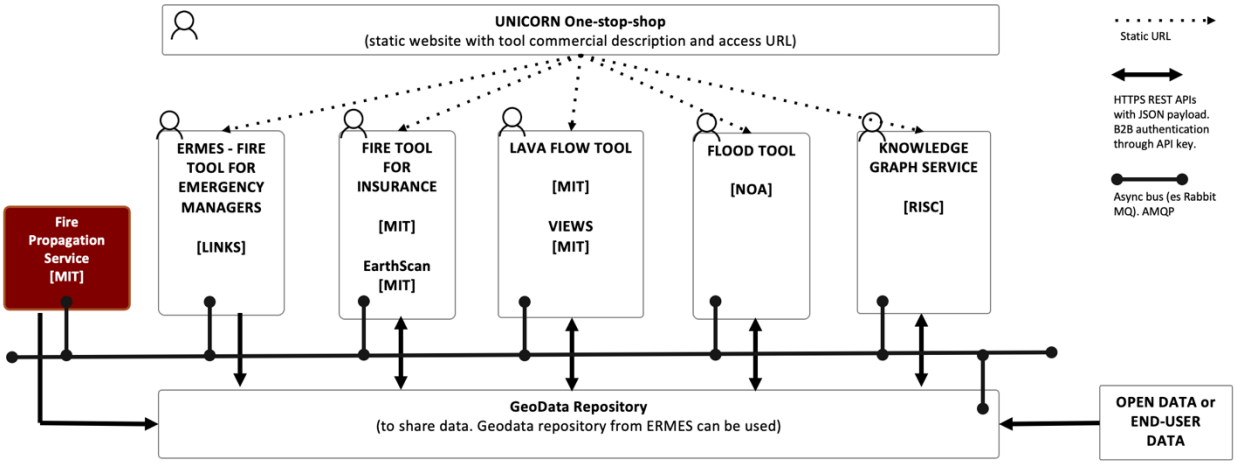

Figure 1 - The UNICORN Web-Portal Architecture.

At the top of the figure (Figure 1), the UNICORN one-stop-shop is presented. This refers to a focused online presence that provides details for each partner hazard service. Specially, it can provide direct access to the service and detail use conditions. The goal is to draw customers to the UNICORN natural hazard shop window and the benefit of this setup is that search engine optimization (SEO) can be focused on the solutions (as opposed to project requirements).

The tuning of SEO is vital to UNICORN services because it drives traffic from search engines and supports long-term traffic to the web-portal to convert users and adopt UNICORN solutions. This builds reputation which in turn should increase the credibility and trust in UNICORN services. The other goal of the SEO is to help reach target audiences and communities at the right time. Natural hazard solutions are not usually considered under disaster strikes and there, SEO plays an important role in putting UNICORN at the top of searches for specific hazards. Finally, SEO supports digital marketing and content strategy outside the 'project' scope of UNICORN. This increases business development and post-project sustainability.

Through the web-portal, users will have direct access to the UNICORN services. As shown in the Figure 1, the services span different natural hazards including floods, lava flows, and wildfires. The access to the services at this point is partner specific because they navigate outside of the UNICORN ecosystem and into the partner solution. The benefit of this strategy is that partner implementations can be kept with minor changes to access currently available services before UNICORN proposed developments are implemented. The need for technical integration into new infrastructures by partners is minimal.

Through the UNICORN web-portal, open datasets will also be shared. As shown on the bottom of the web-portal architecture graphic (Figure 1), all the partners can make their shared data available through a data lake solution. The data lake solution is a geospatial data repository that facilitates access to hazard related data and information produced or used by the UNICORN partners. This data will be formatted using industry standards and using FAIR principles for access.

The UNICORN web-portal data component is built around a shared data lake architecture enabling secure, scalable, and standardized access to data products from multiple partners. Features include:

- Standardized data formatting to ensure consistency and reusability. All shared data will adhere to common geospatial data formats to ensure compatibility across partner services and simplify integration. The data schemas will adhere to European standards such as INSPIRE to meet disaster management needs.
- Data access control to ensure authenticated access. The portal integrates with the data lake to provide role-based access to ensure protected datasets are not exposed to unauthorised users while providing access to open datasets. Metadata tagging will provide additional information to enhance search capabilities and provide licensing details.
- Scalable storage and retrieval to meet the dynamic needs of the hazard community. The data lake will be designed for scalability, supporting potentially large volumes of current and historical data generated by the UNICORN services and use cases.

Benefits of the web-portal architecture in the context of UNICORN

The UNICORN web-portal will facilitate data exploration and access for users while supporting partners in publishing and updating datasets in alignment with UNICORN's interoperability principles. The UNICORN shop functions as the online storefront for services made available through the partners' services. It offers a curated presentation of each partner's services that includes a detailed description of the offer, provides access and usage conditions, and presents licensing and support information.

Drawbacks of the web-portal architecture in the context of UNICORN

While the web-portal provides access to multi-hazard services through a single point of entry, the services are not linked and do not provide similar user experiences.

4.2 The UNICORN Micro-Services Platform

The UNICORN project's primary objective is to provide businesses and policymakers with Copernicus-based applications with the aim to enhance the preparedness of local authorities, citizens, and industries for more frequent extreme natural hazard events and geohazards. The UNICORN services will further develop enhancements to their Copernicus based services to improve prediction and foster better resilience to climate change ultimately to strengthen local emergency management and facilitate short-term recovery processes. These will be delivered as a series of tools for the early warning, forecasting and monitoring of natural hazards.

One of the key requirements revealed through the UNICORN user requirements report [RD.1] by the users is the need to access fewer services to connect and retrieve the information required to do their daily work. This particular requirement was the basis behind the UNICORN micro-services platform architecture which is shown in the following figure (Figure 2). It is also designed to provide a simple interface to showcase and demonstrate the partner-specific services.

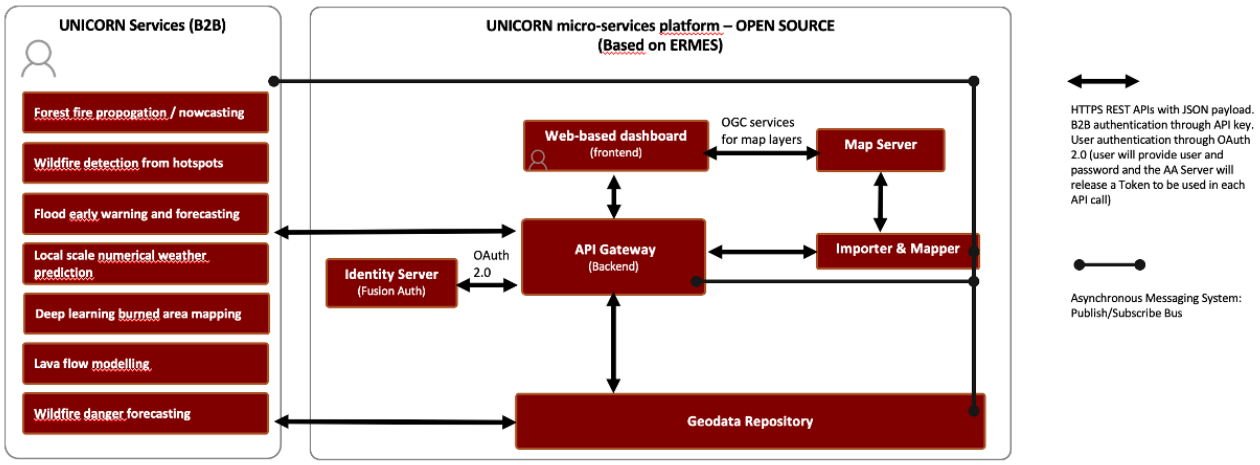

Figure 2 – The UNICORN micro-services platform architecture.

The UNICORN micro-services platform will serve as the operational demonstrator of the services and provides a modular and scalable architecture capable of integrating the services contributed by different partners. On the left side of Figure 2 are the different UNICORN services which need to be orchestrated and integrated into the platform. These services use different inputs including different Copernicus Services as well as Sentinel EO imagery. Therefore, it is necessary that the UNICORN micro-services platform not only make it possible to ingest the different products produced by the services but also receive information from users which provide inputs and triggers for those services.

This particular micro-services platform architecture and implementation will be building on the successful technology demonstrated in the SAFERS[2] project. The SAFERS open-source emergency management platform[3] will be updated to the latest libraries and associated services to make sure that it adheres to the latest security standards and technology patterns. The technical updates will also be associated with a name change to foster future uptake: ERMES - Fire tool for emergency managers. The overall system was conceived with a modular architecture (as shown above) to support not only hazard services but also the services used in conjunction with other platforms or existing systems such as the Copernicus Services or access to Sentinels imagery. Therefore, the UNICORN micro-services platform architecture in theory should allow for maximum flexibility and be able to provide different types of services that can meet a multitude of customer needs.

The schematic representation on the right side of the figure (Figure 2) shows the main components of the architecture highlighting the data and message exchanges between software components, security, third-party systems, and end-users. It also was designed to encompass the different hazard management phases: prevention and preparedness; detection and response; adaptation and restoration. The following sub-sections provide more details for each of the components.

4.2.1 The Identity Server

The UNICORN microservices platform will incorporate a Customer Identity and Authentication Management (CIAM) component to securely manage user authentication, authorization, and profile data, ensuring secure and seamless

[2] https://safers-project.eu/

[3] https://links-ads.github.io/projects/safers/

integration of the system components. This component described in the architecture figure (Figure 2) as the identity server decouples user registration, identity management and authentication from the service logic to enhance scalability, maintainability and security. This is also common practice in modern cloud-based software architectures.

For the UNICORN platform, the OAuth 2.0 (https://oauth.net/2/ / https://datatracker.ietf.org/wg/oauth/about/) was chosen because it is the industry-standard protocol for authorization and focuses on client developer simplicity.

Furthermore, this type of CIAM can simplify the implementation of Single Sign-On (SSO) and federated identity integration with third-party providers which may be needed in the future for services deployment.

The integration of OAuth 2.0 for the CIAM was also selected to comply with potential GDPR because it allows for data separation, i.e. maintaining a (private) user database independent from core application services to maximise privacy by simplifying data anonymization and isolation.

The identity server will integrate with the UNICORN micro-services platform via an API gateway, routing authentication requests securely using HTTPS and TLS. Monitoring tools will track performance and security events to feed into iterative improvements. UNICORN partner agreements will formalize data-sharing and authentication protocols, ensuring governance and alignment with the platform security requirements.

4.2.2 The API Gateway

An Application Programming Interface (API) Gateway is a server that acts as a single-entry point for all client interactions with a system composed of multiple backend services especially in the context of a micro-services architecture. This intermediary manages requests, handles tasks such as routing, composition, and protocol translation, and enforces security, monitoring, and rate limiting.

The UNICORN platform API gateway is needed to manage the different independent services through synchronous interactions. These synchronous interactions are meant for lightweight, real-time exchanges where latency is minimal. The services will be exposed as REST APIs where the endpoints are accessed via HTTP requests and require valid authentication tokens for secure communication. The REST APIs are industry standard implementations, and the API gateway simplifies integration, improves security, and centralizes common concerns that would otherwise need to be duplicated across services.

The key functionality of the UNICORN platform API gateway is linked to the following:

- Routing requests – the API gateway directs incoming API requests to the appropriate backend service based on the request's path, headers, or other criteria.
- Authentication and authorization – the API gateway provide services to validate credentials such as the needed OAuth 2.0 tokens to ensure only authorized clients access services or data.
- Rate limiting and throttling – the API gateway provides a means to control the number of requests a client can make to prevent overloading backend services. This is a vital component especially in high-demand situations to manage critical service infrastructure.
- Load balancing – if needed, the API gateway can be configured to distribute requests across multiple instances of a service to ensure scalability and reliability.
- Protocol translation – the API gateway can be used to convert client requests, e.g. HTTP/REST, into formats understood by the UNICORN backend services and enabling interoperability across partner services.
- Response aggregation – the API gateway can be used to combine data from multiple UNICORN services into a single response to streamline client interactions.

- Monitoring and logging – any operational service must be able to monitor and track performance, usage, and errors to help improve the system and maintain peak performance. The API gateway can be used to produce service metrics useful for platform analysis.
- Security enforcement – the API gateway will implement encryption to help protect against security threats and ensure compliance with privacy standards like GDPR.

A different solution is proposed for services with long-running processes that cannot be done synchronously and/or with periodic tasks and ad hoc requests and are described below under the section messaging layer.

4.2.3 The Messaging System

The UNICORN micro-services architecture is composed of multiple components that need to communicate effectively. In the UNICORN platform, the RabbitMQ (https://www.rabbitmq.com/) message broker was chosen for this role because it can support the data sharing, service triggers, and visualization workflows being developed. RabbitMQ is an open-source message broker software that facilitates communication between different applications. It acts as a middleware, enabling applications to send and receive messages asynchronously and was chosen not only because it is known for its reliability, scalability, and support for various messaging protocols but also because of the positive experiences of some of the project partners with the software.

An asynchronous solution was chosen for the messaging system in order to simplify the integration of the UNICORN partner services and products. Asynchronous interactions are ideal for long-running processes, periodic tasks, or ad hoc requests, and the messaging system uses the RabbitMQ solution which will provide a broker-based messaging infrastructure to leverage UNICORN requirements because it decouples the producers and the consumers enabling services to react to events without direct querying. Once a message is published on the message bus, it is routed to and processed by the appropriate service or module.

RabbitMQ was selected for the UNICORN platform due to its lightweight deployment, versatile protocol support, and ease of configuration, which should facilitate partner service integration and align with cost-efficiency and modularity goals. RabbitMQ's flexibility and lower operational overhead better support the diverse, partner-driven services in the UNICORN ecosystem. Security is enforced through authenticated access to queues, using API keys or OAuth tokens, and encrypted connections (TLS). Monitoring tools track message throughput and queue health, ensuring reliability during high-demand crisis scenarios. Partner agreements formalize messaging protocols, ensuring governance and interoperability across the platform.

4.2.4 The Importer and Mapper

A very important component within the UNICORN platform architecture is the importer and mapper component. This geospatial data module within the micro-services platform enables the management and access of geospatial data which is a key product from all the UNICORN partners.

This module consists of two primary interconnected components:

- The mapper part exposes project geospatial data as map layers that can be published using standard OGC services such as WMS and WFS.
- The importer part is a service that listens for notifications indicating changes to available geospatial data such as new dataset uploads, updates and deletions held within the platform. The process goals of the importer include converting data to appropriate formats, updating the list of available map layers, as well as generating lists of available layers in standard formats such as JSON for external querying.

To function correctly, the importer and mapper module is supported with a database to provide persistent storage for the list of available map layer resources as well as associated metadata. To expose these resources to external clients and allow them to be queried and accessed, an API server is provided.

As shown in the Figure 2 data flow, the importer & mapper component are connected by both synchronous and asynchronous connections to support the different aspects of the UNICORN platform. For example, querying map layer functionality will be provided through synchronous access because users expect an immediate response from such a functionality. However, the updating of partner uploaded datasets and map products will be processed asynchronously because of the potential long processing times associated with the hazard services. The importer and mapper module will be able to orchestrate these different requests accordingly depending on the operational process flow. The messaging system will be used to update all relevant components with status messages related to the import and processing of the geospatial data.

The following table summarises the geospatial formats that partner services will deliver to the importer (Table 3). These formats are compatible with the Map Server requirements.

Table 3: Geospatial file formats to be used by partner services to be ingested by the Importer and Mapper component.

UNICORN Partner	Format	Type
MITIGA, NOA, LINKS, Riscognition	GeoTIFF	Raster
LINKS, Riscognition	GeoJSON	Vector
NOA, MITIGA	ESRI Shapefile	Vector
MITIGA	NetCDF	Raster

4.2.5 The Map Server

A map server is a software component that manages and delivers geospatial data, typically in the form of map layers, to clients such as web applications, GIS tools, or mobile devices. It enables users to access and interact with spatial information—such as satellite imagery, terrain models, or thematic layers through standardized web services such as a Web Map Service (WMS). Map servers are commonly used in Geographic Information Systems (GIS) to support decision-making, data analysis, and real-time visualization in fields like urban planning, environmental monitoring, as well as emergency response. Within the UNICORN platform, the map server will process and serve partner map data stored in the repository that will be visualised on the front-end to registered users. The map server provides scalable and geospatial interoperability.

The open-source GeoServer (http://www.geoserver.org) will be adopted for serving the geospatial data to the front-end and providing services to the mapper component (in the import and mapper). GeoServer is specialised software used for serving maps on websites that was designed for interoperability, and it can publish data from any major spatial data source using open standards. A community-driven project, GeoServer is the reference implementation of the Open Geospatial Consortium[4] (OGC) Web Feature Service (WFS) and Web Coverage Service (WCS) standards, as well as a high performance certified compliant Web Map Service (WMS).

[4] https://www.ogc.org/who-we-are/

The map server component will be used to produce and provide the needed map layers in standard open formats and deliver them for visualisation. By providing a robust, standards-based geospatial data solution, the map server module enables partners to share and visualize UNICORN geospatial data.

4.2.6 The Front-End Graphical User Interface

To interact with the UNICORN platform, a graphical user interface (GUI) is needed. This web-based front-end will serve as the platform's user interface providing a unified view of the data and services to support hazard stakeholders. The purpose of the UNICORN front-end is to provide a dashboard to consolidate data from the platform micro-services with the goal of presenting standard workflows to professionals and effectively delivering hazard information. The dashboard design will empower decision-makers with actionable insights to assess, monitor, and respond to different hazard events more effectively.

Within the architecture (Figure 2), the dashboard will communicate with the UNICORN platform backend through a cloud-based API, which interfaces with key system components including the identity and authentication management system, the message bus, the geospatial data repository, and the other UNICORN hazard services. This API will ensure seamless data exchange between the backend and the dashboard, asynchronously (messaging system), scheduled backend processes, or synchronously through direct API requests.

To understand the limits of the system from a user perspective, the front-end will be used to test the usage limits linked to the maximum number of concurrent users and API requests supported. These service scalability metrics will be tracked during the demonstration phase (WP4) where many users will concurrently access the front-end. The metric will indicate the upper bound before degradation of the different modular components that characterise the scalability of the overall system.

The maximum number of concurrent users and the maximum number of API requests supported directly describe the system's ability to grow and will provide quantitative measures of service stability.

The following elements will be provided on the dashboard in order to support the rich hazard data streams available through UNICORN into meaningful, accessible information that will enhance user responsiveness and situational awareness during hazard events, disasters and emergencies.

Alerts – this interface element allows users to interact with alerts. Alerts can be set by area of interest within different time intervals. The dashboard will be able to display alerts received through the UNICORN services and geolocate them on a map. Listing of current and past alerts will also be available.

Hazard Content – this interface element is for interacting with the partner products. It will allow the user to delineate their area of interest and retrieve information associated with the extent. This dashboard element displays shared data from the UNICORN partner services such as maps linked to the flood, wildfire and lava flow use cases. The role of this element is to offer an overview of the situation in a given area and provide responsive data-informed actionability. The information presented will also be able to filter by customising the time interval of the presented map layers. This functionality allows the user to inspect and visualise hazard situations at various moments.

User Management – it will be necessary to provide users a means to register to the UNICORN platform providing relevant information for data access. This can be used to provide roles to users which are linked to data access controls.

Map Manipulation – as a geospatial front-end, users are expected to interact with the map products presented. Therefore, map widgets will provide access to spatial tools that can be used to highlight, co-operate, and enhance information presented through dashboard. These tools will also integrate metadata access so that users can provide additional details when appropriate.

Charts and Graphs – not all hazard information is best presented as map products and therefore the UNICORN dashboard will also provide alternative visualisation options in the form of charts and graphs. This element will be service specific to highlight options available from a particular hazard service.

The front-end will be presented to UNICORN users as a cloud-based web application, making it possible to be accessed from anywhere with a secure (HTTPS) internet connection fostering collaboration and informed decision-making.

An initial view of the front-end user interface (UI) is presented in the following figure (Figure 3).

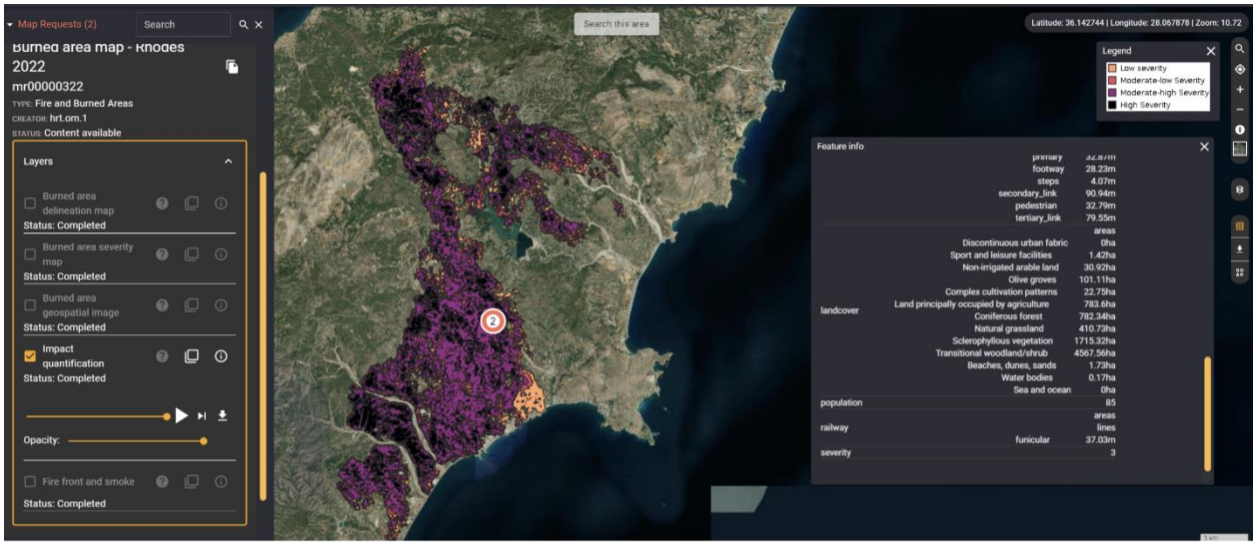

Figure 3 – A mock-up of the UNICORN micro-services front-end user interface. Left side = data layer panel; centre = map panel; right side bar = toolbar.

The UI (Figure 3) is divided into three main sections: the data layer panel (left side), the map panel (centre) and tools (right side bar). The data layer panel is used to browse and select data layers available for visualisation. The layer list will be linked to the service chosen by the user and based on the available datasets. The map panel is where the geospatial information is presented. This information is overlaid on a satellite basemap to help with localisation of the presented layers. On this panel, additional information can also be visualised including a map legend and/or other details such as metadata (text) or statistics in the form of graphs. The toolbar provides the user access to tools which can be used to navigate the map panel including actions such as drawing polygons.

Other functionalities will have slight variations to the presented UI such as when a user needs to make a map request where the data layer panel will allow the user to choose the wanted service and the map can be used to delineate the area of interest.

4.2.7 The Storage Module

The UNICORN platform needs a place to store all the data being produced and shared by the partners. The storage module (Figure 2) is the component of the architecture that will provide this service. This geodata repository will be designed to store and manage a wide range of geospatial and non-geospatial data, including structured, semi-structured, or unstructured data that was generated either by the system or produced by a project partner. To facilitate partner implementation, the data access will be possible either through exposed APIs or web-based

interfaces to support functions for uploading, querying, retrieving, and filtering both data and associated metadata. It will need to support a high-volume of data and be scalable for potential future developments.

To achieve this, the storage module essentially will be made up of two components: the big data storage system and an associated geospatial database. The big data storage system will be used to store the raw files in their different formats. The structured geospatial database will hold the relevant metadata (including metadata in compliance with the INSPIRE metadata directive (ISO 19115/19119)) to ensure interoperability not only across UNICORN partners but also the European hazard community. This setup was devised to support advanced spatial and metadata queries, such as selecting objects within a geographic area or filtering by metadata attributes. Together, these components can handle diverse data formats and ensure efficient and standardized access to all the shared information.

It is expected that throughout the UNICORN project timeline and beyond a significant amount of data will be collected and processed, therefore a big data architecture was adopted to build the platform. A benefit of a big data storage system is that it is built to address the technology issues related to large data volumes and data heterogeneity which traditional relational databases are not fit for. The data lake model stores data in their raw form regardless of the format or structure is a distributed system for security and availability. To ensure reliability and fault tolerance, the data will be replicated across multiple servers which reduces access latency and ensures system resilience even during high demand such as during an emergency response scenario.

Note that the same storage module can be used for both the UNICORN web portal (Figure 1) as well as the UNICORN platform (Figure 2) providing a robust, scalable, and flexible infrastructure for storing, managing, and accessing diverse data critical to the UNICORN hazard system. By providing scalable, reliable storage and retrieval services, the storage module enables UNICORN partners to share and analyse critical hazard data to support informed decision-making and collaboration across stakeholders.

4.2.8 Benefits and Drawbacks

The presented UNICORN micro-services platform architecture was developed to align with service needs.

Benefits of the micro-services architecture in the context of UNICORN

The UNICORN partners need an open and integrated platform to demonstrate the hazard service developments and project use cases. The micro-services platform was designed to easily integrate and use information from different sources including EO imagery from Copernicus and EuroGEO, hazard specific geo-information as well as other open data such as DEMs and thematic layers. The web-based UNICORN platform provides a professional solution expected from hazard stakeholders to securely access hazard and disaster information.

Drawbacks of the micro-services architecture in the context of UNICORN

No single solution fits all scenarios, and the UNICORN platform tries to manage the greatest issues as easily as possible. However, not all UNICORN partner services are ready for integration into the platform. From a technical perspective, this could mean significant changes to their current services not only to communicate between the services but also potentially how to trigger and access the outputs. Furthermore, due to business IP it is possible that hazard related data may not be shared through the storage module solution. This means that the cloud-based front end would not be able to present the outputs. The team is working together to overcome this barrier.

5 Conclusions

As outlined in this deliverable, the UNICORN architecture establishes a robust, interoperable, and user-centric service architecture to address holistically the user requirements of the hazard stakeholders as well as the partner Copernicus based services. Two separate architectures are presented based on different needs: the UNICORN web-portal architecture and the UNICORN micro-services platform architecture. The system architecture describes the overall structure and organization of the complete UNICORN system including the different components, their relationships, data flows, and interactions and helps bring the partners into a holistic understanding of the implementations.

The web portal serves as a centralized gateway, facilitating data exploration and service access while promoting partner offerings through a curated UNICORN Shop. Its integration with a scalable data lake ensures standardized, secure, and FAIR-compliant data sharing, supporting interoperability and accessibility.

The UNICORN micro-services platform provides a flexible backend for orchestrating partner services, underpinned by industry standard components such as the Customer Identity and Authentication Management (CIAM) system, API Gateway, RabbitMQ messaging system, and Geodata Repository. These components collectively ensure authenticated access, efficient data exchange, and real-time visualization, addressing user requirements for high availability, scalability, and security, as identified in D2.1.

The developed architectures try to align system capabilities with real-world user requirements, technical interoperability standards, and business sustainability. By doing so, UNICORN ensures that its infrastructure meets the expectations of both end-users in emergency management and project partners aiming for commercial uptake beyond the project's lifecycle.

The following key architectural goals were considered during the development: interoperability, scalability, security, modularity, and accessibility which guided the UNICORN system design, fostering a loosely coupled, service-oriented architecture that balances research innovation with commercial sustainability. The adoption of industry standards including OAuth 2.0, OGC, and INSPIRE, and modern technologies will help integrate partner service integration. To implement the proposed architectures, partner agreements and service level agreements will help ensure long-term viability beyond the project's timeline.

The four use cases will validate the architecture's effectiveness, demonstrating improved prediction, early warning, and emergency management capabilities across diverse hazard scenarios.

Therefore, the UNICORN architecture provides a forward-looking framework that empowers partners to advance Copernicus-based services, supports stakeholders in managing climate-driven hazards, and lays the foundation for a resilient European landscape. Future iterations of this deliverable will refine the architecture based on use case outcomes, partner feedback, and technological advancements, ensuring alignment with the project's vision of fostering innovation, collaboration, and societal benefit.

In the next steps, UNICORN will implement the architectures to showcase the impact of the four use cases through an end user validation that will help build a more resilient European hazard stakeholder landscape.

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