HEIMDALL: A TECHNOLOGICAL SOLUTION FOR MULTI-HAZARD MANAGEMENT SUPPORT INCLUDING WILDFIRES

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Context of the HEIMDALL Solution

Managing forest fires and other disasters usually involves multiple emergency management organisations, even multiple jurisdictions and countries in case of cross-border events. Following the initial disaster event, cascading effects can further amplify the degree and complexity of disaster situations. This imposes a high need and degree of cross-organisational communication and cooperation, not only during response but also in the preparedness phase, between all stakeholders (command and control centres, civil protection units, medical services, police and fire fighting units). However, relevant studies have revealed that collective interoperability is not sufficiently achieved, which reduces the ability to perform collaborative activities, including decision making and action implementation (House, 2014). Moreover, information overload and uncertainty in a crisis situation lead to reduced situation awareness and decision making capabilities.
Managing disasters begins before the disaster happens through being ready and aware of hazards, considering risks, possibilities and preventive measures, building scenarios and training. There is clearly a need to ensure efficient societal preparedness, to improve incident and emergency situation response mechanisms, in order to reduce impacts on people, property, the environment, and on society as a whole. An element of this improvement should be the provision to disaster risk management first responders of a flexible platform for multi-hazard emergency planning and management. Such a platform makes use of innovative technologies, for the definition of realistic multi-disciplinary scenarios and response plans. Implementing such a tool is the ambition of the HEIMDALL H2020 European project (HEIMDALL, 2017).
In the following sections the concept of the HEIMDALL project is outlined and demonstrated within the context of wildfire management.

A Multi-Hazard Cooperative Management Platform

HEIMDALL, a Horizon 2020 funded project, stands for Multi-Hazard Cooperative Management Tool for Data Exchange, Response Planning and Scenario Building. HEIMDALL aims to improve immediate and long-term collaborative strategic planning on a regional scale among the many affected disaster risk management and response stakeholders. The objective is to design and provide decision makers, and other stakeholders, a platform offering a wide range of tools which facilitate emergency management. In particular, HEIMDALL aims to support technically different typical response planning activities involving complex multi-hazard scenarios (Friedemann, 2018). The main solutions that have been designed and implemented include the: (a) support in the creation, analysis and exchange of realistic multi-disciplinary disaster scenarios, (b) provision of more, better, clearer and validated data, (c) recording of conditions, actual events and actions as the situation evolves, (d) analysis of possible futures of a situation and potential consequences to assess the effectiveness of potential working strategies and identify options and contingencies, (e) evaluation and revision of response plans based on lessons learnt from disasters, (f) inter- and cross-organizational communication and sharing of existing knowledge, situational information, disaster scenarios, strategies and response plans including communication to the public. Domain standards are respected where applicable.

HEIMDALL results are the fruit of a wide variety of technological specialists and potential end-users collaborating. End users from medical emergency services, police and firefighting units, civil protection, command and control centres from different organisations, disciplines and European countries are participating in the project. This enables the platform to address as best as possible the requirements of the different actors involved in disaster risk management. The project addresses some of the main disaster types regularly affecting European countries – forest fires, floods and landslides – including scenarios of cross-border incidents, multi-disciplinary events, inter-organisational cooperation and population awareness.

HEIMDALL Services

The system is designed as an integrated service platform using various data sources as inputs and proposing a set of services that can be useful to control centres, first responders and local populations during the preparedness and response phases (Fig. 1). Encapsulating all HEIMDALL modules in individual web services is the pre-requisite for multi-disciplinary response and response planning which usually involves various groups of stakeholders in need of different combinations of services. Combining different HEIMDALL services allows for building on top of one another and offering additional features for disaster response and preparedness. The main benefit provided by the system is that it can be easily extended. If a user wants to access new functionalities at a later moment, they can be integrated just like external systems that are already in use.

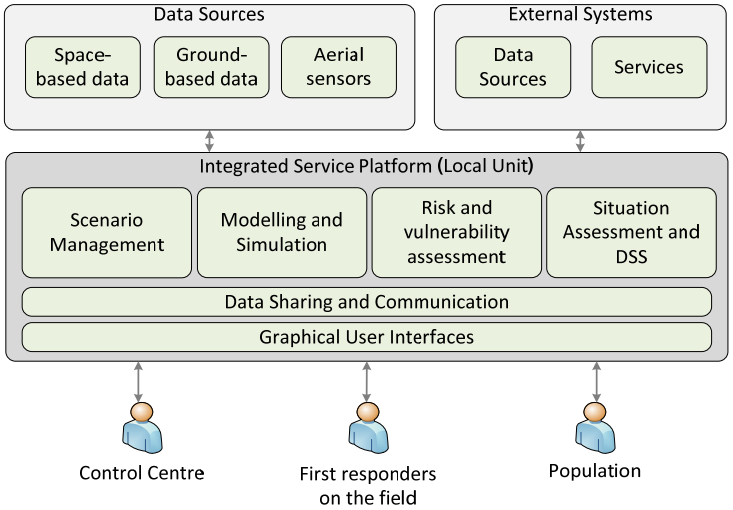

Fig 1. HEIMDALL functional architecture - Source: HEIMDALL deliverable D2.12 (2018)

The platform integrates space-based, ground-based and aerial-based data in order to forecast and monitor disaster events. In the case of wildfires, products highlighting burn scar and hot spots over wide areas are provided thanks to satellite and drone data. External data sources and services, including crowdsourcing and field responders' own data, can also be major inputs.
Scenario management is one of the services offered by the system; it aims at supporting decision makers in building, storing, reviewing and comparing realistic and multidisciplinary scenarios and in tracking decisions, measures taken and lessons learnt. Modelling and simulation are dedicated to forecasting hazard behaviour based on the existing input data. At the moment it is possible to simulate the evolution of forest fire, flood and landslide hazards, but this can be extended in the future. The risk and vulnerability service supports the platform with specific products based on Earth Observation (EO) data and simulated models, assessing the consequences of a situation in terms of both physical and human exposure and impacts. Situation assessment functionality integrates all relevant information sources to provide a sound and clear composite picture of the evolving situation, including a standards-based situation summary for overview and sharing. Decision support generates the information base for decisions related to response-oriented tasks such as contingency management; these functionalities combined will provide the possibility for the end users to perform an analysis of different possible scenarios, e.g. worst-case assumptions.
Communication mechanisms and technologies support information sharing among the relevant stakeholders, including first responders deployed on the field and the population at risk. Satellite-based connectivity in remote

areas will be provided where terrestrial alternatives are unavailable enabling communication between first responders in the field and back and forth with the control centre. Information can also be shared with other authorities, neighbouring municipalities and countries. Emergency management message standards such as the EDXL (Emergency Data eXchange Language) group of standards will be utilized in to overcome 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 (Friedemann, 2018).

HEIMDALL and Wildfire Management

Today, EO data have largely demonstrated their potential in disaster management, and are widely used by the decision makers in case of forest fires, in particular through operational emergency management mechanisms, e.g. Copernicus Emergency Management Service (EMS) Rapid Mapping or the International Charter "Space and Major Disasters". The HEIMDALL platform integrates this kind of data in order to generate and provide reliable and high-quality services highlighting the extent of the burnt areas, fire hotspots, and their evolution over time.
Thanks to their thermal information capabilities, moderate spatial resolution satellite sensors such as the Moderate Resolution Imaging Spectro-radiometer (MODIS) can be used for detecting active fires with a size of >900 m² on a daily basis. The MODIS Fire Service provides hot spots in near-real time for Europe and surrounding countries, including for every detected fire hot spot information about its latitude and longitude, vegetation and landcover.
Burn scar mapping and monitoring is another essential information service provided to crisis managers for supporting the disaster preparedness, response and recovery phase. A fully automatic burn scar processor based on high resolution satellite imagery, such as those of the European Sentinel-2 satellite mission, is developed within HEIMDALL to enable systematic monitoring of burnt area extents. The result is a georeferenced layer highlighting the extent of recent burn scars at a certain time with respect to the pre-disaster situation, at a 10m spatial resolution. The same type of information can be derived from very high resolution imagery, such as from the French Pléiades-HR sensors, at infra-metric resolutions.
A semi-automatic processor for fire severity/grading assessment is also integrated within HEIMDALL, in order to evaluate the level of damage on vegetation, from a couple of pre and post-event satellite images (Fig. 2). This information is the basis of the Earth Observation impact assessment on buildings, road network, population and landcover.
The information derived from Earth Observation data is automatically integrated into the HEIMDALL platform and updated as soon as new data becomes available.

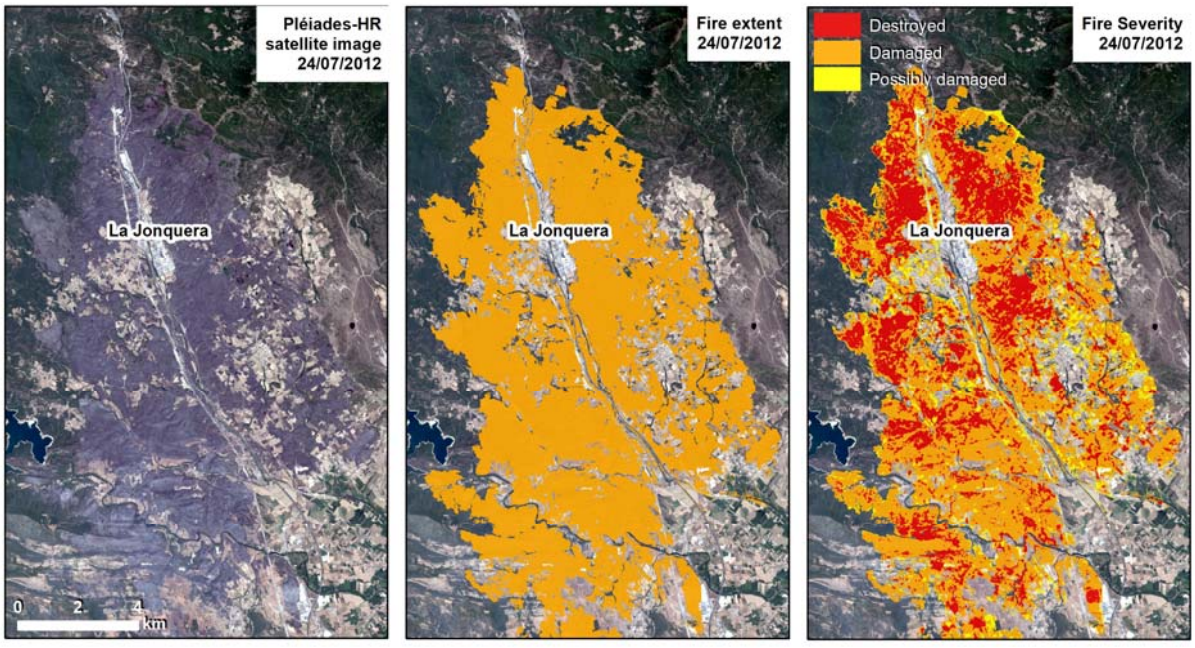

Fig.2: Satellite based burn scar mask and fire severity over La Jonquera, Spain, 24 July 2012 – Source: Pléiades-HR image, © CNES 2012, distribution Airbus DS, processing SERTIT

Within HEIMDALL, drone imagery is considered as one of the data sources and, in particular, the use of micro aerial vehicles as in drones at hand. The drones' role in HEIMDALL is enabling an operator to monitor an area of interest in order to localize potential forest fires hotspots, as depicted in Fig. 3. The proposed solution has the following key ingredients: (i) the use of a swarm, instead of a single drone, to increase system efficiency and robustness (Viseras, 2018), and (ii) a fully autonomous system. The latter implies that the system requires little intervention from an operator to control drones carrying out their assigned task.
Drones are equipped with the following modules: visual and thermal cameras to detect hotspots, an on-board computer to process images online and to run drones flying algorithms, a long-range communication modules that permits sending an online video stream to the operator over distances that range between 1 km and 5 km. Besides, the operator is equipped with a tablet. In the tablet, a graphical user interface permits the drone to interact and monitor the drones. In addition, the tablet executes a route planning algorithm that (i) coordinates drone movement, and (ii) plans routes that permit efficient area coverage while avoiding inter-drone collisions. Finally, it must be remarked that, although only forest fires are considered within the scope of HEIMDALL, the system can be also employed to monitor any other information of interest.

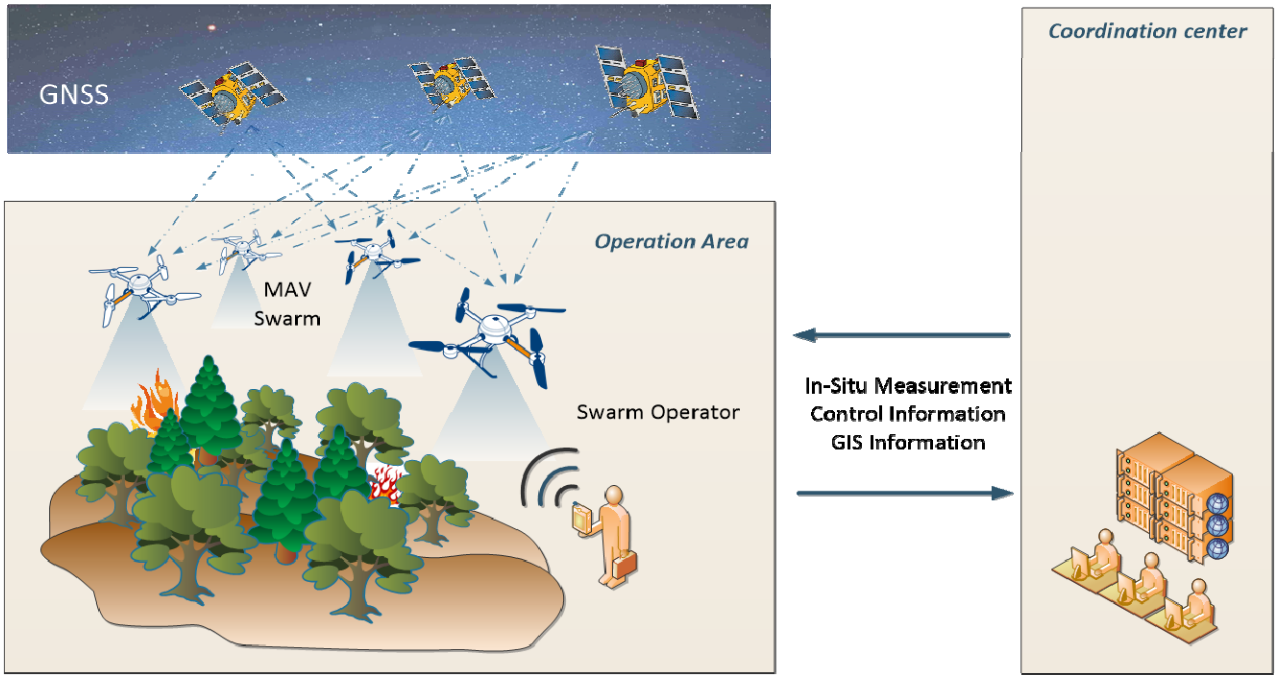

Fig. 3: A swarm of drones (MAVs) monitoring an area to search for potential forest fire hotspots

The fire simulation and modelling component of HEIMDALL characterises and predicts fire spread and behaviour in diverse and complex fire conditions. Strategies and tactics to suppress wildland fires depend, in fact, on fire analysis which is generally based on fire simulations. In this sense, many agencies worldwide rely on Wildfire Analyst to conduct their analysis in real-time, as a part of a set of innovative propagation modes, including real time fire data assimilation (Ramirez et al. 2011). All this information combined with expert knowledge improves the decision-making process of the first responders and incident commanders. In HEIMDALL the forest fire simulator is based on Wildfire Analyst simulation capabilities. The tool allows the simulation of fire spread and behaviour based on user inputs introduced directly through the Graphical User Interface (GUI). In particular, input parameters such as weather conditions, ignition points and lines and simulation hours can be defined by the user or retrieved from other sources. The forecasted weather parameters can be obtained either from a weather web service or from weather sources supplied by the user. Ignition geometries can be obtained from EO data or even from a swarm of drones which is operating during fire suppression activities. Furthermore, real-time data assimilation allows the operational adjustment of previously performed forest fire simulations, enabling the forest fire simulator to learn from the ingested information and provide thereafter more pertinent and realistic results in future simulations (Fig. 4). This data assimilation could be based on observations of the fire front location at a certain time, on information provided by the swarm of drones or even on updated EO data. The forest fire simulator provides a set of maps that translate the spread and behaviour of the fire in space and time to aid the first

responders in taking preventive or operational decisions during suppression activities. Outputs such as fire perimeters and fire-line intensity are used by the Risk and Vulnerability assessment module to perform impact assessment and to provide therefore further useful decision-making support to end-users.

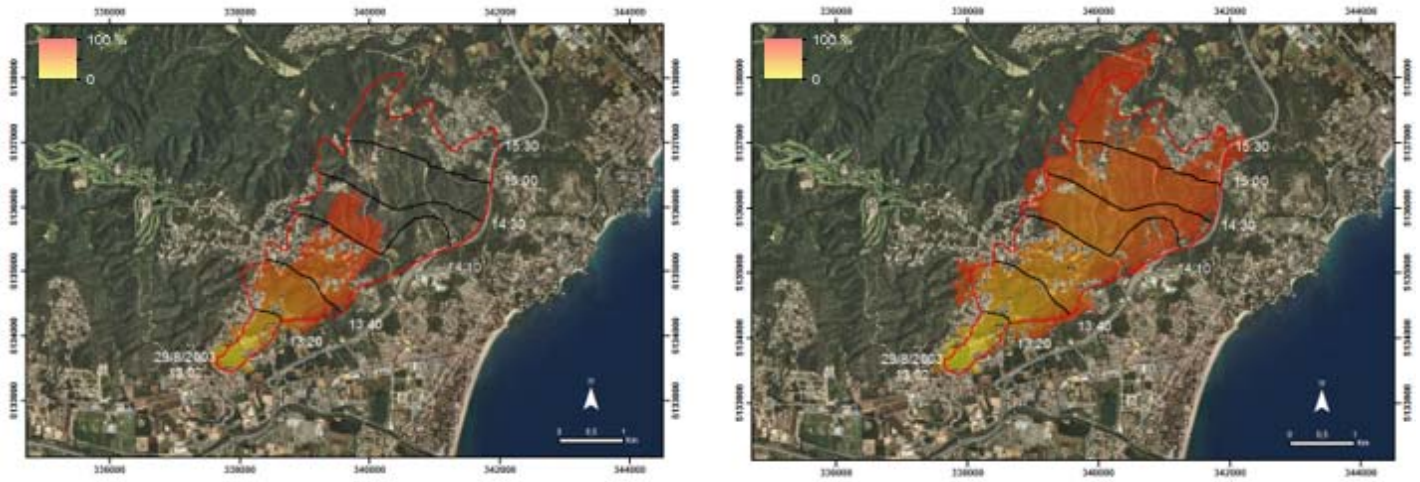

Fig. 4: Simulation of a forest fire before (left) and after (right) the adjustment of the fire rate of spread based on observations. Red line represents the real fire perimeter, the orange gradient scale the simulated time of arrival

Benefits of HEIMDALL from the point of view of the first responders

The complexity of natural disasters is evident. In this sense, HEIMDALL offers facilities and benefits to both preparedness and response phases, and furthermore within the three different levels of response: strategic, tactical and operational. HEIMDALL services and tools are designed, by gathering user expectations and requirements in a collaborative design methodology, to cover the various needs of emergency management actors.

In the preparedness phase, the system allows users to store and share scenarios with other authorities which are built on hazardous situation conditions (weather data, wildfire risk indexes, etc.) and which might lead into an incident. These scenarios are based on user experience and allow them to associate lessons learnt from specific incidents and incident action plans. During the response phase, at a strategic level, the possibilities offered by HEIMDALL allow command and control centres to have a global view of the incident in real time. By making use of modelling and simulation tools, combined with data fusion techniques, HEIMDALL provides a better understanding and an improved situation assessment which includes associated vulnerability. In this way, the incident commander can evaluate the resources available, the objectives set, record the actions carried out, monitor operations and the situation at a strategic level and cooperate with other agencies through agreed coordination protocols and previously established channels.

At an operational and tactical level, an incident commander will have real-time information about the situation, its evolution and possible impacts on assets or people. This facilitates decision making and the evaluation of the applied strategy's effectiveness.

Through HEIMDALL the first responders in the field have real-time information concerning the risk, allowing them to take the necessary measures to improve care and safety. In addition, they can not only evaluate the incident action plan and the progress of tactical objectives, but they can also enrich the repository of the platform with lessons learnt and scenario information, making future actions more effective. Furthermore, first responders can improve operations through emergency drills, a possibility offered by the platform through simulators and scenario creation. Another important emergency management aspect to consider is the communication strategy. Hence, HEIMDALL provides reliable information to share with politicians, media or population.

In conclusion, natural destructive phenomena cannot be avoided but the consequences and the negative impact can be reduced. Through technology, HEIMDALL aims to facilitate cooperation and coordination among agencies, assisting them with the best information to prevent and, in any case, act, respond and effectively plus efficiently manage emergencies caused by natural disasters. In this way, not only is preparation and response improved, but also the capacity for recovery and adaptation enhanced.

Summary and Perspectives

HEIMDALL's Multi-Hazard Cooperative Management Tool for Data Exchange, Response Planning and Scenario Building is aimed at facilitating all phases of disaster management from prevention/mitigation, through crisis management to recovery. Through extensive work with engaged users HEIMDALL's platform is beginning to offer user-friendly modules covering a whole array of functions including: Data Source Access, Scenario Management, Modelling and Simulation, Risk and Vulnerability, Impact Assessment, Situation Assessment, Decision Support, Data Sharing and Communication. Within this paper HEIMDALL partners have outlined the system within the context of Wildfire management, a topic of the utmost importance.
A first version of the HEIMDALL platform was validated in a workshop in October 2018 with various end-users. More releases will follow with the objective of publishing a pre-operational platform at the end of 2020 which could be used by HEIMDALL's end users, before extending it to additional users. Moreover, the system will in the near future be extended to cover other natural and man-made hazard types. Further information will follow: http://heimdall-h2020.eu/.

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Presenter's bio

Stéphanie Battiston is the deputy head of ICube SERTIT's rapid mapping service (University of Strasbourg), highly involved in operational emergency management mechanisms: the Copernicus EMS Rapid Mapping and the International Charter Space and Major Disasters.