D2.12
HEIMDALL System Architecture

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1.0.F	11/04/18	Final version	DLR

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List of Acronyms

AoS	Area of Simulation
API	Application Programming Interface
C&C	Command & Control Centre
CAMS	Copernicus Atmosphere Monitoring Service
CAP	Common Alerting Protocol
CMEMS	Copernicus Marine and Environment Monitoring Service
CMU	Crisis Management Unit
DataEo	Earth Observation Data Source
DataEx	External Data Source
DataSitu	In Situ Data Source
DB	Database
DS	Decision Support
ESB	Enterprise Service Bus
ETA	Estimated Time of Arrival
DES	Decision Support Information
FFS	Forest Fire Simulator
FR	First Responder
FTP	File Transfer Protocol
GB	Ground Based
GDACS	Global Disaster Alert and Coordination System
GIS	geographic information system
GOI	Geographical Locations of Interest
GPS	Global Positioning System
GUI	Graphical User Interface
IA	Impact Assessment
IG	Information Gateway
ISA	Impact Summary
ISAS	Impact Summary Service
LU	Local Unit
MODIS	Moderate Resolution Imaging Spectroradiometer
P2P	Peer to Peer

POI	Points of Interest
RVA	Risk and Vulnerability Assessment
SA	Situation Assessment
SAR	Synthetic Aperture Radar
SatCom	Satellite Communication
Scen	Scenario
SP	Service Platform
SM	Scenario Management
SMAC	Scenario Matching
UeRM	User Role Management
UI	User Interface
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Service

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Executive Summary

This document provides the HEIMDALL system architecture. It is the companion deliverable to D2.11 – Service Concept Specification [1] and defines the system architecture that is necessary to provide the services and products of HEIMDALL. The system elements are identified based on the requirements defined in Task 2.3 and provided as a first version in D2.6 [2]. The interfaces between system elements and with external agents are identified and presented where service requirements, rules input data and data exchange formats to other connected systems are considered. The system modules presented here will be further specified during the project and presented in dedicated deliverables for milestone 2 (M18) and 4 (M42).

1 Introduction

HEIMDALL will provide services and products scenario planning and scenario building for first responders (FR), command and control centres (C&C) and incident managers of different actors involved in natural and man-made hazard responding. Several services and products have been identified and presented in D2.11. We here present the corresponding system architecture that is able to offer the identified services. The setup is divided in a local unit that provides all necessary features to single authority. A high level illustration is shown in Figure 1-1 which uses different data sources, space, ground and aerial based as inputs. External systems and data sources can be integrated, too. A local unit provides services for scenario management, modelling and simulation features to forecast the behaviour of hazard, risk and vulnerability assessment, situation assessment and decision support. Data sharing and communication has two aspects in HEIMDALL, first considering the local unit, communication within the organisation is addressed, and data can be shared with the FR and C&C. Furthermore, the population can be informed to increase public awareness. Second, the information can be shared with other authorities, for instance with organisation of different disciples or neighbouring countries or municipalities.
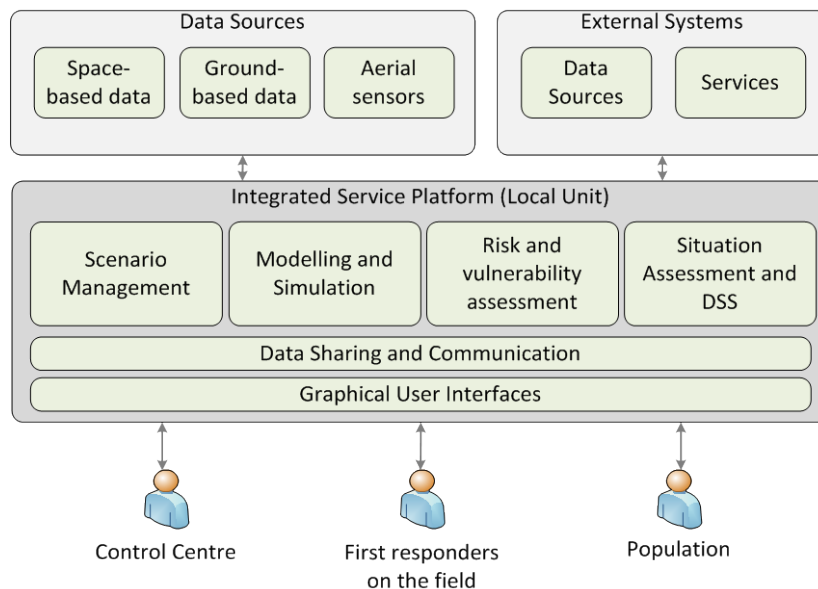
Figure 1-1: Local Unit service architecture

For this, it is possible to interconnect different local units in a federated architecture as presented in Figure 1-2. A global catalogue is used for information discovery and initiating the connections. The connection itself is established in a peer 2 peer (P2P) way and content orient based.
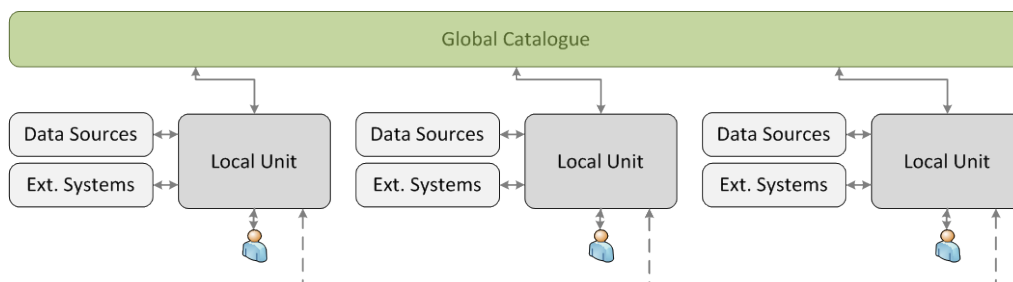
Figure 1-2: Federated architecture

HEIMDALL follows an agile approach for the development. Consequently, we consider the general architecture and core products as fixed since it is based on core user requirements, however, for some fields and modifications are expected because of an iterative approach having multiple validation and development cycles with end-user involvement.

The following sections are organized as follows:

- Section 2 specifies the system elements of the local unit and shows the provided by them as well as the interfaces.
- Section 3 describes the federated architecture and the specific modules required to establish a connection among multiple actors of different organisations.
- Finally, section 4 summarizes and concludes the document.

2 Local Unit

In Figure 1-1 the architecture of a local unit (LU) is presented including the interfaces (ESB, I1 – I10). On the left hand side the system inputs are presented which are further detailed in section 2.8 and 2.9. The simulators (Simu) shown in the centre upper part include simulators for fire, flood and landslide as presented in section 2.4. Modules that are using the simulation results as input are shown below and are namely the risk assessment (RVA), the impact summary (IA) generation and decision support (DS). On the right hand side everything needed for communication is shown. An information gateway (IG) connects the system via satellite communication (SatCom) or the commercial internet with a receiver application for smartphones for the FRs or the general public. For the federated architecture, the system can connect to a catalogue and provides the dedicated interface to other system instances. In the lower central part of the figure, the user role management module (UeRM) (further explained in section 2.2) the graphical user interface (GUI – see section 2.10) and the scenario management (SM) (section 2.3) are illustrated. The overall interconnecting middleware the service platform that orchestrates the whole system is defined in section 2.1.
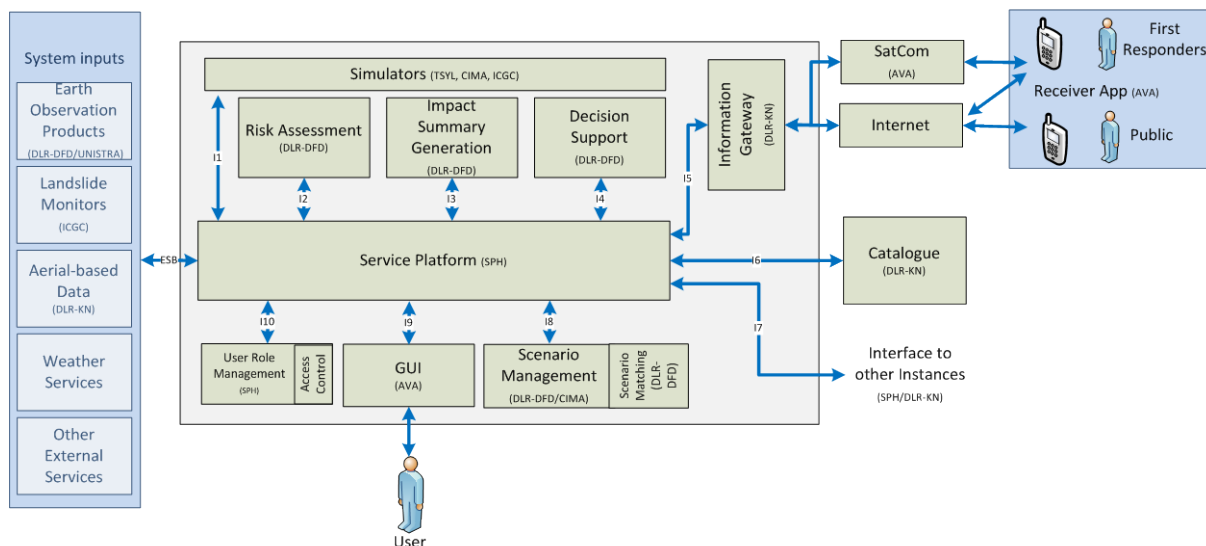
Figure 2-1: Local unit architecure

In each sub-section below, the modules are considered as a "black box" which provides the services described in D2.11 and the inputs and outputs to the "black box" and the consumer or provider are defined. For the sake of clarity, the interfaces (ESB, I1 – I10) in Figure 2-1 are combined. One interface per module shown that actually represents a bundle of interfaces to other modules. However, all the communication will be done via the service platform (SP) so indeed the interface can be represented by a single connection to the SP. The actual interfaces to other modules are indicated by the tables in the following sections, since here the inputs and the provider as well as the consumer are shown. To each of them an interface must be developed which will be done in the dedicated deliverables of each module. For the simulators the first version of I1 will be in D5.12 at M2, for the risk assessment I2 in D6.4 at M18, for the impact summary I3 in generation D6.7 at M18, for the decision support I4 in D6.10 at M18, for the SP the ESB in D4.1 at M18, for the user and role management module I10 in D4.4 at M20. The interface I9 of the GUI will be described in D4.7 at M18, I8 for the scenario management in D6.15 at M18, I5 for the IG and the SatCom in D4.16 at M22. The catalogue interface I6 and I7 the interfaces to other instances will be presented in D4.13 at M18. The Landslide monitors and aerial based data interface will be defined in D5.4 at M18, the ones for EO in D5.1 and the ones for external services in D5.9 in M22, respectively.

2.1 Service Platform

The core element of the HEIMDALL architecture is the service platform (SP), as presented in Figure 2-1, offered to each individual authority for response planning and scenario building. The SP accommodates and interconnects various internal services and modules (such as workflow orchestration service, the SP monitoring module, as well as interfaces with the rest of the HEIMDALL modules) for multi-hazard management. Hence, the SP implements a repository for geospatial and plain data as well as a GIS engine for data representation and transformation. Moreover, the SP offers interfaces for internal and external data sources as well as interfaces for the horizontal, peer-to-peer communication with other Local Units (see Section 3). A graphical user interface (see section 2.10) will facilitate interaction with the end users in an intuitive and user-friendly manner. Overall, the SP and its user interface will offer to end users a complete integrated environment for response planning and scenario building, also facilitating the exchange of data with other authorities.

With the help of the following services, the user shall be able to:

- Retrieve cartographic data from a web map service (WMS)
- Retrieve map features from a web feature service (WFS)
- Retrieve coverage information from a web coverage service (WCS)
- Submit coverages and features to the georeferenced data repository
- Submit events and observations to the georeferenced data repository
- Retrieve/submit data to a general purpose (non-georeferenced) data repository

Table 2-1 describes the outputs provided by the SP with regard to data storage, the inputs needed to generate each output, the modules or external elements providing each of the inputs and the modules consuming the corresponding outputs.

Table 2-1: Service Platform storage services inputs and outputs

Products and/or Services	Inputs needed *inputs to generate each output*	Provided by *module or external system providing the input*	Used by *module consuming the product/service*
Georeferenced data storage service	The invocation of the OGC compliant API provided by the SP requesting to store/retrieve/edit/etc. data.	External services	GUI
GIS database	Georeferenced data	Georeferenced data storage service	SP GUI
"Plain" data storage service	The invocation of the API provided by the SP requesting to store/retrieve/edit/etc. data.	External services	SP GUI
"Plain" database	A database that allows the storage and retrieval of plain data information.	"Plain" data storage service	SP GUI
Historic data service	Provide access to historic data (past incidents)	SP	GUI SM

Additionally, the services in Table 2-2 shall be used to:

- Acquire data (either raw or processed) not provided by the currently installed data sources or tools.

- Communicate sensor data, events and simulation results and retrieve decisions/ recommendations.

Table 2-2: Service platform additional services inputs and outputs

Products and/or Services	Inputs needed	Provided by	Used by
Workflow invocation service	The workflow description (sequence of services invoked and products manipulated) provided by the LU of a remote Unit (remote invocation of process).	SP (local or remote)	All other HEIMDALL services
SP Monitoring	Basic monitoring metrics regarding SP operation, regarding resource utilisation and generated products, through log files.	SP	SP
Interfaces with various services	Valid user credentials	GUI	All other HEIMDALL services
	Access rights	UeRM	
	Products and services	SP Catalogue	

2.2 User and Role Management

With regard to user and role management (see Table 2-3), the authentication module shall allow a user or an application/service to access the system based on the credentials provided (specifying access rights/privileges to resources). Only users/applications/services with valid credentials will be allowed to access the system.

The access control module shall apply selective restriction to HEIMDALL resources (services/products and actions on them). Valid users will have access to the resources based on their role and access rights.

Table 2-3: User and role management services inputs and outputs

Products and/or Services	Inputs needed	Provided by	Used by
Authentication	Username and password of the user	GUI	GUI Smartphone application
	A valid token, in the case a token-based method is used	UeRM	

Access control	Valid login credentials (successful authentication)	GUI	SP UeRM
	Active role of the user	UeRM	

Through the admin console (see Table 2-4), the SP administrators can centrally manage all aspects of the user management server, whereas through the account management console, users can manage their own accounts. In addition, the user profile shall hold their preferences, as shown in D2.11, facilitating a smoother operation from the user perspective.

Table 2-4: Administrator services inputs and outputs

Products and/or Services	Inputs needed	Provided by	Used by
Admin console	Valid admin credentials	GUI	GUI UeRM
Account management console	Valid user credentials	GUI	GUI UeRM
User profile	The user preferences as shown in D2.11.	UeRM	Access control

2.3 Scenario Management

The HEIMDALL project aims at supporting decision makers in building, storing and reviewing realistic, multidisciplinary scenarios. A scenario should consist of a real or hypothetical hazard and current conditions in the local area, information on where physical impacts are likely to occur, and how they will interact with people and buildings, what measures, resources and forms of organization are needed in order to reduce the consequences. During a disaster situation, scenario objects provided by the system act as a recording of actual events and actions as the situation evolves as well as a means for tracking lessons learnt in the aftermath of a disaster. As a matter of fact, users can define scenarios which represent both – real situations and fictive simulated scenarios.

Scenario management is comprised of three major components:

- Scenario Management (SM) component
- Scenario Repository
- Scenario Matching (SMAC) component

The SM component enables clients (e.g. the GUI) to create, store, retrieve, edit and delete scenarios and response plans. In addition, a scenario shall be able to be copied, e.g. in order to derive a fictive scenario from a real situation. Furthermore, it provides functionality to connect to a scenario all related incident information provided by the different internal and external data sources, simulation results, risk and impact assessment information, decisions made, measures taken and lessons learnt. In that sense, a scenario object (JSON object) acts as a pool of information and knowledge for effective situation assessment and plan formulation. The association of information to a scenario is assumed to be performed by the user over the UI. Some automatically acquired information such as weather conditions are assigned by the HEIMDALL system. Users shall be able to access all information associated to a scenario in order to explore them in detail. At any time during a scenario lifecycle a snapshot of the current sensor data and available information can be generated for analysis, situation reporting and archiving purposes. Based on a sequence of scenario snapshots end users are able to retrace the scenario evolution. Scenarios, scenario snapshots and

response plans are stored in a Scenario Repository. The situation reporting functionality is outlined in Section 2.6.

The SMAC component matches for a given situation a list of similar historic or fictive scenarios. With the scenario matching functionality, users can find similar situations in a database and look for the taken response measures and their outcomes. They can use this information to evaluate suitable strategies for the situation at hand or to simulate different options of what could happen and what effects prevention or mitigation measures would have if applied, for instance, by simulating the effect of fire breaks on the situation evolution (i.e. what-if analysis). The SMAC can provide the different parameters for the definition of the simulated options in the form of incident behaviour observed in historic scenarios, measures taken, evaluations made, etc. Table 2-5 shows the products SM and SMAC generate.

As a basis for multi-criteria pattern matching, analysis, and comparison of scenarios suitable multi-hazard and risk-based comparison metrics will be identified and formalized. These metrics will build upon the determination of suitable distance factors and relations between scenarios in terms of time and space, rule-based algorithms, geospatial analysis, and emergency response knowledge. Matching criteria and metrics are configurable and visible to the end users in order to foster matching-process customization and optimization.

Table 2-5: Scenario Management and Scenario Matching products

Products and/or Services	Inputs needed	Provided by	Used by
Scenario	Scenario information: • Type (real/simulated), • Name, identifier • Hazard type • Hazard time • Hazard location • Hazard behaviour • Impact scale • Risk level • Casualties and injured • Weather conditions (wind speed, wind direction, temperature, relative humidity) • Credibility Associated information: • Internal and external data (i.e. EO-based products, Aerial-based products, landslide monitoring products, crowdsourced and first responder data) • Simulation results • Risk and vulnerability products	GUI (user input: scenario information + association of products below) Associated information from: Internal and external data sources, SP, Simu, RVA, SA, DS Internal: SM (for associating response plans, decisions, countermeasures, lessons learnt, similar scenarios and simulated options)	Simu, RVA, SA, DS, GUI

	• Impact summary information (impact, potential interacting hazards, situation evolution) • Decision support information • Related scenarios • Response plans • Decisions • Lessons learnt • Countermeasures		
Scenario snapshot	Scenario identifier Date/time Instance of a scenario at a specific point in time including all associated information	GUI (user input: description/notes)	GUI (for analysis) SA, DS (for response plan/situation report generation)
Response plan	Inputs should allow the system the compilation of response plans. Detailed inputs will be defined in the corresponding technical specification D6.14.	GUI (user input) SM (scenario/incident information and similar scenarios) Simu (results) SA, DS, ISA information, DES information	GUI SM (for association to scenario)
Decision	Inputs should allow the system the compilation of decisions. Detailed inputs will be defined in the corresponding technical specification D6.14.	GUI (user input)	GUI SM (for association to scenario)
Measure	Inputs should allow the system the compilation of measures. Each measure must refer to the scenario it applies, to the response plan and decision if measure is taken in order to achieve goals set in the plan and decision. Evaluation (text) or rating (positive/negative) Detailed inputs will be defined in the corresponding technical specification D6.14.	GUI (user input)	Simu SM (for association to scenario) GUI

Lesson learnt	Inputs should allow the system the compilation of lessons learnt. Detailed inputs will be defined in the corresponding technical specification D6.14.	GUI (user input)	SM (for association to scenario) GUI
List of similar scenarios	Expert criteria for matching Input parameters or input scenario snapshot	Configuration (expert criteria) GUI (input parameters or snapshot ID)	GUI SM (for association to scenario snapshot)

2.4 Modelling and Simulation

The modelling and simulation module is the HEIMDALL's modelling component, simulating the behaviour and extension of multiple hazards. With this in mind, the module integrates several simulation tools, each of them addressing a specific hazard. The hazards that are addressed within the project are forest fires, landslides and floods, but thanks to the modularity of the system other simulation tools can be easily integrated within the system in the future. Each of these simulation tools needs to receive inputs from other internal HEIMDALL components and/or external systems for processing the outputs related to the estimations of the hazard extent and behaviour. In addition, some of the created outputs will be used as input to other system elements. Table 2-6, Table 2-7 and Table 2-9 list the relevant products of the simulation tools for each hazard and define the necessary inputs that are needed to generate the corresponding product, the module or external system providing the input, as well as the consumer modules that use the created simulation products. The specified products will be mainly used by the risk and vulnerability assessment module, the situation assessment and decision support modules to generate their products.

2.4.1 Flood Simulation

In Table 2-6 planned products of the flood simulator are shown. It furthermore, identifies the inputs, the unit of the input indicated in squared brackets and the components that shall provide this input data and the consumers of the products.

Table 2-6: Flood simulation inputs and outputs

Products and/or Services	Inputs needed	Provided by	Used by
Real-time flood extensions (Simplified model)	Selection of AOI [polygon]	GUI	SM, RVA, SA, DS
	Digital Terrain Model [grid]	DataEX	
	Layer of the levees location [polyline]	DataEX	
	Number of streams (e.g. confluence case) [double] Input discharge location(s) [single point or multiple points] Peak discharge	GUI	

	value(s) [double]		
	Peak discharge(s) timing [time]		
	Flood duration [double]		
Real-time water depth (Simplified model)	Selection of AOI [polygon]	GUI	SM, RVA, SA, DS
	Digital Terrain Model [grid]	DataEX	
	Layer of the levees location [polyline]	DataEX	
	Number of streams (e.g. confluence case) [double]	GUI	
	Input discharge location(s) [single point or multiple points]		
	Peak discharge value(s) [double]		
	Peak discharge(s) timing [time]		
	Flood duration [double]		
Flood extensions (Complete model)	Selection of AOI [polygon]	GUI	SM, RVA, SA, DS
	Digital Terrain Model [grid]	DataEX	
	Layer of the levees location [polyline]	DataEX	
	Number of streams (e.g. confluence case) [double]	GUI	
	Input discharge location(s) [single point or multiple points]		
	Peak discharge value(s) [double]		
	Peak discharge(s) timing [time]		
	Flood duration [double]		
Water depth (Complete model)	Selection of AOI [polygon]	GUI	SM, RVA, SA, DS
	Digital Terrain Model [grid]	DataEX	
	Layer of the levees	DataEX	

	location [polyline]		
	Number of streams (e.g. confluence case) [double]	GUI	
	Input discharge location(s) [single point or multiple points]		
	Peak discharge value(s) [double]		
	Peak discharge(s) timing [time]		
	Flood duration [double]		
Water velocity (Complete model)	Selection of AOI [polygon]	GUI	SM, RVA, SA, DS
	Digital Terrain Model [grid]	DataEX	
	Layer of the levees location [polyline]	DataEX	
	Number of streams (e.g. confluence case) [double]	GUI	
	Input discharge location(s) [single point or multiple points]		
	Peak discharge value(s) [double]		
	Peak discharge(s) timing [time]		
	Flood duration [double]		
Dynamic mapping tool (hydrological model and simplified hydraulic)	Selection of AOI [polygon]	GUI	SM, RVA, SA, DS
	Digital Terrain Model [grid]	DataEX	
	Layer of the levees location [polyline]	DataEX	
	Number of streams (e.g. confluence case) [double]	GUI	
	Input discharge location(s) [single point or multiple points]		
	Peak discharge value(s) [double]		

	Peak discharge(s) timing [time] Flood duration [double]		
	Location of mitigation measure on DTM grid [point and click] local mitigation measure value (+/- level)	GUI	
	Location of mitigation measure on levees layer polyline [select and click] local mitigation measure value (+/- level)	GUI	

2.4.2 **Forest fire Simulation**

Table 2-7 displays the products that are planned to be provided by the forest fire simulator, the necessary inputs to generate these results, the components that shall provide the input data as well as which modules are planned to make use of the resulting products.

Table 2-7: Forest Fire Simulation products, related inputs and relation with other system components

Products and/or Services	Inputs needed	Provided by	Used by
Time of arrival	Weather parameters: • Wind speed (in the direction of wind. (Km/h) • Wind direction (º) • Air temperature (ºC) • Relative humidity (%) • Cloudiness (Yes/No)	DataEX	SM, SA, DS, GUI
	Hours of simulation (h)	SP and/or GUI	
	Selection of adjustment	GUI	
	One or multiple geometries with associated date and time	DataSitu or GUI	
	Simulation start date and time	SP or GUI	
	Area of simulation (AoS)	SP	
	Firebreaks	GUI and forest fire	

		simulator (FFS)	
Fire perimeter	Weather parameters: • Wind speed (in the direction of wind. (Km/h) • Wind direction (º) • Air temperature (ºC) • Relative humidity (%) • Cloudiness (Yes/No)	DataEX	SM, SA, DS, GUI
	Hours of simulation (h)	SP and/or GUI	
	Selection of adjustment	GUI	
	One or multiple geometries with associated date and time	DataSitu or GUI	
	Simulation start date and time	SP or GUI	
	Area of simulation (AoS)	SP	
	Firebreaks	GUI and FFS	
Minimum Travel Time (MTT) fire paths	Weather parameters: • Wind speed (in the direction of wind. (Km/h) • Wind direction (º) • Air temperature (ºC) • Relative humidity (%) • Cloudiness (Yes/No)	DataEX	SM, SA, DS,GUI
	Hours of simulation (h)	SP and/or GUI	
	Selection of adjustment	GUI	
	One or multiple geometries with associated date and time	DataSitu or GUI	
	Simulation start date and time	SP or GUI	
	Area of simulation (AoS)	SP	
	Firebreaks	GUI and FFS	

Flame length	Weather parameters: • Wind speed (in the direction of wind. (Km/h) • Wind direction (º) • Air temperature (ºC) • Relative humidity (%) • Cloudiness (Yes/No)	DataEX	SM, SA, DS, GUI
	Hours of simulation (h)	SP and/or GUI	
	Selection of adjustment	GUI	
	One or multiple geometries with associated date and time	DataSitu or GUI	
	Simulation start date and time	SP or GUI	
	Area of simulation (AoS)	SP	
	Firebreaks	GUI and FFS	
Fire intensity	Weather parameters: • Wind speed (in the direction of wind. (Km/h) • Wind direction (º) • Air temperature (ºC) • Relative humidity (%) • Cloudiness (Yes/No)	DataEX	SM, SA, DS, GUI
	Hours of simulation (h)	SP and/or GUI	
	Selection of adjustment	GUI	
	One or multiple geometries with associated date and time	DataSitu or GUI	
	Simulation start date and time	SP or GUI	
	Area of simulation (AoS)	SP	
	Firebreaks	GUI and FFS	

Rate of Spread (ROS)	Weather parameters: • Wind speed (in the direction of wind. (Km/h) • Wind direction (º) • Air temperature (ºC) • Relative humidity (%) • Cloudiness (Yes/No)	DataEX	SM, SA, DS, GUI
	Hours of simulation (h)	SP and/or GUI	
	Selection of adjustment	GUI	
	One or multiple geometries with associated date and time	DataSitu or GUI	
	Simulation start date and time	SP or GUI	
	Area of simulation (AoS)	SP	
	Firebreaks	GUI and FFS	
Out of suppression capacity	Weather parameters: • Wind speed (in the direction of wind. (Km/h) • Wind direction (º) • Air temperature (ºC) • Relative humidity (%) • Cloudiness (Yes/No)	DataEX	SM, SA, DS, GUI
	Hours of simulation (h)	SP and/or GUI	
	Selection of adjustment	GUI	
	One or multiple geometries with associated date and time	DataSitu or GUI	
	Simulation start date and time	SP or GUI	
	Area of simulation (AoS)	SP	
	Firebreaks	GUI and FFS	
Forest fire impact relevance assessment	Census data and/or Land use economic data	Simu or DataEx	SM, SA, DS, GUI

	Weather parameters: • Wind speed (in the direction of wind. (Km/h) • Wind direction (º) • Air temperature (ºC) • Relative humidity (%) • Cloudiness (Yes/No)	DataEX	
	Hours of simulation (h)	SP and/or GUI	
	Selection of adjustment	GUI	
	One or multiple geometries with associated date and time	DataSitu or GUI	
	Simulation start date and time	SP or GUI	
	Area of simulation (AoS)	SP	
	Firebreaks	GUI and FFS	
Impact oriented fire paths	Census data and/or Land use economic data	Simu or DataEx	SM, SA, DS, GUI
	Weather parameters: • Wind speed (in the direction of wind. (Km/h) • Wind direction (º) • Air temperature (ºC) • Relative humidity (%) • Cloudiness (Yes/No)	DataEX	
	Hours of simulation (h)	SP and/or GUI	
	Selection of adjustment	GUI	
	One or multiple geometries with associated date and time	DataSitu or GUI	
	Simulation start date and time	SP or GUI	
	Area of simulation (AoS)	SP	
	Firebreaks	GUI and FFS	

2.4.2.1   Pyro-geomorphometry

The service that provides the following products shall calculate/identify for a given area the geological elements of the terrain that influence the way the fire behaves and spreads, i.e. the elements that accelerate or decelerate the progression of fire. These elements are specified in Table 2-8.

Table 2-8: Pyro-geomorphometry products, related inputs and relation with other system components

Products and/or Services	Inputs needed	Provided by	Used by
Mountain ridges	Area of simulation (AoS)	SP and/or GUI	GUI
Consolidation lines	AoS	SP and/or GUI	GUI
Valley nodes	AoS	SP and/or GUI	GUI
Vertical walls	AoS	SP and/or GUI	GUI

2.4.3 Landslides

Products derived from landslide simulation, with the corresponding inputs and correlations with other modules are listed in Table 2-9.

Landslide simulator will provide three products: terrain movement susceptibility map, trends of triggering conditions that can trigger terrain movements and scenarios of potential landslide warning areas based on triggering conditions evolution. First two products are obtained from external inputs. The third product uses the two previous products combined as inputs.

All three products should be shown in the GUI, together with the inputs of all of them. At the same time, while the terrain movement susceptibility map will be used as an input by the risk assessment module, the other two products will be used only for the situation assessment, decision support and scenario management.

Table 2-9: Landslide simulator services inputs and outputs

Products and/or Services	Inputs needed	Provided by	Used by
Terrain Movement Susceptibility map	Digital Elevation Model	DataEx	Simu, SM, RVA, SA, DS, GUI
	Other cartographic information (source areas, geology, etc.)	DataEx	
Trends of triggering conditions that can trigger terrain movements	Weather data	DataEx	Simu, SM, RVA, SA, DS, GUI
Scenarios of potential landslide warning areas based on triggering conditions evolution.	Trends of triggering conditions that can trigger terrain movements	Simu	SM, RVA, SA, DS, GUI
	Terrain Movement Susceptibility map	Simu	
	Sentinel-1 Information about landslides	DataEO	

	Near real-time terrain movement information	DataSitu	

2.5 Risk and Vulnerability Assessment

The Risk and Vulnerability Assessment module (RVA) will support the HEIMDALL platform with designated risk products. The bases for the assessment are the generated hazard information (flood, landslide or forest fire) products from the Earth observation (DataEo) or simulation modules (Simu). The hazard information is used to identify the exposed elements, i.e. elements that are affected by a certain hazard. The exposed elements are composed by the physical elements (physical exposure) and the human elements (human exposure) which serve as input for the human and physical impact assessments. In the impact assessment products the expected impact on the population and the valuable assets affected by the occurring incident are estimated. Table 2-10 lists the relevant products of the RVA module and defines the necessary inputs that are needed to generate the product, the module or external system providing the input, as well as the consumer modules that use the created RVA products. The specified products will be mainly used by the situation assessment and decision support modules (compare section 2.6) to generate their products.

Table 2-10: Risk and Vulnerability Assessment Products

Products and/or Services	Inputs needed	Provided by	Used by
Human impact assessment	Census data	External services	SA DES
	Critical infrastructure information	External services	
	Observed Crisis Information	DataEO	
	Simulated crisis information	Simu	
	Human exposure	Internal: exposure estimation	
Human exposure	Observed crisis information	DataEO	DES SA RVA
	Simulated crisis information	Simu	
	Census data	External services	
	Physical exposure	Internal: Exposure Estimation	
Physical exposure	Observed crisis information	DataEO	DES SA RVA
	Simulated crisis information	Simu	

	Critical infrastructure information	External services	
Physical impact assessment	Observed crisis confirmation	DataEo	SA DES
	Simulated crisis information	Simu	
	Susceptibility information	DataEx	
	Physical exposure	Internal: exposure estimation	
Multi-hazard risk	Observed crisis information	DataEO	DES SA
	Simulated crisis information	Simu	
	RVA products	Internal: hazard specific exposure and impact products	

2.6 Situation Assessment and Decision Support

HEIMDALL situation assessment and decision support services aim at providing relevant information products in the process of response planning. End users need information which supports them to understand the situation and the cascading effects, to identify the value of information for decision making and with coordination. The following situation assessment and decision support information products can be provided in different phases of the response planning process:

- Similar scenarios matched by the scenario matching service (SMAC) containing information on decisions and prevention and mitigation measures taken, their positive or negative evaluation and lessons learnt (see section 2.3 Scenario Management)

- Impact summary information (ISA Information) generated by the impact summary service (ISAS) on relevant infrastructure and people at risk, on potential cascading effects and on situation evolution which supports, together with simulation and risk and vulnerability assessment tools, the evaluation of simulated options during what-if analysis (see Table 2-11).

- Response-oriented decision support information (DES information) generated by DES on potentially save response infrastructure which supports the identification of options and contingencies (see).

- Standards-based scenario snapshot containing all information relevant for situation awareness, plan formulation, communication and information sharing, e.g. EDXL-CAP, EDXL-SitRep. During implementation this functionality will be technically separated from the other software components of situation assessment and decision support. The generation of standards-based products based on scenario snapshots is part of situation assessment and decision support just from a functional / user point of view. Technically, it is based on direct access to the database of scenario management.

For end users, an important decision making activity is a what-if analysis of the different simulated options sourcing from different foreseen hazard evolutions and potential measures of prevention and control in order to explore the consequences of impacts and measures to be performed in these options. The HEIMDALL system can assist decision makers to generate alternative scenarios (using scenario management functions) and assess their

potential evolution and consequences using simulation, risk and vulnerability assessment and ISAS functions. Decision makers such as incident commanders in the field can display and explore these alternative scenarios in a GUI or browse through them when they are presented in the form of a situation report. Based on such a situation report which contains a comparison of the top best-fitting planning scenarios each with relevant information on probability and consequences, their knowledge of the context and their experience they are able to take an informed decision on the best-fitting scenario option and the appropriate working strategy.

ISA information can be generated for pre-defined geographical locations of interest (GOIs) in order to allow end users to customize significant infrastructure according to their organizational strategies and constraints. The ISAS integrates different layers of information provided by end users and other HEIMDALL modules to generate an impact summary for these GOIs. The selection of additional GOIs for impact assessment over the GUI allows end users to generate impact assessment information for dynamic objects such as response teams.

An example for DES information is a list of potentially safe (potentially not affected for a given time) alternative forward command post sites which, when included in a situation report, can help the decision maker to meet the best possible contingencies in case that a forward command post need to be moved. In order to reflect the internal diversity of end users in terms of different legal frameworks, national, regional and organizational strategies, roles and profiles, end users are able to customize infrastructure such as alternative forward command post sites which will be considered for the generation of DES information. In addition, decision makers can configure rules and thresholds and modify DES information according to their individual and organizational needs and knowledge.

Table 2-11: Impact Summary (ISA) information products

Products and/or Services	Inputs needed	Provided by	Used by
GOIs at risk	Pre-defined GOIs Expert criteria (e.g., levels of detail, ranking of infrastructure, etc.) Additional selected GOIs Simulation results Impact assessment and risk information Incident information	Configuration (expert criteria, pre-defined GOIs) GUI (selected GOIs) SM (for simulation, impact/risk, incident information); requires access to: Simu (results) RVA (results) Data Sources	GUI (show) SM (connect to scenario; include in response plan) DES
People at risk	Population numbers Simulation results Impact assessment and risk information	SM (for simulation, impact/risk); requires access to: Simu (results) Risk (results)	GUI (show) SM (connect to scenario; include in response plan)
Potential cascading effects/related hazards	Pre-defined interacting hazards Pre-defined interacting infrastructure at risk Simulation results Impact assessment	Configuration (pre-defined hazards, infrastructure) SM (for simulation, impact/risk, incident information); requires access to:	GUI (show) SM (connect to scenario; include in response plan)

	and risk information; multi-risk information Incident information	Simu (results) RVA (results) Data Sources	
Hazard evolution information	Last scenario snapshot Simulation results Impact assessment and risk information; multi-risk information Incident information	SM (last scenario snapshot); requires access to: Simu (results) RVA (results) Data Sources	GUI (show) SM (connect to scenario; include in response plan)
Standards-based situation report	Scenario snapshot containing scenario information including (optional): Similar scenarios (scenarios resulting from scenario matching with actions/countermeasures taken and lessons learnt) Simulated options (scenarios resulting from what-if-analysis with simulation, impacts, probabilities)	Scen	GUI

Table 2-12: Decision support (DES) information products

Products and/or Services	Inputs needed	Provided by	Used by
Information about safe, significant infrastructure	Pre-defined GOIs Expert criteria (e.g., levels of detail, ranking of infrastructure, etc.)Simulation results Impact assessment and risk information Incident information GOIs at risk	Configuration (expert criteria, pre-defined GOIs) Scen (for simulation, impact/risk, incident information); requires access to: Simu (results) RVA (results) Data Sources ISA (for GOIs at Risk)	GUI (show) SM (connect to scenario; include in response plan)
Information about safe response infrastructure	Pre-defined potentially suitable forward command post sites Expert criteria (e.g. ranking of infrastructure) Out of suppression information from fire	GUI Simu RVA	GUI (show) SM (connect to scenario; include in response plan)

| | simulation | | |
| | Impact assessment from Risk | | |

2.7 Communication to Remote Areas

The HEIMDALL system shall be capable to assure a continuous connection through satellite communications from the local units to end users. The satellite communications link will be provided through a rapidly deployable, lightweight and portable Ka-band satellite terminal that can be transported and installed at any necessary case on site. Apart from the antenna, installation of a modem will be required to generate a Wi-Fi network. Once the antenna and the modem are installed, any end user that is within the Wi-Fi network coverage area will be able to connect to the Internet and therefore, access the available services. Table 2-13 shows the different inputs and outputs for the satellite communications module.

Table 2-13 - Communication to Remote Areas inputs and outputs

Products and/or Services	Inputs needed	Provided by	Used by
Ka-band Satellite Communications	Successful configuration and installation	N/A	First responders' users

2.7.1 **Information Gateway**

In order to increase the awareness of the population and to interconnect the first responders in the field with the HEIMDALL system an information gateway (IG) is implemented at HEIMDALL site. In case of the population the gateway can be used to distribute alert messages based on the common alerting protocol (CAP) which is the de facto standard for warning and alerting messages used worldwide [3]. The communication to first responders will offer some more information and will allow accessing most information available in the system. For this the IG connects to the scenario management module and the situation assessment services to provide the dedicated information. The counterpart of the information gateway in HEIMDALL is a smartphone application that is able to receive the messages from the IG. Since the IG is standard based other types of receivers are also possible.

Table 2-14: Information gateway inputs/outputs

Products and/or Services	Inputs needed	Provided by	Used by
FR information service	SitRep Scenario UeRM	Situation Assessment Scenario Management	Smartphone application
Alerting service	CAP message	GUI	Smartphone application

2.7.2 **Smartphone Application**

The development of a smartphone application will provide HEIMDALL's end users with an alternative way to receive and provide relevant information from and to the system. This data will be received/sent by accessing the different data and services available through the service platform. From the service point of view, two smartphone applications, one for the public and one for the FR in the field, are foreseen. However, the public one can be seen as a light version of the FR since it offers reduced functionality but the core is the same. Consequently, a single smartphone application will be developed during the project that

includes all functionalities for the FR and could potentially be reduced to a version for the public, if time of the project allows for it.

Table 2-15: Smartphone application products

Products and/or Services	Inputs needed	Provided by	Used by
Authentication	Username and password of the user	First responders users	SP
Alerts receiver	CAP message	Information gateway	First responders users Population users
Information receiver	Situation reports Response plans Decisions	IG	First responder
Hazard	GPS location Hazard type Images Extra further information related to the hazard	First responders users	SP
Incident	GPS location Incident type Images Extra further information related to the incident	First responders users	SP
First responders' location	GPS location User's unique identifier	First responders users	SP GUI
Chat	User's unique identifier Text content to be transmitted	First responders users	First responders users GUI

2.8 Data Sources

2.8.1 Space-Based Data

Several processing chains are used within HEIMDALL to provide crisis information related to floods, forest fires and landslide events based on Earth observation data. An overview about the respective inputs and outputs are listed in Table 2-16.

Table 2-16: Space-based Data products

Products and/or Services	Inputs needed	Provided by	Used by
Flood extent	Sentinel-1 (GRD), TerraSAR-X, and VHR optical satellite data	Satellite EO systems	GUI, RVA, Simu
Burn scar	Sentinel-2 (GRD) satellite data	Satellite EO systems	GUI, RVA, Simu

Fire hot spots	MODIS satellite data	Satellite EO systems	GUI, RVA, Simu
Landslide extent	Sentinel-2 (GRD) satellite data	Satellite EO systems	GUI, RVA, Simu
Information about landslides	Sentinel-1 (SLC) satellite data	Satellite EO systems	GUI, RVA, Simu

2.8.2 **Ground-Based Data**

During a crisis triggered by a landslide, excluding unexpected rock falls, rock avalanche or extremely rapid debris flows, there is sufficient time to organize the availability of the necessary data sources to provide HEIMDALL products. For this reason, with respect to the fire or flood events, the area threatened by the landslide can usually be defined, and the installation of sensors optimized, also in case of new landslides. An idea of the landslide movement is a fundamental input to optimize the ground observations, including the ground based (GB) SAR measurements. Using these inputs elements, all the products available by HEIMDALL, summarised in Table 2-17, allow optimizing the crisis management, organizing and following the evolution of the event.

Table 2-17: Ground-based data inputs and outputs

Products and/or Services	Inputs needed	Provided by	Used by
Terrestrial radar data for landslide monitoring	Landslide area coordinates.	DataSitu, GUI	SA, DataSitu
	Idea of the direction of the expected deformation, from field observations or measurements	DataSitu, GUI	
Geotechnical/hydrological sensors data for landslide monitoring	Idea of the direction of the expected deformation, from field observations or measurements	DataSitu, GUI	SA, DataSitu
Geodesic or topographic surveys	Idea of the direction of the expected deformation, from field observations or measurements	DataSitu, GUI	SA, DataSitu
	Position of the benchmarks	DataSitu	Simu
Near real-time terrain movement information	Terrestrial radar data for landslide monitoring	DataSitu	Simu, SM, RVA, SA, GUI
	UAV data	DataSitu	
	Incidences reported by emergency services	GUI	
	Geotechnical/hydrological sensors data for landslide monitoring	DataSitu	

| | Geodesic or topographic surveys | DataSitu | |

2.8.3 **Aerial Sensors**

Aerial sensors allow an operator to monitor a hazard. In particular, we consider hotspots that may remain after a fire. The monitoring process is implemented by a module that offers the products described in Table 2-18, for which we specify the inputs to the modules, the inputs provider, and the user of the module.

Table 2-18: Aerial sensors services inputs and outputs

Products and/or Services	Inputs needed	Provided by	Used by
Geo-referenced alert signal	Area of interest to be monitored Drone's flying height Confirmation to start/finalize a mission	Operator	GUI
Pictures	Area of interest to be monitored Drone's flying height Confirmation to start/finalize a mission	Operator	GUI
Thermal pictures	Area of interest to be monitored Drone's flying height Confirmation to start/finalize a mission	Operator	GUI
On-demand video stream	Area of interest to be monitored Drone's flying height Confirmation to start/finalize a mission	Operator	GUI

2.9 External Systems

Apart from the data provided by the HEIMDALL modules, it is foreseen that the HEIMDALL workflows will also involve externally available information by third party providers, such as e.g. weather data. For this purpose, the SP will implement service-specific interfaces as plugins that will retrieve the information from the external service provider using the service provider's API, adapt it and feed it to the SP via the already provided open interfaces. It is also foreseen that HEIMDALL-generated information will need to be communicated to external services. Table 2-19 presents the candidate external services. More information about the APIs and how they are used within HEIMDALL will be provided in D5.9.

Table 2-19: External systems inputs and outputs

Products and/or Services	Inputs needed	Provided by	Used by
Service-specific interfaces as plug-ins	Service API	External services	SP

Enterprise Service bus	ESB hosts the various services and interface proxies to external systems. It enables the use of HTTP/REST, FTP and other protocols for accessing the external interface services and products.	SP	All other HEIMDALL services
Copernicus EO services	Information for emergency response in relation to different types of disasters	Copernicus emergency management service	SP SM Simu SA DS
	Seasonal forecasts and climate predictions by holding records on temperatures, rainfall and drought, sea levels and ice sheets.	Copernicus climate change service	
	Enhanced atmospheric environmental information available as analyses, re-analysis and forecasts	Copernicus atmosphere monitoring service	
	Geographical information on land cover/land use.	Copernicus land monitoring service	
	Near real-time products, multi-year products, in-situ observations and forecasts.	Copernicus marine and environment monitoring service	
GDACS information	Real-time access to web-based disaster information systems and related coordination tools.	GDACS	SP SM
Meteorological and hydrological information	Weather and hydrological parameters (wind, wind direction, temperature, relative humidity, precipitation, etc.) Forecast over 3, 6, 9, 12, 24, 36, 48h	External services	SP Simu
Cartographic data	Various layers including, geography, bathymetry, administrative, etc.	External services	SP Simu

Products and/or Services	Inputs needed	Provided by	Used by
	grids.		
Census data	Population density of the areas of interest.	External services	SP SA DS
Critical infrastructure information	Assets that are essential for the functioning of a society and economy.	External services	SP Simu SA DS
Asset location	The location of the assets on the map	External services	SP SA DS
Information received from drones	Data captured from the drones	External services	SP Simu SA DS
Crowdsourcing information from FRs	Information received through the smartphone application	Smartphone application	SP SM SA DS
Information received from social media and other services	Information received from social media Information received from 112 services	External services	SP SM

2.10 Graphical User Interface

The graphical user interface (GUI) is the main visual tool for end users to interact with the HEIMDALL system. End users will have access to the GUI via a standard internet browser, like, Chrome. The GUI will provide access to most of the data information and services by communicating to the different modules through the Service Platform. Table 2-20 describes the inputs and outputs needed to provide the GUI services.

Table 2-20: GUI products

Products and/or Services	Inputs needed	Provided by	Used by
Provide information to the GUI	Login credentials Roles and users definition Graphical data and metadata information Simulation results	SP	End users
Provisioning of products and services to users	Administrators functionalities Monitoring of mobile	SP	End users

	assets		
	Ability to run simulations		
	Incident and scenario management		
	Risk assessment		
	Response plans		
	Decision support capabilities		

The services presented in Table 2-20 are high level from service point of view. From the architecture point of view it is useful to further detail the two products. Hence, the products and services provided by the GUI to the end user have been detailed in Table 2-21, detailing the services and products that are provided by the GUI to the end-user.

Table 2-21: GUI detailed products

Services	Inputs needed	Provided by	Used by
Login	Username and password	End users	SP
Roles/Users	Roles instances definition Users instances creation	SP Administrator	Administrator End users
System administrators features	Roles information and accessibility Users information and role	Administrator	SP
Data display	Earth observation products Aerial based data Landslide monitors Crowdsourced and first responders data External systems	SP	End users
Monitoring	Mobile assets location	SP	End users
Simulations	Simulation results Simulation triggering capabilities	SP	End users
Incident management	Incident information Incident timeline of events	SP	End users
Scenario management	Scenario information Scenario snapshot generation and selection capabilities Information-to-scenario	SP	End users

	association capabilities		
	Scenario matching capabilities		
Risk assessment	Forecasted risk assessment information	SP	End users
Impact summary	Impact summary display and modification capabilities		
	Situation report generation capabilities		
Response plans	Response plans for a scenario	SP	End users
	Lessons learnt from previous scenarios		
	Decisions taken during an scenario		
	Measures taken during a scenario		
Decision support	Decision support information generated by the system	SP	End users
Notifications	Arrival of new incidents	SP	End users
	Decision support suggestions		
	Simulation results available		
Catalogue for data sharing	Granted access	SP	End users
	Shared information		
Alert creation	Alert information	End users	IG
FR information service	SitRep	SP	IG
	Scenario		

3 HEIMDALL Connected

HEIMDALL connected refers to the federated architecture and is part of the architecture that enables the interconnection of multiple local units (LU) for efficient data exchange to facilitate the cooperation among end-users based on content oriented concepts. Natural and man-made hazards are highly complex situations requiring effective cooperation and communication of all stakeholders, from C&Cs assessing the risk for the population and infrastructure and preparing and coordinating the response, civil protection units and medical services save lives, police and fire fighting units regulating and responding to the hazard. Here, the end-users need at any point in time information and control about who can access which data. With the federated architecture based on content-oriented design this is achieved and at the same time ensures security. A data and service catalogue helps with the information discovery and the connection to other authorities. The system takes care to tailor the data so that every user can access it in his/her preferred or mandatory format. As mentioned, HEIMDALL makes use of common data formats, mostly based on open standards for this. Figure 3-1 shows an example with two connected LUs, for user A and user B. The setup can be extended for other users however, main module for the interconnection is the catalogue.
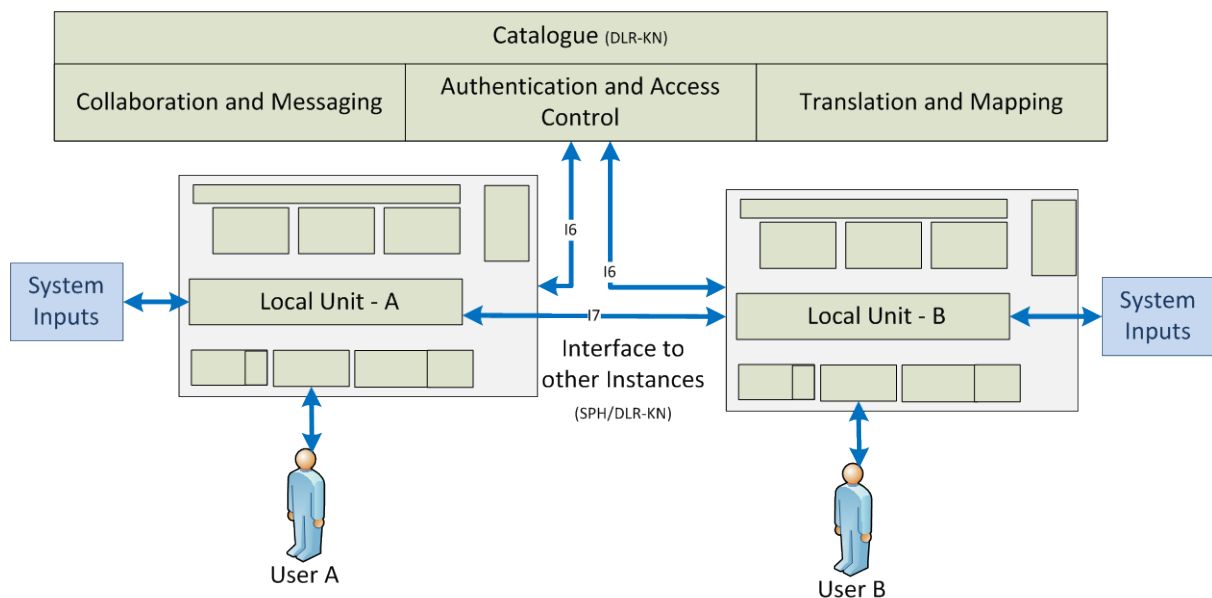

Figure 3-1: Federated architecture example

This approach provides flexibility at different levels: on one hand, different services can be available in each local unit and made accessible to users accessing other local units by means of publishing them in the catalogue. On the other hand, additional external services can be easily added to the overall architecture by publishing the corresponding services or information in the catalogue and establishing the corresponding connection, without additional integration efforts.

3.1 Catalogue

The catalogue is the core unit for the interconnection of multiple LUs. It will provide several services that enable efficient communication among the end users which are:

- As basis for the interconnection the catalogue manages the addresses of the LU and provides them for P2P connection if the permission has been given.
- By the use of standards for cross-national interoperability and information exchange HEIMDALL will provide a mapping and translation of standardized formats.

- End users can publish their data to other users using the system. They grant access of specific data sets or all data. HEIMDALL offers an information discover service for this published data.
- A collaboration and messaging platform is provided for rapid sharing and exchange of text messages as well as multimedia content among end users.

Table 3-1: Catalogue inputs/outputs

Products and/or Services	Inputs needed	Provided by	Used by
Connection to other LU	Connection Parameters	Interfaces to LU	Interface to LU
Information Discovery	Shared Content and metadata	GUI LU	GUI LU
Translation and mapping service	Shared Content and metadata	GUI LU	GUI LU
Collaboration and messaging	Data input by the user	GUI	GUI

3.2 Interfaces to other Local Units

The SP shall be able to communicate with other Local Units by making full usage of the HEIMDALL interoperability features.

Through the HEIMDALL Data and Service Catalogue, part or whole of the SP services and products shall be available to other Local Units within the same region, country as well as in cross-border events. Data exchange is mainly performed over HTTP directly to the Catalogue. Geospatial data can be published/retrieved via the OGC-compliant services (WFS, WCS) and can be retrieved fully rasterised via the WMS service. In addition, a REST-based interface will be available.

Furthermore, the SP shall be able to communicate with the population at risk making use of the Information Gateway, from where alarms and messages are going to reach the public. In a similar fashion, the Information Gateway shall also be used to disseminate relevant information to the first responders on the field.

4 Conclusion

This deliverable presented the HEIMDALL system architecture including the identified system elements and the corresponding interfaces. It showed the local unit that can be used by a single authority for response planning and scenario building during all phases of the disaster management cycle. The local units can be connected in a federated architecture in order to foster the collaboration of end users of different disciplines and countries. The presented architecture is the enabler to provide the HEIMDALL service and products defined in D2.11 [1].

5 References

[1] Barth et al., HEIMDALL D2.11: "Service Concept Specification", March 2018

[2] Barth et al., HEIMDALL D2.6: "HEIMDALL Requirements Report – Issue 1", September 2017

[3] OASIS Standard, Common Alerting Protocol Version 1.2, 01 July 2010, available at: http://docs.oasis-open.org/emergency/cap/v1.2/CAP-v1.2-os.html [last accessed: 03/04/18]