MONITORING MAJOR THREATS: THE CONTRIBUTION OF SATELLITE TECHNOLOGIES

In recent years, a diverse range of major disasters have occurred: earthquakes, tsunamis, floods, volcanic eruptions, pandemics, food shortages, to name but a few. The cost of such disasters is enormous - not just in terms of human lives, but also in terms of the cost to the economy. Shocks on this scale can set back the performance of a national or regional economy by months if not even years. Work at OECD on risk management issues points to the crucial importance of early risk identification and early warning. And this is where science and technology come into the picture. They have a vital role to play in deepening understanding of risk factors, in detecting the impending disaster, in mapping its possible consequences, and preparing the terrain for the emergency response. Space technologies (Earth observation, telecom, navigation, positioning, and timing), combined with information and communication technologies can assist in the surveillance of major threats today and in the near-to-medium term future. This factsheet presents the key findings and proposals for action resulting from the OECD Space Forum project "Monitoring global threats: the contribution of satellite technologies".

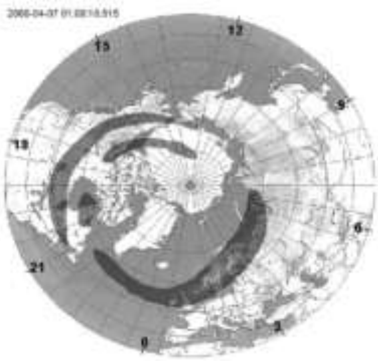
The new context of global risk management

Recent years have witnessed a plethora of major disasters: earthquakes, tsunamis, floods, pandemics, food shortages, collapsing fish stocks, to name but a few, have all left their mark. The economic cost of natural catastrophes and man-made disasters worldwide amounted to some USD 370 billion in 2011. Continuing population growth, climate change, the rapid expansion of cities, the concentration of economic assets, the pace of globalisation and increasing interdependence, are all likely to ensure that the 21st century will witness more and increasingly costly shocks, some familiar, others new. Many of these disasters, though large in scale, will only have a national or regional impact. Others may be bigger, spilling across national borders and disrupting essential global value chains. Yet others could be truly global in nature, severely affecting several continents at once and calling for special approaches and measures.

Climate change – Climate change is emerging as one of the greatest long-term challenges facing society. A warmer earth leads to modifications in rainfall patterns and fresh water availability, rises in sea level, extreme weather events, and varying effects on plants, wildlife and human activities. Since a degree of uncertainty is still attached to the various predictions and the science underlying them – as demonstrated by the long-standing worldwide scientific and political debate on these matters – better data, analysis and science are needed to further our knowledge both of climate change and of its effects on the natural environment and human activity.

Population growth and concentration of economic assets – The world's population has already reached 7 billion people, and current projections see it rising to over 9 billion by the middle of this century. Rising human consumption will continue to place severe pressure on the earth's ecosystems, through the over-harvesting of animals and plants, and the extraction of natural resources from land and sea. In parallel, increasing urbanisation has resulted in a rising number of megacities around the world with high concentrations both of people and assets in relatively small, compact areas. With such dense convergence of populations and collective wealth around geographic centres, the risk of a catastrophic event producing severe damage and loss has risen significantly.

The global footprint of geomagnetic storm from April 2000



Source: OECD (2011), *OECD Future Global Shocks: Improving Risk Governance*, OECD Publishing.

Growing likelihood of cascading effects – In today's tightly interconnected world, the effects of extreme weather events, environmental disasters, or critical infrastructure breakdown can cascade quickly across a country's economy and society. And when mobility, economic interconnectedness and supply chains attain the global dimensions we see today, then those same cascading effects can scale up to a level that affects many other countries and, indeed, other continents. The 2011 floods in Thailand, where one-third of the world's hard disk drives are produced, had a domino effect on shipments of hard disks, affecting supply chains and prices across the international industry. Disruptions to air freight carriers' hubs, usually due to inclement weather conditions (snowstorms, cyclone alerts), tend to result in bottlenecks and delayed deliveries to some key industries around the world. When several hubs are affected, the cascading effects can be even more pronounced, as in the case of the 2010 volcanic eruption in Iceland, which produced an ash cloud over much of Europe's airspace. With numerous major air hubs paralysed, many companies were unable to deliver products or key components to markets and production systems throughout Europe.

Selected risks reviewed in the course of the OECD study

GENERAL THEME (Location and date of OECD workshop)	THREATS ADDRESSED
1. NATURAL DISASTERS Brussels, 23 Feb. (Hosted by EuVri)	Earthquakes* Tsunamis* Geomagnetic storms* Cyclones Floods Volcanoes
2. OCEAN SURVEILLANCE London, 23 March, (hosted by Inmarsat)	Illegal fishing* Organized crime at sea: piracy* Illegal immigration (human trafficking) Sea pollution
3. TRANSPORT AND POWER SURVEILLANCE Stuttgart, 4 May (Hosted by EuVri)	Risks to air traffic* Transport of hazardous material Energy infrastructure risks (e.g. gas transport)* Road congestion
4. HEALTH RISKS Paris, 5 June (Hosted by EuVri)	Pandemics* Air pollution* Fresh water supplies Food security
5. SPACE SECURITY: A CRITICAL INFORMATION INFRASTRUCTURE AT RISK Paris, 9 July (Hosted by CNES)	Illicit signal interferences (increased jamming of satellites' signals, cybersecurity)* Collisions in orbit (space debris, collision between operational satellites)*

*Specific threat addressed during OECD workshops

The objective of the study and the risks considered

The aim of this OECD study is to assess the current and future contribution of space systems to addressing some major threats to 21st century society. Recent OECD work in the field of risk management (Future Global Shocks, OECD, 2011) concluded that it is becoming increasingly important to improve the assessment, early detection and monitoring of major risks, including the pathways along which they spread. In particular, more effective use of science and technology is required to enhance capacity for monitoring and early warning.

In this regard, space systems have an important role to play. In order to better understand that role, this study set out to assess the current and future capabilities of space systems in supporting the assessment, early warning, surveillance and response to some twenty threats, ranging from natural disasters (earthquakes, tsunamis, geomagnetic storms), piracy and illegal fisheries, to major health risks (pandemics, air pollution). The analysis was supported by five workshops which were held in the first half of 2012 in co-operation with experts from the space community and practitioners in Brussels, London, Stuttgart, and twice in Paris. The workshops gathered more than a hundred experts from academia and research institutes, non-governmental organisations, and the private sector, as well as fourteen intergovernmental organisations.

What are the capacities of space applications in helping monitor major risks and provide early warning?

The modern global economy is characterised by interconnectedness, greater complexity, heightened vulnerability, and faster propagation of the effects of disruption and disasters. In this new risk management context, space tools (earth observation, telecommunication, navigation, positioning, and timing) are found to be well suited to addressing many of the major threats reviewed in the study, both by allowing the acquisition of crucial data and the monitoring of propagation pathways, and by forming back-up hubs for telecommunications when needed. Their usefulness spans several risk management functions:

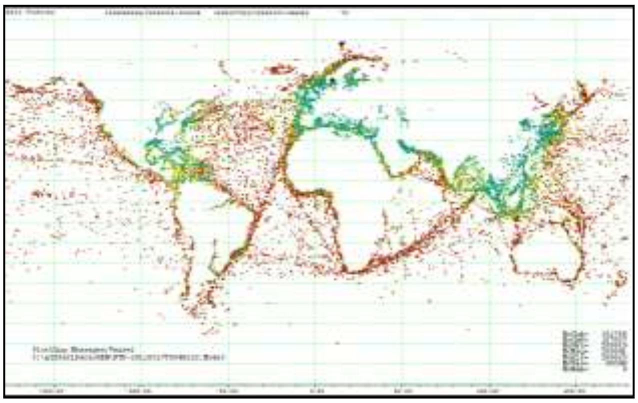
Initial assessment of risks: Space cannot provide all the information required for risk assessments. Risk mapping, however, does benefit considerably from satellite earth observation and positioning. The scientific accomplishments due to satellite use are already numerous, as satellite missions have brought on major scientific breakthroughs particularly in climate observation and earth resource monitoring (e.g. satellite detection of long-term damage to the ozone layer leading to the passage of the Montreal Protocol in 1987; and detection and monitoring of the dramatic changes in the extent of Arctic sea-ice coverage). For geological hazards, remotely sensed topographic data, combined with precise positioning, provide unprecedented mapping of landscape and architectural characteristics, allowing the detection of surface fault-lines. Even with major risks less obviously suited to satellite deployment, such as epidemics, satellite data are increasingly used: epidemiology combines medical parameters, weather conditions, entomology and general land use information to detect possible tipping points in disease occurrences (e.g. dengue fever, malaria).

Forecasting and monitoring risks: Building on their capacities for risk assessment, satellites play a crucial role in global routine surveillance. The data they constantly collect is in many cases used in scientific models, providing essential forecasting capabilities; and when an event occurs, they contribute to monitoring the propagation of threats (e.g. tsunami progression and impacts, the development of severe droughts and their effects on global food supplies). As an illustration of space systems' contribution to forecasting capabilities, significant improvements have been achieved in weather predictions over the past decade, due in large part to a larger international fleet of improved meteorological satellites, bringing about substantial gains in the accuracy of forecasts of large-scale weather patterns in both hemispheres. This has directly benefited early warnings of major hydrometeorological hazards (such as cyclones, thunderstorms, heavy snowfall, floods and heat waves, to name but a few). With respect to monitoring, the ubiquitous surveillance capability of satellites is applied to international borders and transportation hubs. These systems, based on imagery and real-time tracking, combined with other surveillance mechanisms, contribute to detecting and tracking the cascading effects of illegal practices or accidents (e.g. tracking illegal fishing operations; spread of piracy; sea pollution and accidents impacting populated coastal areas (fisheries, tourism and ecosystems).

Dissemination of warnings: In addition to warnings relayed by authorities to millions of people via commercial satellite television broadcasts, a number of operational early warning systems rely on satellite transmissions to dispatch real-time data alerts. Tsunami warning systems, for instance, are complex networks using data from seismic networks, buoys at sea and communications from ships, transmitting data via satellites. One conclusion to be drawn from recent tsunami events is that warning systems could be improved by further developing the density of the existing networks of stations and promoting the inclusion of other sensors, like continuous real-time global positioning observations.

Rapid response: Satellite links often represent the only option in places in the world where ground systems are not deployable. This is particularly true of telecommunications networks. Examples are the high seas, remote and sparsely populated regions, and land areas devastated by natural disasters. In the wake of the earthquake and tsunami in Japan in 2011, satellite was the only viable route for telecommunications for almost two months.

A glimpse at sea traffic via satellite monitoring of ships' automatic identification system (AIS)



Source: Norwegian Space Centre

How well positioned are space infrastructures and services to deal with major risks in future?

Four challenges should be tackled if space technologies' contribution to monitoring major threats is to be significantly improved:

Challenge 1. Meeting the daily needs of very diverse users - A more systematic approach to the use of space-based capabilities has emerged in recent years both nationally and internationally, but a key challenge that remains is meeting the daily needs of users, not only scientific organisations but also various governmental agencies, international organisations, local planners and private users (e.g. fishermen, farmers). The close relationship between data users and data producers that exists in the case of weather applications is the exception rather than the rule. In other areas, such as risk management applications, the customer base is large and diverse, with very different levels of expertise. The need to demonstrate added-value and cost-efficiencies should become the norm for new technological solutions integrated in early warning systems.

Challenge 2. Remedying the gaps in the coverage of space systems - Several of the risks identified in the report depend on an observing system involving a crucial satellite component. However, potential users are often little inclined to learn how the information they need is actually produced. They are more concerned about the timeliness, accuracy and pertinence of the information and services. For satellite data to contribute fully and effectively to many of the early warning systems identified, the systems must be implemented and operated in such a manner as to ensure that gaps are addressed (i.e. satellites' revisit time, adequate resolution, real-time reactivity when necessary, sustained data products and archiving). This is a major technical and resource challenge.

Vegetation map based on data from sensors carried on different satellites

Source: NASA

Challenge 3. Exploiting the benefits of technology convergence - The third challenge involves capitalising on the potential complementarities that exist among emerging strands of technological innovation, and exploiting the benefits of technology convergence both within and outside the space sector. The benefits of technology convergence will increasingly be used in major applications from aeronautics (with intelligent aircraft that will become more and more automated and satellite navigation guiding to cope with increasing air traffic), to the role of new information technology applications (such as crowd sourcing for real-time information in times of disaster) and biomarkers in managing major health risks. Although the opportunities for open innovation are growing, one key challenge is the need to operationally integrate very different systems so they can work together.

Challenge 4. Processing large amounts of data and integration - The fourth challenge concerns data needs – how to generate and access more relevant data, how to improve analysis and evaluation of those data, and how to facilitate data sharing among sectors, institutions and countries. Key data challenges exist concerning the actual development of the required systems and the sustainability of the respective earth observation, communications, and navigation infrastructures. Space applications already have to manage an extraordinary array of diverse data – from geospatial information and raw satellite imagery, for example, to real-time sensory data feeds. Climate parameter observations for example are currently measured by several organisations for a variety of purposes. However, a variety of different measurement protocols are used, which results in a lack of homogeneity in the data (in space and time). This heterogeneity limits the use of the data for many applications and constrains the capacity to monitor and assess weather, natural resources and climate evolutions. Help will no doubt be forthcoming from major advances in data processing and storage (e.g. improvements in supercomputing, use of clouds, etc.), but such progress may also need to be accompanied by greater sharing of data and calibration of information across national, international and institutional borders.

Proposals for action

The challenges are such that policy-makers should take advantage and exploit as much as possible capabilities derived from existing technologies. The central message of this document is therefore that space systems should not be regarded merely as research and development systems, but also as important components of a critical communication and information-based infrastructure for modern societies. In combination with new and emerging technologies from many different disciplines, space technologies play an important role for the management of major risks, by contributing to warning and responses, and they possess the potential to make an even greater contribution in the future. In the new global risk management context, however, a number of multi-layered strands of action should be pursued if space infrastructures and services are to respond effectively to the challenges ahead.

1. Strengthening and developing regional and global "risk radars", including use of satellite-based information and communications

The rationale for setting up surveillance systems at regional and global level is to improve early warning and thereby contribute to saving lives and help avoiding crippling economic costs. By increasing the density of sensors, developing the technology to deliver reliable warnings to users, and sharing almost-real-time data on climate, floods, earthquakes, extreme weather events and so on, with many potential data users around the world (including the general public), national authorities and local communities gain access to information that they may not otherwise have obtained.

"Risk radars" are needed, and these would gain from more effective and efficient inclusion of satellite-based information and communications. As many of these surveillance systems are domain-specific and dedicated to one or several hazards (e.g. food security, floods) with a focus on the regional dimension (e.g. oil pollution surveillance in the Baltic Sea), their requirements differ. However, further dialogue between different communities of users is needed. This is a key mission for the space community, public agencies and commercial operators alike: to connect with user communities and other developers of sensors, to explore with them and convincingly demonstrate what capabilities can be derived from satellite-based information and communications for their specific needs.

2. Moving to a satellite infrastructure management model for earth observation

Transitioning some observation systems from research to long-term operations is in many countries a key governance issue not yet resolved. This is a dilemma faced by many space agencies that are required to maintain observational capabilities for particular data variables (e.g. for the preservation and continuation of satellite climate data records) without adequate long-term funding of recurring missions. Several early warning systems already rely on operational sensors, which have been flying for decades on various satellites (e.g. measuring sea-level, land characteristics, soil moisture).

Finding the right mix of funding mechanisms remains the main challenge, which can be met by trying new approaches. The classical model is to develop a government-funded mission, providing quasi-free access to the data, particularly in times of crisis. This model should endure in many cases, since it brings benefits to large communities of users, and can be considered a component of a public infrastructure. However, the funding mechanisms for the extension and improvement of the infrastructure should come from a mix of government participation and involvement of the user base.

From the start, public agencies with a stake in the system have a role in funding at least parts of the infrastructure, and they develop partnerships with commercial operators via different economic models. Aside from developing fully dedicated systems, one new option is “hosted payloads”. Selected earth observation sensors can be flown on commercially owned and operated satellites. The practice is already used for some government communications equipment, which is ‘hosted’ on commercial satellites. This solution may provide new cost-efficiencies and opportunities for both public agencies and commercial operators. The cost of operations and data processing of new missions should be compensated to some degree by financial contributions from public and private users. This can be achieved via aggregation of demand to encourage economies of scale, and dedicated anchor contracts.

Hurricane forming, as seen from space

Source: NOAA

3. Sustaining investment in fundamental research and development remains important

Improving the satellite infrastructure is one of the avenues that should be pursued to generate reliable data for use in early warning, Its many contributions -- from providing original data for scientific models to real-time information and communications when disasters occur -- are invaluable. More research and development is needed in the space community in order to help fill a number of knowledge and technical gaps, as well as to develop the next generation of systems. As part of this agenda, addressing the issue of the rising number of space debris in orbit, threatening the future developments of the space infrastructure, needs to lead to concrete steps forward.

But in addition, better understanding of the complexity of present-day risks and how they unfold (i.e. the need for improved knowledge of their thresholds and tipping points) requires better data integration from many diverse sources. The interrelationships between better observing systems, improved analyses, modelling, and better understanding of processes require sustained public support for fundamental research and technology programmes. The significant development of information technologies, social media, biomarkers and other breakthroughs in data processing, provide the opportunity for more innovation. This calls for policy decisions on technology roadmaps, aiming for technology convergence in some cases, and increased international co-operation to address the challenges of complementary systems and better data integration.

For more information

http://oe.cd/spaceforum

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