D6.10

Decision Support Specification and Implementation Report - Draft

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List of Acronyms

AB	Advisory Board
API	Application Programming Interface
C&C	Command & Control Centre
CDM	Change Detection Module
CIMA	Centro Internazionale in Monitoraggio Ambientale – Fondazione CIMA (CIMA Foundation)
DB	Database
DES	Decision Support Service
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V.
DLR-DFD	Deutsches Zentrum für Luft- und Raumfahrt e.V.; German Remote Sensing Data Center
DLR-KN	Deutsches Zentrum für Luft- und Raumfahrt e.V.; Institute of Communications and Navigation
DS	Decision Support
DSS	Decision Support System
ELSI	Ethical, Legal and Social Issues
EO	Earth Observation
EUW	End User Workshop
FCP	Forward Command Post
GOI	Geographical Object of Interest
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
IPsec	Internet Protocol Security
ISA	Impact Summary
ISAS	Impact Summary Generation Service
JSON	JavaScript Object Notation
LULC	Land Use and Land Cover
OGC	Open Geospatial Consortium
PE	Plan Execution
PF	Plan Formulation
REST	Representational State Transfer

RVA	Risk and Vulnerability Analysis
SA	Situation Assessment
SAW	Situation Awareness
SITREP	Situation Report Generation Service
SMAC	Scenario Matching Service
SMES	Scenario Management Service
SP	Service Platform
TOC	Table of Contents
TR	Technical Requirement
UI	User Interface
URL	Uniform Resource Locator
VM	Virtual Machine
VPN	Virtual Private Network
WP	Work Package

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Executive Summary

This document presents the HEIMDALL decision support concept and technical component design. The concept has been elaborated in close collaboration with the end users, the project lead and the ELSI research partners in order to ensure an appropriate and desired degree of decision support by technology. Thus, the first of the two main objectives of this document is to provide an overview over the different decision support approaches developed and implemented by WP6 suitable for strategic response planning. The second objective is to present a technical specification which enables technical contributors and partners to understand how to develop, deploy, configure and use the decision support components developed and implemented in T6.4. Therefore, topics include the external and internal architecture design, interfaces, data structures, formats, functionality, methods, configuration and software issues.

The main task contributing to this deliverable is T6.4 – Decision Support Services. However, significant contributions were made by tasks T3.1 – Stakeholder Management, WP8 – Ethics Requirements and T2.4 – Service Concept Specification and System Architecture as tool-assisted decision making is a pivotal concept in the HEIMDALL system. The overall HEIMDALL situation assessment and decision support approach has been elaborated together with task T6.3. Scenario management and comparison concepts are contributed by task T6.5.

The two decision support functionalities described in this deliverable are the Decision Support Service (DES) and the Change Detection Module (CDM). The DES generates for a user-specific area of interest aggregated information on safe infrastructure for a hazard situation. This so-called DES information supports end users in C&C, FCPs and in the field to identify options and contingencies and to decide on the path to follow to achieve the desired outcome. The CDM assists decision makers in the identification of changed land cover and land use over time in the area of interest and is intended to be used as an add-on to scenario matching.

1 Introduction

This document describes efforts performed and results produced so far in the HEIMDALL project in finding and designing technical solutions which provide decision support to the different groups of end users during the strategic response planning process. In particular, solutions are highlighted which support the end users' contingency planning activities, suitable to all involved perspectives. The document focuses on the Decision Support Service (DES), the different types of generated information products, the so-called DES information and on the Change Detection Module (CDM) used for the refinement of scenario matching results.

At this early stage of the HEIMDALL project, the focus of this document lies in a first component design with a basic specification of technical details. As implementation hasn't started yet, the document contains no test plan and no implementation report. The HEIMDALL project aims at a collaborative design which is a methodology that involves people who will be affected by new technologies throughout all design phases [1]. Unlike traditional approaches to develop information systems of having a fixed product and/or system idea that does not change or evolve as the development process take place, an agile approach is a response to the need for a flexible and iterative process to be able to consider unexpected changes [2]. For example, intermediary results of system developments will be presented at end user workshops and iterated together with the end-user partners. Deliverable D6.11 due in M38 [3] will present the mature DES and CDM component design together with a detailed technical specification.

In particular, the document is organised as follows:

- Section 2 specifies the technical requirements for the DES component.
- Section 3 describes the DES and CDM in the context of the overall HEIMDALL system, inputs and outputs and interfaces with other HEIMDALL components.
- Section 4 starts with background on tool-assisted decision support. Then, the section elaborates how HEIMDALL aims to support decision making in strategic response planning of the involved end users. The section concludes with an overview of DES and CDM building blocks, functionalities and workflows.
- Section 5 presents the detailed DES and CDM specifications including the description of criteria and metrics, results, REST API, configuration and implementation details.
- Finally, section 6 summarizes the work carried out so far and gives an outlook to the work that still needs to be done.

2 Technical Requirements

This section includes the list of technical requirements for the DES module. As the need for the CDM functionality has emerged only recently at EUW2 in October 2018, user requirements have not been stated yet. Requirements for the SMAC apply (see D6.14 [13]).

2.1 Interface Requirements

2.1.1 **Hardware Interfaces**

The DES shall be accessible via Ethernet. If a Virtual Private Network (VPN) is used it must offer IPSec compatibility.

2.1.2 **Software Interfaces**

The DES shall be deployed as Linux-based container and/or virtual machine (VM).

2.1.3 **Communication Interfaces**

The DES shall be connected to the other HEIMDALL components through the Service Platform (SP).

The DES component shall be designed as RESTful web service allowing clients to communicate with it using common HTTP methods (e.g. GET, PUT) and/or for georeferenced data OGC methods (based on HTTP).

Focused on providing a lightweight and easily consumable output format, the data shall be exchanged using JSON serialization and the formats specified by the respective OGC standards.

2.2 Functional Technical Requirements

2.2.1 **Short-Term Features**

Table 2-1: Technical Requirement TR_DS_1

Requirement ID:	TR_DS_1
Related SR(s):	• Sys_SADS_14
Description: The DES shall generate and provide DES information that describes potentially safe emergency response infrastructure (e.g. C&C sites). DES information is compiled by intersecting the outputs of the simulation modules, impact assessment (RVA) information and pre-defined geographical base. No further data enrichment shall be performed.	
Rational: The user shall be supported in contingency planning by DES information generated by the system. DES information shall not infer possible decisions. Instead, decisions are solely taken by the user. DES information generated by the system enables the user, upon modifying inputs and conditions, to better identify risks for emergency resources and anticipate which emergency response infrastructure would most probably remain safe (i.e. not affected by a hazard).	
Stimulus: After running a simulation, RVA and ISAS the SP requests the generation of DES information for the selected scenario, the generated simulation results, impact assessment and ISA information.	
Response: The DES returns DES information for the selected scenario, e.g. for display in the	

UI or for inclusion in a situation report.
Verification Criterion: DES information for a scenario can be requested
Notes: none

Table 2-2: Technical Requirement TR_DS_2

Requirement ID:	TR_DS_2
Related SR(s):	• Sys_SADS_13
Description: The DES shall provide means for configuring thresholds for the generation of DES information which describes potentially safe emergency response infrastructure (e.g. C&C sites). Configuration shall be done before the system is started (configuration file).	
Rational: The users shall be able to configure rules and thresholds for DES processes according to their individual and organizational needs.	
Stimulus: Rules and thresholds shall be set and modified through configuration in a text file.	
Response: -	
Verification Criterion: Rules and thresholds shall be able to be set and modified through configuration before the system is started. Configuration changes shall be visible in DES process results.	
Notes: none	

2.2.2 **Mid-Term Features**

Table 2-3: Technical Requirement TR_DS_3

Requirement ID:	TR_DS_3
Related SR(s):	• Sys_SADS_14
Description: The DES shall generate and provide DES information which describes potentially safe environmental assets (e.g. sand pits). DES information is compiled by intersecting the outputs of the simulation modules, impact assessment (RVA) information and pre-defined geographical base. No further data enrichment shall be performed.	
Rational: The user shall be supported in contingency planning by DES information generated by the system. DES information shall not infer possible decisions. Instead, decisions are solely taken by the user. DES information generated by the system enables the user, upon modifying inputs and conditions, to better identify risks for emergency resources and anticipate which environmental assets should remain safe (i.e. not affected by a hazard).	
Stimulus: After running a simulation, RVA and ISAS the SP requests the generation of DES information for the selected scenario, the generated simulation results, impact assessment and ISA information.	
Response: The DES returns DES information for the selected scenario, e.g. for display in the UI or for inclusion in a situation report.	

Verification Criterion: DES information for a scenario can be requested
Notes: none

Table 2-4: Technical Requirement TR_DS_4

Requirement ID:	TR_DS_4
Related SR(s):	• Sys_SADS_13
Description: The DES shall provide means for configuring thresholds for the generation of DES information which describes potentially safe environmental assets (e.g. sand pits). Configuration shall be done before the system is started (configuration file).	
Rational: The users shall be able to configure rules and thresholds for DES processes according to their individual and organizational needs.	
Stimulus: Rules and thresholds shall be set and modified through configuration in a text file.	
Response: -	
Verification Criterion: Rules and thresholds shall be able to be set and modified through configuration before the system is started. Configuration changes shall be visible in DES process results.	
Notes: none	

Table 2-5: Technical Requirement TR_DS_5

Requirement ID:	TR_DS_5
Related SR(s):	• Sys_SADS_15
Description: The DES shall provide means for adding and modifying the DES information.	
Rational: The user shall be enabled to add or modify DES information according to his/her knowledge, role and goals.	
Stimulus: The user updates existing DES information for a selected scenario over the UI.	
Response: Status OK if modification successful, otherwise error status message	
Verification Criterion: DES information referring to a scenario can be modified at any time	
Notes: none	

2.3 Other Requirements

2.3.1 **Short-Term Requirements**

2.3.2 **Mid-Term Requirements**

Table 2-6: Technical Requirement TR_DS_6

Requirement ID:	TR_DS_6
Related SR(s):	• Sys_SADS_17
Description: The DES shall be transparent on the mechanisms and used criteria.	
Rational: The user is the one liable so all decisions presented by the system must be transparent to the user and the underlying criteria.	
Stimulus: -	
Response: -	
Verification Criterion: All thresholds are accessible through configuration and visible.	
Notes: none	

3 Reference Architecture

This section describes the DES and CDM components in the context of the overall HEIMDALL architecture. Afterwards, the different inputs and outputs expected from the component are listed. Finally, the section describes the interfaces needed to allow the component communicate with the other components.

3.1 HEIMDALL Overall Architecture

Figure 3-1 illustrates the HEIMDALL overall architecture highlighting the DES and the SMAC components. The DES as well as its sub-modules is treated as a “black box” within the overall architecture. As can be observed in the diagram the DES performs all communication and interactions with the other components of HEIMDALL through the SP. Interface 4 (I4) serves as the general interface.

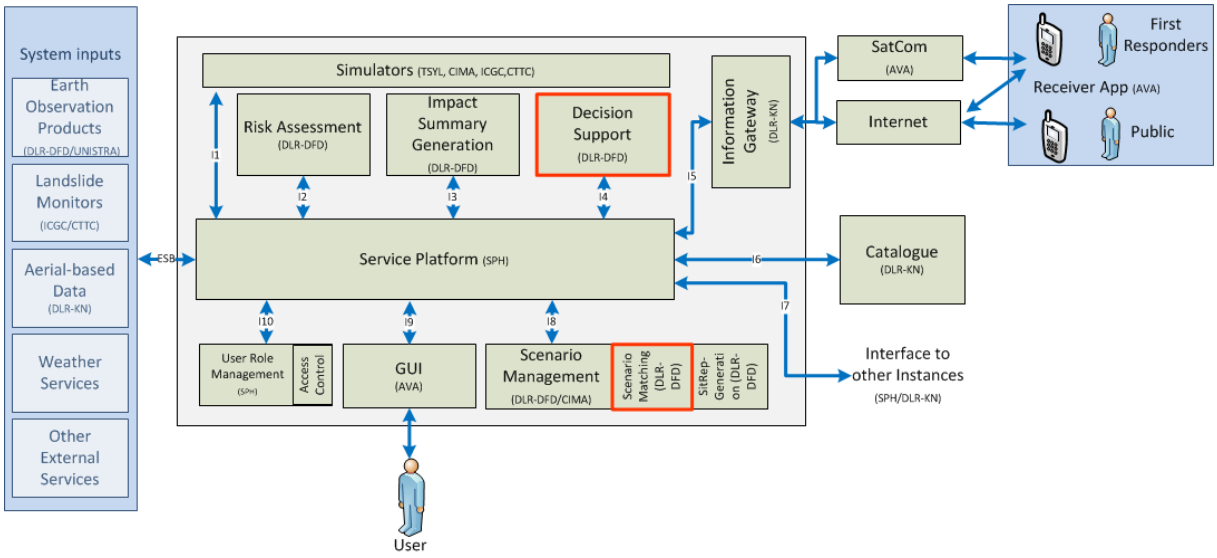

Figure 3-1: HEIMDALL overall architecture

The DES enables clients (e.g. the UI) to generate DES information for a specific scenario. This DES information will support end users in C&C, FCPs and in the field to identify options and contingencies and to decide on the path to follow to achieve the desired outcome.

For the time being, the CDM is designed as a sub-module of the SMAC performing operations on request by the parent process. Therefore, no direct communication with other components is foreseen. Other components communicate with the SMAC over interface 8 (I4). As part of the scenario management the SMAC is described in D6.14 [13].

3.2 Inputs and Outputs

Table 3-1 gives an overview of DES inputs and outputs with a short description respectively. A detailed description of DES inputs, outputs and formats can be found in the API specification in section 5.1.4.

Table 3-1: DES inputs and outputs

Output	Short description	Inputs needed	Format
Information about safe, significant infrastructure	Total number of potentially safe buildings in GOI List of potentially safe infrastructure until time x in GOI (e.g. safe	Pre-defined GOI(s) defining the area of interest Expert configuration Hazard information (i.e. simulation results or	Descriptive JSON-based format Georeferenced objects where applicable, e.g. in GeoJSON format

	hospital, safe route until time x).	observation-based information) Impact assessment (RVA) information (Risk and damage on a per-building level)	
Information about safe response infrastructure	Total number of potentially safe response infrastructure in GOI List of safe infrastructure with selected building function(s), e.g. alternative C&Cs and FCP sites, firewater-reservoirs, sand pits for filling sand bags, materials storage, rescue equipment storage, etc.	Pre-defined GOI(s) defining the area of interest Expert configuration (e.g., selected response-related building functions of interest) Hazard information (i.e. simulation results or observation-based information) Impact assessment (RVA) information (Risk and damage on a per-building level)	Descriptive JSON-based format Georeferenced objects where applicable, e.g. in GeoJSON format

3.3 Interfaces with other HEIMDALL components

The DES provides access to its data resources and functionality by use of a RESTful web service interface. Figure 3-1 shows I4 as the major interface connecting the SP with the DES (see Table 3-2 for details on I4).

Table 3-2: Interfaces with other components

Interface	**Short description**	**Methods**	**Protocol**
I4	RESTful web service interface	GET, POST, PUT, DELETE	HTTP(S)

The DES as a web service provides a REST API for accessing, creating, updating and deleting of its data resources. Any input needed by the component must be attached as a data resource by the client to the request.

As mentioned before, the CDM is currently not designed to provide any exposed interface as it will be integrated as a sub-module into the SMAC.

4 Module Functionality

For many decades, Decision Support Systems (DSS) have been developed and employed in the field of disaster management in order to “complement the cognitive processes of humans in their decision making” [4]. In the German-Indonesian Tsunami Early Warning (GITEWS) project DLR has designed and developed a situation assessment and decision support workflow (DSS workflow) for the DSS of the Indonesian Tsunami Early Warning System InaTEWS [5][6]. In the Project on a Multi-Hazard Open Platform for Satellite Based Downstream Services (PHAROS) the DSS workflow has been refined and applied to the wildfire domain [7]. Based on the overall HEIMDALL service concept [8] we have elaborated a service-based, multi-hazard approach to the DSS workflow which fosters customized utilization and combination of the different DSS building blocks in different contexts. D6.7 [9] describes the background and the HEIMDALL approach to tool-assisted situation assessment and decision support in detail.

4.1 Contextual, Ethical, Legal and Social Considerations

It strongly depends on the processes to be supported, their legal and organizational context, their degree of structuredness and the existence of best practices and SOPs that may be automated whether DSS leave the generation of situational awareness (SAW) on the different levels to the user (less automatic) or whether they provide fully automatic decision options among which the user has just to choose. In sudden-onset types of disasters such as tsunami events in Indonesia authorities are forced to disseminate an appropriate warning at the earliest point in time under pressure to respond to dynamic uncertain conditions. With these circumstances in mind, the InaTEWS DSS has been designed to provide a high degree of computerized situation assessment and decision support. For example, the DSS automatically selects a “preferred” simulated tsunami propagation and inundation scenario based on an aggregation of the best-matching scenarios under consideration of quality and error measures. While this type of automated support has proven to be helpful in numerous operational tsunami early warning situations [5] [15], long-term response planning activities identified so far in the HEIMDALL context [10] require a much more data-driven approach without decision automation. In the field of data-driven DSS the key is having easy and rapid access to a large amount of accurate, well-organized multidimensional data [11]. Based on this data users are able to perform situation and risk analysis, assessment and strategic planning more efficiently. This applies particularly for wild fire and flood hazards which materialize over days before they get imminent thus require a high degree of user expertize in their management.

Also from an ELSI perspective data-driven decision support has been assessed to be more appropriate and desired. Two major categories of ELSI issues have been identified by WP8 as critical for tool-assisted decision support in HEIMDALL: respect for autonomy and integrity. The respect for autonomy might be restricted if decision support is implemented against the will or not reflecting the internal diversity of end-users. In order to prevent this restriction it has been advised to identify and select important characteristics the tools aim at based on end-user needs, social acceptability, social acceptance and technological safety. Integrity issues might come up if responsibility structures for tool-assisted decision-making were neglected. As a measure of prevention critical discussions of technological risks, of the need and wishes for decision support with the end users and of the ethical issues arising from decision support have been proposed [12] and conducted. As a result of these discussions between the project lead, the ELSI research partners and the end-users the focus of computerized decision support has been shifted from automated system actions (e.g. decision proposals for routes of actions, tasking of models and simulations) to the preparation and provision of relevant SAW information. In particular, these design decisions have been made:

- The system does not infer and propose decisions or routes of actions. Instead, decision support is provided in the form of goal-oriented SAW and decision support

information which users can base their decisions on (e.g. safe route until time x, safe alternative FCP site, etc.).
- Decisions are taken solely by users in the C&C or FCP according to their individual knowledge, and their individual and organizational responsibility, needs and goals
- Users always have the possibility to add and modify information according to their individual knowledge, and their individual and organizational responsibility, needs and goals
- Criteria and thresholds for decision support processes are configurable for users according to their individual knowledge, and their individual and organizational responsibility, needs and goals
- The user is the one liable so all decisions and the underlying criteria and thresholds presented by the system must be visible to the user
- Information supporting decision making is integrated into standardized situation reports as far as possible to facilitate the distribution of information products to the relevant stakeholders (e.g. for staff meetings, publishing on the web, transfer between incident commanders and field resources, transfer to other C&Cs and organizations, etc.)

4.2 Decision Support in Strategic Response Planning

Together with the end-user partners, a major objective of the first project phase was the definition of the different activities in their response planning process mentioned before and how HEIMDALL can technically support these activities (see D2.11 [8] and [10]). In D6.7 [9] the term SAW information encompasses different types of information relevant to the decision maker in the three phases of the decision making process, Situation Assessment (SA), Plan Formulation (PF), and Plan Execution (PE). In the SA phase, situation and impact assessment information helps the different involved stakeholders to identify risks to people, property and environment and to decide on the working strategy for the response planning to come. In the PF phase, information on options and contingencies is needed: if the fire escalates, what is required? If a FCP is at risk, where in the vicinity can another one be set up? If casualties are recovered, is there somewhere to take them? In the PE phase decisions and measures taken need to be tracked for future reference. Additional capabilities developed for HEIMDALL tools provide further intelligence which refines the SAW information presented. For example, scenario matching techniques will be fine-tuned using EO-based change detection in land cover and land use (LULC) over time. WP6 contributes the information products and functionalities listed in Table 4-1 designed so far to support decision making in strategic response planning.

Table 4-1: WP6 decision support products and functionalities

HEIMDALL product	**Decision-making Phase**	**Supports stakeholders in activity**	**HEIMDALL tool (functionality)**	**Deliverable**
Impact assessment	SA	Risk and impact assessment: analysis of the consequences of a situation at hand resp. scenario Analysis of possible future scenarios: planning and assessment of different future scenarios with alternative conditions and situational parameters	RVA module (situation assessment)	D6.4

ISA information – aggregated impact summary for an area of interest	SA	Risk and impact assessment: analysis of the consequences of a situation at hand resp. scenario in an area of interest Analysis of possible future scenarios: planning and assessment of different future scenarios with alternative conditions and situational parameters	ISAS	D6.7
DES information - safe (response-oriented) infrastructure	**PF**	**Contingency management: Analysis of contingencies and options, e.g. identification of safe shelters and material storages**	**DES**	**D6.10 (this deliverable)**
Similar scenarios	SA	Scenario matching: Analysis of similar situations in the past	SMAC	D6.14
Changes in LULC over time	**SA**	**Scenario matching: LULC change detection as additional indicator for similarity of scenarios.**	**CDM (EO-based change detection module)**	**D6.10 (this deliverable)**
ISA information - total economic damage in similar scenarios	SA	Cost analysis	ISAS	D6.7
Decisions and measures taken, lessons learnt in similar scenarios	PF	Analysis of decisions and measures taken and lessons learnt in similar scenarios as potential decision options for the situation at hand	SMES	D6.14
Impact assessment for hypothetic measures	SA/PF	Risk and impact assessment of possible future scenarios: analysis of the consequences of hypothetical prevention and mitigation measures	RVA/ISAS/SMES	D6.4/D6.7/D 6.14
Situation report	SA	Cross-stakeholder cooperation and communication: Utilization of emergency management message standards such as the EDXL (Emergency Data eXchange Language) group of standards (see D6.7) which includes decision support information to overcome the problems of interoperability and semantic heterogeneity and to ensure the optimal provision of disaster-related information for fast decision-making in a highly coordinated manner	SITREP	D6.7

4.3 Decision Support Functionality in D6.10

In this deliverable two of the above presented products and tools are specified:

- Identification and aggregation of DES information for an area of interest (in the form of a specified GOI) by the **Decision Support Service (DES)** on potentially save response-oriented infrastructure which supports the identification of options and contingencies
- Changes in LULC over time processed by the EO-based **Change Detection Module (CDM)** which will be used by the SMAC as an additional indicator for similarity of scenarios

DES information on potentially safe (potentially not affected for a given time) task-oriented infrastructure, customized towards the addressing organization, is generated based on a fusion of expert, scenario, simulation, and impact assessment information for real and fictive scenarios. Examples for DES information are locations of accessible response materials, safe routes and bridges, alternative locations for C&Cs and FCPs and possible target areas for evacuation. When included in a situation report, this information can help the decision maker to decide on the path to follow to achieve the desired outcome. We expect the combination of this intelligence and the efficient use of means for standards-based communication and information sharing to eventually foster decision making based on informed collaborative reasoning and contingency planning.

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 potential FCP 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.

The CDM will be implemented and integrated as a module of the SMAC. The idea to introduce this functionality into HEIMDALL is motivated by a major challenge that end users are facing when comparing a situation with historic scenarios which has been identified repeatedly in discussions (e.g. at EUW2 in October 2018): The same hazard situation in the same location at the same time of year, month and day with the same weather conditions may lead to a totally different scenario due to frequent changes in land cover. Often, forest fuels change due to deviating climate conditions or prescribed burnings performed every year as a preventive activity of fire and rescue services. Construction affects fuels, too, as well as courses of waterways. Therefore, we aim at performing pixel-based change detections based on categorized EO raster data presenting the LULC at the location and date of the compared scenarios to give end users an additional indicator for their similarity. Besides integrating the CDM into the SMAC, the analysis products could be provided in the HEIMDALL map, in tables and in diagrams.

4.4 Architecture

The DES consists of the actual web service component and a DB as shown in Figure 4-1. It is currently under discussion whether the DES uses the ISAS DB as both integrate the same set of input data. The DES as a RESTful web service provides a HTTP-based REST API which allows clients such as the HEIMDALL SP to communicate with the service.

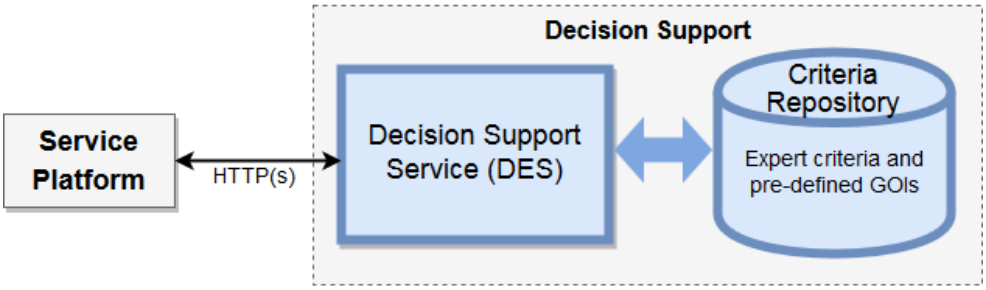

Figure 4-1: DES building blocks

The CDM will be implemented as a module integrated into the SMAC component. Figure 4-2 outlines its position in the SM architecture. Results will be directly used by the SMAC. It is to be discussed with the HEIMDALL consortium whether products shall be made accessible over an open API, for example for displaying them in the HEIMDALL UI.

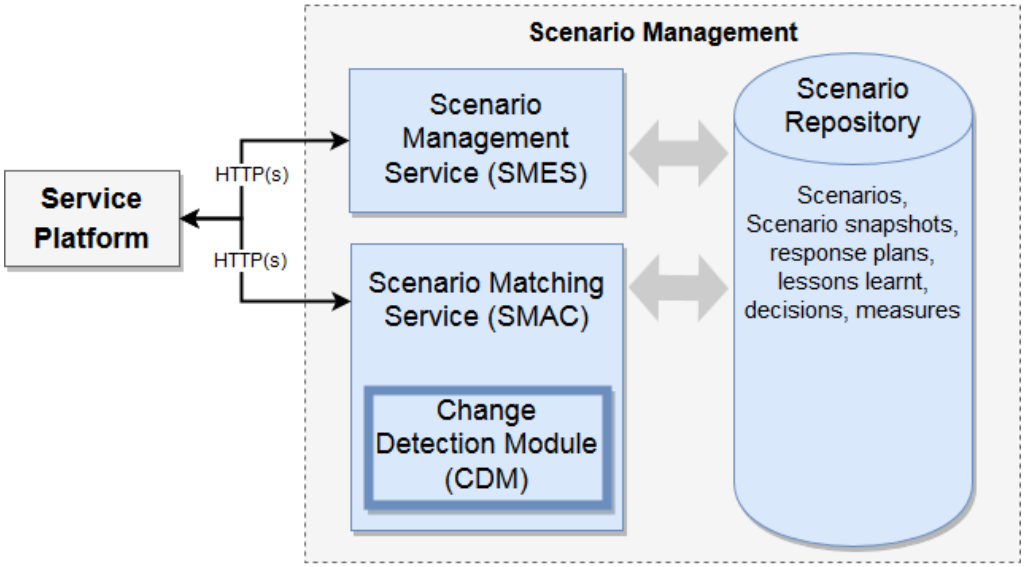

Figure 4-2: Scenario management modules with the CDM being highlighted as a building block of the SMAC component

4.5 REST API Conventions

The DES REST API communicates using JSON as the primary data-interchange format. The format will be based on shared conventions for designing web APIs, e.g. the JSON API conventions [14]. The concrete JSON structure of the DES resources is subject to frequent change as the different HEIMDALL modules mature. For example, data types may change or end users will require additional values in a list of possible values. Based on common procedures and technologies in web development the DES API documentation will be built and deployed together with every software release. This way, the API documentation shall remain always up-to-date.

We assume that the DES module will be installed in the HEIMDALL VPN and shall be therefore accessible over an URL like this:

```
http://esb.heimdall.sp/services/rest/des/
```

Therefore, all URLs used in the examples in the following part of this document refer to this global URL. For example, the request

```
POST /jobs HTTP/1.1
```

Would be resolved to

```
POST http://esb.heimdall.sp/services/rest/des/jobs HTTP/1.1
```

4.6 Workflows

This section describes a first general workflow in order to foster a deeper understanding of how the decision support services work. In future versions of this document, further workflows will likely be added.

4.6.1 General DES Information Generation Workflow

DES information is generated in the PF phase of the decision making process when the end user needs this information as a basis for decision making on options and contingencies. Figure 4-3 outlines the general workflow.

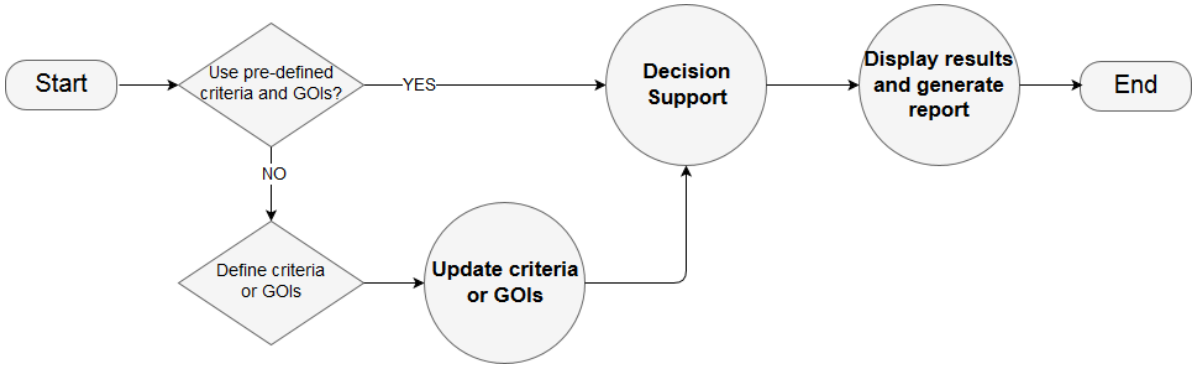

Figure 4-3: General decision support workflow

The workflow is started on demand, either by the end user or by a workflow component. It makes sense to collect first all input data and configure the needed criteria and pre-defined GOIs before starting the DES information generation. DES information can be used to display it in the UI and to list it in a situation report in an additional information block.

5 Technical Specification

5.1 Decision Support Service (DES) Specification

5.1.1 **Information Fusion**

The DES aggregation process will make use of the information fusion strategies described for the ISAS in D6.7. Hazard information (simulation- and observation-based) and impact assessment information (physical and human) are intersected and aggregated using configured expert criteria and metrics with pre-selected GOIs defined by the user.

5.1.2 **DES Information**

In contrast to the ISAS, the DES identifies for a given area of interest (in the form of a GOI) infrastructure, in particular response infrastructure, which won't be affected within a specific period of time according to the given hazard information. For a GOI the following DES information is generated:

- Total number of safe infrastructure in GOI
- Total number of safe response infrastructure in GOI
- List of safe infrastructure
- List of safe response infrastructure

Please note that both, the area of interest and the resulting safe infrastructure objects are designed as GOIs. Use cases include:

- List of potentially save (potentially not affected for a given time) alternative FCP sites in the area which, when included in a report, can help the decision maker to meet the best possible contingencies in case that a forward command post need to be moved.
- List potential sheltering options in the area (potentially not affected for a given time)
- Find water reservoirs for firefighting or sand pits for filling sandbags in the area

5.1.3 **Multi-criteria Decision Support**

A major task performed in T6.4 in the first period of the project has been to collect and compile hazard- and task-specific domain knowledge in the form of user requirements and expert criteria and metrics, in particular from the different groups of emergency management experts in the consortium and AB from different countries and disciplines. This domain knowledge has been used to shape design, assessment, processing and fusion techniques of the different situation assessment and decision support components on a **per hazard type** basis. For example, depending on the hazard type, the level of detail in hazard information can be different and therefore hazard-specific impact assessment concepts have been elaborated either working with simulated or observed hazard information (see D6.1). Accordingly, different impact classifications apply to each hazard type and impact assessment concept. DES aggregation and fusion techniques must consider these specifics. As to task-specific decision support, different levels of responsibility, legal frameworks and organizational procedures require flexible solutions for the specification of criteria and weights that are applied to the scenario matching process. Identified rules, thresholds, workflows or other appropriate means of customization are transformed into an appropriate service configuration.

In a second step, we identified **common, cross-domain aspects** in the domain knowledge and applied these aspects to the high-level information fusion processes performed by situation assessment and decision support services. In these processes the disjoint hazard-specific pieces of information are related to each other, compared to user goals and objectives and mapped to generalized data models and terminologies. Examples are the harmonized scenario, response plan, and lessons learnt data models and the GOI entity as a means for specifying a target area of interest for the information aggregation. At the same

time, these common concepts have been designed to always provide means for a certain degree of customization.

As a possible way of finding criteria and metrics that produce the most promising results out of criteria-based processes such as scenario matching, ISA and DES information generation is to perform **system trails** with the end users in training sessions. In such trials end users are presented with the tool and a **default configuration of criteria and metrics** (based on identified needs and assumptions). In consecutive trials users **fine-tune the configuration** so that the produced results are assessed as appropriate. The more training data (e.g. scenarios) is available the better the results. The finalized configuration is used for immediate response situations. For the time being, the consortium has agreed upon performing trials for the scenario matching component. Once, the ISAS and DES will be integrated into the HEIMDALL system, it makes sense to perform this procedure also for these components.

5.1.3.1 Criteria and Metrics

The DES makes use of pre-defined criteria and metrics in order to generate the most useful DES information as a basis for decision making in contingency management. Through the diversity of end users in terms of different legal frameworks, national, regional and organizational strategies, roles and profiles, these criteria and metrics depend strongly from the stakeholders which shall be addressed. Therefore, it's fundamental to identify common and individual criteria and metrics for the different stakeholders to be supported by the DES. These criteria and metrics will be incrementally developed and evaluated in collaboration with the end user partners. First discussions have revealed a need for the consideration of the following criteria and metrics which will be refined in future discussions:

- Different selections and pre-definitions of relevant response-oriented infrastructure
- Pre-definition of potential alternative FCP sites
- Different prioritizations of infrastructure
- Single-hazard vs. multi-hazard impact assessment
- Different DES information products of interest, different product attributes of interest
- Different thresholds (e.g. maximum damage for declaring "safe")
- Different temporal horizons of interest (e.g. safe until time x)
- Transparency of data source whereof the end user might pre-select
- Visibility of configuration and pre-selection
- Visibility of limitations (e.g. in data resource)

5.1.3.2 Configuration of Criteria and GOIs

In order to reflect the internal diversity of end users they DES will provide the possibility to customize criteria, rules and other definitions of process behaviour which will be considered during the generation of DES information.

For the DES, similar configuration methods and options will be developed and implemented as for the ISAS. These options allow for making the configuration and customization transparent. For example, the list of safe GOIs can be filtered against query parameters and complex searches in the URL. As a result only those elements are returned which correspond to the filter query. The following example request (preliminary) returns only GOIs with infrastructure type "shelter":

```
GET /des/job/<some-id>/gois?type=shelter
```

Please refer to D6.7 for details on these methods and options.

5.1.4 **REST API**

The DES will provide a REST API similar to the ISAS API specified in D6.7 (please refer to D6.7 [9] for details). The REST API will enable clients such as the SP or UI to trigger the DES information generation process and to access and modify DES information products. The specification in this chapter describes a first design which is intended to be refined during the next months as a base for the first implementation works. The detailed design will be presented in the follow-up deliverable D6.11.

Similar as for ISAS, the user will be able to define DES generation jobs and to access results. The basic workflow is shown in Figure 5-1. The idea is to start a job for one or multiple pre-defined GOIs, e.g. an administrative areas, regions of interest, etc. defined by the operator. For example, the following request creates a **job**:

```
POST /jobs HTTP/1.1
Content-Type: application/vnd.api+json
Accept: application/vnd.api+json
```

With the body:

```
{
   “data”: {
      “type”: “jobs”,
      “attributes”: {
         "name": "Safe shelters in La Jonquera municipality for fire hazard xy"
      }
   }
}
```

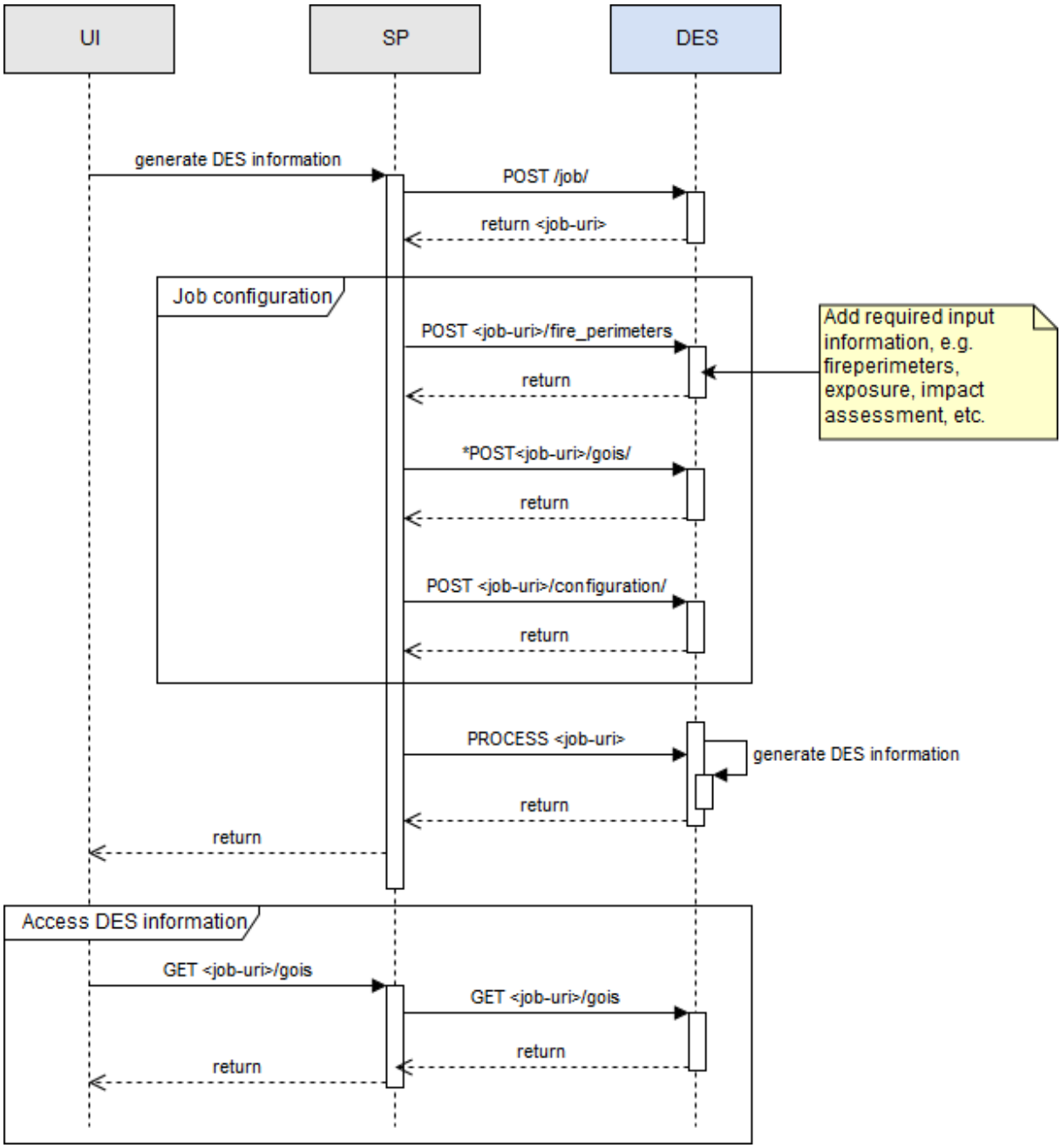

Figure 5-1: General DES workflow

The response could look like:

```
HTTP/1.1 201 Created
Location: http://esb.heimdall.sp/services/rest/des/jobs/234
Content-Type: application/vnd.api+json

{
   “data”: {
      “type”: “jobs”,
      “id”: “234”,
      “attributes”: {
         “name”: “Safe shelters in La Jonquera municipality for fire hazard xy”,
```

```
          “createtime”: “2018-07-17T11:23:21”,
          “status”: “pending”
       },
     “links”: {
          “self”: “http://esb.heimdall.sp/services/rest/des/jobs/234”
       },
     “relationships”: {
          “gois”: {
               “data”: {
                    “links”: {
                         “related”:
“http://esb.heimdall.sp/services/rest/des/jobs/234/gois”
                    }
               }
          },
          “fire_perimeters”: {
               “data”: {
                    “links”: {
                         “related”:
“http://esb.heimdall.sp/services/rest/des/jobs/234/fire_perimeters”
                    }
               }
          }
       }
}
```

Pre-defined GOIs, necessary input information and configuration are created as new DES data resources subordinated to the job using further POST requests. For example, the following request creates a **pre-defined GOI** for a job:

```
POST http://esb.heimdall.sp/services/rest/des/jobs/234/gois HTTP/1.1
Content-Type: application/vnd.api+json
Accept: application/vnd.api+json
```

With the GOI in the body (preliminary GOI element structure):

```
{
  "type": "goi",
  "id": "052a6a25-6e13-461d-b768-c66633345f454",
  "attributes": {
     "name": "La Junquera municipio",
     "geometry": {
        "type": "Polygon",
        "coordinates": [
```

```
          [
            [
              2.837734222412109,
              42.4423344873224
            ],
            [
              2.838764190673828,
              42.416740164543064
            ],
            [
              2.8595352172851562,
              42.39291031675311
            ],
            [
              2.888202667236328,
              42.38898005764399
            ],
            [
              2.8967857360839844,
              42.406727660927984
            ],
            [
              2.8957557678222656,
              42.43638030553687
            ],
            [
              2.8873443603515625,
              42.45246796368671
            ],
            [
              2.837734222412109,
              42.4423344873224
            ]
          ]
        ]
      }
   }
}
```

Please note that the generated DES products won't be available immediately after job creation. This is intended as the generation process can take some time. To **start the job**, a HTTP process request must be sent like this:

```
POST http://esb.heimdall.sp/services/rest/des/jobs/234 HTTP/1.1
Content-Type: application/vnd.api+json
Accept: application/vnd.api+json
```

Once the job is finished, the results can be fetched like this:

```
GET http://esb.heimdall.sp/services/rest/des/jobs/234/gois HTTP/1.1
Accept: application/vnd.api+json
```

The returned GOI contains the total number of safe infrastructures and safe response infrastructures and links to the corresponding GOI lists:

```
HTTP/1.1 200 OK
Content-Type: application/vnd.api+json
{
    "links": {
        "first": "
http://esb.heimdall.sp/services/rest/des/job/234/gois?page%5Bnumber%5D=1",
        "last": "
http://esb.heimdall.sp/services/rest/des/job/234/gois?page%5Bnumber%5D=1",
        "next": null,
        "prev": null
    },
    "data": [
        {
           "type": "goi",
           "id": "052a6a25-6e13-461d-b768-c66633345f454",
           "attributes": {
               "name": "La Junquera municipio",
               "totalsafe": "454",
               "totalsaferesponse": "2",
               "geometry": {
                  …
               }
          },
           "relationships": {
              "safegois": {
                 "data": {
                    "links": {
                       "related":
"http://esb.heimdall.sp/services/rest/des/jobs/234/gois?filter=safe+istrue"
                    }
```

```
                }
             },
             "saferesponsegois": {
                "data": {
                   "links": {
                      "related":
"http://esb.heimdall.sp/services/rest/des/jobs/234/gois?filter=safe+istrue&
type=shelter"
                   }
                }
             }
          }
       }
    ]
}
```

Table 5-1 lists the functionality related to jobs. Table 5-2 lists the functionality related to DES results.

Table 5-1: Functionality related to jobs

ID	Functionality	Interface method	Data exchanged and data representations
DES_J_01	Create DES generation job	HTTP POST /jobs	Request body: Job resource (JSON) with basic job parameters. Response body: Created job resource
DES_J_02	Access job Use case: poll job status	HTTP GET /jobs/<id>	Request body: nothing Response body: JSON representing the job resource
DES_J_03	Save job	HTTP PUT /jobs/<id>	Request body: job resource (JSON) Response body: nothing
DES_J_04	Delete job	HTTP DELETE /jobs/<id>	Request body: nothing Response body: nothing

Table 5-2: Functionality related to results

ID	Functionality	Interface method	Data exchanged and data representations
DES_G_01	Create GOIs Use case: Pre-definition of an area of interest, manual generation of a	HTTP POST /gois	Request body: List of GOIs (JSON). Automatically generated

	list of safe GOIs		parameters shall be omitted Response body: Created GOIs list resource
DES_ G_02	Access GOIs (including available DES information)	HTTP GET /gois	Request body: nothing Response body: JSON representing list of GOI resources
DES_G_03	Save GOI Use case: End users want to modify a safe GOI by hand	HTTP PUT /gois/<id>	Request body: GOI resource (JSON) Response body: nothing
DES_G_04	Delete GOI	HTTP DELETE /gois/<id>	Request body: nothing Response body: nothing

5.1.5 **Implementation Details**

The DES will be implemented in the same way as the ISAS module. For further information refer to the section on implementation details in D6.7 [9].

The implementation language of the DES component is the general purpose, high-level language Python. This language focuses on high productivity, code readability and offers a wide variability of supporting software libraries.

The language is built on a dynamic type system and offers automatic memory management which makes is resilient against a wide range of common errors like buffer overflows or memory leaks.

While the language supports multiple programming paradigms the implementation of this module mostly follows an object-oriented approach with occasional usages of functional elements.

5.1.5.1 Implementation framework and software libraries

The Web API will be implemented using the Django framework, an open source web application framework which follows the Model-View-Controller pattern. The framework includes geographic datatypes and functions following the Simple features specification of the Open Geospatial Consortium (OGC).

In addition to the generic Django framework the “Django REST Framework” shall be used as a toolkit to implement the REST API.

As mentioned in section 2.1.3 JSON is the preferred format for exchanging data and generating output information.

5.1.5.2 Data storage

The internal data storage will be implemented using the DB abstraction layer of the Django framework backed by a PostgreSQL DB system.

PostgreSQL is object-relational DB system with the goal to implement a high standard compliance following the ISO SQL:2011 standard. The system itself can reliably handle high workloads and many concurrent users.

5.1.5.3 Data infrastructure

The generation of the DB tables to store the data of the DES component is handled by the migration system of the Django framework. References described in the model layer of the

DES component are converted to foreign keys in the DB automatically by the migration system. This way the DB system guarantees the referential integrity defined in the web application without the need to maintain the DB scheme separately from the application itself.

5.1.5.4 Hardware

The hardware used for the implementation of this module are two virtual machines based on a 64bit Linux distribution. As the first VM is for testing the second VM is for developing. Both VM's have 4 CPU cores each as well as 1 TB disk memory and 32 GB RAM. A proper Ethernet connection is crucial as well as a connection to the HEIMDALL VPN.

5.2 Change Detection Specification

In order to reflect frequent changes in land cover and land use (LULC; e.g. changing forest fuels) the CDM performs pixel-based change detections based on LULC raster data. The identified changes give end users an additional indicator for similarities between scenarios that can be wide apart in terms of time. As the need for this functionality has emerged only recently at EUW2 in October 2018, the section describes the module vision. The final design and specification will be provided in the final deliverable D6.11.

Change detection describes the process of comparing multi-temporal data sets in order to detect changes in certain classes of interest, e.g. changes in land cover for different dates of imaging. As for the CDM **post classification change detection** is used prior to image algebra change detection.

5.2.1 **Functionality**

The CDM takes classified EO raster data as input. Thus, all input data must share a common classification. The user is enabled to provide additional meta information such as assignment of values and corresponding class descriptions in form of CSV or SLD (Styled Layer Descriptor) files.

Ideally, the input data were acquired by the same or similar sensor with the same resolution to ensure data compatibility. As it is unlikely to fully meet those requirements, the CDM provides two procedures for geometric raster correction:

- Crop the input data to a common overlapping extent if geometric origin and spatial resolution are equal
- Warp the input data to a common coordinate reference system with equal extent and spatial resolution

5.2.2 **Requirements Input Data**

In order to achieve correct change detection results, the pixel values of the input data must be categorised in semantically meaningful classes, e.g. for land cover data: roads, buildings, dense vegetation, light vegetation, water etc.

To avoid class misregistration due to mismatched class boundaries, the input data must share the same geometric properties (coordinate reference system, spatial resolution and pixel origin).

This has to be taken into account when LULC raster data sets are ingested into the HEIMDALL system for use by the CDM module.

5.2.3 **Output Data**

The CDM outputs raster data with information about lost, gained or unchanged pixel values of the corresponding classes. Furthermore, raster statistics give more information about classes with most change or which class gained/lost pixels compared to other classes.

The loss, gain and unchanged values in specific classes can be used by the SMAC to identify similarities and mismatches regarding LULC in compared scenarios.

5.2.4 **Implementation Details**

The implementation language of the CDM is the general purpose, high-level language Python. A main script invokes several subscripts for data harmonization (e.g. geometric correction) and performing the change detection itself.

6 Conclusion

This document provided an overview of work conducted so far in task T6.4 in close collaboration with the other tasks in WP6, with the end user and ELSI partners in the project consortium. The overall HEIMDALL decision support concept has been highlighted under consideration of multi-hazard, cross-domain, and ELSI aspects.

In the specification part, the Decision Support Service (DES) and the Change Detection Module (CDM) have been presented in detail. The DES identifies and aggregates information on potentially save response-oriented infrastructure for an area of interest which supports the identification of options and contingencies. The EO-based CDM detects changes in land cover and land use over time which will be used by the SMAC as an additional indicator for similarity of scenarios.

On the basis of this specification the involved technical partner DLR-DFD shall be able to develop the first releases of the components. We also expect that software development of other HEIMDALL components connecting to DES and the scenario matching component can take place simultaneously and integration of the both in the overall HEIMDALL system shall be facilitated.

The component design is based on concepts developed in close collaboration with end users from different countries and disciplines, which namely are Fire and Rescue Services (FRS), Police, Medical Services (MS), Civil Protection (CP) and Command and Control Centres (C&C). Requirements and solutions evolve through collaborative design and the HEIMDALL agile information system development considers the needs of end users and other stakeholders. Intermediary system releases based on this design document and on the case studies developed by the end users shall be demonstrated in real-environment conditions, for example during the third End User Workshop (EUW3) in April 2019. These demonstrations and exercises give the end users the possibility to reflect on current solutions, to validate these and to identify problems. User feedback is acquired during demonstrations and exercises. This information leads to re-iterations of technical requirements and the component design. Furthermore, in in-depth discussions, expert criteria and metrics for the different decision support products will be refined. The follow-up deliverable D6.11 due in M38 will reflect these and all other refinements.

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