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FROM SPACE TO SAFETY: AN ANALYSIS OF END-USER EXPERIENCES WITH SATELLITE-BASED SERVICES FOR DISASTER RISK MANAGEMENT

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Abstract

The risk of more frequent and severe extreme weather events and disasters increases as the impacts of climate change become more pronounced. Adequately managing disaster risks throughout the entire disaster risk management cycle is fundamental for protecting citizens and societies from the impacts of disasters. Satellite technologies play an increasing role in supporting disaster risk management efforts, with capabilities such as the European Union Copernicus Programme enabling services and solutions providing accurate, reliable, and timely data to responders and decision-makers. Connecting satellite technologies with end users remains a key activity to ensure their needs are reflected in satellite-based services. The European Union Agency for the Space Programme (EUSPA) and Eurisy have collaborated on a series of national workshops "Satellite-based Services for Disaster Risk Management", bringing together policy experts and decision-makers, service providers, and end-user communities to discuss how satellite-based services can better meet the needs of users going forwards. In parallel to these workshops, a survey has been conducted on users' awareness, needs, challenges, and benefits from satellite-based services. The results of the survey data show both an awareness of, and willingness to use, satellite technologies for disaster risk management. Challenges and barriers remain, in particular the economic cost of initially implementing satellite technologies, and the technical competencies to user satellite-based services. We also find that user experience significant benefits using satellite technologies, including organisational improvement, and in fact those who conduct quantitative analyses report financial and efficiency savings over time. In order to better understand and demonstrate the value of satellite technologies for disaster risk management, Eurisy has developed an interactive dashboard, targeted primarily towards users' communities.

Keywords: disaster risk management, EUSPA, satellite applications

Acronyms/Abbreviations

C3S Copernicus Climate Change Service
CAMS Copernicus Atmosphere Monitoring Service
CAS Galileo Commercial Authentication Service
CEMS Copernicus Emergency Management Service
CLMS Copernicus Land Monitoring Service
CMEMS Copernicus Marine Service
CSS ESA Civil Security from Space Programme
EGNOS European Geostationary Navigation Overlay Service
EO Earth Observation
EO Earth Observation
ESA European Space Agency
EU European Union
EUSPA European Union Agency for the Space Programme
EWSS Galileo Emergency Warning Satellite Service
GHSL Global Human Settlement Layer
GOVSATCOM Governmental Satellite Communications
HAS Galileo High Accuracy Service
JRC Joint Research Centre
OS Galileo Open Service
OSNMA Galileo Open Service Navigation Message Authentication
PRS Galileo Public Regulated Service
R3 Rapid and Resilient Crisis Response
RLS Galileo Return Link Service
S4GF Space for Green Future
SAR Search and Rescue
SAR Synthetic Aperture Radar
SSA Space Situational Awareness
UCP User Consultation Platforms

1. Introduction

1.1 Disasters and Disaster Risk Management

The risk of natural disasters, and the human and economic impacts of these disasters are increasing. The number of weather-, climate- and water-related disasters has increased five-fold over the past fifty years [1], with approximately 400 natural disasters occurring every year on average across the world [2]. Although attributable to improvements in recording natural disasters, there is

strong agreement that the impact of human-caused climate change on the frequency and intensity of natural disasters and the broader Earth system [3]. Regardless of future reductions in net carbon emissions, the risks of disasters will almost certainly continue to increase as the effects of global warming become increasingly present.

Whilst singular natural disaster occurrences are inherently difficult to attribute to climate change, a number of particularly severe disaster events in recent years serves as a stark warning of the impacts of climate change, yet to be fully realised. In Europe alone, multiple recent events have proved the continent is not immune from the global impacts of climate change. In July 2022, flooding caused by extreme rainfall across Germany, Belgium, and the Netherlands led to the deaths of 243 persons, causing nearly 50 billion Euros in damages, and leaving long-lasting effects on communities [4]. The number of wildfires has increased dramatically, with over 1,300 fires recorded in the European Union (EU) in 2024 so far, with Italy, Romania, and Spain the most impacted countries by the number of fires [5], continuing the 'unprecedented' trend of increasing occurrence of fires through from 2023 [6]. Overall, the human and economic costs of increasingly frequent and severe disaster events exert a growing toll on societies, increasing dangers to vulnerable persons, damaging communities, further straining infrastructure and healthcare systems, and causes significant financial costs to governments, businesses, and households.

In parallel to efforts to reduce climate change causing emissions towards 'net-zero', societies must therefore also continue increase their resilience and enhance protection measures for when disasters do occur. Progress has been made across countries and regions in developing early warning systems, building more resilient infrastructure, and improving disaster risk management practices, which can be evidenced by the reduction in lives lost from disasters over the past fifty years [7]. More must be done however, to develop solutions and connect these with operational users in disaster risk management.

Broadly, disaster risk management consists of planning and implementing efforts to avoid, reduce, and manage disaster risks and hazards whilst protecting and strengthening communities against disasters when they do occur. Commonly viewed through a cycle of four phases: Mitigation, Preparation, Response (sometimes also Relief), and Recovery, the disaster risk management cycle provides a basic means of conceptualising the different needs, challenges, and activities that must be undertaken at each stage in order to reduce as much as possible the impact and disruption of disasters. For example, during mitigation and preparedness it is particularly important to understand which specific areas within a given zone would be particularly vulnerable to a disaster, whether due to their geographic or socioeconomic features. During the response phase, when a disaster is no longer avoidable, it is then crucial to be able to communicate with, and deliver resources to, persons in this area to reduce the risk of harm and provide support. Each of these phases also comes with particular challenges, whether due to lack of information, awareness, targeted resources, or due to the impact of the disaster itself hammering relief efforts, through damage to communications infrastructure for example.

1.2 Space Technologies and Disaster Risk Management

Space technologies play an increasingly important role throughout the disaster risk management cycle, with new capabilities from the proliferation of satellites over the past decades enabling new and innovative services supporting disaster risk management efforts. Earth Observation satellites can monitor and map (the risk of) wildfires, informing firefighters of particularly susceptible areas, as well as the scope and movement of ongoing blazes. Navigation satellites help to locate vulnerable persons in distress, guiding rescuers to vessels at sea or trapped persons on land. Communications satellites meanwhile, enable resilient and secure communications between first responders, allowing for ongoing coordination even when the terrestrial infrastructure is inoperable. By incorporating space technologies with on-the-ground infrastructure and capabilities, civil protection authorities and communities are presented with the opportunity to access actionable information gained from accurate and timely data. This information, however, in order to be useful to different user communities, must be delivered in manner which accounts for their particular needs and requirements. It should not be expected a priori that the presence of satellites or the development of services deriving their data will necessarily lead to the uptake of satellite-based services and their associated benefits. Ensuring that end-users are adequately informed about the distinct advantages of space technologies (reliable, timely, accurate, quality data), and that the perspectives of end-users are known, including the challenges and barriers they face before incorporating satellite-based technologies, is crucial to connect end-users with the most appropriate and effective means to enable their operations.

In this paper, we will explore satellite technologies' capabilities and their role in disaster risk management, focusing on the EU. We will then examine the efforts to connect EU space capabilities with end-users in the field of disaster risk management, utilising the results of a User's Survey conducted during an ongoing series of workshops; "*Satellite-based Services for Disaster Risk Management*" organised by the European Union Agency for the Space Programme (EUSPA) in collaboration with Eurisy. We focus in particular on end users': awareness & utilisation of satellite technologies, their needs, the

challenges they face, and the benefits they derive from satellite technologies. These survey results and findings leads into the development of an interactive dashboard, which is introduced at the end of the paper. The paper concludes that whilst satellite capabilities play an important and increasing role in disaster risk management, more must be done to adequately connect these technologies with end-users, suggesting some potential modes to accomplish this.

2. EU Space Capabilities for Disaster Risk Management

EUSPA, the EU agency which oversees EU Space Programme, is composed of six main pillars of activities, each of which contributes to disaster risk management. The six pillars are: European Geostationary Navigation Overlay Service (EGNOS), Galileo, Copernicus, Governmental Satellite Communications (GOVSATCOM), Iris^2, and Space Situational Awareness (SSA), each providing for or enabling services or capabilities which directly support disaster risk management efforts.

2.1 Earth Observation

The Copernicus programme is the world's largest provider of Earth Observation (EO) data, providing over 25 terabytes of data every day. Composed in space by the Sentinel satellites and contributing missions and complemented by in situ data sources, with 6 upcoming Sentinel Expansion missions providing additional and complementary capabilities, Copernicus is the flagship EO programme managed and operated by the EU in collaboration with ESA and supported by a range of public and private European entities.

Copernicus data is currently provided on a free and open access policy, meaning that anyone, anywhere can access and exploit Copernicus data free of charge. Copernicus plays a major role in supporting disaster risk management through numerous initiatives, most notably is how it enables the Copernicus Emergency Management Service (CEMS), a part of the EU Civil protection mechanism overseen by the EU Joint Research Centre (JRC). CEMS is one of six Copernicus service, overseen by the Entrusted Entities as providing services to users in a domain. CEMS is specifically designed for civil protection authorities in EU member states who are often designated (alongside other national authorities) as Authorised Users, with the competence to activate the service, triggering the creation of specialised and localised products to support efforts to monitor and manage the disaster or risk.

CEMS is composed of 3 main sections of products: On-demand Mapping, Early Warning and Monitoring, and Exposure Mapping. On-demand Mapping provides specific maps when activated for a given area with Rapid Mapping for expedited production and delivery of maps in the face of an ongoing disaster situation. Products delivered by Rapid Mapping include initial Area of Interest and delineation mapping of affected areas, followed by more detailed mapping for responders, such as the extent of damage alongside the location of nearby infrastructure. Risk and Recovery Mapping, meanwhile, helps locate and analyse specific threats, such as areas susceptible to wildfires, or supports decision-makers coordinate recovery efforts following a disaster.

Three observatories comprise the Early Warning and Monitoring portion of CEMS: Floods, Fires, and Droughts, each providing overviews and a range of processed variables by which to monitor and assess localised risk levels for each disaster threat. Exposure Mapping, consisting primarily of the Global Human Settlement Layer (GHSL), which combines satellite and census data to produce datasets and maps of built, classified, and populated areas, supporting responders and decision-makers to better understand the human impact of disasters and coordinate response and recovery efforts.

Operational since 2012, CEMS, through the On-Demand Mapping has contributed to 866 disasters and disaster risks worldwide (699 Rapid Mapping activations and 167 Risk and Recovery Mapping activations as of 11th September 2024). It has seen increasing utilisation by authorised users over time, in particular the Rapid Mapping component for floods and wildfires (see Table 1). An example of CEMS in support of a specific recent disaster was during the wildfires in Greece during the summer of 2024, a particularly severe period for wildfires leading to six separate activations of CEMS in Greece in just 28 days between 30th June and 27th August. During this time CEMS covered over 15,800 hectares, producing and delivering maps to understand the extent of fires and damage assessment, supporting responders and firefighters to delineate, coordinate, and accurately and effectively tackle the fires. The timely support provided by CEMS helped ensure that despite this year's fire seasons being one of the worst this century, the burned area per fire was in fact lower than average for the past 20 years, according to Greek Minister of Climate Crisis and Civil Protection, Vassilis Kikilias [8].

Other Copernicus Services also contribute to disaster risk management, civil safety and protection; the Security Service components support border protection, maritime safety, and Support to EU External and Security Actions. Copernicus Atmosphere Monitoring Service (CAMS) monitors, analyses, and forecasts atmospheric conditions, including for example air quality, informing on the near-term extent of pollutants in the air they breathe, supporting decision-makers and health authorities to protect vulnerable populations. The Copernicus Land Monitoring Service (CLMS) monitors land use, important for understanding how different

features and utilisations of land impact and are impacted by disasters, with the European Ground Motion component monitoring landslides and displacements. The Climate Change Service (C3S) provides crucial information on the current and future state of climate change, usable not only by climate scientists and researchers but also policy and decision makers for risk assessment and management. Finally, the Copernicus Marine Service (CMEMS) supports maritime safety for commercial and civil operators, for example for supplying data contributing to producing automated ice charts, enabling maritime operators in the Arctic to navigate safely [9].

*Table 1 Number of CEMS Rapid Mapping activations per year per disaster. Data: emergency.copernicus.eu [10] *Up to 12-Sept-2024*

Event Type	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024*	Total
Earthquake	2			3	4	5	4	4	3	2	4	2		**33**
Epidemic							1		1					**2**
Flood	6	8	22	13	13	13	28	21	34	19	18	27	9	**241**
Humanitarian						1	3	1						**5**
Industrial accident	1	1	2					1	1		1	1		**8**
Mass movement						2	1	1	1		1	2	1	**9**
Other	5	8	16	7	4		2	1	1			1	1	**46**
Storm				4	6	15	11	14	11	3	7	7	4	**91**
Transport accident													1	**1**
Volcanic activity							3		1	4	1			**9**
Wildfire	7	2	3	4	6	3	19	33	17	34	54	25	23	**244**
Total	**21**	**36**	**45**	**31**	**33**	**63**	**72**	**76**	**70**	**62**	**86**	**65**	**39**	**699**

2.2 Satellite Navigation

Europe's sovereign GNSS capabilities are provided for by EGNOS and Galileo, with the former largely contributing towards enhanced aviation, maritime navigation, as well as agriculture. Galileo represents the most accurate GNSS system in the world, composed of 23 currently operational satellites (as of August 2024). The Galileo constellation of satellites enable, alongside the Open Service (OS) (the open and free navigation service used by citizens in Europe and across the globe through Galileo-enabled devices) six live or upcoming services: High Accuracy Service (HAS), Public Regulated Service (PRS), Search and Rescue Service (SAR), Open Service Navigation Message Authentication (OSNMA), Commercial Authentication Service (CAS), and the Galileo Emergency Warning Satellite Service (EWSS). Focusing on just the SAR service and upcoming EWSS contributions to disaster risk management, both provide crucially important and innovative services to users and responders facing a disaster scenario. The SAR service locates persons in distress for first responders, and since 21st January 2021 the Return Link Service (RLS) also signals to compatible distress beacons that the distress message has been received by the relevant command centre. The EWSS meanwhile provides signalling to Galileo-enabled devices within an area susceptible to an immediate disaster threat. Competent authorities can define the susceptible area and send a message to all Galileo-enabled devices in this area, including mobile phones, cars, public displays, and sirens, providing warning and instructions. The clear advantage of this service is that is communicates directly to populations from the Galileo satellites, and so does not depend on terrestrial infrastructure still being functional. Galileo also contributes to COSPAS-SARSAT, an intergovernmental search and rescue initiative composed of 45 participating states [11] with Galileo providing the largest space and ground segment contributions as well as being the only RLS Provider.

2.2 Satellite Communications

Satellite communications are an increasingly important part of European satellite needs and integral for disaster risk management efforts. When a disaster strikes it is often the terrestrial communication network which is most susceptible to outages, creating difficulties and risks for victims to signal for assistance and for first responders to communicate with each other and with at risk or affected populations. The needs for secure governmental communications capabilities are particularly pronounced in the field of disaster risk management and civil protection, with EUSPA themselves forecasting the bandwidth demand of governmental satellite communications for crisis management uses constituting nearly half of total demand, itself expected to increase more than five-fold by 2040 [12].

Two primary initiatives represent the increasing activities of the EU in satellite communication: GOVSATCOM and IRIS2. GOVSATCOM brings together existing national capabilities into a common EU pool of services, enabling member states to easily find and access secure governmental communications. Users will access services through a help desk during a crisis, with the EU funding reserved for GOVSATCOM capabilities to guarantee access to users quickly and reliably.

In order to understand the needs of users and match GOVSATCOM capabilities to these use cases, the EUSPA coordinated the ENTRUSTED project [13], running from 2020 to 2023. The ENTRUSTED project brought together a consortium of institutional users from 13 EU member states and 7 EU entities to develop and analyse use cases to co-create the GOVSATCOM

requirements based on consultations with approximately 450 users. In order to build upon the successes of the ENTRUSTED project, EUSPA is currently developing a new network to link end users and industrial service providers through workshops, pilots, and demonstration events.

Other European initiatives also seek to enhance the presence of satellite communications in the area of disaster risk management. The European Space Agency's (ESA) Civil Security from Space Programme (CSS) aims to develop a federated system of systems utilising pre-existing space capabilities and incorporating innovative technologies such as Artificial Intelligence, Machine Learning, and Internet of Things to develop hubs based around national needs and specific disaster threats. The CSS programme is developed in the context of the ESA Accelerators initiative, specifically the Rapid and Resilient Crisis Response accelerator (R3), which aims to "accelerate the use of space" [14] in society by developing partnerships across key relevant actors who could potentially enhance their use of space data to address major societal challenges.

2.4 The User in EU Space Capabilities

The user is central to EU Space Programme capabilities and activities, alongside delivering on EU policy objectives and supporting the development of the commercial space sector, driving each stage of the full range of activities EUSPA conducts. Indeed "linking space to user needs" remains the core driving mission of the agency. As such EUSPA focuses heavily on user engagement and understanding user's needs, in order to develop and deliver its services. On prominent form this takes are the User Consultation Platforms (UCP), conducted in each of the 15 market segments, of which EUSPA focuses yearly on approximately half [15]. The UCPs offer the opportunity to gather stakeholders for each market segment, from service providers, EU experts, and in particular user communities, to define user needs and specify requirements from EU space capabilities. The UCPs are conducted throughout the year, in order to enable wide enough participation and to thoroughly define needs and requirements in consultation with users, culminating in a User Needs and Requirements report for each market segment analysed. The most relevant UCPs to disaster risk management are Resilient Societies, conducted in 2023 [16], and Emergency Management and Humanitarian Aid, last completed in 2022 and currently underway as part of the 2024 UCP.

Connecting end users with EU capabilities and services, as well as the range of commercial services offered by providers across Europe remains a key challenge in increasing the uptake for satellite-based service for disaster risk management as well as incorporating the experiences of users into improving services. To address this challenge EUSPA has organised, in collaboration with Eurisy and relevant national bodies, a series of national workshops "*Satellite-based Services for Disaster Risk Management*" in EU member states. As of August 2024, seven such workshops have been conducted in: Greece, Hungary, Cyprus, Slovakia, Belgium, Portugal, and Bulgaria, with four workshops foreseen per year. The workshops bring together high-level policy experts at national and EU-level, a selection of national providers developing operational services to address a range of disaster threats, as well as representatives of users, including civil protection authorities, to understand their experience utilising satellite data in their work. In facilitating dialogue between these different groups, the workshops aim to demonstrate the value and benefits of satellite data for different disaster risks, whilst also better understanding the barriers and challenges users face in integrating satellite data in their work.

3. Users' Survey

To provide a more consistent understanding of end-users' experiences and perspectives a survey has been conducted in parallel to each workshop, gathering quantitative and qualitative data focused on appraising the: awareness & utilisation of satellite technologies, needs, challenges/barriers, and benefits from using satellite-based services.

4.1 About the Sample

Through the seven workshops EUSPA and Eurisy have conducted, a survey of national end-users has been conducted alongside the workshop at six, resulting in a total number of 153 responses (n = 153), with the vast majority operating in the workshop country. Responses from each country are not evenly distributed, reflecting the different distributions of workshops, with some reaching a more policy-oriented audience and others reaching greater numbers of (potential) users, reflected in Figure 1.

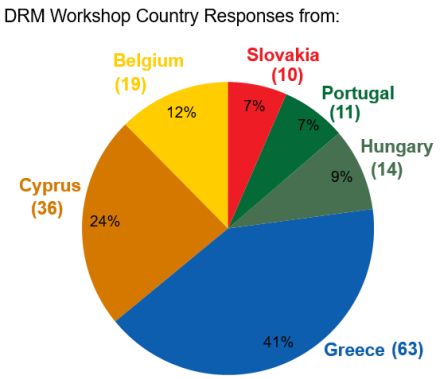

Figure 1: Survey response per workshop country

Figure 2: Representation of sample by organisation type and area of operation

Although a quarter of all respondents represent public national entities, when looking into the operating areas of different types of actors present at the workshops, those most commonly involved in Disaster Risk Management and Environmental Protection work on behalf of research institutes or universities. Public national authorities, on the other hand, tend to describe their main field of work as "Other", suggesting, although national civil protection authorities are generally represented in the survey workshop, there is a greater need to engage other national authorities in the work of disaster risk management in civil protection. Two sectors are remarkably unrepresented, those of Tourism/Leisure, as well as Insurance and Financial Services, despite the large impact disasters can have tourist areas and substantial insurance costs and complexities which space technologies can contribute, for example by providing localised alerts to visitors through the Galileo EWSS in their own language [17], or by providing evidence to estimate damages from disasters, enabling quicker and accurate damage assessments and payouts.

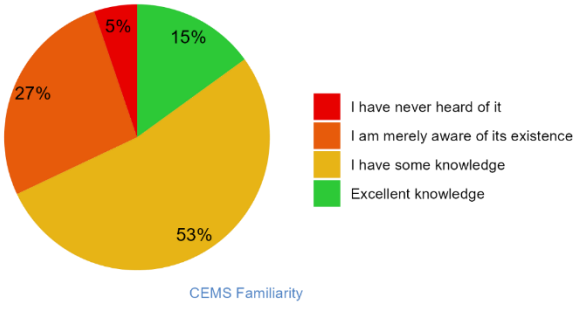

Figure 3: Users familiarity with CEMS

4.2 Awareness & Utilisation of Satellite Technologies

Most respondents have some awareness of key services enabled by satellite technologies, such as CEMS, however only a small minority (15%) report having the highest level: "Excellent knowledge" of CEMS. Approximately a third are at most only aware of its existence. Further efforts are therefore needed to highlight the role CEMS plays in supporting disaster risk management efforts, which could include identifying and disseminating examples and testimonials the role CEMS plays in supporting disaster relief efforts, highlighting the specific impacts CEMS makes during disasters from the perspective of users and operational responders.

The vast majority of respondents utilise satellite technology, with 77% responding "Yes" compared to just 17% stating they do not currently. The most utilised satellite application by a considerable margin is Earth Observation (40.3%), showcasing its established presence in disaster risk management, likely due in part to the Copernicus Programme capabilities and open data policy. Satellite communications are the least utilised satellite applications (15.1%), demonstrating the need, in comparison to EO, to develop capabilities at regional level, such as GOVSATCOM and IRIS[2], and connecting these with national and sub-national actors responsible. GOVSATCOM can play a particularly prominent role as it utilises pre-existing national capabilities and guarantees their availability and accessibility to governments during crises.

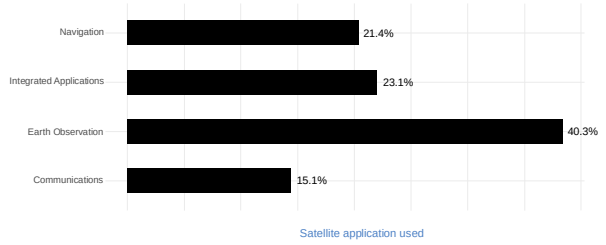

Figure 4: Satellite application used

4.3 Needs

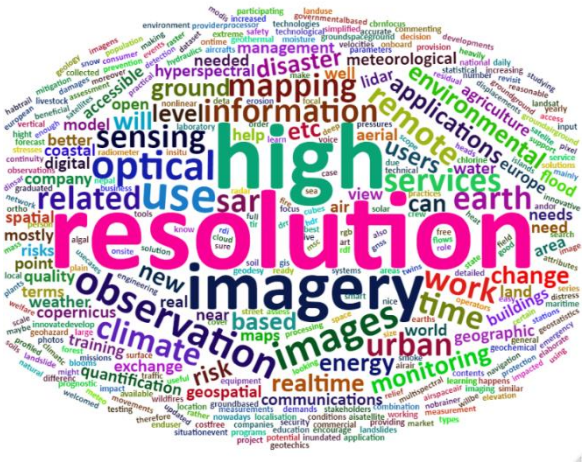

Figure 5: Users data needs

Respondents articulated a wide variety of needs, when asked what kind of data would support their work. Perhaps unsurprising, from satellite data the most frequently citied need was related to higher resolution EO imagery, with associated high frequency words indicating this refers to spatial resolution. Beyond specific technologies (e.g. optical, SAR), we also note users expressing particular service needs (e.g. mapping, monitoring), as well as use cases they need data for (e.g. floods, urban). The diversity of needs communicated poses a challenge on how to efficiently meet such a broad spectrum, alongside the potential correspondence between what users can express they need more specifically being within the bounds of what possibilities they are aware of from satellite technologies. Considering that many of the needs expressed are provided for in existing capabilities (with many being provided for by the Copernicus programme) these findings should be taken to target and refine awareness raising, ranging from matchmaking via workshops to co-design of services, based on pre-existing capabilities.

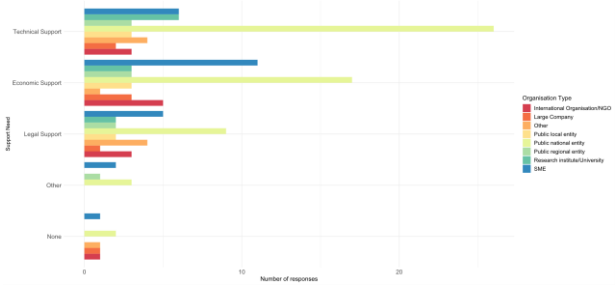

Figure 6: Support need by organisation type

In order to integrate satellite technology within their work on a practical level, respondents overwhelmingly need some form of support (95.7%), by far most commonly expressed is technical (38.1%) or economic support (33.1%). Although the distribution of support needs is more or less even between the countries surveyed, we do notice some difference between the type of organisation. In general terms, national and subnational entities may tend to require technical support

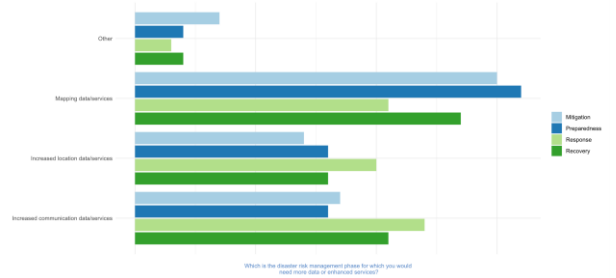

Figure 7: Satellite data need per DRM cycle phase

(as well as economic support), whilst private entities, in particular SME's tend to state they require economic support to integrate satellite data.

During the disaster risk management cycle users predominantly need more or enhanced mapping and data services across each phase, which the exception of response, during which users require at equal extents mapping, location, and communications services. Communications services in particular appear more sought after during the response and recovery phases, whereas further mapping data and services are needed at a relatively lesser extent during the Response phase, suggesting that CEMS Rapid Mapping may meet these data and service needs, but the lesser comparable activations of the Risk and Recovery Mapping suggests its potential uses and benefits in supporting disaster mitigation, preparedness, and recovery are not as well known about by users.

4.3 Challenges

Almost all respondents (93.3%) faced some kind of challenge in incorporating satellite technologies within their work, closely linked to the needs expressed to adopt or further enhance use of satellite technology. Technical challenges in particular stand out as the most common factor cited, followed by economic challenges. Organisational and administrative challenges are also common, however, suggesting a more holistic understanding of potential users' operative needs and workflows is necessary, alongside fostering institutions to embrace more innovative technologies. Given our survey finds users find external funding and training the most helpful to adopt satellite-based services, one established means to continue to accomplish this could be through use case demonstrations or pilot projects with a specific component on capacity building with integrated users. Such initiatives combine external funding to provide impetus and reduce risk, as well as incorporate capacity building activities to enable users to continue to user services after the cessation of funding.

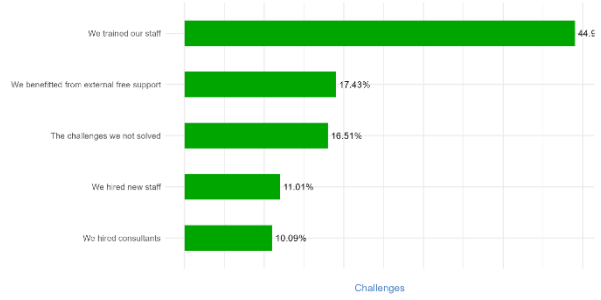

Figure 8: Users methods of overcoming challenges faced

Indeed, when asked how challenges were overcome, training staff is revealed as the most common and effective means, suggesting that once the service is established, it is internal know-how which enables continuity in using satellite-based solutions.

4.4 Benefits

Users experience benefits from satellite technologies; however, these are most often felt in qualitative, rather than quantitative form. Organisations benefit from satellite technologies by making better decisions and providing better services, however, most do no conduct quantitative assessments into the precise amount of money or time saved by incorporating satellite-technology (only 30% stated they did conduct a formal assessment of benefits). Of those that did conduct a formal assessment of benefits, however, 72% reported a savings in money of 5% of their annual budget or greater. Despite the initial high cost of implementing satellite technologies, the lower relative operating cost and efficiencies gained in using satellite technologies, such as automated monitoring over large swathes of area that previously required on-site inspections, do result in significant savings for departments and organisations.

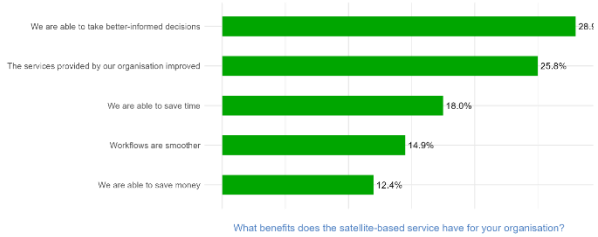

Figure 9: Benefit of satellite-based service

Whilst the data provides a number of important insights in and across different national perspectives on utilising satellite-based services for disaster risk management, scaling up the survey distribution and analysis allows for understanding at the EU-level, updated regularly, and presented to a broader audience. To achieve this Eurisy is launching the survey openly and continuously, with the data analysed as a component of the Interactive Dashboard for Disaster Risk Management, developed by Eurisy.

5. Interactive Dashboard for Disaster Risk Management

The Interactive Dashboard for Disaster Risk Management ("Dashboard") has been developed by Eurisy to provide interested parties, in particular (potential) users, relevant policy makers, and service providers an accessible and interactive means to explore different satellite capabilities for disaster risk management as well as an aggregation and visualisation of different data sources, including the users survey conducted by Eurisy.

The Dashboard has been developed using R, a programming language predominantly used in data science and statistics and transformed into an interactive online dashboard through R Shiny, an R package specifically designed for seamlessly creating interactive web dashboards for data visualisations.

The dashboard is structured into 4 main sections: a home page, a survey analysis section, a services catalogue, and a workshop repository. The home page provides a general introduction to the dashboard itself, and primarily serves to introduce visitors to the topic of disaster risk management and the contributions satellite technologies play throughout the disaster risk management cycle.

5.1 Survey Analysis

The survey analysis section contains interactive visualisations of the results of the survey. The aim of this section is to present the results of the survey with sufficient context and explanation for visitors, whilst also enabling the dashboard user to select and highlight various dimensions of the data and results that are of particular relevance and interest to them. In order to accomplish this, the visualisations are first and by default presented in aggregate form, featuring the results of all survey respondents. A representative selection of visualisations were chosen to be displayed, in order to present a narrative of users experience. The structure of the survey visualisations presents users experience in a similar structure to the survey analysis conducted above, in terms of users: current utilisation, needs, challenges, and benefits of using satellite-based services for disaster risk management. By needs, as opposed to requirements, we primarily refer to non-technically specific pre-requisites and desires held by a user a satellite-based service must satisfy in order to be (successfully) implemented. Needs therefore combine both objective (such as resolution or imagery type) and subjective (such as the type of support they feel is necessary) elements. The Dashboard enables users to filter information specific to their country and/or their particular field of operations, providing specific and local insights to be drawn from the data, where sufficient numbers of observations allow.

To provide context and guide visitors, the graphs of aggregated data are accompanied by brief explainers to support understanding of the results. To achieve this, Eurisy regularly reevaluates new data from the survey as new responses are provided, updating the analyses and supporting context accordingly. Over time, the dashboard will continue to develop the survey visualisation to reflect the evolving needs of end users as well as the European space ecosystem.

5.2 Services Catalogue

The Service Catalogue provides (potential) users, as well as those interested in learning more about satellite-based services for disaster risk management, a range of operational examples of commercial services specifically addressing disaster risks using satellite technologies. The

purpose is not to sell services, and so therefore Eurisy does not accept any commission or fee for the addition of services to the catalogue. Rather, the service catalogue is an informational tool for users to easily find and better understand different services on offer. The list of services was developed initially through those demonstrated during the workshops, with an open submission process for the addition of services to the catalogue.

Each entry aims to provide an introduction to the service on offer, providing a brief description of its capabilities for interested users to learn more via links to the company's website. Users can also search and compare services on the catalogue via the filters, which are delimited into 3 categories, with each service provider capable of selecting up to three pre-defined choices in each category which best reflects their service. The Technology filter contains the specific satellite technology utilised by the service (e.g. Synthetic Aperture Radar (SAR)), the Use filter defines what type(s) of disaster or disaster risks the service can contribute towards, so that specific users, such as fire responders, can quickly find services applicable to their role. Finally, the Service tag specifies what specific type of service is offered, such as an Early Warning System or Digital Twin, allowing users to filter based on their specific needs. The filter categories can be combined, and multiple choices can be input, adding to the specificity users can give in searching for particular services. Given the differences in the level of knowledge or awareness some users may have on technologies or services, and the informative purpose of the Service Catalogue, users can select each filter choice to be provided a brief description written in clear, non-technical language.

5.3 Workshop repository

The workshop repository serves to host the resources from each national workshop in the "Satellite-based Services for Disaster Risk Management" series. It includes all past and confirmed upcoming events, including for past events the link to the repository of presentations given at the workshop, the web article summarising the event, and the final report prodced for workshops. For upcoming events it includes the date, location, and points the user to register.

5.2 Other sections

The dashboard also hosts the survey itself, which has been adapted to enable it to be continuously accessible for users throughout Europe to complete. It should be noted, however, that survey responses are not linked instantly to the survey visualisations on the dashboard. This is to ensure that the data can be cleaned and prepared manually on a recurrent basis, at which point the results and overall findings can be analysed and incorporated into the survey analysis section to provide updated context. Finally, the dashboard also includes an about sections, summarising the role of Eurisy as a non-profit association of space agencies and organisations working to bridge the gap between space and society, as well as, introducing the purpose of the dashboard in the context of the mission and activities of Eurisy.

6. Conclusions

Satellites play an increasingly important role in disaster risk management. The EU has developed through EUSPA an advanced range of capabilities and services, in particular using Earth Observation and satellite navigation, with users at the heart of these offerings, all contributing to disaster risk management efforts. Satellite communications are set to play an increasing role as demands for bandwidth increase and the supply of capabilities through initiatives such as GOVSATCOM and Iris^2 come into fruition.

All satellite technologies must provide the end-user with actionable information, meeting the specific needs of different communities, and taking into account the challenges and barriers end users face incorporating technologies into disaster risk management operations. Despite efforts to accomplish these, our data shows there is still work that must be done in order to bridge the gap between satellite technologies and end-user communities. Users have a wide diversity of needs, dependent on a range of factors, including the specific phase of the disaster risk management cycle. Most needs expressed can be met by currently existing capabilities, however, uses in general face similar challenges when implement satellite-based services. In particular, users continue to face primarily economic and technical challenges and express the need to obtain such support in order to implement satellite technologies in their work.

To better understand the needs, challenges, and benefits end users face across Europe, Eurisy has developed an interactive dashboard on satellite-based services for disaster risk management. The dashboard provides an overview of regularly updated aggregated survey data alongside a services catalogue to connect existing services with users. The dashboard aims to inform users, policymakers, and the broad space and disaster risk management communities on the potential of satellite technologies to address the growing risks of extreme weather events and disasters, whilst highlighting the perspective of the operational end-user and centring their needs.

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