UK Space Agency International Partnership Programme

Space for Disaster Resilience in Developing Countries

October 2018

UK SPACE AGENCY

https://www.gov.uk/government/organisations/uk-space-agency

The UK Space Agency leads the UK efforts to explore and benefit from space. It works to ensure that our investments in science and technology bring about real benefit to the UK and to our everyday lives. The Agency is responsible for all strategic decisions on the UK civil space programme. As part of the Department for Business, Energy & Industrial Strategy, the UK Space Agency helps realise the government's ambition to grow our industry's share of the global space market to 10% by 2030.

The UK Space Agency:

- supports the work of the UK space sector, raising the profile of space activities at home and abroad
- helps increase understanding of our place in the universe, through science and exploration and its practical benefits
- inspires the next generation of UK scientists and engineers
- regulates and licences the launch and operation of UK spacecraft, launch operators and spaceports
- promotes co-operation and participation in the European Space Agency and with our international partners

International Partnership Programme

https://www.gov.uk/government/collections/international-partnership-programme

The International Partnership Programme (IPP) is a five year, £152 million programme run by the UK Space Agency. IPP focuses strongly on using the UK space sector's research and innovation strengths to deliver a sustainable economic or societal benefit to emerging and developing economies around the world.

IPP is part of and is funded from the Department for Business, Energy and Industrial Strategy's (BEIS) Global Challenges Research Fund (GCRF): a £1.5 billion fund announced by the UK Government, which supports cutting-edge research and innovation on global issues affecting developing countries.

Caribou Space

www.caribou.space

Support organisations to bridge the space and development worlds. We work with governments, space agencies, development agencies and private sector space companies.

Caribou Space: David Taverner, Tim Hayward and Kishor Nagula

David Hodgson (independent) and David Cotton (Satellite Oceanographic Consultants Limited)

Contents

UK SPACE AGENCY

Acknowledgments

UK Space Agency and Caribou Space would like to acknowledge the following contributing authors:

– David Hodgson
– David Cotton, Satellite Oceanographic Consultants Limited (SatOC)

UK Space Agency and Caribou Space would also like to thank the following persons who provided input and review:

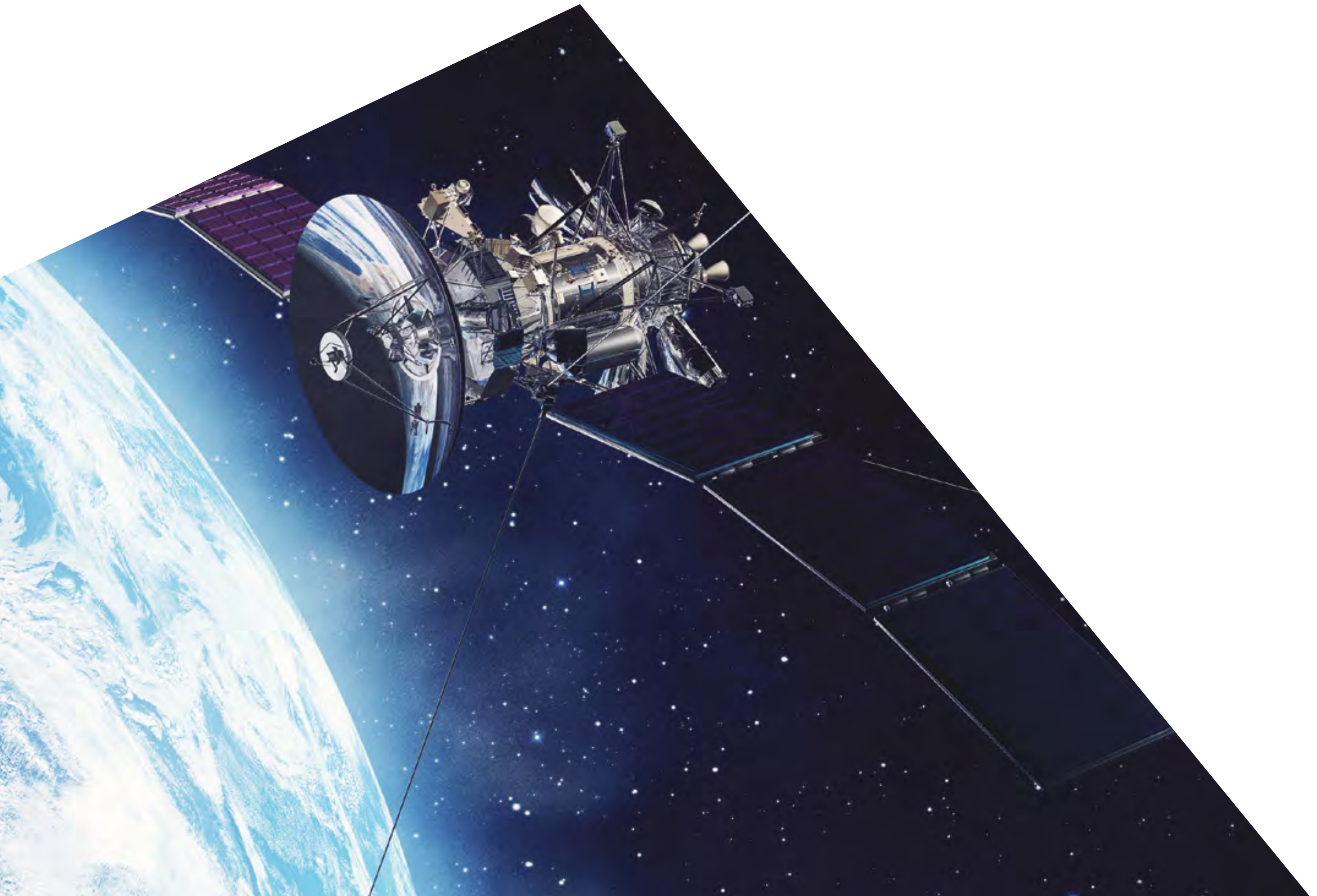
– Andrew Kruczkiewicz, Columbia University
– Brent Carbno, Ericsson
– Clement Bruguera, Télécoms Sans Frontières
– Colm Jordan, British Geological Society
– Elena Lobo, Satellite Applications Catapult
– Helen Campbell, Red Cross
– James Cemmell, Inmarsat
– Keiko Saito, GFDRR (World Bank)
– Melanie Clift, Airbus Defence and Space
– Nicholas McCarthy, University of Queensland & One Concern
– Ola Domagalska, Stevenson Astrosat
– Olly Parsons, GSMA
– Paul Healy, Rheatech
– Salma Farouque, UN World Food Programme
– Simon Gray, Eutelsat
– Stephen Charlick, Clyde Space

Background

The report is produced under the International Partnership Programme, a five-year, £152 million programme run by the UK Space Agency. IPP uses the UK space sector's research and innovation strengths to deliver a sustainable, economic and societal benefit to developing countries. Projects within IPP span a whole range of themes including: building disaster resilience; improving agriculture; reducing deforestation; preventing and reducing maritime pollution and illegal fishing; and optimising renewable energy production.

IPP is part of the Department for Business, Energy and Industrial Strategy's (BEIS) Global Challenges Research Fund (GCRF), a £1.5 billion Official Development Assistance (ODA) fund which supports cutting-edge research and innovation on global issues affecting developing countries. ODA-funded activity focuses on outcomes that promote long-term sustainable development and growth of countries on the OECD Development Assistance Committee (DAC) list. IPP is fully ODA compliant, being delivered in alignment with UK aid strategy and the United Nations' (UN) Sustainable Development Goals (SDGs).

This report outlines why and how the space industry has a critical role to play in addressing major challenges within disaster resilience in emerging and developing economies. It is part of a series of five sector-focused reports, including agriculture and forestry. The report sets out one view of how space can help, but it is recommended that the report is read alongside other relevant resources, some of which are listed under Additional Reading and Resources.



Flooded village in lowland of Great river ▼

Executive summary

This report shows how space solutions can be deployed to great effect by developing countries to help solve environmental and societal challenges related to disaster resilience. The primary audience is the development and disaster resilience sector, and it is written as an introductory primer on the role of space in disaster resilience.

Structure

Space technology and its application to disaster risk is evolving rapidly. This report seeks to highlight the valuable work and insights provided by IPP. In doing so, it provides an overview of the subject together with examples of current thinking within IPP and similar international programmes.

There are four sections:

- **Background on disaster resilience and frameworks:** provides the contextual challenge of disaster resilience and overviews existing efforts to address disaster resilience, including the UN Sendai Framework for Disaster Risk Reduction
- **Case for space:** draws on the IPP disaster resilience portfolio to show that satellite can support the four critical areas in the Sendai framework in line with the Sendai specific recommendations for space
- **Seizing the opportunity:** details what space solutions for disaster resilience exist, the different use cases, sustainability and business models, and stakeholder landscape
- **Additional information and guidance:** the next steps once the opportunity is understood, with guidance on: accessing, processing and analysing satellite data; organisations to work with; and where to find further resources

There is also an Annex providing an overview of IPP's disaster resilience projects.

Audience

The report is intended for different audiences with specific takeaways for each.

Audience	Why read this report?
Government agencies involved in disaster resilience	– Understand the opportunity for space solutions to add value to disaster resilience in the country – Learn about existing space solutions for disaster resilience, who to work with and where to find more information
NGOs and research agencies in developing countries	– Learn about the opportunity for space solutions to benefit disaster resilience in developing countries, and who you can partner with to build your own space solution
Private sector supporting disaster resilience in developing countries	– Learn about the opportunity for space solutions to benefit your business or project – Understand the process of accessing and using satellite data, what resources you may need and who to partner with
Space sector	– Learn about existing collaborations between the UK space sector and disaster resilience partners in developing countries, and how space technology is tackling disaster resilience challenges and building local capacity

Background on use of space in disaster resilience

Natural disasters – cyclones and hurricanes[1], floods, droughts, earthquakes and volcanoes – have impacted 3.5 billion people totalling an estimated US$1.9 trillion in economic losses since 2000.[2] Developing countries are disproportionality impacted by disasters. The average annual damage from 1980 to 2015 was 1.5% of GDP in developing countries, compared to 0.3% of GDP in developed countries and the average share of affected population over the same period was 3.0% in developing countries, compared to 0.4% in developed economies.[3]

The UN Sustainable Development Goals are a set of 17 aspirational 'Global Goals' for development, three of which include disaster resilience as a target ('no poverty', 'sustainable cities and communities', and 'climate action'). In addition to the SDGs, the UN has established the Sendai Framework for Disaster Risk Reduction, which will lead to the 'substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries'.[4]

1 National Ocean Service. 'Hurricanes, cyclones, and typhoons are all the same weather phenomenon; we just use different names for these storms in different places', https://oceanservice.noaa.gov/facts/cyclone.html. Accessed July 2018

2 Moody's Investor Services. 'Understanding the Impact of Natural Disasters: Exposure to Direct Damages Across Countries', https://www.eenews.net/assets/2016/11/30/document_cw_01.pdf. Accessed July 2018

3 As above

4 UNISDR. 'Sendai Framework for Disaster Risk Reduction', http://www.unisdr.org/we/coordinate/sendai-framework. Accessed July 2018

The Sendai framework also makes specific recommendations about the use of space solutions to address disaster resilience, including:

- 'to promote real time access to reliable data, make use of space and in situ information'
- 'to promote and enhance...communications and geospatial and space-based technologies and related services; maintain and strengthen in situ and remotely-sensed earth and climate observations'[5]

The Sendai framework articulates four critical action areas which space solutions support:

1. **Understanding disaster risk:** for example, earth observation (EO) improves accuracy of disaster forecasts
2. **Strengthening disaster risk governance:** for example, EO improves government's planning and prioritisation of disaster response
3. **Investing in disaster risk resilience:** for example, EO supports a robust insurance market through improved calculation of risk
4. **Enhancing disaster preparedness for effective response:** for example, satellites provide critical national communications infrastructure, particularly when terrestrial networks are damaged or absent in remote regions

Sustainability of space solutions for disaster resilience

Successful sustained integration of space solutions in the disaster resilience sector require a business model that will ensure continuity of solutions and services developed under projects funded through programmes such as IPP, beyond initial funding.

Stakeholders need to identify sufficient revenue streams to cover operational costs in the long term, thereby ensuring the continuation of the solution and the positive impact.

A range of sustainability models is possible, including:

- commercial revenue
- government investment/revenue
- donor funding

Conclusions

The space sector is well placed to contribute new types of information to form part of the solution to the major challenges facing the disaster resilience sector today, in both developed and developing countries. The unique benefit that space solutions provide is global, repeatable, scalable data that can deliver high value insights about our dynamic planet, especially within developing countries where existing data and insight is poor.

This report draws on the above IPP disaster resilience portfolio to show that satellite can support the four critical areas in the Sendai framework in line with the Sendai specific recommendations for space. The report also provides guidance for development and disaster resilience practitioners as to how they can utilise space solutions for disaster resilience.

Use of space technology in disaster resilience is complex and requires significant skill, capability and infrastructure. This document is a primer to using space solutions in disaster resilience and signposts to data sources, potential partners and additional reading.

Now is the time to seize this opportunity.

5 United Nations Office for Disaster Risk Reduction. 'Sendai Framework for Disaster Risk Reduction 2015-2030', http://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf. Accessed July 2018

Background on disaster resilience and frameworks

The disaster resilience challenge in developing countries

Disasters caused by natural hazards – for example cyclones and hurricanes[6], floods, droughts, earthquakes and volcanoes – have impacted 3.5 billion people totalling an estimated US$1.9 trillion in economic losses since 2000[7], with the potential of pushing nearly 100 million people into extreme poverty by 2030.[8] Without making these regions more resilient against such disasters, millions more could be impacted, increasing economic losses up to US$314 billion per year.[9] There is also risk that the original disaster can lead to another (compound disasters), amplifying the negative impacts, such as an earthquake preceding tsunamis, fires, landslides and disease outbreaks.[10]

In addition, women are particularly vulnerable to natural disasters. For instance, it has been suggested that women may be up to 14 times more likely than men to die during a natural disaster.[11]

Therefore, it is critical to strengthen countries' resilience (ability to adapt to a variety of changing conditions and to withstand shocks while still maintaining its essential functions[12]) against natural disasters. This can be through mainstreaming disaster risk management into national and local frameworks of laws, regulations and public policies as well as operational plans and processes and education. This spans all stages of the disaster management including preparedness, response, recovery and future mitigation.

In developing countries, people often live in high risk locations such as flood zones or urban slums. This is to access economic opportunities, such as jobs or business income and usually at lower living costs. For those living in flood zones, they value proximity to cheaper transport and jobs driven by exports, while those living in congested urban settings value access to public services and amenities, as well as higher wages and more productive work.[13] However, natural disasters such as droughts, flood and earthquakes expose populations to potential loss of life, displacement from homes, and loss of assets and savings, such as homes, livestock and crops.

Developing countries are disproportionally impacted by disasters. The average annual damage from 1980 to 2015 was 1.5% of GDP in developing countries, compared to 0.3% of GDP in developed countries. The average share of affected population over the same period was 3.0% in developing countries, compared to 0.4% in developed economies.[14]

---

6 National Ocean Service. 'Hurricanes, cyclones, and typhoons are all the same weather phenomenon; we just use different names for these storms in different places', https://oceanservice.noaa.gov/facts/cyclone.html. Accessed July 2018

7 Moody's Investor Services. 'Understanding the Impact of Natural Disasters: Exposure to Direct Damages Across Countries', https://www.eenews.net/assets/2016/11/30/document_cw_01.pdf. Accessed July 2018

8 As above

9 World Bank. 'Disaster Risk Management', http://www.worldbank.org/en/topic/disasterriskmanagement/overview. Accessed July 2018

10 UNISDR. 'Compound Disasters and Compounding Process', https://www.unisdr.org/we/inform/publications/50226. Accessed July 2018

11 Peterson, K. (2007). 'Reaching Out to Women When Disaster Strikes', https://www.soroptimist.org/. Accessed July 2018

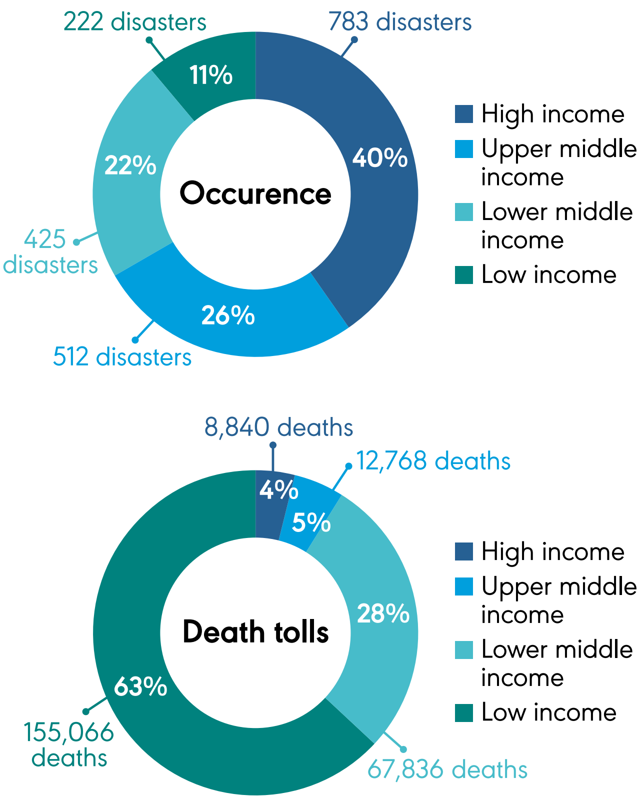
12 World Bank. 'Investing in Urban Resilience', https://www.gfdrr.org/en/invest-in-urban-resilience. Accessed July 2018

13 World Bank Group. 'Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters', https://openknowledge.worldbank.org/handle/10986/25335. Accessed July 2018

14 Moody's Investor Services. 'Understanding the Impact of Natural Disasters: Exposure to Direct Damages Across Countries', https://www.eenews.net/assets/2016/11/30/document_cw_01.pdf. Accessed July 2018

As per Figure 1[15], low income countries dealt with fewer storm disasters than high and upper middle-income countries but had disproportionately more deaths (over 15 times more). This is because infrastructure and buildings may not be as resilient, disaster response procedures less sophisticated, and 'poor people are exposed to hazards more often, lose more as a share of their wealth when hit, and receive less support from family and friends, financial systems, and governments'.[16]

Figure 1: Occurrence and Death Toll from Storm Disasters



In addition to loss of human life, there is economic damage through loss of housing, infrastructure, industry and agriculture, as these examples illustrate:[17]

- in Kenya, the 1997-98 floods caused US$670 million worth of damage to transport infrastructure and US$270 million to the agriculture sector
- in Malaysia, the monsoon floods in 2014 displaced 250,000 people from their homes amounting to nearly US$280 million in recovery efforts
- in the Philippines, the 88 typhoons from 2004 to 2014 have caused US$13.7 billion in damage

UN Sustainable Development Goals and disaster resilience

The UN Sustainable Development Goals (SDGs) are a set of 17 aspirational 'Global Goals' for development with 169 targets between them for 2030. These are spearheaded by the United Nations, through a deliberative process involving its 193 member states, as well as global civil society.[18] The UN SDGs are the primary development framework for IPP.

15 Centre for Research on the Epidemiology of Disasters. 'The Human Cost of Natural Disasters 2015', http://emdat.be/human_cost_natdis. Accessed July 2018

16 World Bank. 'Unbreakable', https://openknowledge.worldbank.org/handle/10986/25335. Accessed July 2018

17 Examples from IPP project documentation

18 Wikipedia. 'Sustainable Development Goals', https://en.wikipedia.org/wiki/Sustainable_Development_Goals. Accessed July 2018

Figure 2: UN Sustainable Development Goals

Disaster resilience is a goal within three of the UN SDGs: '1: No Poverty', '11: Sustainable Cities and Communities', and '13: Climate Action', with specific targets to:[19]

- by 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters (SDG 1)
- by 2030, significantly reduce the number of deaths and the number of people affected, and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters – including water-related disasters – with a focus on protecting the poor and people in vulnerable situations (SDG 11)
- strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries (SDG 13)

The UN Sendai framework

In 2005, the United Nations convened national governments and disaster relief organisations to agree on the steps needed to approach disaster resilience globally. The output was the Hyogo framework, a 10-year plan to promote a strategic and systematic approach to reducing vulnerabilities and risks to hazard while underscoring the need for, and identifying ways of, building the resilience of nations and communities to disasters.[20]

19 United Nations. 'United Nations Sustainable Development Goals', http://www.un.org/sustainabledevelopment. Accessed July 2018

20 International Strategy for Disaster Reduction. 'Hyogo Framework for Action 2005-2015', http://www.unisdr.org/files/1037_hyogoframeworkforactionenglish.pdf. Accessed July 2018

UK SPACE AGENCY

Flooded road in Thailand ►

Since implementation, countries have strengthened their disaster risk management capabilities and have bolstered their resilience against natural disasters. However, with evidence indicating that the exposure of persons and assets in all countries has increased faster than vulnerability has decreased, the United Nations reconvened disaster risk stakeholders in March 2015. The objective was to create a new framework that accounts for the economic, social, cultural, health and environmental impacts in the short, medium and long term, especially at local and community levels.

This new 10-year framework, the Sendai Framework for Disaster Risk Reduction, will lead to the 'substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries'.[21]

As illustrated in Figure 3, the Sendai framework articulates four critical areas where focused action is needed. These four areas, discussed below, should be addressed at all levels of governance, starting at the local and ending at global.

Understanding disaster risk: For countries to become more resilient to natural disasters, they first need to better understand disaster risk. This comes from better understanding the different dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment.

Strengthening disaster risk governance: It is critical to have disaster risk governance at all levels of government, starting at the municipality and up to the national level, for effective management of disaster risk. Having a clear vision, plans, guidance and co-ordination among stakeholders is essential for managing disaster risk.

Investing in disaster risk resilience: Private and public investments in disaster risk resilience and prevention are essential to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment.

Enhancing disaster preparedness for effective response: It is essential that governments seek to ensure preparedness for effective response and recovery at all levels. Disasters have demonstrated that the preparation for the recovery, rehabilitation and reconstruction phase is critical to 'build back better'.[22]

---

21 UNISDR. 'Sendai Framework for Disaster Risk Reduction', http://www.unisdr.org/we/coordinate/sendai-framework. Accessed July 2018

22 The United Nations. 'Sendai Framework for Disaster Risk Reduction 2015-2030', http://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf. Accessed

▼ Aftermath of earthquake in Nepal

Figure 3: Sendai Framework for Disaster Risk Reduction[23]

Scope and purpose

The present framework will apply to the risk of small-scale and large-scale, frequent and infrequent, sudden and slow-onset disasters, caused by natural or manmade hazards as well as related environmental, technological and biological hazards and risks. It aims to guide the multi-hazard management of disaster risk in development at all levels as well as within and across all sectors.

↓

Expected outcome

The substantial reduction of disaster risk and losses in lives, livelihoods and health in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.

↓

Goal

Prevent new and existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political, and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and strengthen resilience.

↓

Priorities for action

1. **Understanding disaster risk**
2. **Strengthening disaster risk governance** to manage disaster risk
3. **Investing in disaster risk reduction** for resilience
4. **Enhancing disaster preparedness for effective response,** and to 'build back better' in recovery, rehabilitation and reconstruction

July 2018

23 UNISDR. 'Chart of the Sendai Framework for Disaster Risk Reduction', http://www.unisdr.org/files/44983_sendaiframeworksimplifiedchart.pdf. Accessed July 2018

The case for space

Space solutions support disaster resilience

Developing countries need impactful and cost-effective approaches to prepare, respond and recover from disasters. Space solutions address these challenges by using the unique capabilities of satellites for earth observation, communications, and navigation.

Earth observation (EO) satellites provide images and data of land, oceans and the atmosphere to plan for, observe and respond to disasters. EO is used extensively to observe, monitor and map the natural environment and human activity on global, national and local scales.

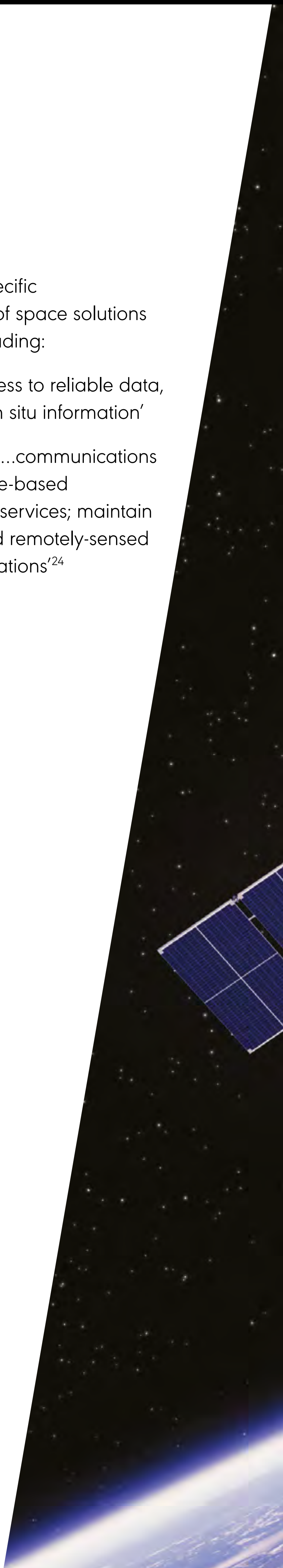
Satellite communications (SatComms) have ubiquitous coverage and provide critical communications services for voice and data if terrestrial networks are partially or fully unavailable. Mobile and broadband communications can be built for high resilience but are often damaged during disasters, and may be absent in remote or rural regions.

Global Navigation Satellite System (GNSS) satellites send positioning and timing data from space to a wide variety of devices, with receivers, that determine accurate location and time. Many countries operate a Satellite-based Augmentation System (SBSS) that increases the accuracy of the original GNSS measurements and broadcasts. This as an augmentation, or overlay, using geostationary satellites at continental scales.

The Sendai Framework makes specific recommendations about the use of space solutions to address disaster resilience, including:

– 'to promote real time access to reliable data, make use of space and in situ information'

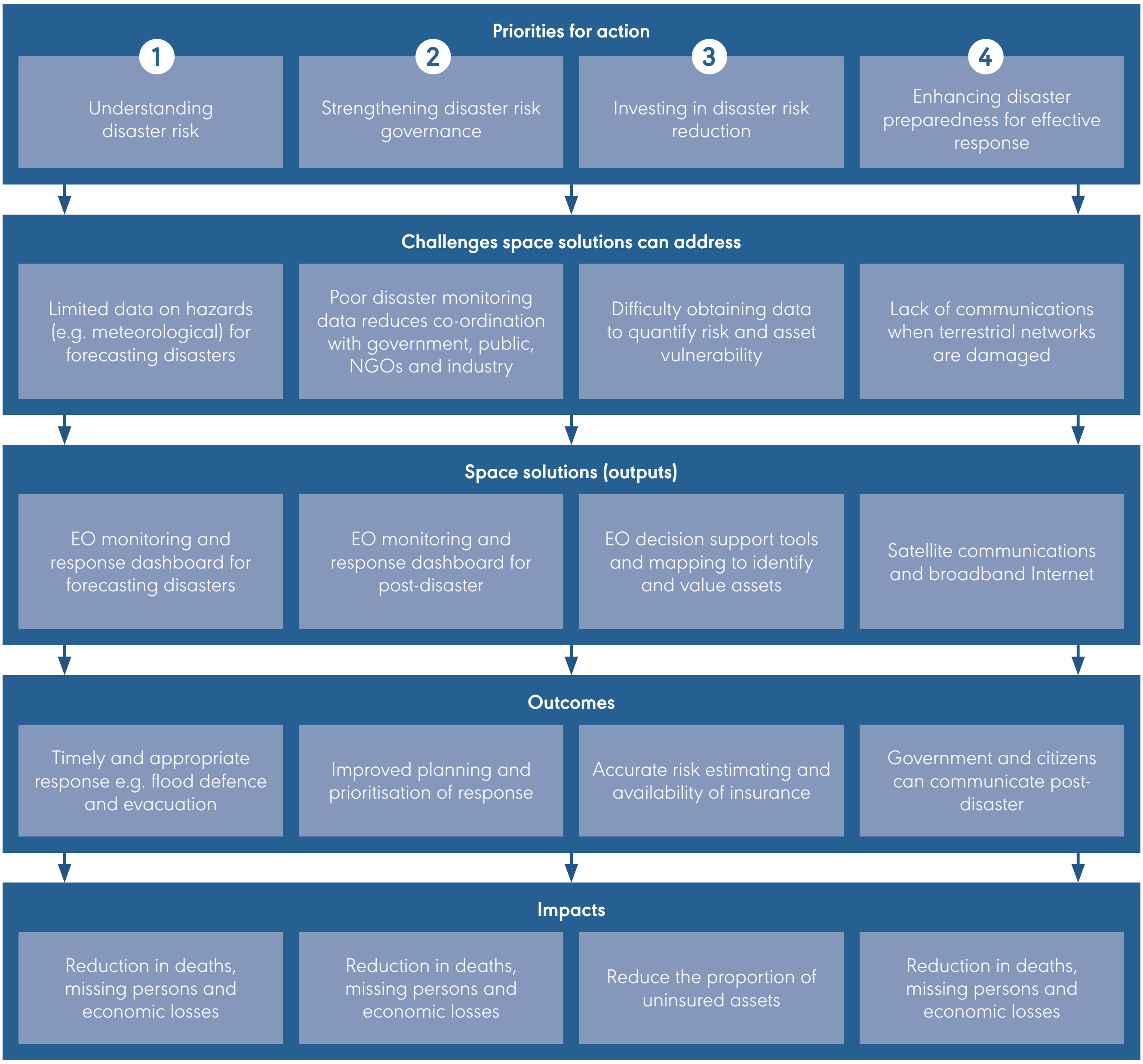
– 'to promote and enhance...communications and geospatial and space-based technologies and related services; maintain and strengthen in situ and remotely-sensed earth and climate observations'[24]



24 United Nations Office for Disaster Risk Reduction. 'Sendai Framework for Disaster Risk Reduction 2015-2030', http://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf. Accessed July 2018

Satellites have broad applications in disaster risk management. Examples of the ways that space solutions support the Sendai framework's priorities for action and the subsequent outcomes and impacts are shown in Figure 4 below.

Figure 4: Space solutions support the Sendai priorities for action



Earth observation improves accuracy of disaster predictions: Many developing countries lack the infrastructure to gather and process the data needed to predict when and where natural disasters might occur and what the impact would be. Capacity to respond to the disaster is often overwhelmed. EO can be used to support the identification and observation of hazards over time to enable and update risks analysis. EO provides wide and accurate geographic observation which can be regularly updated, and benefits from significant insights available in historical data. When incorporated with ground-based data such as weather stations and meteorological forecasting models, EO improves the accuracy of disaster forecasting, particularly for weather related events such as cyclones, hurricanes, flood and droughts. Accurate forecasting allows timely activation of emergency plans including flood defences and evacuation, which reduces the number of deaths, missing persons and economic losses.

Earth observation improves government's planning and prioritisation of disaster response: In developing countries there is limited information, visibility and communications around post-disaster population movements and infrastructure damage. This leads to difficulties in co-ordinating response across multiple government agencies, donors, NGOs and the private sector. Near real-time disaster monitoring through EO enables improved planning and prioritisation of the response by government, NGOs and private sector. These solutions provide the ability to show and share disaster monitoring information quickly, so decision makers can make smarter decisions to reduce the number of deaths, missing persons and economic losses.

Earth observation supports a robust insurance market through improved calculation of risk: Over 40% of economic losses are insured in developed countries, compared to 10% and 5% in middle and low-income countries respectively. Existing insurance schemes for disaster relief use information from ground observation to identify and value assets, which can be subject to delays and inconsistencies. This leads to inaccurate estimation of risk and insurance premiums, and therefore limited availability of affordable insurance coverage. EO data can identify and estimate the value of assets such as homes, infrastructure, livestock or crops over wide areas, with the precision required to price and offer insurance products. This can increase the proportion of insured assets which may allow the poor to escape the poverty cycle through access to insurance pay-outs.

Earth observation and satellite communications can improve the accuracy and co-ordination of response: In the event of a natural disaster, local disaster response centres can leverage satellite networks to have full situational awareness of the event. These centres will be able to receive images and videos from the site of the catastrophe through EO data.

While efforts are being taken to increase the resilience of terrestrial communication networks, these can often be damaged during disasters, or are not always present in remote or rural regions. This renders co-ordination between government, donors, NGOs and the private sector, and the wider public difficult, if not impossible. As a result, people are unable to contact and find friends and family, and resources and services are delayed and uncoordinated, slowing the process of recovery and reconstruction.

Satellites, being space based, are unaffected by disasters and provide valuable communications post-disaster. They provide the ability to stay in contact with the outside world via both voice and data through the satellite communications network.[25] They can provide emergency communications for government, donors, NGOs and the private sector and also support the resilience of terrestrial mobile networks, which is critical to allow accessible communications to the wider public. Communications are essential for a rapid and effective response.

25 Inmarsat. 'Indonesia enhances disaster preparedness with pre-emptive deployment of AnsuR 'ASIGN' and Inmarsat BGA', https://www.inmarsat.com/press-release/indonesia-enhances-disaster-preparedness-pre-emptive-deployment-ansur-asign-inmarsat-bgan/. Accessed July 2018

Charters and emergency services for use of space solutions in disaster resilience

Guiding the application of each of the four different space solution outputs are several charters and emergency services. They establish the necessary connections between data providers, information developers, and end users to ensure that decision-makers in the disaster resilience community can benefit from satellite technology.

The International Charter for Space and Major Disasters: This charter is a global mechanism for countries to access satellite imagery in support of their disaster response activities. The charter can provide rapid access to data from a virtual constellation of satellites owned by space agencies and satellite operators. Data is provided at no cost to Authorised Users and any organisation with a national mandate for disaster response can apply to be an Authorised User.

Crisis Connectivity Charter: This charter formalises terms and protocols designed to accelerate the ability of emergency response teams to access satellite-based communications when local networks are affected, destroyed or overloaded after a disaster. The Crisis Connectivity Charter is led by the world's leading satellite operators Inmarsat, Eutelsat, Hispasat, Intelsat, SES, Thuraya and Yahsat, under the umbrella of the EMEA Satellite Operators Association (ESOA) and the Global VSAT Forum (GVF).

Copernicus Emergency Management Service (Copernicus EMS): Provides rapid mapping and information for emergency response in relation to different types of disasters. These include meteorological hazards, geophysical hazards, deliberate and accidental man-made disasters and other humanitarian disasters as well as prevention, preparedness, response and recovery activities.

Impact and cost-effectiveness of space solutions for disaster resilience

IPP approach to assessing the impact and cost-effectiveness of space solutions for disaster resilience

As an ODA[26] funded programme, IPP is required to evaluate and communicate its impact on development challenges around the world. IPP has developed a rigorous monitoring and evaluation (M&E) framework using UK government and OECD[27] best practice. This includes measuring the cost-effectiveness of the space solutions for disaster resilience, to assess the cost of achieving the disaster resilience impacts relative to alternative, existing methods.

A detailed CEA of all IPP projects, including the disaster resilience projects, is currently being undertaken and UKSA will publish programme-level results of this analysis in 2019. This report will be updated in 2021 with impact data and CEA data from IPP disaster resilience projects in Africa, South America and Asia. Central to investment in space solutions for developing countries is that:

Space solutions, including EO, SatComms and GNSS, provide the least costly method for achieving a series of specified improvements within disaster resilience sector (specifically in developing countries) without having any negative impact on the sector or more broadly.

The benefits brought by space-based assets (particularly EO) means that they possess the following strengths relative to alternative methods of data collection (such as planes, Unmanned Aerial Vehicles (UAVs) or ground-based teams):[28]

- collection of data at regular frequency (temporal resolution)
- collection of data over large areas (scale) and in remote, inaccessible areas

26 Official Development Assistance

27 Organisation of Economic Co-operation and Development

28 London Economics 'Value of satellite-derived Earth Observation capabilities to the UK government'

Drought in Libya ▶

- fast turnaround of data (supporting in-year use)
- lower average data processing costs (through automated processes)
- consistency of data collected multiple times across a long time-series
- objectivity and lack of human error or bias in data collection
- potential to reuse the data for other applications
- access to communications that are unaffected by disasters

Forecasted impacts from IPP disaster resilience projects

Disaster resilience is the largest sector within the IPP portfolio with 11 projects receiving around £40 million of funding from IPP. Within these projects there are 60 UK and other space sector and academic institutions supporting 23 international partners, which include government agencies, NGOs, insurance companies, research agencies, and academic institutions. These projects are across Asia and the Pacific (eight countries) and Africa (four countries).

Seven of these projects launched in 2017, four in 2018 and all will conclude by 2021. The final results are yet to emerge from the projects, however each project's monitoring and evaluation workstream forecasts out the project impacts.

Projects in the IPP portfolio support actions to increase resilience to disasters, risks and climate change by:

Improving the understanding of disaster risk, and accuracy of disaster predictions

- Nine IPP projects are aiming to improve the accuracy of disaster risk and predictions across Africa and Asia. This is mainly in the form of models and simulation tools that allow government decision makers to run simulations of how various disasters (cyclones, earthquakes, monsoons, hurricanes, floods and droughts) will impact local populations and infrastructure. The projects range from improving the geographical accuracy of where and when disasters will strike, to those identifying and intervening in areas at risk of a preventable disaster.
- The impacts of this will be measured in the reduction in direct economic losses, and number of people killed and affected by disasters in each country.[29]

---

29 Most projects are aiming for modest improvements in the GDP and human costs of disasters as they are being trailed during IPP in limited regions to prove the concept of the technology. Overarching targets have not been set as it is not appropriate to set targets on the human and economic costs of disasters.

Strengthening government's planning and prioritisation of disaster response

- Five IPP projects are supporting government ministries to plan for and prioritise their response activities during a disaster situation. They will provide near real-time situational analysis of disasters as they develop to allow tracking of: where and how the event is progressing; migration patterns; and where government intervention may be most effective to stem the human and economic costs of the disaster.
- These projects will train over 200 individuals in project countries to use disaster monitoring systems to support decision making. It will allow different stakeholders (across government ministries, NGOs and private stakeholders) to better co-ordinate to create a more cohesive response plan.
- A direct result of this is expected to reduce economic losses and number of people killed and affected by disasters in each country.

Supporting more robust insurance markets through improved calculations of risk

- Five IPP projects are actively targeting insurance (and re-insurance) markets to provide them with more accurate information to calculate risks and provide more widespread and affordable insurance policies to those at risks of disasters. Primarily (but not exclusively) focused on agricultural insurance, these projects are aiming to ensure that more smallholders are able to access insurance and that premiums are more affordable for them.
- Projects are aiming for a range of 5-25% increases in insurance penetration and an average decrease in premiums of 10%, which will contribute to reducing the number of people negatively affected by disasters.

Enhancing preparedness for effective response through improved emergency communications

- Two IPP projects are investing in robust satellite communications systems to supplement damaged terrestrial systems during and post-disaster events. These networks allow for the transmission of emergency messages to ensure that remote and isolated populations can receive necessary medical care, emergency supplies and basic services.
- These IPP projects will ensure that basic services are restored to disaster affected communities, and so reduce the number of people affected, and the severity of the effect on their lives.

Public domain evidence of the impact and cost-effectiveness of space solutions for disaster resilience

In addition to the forecasted impacts from IPP disaster resilience projects, there is public domain evidence of the impact of space solution in disaster resilience.

Table 1: Public domain evidence of the impact of space solution in disaster resilience

Space solution for disaster resilience	Evidence of impact in developing countries
Earth observation improves the accuracy of disaster forecasting and prediction	The socio-economic value of hydrological and meteorological (hydromet) information from space-based infrastructure within disaster risk management is broadly demonstrated[30] in combination with the added economic benefits, such as to agriculture. Through 'relatively modest'[31] investment, countries with less developed hydromet services and early warning systems can also benefit significantly from existing international infrastructure. Satellite data now increases the accuracy of modern Numerical Weather Prediction (NWP) to the point that the loss of all satellite data would result in the 'catastrophic loss of forecast skill in both hemispheres'. This would be 'much more damaging than the removal of all in situ (conventional) observations'.[32] For the Famine Early Warning Systems Network, (FEWS NET)[33] earth observation imagery, together with other agroclimatology data, is critical for projecting food insecurity and future food assistance needs through scenario development. Such a system would be impracticable today on continental and regional scales without the use of EO.
Earth observation improves government's planning and prioritisation of disaster response	EO provides a quantitative and comparable reference baseline of hazards and impacts. Satellite imagery where 'a high level of accuracy and detail can be obtained' adds significant value to hazard mapping and modelling. Maps 'are widely used in hazard identification and assessment and can provide accurate records of the location, probable severity and occurrence of hazards'.[34] When stored in a GIS, instant and consolidated access can be provided to large and complex datasets that can be summarised according to needs. Infectious diseases represent a public health disaster risk that requires planning at a government and federal level. In analysing the impact of integrating EO into the U.S. Geological Survey's (USGS) prototype Malaria Early Warning System (MEWS) for malaria control in sub-Saharan Africa, NASA suggested that 'the impact would be on the order of a half million or more avoided [malaria] cases per year'.[35]

30 World Meteorological Organization. 'Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services', http://www.wmo.int/gfcs/sites/default/files/wmo_1153_en.pdf. Accessed July 2018

31 World Bank. 'A Cost Effective Solution to Reduce Disaster Losses in Developing Countries', https://elibrary.worldbank.org/doi/abs/10.1596/1813-9450-6058. Accessed July 2018

32 McNally, A. 'The impact of satellite data on NWP', pp. 1-10, https://www.ecmwf.int/sites/default/files/elibrary/2015/11061-impact-satellite-data-nwp.pdf. Accessed July 2018

33 FEWS NET. http://www.fews.net. Accessed July 2018

34 Overseas Development Institute. 'Disaster Risk Reduction', p. 52, https://goodpracticereview.org/wp-content/uploads/2015/10/GPR-9-web-string-1.pdf. Accessed July 2018

35 NASA. 'Measuring Socioeconomic Impacts of Earth Observations A Primer', https://appliedsciences.nasa.gov/system/files/docs/SocioeconomicImpacts.pdf. Accessed July 2018

Space solution for disaster resilience	Evidence of impact in developing countries
Earth observation supports a robust insurance market through improved calculation of risk	EO data fills gaps over a broad scale to enhance insurance product quality and increase the viability of index insurance products. Index-based insurance has potential[36] to offer quick claims settlement processes that are more objective. For example, payouts can be linked to observations of and proxies for losses – such as yield, satellite data and weather triggers. A significant challenge for index-based insurance is reducing basis risk, the difference between index measurements and the actual losses of an insured individual and a measure of insurance product quality.[37] EO, in combination with other data sources, helps insurers reduce basis risk. For example, the World Bank project with the National Agriculture Insurance Scheme (NAIS) in India found that 'Combining yield, weather, and satellite data in sensible ways can lead to higher quality, more cost-effective products than just using one type of data'.[38] Satellite data was used to target crop cutting experiments (CCEs) for generating a yield index. Where there is a high correlation between satellite data and crop yields, it was found that use of satellite data can either reduce the cost of the CCEs by a factor of four or improve accuracy by a factor of two. The NAIS provides agriculture insurance coverage for nearly 30 million farming households. EO data allows rapid assessment of damages for loss control. The use of EO for rapid overall loss estimates in reinsurance is common practice.[39] EO technologies have significant potential to enable quantitative assessment of hazard risk exposure. For example, EO allows you to make direct observations for use in physical vulnerability assessment.[40]
Earth observation can improve the accuracy and co-ordination of response	EO data enables accurate mapping of disaster impacts. When incorporated within mapping and GIS, EO gives a sharable and updatable intelligence picture for responders and civil contingencies authorities, due to the regular revisit of the satellite and update of imagery (temporal frequency). The technical benefits and high degrees of accuracy that can be achieved are well known, for example in flood monitoring[41] but analysis of cost-effectiveness of rapid mapping for emergencies as a discrete activity is rare.
Satellite communications can improve the accuracy and co-ordination of response	SatComms provide for early warning and direct-to-citizen communications as a critical component of disaster management. Emergency communications system such as Japans J-Alert[42] encompass a satellite communication-backed national infrastructure for earthquake and tsunami early warning. J-Alert provides public alerting through a system of loudspeakers, media and mobile broadcasts. Other have noted the system to be 'financially feasible'[43] but as other reports show, outside Europe there are 'very few quantitative assessments of the cost benefit of early warning systems'.[44]

36 J. E. Flatnes and M. R. Carter. 'Fail-safe index insurance without the cost: a satellite based conditional audit approach', pp. 1–27, https://basis.ucdavis.edu/sites/g/files/dgvnsk466/files/2017-05/Satellite_based_conditional_audit_index_insurance_170217.pdf. Accessed July 2018

37 Overseas Development Institute. 'Disaster risk insurance and the triple dividend of resilience', https://www.odi.org/sites/odi.org.uk/files/resource-documents/11759.pdf. Accessed July 2018

38 The World Bank. 'Agricultural Data and Insurance: Disaster Risk Financing and Insurance Technical Note', November 2013

39 Lloyds. 'Satellite data - assessing post-event losses', https://www.lloyds.com/news-and-risk-insight/news/market-news/industry-news-2014/how-satellite-data-can-help-reinsurers. Accessed July 2018

40 United Nations University – ITC School on Disaster Geoinformation Management (UNU-ITC DGIM). 'Multi-hazard risk assessment', pp. 1–371, https://kartoweb.itc.nl/kobben/files/RiskCity/Guidebook%20MHRA.pdf. Accessed July 2018

41 J. Sanyal and X. X. Lu, 'Application of Remote Sensing in Flood Management with Special Reference to Monsoon Asia: A Review', Nat Hazards, volume 33, no. 2, pp. 283–301, August 2004. https://link.springer.com/article/10.1023/B:NHAZ.0000037035.65105.95. Accessed July 2018

42 C. Lkhamjav, 'Earthquake early warning systems', Asian Disaster Reduction Center, July 2014

43 Boston Consulting Group Centre for Public Impact. 'J-Alert: disaster warning technology in Japan', https://www.centreforpublicimpact.org/case-study/disaster-technology-japan. Accessed July 2018

44 UNISDR/World Bank. 'Costs and benefits of early warning systems', https://www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/Rogers_&_Tsirkunov_2011.pdf. Accessed July 2018

Seizing the opportunity

As highlighted above, there is a strong case for space solutions to address disaster resilience challenges in developing countries. In addressing these challenges, organisations and companies offering space solutions require:

- a space solution
- stakeholders and customers
- a sustainability model

Space solution

A space solution is the combination of both technology and non-technology elements that together address the disaster resilience challenge. The common space-based technologies which provide the building blocks for a solution include:

- earth observation (EO)
- satellite communications (SatComms)
- Global Navigation Satellite System's (GNSS) (precise timing and location)

Earth observation

Space solutions using EO employ remote sensing technology and techniques from a range of different sensors on-board satellites. Remote sensing[45] is the science of obtaining information about objects or areas from a distance and includes the use of sensors on aircraft, satellites and UAVs. EO satellites image and record data over time about the earth's atmosphere, oceans, and land surface at planetary scale down to street level.

As highlighted in section 'Space solutions support disaster resilience', EO is typically used in disaster resilience projects as below:

Earth observation (EO) improves the accuracy of meteorological disaster forecasting

Hurricanes and cyclones are rapid-onset disasters. EO provides accurate status of current environment conditions which is fundamental to forecasting the risk of disasters, and in combination with ground based meteorological data (such as weather stations, and meteorological forecasting models), EO improves the accuracy of disaster forecasting. This includes forecasting time and location of landfall, the subsequent path over land and populated areas, and the severity. As hurricanes and cyclones approach land, specific EO satellites are tasked to provide high resolution, up-to-date imagery of the areas at risk.

Wildfires are a rapid onset disaster that occur across much of the developing world. Detection of the fires while they are small is critical to ensuring the fires are extinguished before spreading out of control. EO from geostationary satellites is used to enable the Advanced Fire Information System (AFIS)[46] to identify and alert of wildfires. EO from nanosatellites is being trialled to improve the ability of identifying small fires (under 100 square metres).

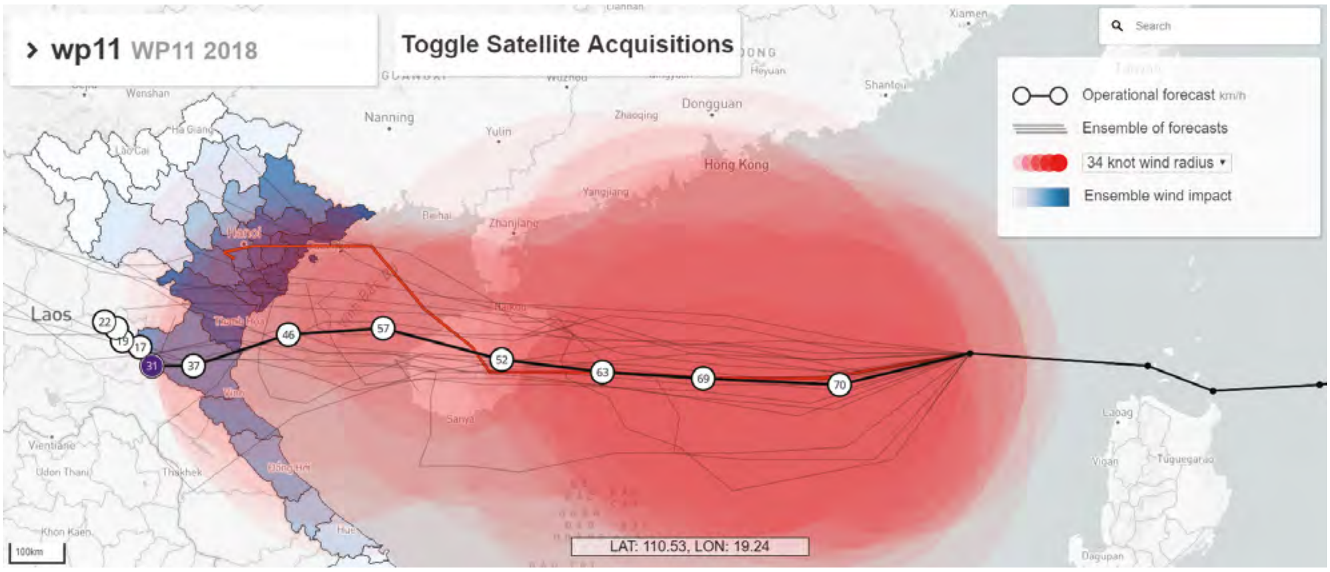
Flooding is a rapid onset disaster that EO mitigates by improving accuracy of forecasts of flooding extent in terms of location, timing and severity. Freely available EO data from Landsat and Sentinel are at sufficient resolution and refresh cycle to build a base map of the region against which flooding prediction models can be built. As the risk of flooding increases, additional satellites are tasked to provide high resolution, up-to-date imagery of the specific areas at risk. The EO data are supplemented with ground-based data from rainfall radar and water level sensors. The solutions rely on the combination of these multiple space and ground-based data sets to improve flood forecasting.

---

45 NOAA. 'What is remote sensing?', https://oceanservice.noaa.gov/facts/remotesensing.html. Accessed July 2018

46 The Advanced Fire Information System (AFIS) is a satellite-based fire information tool that provides near real time fire information to users across the globe

Figure 5: Hurricane Monitoring Dashboard for South East Asia



Drought is a slow onset disaster that EO can help forecast by providing enhanced data on land use and topology, meteorology, ground water, soil moisture and crop health, which enables forecast models of drought in the target region. The solutions provide risk information over multiple time horizons including current, immediate and future. FEWS NET (see Table 3) is an example of a satellite-based global early warning and analysis system for food insecurity.

Heatwaves, particularly in urban geographies, benefit from forecasting of heat effects and consequent mitigation plans.

All these solutions feed into decision makers at all levels of the country including government, NGOs, donors, private sector and the public, to allow appropriate disaster response plans to be activated in a timely and effective manner. Those organisations can then deploy disaster response assets such as medical supplies, food, engineering stores and security services to regions of highest risk.

Earth observation improves government's planning and prioritisation of disaster response

Near real-time disaster monitoring through EO enables improved planning and prioritisation of the response by government, NGOs and industry, leading to reduction in deaths, missing persons and economic losses.

EO provides accurate, up-to-date situational awareness and resource mapping in post-disaster scenario to identify population movements and infrastructure damage. This gives decision makers efficient command and control of response assets to those areas most affected.

One of the benefits is the ability to fuse a wide set of data into a single disaster response monitoring dashboard. This includes space-based EO data with Global Navigation Satellite System (GNSS) data to locate response teams and assets, and data sources from existing systems being used by the government in a disaster scenario.

Stevenson Astrosat: Recovery and Protection in Disaster (RAPID) for Vietnam

RAPID will support Vietnam to prepare and respond to typhoon disasters, which will increase social and economic resilience. The project aims to improve the efficiency, response times and accuracy of first responders in disaster situations.

See Annex A for detailed case study.

Satellite Applications Catapult: Earth and Sea Observation System (EASOS)

EASOS provides high-quality information in an integrated dashboard, which acts as a planning and response decision support for flooding, marine pollution, and illegal logging.

See Annex A for detailed case study.

Figure 6: Example disaster response monitoring dashboard

Earth observation supports a robust insurance market through improved calculation of risk

Accurate identification and estimation of the value of assets, such as homes, infrastructure, livestock or crops, and the subsequent estimation of economic losses after a disaster, is critical to the provision of affordable insurance.

EO data is used to identify, categorise and value physical infrastructure such as buildings, to provide insurance companies with an accurate profile of the value-at-risk over wide geographic areas. This allows insurance companies to accurately price premiums that are both affordable to the customer and sustainable to the insurance company.

EO is also used to improve the accuracy of the trigger for payments after a disaster. Many insurance schemes in developing countries are based on indexes to avoid the need to receive and process huge numbers of individual claims, which is extremely difficult to administer and at risk of fraud. These indexes are based on metrics of the severity of the impact, for example 'average livestock mortality rate' exceeding a certain threshold, in a certain geographic area.

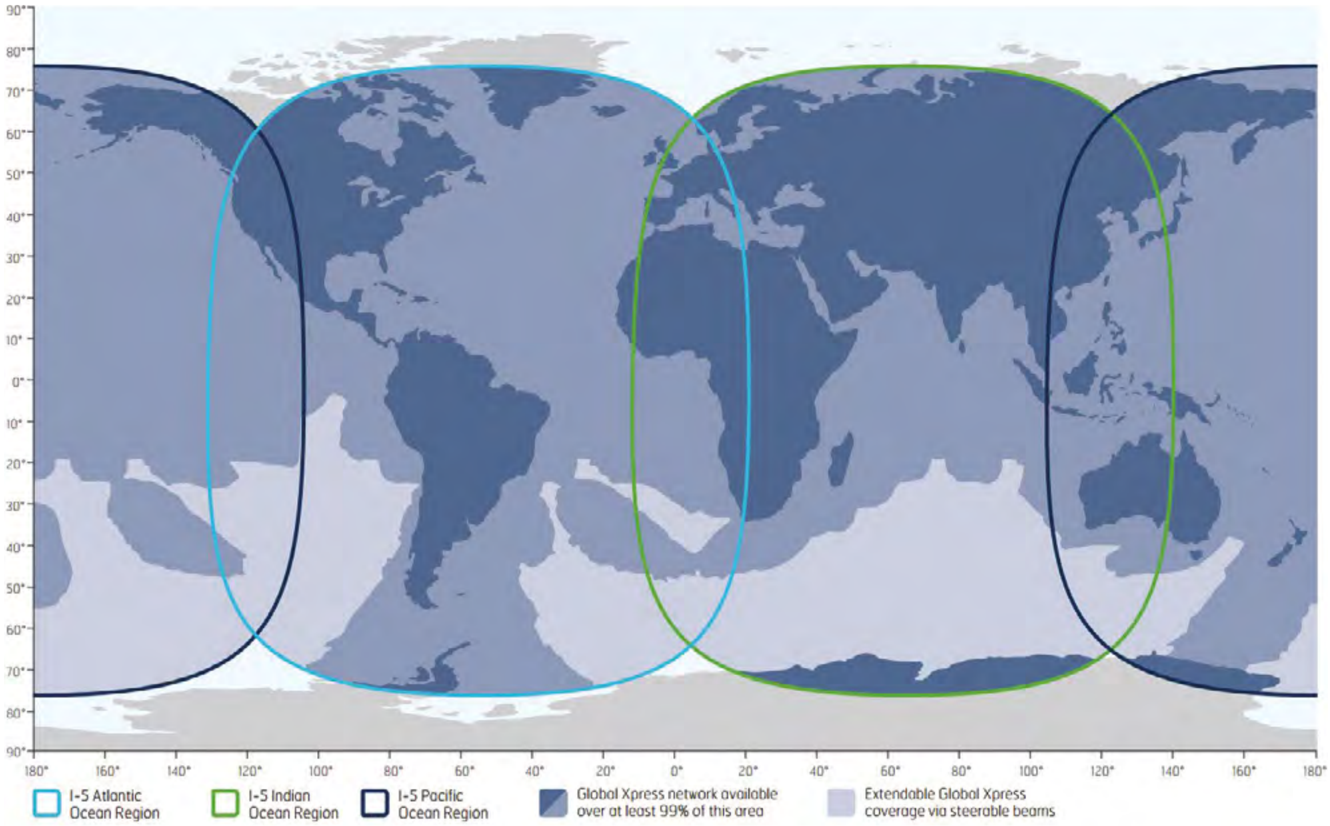
However, they are commonly based on very wide geographic areas, which brings significant inaccuracy into the triggering of payments, and a perception of underlying unfairness is a barrier to uptake. EO addresses this by giving a more accurate view of disaster impact on much smaller geographic areas, thereby triggering payments to policy holders who were truly impacted.

Airbus space and defence flood and drought resilience in Ethiopia and Kenya

The project uses EO satellite imagery, hydrological, hydraulic and economic modelling to help decision makers improve resilience to flood and drought. In Ethiopia, the objective is to: provide donors, investors, and decision makers in government with improved information on the economic consequences of flood and drought so they can co-ordinate land and infrastructure development, manage natural resources and target social security and emergency response policies. In Kenya, decision makers in insurance markets will use better risk information for more effective product and price competition leading to greater insurance coverage.

See Annex A for detailed case study.

Figure 7: Inmarsat Global Xpress coverage



SatComms

Fixed and mobile satellite communication services can offer telephony and Internet access at times when traditional connectivity is not viable. There are over 2,000 communication satellites currently in orbit, used by both private and public sectors.[47] They transmit voice and data to a ground receiving station or moveable terminal.

Geostationary (GEO) satellites are located around 36,000 km above the Earth in a fixed position, and can provide communications services including voice, video and broadband data. LEO satellites operate in orbits between 780 km and 1,500 km (depending on the system) and provide voice and low speed data communications.

SatComms provides very wide coverage over entire continents as highlighted by the near global coverage of Inmarsat Global Xpress in Figure 7 (see Inmarsat: Reducing the Impact of Natural Disasters through SatComms). Modern high-throughput satellites (HTS)[48] provide mobile broadband comparable speeds with less than 10Mbps download speed. The bandwidth capacity of the HTS has increased tremendously in the past 10 years, where the first HTS had 45 gigabits per second (Gbps) of capacity while more recently launched satellites offer roughly 130 to 145 Gbps.[49]

47 Geeks without Frontiers. 'Community Connect', http://geekswf.org/wp-content/uploads/2017/10/Community-Connect-Master-18-Oct-2017-Final.pdf. Accessed July 2018

48 Wikipedia. 'High-throughput satellite', https://en.wikipedia.org/wiki/High-throughput_satellite. Accessed July 2018

49 OECD Digital Economy Papers. 'The Evolving Role of Satellite Networks in Rural and Remote Broadband Access', http://www.oecd-ilibrary.org/docserver/download/7610090d-en.pdf?expires=1512636311&id=id&accname=guest&checksum=D3E95261F61C895B2A95F00CB758C9F4. Accessed July 2018

These capabilities position SatComms effectively as a means of communication in disaster resilience in regions with no terrestrial network coverage, or where the network has been damaged by the disaster. The limitation of SatComms for disaster resilience is the cost of using the satellite link for significant Internet traffic, as cost of data transmission is higher than with terrestrial networks. Another limitation is bandwidth constraints, which can become a problem when government, NGOs and the private sector are all trying to access the same network.

On the ground, a terminal is required to receive the signal. Modern terminals are portable and lightweight, making them highly transportable for rapid deployment in a post-disaster scenario. Handheld satellite terminals, though limited to voice and low-rate data, can also be used for rapid deployment. Auto-tracking terminals that self-adjust the position of the antenna to the satellite are common and can be deployed by teams without technical skills. Weatherproof cases protect from rain and wind which is critical in weather related disasters such as hurricanes and cyclones.

Importantly, users do not need access to a satellite phone to take advantage of satellite communications. Satellite terminals can establish Wi-Fi zones or provide backhaul to the terrestrial mobile network (2G, 3G, 4G), enabling relief workers and individuals in affected areas to co-ordinate and communicate using their own devices and applications.

These combined capabilities allow SatComms to provide a fast, rugged, self-contained, in-field and user-friendly global communications link. This enables people to contact and find friends and family, and for disaster response assets such as medical supplies, food, engineering stores and security services to be sent to regions of highest risk. It also improves the safety of first responder teams, improving their speed and effectiveness.

Inmarsat reducing the impact of natural disasters by using SatComms

The project will improve welfare and economic development in the Philippines through improved disaster resilience, preparedness and response. Inmarsat will design and install a SatComms solution, deliver connectivity, establish management arrangements, and train people to create widespread operational capability for satellite-based disaster communications.

See Annex A for detailed case study

Global Navigation Satellite System

A Global Navigation Satellite System (GNSS) is a satellite system used for navigation and timing. GNSS includes the Global Positioning System (GPS), Galileo and GLONAS. GNSS satellites transmit the global signals used by devices (receivers) to determine accurate global position and time. Location can be determined as latitude, longitude and altitude to within few meters. Even higher accuracy can be achieved with SBSS.

Stakeholder and customers

Stakeholders have unique roles in each phase of the disaster resilience cycle. Led by national governments, these efforts also require donors, NGOs and the private sector to help minimise the number of lives impacted and economic losses.

Organisations in the space sector will have varying relationships to these organisations, including as customers. Figure 8 is a representation of examples of how such organisations engage with space solutions and is not intended as a comprehensive mapping exercise.

Figure 8: Role of organisations and relationship to space sector organisations

Organisation type	Examples	Roles	Relationship to space organisation
National / local government	– National Disaster Management Agency – Department of the Environment – Police and military	– Risk assessments and strategy – Lead and co-ordinate response – Co-ordinate and fund recovery	– Customer of EO monitoring and response dashboard – Customer for emergency satellite communications
Donor	– World Bank – United Nations Office for Disaster Risk Reduction – USAID: Office of Foreign Disaster Assistance	– Risk assessments, emergency planning and public awareness – Financial capital for disaster resilience	– User of EO monitoring and response dashboard – Source of funding for development of space solutions – Customer for emergency satellite communications
NGO	– Telecoms Sans Frontiers – International Federation of Red Cross and Red Crescent Societies – CARE	– Provide services to support recovery – Community education and preparation	– User of EO monitoring and response dashboard – Customer for emergency satellite communications
Private sector	– Caterpillar – AXA, Swiss Re – Inmarsat	– Risk insurance products – Emergency satellite communications – Recovery and reconstruction	– Suppliers and customers of satellite communications – Suppliers and customers of EO driven insurance risk models

National/local government: The government has the role of leading the disaster resilience efforts, through risk assessment and strategies, co-ordination of the response, and funding recovery and reconstruction. Space organisations support government through sale of EO monitoring and response dashboards and provision of emergency satellite communications.

Donors: Donors such as the World Bank and the UN support the government by providing risk assessments, emergency planning and improving public awareness. Donors are also sources of financial capital. In co-ordination with government they would be a user and buyer of the EO monitoring and response dashboards to aid the response efforts. Space organisations can source financial capital from donors to support development of their solutions. Donors are also increasingly utilising insurance mechanisms to enhance resilience, for example the London Centre for Global Disaster Protection.

NGOs: NGOs support the recovery post-disaster by ensuring government, industry and the public have access to critical services such as food, water, power and communications. Like donors, they would be a user of the EO monitoring and response dashboards, in co-ordination with government, to aid the response efforts.

Private sector: The private sector offer insurance to provide financial security, including against risk of asset losses. In a response and recovery phase they will provide emergency infrastructure such as satellite communications, and then work with government on the reconstruction of critical infrastructure including buildings, power, transport and utilities. The wider private sector are often the customers for satellite communications, while the insurance sector are customers for EO-based risk models, while space organisations within the private sector provide these services.

Sustainability models

In ODA funded projects, sustainability is defined by the Organisation for Economic Cooperation Development Assistance Committee as 'concerned with measuring whether the benefits of an activity are likely to continue after donor funding has been withdrawn'.[50] In the UK Space Agency's International Partnership Programme (IPP), all projects are developing a sustainability model that will ensure that the positive impacts of the project continue after UKSA grant funding ends.

Sustainability models are critical to ensure that the costs and margins associated with long term provision of the space solution are available from either government procurement, private sector customers, or ongoing donor funding. Capacity building and training provided to the local stakeholders and customers ensures that they can adopt, use and maintain space solutions over the long term, which supports sustainability. The capacity-building approaches in IPP include training workshops, hands-on training, job shadowing and training documentation.

There are many costs associated with the space solutions including: staff; EO data acquisition; computing and bandwidth infrastructure; SatComms terminals; SatComms transmission; and capacity building and training.

Within disaster resilience, a business to government (B2G) sustainability model is most common. This model works well in disaster resilience as the primary stakeholder is often the government (see 'Stakeholder and customer landscape').

A 'spend to save' model is common, whereby the government investment ensures a greater cost saving over future years (both saving on the costs of their existing disaster resilience efforts, and savings through reducing economic losses from disasters).

Business to business (B2B) is the second most common business model in disaster resilience, with a focus on the sale of EO-driven risk models to the insurance sector. Insurance companies value the capability of EO data to identify, categorise and value assets such as buildings, and to improve the payment trigger mechanism in a post-disaster event, and are therefore willing to pay space companies for such capability.

In a post-disaster scenario, both the private and public sector need to continue their activities. For communications infrastructure, SatComms offers solutions when there is no coverage from terrestrial networks or those networks are damaged.

International space companies selling their disaster resilience service into a foreign market often use a local intermediary to facilitate the business development and sales activities. These local players understand the local context and the stakeholder and customer landscape, and are often required to legally sell within the market, particularly to government customers.

50 OECD. 'DAC Criteria for Evaluating Development Assistance', http://www.oecd.org/dac/evaluation/daccriteriaforevaluatingdevelopmentassistance.htm. Accessed July 2018

Additional information and guidance

Overview

The preceding chapters of this report have highlighted the opportunity for space solutions to bring benefits to disaster resilience. This chapter provides guidance for development and disaster resilience practitioners as to how they can utilise space solutions for disaster resilience.

Satellite orbits

Satellites are critical infrastructure in space solutions for disaster resilience and are launched into different orbits around the earth to enable achievement of different mission goals.

Geostationary (GEO): satellites are located 36,000 km above the Earth. The fixed positions of satellites in GEO provide for regional telecommunications services including: voice, video and broadband data; and 'full disc' weather services.

Medium Earth Orbit (MEO): located between 20,000 to 36,000 km above the earth. Fixed, predictable and nearly circular orbits satellites provide GNSS satellites good coverage of the earth's surface for navigation and timing services.

Low Earth Orbit (LEO): below 2,000 km above the earth. Satellites continually orbit the earth to allow global coverage within a 'revisit period'. Increasingly, multiple LEO satellites operate together in 'constellations' to increase coverage and observation opportunities. LEO satellites commonly use sun-synchronous orbits, meaning they are crossing the equator at same local time of day. Satellites in LEO provide voice and low speed data communications and a variety of earth observation services.

Earth observation

EO data from earth observation satellites comes from a variety of sensors. Satellite sensors are commonly divided into active and passive, each offering different benefits and constraints. A sensor can often be referred to using other names including camera, instrument and payload. The exact terminology depends on the sensor type.

Passive sensors receive emitted or reflected energy, typically from the earth's surface (land, ice or ocean). Examples of passive sensor include instruments and cameras that can detect visible wavelengths, infrared and thermal (for surface temperatures), and microwave wavelengths (for surface roughness, soil moisture and salinity).

Active sensors both emit and receive signals and include radars such as synthetic aperture radar (SAR), radar scatterometers, radar altimeters, weather radar and light detection and ranging (LIDAR).

Earth observation usually refers to remote sensing with satellite-based sensors but also includes other platforms, such as aerial. The sensors used on other platforms are often the same as for satellites and in many cases, sensors are 'flown' or tested on aerial platforms before being used on satellites.

EO solutions are dependent on: the satellite input data used; other data they are combined with; and the processing and analysis techniques applied. EO data varies from sensor to sensor in terms of the parameters that are measured and the spectral, spatial and temporal resolution of the products. It is important when choosing sources of satellite data to consider the characteristics of the features to be examined.

EO-measured parameters on land

Measurement of land parameters and associated changes can be used in many applications, including disaster risk. Common direct and derived measurements include:

- surface and terrain height
- land cover and land use
- geology and geographical features
- biophysical parameters (e.g. vegetation health)
- water and ice
- temperature (thermal)

All these measurements are of interest for disaster risk, but we are interested in the location of people, buildings and infrastructure.

Many EO satellites with land observing capabilities are operated by public and private organisations. Examples of public global land monitoring include the Landsat and Copernicus Sentinel programmes with timescales of 5 to 16 days for global coverage. An increasing number of nations run national land remote sensing programmes using state owned or third party satellites. Commercial systems are also available that can often offer higher resolution and/or observation frequency at a cost. International programmes exist for routine monitoring of hazards for disaster risk reduction, including the GEO Geohazard Supersites and Natural Laboratories (GSNL) initiative.

EO-measured parameters on oceans

In addition to the imagery available from high resolution optical and radar satellites, as described in the subsequent sections, the following ocean parameters relevant to disaster resilience can be measured from space:

- sea level
- ocean waves
- ocean winds
- sea surface temperature
- ocean colour / water quality (chlorophyll, algal blooms and suspended sediment)
- oil slicks, ship detection, surface currents, wave spectra

Many of these data products are available in real time. This is necessary for assimilation into operational forecast models; providing up-to-date information and warnings on extreme or dangerous ocean conditions; monitoring the track and extent of storm events; and to inform operational planning. Also, historical data is available as climatologies, and can be used to support long term planning and the development of coastal risk management strategies.

Examples including ESA Globwave[51] and Globcurrent[52] projects. The ESA earth observation pages and the Copernicus Marine Environmental Monitoring Service provide further information on missions, sensors, data products and access to data.[53] [54]

---

51 GLOBWAVE. 'Globwave', http://globwave.ifremer.fr/. Accessed July 2018

52 GLOBCURRENT, http://www.globcurrent.org/. Accessed July 2018

53 ESA. 'Earth Online', https://earth.esa.int/web/guest/home. Accessed July 2018

54 European Commission. 'Copernicus-Marine Environment Monitoring Service', http://marine.copernicus.eu/. Accessed July 2018

Spectral resolution

EO sensors use the electromagnetic spectrum (Figure 9) to 'see' the Earth. Spectral resolution refers to the number of colours or discrete spectral samples that are recorded for each image pixel. Typically, the presence of more spectral wavebands increases the ability of the imagery to discriminate between different features such as land cover, as there is more information and therefore more discriminating power in the image.

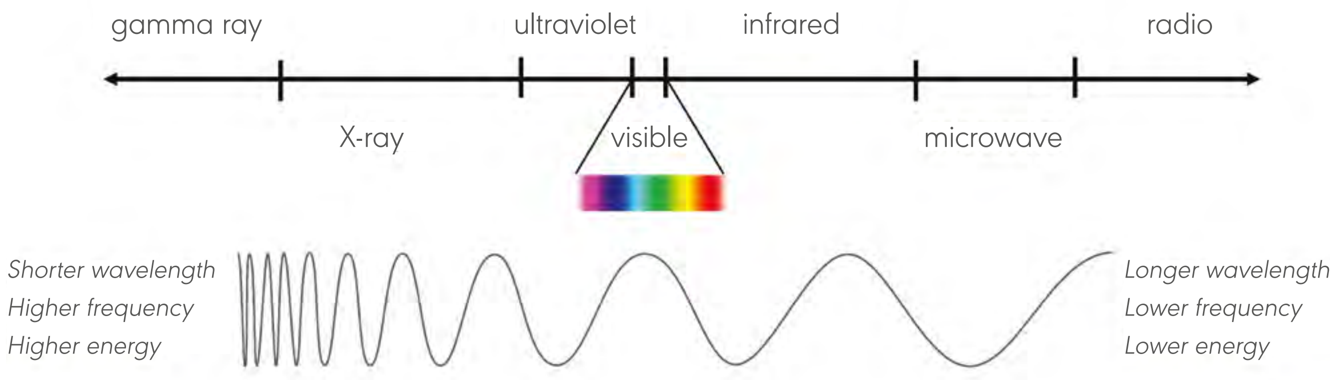
Optical sensors: Multispectral satellites are common in EO (often referred to as optical satellites), providing images of the Earth's surface and atmosphere captured in the visible and infrared portion of the electromagnetic spectrum. They have a broad set of applications including agriculture, land-cover mapping, damage assessment associated with natural hazards and urban planning, but are limited to cloud-free conditions and daytime operation.[55] Other applications include generating digital elevation models (DEM) which are 3D representation of the terrains surface, which is critical information for forecasting flooding extents. Optical data is easier to process and understand and so is a more easily transferable technology.

Most optical sensors are constrained to daylight use and cannot be used at night, although applications of 'night light' data to map human activity and power availability are possible.

Multispectral sensors generally capture information from around 3 to 16 spectral bands. Hyperspectral sensors can capture hundreds or thousands of bands, each representing a much narrower wavelength of the electromagnetic spectrum. Having a higher level of spectral detail in hyperspectral images improves the ability to see the unseen – the many characteristics of the land surface that the human eye cannot see. However, having so many bands increases the complexity of data quality management and handling.

In comparison to other sensor types, a small number of satellites carrying hyperspectral payloads have been launched to date.[56] The use of hyperspectral EO has previously been more research oriented with applications including water resources and quality and complex vegetation analysis. Airborne hyperspectral remote sensing can be more readily available but the cost of acquiring images is relatively high and is therefore better suited to smaller scale, targeted surveys.

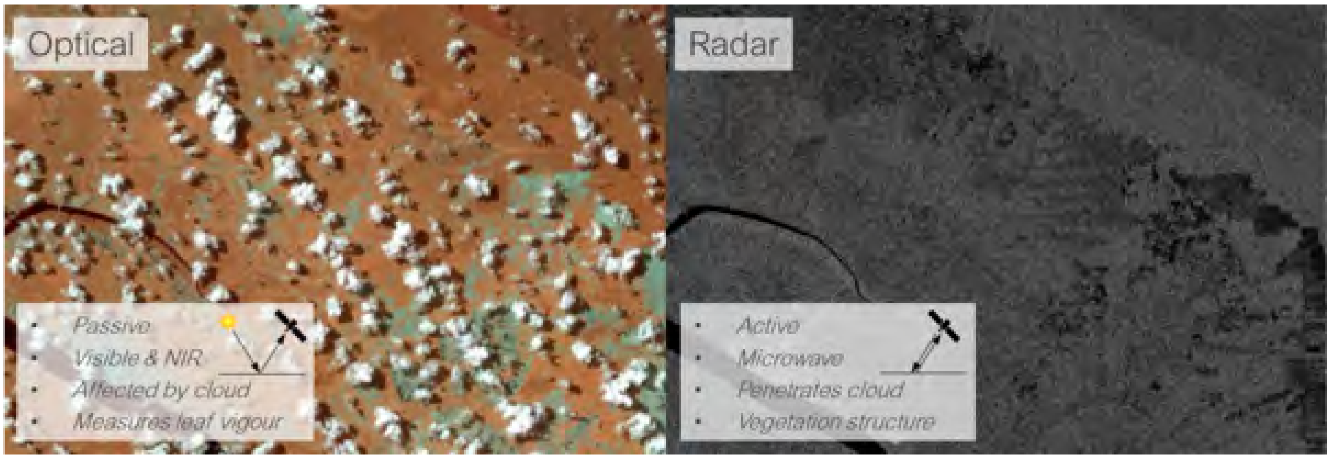
Figure 9: The Electromagnetic Spectrum



55 European Space Agency. 'Optical Missions', http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Optical_missions. Accessed July 2018

56 These includes Hyperion/EO-1, Coastal Ocean (HICO)/Hyperspectral Imager and CHRIS/PROBA. Several satellite missions are upcoming and planned. This includes EnMap, PRISMA, HISUI, PRISMA, TianGong-1, Shalom, HyspIRI, HypXIM and Resurs-P

Figure 10: The Differences between optical and radar satellites



Synthetic aperture radar[57] **(SAR)** is an active system that transmits a beam of radiation in the microwave region of the electromagnetic spectrum. The data captured reveals information about the structural characteristics of the Earth's surface. Many measurements of surface structure and land features (including displacement, subsidence and material flow) are valuable for disaster risk reduction for seismic and volcanic hazards. SAR is also used for generating digital elevation models (DEM) and detecting standing flood water in non-urban areas. A key advantage of SAR is that it not affected by cloud cover, although precipitation can affect data.

Light Detection and Ranging (LIDAR) is a surveying method that measures distance to a target by illuminating that target with a pulsed laser light and measuring the reflected pulses with a sensor. Differences in laser return times and wavelengths can then be used to make digital 3D representations of the target. LIDAR can penetrate forest canopies and is commonly used with airborne platforms such as planes and unmanned aerial vehicles (UAVs) which limits the geographic coverage.

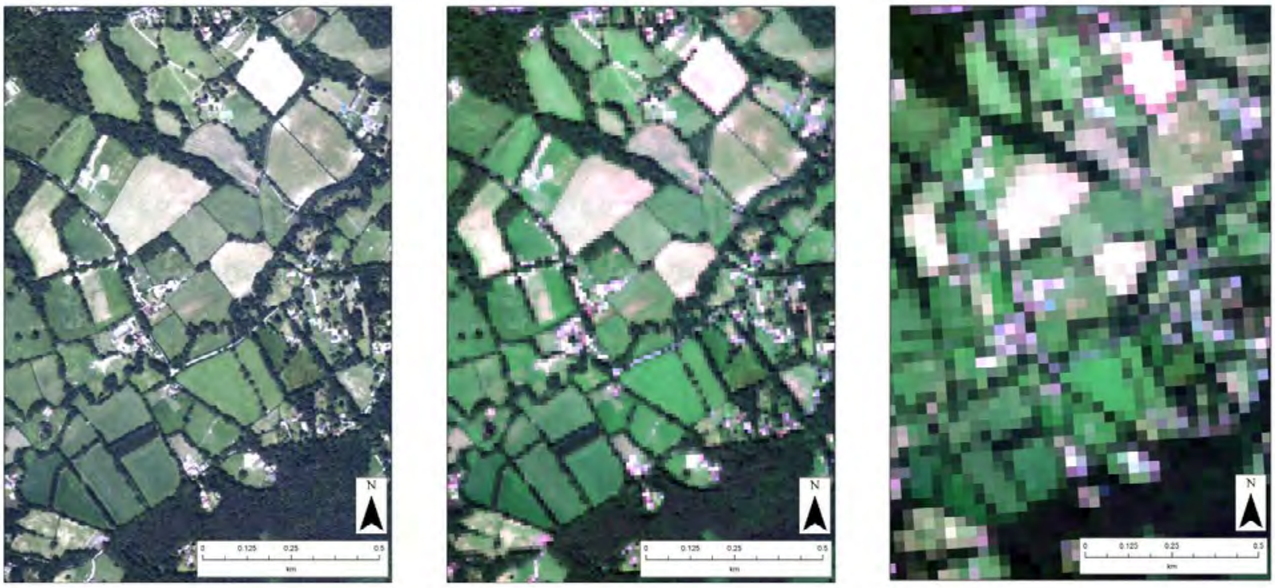
Spatial resolution

Spatial resolution refers to the pixel size of an image. The higher the spatial resolution, the greater the ability to identify and 'see' more detail in an image (Figure 11). Typically, a higher spatial resolution means a smaller image extent (the area covered by a single image). When discussing the resolution of imagery in this report the following terminology is used:

Abbreviation	Image resolution (metres)
LR (low resolution)	20+
MR (medium resolution)	10-20
HR (high resolution)	5-10
VHR (very high resolution)	1-5
AP (aerial photography)	0.3-0.5

57 A. Moreira, P. Prats-Iraola, M. Younis, G. Krieger, I. Hajnsek, and K. P. Papathanassiou, 'A tutorial on synthetic aperture radar', IEEE Geoscience and Remote Sensing Magazine, vol. 1, no. 1, pp. 6–43, April 2013

Figure 11: Representation of a WorldView-2 image (VHR, 1.84m2 pixels), Sentinel-2 image (HR, 10 m2 pixels) and a Landsat 8 image (LR, 30m2 pixels) for the same area



Temporal resolution

Temporal resolution is related to the repeat frequency with which a system can acquire images of the same location. For satellite EO, this is mainly determined by the revisit time of a satellite over the same location, which is a function of the satellite orbit. However, with optical sensors, environmental factors such as cloud cover have an overriding impact on the availability of suitable images.

One of the current trends in EO is to maximise the use of time series that new EO constellations provide. For example, the weather independent availability of Sentinel-1 SAR gives ultra-high temporal data as the basis for analytics.

Sources of earth observation data

Satellites are one of the most extensive forms of remote sensing: as of 2016 there were over 400 EO satellites in orbit, and at least 400 more are expected to be launched by 2025.[58] There are numerous sources of EO data that can be accessed for use in disaster resilience.

Active assets are those that are available to receive direct request for specific tasking to provide up-to-date data for a specific region (such as the disaster zone). Table 2 highlights some of the organisations that provide EO data and products in disaster scenarios.

58 The Parliamentary Office of Science and Technology, http://researchbriefings.parliament.uk/ResearchBriefing/Summary/POST-PN-0566. Number 566, November 2017. Accessed July 2018

Table 2: Organisations providing request based, free space derived services[59]

Initiative	Description (from websites)	Access guidelines
Copernicus Emergency Management Service[60]	Copernicus Emergency Management Service (Copernicus EMS) provides free access to mapping and alerting for emergency management.	Emergency Management Service - Mapping - Quick Start Guide
International Charter Space and Major Disasters[61]	International Co-operation of 16-member space agencies, providing free access to satellite imagery for global disasters.	Activating the Charter
Sentinel Asia[62]	Led by Asia-Pacific Regional Space Agency Forum (APRSAF), Sentinel Asia is an international collaboration among space agencies, disaster management agencies, and international agencies for applying remote sensing and Web-GIS technologies to support disaster management in the Asia-Pacific region.	Sentinel Asia
SERVIR[63]	SERVIR, a joint venture between NASA and the USAID, provides state-of-the-art, satellite-based Earth monitoring, imaging and mapping data, geospatial information, predictive models and science applications to help improve environmental decision-making among developing nations in eastern and southern Africa, the Hindu-Kush region of the Himalayas and the lower Mekong River Basin in Southeast Asia.	SERVIR Global
UNITAR's Operational Satellite Applications Programme – UNOSAT[64]	UNOSAT is a technology-intensive programme delivering imagery analysis and satellite solutions to relief and development organisations.	UNOSAT Rapid Mapping Service
US State Department Humanitarian Information Unit[65]	The mission of the Humanitarian Information Unit (HIU) is to serve as a US government interagency center to identify, collect, analyse, and disseminate all-source information critical to US government decision-makers and partners in preparation for and response to humanitarian emergencies worldwide.	Commercial Satellite Imagery Request Process

59 Open Data for Resilience Initiative (World Bank). 'Satellite Assets for Emergency Situations – An Overview', https://docs.google.com/document/d/1rOXrcSYHJyV_fvvrsQSG3oWnCxuf1LBSIxeL2NI9HcQ/edit. Accessed July 2018

60 European Commission Copernicus. 'Copernicus Emergency Management Service', http://emergency.copernicus.eu/. Accessed July 2018

61 International Charter Space and Major Disasters. 'The International Charter', www.disasterscharter.org. Accessed July 2018

62 APRSAF. 'Sentinel-Asia: Disaster Management Support System In The Asia-Pacific Region', http://www.aprsaf.org/initiatives/sentinel_asia. Accessed July 2018

63 SERVIR Overview, https://www.nasa.gov/mission_pages/servir/overview.html. Accessed July 2018

64 UNITAR. 'UNITAR's Operational Satellite Applications Programme – UNOSAT', https://unitar.org/unosat/. Accessed July 2018

65 Humanitarian Information Unit, https://hiu.state.gov/. Accessed July 2018

Passive assets are data streams made publically available via the internet for free, as listed in Table 3.

Table 3: Free space derived services available to all via the internet

Disaster type	Initiative	Description (from websites)	Resolution	Refresh rate
Multiple	Copernicus Emergency Management Service[66]	The Copernicus Open Access Hub (previously known as Sentinels Scientific Data Hub) provides complete, free and open access to Sentinel-1, Sentinel-2 and Sentinel-3 user products.	Sentinel 1: 5 meter Sentinel 2: 10 meter Sentinel 3: variable according to sensor	Sentinel 1: 12 days Sentinel 2: 5 days Sentinel 3: variable according to sensor, and latitude
Multiple	DigitalGlobe Open Data[67]	DigitalGlobe is committed to helping everyone See A Better World™ by providing accurate high-resolution satellite imagery to support disaster recovery.	0.3m	Multiple
Multiple	Google Earth Engine[68]	A planetary-scale platform for Earth science data and analysis.	Multiple	Multiple
Multiple	NASA Earthdata Search (previously Reverb/ECHO)[69]	Search, discover, visualize, refine, and access NASA earth observation data.	Multiple	Multiple
Multiple	NASA EOSDIS Worldview[70]	Interactive interface for browsing full-resolution, global, near real-time satellite imagery. Supports time-critical application areas such as wildfire management, air quality measurements, and weather forecasting.	Multiple	Multiple

66 Copernicus. 'Welcome to the Copernicus Open Access Hub', https://scihub.copernicus.eu/. Accessed July 2018

67 Digital Globe. 'Open Data Program', https://www.digitalglobe.com/opendata. Accessed July 2018

68 Google Earth Engine. 'A planetary-scale platform for Earth science data and analysis', https://earthengine.google.com/. Accessed July 2018

69 NASA. 'EARTHDATA Search', https://search.earthdata.nasa.gov/. Accessed July 2018

70 NASA. 'WORLDVIEW', https://worldview.earthdata.nasa.gov/. Accessed July 2018

Disaster type	Initiative	Description (from websites)	Resolution	Refresh rate
Multiple	USGS Earth Explorer[71]	The USGS operates the Landsat satellites and provides a portal to the largest archive of remotely sensed land data in the world, supplying access to current and historical images.	Landsat 7: 15m, 30m, 60m Landsat 8: 15- 100 meter	Landsat 7: 17 days Landsat 8: 16 days
Flood	MODIS Near Real-Time (NRT) Global Flood Mapping Project[72]	NASA's MODIS instrument onboard the Terra and Aqua Satellites provides twice daily near-global flood monitoring at 250 meter resolution.	250m	Twice daily
Flood (Oceans)	Aviso[73]	Access to near real time and archived multi-mission satellite altimeter data for sea level, winds and waves.	7km (along track)	Daily
Flood (Ocean winds)	Metop (EUMETSAT)[74]	Access to near real-time and archived ocean wind data.	25 km	Up to twice daily
Fire	NASA Fire Information for Resource Management System (FIRMS) Active Fire Data[75]	The Fire Information for Resource Management System (FIRMS) was developed, to provide near real-time active fire locations.	MODIS (1 km) and VIIRS (375 m)	Daily
Drought	The Famine Early Warning Systems Network (FEWS NET)[76]	FEWS NET is an early warning and analysis system for food insecurity. It provides evidence-based analysis on 34 countries. Created by USAID to help decision-makers plan for humanitarian crises.	Various	Various

71 USGS. 'EarthExplorer', https://earthexplorer.usgs.gov/. Accessed July 2018

72 NASA. 'NRT Global Flood Mapping', https://floodmap.modaps.eosdis.nasa.gov/projSummary.php. Accessed July 2018

73 AVISO, https://www.aviso.altimetry.fr/en/home.html. Accessed July 2018

74 EUMETSAT. 'METOP', https://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Metop/index.html. Accessed July 2018

75 NASA. 'Fire Information for Resource Management System (FIRMS)', https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms. Accessed July 2018

76 USGS. FEWS 'Project Overview', https://earlywarning.usgs.gov/fews/overview. Accessed July 2018

Additionally, there are several private sector companies that offer access to EO data. The prices can range from a few dollars per square kilometer for archival imagery to more than US$50 per square kilometer for new tasking of multispectral imagery.[77] These companies are listed in Table 4.

New business models are opening opportunities for development and disaster resilience stakeholders to access commercial quality imagery,[78] including older imagery being available for free or at significant discounts, and imagery 'rental' as providers offer analytical and processing services they will create business and pricing models to accompany the provision of the EO data.

Table 4 provides a list of commercial available EO data. The list is not exhaustive but provides a flavour of what is currently available.

Table 4: List of commercially available satellite assets

Company	Description (from websites)	Resolution	Refresh rate
Airbus Defence and Space[79]	Based on a constellation of earth observation satellites, Airbus Defence and Space's geo-intelligence experts offer a sophisticated portfolio: From pure satellite imagery to value-added products and all the way to efficient data management solutions and leading-edge software.	0.25m	Daily
Deimos Imaging[80]	Deimos Imaging, one of the world-leading satellite imagery providers, owns and operates the DEIMOS-1 and DEIMOS-2 satellites.	22m, 0.75m	Every 3 days
DigitalGlobe Open Data[81]	DigitalGlobe is committed to helping everyone See A Better World™ by providing accurate high-resolution satellite imagery to support disaster recovery.	0.3m	Multiple
DMCii[82]	The DMC is a unique earth observation (EO) satellite constellation that delivers high frequency imaging anywhere on the globe from a long established and growing collection of satellites.	2.5m, 5m, 22m, 32m	Daily
MDA[83]	A world-class supplier of space-based and airborne surveillance solutions, satellite ground stations, and associated geospatial information services.	Multiple	Multiple

77 Open Data for Resilience Initiative (World Bank), 'Satellite Assets for Emergency Situations – An Overview', https://docs.google.com/document/d/1rOXrcSYHJyV_fvvrsQSG3oWnCxuf1LBSIxeL2NI9HcQ/edit. Accessed July 2018

78 Satellites in global development. 'The state of satellites', http://landscape.satsummit.io/. Accessed July 2018

79 Airbus. 'Geo-Intelligence Services and Products', http://www.intelligence-airbusds.com/en/11-products-services. Accessed July 2018

80 Deimos imaging. 'Deimos imaging - satellite imagery with top-quality service', http://www.deimos-imaging.com. Accessed July 2018

81 Digital Globe. 'Open Data Program', https://www.digitalglobe.com/opendata. Accessed July 2018

82 DMC International Imaging. 'DMC Constellation', http://www.dmcii.com/?page_id=9275. Accessed July 2018

83 MDA. 'Surveillance and Intelligence', https://mdacorporation.com/corporate/surveillance-and-intelligence. Accessed July 2018

Company	Description (from websites)	Resolution	Refresh rate
Planet[84]	Founded in 2010 by a team of ex-NASA scientists, Planet is driven by a mission to image the entire Earth every day, and make global change visible, accessible, and actionable.	3m and 0.8m	Daily
Telespazio Vega UK[85]	Telespazio is one of the major global suppliers of geospatial application solutions and services. Telespazio VEGA is active in all areas relating to the earth observation market, from acquiring and processing satellite data to developing and selling software and products.	1m	Multiple

84 Planet, https://www.planet.com/. Accessed July 2018

85 Telespazio. 'Geoinformation Services', http://telespazio-vega.com/solutions-services/geoinformation-services. Accessed July 2018

Processing earth observation data

The software tools for processing and analysing satellite data include image processing software and geographical information systems (GIS). This software includes specialised tools that correct and adjust images to improve location accuracy and provide the ability to identify features on the imagery. To automate these processes, these systems use algorithms and functions to extract information from the image. There are four phases to extract information from imagery.

– **Acquisition of raw data:** This is either from archive imagery, recently captured imagery or tasking bespoke requests. Each of these will vary in their complexity, cost and value to different applications. Things to consider include location and date of the features of interest.

– **Conversion of raw data into analysis ready format:** This process can include, but is not limited to, orthorectification, georeferencing and radiometric/atmospheric correction[86], TOPSAR processing, Single Look Complex (SLC) processing and interferometric processing. It is important to consider the types of analysis that will be conducted during the next stage and availability of storage space and computing power.

– **Analysis of the data:** This is a diverse phase that can include manual human interpretation and automated interpretation (through using algorithms to quantitatively analyse the features of interest). This stage also provides visualisation of the data and communication of uncertainty, which are important components for decision makers. EO big data and cloud computing can benefit from artificial intelligence, particularly machine learning algorithms which can analyse terabytes of data, discover hidden patterns, and make accurate predictions which become more accurate as more data is fed to the algorithm. Things to consider here include types of features to be mapped, extent to map, availability of technology and skills.

– **Validation of the outputs:** This involves assessing the validity of the results either by comparing with known values or using reference data (such as field observations to compare with the outputs from the image analysis). Things to consider here include the expertise to understand expected values and the logistics and costs involved when collecting reference data.

International organisations within the space sector are working to reduce the barriers that individuals face when accessing, processing and analysing EO data. While there is a vast amount of EO data available for free, when it comes to downloading and storing the data, there are many logistical challenges.

The European Union's Copernicus programme recently launched the Copernicus Data and Information Access Services (DIAS)[87] to make the process of accessing data and information easier and to avoid issues associated with downloading and storing data. DIAS will provide a cloud-based one-stop shop for all Copernicus satellite data and imagery as well as information from the six Copernicus services, and will also provide access to sophisticated processing tools and resources.[88]

Increasingly, cloud service providers are making EO data and processing available in powerful online storage and computing platforms. An example of this is NOAA's Big Data Project (BDP)[89] in collaboration with several cloud service providers.

86 Orthorectification: uses elevation data to correct terrain distortion in aerial or satellite imagery. Georeferencing: aligning geographic data to a known coordinate system so it can be viewed, queried, and analysed with other geographic data. Radiometric correction: is the process of removing the effects of the atmosphere on the reflectance values of images taken by satellite or airborne sensors. https://support.esri.com/en/other-resources/gis-dictionary. Accessed July 2018

87 European Space Agency, http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Accessing_Copernicus_data_made_easier. Accessed July 2018.

88 As above

89 NOAA. 'Big Data Project', http://www.noaa.gov/big-data-project. Accessed July 2018

Products and services from earth observation

Mapping products derived from satellite imagery are used increasingly in disaster risk management. With hazard mapping, hazards can be observed over time to track changes and update models for risk evaluation. Hazards over large scales and in inaccessible regions can be monitored in this way and multiple hazards can be observed simultaneously. Environmental and human induced changes in landscapes, including urban areas, settlements and natural resources can be mapped to assess changes in exposure to hazards and impacts on risk.

Satellite observations can be performed routinely and calibrated to provide consistent measurements over time for quantitative risk assessment. A high degree of accuracy can be achieved in conjunction with observations from ground-based sensors.

During disaster response, rapid mapping services show the disaster extents and damage to support disaster management and relief planning. Post-disaster progress towards recovery and rebuilding can be monitored by responsible authorities.

Compliance with safety-related legislation (such as building codes) can also be mapped to limit exposure.

Mapping products derived from satellite imagery are increasingly processed into digital map layers and delivered entirely through online services and GIS. Once processed these valuable information layers represent a record and reference for further use in disaster risk management. Online services also allow easy sharing of data related to disaster risk management between stakeholders in the public, private, academic and research sectors. Correctly formatted and with appropriate open data policies they can also be a valuable source of information for citizens and potential source of innovation for data usage.

Sourcing earth observation expertise

Currently, the use of earth observation in disaster resilience is complex and requires significant skill, capability and computing infrastructure. Considerable skills and capabilities are required in the fields of software engineering, geographic information systems (GIS), machine learning, and user interface design to convert the EO data into a decision support system. Computing infrastructure is required including significant data storage capacity, internet bandwidth and processing power.

Therefore, organisations active in disaster resilience such as government, private sector, donors, and NGOs will need to source specialist expertise to support them to apply EO to their disaster scenario.

Table 5 lists some organisations that are part of the UKSA's IPP with the required skills and experience working with EO in disaster resilience. This list is not intended to be exhaustive as there are many other organisations with experience in this sector.

Table 5: List of EO expert organisations in disaster resilience

Company	Description
Airbus Defence and Space[91]	Airbus Defence and Space (ADS) provide satellite services and products based on earth observation technologies.
Ambiental[92]	Ambiental provide advanced tools, data, digital maps and expert advice on flood risk assessment and management, to help predict the location and severity of flooding, prevent damage, and protect lives, property and assets.
British Geological Society[93]	A world-leading geoscience centre for: survey and monitoring; modelling and research; data and knowledge.
Rheatech[94]	Develop earth observation applications that address global environmental issues.
Satellite Applications Catapult[95]	A world-leading technology and innovation company, helping the UK realise the potential from satellite applications and space data.
Satellite Oceanographic Consultants[96]	Expert consultancy on the applications and exploitation of satellite oceanography.
Stevenson Astrosat[97]	Experts at sourcing, analysing and deploying satellite driven data. Everything from regional geology maps to global weather data, helping you plan and track your next big project.

Academic earth observation expertise

The academic sector is a source of considerable interdisciplinary expertise in research and applied remote sensing and earth observation. The university and research community[97] holds unique knowledge of hazards for disaster risk management and frequently incorporates EO data into advanced monitoring and modelling. Research networks for disaster risk research and policy development include the European Union Disaster Management Knowledge Centre[98].

90 Airbus. 'Earth Observation', https://www.airbus.com/space/earth-observation.html. Accessed July 2018

91 Ambiental, http://www.ambiental.co.uk/. Accessed July 2018

92 British Geological Survey, http://www.bgs.ac.uk/. Accessed July 2018

93 Rhea Group. 'Earth Observation', https://www.rheagroup.com/earth-observation. Accessed July 2018

94 Satellite Applications Catapult, https://sa.catapult.org.uk/. Accessed July 2018

95 SATOC, http://www.satoc.eu/. Accessed July 2018

96 ASTROSAT, https://www.astrosat.space/. Accessed July 2018

97 C. Dickinson, A. Aitsi-Selmi, P. Basabe, C. Wannous, and V. Murray, 'Global Community of Disaster Risk Reduction Scientists and Decision Makers Endorse a Science and Technology Partnership to Support the Implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030', International Journal of Disaster Risk Science, vol. 7, no. 1, pp. 108-109, March 2016

98 European Union Disaster Management Knowledge Centre, https://drmkc.jrc.ec.europa.eu. Accessed July 2018

International organisations

Intergovernmental organisations (IGO)[99] and international non-governmental organisations (INGO)[100] have an important role in the use of EO for disaster resilience. These organisations have significant knowledge, influence on regulation and policy, networks, and funding opportunities within their respective mandates.

Table 6: International organisations supporting space solutions for disaster resilience

Company	Description
Committee on Earth Observation Satellites[102]	CEOS ensures international co-ordination of civil space-based earth observation programs and promotes exchange of data to optimise societal benefit and inform decision making for securing a prosperous and sustainable future for humankind. CEOS has a working group (WGDisasters) that aims to increase and strengthen satellite earth observation contributions to the various Disaster Risk Management (DRM) phases.
European Space Agency[103]	The European Space Agency, together with other organisations, is contributing its space infrastructure towards enabling more effective response to emergencies, whether they are large natural disasters or small remote events. Several ESA programmes and projects include elements specifically related to disaster risk including the joint ESA and World Bank initiative EOWORLD2.[104]
GEO[105]	The Group on Earth Observations (GEO) is an intergovernmental organization working to improve the availability, access and use of earth observations for the benefit of society. They have a 2017-2019 work programme for Earth Observations for Disaster Risk Management.[106]
Global Facility for Disaster Reduction and Recovery (World Bank)[107]	GFDRR is a global partnership that helps developing countries better understand and reduce their vulnerability to natural hazards and climate change. GFDRR has an initiative called OpenDRI[108] which brings the philosophies and practices of the global open data movement to the challenges of reducing vulnerability and building resilience to natural hazards and the impacts of climate change across the globe.

99 Wikipedia. 'Intergovernmental organization', https://en.wikipedia.org/wiki/Intergovernmental_organization. Accessed July 2018

100 Wikipedia. 'International non-governmental organization', https://en.wikipedia.org/wiki/International_non-governmental_organization. Accessed July 2018

101 Committee on Earth Observation Satellites. 'Overview', http://ceos.org/about-ceos/overview/. Accessed July 2018

102 ESA. 'Disaster Relief and Emergency Management', http://www.esa.int/Our_Activities/Preparing_for_the_Future/Space_for_Earth/Space_for_health/Disaster_Relief_and_Emergency_Management. Accessed July 2018

103 ESA. 'ESA and the World Bank Join Forces', http://www.esa.int/Our_Activities/Observing_the_Earth/ESA_and_the_World_Bank_join_forces. Accessed July 2018

104 Group on Earth Observations. 'Earth Observations for the Benefit of Humankind', http://earthobservations.org/index2.php. Accessed July 2018

105 Group on Earth Observations. 'Earth Observations for Disaster Risk Management', http://earthobservations.org/activity.php?id=87. Accessed July 2018

106 GFDRR, https://www.gfdrr.org/en. Accessed July 2018

107 Open Data for Resilience Initiative, https://opendri.org/. Accessed July 2018

Company	Description
GSMA Disaster Response[109]	Through this global initiative, the Disaster Response Programme will use its unique position to lead the mobile industry in improving network preparedness and restoration, and providing more effective, co-ordinated support to humanitarian responders and disaster affected populations.
GVF[110]	GVF has become the single and unified voice of the global satellite communications industry. Headquartered in London, with a regional office in Washington DC and global affiliates, the GVF is an independent, non-partisan and non-profit organisation with 200+ members from every major region of the world.
NETHOPE[111]	NetHope joins the world's largest non-profits with technology innovators worldwide. We act as a catalyst for productive collaboration, innovation, and problem-solving to reimagine how technology can improve our world.
UNITAR's Operational Satellite Applications Programme – UNOSAT[112]	UNOSAT is a technology-intensive programme delivering imagery analysis and satellite solutions to relief and development organisations.
UNOOSA[113]	The United Nations Office for Outer Space Affairs (UNOOSA) is the United Nations office responsible for promoting international cooperation in the peaceful uses of outer space. United Nations Platform for Disaster Management and Emergency Response (UN-SPIDER) ensures that all countries and international and regional organizations have access to and develop the capacity to use all types of space-based information to support the full disaster management cycle.
Telecoms Sans Frontier[114]	TSF is the only NGO in the world specializing in emergency telecommunications and new technologies.

Additional reading and resources

- Satellite Earth Observations in Support of Disaster Risk Reduction (CEOS and ESA)
- Sharing Space-Based Information: Procedural Guidelines for Disaster Emergency Response in ASEAN Countries (UN ESCAP, UNOOSA)
- Satellite Assets for Emergency Situations – An Overview (Live Document) (World Bank – OpenDRI)
- Using high resolution satellite data for the identification of urban natural disaster risk (World Bank, Institute for the Protection and Security of Citizens, JRC European Commission, GFDRR)
- Disasters Webinars (NASA)

108 GSMA. 'Disaster Response', https://www.gsma.com/mobilefordevelopment/programmes/disaster-response. Accessed July 2018
109 GVF. 'About', https://gvf.org/about-gvf/about-gvf.html. Accessed July 2018
110 NETHOPE, https://nethope.org/. Accessed July 2018
111 UNITAR. 'UNITAR's Operational Satellite Applications Programme – UNOSAT', https://unitar.org/unosat/. Accessed July 2018
112 UNOOSA, http://www.unoosa.org/oosa/index.html. Accessed July 2018
113 Telecoms Sans Frontier, http://www.tsfi.org/en. Accessed July 2018

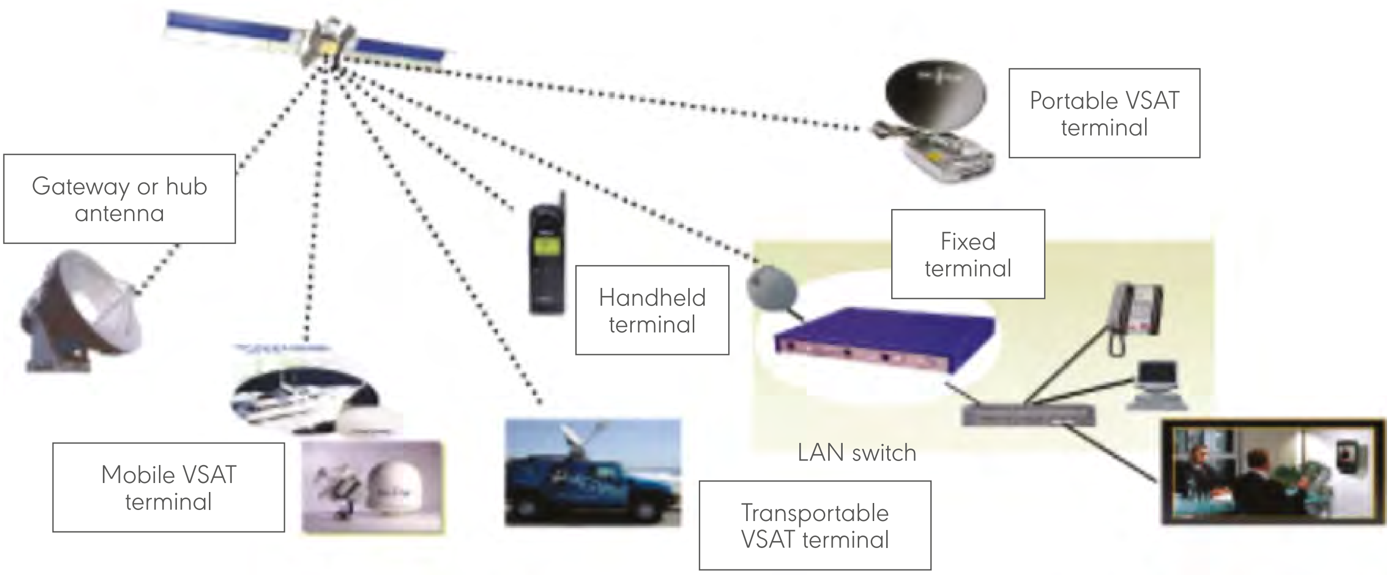
SatComms

Satellites, being space based, are unaffected by disasters and provide valuable communications post-disaster. They can provide emergency communications for government, donors, NGOs and the private sector. They also support the resilience of terrestrial mobile networks, which is critical to allow accessible communications to the wider public. They can connect rural areas that are unreachable by terrestrial networks. By design, satellites have near global coverage that make them a crucial part in response to natural disaster and emergencies.[114]

SatComms disaster resilience use cases

To utilise SatComms for disaster resilience, organisations including government, donors, NGOs and private sector, must define and plan the type of terminals they will need before and after an emergency. This planning requires an understanding of the different use cases and capabilities of the various system types outlined below.

Figure 12: High level typology for satellite communications[115]



114 Geeks without frontiers. 'Community Connect', http://geekswf.org/wp-content/uploads/2017/10/Community-Connect-Master-18-Oct-2017-Final.pdf. Accessed July 2018

115 As above

Under the typology in Figure 12, satellite communications support disaster resilience, as follows:[116]

– **Handheld mobile satellite communications (handheld terminal):** If terrestrial networks are absent or damaged, handheld satellite telephone systems provided by mobile satellite service providers can be used for voice communications. The handheld terminals are small, mobile phone sized devices, starting as US$40 per week for rental, US$400 to US$2000 for purchase, with tariffs on a per-minute basis, starting at under a dollar a minute.

– **Portable and transportable mobile satellite communications (mobile and transportable VSAT terminal):** These are transported and operated from inside a car, truck or maritime vessel, as well as in helicopters and other aircraft. They are used for data-intensive, high-speed connections for services such as damage assessment, command and control, and other applications for voice, video and data. Depending on the satellite system and type of equipment, they can be up and running from 5 to 30 minutes usually without the support of expert technical staff and deployed anywhere. Higher price for satellite terminal prices translates to more robust service, higher reliability, faster delivery and a wide range of other features and options.

– **Fixed satellite communications (fixed terminal):** These are used when the equipment is required for longer time periods (under one week) and very high bandwidth uses such as full broadcast-quality video and substitution for terrestrial network infrastructure. Scenarios include pre-disaster applications such as redundancy for terrestrial networks, high bandwidth service to remote regions, as well as post-disaster recovery operations. Qualified technical teams are required to install such equipment.

Modern High Throughout Satellites (HTS) are providing cost effective, faster, high quality communications and broadband services. The ground-based terminals used to receive satellite signals have decreased materially in size and dropped in cost (under US$300 compared to nearly US$10,000 a decade ago). A recently launched service in sub-Saharan Africa is offering data plans that offer a 10GB monthly volume limit (through to unlimited) with download speeds of up to 20 Mbps, starting at US$30 depending on the geography. Recent innovations have brought down the cost of installation to a few hundred US dollars and, depending on the distributors and the countries, and installation time to as little as 2.5 hours.[117]

Sourcing SatComms suppliers

There are many global satellite network operators, and in addition regional or national operators, providing the fixed and mobile SatComms services. Also, there are several operators of systems providing service to handheld satellite phones.

For fixed and mobile SatComms services, disaster resilience organisations can either procure directly from the satellite network operators themselves or procure through a wide range of resellers and network integrators that provide end-to-end communications services, including VSAT terminals and satellite bandwidth access. Handheld satellite phones can be bought or leased through local resellers through a service contract, and these companies can be easily found through the internet.

116 Geeks without frontiers. 'Community Connect', http://geekswf.org/wp-content/uploads/2017/10/Community-Connect-Master-18-Oct-2017-Final.pdf. Accessed July 2018

117 As above

Table 7 is not intended to be exhaustive as there are many other organisations with experience in this sector. For an extensive list of satellite network operators see the 'disaster preparedness' section of the member directory hosted by GFV.[118]

Table 7: Selection of satellite network operators

Company	Description
Avanti[120]	Avanti Communications Group is a leading satellite operator, providing Ka-band satellite data communications services across the UK, Europe, the Middle East and Africa.
Eutelsat[121]	Through capacity commercialised on 39 satellites positioned to serve users in 150 countries in Europe, Africa, Asia and the Americas, Eutelsat is one of the world's leading satellite operators.
Inmarsat[122]	As the industry leader and pioneer of mobile satellite communications, Inmarsat has been powering global connectivity for nearly four decades. They offer an unrivalled portfolio of global satcom solutions and value-added services to keep you connected at all times – whether travelling on land, at sea or in the air.
Intelsat[123]	Intelsat operates the world's first Globalized Network, delivering high-quality, cost-effective video and broadband services anywhere in the world. Intelsat's Globalized Network combines the world's largest satellite backbone with terrestrial infrastructure, managed services and an open, interoperable architecture to enable customers to drive revenue and reach through a new generation of network services.
Viasat[124]	Viasat is the global communications company that believes everyone and everything in the world can be connected. For more than 30 years, Viasat has helped shape how consumers, businesses, governments and militaries around the world communicate.

Additional reading and resources

- Community Connect: Best Practices for Satellite Network Operators, Regulators, and Service Providers and Integrators (Geeks without frontiers)
- Crisis Connectivity Charter (Emergency Telecommunications Cluster, United Nations Office for the Co-ordination of Humanitarian Affairs, ESOA, GVF)
- First Responders Guide to Satellite Communications (Satellite Industry Association)
- Satellite Communications: An Essential Tool For Emergency Management And Disaster Recovery (Disaster Resource Guide)
- Humanitarian Connectivity Charter Annual Report 2016 (GSMA)
- Utilization of telecommunications/ICTs for disaster preparedness, mitigation and response (ITU-D)

118 GVF. 'Member Directory', https://gvf.org/about-gvf/membersdirectory.html?view=companyprofiles&type=solutions&search=22. Accessed July 2018

119 Avanti. 'About', http://www.avantiplc.com/. Accessed July 2018

120 Eutelsat. 'Our Business', http://www.eutelsat.com/en/group/our-business.html. Accessed July 2018

121 Inmarsat. 'About us', https://www.inmarsat.com/about-us/. Accessed July 2018

122 Intelsat. 'The Intelsat Globalized Network', http://www.intelsat.com/about-us/overview. Accessed July 2018

123 Viasat. 'About Viasat', https://www.viasat.com/about. Accessed July 2018

Global Navigation Satellite System

GNSS is critical to many aspects of solutions for disaster resilience. Networks of GNSS receivers and receiving stations provide infrastructure[124] for national positioning services and geodetic reference. For emergency response, GNSS allows for accurate and consistent georeferenced incident data. This assists many activities including: search and rescue; asset and personnel location; and debris management. GNSS is also valuable for re-mapping in recovery and reconstruction.

GNSS allows precision monitoring. For seismology, the monitoring and alerting of surface deformation over wide areas is possible. Commercial rugged GNSS receivers are available that include integrated seismic instruments and recorders.

Early warning systems for tsunami (ocean wave) typically employ GNSS on buoys in open ocean to measure water depth and ocean surface displacement.

Sensors on ground and satellites are increasingly making use of GNSS signals for meteorology, in particular the measurement of atmospheric water vapour essential to forecasting precipitation (rainfall).

GNSS-R Reflectometey (GNSS-R) is a rapidly evolving technique able to measure ocean mesoscale features, initially in sea-state (see the US CYGNSS mission).

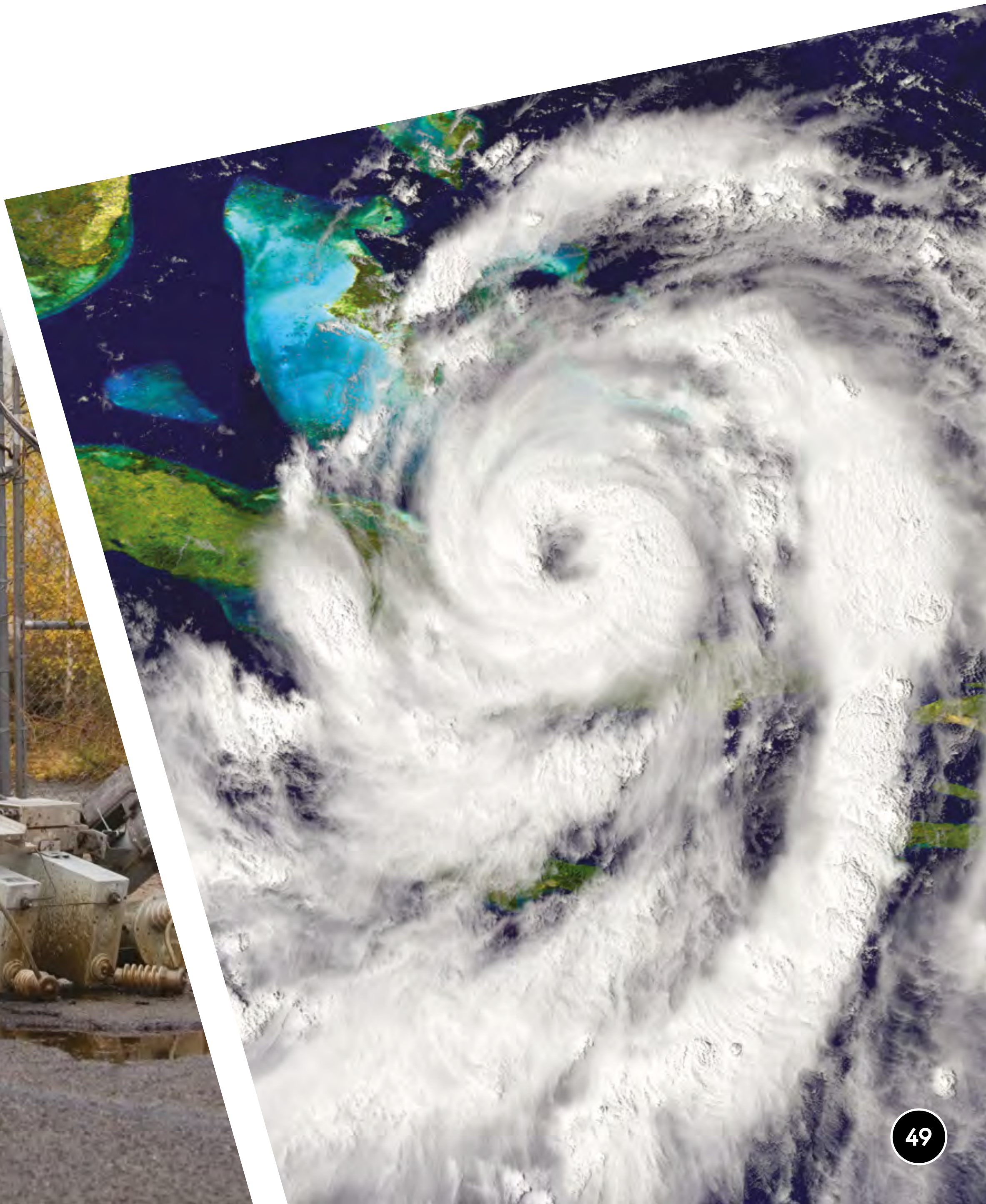
GNSS is also integral to location-based social media as an increasingly valuable source of incident information.

Cyclone damaged power lines ▲

124 Geoscience Australia, 'National Positioning Infrastructure Capability', http://www.ga.gov.au/scientific-topics/positioning-navigation/positioning-for-the-future/national-positioning-infrastructure. Accessed July 2018

Annex A: IPP disaster resilience projects

IPP currently has 11 disaster resilience projects with a group starting in January 2017 and another group in March 2019, and are in their early phases. As such, it is too soon to identify results and lessons. These case studies will be updated in the later stages of IPP to capture and communicate results and lessons.



Aerial view of a Maasai village in Kenya ▶

Airbus Defence and Space

Earth observation-enabled decision support for flood and drought resilience in Ethiopia and Kenya

Project overview

- **Target countries:** Ethiopia and Kenya
- **Project lead:** Airbus Defence and Space
- **Project consortium:** Oxford University, Sayers and Partners LLP (SPL), GeoSAS Ltd, Vivid Economics
- **International partners:** Ethiopian Development Research Institute (EDRI), Building Africa (BUA) Kenya

United Nations Sustainable Development Goals

Project objectives and impact

The overall aim of the project is to use satellite images, hydrological, hydraulic and economic modelling to help decision makers improve resilience to flood and drought in Ethiopia and Kenya.

In Ethiopia, the objective is to provide decision makers (government, donors and investors) with improved information on the economic consequences of flood and drought to better co-ordinate land and infrastructure development, manage natural resources and target social security and emergency response policies. The target is to achieve a 0.5% reduction in population exposed to flood in the Awash river basin by 2024, compared to pre-project levels. This will be done by enabling the government to make decisions about where best to make infrastructure investments or land use changes.

In Kenya, decision makers (in insurance markets), will be able to use better information on risks to increase insurance coverage through more effective product and price competition. This will be measured by a reduction in the population at risk from hunger by 2019 compared to pre-project levels, by demonstrating the efficacy of EO data for the micro-insurance market.

In both countries, the project will also aim to substantially increase local capacity for policy making and the development of insurance products where this uses EO information.

Satellite solution

At the centre of this project is a user-friendly online dashboard employing satellite EO data, hydrological and economic modelling, and machine learning techniques to map risks and vulnerabilities to flood and drought. The mapping platform will provide risk and vulnerability information for three-time horizons: current, future, and immediate. It will integrate satellite imagery on: land use and topology; hydrological models of watersheds; economic models of the relationship between agricultural production and economic outcomes; and future climatic, demographic, and economic projections.

It will provide more detailed information on the threats posed by floods and droughts than is currently available by using the ESA's Sentinel 2 satellite, augmented with Airbus' UK-DMC2 satellite (and KAZ-ST-SAT as its successor once launched) to ensure the best chance of cloud-free coverage. This will offer greatly improved resolution both spatially and temporally.

The system will be able to detect drought or flood struck areas, map the relevant degree of severity and (in Kenya) support decisions on the payouts of insurance to eligible farmers by providing a Vegetation Health Index, a significant improvement to the current weather-based systems. The Vegetation Health Index uses satellite imagery at the level of individual farmer fields to monitor crops through the growing season. End users can use this information to take preventative measures to improve their yields, and (in Kenya) insurers will be better able to accurately predict individual farm risk levels.

Sustainability model

Ensuring there is sufficient local ownership of the tool in both Ethiopia and Kenya is key to the success of this project. Target audiences will be trained at all crucial stages to ensure that the analytical tools and recommendations are transferred. These will be supported by written training materials and user guides to ensure sustained knowledge transfer.

The costs of maintaining and expanding the system after project completion are limited, as core analytic tools are designed to draw upon readily available data sources including primary satellite data. At the same time, the costs of these updates will gradually fall due to machine learning, so the capacity to use and adapt the system to new challenges will be key to long-term uptake of the service. To ensure the long-term commercial success of the project, key stakeholders in both countries are being targeted.

For Ethiopia as a centralised economy, the key stakeholders for sustainability of the project are at ministry level. For the government to implement the planned 'Climate Resilience Green Economy', long term procurement of this service is intended to provide value for money in making key planning and investment decisions in the Awash basin and more broadly across the country.

For Kenya, the intention is to demonstrate the efficacy of satellite data to provide government ministries and farmers with accurate and up-to-date information about the health of crops. Of particular importance is to take vegetation health indices, as an alternative or enhancement to traditional weather station data, and to embed this within the micro-insurance company's business models and enable wider uptake of micro-insurance. By engaging with various national insurance providers (as well as relevant government ministries) the project aims to encourage long-term commercial uptake of the service.

Avanti Communications

Satellite enablement for disaster risk reduction in Kenya (SatDRR)

Project overview

- **Target countries:** Kenya
- **Project lead:** Avanti Communications
- **Project consortium:** Airbus Defence and Space, Kenya Red Cross Society, Global RadioData Communications, Torchlight Group

United Nations Sustainable Development Goals

Project summary

Kenya is prone to both slow-onset natural disasters like droughts and rapid-onset disasters like floods, mudslides and disease outbreaks. Climate change is leading to increases in both the frequency and intensity of natural disasters, while population growth, regional unrest and forced population movement drives conflict. The recurrent nature of these disasters in Kenya inherently affects the capacity of communities to recover, which lowers economic output and holds back development year on year.

Effective, well-organised and prepared responses help mitigate the effects of disasters. Satellite systems provide a secure, resilient, always-on infrastructure in disaster situations – providing critical tools for emergency communications and situation assessment.

Working with government agencies and the Red Cross Society in Kenya, Avanti and its partners will undertake a disaster risk reduction (DRR) development programme, which will use satellite technology to improve Kenyan capacity to effectively plan for and respond to disasters.

The project will support the development of Kenyan agencies and responders by:

- engaging with Kenyan partners to understand their disaster management priorities, identify solutions and embed capability through policy support, knowledge transfer, specialist training and field exercises
- building the capacity of Kenyan staff to prepare, deploy and utilise satellite services for DRR
- provide a pilot platform for local actors to deploy satellite communication and EO services for DRR
- enhancing co-ordination, command and control of disaster response at local, regional and national level

Nairobi, Kenya ▼

Satellite solution

SatDRR Kenya will demonstrate the added value of satellite services for disaster management, in particular:

– the use of satellite communications to provide both a national resilient infrastructure and effective post-disaster communications where terrestrial alternatives are compromised

– how EO data can be used to support more effective strategic planning, situational awareness for delivery of disaster relief and monitoring recovery activities post-crisis

The project will provide secure fixed and mobile satellite communications via Avanti's Ka-band satellite, HYLAS 2, for emergency situations such as famine, floods and disease outbreak. The project will also provide a flexible web-based dashboard offering a variety of tailored EO information services so users can access information on large-scale disasters such as floods and droughts from a variety of satellite data sources.

Access to satellite services will be underpinned by a capacity building and knowledge transfer programme.

Project impact

The overall goal of the project is to strengthen Kenyan capacity for disaster prevention, preparedness, response and recovery using communication and EO satellite services. This will:

– reduce human, social and economic impact of disasters on affected communities

– increase investment in disaster risk reduction, leading to savings in the cost of response and recovery

– Sustainably exploit satellite services, leading to ongoing DRR benefits in Kenya

British Geological Survey

Modelling Exposure Through Earth Observation Routines (METEOR)

Project overview

- **Target countries:** Nepal and Tanzania
- **Project lead:** British Geological Survey
- **Project consortium:** Humanitarian Open StreetMap, ImageCat Inc, Oxford Policy Management, Fathom, Global Earthquake Model (GEM)
- **International partners:** National Society for Earthquake Technology (NSET) (Nepal), Disaster Management Department, Prime Minister's Office (Tanzania), National Society for Earthquake Technology (NSET) (Nepal)ImageCat Inc, Oxford

United Nations Sustainable Development Goals

Project summary

The escalating impacts of natural hazards are caused mostly by increasing exposure of populations and assets. It is estimated that the world will see the construction of one billion new dwellings by 2050 and this growth may lead to rapid increase in risk.

A major challenge when making disaster risk management (DRM) decisions in official development assistance (ODA) countries is poor understanding of the distribution and character of exposure to these hazards. METEOR takes a step-change in the application of EO exposure data to allow quantitative assessment of exposure, leading to better-informed DRM decisions.

Working with partners in Nepal and Tanzania, we will test and validate the process of producing and utilising exposure data. Co-designing results internationally will help improve response to hazards and promote welfare and economic development. Country-wide, openly-available exposure data will be rolled out for the 48 least developed ODA countries.

Project objectives

The project objectives are to:

- increase the resilience of Nepal and Tanzania to natural hazards through integration of robust and open building exposure data derived from satellite data
- improve capacity for stakeholders in the use of exposure data in disaster risk reduction and DRM in Nepal and Tanzania
- deliver robust and open protocols for exposure development
- deliver open-source, national-scale building exposure data for all 48 counties on the DAC list of least developed ODA recipients
- directly contribute to UN Sustainable Development Goals and Sendai framework by improving resilience and adaptive capacity to hazards and substantially increasing the availability of and access to disaster risk information

Satellite solution

METEOR will improve upon existing EO methods for characterising the built environment. Working in unison with our partners and end users, we will develop and share protocols to produce robust exposure information and promote its use to strengthen the resilience and adaptive capacity of Nepal and Tanzania (in particular) to natural disasters. The application of EO data allows us to utilise the same robust process across borders, which is a critical issue when using traditional census data that tend to have different classification systems and protocols. EO tools offer the most effective way to produce consistent and open exposure in data poor countries, many of which have rapidly-expanding urban areas.

Project impact

- To substantially increase the availability of (and access to) more robust disaster risk information for all 48 countries on the DAC list of least developed ODA recipients
- To strengthen the resilience and adaptive capacity to natural disasters of Nepal and Tanzania
- To build a network of stakeholders better placed to act as leaders of DRM/DRR in their geographic region

Overlooking Namche Bazar, Nepal, epicentre of earthquake ▶

Clyde Space

FireSat

Project overview

- **Target countries:** South Africa, Kenya, Namibia
- **Project lead:** Clyde Space Ltd
- **Project consortium:** University of Strathclyde; Satellite Applications Catapult
- **International partners:**
  South Africa: SANSA; CSIR; Department of Science and Technology; Cape Peninsula University of Technology (CPUT); Stone Three (S3)
  Kenya: Technical University of Kenya
  Namibia: Namibian Institute of Space Technology

United Nations Sustainable Development Goals

Project objectives and impact

The ultimate objective of FireSat is to reduce the human and financial costs of wildfires in southern Africa significantly. It will do this by providing the international partners with the ability to detect small area fires (of $90m^3$). In addition to this overarching impact, the project will:

- build the technical skills base in southern Africa by funding 9 MSc and 3 PhD studentships through Cape Peninsula University of Technology, Namibian University of Science and Technology, Technical University of Kenya in South Africa and University of Strathclyde in the UK
- further the use of satellite technology in infrastructure/applications development in southern Africa

Satellite solution

The existing Advanced Fire Information System (AFIS) is used in 70 countries and is the national fire information system in South Africa where it was initially developed. The system works, at present, by providing a service which enables users to input details of fires which they observe from the ground and utilises a few existing satellite platforms. The existing system can only provide high temporal resolution or high spatial resolution, not both. The FireSat, solution inputs new space-based data streams into AFIS, at a higher spatial and temporal resolution, enabling a significant step change in detecting and preventing small fires from escalating into wildfires. This is done via the launch of a constellation of small satellites.

There are two options for constellations being assessed for the FireSat Mission. One would be deployed from the International Space Station (ISS) and one deployed into a Sun Synchronous Orbit (SSO). The ISS solution would give a slightly higher revisit rate over the African regions and a better spatial resolution, but the lifetime of the satellite would reduce based on the lower orbit altitude.

Figure 13: Ground station coverage and FireSat area of interest

The ground stations, which are being installed, will be utilised once the constellation is in place. This ground station network will be available to realise low-latency data retrieval, in most cases this will offer real time data download (while in view of the ground station). Figure 13 shows the ground station coverage (red circles) and the area of interest (green box).

Sustainability model

The FireSat system will deliver an operational in-country capability for fire detection. It will also support capacity building on the development and usage of low-cost nanosatellites in southern Africa. In addition to the academic trainings above, the FireSat project will train delegates from each of the three countries involved on the use of Missions Lab infrastructure for continued use of the project outputs.

FireSat will ensure commercial sustainability of the project through its integration with AFIS. Going forward, AFIS is expected to support the operational requirements and provide funding of the mission, with the intention to grow a stronger, self-sustaining solution.

Bushfire in South Africa ▲

eOsphere Limited

SIBELIUs: Improved resilience for Mongolian herding communities

Project overview

- **Target countries:** Mongolia
- **Project lead:** eOsphere Limited
- **Project consortium:** Deimos Space UK, University of Leicester, Micro-insurance Research Centre UK (MIRCUK)
- **International partners:** National Agency for Meteorology and Environmental Monitoring of Mongolia (NAMEM), Agricultural Reinsurance (AgRe), Ministry for Agriculture and Light Industry, Administration for Inter-Aimag Otor Pastureland Use and Co-ordination, Center for Nomadic Pastoralism Studies (CNPS)

United Nations Sustainable Development Goals

Project summary

Mongolia is a large and extremely rural country with approximately 30% of its population dependent on livestock herding. These populations are exposed to extreme weather events, known as dzuds, which are increasingly exacerbated by climate change and are highly damaging to Mongolia's economy and devastating for the poorest herders. A typical dzud can impact tens of thousands of herders, many of whom will lose all their livestock leaving them in extreme poverty, with associated impacts for the wider economy.

SIBELIUs will provide greater dzud-resilience for herders by providing Mongolia's National Agency for Meteorology and Environmental Monitoring (NAMEM) with improved capacity for distributing new and upgraded environmental products to key stakeholders supporting herding communities. An aspect of the project is to channel the benefits of improved products through three existing networks:

- the Mongolian Index Based Linked Livestock Insurance scheme (set up by the World Bank in 2006)
- Otor Grazing Reserves which provide emergency grazing for use in dzuds
- NAMEM's existing network of regional centres

As a vital component of the project, SIBELIUs will work with herders at selected case study sites to analyse their information requirements, to better understand barriers to uptake of previous insurance products, and to ensure their voices and priorities are heard in the development and distribution of new satellite-based environmental products.

Satellite solution

SIBELIUs will improve the dzud-resilience of the Mongolian herding population by integrating satellite-derived environmental information into existing government and insurance networks. Mongolia's herding communities can be devastated by dzuds, usually comprising a dry summer, adversely affecting pasture growth, followed by a cold winter with deep snow. Key satellite derived products will include those providing information on grazing capacity, snow depth and 'dzud risk maps' aiming to predict the likelihood of dzud events in advance.

Project impact

– Improve the dzud-resilience of the Mongolian herding population by better integrating new satellite-derived environmental information into existing government and insurance networks

– Assist in building capacity at Mongolia's National Agency for Meteorology and Environmental Monitoring (NAMEM) for distributing new and upgraded environmental products to key stakeholders supporting herding communities

– Work with local stakeholders, including herding households at case study sites, to co-produce and design products in order to take account of their needs and requirements

– Provide access to new sources of satellite data to facilitate new improved high resolution regionally sensitive dzud prediction products and grazing capacity information for distribution to end users: regional meteorological centres, the insurance sector and the Otor Reserve Administration

– Aim to decrease the number of directly affected persons and direct economic losses attributed to dzud related disasters

– To further develop and strengthen links between UK and Mongolian institutions for better understanding and tackling climate-related extreme events

▼ Mongolian livestock

Inmarsat

Reducing the impact of natural disasters by using SatComms

Project overview

- **Target countries:** Philippines
- **Project lead:** Inmarsat Global Plc
- **Project consortium:** Satellite Applications Catapult, Télécoms Sans Frontières (TSF), TD International, Devex
- **International partners:** Department of Social Welfare and Development (DSWD), Philippines

United Nations Sustainable Development Goals

Project objectives and impacts

The central aim of this project is to improve welfare and economic development in the Philippines through improved disaster resilience, preparedness and response. It does this by prepositioning powerful but easily deployable equipment, supported by training, for national and local disaster response communications. Deployment to disaster areas provides the infrastructure to run at scale and quickly with the national co-ordinating authority as project partner.

The project will: design and install solutions and systems; deliver connectivity; establish management arrangements; and train and exercise people to create widespread operational capability for satellite-based disaster communication management.

It will bring the following benefits to the pilot regions in the Philippines:

- communities that are more resilient to disasters
- independent resilient capability to the southern regional centres to communicate between the local disaster response command centres and regional and national disaster command centres (Manila) in the pilot
- reduced deaths, injuries, and disease, as well as lessened human suffering through loss of shelter, food deprivation, and social ties

Satellite solution

Despite significant progress made in the Philippines, there remains significant need for improved communications in emergency situations. The project will deploy five new pieces of Global Xpress (GX) satellite equipment, which are easily transportable and with capacity in order of magnitude more than earlier systems. Global Xpress (GX) terminals allow communications at high speeds for emergency response teams and therefore provide a step change for disaster response.

Ten BGAN terminals will also be used in this project to complement the larger bandwidth GX solution for smaller regions near the affected city.

Figure 14: Solution architecture

CONCEPT OF OPERATIONS

The solution contains highly mobile medium bandwidth BGANs (which use Inmarsat 4 global satellite network) and portable high bandwidth GX (which use the Inmarsat 5 global satellite network). For highly mobile relatively low bandwidth solution, two kinds of BGANs are being used (Manual and Auto Pointing).

– For manual pointing, the Cobham explorer 710 terminal is an ultra-portable BGAN terminal, which supports high data rate (HDR) streaming of up to 650 kbps. It introduces smartphone apps to the world of BGAN connectivity, enabling users to wirelessly connect their own devices for voice calling and data connectivity. It is world smallest and lightest Class 1 BGAN terminal and the first platform to make use of Inmarsat HDR streaming services.

To facilitate an out-of-the-box solution, Inmarsat has also provided the MCD-4800 Mobile Communications Device (also known as 'the football'), an auto-pointing BGAN satellite terminal that requires no user training to operate. It is a powerful Wi-Fi hotspot accessible by any wireless device within a 100-metre range for up to five hours on internal battery power. It is enclosed in a watertight hardened plastic Pelican case, and the case lid does not need to be opened in order for it to fully function. It operates in heavy rain, will transmit with up to 20mm of ice build-up and can withstand immersion in water up to a metre. An external battery is included in the provided solution to extend the battery life by another four hours.

For high bandwidth in a transportable solution, Inmarsat 5th Generation Ka band satellite platform called Global Express (GX) is being used. It is a rugged and portable auto-acquire system configured specifically for operation on the Inmarsat Global Express network. The terminal also comes with embedded wide local area network (WLAN) access point and four local area network (LAN) interface. An LCD panel and one click auto-acquire enables the user to access the satellite network within minutes.

Sustainability model

Nationally, disaster response in the Philippines is organised around an effective inter-departmental national disaster council, which has demonstrated the ability to innovate and learn from disaster scenarios. Consequently, the Philippines provides an excellent testing ground for a new technology or practice into the disaster response toolkit – they have the need, they have the infrastructure to embed and sustain new capabilities, and lessons from the Philippines can be quickly scaled across the region and to other disaster-prone countries.

Sustainability will be achieved by demonstrating to DSWD (the lead agency on disaster preparedness and response) the effectiveness and speed of implementation and ease of use of Inmarsat mobile SatComms solutions.

It is expected that budgets will be assigned within the DSWD to fund the programme outcomes either to the same scale or larger from March 2019. This requires the influencing of key stakeholders to ensure they are aware of the programme, view it positively and ensure that funding decisions are made in the Philippines government in time for implementation in 2019.

Other opportunities that may arise and be exploited from either utilising the knowledge gained from the project and selling similar products and services in a resilience scenario to: other agencies of the Philippines government; local government in the Philippines; other government suffering from similar disaster resilience conditions; or commercial organisations interested in boosting their network resilience in the event of a disaster.

◄ Manila, Philippines

Rheatech

Drought and Flood Mitigation Service (DFMS)

Project overview

- **Target countries:** Uganda
- **Project lead:** Rheatech
- **Project consortium:** Environment Systems, Pixalytics, Databasix, AA International, AgriTechTalk International, HR Wallingford, UK Met Office, Mercy Corps, Oxford Policy Management
- **International partners:** Ministry of Water and Environment, Uganda; Kakira Sugar Company

United Nations Sustainable Development Goals

Project objectives and Impact

This DFMS project aims to provide accurate flood and drought predictions to a range of farmers, from subsistence to large commercial, so that they can use that information to adjust their farming and livestock activities. This would have the ultimate impact of reducing agricultural losses they would otherwise suffer from flood and drought impacts or significant changes in the seasonal weather. It aims to:

- improve crop yields and livestock condition
- improve gross income of small-holder farmers and pastoralists

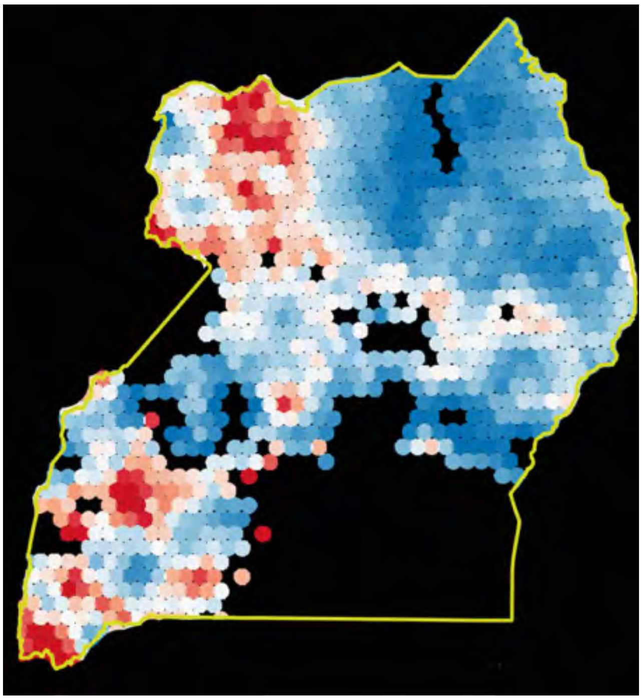
In parallel, it also aims to build the capacity of the government agencies responsible for early warning systems to use flood and drought predictions to improve their ability to support farmers in case they were affected by flood or drought impacts.

Satellite solution

The Drought and Flood Mitigation Service (DFMS) will be delivered on a new, open, easy-to-use and scalable early warning platform (EWP) that will integrate multiple data sources, models and services. The platform is designed to assimilate heterogeneous data sources ranging from satellite and meteorological data, as well as community and mobile sources which would be used for ground truthing. The platform would be able to support any other software development around it, for other types of early warning systems to be integrated.

DFMS is an integrated chain of services and models implemented on the EWP. It will make use of: agricultural information; meteorological data; ground water data; satellite data from Soil Moisture and Ocean Salinity (SMOS) satellite and Copernicus and Landsat Satellites; and information from existing climate forecast services, to build environmental models of climate, ground and surface water in the target region. These models will be used to guide decision makers in drawing key conclusions, and assess the impact of any actions taken in terms of advice to farmers to avoid disasters or how to maximise yields.

Figure 15: Soil moisture levels across Uganda



The resolution of DFMS combined weather and hydrological forecasts is significantly higher than other existing systems or services that provide information at a parish level to impact on local farmer's crop yields and livestock performance. Building trust with users with reliable data and forecasts will encourage them to take action based on the DFMS.

By combining meteorological forecast, EO, and ground observation data, DFMS provides greater analysis, analytics and insight tools for decision-making at multiple levels for drought, flood and agriculture practices. Dissemination is improved by DFMS providing users with web-based access which is tailored to specific user needs and with a high frequency of data updates. Additionally, historical and future climate analysis will enable long term infrastructure and agriculture planning by government or private sectors.

Sustainability model

After deployment of the system, users will be trained on how to use and disseminate weather forecasts, hydrological forecasts, flood and drought risk indexes, and EO derived indexes coming from the system. Government staff will also be trained on the use of early warning data for decision and policy making.

The DFMS project consortium will seek commercial sustainability for the project via both government procurement and by providing the service commercially to industrial partners. The Ministry of Water and the Environment is intended to be the core anchor tenant (user) of DFMS, with further users, services and workflows embedded with Office of Prime Minister, Ugandan National Meteorological Authority, Ministry of Agriculture Animal Industry and Fisheries and the National Agriculture Research Organisation. Local businesses, like Kakira Sugar, could subscribe to the service to provide their out-growers with much better and more comprehensive forecasts and indices.

Furthermore, it can be readily seen that the approach for DFMS is easily extensible to all of Uganda and other countries at a future stage.

Satellite Applications Catapult

Earth and Sea Observation System (EASOS)

Project overview

- **Target countries:** Malaysia
- **Project lead:** Satellite Applications Catapult
- **Project consortium:** Janus TCD, Geocento, Ambiental, Plymouth Marine Laboratory, AutoNaut, Riskaware, Telespazio Vega, EO Inc., Leicester University, Oxford University, eOsphere
- **International partners:** National Defence University of Malaysia (NDUM) and 25 Malaysian Agencies and Departments

United Nations Sustainable Development Goals

Project objectives and impact

The primary objective of EASOS is to develop a solution that provides high-quality information in an integrated dashboard, which acts as a decision-support tool and helps improve planning capabilities, prevention strategies and response to major events related to floods, marine pollution, and illegal logging. In addition to reducing costs of these events, EASOS aims to assist Malaysian authorities to:

Reduce the number of people affected by flooding by:

- improving overall awareness of flood risks across the country
- generating alerts that support rapid decision making during a flooding incident, that show recommended evacuation routes, and activate flood defences in a timely manner
- providing improved advanced warning times on flood risk, better information about impacted areas and population at risk, and prediction of improving or worsening conditions

Reduce the number of marine pollution events in the Malacca Straits by:

- forecasting oil dispersal direction and providing an indicator of risk to any environmentally sensitive areas to enable evasive action such as deployment of booms
- enhancing oil detection from satellite and locating illegal discharges from ships
- assisting the Malaysian coastguard to interdict offending vessels and in the long term deter vessels from illegal discharges

Reduce illegal logging activity by:

- processing optical and radar data to show images of overall shape of deforestation over large geographical areas enabling agencies to make informed decisions about forestry management
- providing frequent change detection of the forest canopy over smaller areas of interest (hotspots), providing alerts to illegal logging activity and allowing comparisons of the change with the logging register for validation purposes
- tagging trees harvested legally using remote applications which enables officials to monitor timber through the supply chain to provide end-to-end traceability

Satellite solution

EASOS offers a world-leading situational awareness platform designed to monitor and manage flood risk, oil pollution and deforestation from illegal logging. It combines terrestrial data with satellite-derived EO data, providing near real-time information that can be used as a decision support tool for each of these environmental challenges. The platform will integrate data from multiple sources (including EO, satellite imagery, GIS mapping, and useful datasets such as soil, road, asset location, databases and historic information).

How the dashboard works for each EASOS domain:

FloodWatch:

Flood forecasting: The flood forecast is simulated using current and forecasted rainfall and live telemetry. The system uses ground-based rainfall radar inputs and water level sensors. The platform models the current catchment state and makes predictions based on rainfall forecasts, modelling flood hazards up to seven days in the future (outputs are refreshed every hour). Predictions are shown by either flood event maps, or flood levels/depths and impact forecasting regarding affected populations and infrastructure damage.

FloodMap™: Sophisticated flood hazard maps are produced for fluvial (river), pluvial (flash) and tidal (sea) flooding based on historic and current satellite data. Surface flood water maps analyse multiple layers of data to provide insight into additional types of flooding, with higher precision, enabling better land use planning process and pro-active disaster risk management.

Risk analysis: Catastrophe modelling analysis which considers the combination of hazard and exposure to model flood impacts to support flood risk management.

MarineWatch:

Oil slick detection: Synthetic Aperture Radar (SAR) satellite observation penetrates cloud cover and provides high resolution imagery (up to 10m) in all weather conditions. Data is typically available once every 12 days, reducing to every 6 days when Sentinel 1-b data is available online. Algorithms identify dark areas with descriptive statistics that distinguish likely oil spills and highlight these on imagery aligned to maps. Using known events, the algorithms are trained to identify spills in open waters with greater accuracy that are difficult to detect with any other method.

Oil destination modelling: This model forecasts the path and dispersion of the oil slick at hourly intervals for 72 hours into the future from when the slick was detected. The oil particle tracking uses oil properties, ocean depth (bathymetry), tides and forecast data (ocean currents, meteorology and wave height). It offers early warning of potential coastal pollution and an indicator of likely risk and impact to environmentally sensitive areas from a pollution event.

Satellite ship detection: Source estimation modelling is an inverse modelling technique that runs backward from a detected slick predicting the possible sources of the oil. The Automatic Identification System (AIS) datastream will be augmented by SAR imagery to help identify offending vessels.

Autonaut: An autonomous self-powered vessel for marine surveillance and monitoring, instruments can identify oil types (such as crude or refined), and marine environmental health indicators such as turbidity (the cloudiness of water), which is a key test of water quality.

ForestWatch:

Change detection over a large geographical area: Satellite detection covering large geographical areas i.e. at state level provides regular and pre-planned monitoring within forest areas every 24 days, showing the user whether deforestation activities are in licenced or non-licenced logging areas.

Change detection over a small geographical area: Users can target a change detection every four days for smaller areas of interest for as long as needed. Higher resolution imagery reports on changes above $50m^2$ of forest canopy which are detected automatically and alert the user if change is detected.

Change validation over a small geographical area: This potentially twice daily service allows users to visually identify activity in areas informed by the change detection. It provides remote sensing expert users information within the previous 12 hours, and detects features such as new access routes, heavy plant machinery and forest edge movement.

Forest+: Offering supply chain traceability that digitally tracks logs from the felling site to the community concession and through to the timber mill. It is designed to provide a real-time notification system via a smartphone application.

Sustainability model

To ensure sufficient capacity building in Malaysia to operate and maintain EASOS, a significant training effort will be implemented throughout the operational trial phase of the project. This will demonstrate how the analysis and information alerts provided via the EASOS dashboard can support effective decision making and achieve the intended impact in each of the three areas of the project.

EASOS is both groundbreaking and ambitious, in that Malaysia is the first country to bring together 26 government agencies and departments that could access data across a whole range of applications. EASOS system currently addresses three areas, however it could be scaled up to include other sectors, such as precision agriculture or renewable energy.

The commercial sustainability of the EASOS will depend on procurement by the Malaysian government and their commitment to investing in the ongoing monitoring of environmental challenges faced by the country.

Satellite Oceanographic Consultants

Coastal Risk Information Services (C-RISe)

Project overview

- **Target countries:** Madagascar, Mozambique, South Africa
- **Project lead:** Satellite Oceanographic Consultants Ltd
- **Project consortium:** National Oceanography Centre, Bilko Development Ltd
- **International partners:**
  Mozambique: National Institute of Hydrography and Navigation (INAHINA), Eduardo Mondlane University, National Institute of Meteorology (INAM)
  Madagascar: National Oceanographic Research Centre (CNRO); Institut Halieutique et des Sciences Marines (IH.SM); Direction Generale de la Meteorologie (DGM); WWF Madagascar; Conservation International, Regional Maritime Information Fusion Centre (RMIFC)
  South Africa: Council for Scientific and Industrial Research (CSIR)

United Nations Sustainable Development Goals

Project objectives and Impact

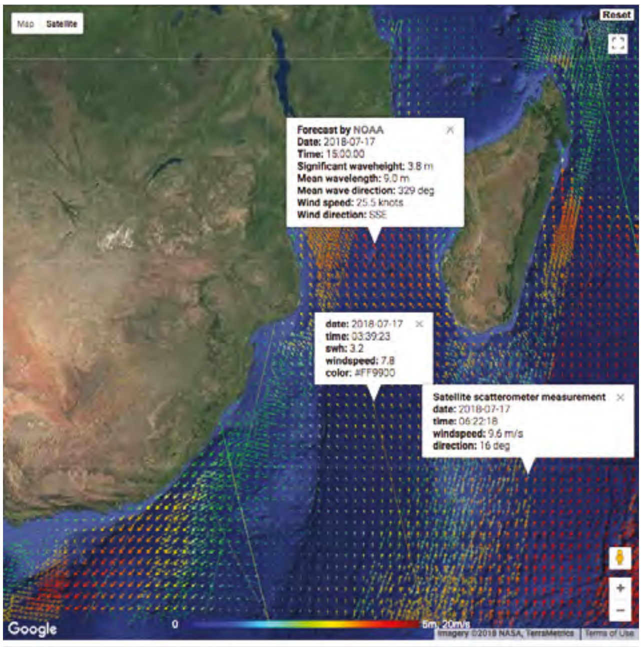
C-RISe attempts to address development challenges by providing access to information on coastal threats, enabling countries to put in place plans to protect coastal communities and safeguard economic activity. In doing so, they reduce the impacts of sea level changes, including the high social and economic costs. It is focused on delivering the information and skills to enable better understanding of risks from sea level change. This enables, for example, coastal developments to be designed with less uncertainty and greater resilience.

The prime impacts the project is aiming to address are:

- increasing the use of satellite derived marine climate information in decision-making processes, climate adaption strategy documents, and management plans

With each international partner, C-RISe will deliver use-case specific impacts. For example, an understanding of the wind, wave and sea level climatology over the past two decades in the Mozambique Channel will be used by the Madagascan Met Office (DGM) to inform the development of their marine forecast services. The same information will be used by the WWF and Conservation International to understand and plan for climate threats as part of Integrated Coastal Zone Management and management of Marine Protected Areas. Mozambique's National Institute of Hydrography and Navigation (INAHINA) will use C-RISe data as both hard evidence and to provide a better understanding of the marine meteorological parameters along their coastline. These organisations will then be supported to apply this knowledge to improve the delivery of the services they provide, enabling more competitive and resilient marine activities.

Figure 16: C-Rise data portal demonstration



Satellite solution

C-RISe will provide EO data on coastal risk and analyses providing detail on the regional characteristics of climate change in key ocean parameters. C-RISe will also provide tools, training and support for local agencies, to build local capability to provide scientific interpretation and deliver more robust information to decision-makers. It takes a collaborative approach to local data validation and interpretation, which has two important benefits to the target country: it builds human and institutional capacity to deliver information on coastal risks; and will deliver robust information that combines world-class, EO-based science with local expertise from the region.

Data products to be made available will include historical coastal sea level, ocean wind and wave climate, and analyses of trends and regional variability. Information on current ocean conditions, as measured by the latest satellite passes, will also be provided.

This information will be available through the C-RISe map-based portal, which will also allow users to download the underlying data products. The portal will be configured to function with limited internet connectivity. Results will be validated by local users (who will have been trained by the C-RISe consortium). While assessing the utility of the existing C-RISe products, the team will also consider the potential value of other coastal information products and services, including new data sets being developed by the satellite oceanography team at NOC, and across the marine science community, not currently within the service portfolio.

Sustainability model

Local training and capacity building is a core component of the C-RISe project, to ensure that partners can access coastal datasets and develop the tools and skills needed to translate the data into actionable information in the long term, after the use-cases are completed. It is key to the success of the project that a mechanism be established to ensure that data access, processing and application is sustained beyond the funded life of C-RISe.

The consortium is aiming for financial sustainability of the C-RISe portal by working with partners with clear national mandates for building coastal resilience. Organisational and regional capability will be sustained through the provision of training to local partners and university students.

The base of the sustainability plan is founded on its expansion potential, connecting the C-RISe information outputs to as broad a range of users as possible via geographic expansion to new regions and countries; and product expansion to address additional problems.

Through building a wide user base, applications will be stimulated creating further funding options. These range from consortium and membership models to national core funding (such as via met service or hydrography departments). Through the development of the use cases it will be possible to directly quantify the value of the service against a backdrop of increasing risks from coastal hazards.

Stevenson Astrosat

Recovery and Protection in Disaster (RAPID) for Vietnam

Project overview

- **Target countries:** Vietnam
- **Project lead:** Stevenson Astrosat Ltd
- **Project consortium:** Telespazio Vega
- **International partners:** Long Hai Space Technologies (LHST)

United Nations Sustainable Development Goals

Project objectives and impacts

The Recovery and Protection in Disaster (RAPID) project aims to aid the Vietnamese in increasing their social and economic resilience to typhoon-based disaster events using satellite technology. It will do this by enabling Vietnam to be better prepared and more able to respond to typhoon-based disasters. The results will be measured by a statistical reduction of deaths, missing persons and persons affected by disasters each year in Vietnam, and by the reduction in the amount of GDP lost to natural disasters annually.

Although RAPID is of course unable to stop disasters from occurring, the project aims to achieve the above impacts by facilitating efficient decision making in the distribution of first responders to a potential disaster situation/storm threat through the use of targeted geospatial tools.

Satellite solution

The project solution, RAPID, is a disaster management software platform that provides users with clear, instructive, situational information, which enables them to take the best preventative measures or action during disasters.

RAPID fuses satellite and non-satellite information to optimise first response forecasting ability during a potential disaster situation and recovery in a post-disaster situation. Its focus areas are as follows:

- **Typhoon/tropical storm landfall prediction:** giving better awareness of tropical storm events, especially improved landfall prediction and severity indications
- **Critical infrastructure impact planning and risk assessment:** using historical flood data and real-time images during flooding to improve the accuracy of decision making during flood events, including on where to place assets
- **Enhance flood extent mapping timeliness and effectiveness:** through low-latency tasking of multiple satellite feeds, so that data arrives as typhoons and floods occur
- **Support live humanitarian aid and disaster response:** situational awareness and resource mapping using live GPS feeds

▲ Cyclone damaged bridge

Information relevant to each of these four domains is presented to users via a dashboard that is configured according to access tiers, appropriate to each user's role.

At the request of the Vietnamese government, Astrosat is co-located with Long-Hai Space Technologies in Vietnam. The first version of RAPID has been delivered, to allow for stakeholder presentations and initial training and familiarisation of identified end-users. A 16-screen video wall has been constructed, which will primarily serve as the command centre during disaster events.

Work is ongoing to develop a 'RAPID-in-a-Box' implementation to facilitate mobile and flexible deployment of the system. The system will deliver a step-change in disaster response for Vietnam by:

- harnessing the power of big data
- fusing multiple discrete information sources into an integrated dashboard
- capacity for flexible deployment
- faster response to events for interventions to be in time

Sustainability model

The RAPID project's iterative training and trialling process is designed to ensure long-term sustainability and use of the system within Vietnam. By applying a 'train the trainer' approach, the expectation is that building on the initial 10 key trained users will not only help with further roll out nationally, but that they can become a regional resource in South East Asia to train other countries who may adopt the RAPID system.

The primary commercial sustainability model is that a minimum viable product (MVP – in this case the RAPID platform) will be left in Vietnam post-project. The national and local government bodies will be able to subscribe to the MVP with the possibility to sign up for the additional services. Those services will include bespoke, additional data layers. This will give Astrosat and Long Hai Space Technologies the opportunity to provide both centralised and individual services ensuring RAPID system meets the requirements within Vietnam's varied social and geographical landscape.

United Nations Institute for Training and Research (UNITAR) – Operational Satellite Applications Programme (UNOSAT)

CommonSensing

Project overview

- **Target countries:** Fiji, Solomon Islands, Vanuatu
- **Project lead:** UNITAR/UNOSAT
- **Project consortium:** Satellite Applications Catapult, UK Met Office, Devex, University of Portsmouth, Commonwealth Secretariat, Radiant.Earth, Sensonomic
- **International partners:**
  Fiji: Ministry of Lands and Mineral Resources
  Solomon Islands: Ministry Of Environment, Climate Change, Disaster Management and Meteorology
  Vanuatu: Ministry of Climate Change Adaptation, Meteorology, Geo-hazards, Environment and Energy, National Disaster Management Office (NDMO)

United Nations Sustainable Development Goals

Project summary

Small island nations located in the Pacific are exposed to the damaging effects of climate change. Such changes in the climate system have direct effects on the livelihoods, the economy, overall development and the very existence of many small island nations. Urgent action towards increasing the capacity for climate resilience is therefore required.

The overall aim of CommonSensing is to use satellite remote sensing for applications that support three Commonwealth countries: Fiji, the Solomon Islands and Vanuatu to improve national resilience towards climate change. The project's main output is to provide the evidence and data needed for these island states to be able to apply to the Commonwealth Climate Finance Access hub with a much higher degree of success then present. This will allow these island states to obtain the funding they need to protect critical infrastructure and build resilience into their economy to combat the growing effect of climate change. A key aspect of the project is its integration with the Commonwealth's Climate Finance Access Hub to use the established channels for increasing success in accessing climate funds.

CommonSensing will deliver impact in two main areas:

- In terms of EO-derived services, CommonSensing will use EO data to provide partners with access to vital information regarding disaster and climate risks to inform planning, food security needs and impact on the environment. This information will be readily available to users through easily accessible services.
- In terms of sustainability and capacity development, partners aim to contribute to national and regional technical capabilities to inform policy and secure funding for climate change resilience programmes beyond the three-year project. In addition, CommonSensing consortium partners are committed to supporting the long-term sustainability of the information services they develop with the three country partners.

Satellite solution

EO data used in the project includes satellite images from optical satellites, including Sentinel-2, SPOT and Landsat, radar imagery from Sentinel-1 and elevation data from PALSAR. In order to produce solutions with greater efficiency and at reduced cost, partners will work on the systematic and regular provision of data at an analysis ready state, termed ARD, in particular thanks to the use of Data Cube (DC) technology. This project offers a significant opportunity to bring together key stakeholders in ARD and DC technology to advance its maturity, while also addressing key UN-SDG challenges.

Project impact

The partnership will enable the three governments and their ministries and agencies responsible for climate resilience to harness the full potential of satellite EO data to support their policy development and programmes.

Economic benefits

- improved multi-sectoral mitigation/adaptation investments based on climate funds in target countries
- reduced economic losses from natural disasters
- reduced costs in accessing innovative software solutions and EO data

Social benefits

- reduced human losses from natural disasters
- better education and awareness of disaster risk reduction (DRR) and Climate Change Adaptation (CCA) for building resilient communities

Environmental benefits

- better information to support the management of natural resources and improved ecosystem conservation using EO-based solutions
- better information to support the planning and implementation of climate change adaption initiatives to address the adverse impacts of climate change on sustainable development

Glossary

N.B. This glossary references public domain definitions, including extensive use of Wikipedia and the UN Report[125] on indicators and terminology relating to disaster risk reduction, as those definitions are written in an accessible manner to the audiences of this report.

CEA – Cost-effectiveness analysis is a 'value-for-money' analysis. It compares the relative cost of achieving the same impact using alternative approaches and can be used to assess whether one solution provides the least costly method to achieve desired results.

CEOS – Committee on Earth Observation Satellites

Copernicus[126] – the European Union's earth observation programme, looking at our planet and its environment for the ultimate benefit of all European citizens. It offers information services based on satellite earth observation and in situ (non-space) data. The programme is co-ordinated and managed by the European Commission. It is implemented in partnership with the member states, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Océan.

DRM – Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.

DRR – Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development.

Earth observation (EO) – The gathering of information about the physical, chemical, and biological systems of the planet via remote-sensing technologies, supplemented by Earth-surveying techniques, which encompasses the collection, analysis, and presentation of data. EO is used to monitor and assess the status of and changes in natural and built environments.[127]

Electromagnetic spectrum – The range of frequencies (the spectrum) of electromagnetic radiation and their respective wavelengths and photon energies.[128]

EMEA – Shorthand designation meaning Europe, the Middle East and Africa, it is EMEIA if India is included.

125 United Nations. 'Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction', A/71/644, December 2016

126 Copernicus. 'What is Copernicus', http://www.copernicus.eu/main/overview. Accessed July 2018

127 Wikipedia. 'Earth Observation', https://en.wikipedia.org/wiki/Earth_observation. Accessed July 2018

128 Wikipedia. 'Electromagnetic Spectrum', https://en.wikipedia.org/wiki/Electromagnetic_spectrum. Accessed July 2018

EMS – The Copernicus Emergency Management Service (EMS) provides all actors involved in the management of natural disasters, man-made emergency situations and humanitarian crises, with timely and accurate geospatial information derived from satellite remote sensing and completed by available in situ or open data sources.

European Marine Observation and Data Network (EMODnet) – EMODnet consists of more than 150 organisations assembling marine data, products and metadata to make these fragmented resources more available to public and private users relying on quality-assured, standardised and harmonised marine data which are interoperable and free of restrictions on use.[129]

ESA – European Space Agency

Famine Early Warning Systems Network (FEWS NET) – A provider of early warning and analysis on food insecurity. Created by USAID in 1985 to help decision-makers plan for humanitarian crises, FEWS NET provides evidence-based analysis on some 34 countries.[130]

Galileo – Galileo is Europe's Global Satellite Navigation System (GNSS), providing improved positioning and timing information.

GDP – Gross Domestic Product is a monetary measure of the market value of all final goods and services produced in a period (quarterly or yearly) of time. Nominal GDP estimates are commonly used to determine the economic performance of a whole country or region, and to make international comparisons.[131]

GEO – The Group on Earth Observations (GEO) is an intergovernmental organisation working to improve the availability, access and use of earth observations for the benefit of society.

Georeferencing – Aligning geographic data to a known co-ordinate system so it can be viewed, queried, and analysed with other geographic data.[132]

GIS – A geographic information system is a system designed to capture, store, manipulate, analyse, manage, and present spatial or geographic data.[133]

GLONAS – GLONASS, or Global Navigation Satellite System, is a Russian satellite navigation system.

GNSS – Global Navigation Satellite System refers to a constellation of satellites providing signals from space that transmit positioning and timing data to GNSS receivers. The receivers then use this data to determine location.[134]

---

129 EMODnet, http://www.emodnet.eu. Accessed July 2018

130 FEWS NET, http://fews.net. Accessed July 2018

131 Wikipedia. 'Gross domestic product', https://en.wikipedia.org/wiki/Gross_domestic_product. Accessed July 2018

132 ESRI. 'GIS Dictionary', https://support.esri.com/en/other-resources/gis-dictionary. Accessed July 2018

133 Wikipedia. 'Geographic information system', https://en.wikipedia.org/wiki/Geographic_information_systems. Accessed July 2018

134 European Global Navigation Satellite Systems Agency. 'What is GNSS?', https://www.gsa.europa.eu/european-gnss/what-gnss. Accessed July 2018

International Partnership Programme (IPP) – A five-year, £152 million programme run by the UK Space Agency. IPP uses the UK Space sector's research and innovation strengths to deliver a sustainable, economic or societal benefit to developing countries. Projects within IPP span a wide range of themes including: improving agriculture; reducing deforestation; improving disaster response; reducing maritime pollution and illegal fishing; optimising renewable energy; and improving resilience to climate change.

Landsat-1 – A commercial high-resolution optical imaging EO satellite system operating from space. Landsat is a joint effort of the United States Geological Survey (USGS) and NASA.[135]

Light Detection and Ranging (LIDAR) – A surveying method that measures distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor. Differences in laser return times and wavelengths can then be used to make digital 3D representations of the target.[136]

Monitoring and evaluation (M&E) – An objective process of understanding how a project was implemented, what effects it had, for whom, how and why.[137]

MEWS – Malaria Early Warning System (MEWS)

ODA – Official Development Assistance is a term defined by the Development Assistance Committee (DAC) of the Organisation for Economic Co-operation and Development (OECD) to measure aid.[138]

OECD – The Organisation for Economic Co-operation and Development is an intergovernmental economic organisation with 37 member countries, founded in 1961 to stimulate economic progress and world trade.[139]

Orthorectification – Uses elevation data to correct terrain distortion in aerial or satellite imagery.[140]

Radiometric correction – The process of removing the effects of the atmosphere on the reflectance values of images taken by satellite or airborne sensors.[141]

Resilience – The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

Response – Actions taken directly before, during or immediately after a disaster to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.

SatComms – Satellite communications

---

135 USGS. 'Landsat Project Description', https://landsat.usgs.gov/landsat-project-description. Accessed July 2018

136 Wikipedia. 'Lidar', https://en.wikipedia.org/wiki/Lidar. Accessed July 2018

137 Caribou Space

138 Wikipedia. 'Official development assistance', https://en.wikipedia.org/wiki/Official_development_assistance. Accessed July 2018

139 Wikipedia. 'OECD', https://en.wikipedia.org/wiki/OECD. Accessed July 2018

140 ESRI. 'GIS Dictionary', https://support.esri.com/en/other-resources/gis-dictionary. Accessed July 2018

141 As above

Sentinel-3 SLSTR – ESA's Sentinel-3 Sea and Land Surface Temperature Radiometer (SLSTR) is primarily an ocean mission; however, the mission is also able to provide atmospheric and land applications. It provides data continuity for the European Remote Sensing (ERS), Envisat and SPOT satellites. Sentinel-3 makes use of multiple sensing instruments to accomplish its objectives.[142]

UN SDGs – United Nations Sustainable Development Goals

Synthetic aperture radar (SAR) – Synthetic Aperture Radar (SAR) satellites are a form of radar using the motion of the satellite to create a larger 'virtual' antenna that is used to create two or three-dimensional images of objects, such as landscapes.[143]

Terra/Aqua MODIS – MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every one to two days, acquiring data in 36 spectral bands, or groups of wavelengths.[144]

UAV – an Unmanned Aerial Vehicle, commonly known as a drone, is an aircraft without a human pilot aboard.[145]

UKSA – The UK Space Agency

UNOSAT – The United Nations Institute for Training and Research (UNITAR)'s Operational Satellite Applications Programme.

VHR – Very high resolution

142 UKSA Space Agency. 'International Partnership Programme', https://www.gov.uk/government/collections/international-partnership-programme. Accessed July 2018

143 As above

144 As above

145 Wikipedia. 'Unmanned aerial vehicle', https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle. Accessed July 2018

UK SPACE AGENCY