Let's **embrace space**

Space Research achievements under the 7th Framework Programme

European Commission
Enterprise and Industry

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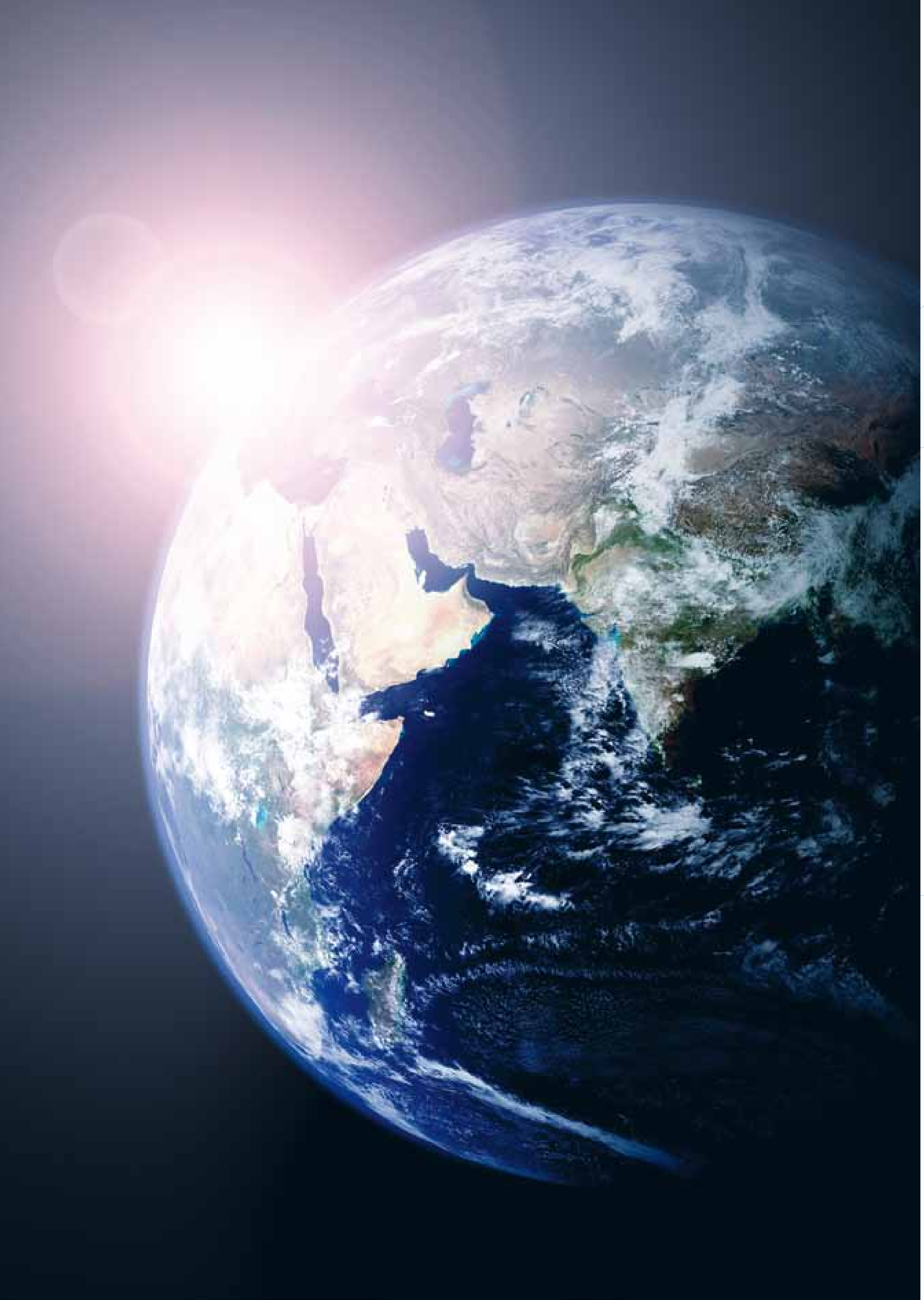

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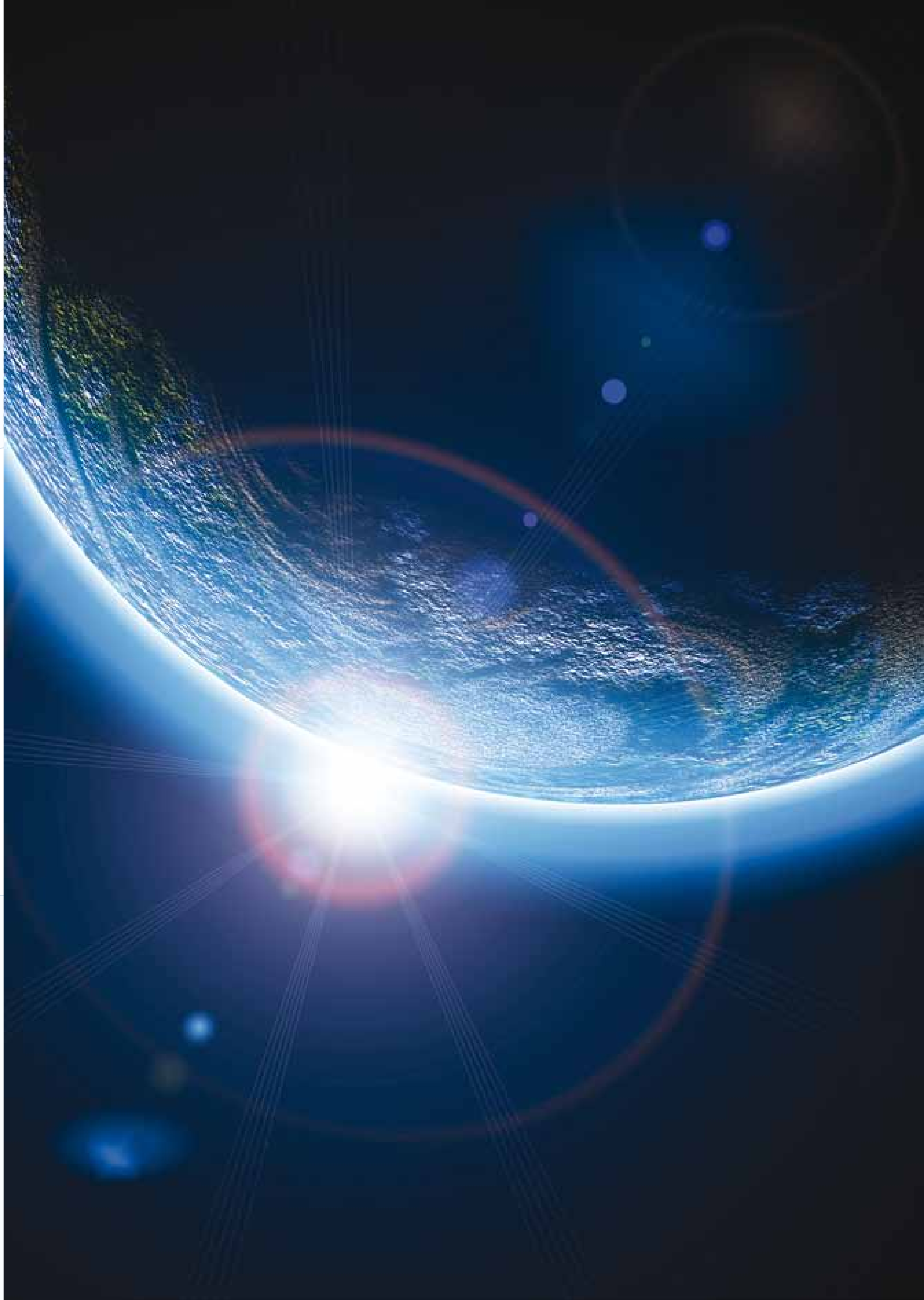

FOREWORD

by European Commission Vice President Antonio Tajani, responsible for Industry and Entrepreneurship

'Earthrise' features our planet as a small oasis against the background of vast dark space.

Paving the way for the modern scientific revolution, we learned from Copernicus, Kepler and Galilei that Earth is not the centre of the universe. Yet this planet remains the centre of our concerns, when today – like those great European scientists of the past – we turn towards space to explore, discover, and gain fundamental insights about our existence.

It has been 50 years since 12 April 1961 when Yuri Gagarin became the first human being in space. Orbiting the Earth, he saw our planet as no human being had seen it before – blue and beautiful. Eight years later, on 20 July 1969, Neil Armstrong landed on the Moon, and the images that we got back from the Apollo mission changed mankind's worldview forever.

Observing our planet, as did Gagarin and Armstrong, is an essential element of Europe's space policy. From the establishment of the European Space Agency in 1975, to the adoption of the first European Space Policy in 2007, Europeans have joined the space odyssey. With the entry into force of the Lisbon Treaty in 2009, Europe as a union has become an actor in space as the Treaty added space policy to the responsibilities of the EU.

Curiosity and innovation are intertwined, and European Space Research has found its place within this strategic junction, central to our 21st century knowledge economy. Throughout the continent, in partnership with scientists from all corners of the world, European researchers, working at universities, small and medium-sized enterprises and some of the world's major space companies, take part in more than 100 European Space Research projects under the EU's Seventh Framework Programme (FP7).

With a budget of 1.4 billion euro between 2007 and 2013, FP7 Space is securing the development of an operational European Monitoring System for Environment and Security (GMES), whilst supporting new research set to take mankind forward on the space journey – with better propulsion systems for interplanetary flights, more advanced rovers for exploring other planets and asteroids, and safer systems for returning spacecraft to Earth through the atmosphere.

In only a few years, FP7 Space has made a difference in the lives of people on Earth and astronauts on the International Space Station. The results of these projects, most of which are still ongoing, are tangible and outlined in detail throughout the following pages, which present the first achievements of FP7 Space midway through the programme. I invite you to explore these pages and to be inspired.

Antonio Tajani

INTRODUCTION

Europe has been active in the space sector for several decades. Europe's ambitions encompass a wide spectrum ranging from launcher development to satellite applications. Space activities are acknowledged as a strategic asset for their contribution to the construction of Europe and the competitiveness of the European economy in the framework of the Europe 2020 process. Space is a tool at the service of a number of EU policy areas, for example in the fields of transport, environment, agriculture, fisheries, telecommunications and security, as well as in support of the Common Foreign and Security Policy and actions for the sustainable development of our planet.

Space appeared for the first time as a separate theme in the 7th Framework Programme with a dedicated budget of € 1.4 billion with the aim of fostering collaborative research across Europe and with international partner countries.

The main topics addressed under the FP7 Space theme are:

> The development and validation of pre-operational GMES services
> Support to the coordinated provision of data to related FP7 projects
> The development of dedicated space infrastructures for GMES (in cooperation with the European Space Agency)
> Support to research in space science and exploration
> The development of new concepts in space transportation, space technologies and critical components to promote the strategic objective of European non-dependence
> Support to research for reducing the vulnerability of space-based systems

In the mid-term of the current Research Framework Programme, the European Commission, in cooperation with the Hungarian EU Presidency, asked the coordinators of the research projects funded under the FP7 Space theme to present their initial achievements. The result is presented in this book. It is a clear demonstration of European expertise in the field of space applications and research and shows the commitment of the European research community and international partners from around the globe to place space-based capabilities at the service of civil society with a view to safeguarding the environment and broadening our knowledge of the solar system and the Universe.

Summary: Space for a safer world

Space Research under the 7th Framework Programme of the European Union

Reinhard Schulte-Braucks, Hartwig Bischoff, Peter Breger, Thierry Brefort, Richard Gilmore, Tobias Skovbjerg Gräs, Mats Ljungqvist, Tanja Zegers, Dirk Zimmer, Hugo Zunker, Anastasia Antoniou

European Commission, Space Research and Development Unit

ABSTRACT

The following introduction to the compilation of papers describes the objectives and first results from projects selected under the first calls for proposals under the FP7 Space Research Programme. It provides a short overview of EU funded space research and the benefits for our society. These papers illustrate how space technologies can improve our knowledge of the sustainability of our living conditions on earth. In addition, they highlight the contribution of space technologies to improving the competitiveness and innovative capacity of European industry.

This introduction aims to give a general overview of the main topics addressed, highlighting a number of projects in each of the areas. However, it is not intended to provide a complete overview of all FP7 projects, rather the presented selection covers projects from the first and second Space Calls for proposals (2008 and 2009). At the time of going to press, the projects from the third call were not yet sufficiently advanced to be able to present initial results in the form of a full paper but short descriptive papers outlining their goals are available on the dedicated Space Research website of DG Enterprise and Industry, ec.europa.eu/embrace-space.

In FP7, the Space theme is divided into two main categories: Global Monitoring for Environment and Security (GMES) and Strengthening Space Foundations (SSF). Whilst the former category supports the development of an independent European Earth Observation capability, the latter applies to a series of fundamental research domains, such as Space Science and Exploration, Space Propulsion and Transportation Technologies, and Critical Technologies for European strategic non-dependence. It should be noted that DG Enterprise and Industry works in close cooperation with the European Space Agency with regard to the Space theme of FP7 for the definition of the topics to be included in calls to ensure that these are fully complementary to ESA's ongoing research programmes. ESA also provides input during the evaluation process to ensure that projects selected for funding do not overlap with projects already funded by ESA, thus eliminating any risk of duplication.

OBSERVATION OF LAND

Land monitoring is one of the most mature areas of GMES. In this domain, operational services are already being facilitated by the GMES Urban Atlas, which provides harmonised land use/land cover mapping of 305 European cities. In addition, GMES land services will soon be provided in line with the GMES regulation and the GMES Initial Operations work programme.

The FP7 Work Programme has laid the foundations for the provision of these operational services. The project geoland2, initiated in 2008, provides a pre-operational monitoring service for land state, land use and land cover status and changes at regional, European and global levels. It provides basic parameters responding to user needs Europe-wide. At local level, the project develops and validates efficient change detection methods for the update of the forthcoming versions of the Urban Atlas. At European level, geoland2 offers five High Resolution layers providing information on impervious areas, forests, grasslands, wetlands and small water bodies. At global level, daily to monthly biophysical parameters on continental vegetation, energy budget and the water cycle are provided in a continuous manner.

These three elements, and their service capacities, will form the basis of the GMES Land Service, which is already being built by the EU through the GMES Initial Operations programme.

This service will greatly facilitate the work of the European Environment Agency (EEA) and national authorities in urban planning, environmental reporting, crop prediction, water management, etc. Furthermore, these services provide a valuable basis for scientific research such as that conducted at the Joint Research Centre (JRC).

Building on the geoland2 services, the development of more specialised services, on specific areas, or for a more specialised user community, is supported through FP7 research. 11 projects were selected for funding in 2010, which will provide concrete support in fields such as snow and ice monitoring, forest monitoring, water management, monitoring of protected sites, risks in urban areas or agriculture development.

Water management is widely addressed, for instance by the *FreshMon* project, which will implement and provide water quality services for rivers and lakes based on the integration of Earth Observation data, in-situ measurements of biological parameters and hydrodynamic modelling. Addressing the issue of snow accumulation and depletion, which is key not only for water resource management but also for important economic areas like winter tourism, the *CryoLand* project will provide a set of tools for monitoring the extent and state of snow cover, glacier ice and lake/river ice based on satellite data, integrated with ground-based measurements.

Water scarcity is becoming an increasingly critical issue in Europe and many other parts of the world, and agricultural water usage must be optimised. *SIRIUS* will develop new services for water management authorities and farmers, including maps detailing irrigation water requirements in different areas and crop water consumption estimates for irrigation.

Forests and protected areas is another topic that is widely supported in FP7. The *EUFODOS* project will produce high-resolution, rapid mapping of forest degradation and damage, and derive specific forest parameters, allowing European Forestry authorities to better plan forest protection measures. The *BIO_SOS* project will provide high-definition land cover imaging and help local authorities to better protect biodiversity.

In urban areas, geohazards such as subsidence, landslides or earthquakes, are potentially lethal and can cause substantial financial and environmental losses. Improved knowledge on the impact of these hazards can help save lives and preserve assets. The *PanGeo* project will provide a free and validated geohazard data layer for the 52 largest European cities. In combination with the GMES Urban Atlas maps, it will help authorities to better assess the consequences of geohazards in the urban environment for more efficient planning and mitigation measures.

MONITORING THE MARINE ENVIRONMENT

Two-thirds of the planet's surface is covered by seas and about half of the world's population lives within 100 km of a coast. Europe has a 70 000 km coastline along two oceans and four seas: the Atlantic and Arctic Oceans, the Baltic, the North Sea, the Mediterranean, and the Black Sea. The EU's maritime regions account for some 40% of its GDP and population, and 22 of the 27 EU member states have a coastline. Europe's maritime spaces and its coasts are central to its wellbeing and prosperity – they are Europe's trade routes, climate regulator, sources of food, energy and resources, and a favoured site for its citizens' residence and recreation. Our interactions with the sea are more intense, more varied, and create more value for Europe than ever before. Yet the strain is showing. We are at a crossroads in our relationship with the oceans.

Europe's well-being is therefore inextricably linked with the sea. Shipping, ports and fisheries remain key maritime activities, but offshore energy (including oil, gas and renewables), and coastal and maritime tourism also generate massive revenues. Sea-ports and shipping allow Europe to benefit from the rapid growth of international trade and to play a leading role in the global economy, while the exploitation of mineral resources, aquaculture, blue biotech and emerging sub-sea technologies represent increasingly important business opportunities. Ensuring that use of the marine environment is genuinely sustainable is a prerequisite for these industries to be competitive. The growing vulnerability of coastal areas, increasingly crowded coastal waters, the key role of the oceans in the climate system and the continuous deterioration of the marine environment all call for a stronger focus on our oceans and seas. Ocean sustainability is today widely recognised as a major global challenge, intimately connected with climate change.

The Space theme of FP7 therefore strongly supports the development of a space-enabled ocean monitoring and forecasting system through the Marine pillar of GMES. The main activity in this area is the Marine Core Service, through the FP7 project *MyOcean*, responsible for the development and pre-operational validation of the Ocean Monitoring and Forecasting component of the GMES initiative. MyOcean represents a very significant research and development effort to improve current ocean modelling and forecasting tools to catch up with other more mature areas such as meteorology and provide an operational forecasting system that is commensurate with the economic and environmental significance of the marine area. The main goal of MyOcean is the definition, design, development and validation of an integrated European capacity to monitor, analyse and forecast the oceans based on the existing know-how and resources in Europe at national level. MyOcean provides products and services that are relevant to marine safety, marine resource management, coastal and marine environment management and weather, climate and seasonal forecasting. MyOcean is a 39-month project, which will be completed in March 2012.

In parallel to MyOcean, a number of research projects have also been funded under the FP7 Space theme with the aim of utilising the products and services made available by MyOcean and conducting the necessary research to develop value-added services for end users (the so-called downstream services), in a number of areas relating to the marine domain. These downstream-service projects address a wide range of issues including the prediction of harmful algal blooms (*ASIMUTH*), the provision of marine water quality information (*AQUAMAR*), studying the influence of river outlets on ocean models (*FIELD_AC*), the delivery of robust sea-ice forecasting services for the Arctic and Antarctic (*SIDARUS*) or the monitoring of the African coastline (*EAMNET*).

MONITORING ATMOSPHERE AND CLIMATE CHANGE

The atmosphere has an immediate impact on our everyday life, in regulating weather and providing the air we breathe. Satellite images of weather patterns have become a well recognised form of monitoring, shown regularly in news media and being instantly accessible through internet and smartphones, often providing spectacular images of imminent severe weather, such as hurricane cloud patterns. Impressive as this may be, state-of-the-art satellites are now able to provide a level of detail that goes far beyond simply imaging the atmosphere from above and can now remotely sense the molecular composition of the atmosphere, detecting the presence of species such as polluting chemicals, greenhouse gases (CO_2 and methane, for example) and microscopic aerosol particles: Monitoring from space allows these to be resolved systematically, layer by layer, as they swirl around the globe.

The *MACC* (Monitoring Atmospheric Composition and Climate) project employs the latest data assimilation and forecasting techniques to complement the weather analyses and forecasting services provided in Europe with predictions of distributions of key constituents of the atmosphere several days in advance. This makes it possible to provide early warning of dangerous UV levels, irritating ozone or aerosol levels. The PASODOBLE project is developing and demonstrating services to provide information for hospitals, pharmacies, doctors and persons at risk. Major international events such as the Olympic Games in London 2012 will benefit from such forecasts. Furthermore, MACC and *PASODOBLE* provide valuable input to local, European and global policy makers, at all levels. The provision of support for compliance monitoring by regional environmental agencies is just one such example.

From initial observations of global warming, a steady consensus has built up that climate change is one of the most serious threats facing the world today, and a research challenge of the highest importance that must be tackled. Observational evidence, embedded consistently into an atmospheric model, represents one of the key contributions to climate change studies by projects like MACC, monitoring the concentrations of the most influential atmospheric species and their fluxes.

Observational data can only contribute meaningfully to climate change analyses if the continuity and consistency with existing data records can be ensured, particularly for the internationally agreed set of Essential Climate Variables (ECVs). A re-analysis of global CO_2, methane and surface fluxes for the period 2003 to 2010 undertaken by MACC provides a major step in this validation process. Detailed maps of global CO_2 fluxes and carbon pools are needed by the climate modelling community to understand and quantify the carbon cycles. Policy makers need to make informed decisions on CO_2 emissions at regional and local scales and citizens wish to be reliably informed on such issues: the novel approach taken by the *CARBONES* project for quantifying and understanding CO_2 surface fluxes is making an important contribution in this by providing a 20-year re-analysis of global spatial and temporal variations of carbon fluxes and pools, whilst establishing consistency with available *in-situ* and satellite data. Similarly, *EURO4M* will reprocess existing satellite products and assess atmospheric ECVs, with special attention to regional re-analysis methods over Europe.

Climate change can only be understood through improved knowledge of the close interactions between the atmosphere, oceans and waterbodies, and the land masses with their vegetation cover. The Arctic and adjacent high latitude regions have been seen to be highly susceptible to climatic and environmental change. Rapid decreases in Arctic Sea ice are just one manifestation of this sensitivity, with alarming consequences for populations and animal life in the Arctic regions. By adopting an earth-system approach, *MONARCH-A* will provide tailored information and products to both assist climate-change research and make available reliable, up-to-date scientific input for the implementation of European and international policies and strategies on climate change and society.

SUPPORT TO THE SAFETY OF CIVIL SOCIETY

Our modern societies are evermore dependent on services using communication and transport networks, energy production and distribution chains and similar infrastructures. In our daily lives we have become reliant on the consistent and reliable provision of such services. Any disturbances, whether man made or of natural origin, could have disastrous consequences. Space technologies form an integral part of such critical infrastructures but also represent a significant resource by providing solutions.

Satellite-based navigation, communication and earth-observation systems are critical components of any crisis management and emergency-response effort. They provide up-to-date geographical information derived from satellite imagery and offer robust communication and navigation capabilities. This allows the European civil protection authorities and international relief efforts in the UN context to provide the best possible services in the immediate aftermath of a crisis as well as in the recovery and prevention/preparedness phases. Examples of such services are flood extent maps, forest fire hot-spots, earthquake damage assessment maps, risk maps, etc. The GMES initiative includes such security and crisis response applications. In this context, the projects *SAFER* and *G-MOSAIC* provide pre-operational GMES services to national authorities, EU bodies, United Nations agencies and NGOs. These and other projects such as *NEWA* develop new technologies and new processing methods to be taken up by future GMES services. The G-MOSAIC project pilots specific services in support of the EU's Common Security and Defence Policy such as refugee camp monitoring, illegal crop monitoring, border monitoring and treaty monitoring. All these activities feed their results directly into the GMES programme recently agreed by the European Union.

Downstream GMES projects such as *DORIS, SUB-COAST* and *EVOSS* work in close cooperation with users in dealing with specific natural risks using space-based techniques for the monitoring and forecasting of landslides and ground deformation in cities and coastal regions and satellite-based earth observation techniques complementing ground-based volcano observatories.

But GMES is not only about space-based information: local information is also vital for assessing the situation on the ground and to validate satellite imagery. The project *GEO-PICTURES* aims to achieve integration of satellite navigation, communication and earth observation and to provide geo-tagged pictures and videos from the field and linked to the GMES emergency response maps.

Finally, space-based services are necessarily reliant on the security and integrity of the space systems themselves. There is a serious and growing threat of collisions between satellites and space debris, of which there is a significant quantity in all orbital regimes, posing the most serious threat in low earth orbit (see space technology chapter). Space weather is another important concern that affects the security of space assets as well as vulnerable ground infrastructure. Space weather effects caused by increased solar activity (predicted to reach the maximum of its 11-12 year cycle in the next few years) may lead to damaged satellites, lower precision in satellite navigation systems and induction currents that may affect power grids, pipelines and communication systems on Earth. These are clearly global problems that require global solutions. Several projects address this topic with international consortia including participation of countries such as the United States, Russia and Ukraine.

RESEARCH TO SUPPORT SPACE SCIENCE AND EXPLORATION

Space Science and Exploration captures the essence of the space endeavour: exploring parts of the solar system never seen or visited before, understanding processes on other planets and moons, and applying new insights to look back at Earth from a different and enriched perspective. Europe has a track record in astronomy (e.g. XMM, Herschel, Planck) and solar physics missions (e.g. Cluster in the ESA science programme) going back several decades. More recently, the first European planetary missions (e.g. Mars Express, Venus Express) have been highly successful in capturing scientific data of the planetary surfaces and atmospheres. The International Space Station microgravity experiments represent yet another facet of space science. Space science and exploration technologies underpin upcoming robotic space exploration missions such as the future ExoMars sample-return missions, and ultimately the ambitions for human exploration of neighbouring planets.

FP7 targets both downstream and upstream research projects in space science and exploration. ESA missions have resulted in a tremendous amount of scientific data to be exploited for fundamental scientific purposes and in preparation for future missions. Up until now, space data exploitation in Europe has been fragmented, being essentially based on national funding mechanisms for space instruments and research. FP7 provides funding for projects which coordinate data use and analysis at European level and integrate data from different instruments, experiments and missions. For a fraction of the total mission cost, this leads to a greatly enhanced science return from past and ongoing missions, in particular in the field of ISS experiments (e.g. *ULISSE*) and solar physics. In addition, several FP7 projects for data analysis and model validation of the solar wind-magnetosphere-ionosphere system (e.g. *SOTERIA, IMPEx*) are leading to an improved understanding and prediction of potentially hazardous space weather. This is also supported by projects such as *ECLAT* for the improved access to magnetosphere data obtained over the last decade by ESA's Cluster mission, complemented by relevant terrestrial measurements.

On the upstream side, projects focus on developing technologies and methodologies to be used in future robotic missions, and eventually human exploration of planetary surfaces. This new field for Europe combines scientific expertise in the analysis of the space and planetary environment (e.g. radiation, atmosphere, surface characteristics) with technology that enables planetary exploration (e.g. entry probes, rovers). For example, the *HAMLET* project measures the radiation effects on a human phantom equipped with over 6 000 radiation detectors on the ISS. A recurring theme in exploration projects is guidance, navigation and control (GNC), which is relevant at all levels, from orbit control, entry descent and landing to the metre-scale rover operations based on 3D visual information from stereo cameras (*PROVISG*). Development of prototypes and testing these in representative (field analogue) environments is key to developing innovative methods and technologies. Such test campaigns are part of FP7 funded projects such as *PROVISCOUT*.

Space exploration, and the associated technical and collaborative challenges, capture the imagination of the general public. Therefore, outreach and education are key aspects of space science and exploration to ensure that Europe can secure the next generation of creative engineers and scientists and thus reach the current goals for a knowledge-based society. Many FP7 projects in this field allow students, and sometimes even very young children (*EUNAWE*), to participate in space projects, building up critical knowledge, skills and enthusiasm for science and technology.

SPACE PROPULSION AND TRANSPORTATION TECHNOLOGIES

The space sector is a strategic asset contributing to the independence, security and prosperity of Europe and its role in the world. European non-dependent access to space is therefore a prerequisite for achieving its strategic objectives. Access to space means launch, propulsion and transport technologies enabling the cost-, energy- and mass-efficient delivery of space assets to their operational position. This may be in earth orbit, planetary or lunar orbit, or in the case of exploration missions, the surface of another planet or moon. Technological innovation and acquisition of European knowledge in the field of propulsion and transportation leads to an overall cost reduction and increase of scientific and operational return for European space missions, and is therefore an investment towards a competitive European space industry and affordable European space programmes.

A number of FP7 projects explore technologies such as electric propulsion (*HiPER, MicroThrust*), plasma thrusters for micro-satellites (*HSP.com*), hybrid propulsion technology (*ORPHEE*), solid propellants (*HISP*) and throttable engines (*SPARTAN*). Further work will have to address issues such as high power electric propulsion.

Planetary exploration missions are more demanding in terms of transport technologies than earth orbiting missions. Therefore, they represent a driver for new transport and Guidance, Navigation and Control (GNC) technologies. An example of a fuel-efficient approach to space travel is aerocapture: rather than using thrusters to reduce speed and enter operating orbit, the aerodynamic drag of the planet's atmosphere is used instead. The *AEROFAST* project is preparing the ground for a flight demonstration of this technology. One of the major challenges in planetary exploration is the entry, descent, and landing of a space vehicle from superorbital speed through an atmosphere (e.g. Mars, Titan). Entry in an extraterrestrial atmosphere is addressed in the project *PHYS4ENTRY*. Equally, if material is to be brought back to earth from exploration missions, earth re-entry technology is required as addressed in the *RASTAS SPEAR* project.

Landing safely on an extraterrestrial surface is one of the most challenging elements of exploration missions. It requires detailed knowledge of the surface topography to be fed back into the landing system in real time. The *FOSTERNAV* project is developing the technology to do this using a LIDAR (Light Detection and Ranging) device.

SPACE TECHNOLOGIES

Another important element of the space theme is space technology. It is an enabling element for strategic projects, for space-based services and applications, as well as for visionary concepts of future programmes and space exploration. Some of these technologies are also addressed as part of other topics, such as space transportation, space propulsion, space exploration and are partly already described under these sections. Other areas relate more specifically to the issue of space debris mitigation, or even removal. In fact, space debris is expected to quickly become a major threat to satellites in the low earth orbit. Another specific area given special attention under the Space Technologies topics is that of so-called "critical technologies for European non-dependence". Access to certain technologies can be crucial for

European industry to maintain its competitiveness or to implement major programmes, such as Galileo or GMES. Some of these technologies are subject to export restrictions in third countries or are provided by a single source only. In such cases, European industry is prevented from in achieving its goals and objectives by factors external to the EU and beyond its control. Thus, the space theme comprises the development of European technologies and the corresponding supply chain for technologies considered critical for Europe's space sector.

One such activity is focused on gallium nitride semiconductor technology, enabling higher frequencies and power densities in satellite electronics, as for example addressed by the *SATURNE* project. This is of significant commercial interest as this technology is used for powerful and thus competitive payloads of communication satellites, as well as for new sensor technologies in the area of earth observation. Other technology areas addressed are micro-electronic components for very high-frequencies and advanced power amplification. For example, Schottky diodes as investigated by the projects *MIDAS* and *TERACOMP*, are key for future remote-sensing technologies both for the earth's atmosphere and that of other planets. Innovative, lightweight and efficient shielding of components and units against space radiation is another topic of interest: The *SIDER* project aims to enhance the competitiveness of European satellites by addressing this issue. Examples of other topics addressed are analogue-digital converters, digital signal processors, cryogenic electronics, atomic clocks and frictionless magnetic drives, to name but a few.

INTERNATIONAL ACTIVITIES IN EUROPEAN SPACE RESEARCH

International cooperation within the Space theme is not only a question of scientific collaboration or technology development. It also aims to serve the widest possible spectrum of the EU's objectives for the economy and social development, environmental protection, education, science, technology and security.

Space represents a prime instrument for developing international cooperation. Monitoring the earth and exploring our solar system and the universe are, by nature, global ventures. In that context, numerous collaborative projects have been initiated with countries outside the EU and beyond the FP7 Associated States in many fields of space research, of which only a few examples are mentioned here.

The scientific partnership with the United States has started with the ProVisG project, which addresses the issue of visual data processing from planetary robotic missions. In subsequent calls in the field of Sun-Earth interactions, which have a strong influence on many important activities on earth such as air traffic, communications and navigation, close links have been established with NOAA, the US National Oceanic and Atmospheric Administration. The space weather projects are building transatlantic networks to investigate solar storms and to issue warnings in case of hazardous situations. In the 4th call the number of US researchers has further increased, which shows the growing relevance of the EU space research programme for international partners.

Since the start of FP7, there has been a significant participation of research organisations from the Russian Federation in nearly all fields of space research, which is also a result of the efficient Space Dialogue initiated in 2006. The main fields of cooperation with European and international scientists concern the monitoring of land and marine ecosphere, microgravity research, processing of data from experiments on the International Space Station, space transportation as well as propulsion and planetary entry technologies. In the first three calls, around 50 Russian partners are participating in 25 projects, too many to be mentioned individually. A first assessment of the 4th call shows that this trend is continuing.

Africa is another focus on the Space theme's international cooperation agenda. The objective is to raise awareness of the added value space can bring to the African countries in managing the challenges they face for food security, water resources, emergency management, land degradation, deforestation and health issues like Malaria propagation. The "GMES and Africa" initiative is also implemented through FP7 projects such as *EAMNet*, which aims at linking Earth Observation information providers, user networks and centres of excellence in Europe and Africa for coastal and marine observations. *GARNET-E* will enhance the ability of African states to use Earth Observation for the management of both natural disasters and humanitarian emergencies resulting from conflicts. The *SAGA-EO* project supports the need to analyse the potential to use space applications to better manage monitoring of climate change, desertification or fires, and water and food resources.

There is also some cooperation with Japan and China under the Space theme of FP7, which should be further developed in future calls. To improve the participation of these countries, outreach efforts have been undertaken in both China and Japan, including the organisation of a thematic event on FP7 space research at the World Expo 2010 in Shanghai. International cooperation with these Asian space-faring nations will remain on the agenda for the second half of the FP7 period.

Part I Earth Observation

Land monitoring

Showing the situation on the ground

geoland2

Operational Monitoring Services for our Changing Environment

Markus Jochum, Steffen Kuntz, Roselyne Lacaze, Marek Banaszkiewicz, Birgitta Olsson, Patrice Bicheron, Markus Probeck, Oliver Leo, Jean Christophe Calvet, Andreas Brink, Erwin Goor

Astrium GmbH Services, Germany, Infoterra GmbH, Germany, HYGEOS, France, Space Research Centre PAS, Poland, Metria, Sweden, SPOT Image, France, GAF AG, Germany, Joint Research Centre Agrifish Unit, Italy, Météo France, France, Joint Research Center Global Vegetation Monitoring Unit, Italy, VITO, Belgium

ABSTRACT

With climate change speeding up and the on-going growth of the World's population, the pressure on nature, biodiversity and our own living conditions increase steadily. To mitigate these threats, by effective adaptation strategies and counter measures, the frequent monitoring of our environment is crucial to provide decision makers and European citizens with accurate, up-to-date and reliable information on the changing conditions of our natural resources. Benefiting from Earth observation satellite data, the GMES Land Services provide such cross-border harmonised geo-information at global to local scales in a timely and cost-effective manner. These monitoring services have been defined, developed and implemented within a series of projects funded since 2003 by the European Commission (geoland, BOSS4GMES) and the European Space Agency (GSE Land / GSE Forest Monitoring).

Building upon the results of the earlier projects, geoland2 now closes the gap between research and the operational implementation of fully mature GMES Land Services, consisting of Core Mapping Services and Core Information Services. The project aims to organise a qualified production network, to build, validate and demonstrate operational processing lines and to set-up a user driven product quality assurance process, to guarantee that the products meet the actual user requirements.

The Core Mapping Services produce basic geo-information on land surfaces such as cover, use and biophysical parameters along with their annual and seasonal changes. This geo-information can thus describe, for instance, the continental vegetation state, the global radiation budget at the surface and the water cycle on the basis of Earth observation satellite data. The mapping products are of broad generic use being a very valuable information source in themselves. They also form the basis for more specialised geo-information services, i.e. the Core Information Services and further downstream applications. In geoland2 the Core Information Services offer specific information for European environmental policies and international treaties on climate change, food security and the sustainable development of Africa. Currently they address a broad variety of thematic fields, like for instance: water quality, forest managing, spatial planning, agri-environmental issues, the global carbon cycle, international food security, etc. In the framework of GMES for Africa, biophysical parameters have been provided to the AMESD (African Monitoring of the Environment for Sustainable Development) stations and specific e-tools are being tested to facilitate local data analysis supporting the sustainable management of natural resources.

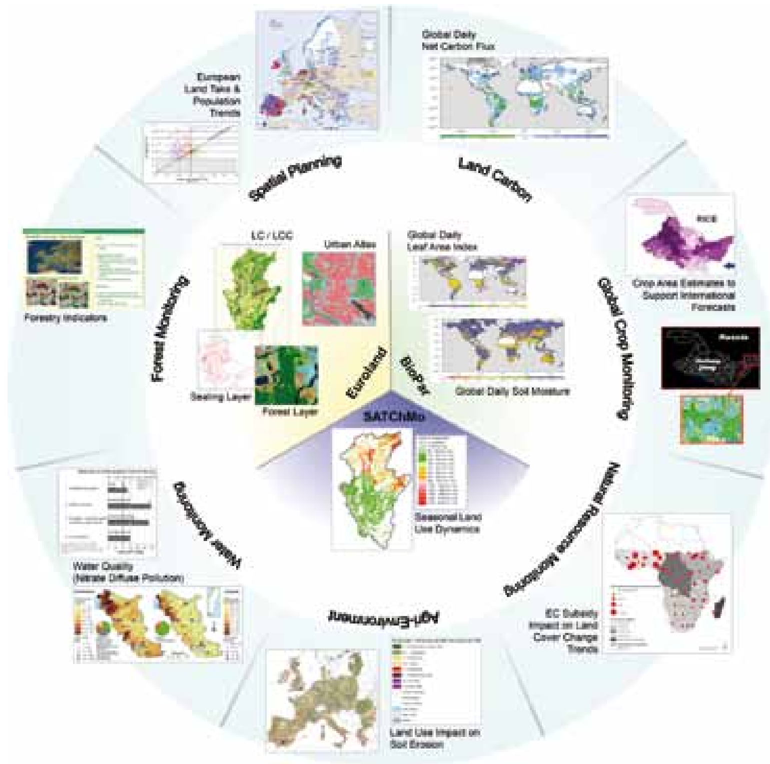

Figure 1: Architecture of geoland2: The project is structured into two layers: the Core Mapping Services (CMS) - as illustrated in the centre of the circle - generate 'basic' land surface products, while the Core Information Services (CIS) - as illustrated in the outer circle - utilise the CMS products to generate specific information products for European policies. The CMS and CIS will furthermore serve as input data for downstream services.

WORK PROGRAMME

geoland2 gathers more than 50 European service provider partners and over 80 major international user organisations and is financed by the European Commission within its 7th Framework Programme. The duration of the project is 4 years. Its general logic follows the principles of GMES service implementation, established first by ESA's GMES Service Elements (GSE). However, it has to be noted that the CMS and CIS belong to two different types of activities:

> The CMS comprise activities of the type "System Design and Pre-Operational Demonstration". They build processing lines and production architecture based on the critical review of existing user needs carried out in previous GMES projects. They conduct R&D activities to design the production lines and to implement new elements for service evolution. Then they set up, test and demonstrate pre-operational prototypes which are ready for operational implementation.

> The CIS focus on activities of the type "Service Consolidation / Evolution". They conduct R&D actions to define specific information products (e.g. for environmental indicators, impact analysis and forecast models) and test products and services coming from the CMS. They conduct with their end-users a utility assessment of these specific products and services, and conduct also a utility assessment of the CMS products they have used as input.

PARTNERSHIPS AND COLLABORATIONS

geoland2 is strongly engaged in the on-going European stake holders discussions from the production perspective to optimise workflows and to finally be able to offer cost and time efficient Land services.

Therefore geoland2 is currently represented in the INSPIRE Annex II Working Group (WG) Land Cover, follows and reviews the outcomes of other Annex II and III WGs and serves, with its demonstration data freely available via the GMES Land portal, as a test bed for INSPIRE experts and Member States.

With Member State experts there has been a close exchange established towards the consolidation of new and less mature services (e.g. for complex quantitative European layers of grassland and wetland parameters). Here, for instance, the regular meetings with the European Environmental Agency's EIONET working group "EAGLE" need to be mentioned, together with frequent meetings with the Implementation Group Land established by the EC (DG Enterprise and Industry).

LAND MONITORING

On a global level geoland2 observes and contributes to GEO/GEOSS activities and is represented in Land Cover working group of GOFC-GOLD (a panel of GTOS) as the regional European representative. In addition, there is a strong relationship to the meteorological domain, i.e. Eumetsat and ECMWF and to the African Observatory of the EC.

ACHIEVED RESULTS

Products and Services delivered include:

> **Euroland:** The European Land Monitoring Service addresses the local (i.e. the Urban Atlas) and the continental component (i.e. high spatial resolution, wall-to-wall land cover parameters and land cover change) of the Land Monitoring Core Service (LMCS). High spatial resolution land surface parameters are available with a minimum mapping unit of 1 ha derived from calibrated EO data with a spatial resolution around 20 m. These so-called High Resolution (HR) Layers build on a set of common layers (e.g. biophysical parametres, indices, and texture features). According to the on-going discussion at present they offer the following thematic content: degree of imperviousness, forest (cover, type, density), grassland intensity, wetland with water level fluctuation and small water bodies. For all the layers the monitoring aspect, i.e. the changes over time, are more important than single time point mapping activities. Demonstration products, freely available, comprise Image2006 and Image2009 cloud masks, and calibrated indices for whole of Europe. A major service which is already pre-operational is the wall-to-wall update of the Imperviousness layer (previously called "European sealing layer"). Other deliverables offer a HR Scandinavian Land Cover dataset and HR and medium resolution (MR) biophysical variables from various European sites, such as fraction vegetation cover and canopy shade fraction.

> **BioPar:** BioPar has produced an extensive range of biophysical parameters, which describes the continental vegetation, the energy budget and the water cycle, for supporting the European policies on environment and water management, agriculture and food security. Continental vegetation variables include Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI), Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), Fraction of Vegetation Cover (FCover), Dry Matter Productivity (DMP), phenological variables, and burnt areas. Energy budget variables include land surface temperature, downwelling short / long-wave surface fluxes and surface albedo. Water Cycle parameters include water bodies and Seasonality (over Africa), soil moisture and freeze/thaw. All the above parameters are produced on a global scale and in near real time.

> **SATChMo:** Seasonal and Annual Change Monitoring Service aims to close the gap between low spatial resolution global coverage and the high spatial resolution local coverage products by providing seasonal to annual European-wide coverage of physical properties describing bio-geophysical information parameters, such as land cover and land cover change. Products will be delivered in the format of indicators, site-based maps, complete continental coverages and statistics. SATChMo will deliver products less frequently yet with more spatial detail than BioPar while providing products more frequently but with less spatial and thematic detail than Euroland. SATChMo operates at continental scale over and Sub-Saharan Africa, addressing each continent independently and delivering services adapted to the specific local user requirements.

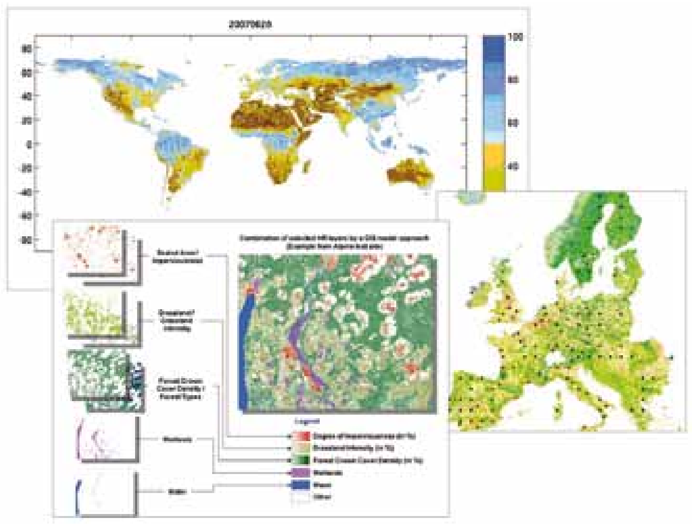

Figure 2: geoland2 Core Mapping Service examples. Top: Soil moisture freeze thaw. Right: European Area Frame Sampling. Down: High Resolution Parameters

> **Spatial Planning:** The Spatial Planning Service provides harmonised and highly accurate Earth Observation based information products and tools to describe, explain and forecast urban land use changes supporting spatial planning from regional to European scale. The service will resolve two of the major constraints with regard to the usage of spatial planning information: on the one hand the service fosters the usage of geospatially explicit information depicting real-world trends instead of lump statistics on aggregated administrative units, on the other hand it utilises homogeneous core land cover/land use mapping products following high thematic and geometric standards, thus allowing for comparable analyses across administrative boundaries. The products generated are Regional and European land take trend indicators, inter alia aiming to support the analysis for the European Environmental Agency's State-of-the-Environment Report 2010 (SOER 2010).

> **Forestry:** The Forest Monitoring Service is developing and demonstrating innovative, timely, cost-effective and quality-assured forest products to support European users in their reporting obligations towards national and international policies such as the UN Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol, the UN Convention on Biological Diversity (UNCBD) etc. The services provide highly accurate and spatially detailed information on the state and development of forests, while suiting different definitions of forest. First indicator and statistics services for representative European demonstration sites available since November 2009 (forest area-based indicators and statistics, forest fragmentation & connectivity indicators, forest type-based indicators).

> **Water:** The Water Monitoring Service addresses water management issues and the implementation of the Water Framework Directive (WFD) and the Flooding Directive. Both directives require quality assured and harmonised information on water quality and quantity as well as tools for predictions. The Water Monitoring Services will provide a pan-European model (based on the existing water models MONERIS and HYPE) aiming to achieve comparability between the local -usually country specific- models in order to address cross-border catchment issues and integrated analysis of transnational water bodies. The product range comprises: Nonpoint pollution potential service and agri-economical assessment of nutrient surplus as demo data sets in selected regions using Euroland and BioPar inputs for selected catchments, hydrological predictions of discharge and likelihood of floods and droughts based on variable Land Cover/Land Use at present and in a changed climate, Long-term water resources, Simulation of soil moisture and local runoff at subcatchment level for estimation of long-term water balance and nutrient loads to enclosed seas & source apportionment.

> **Agri-Environment:** Various EU directives and programmes, such as the Rural Development Programme, the Water Framework Directive, the Nitrate Directive and others, set strategic guidelines for the Common Monitoring and Evaluation Framework by defining objectives and indicators to evaluate the progress and achievement in environmental protection measures. The Agri-Environmental Service will contribute to the improvement of the timely and accurate monitoring of agricultural land use state and its changes at European, national and regional levels by providing common methodologies and indicators covering various temporal, spatial and thematic scales. A set of 20 agri-environmental indicator are available, split into six services ranging from cropping pattern, extensification / land abandonment, water abstraction, soil erosion, to high-nature value farmland and landscape indicators. Data over first demonstration sites are available.

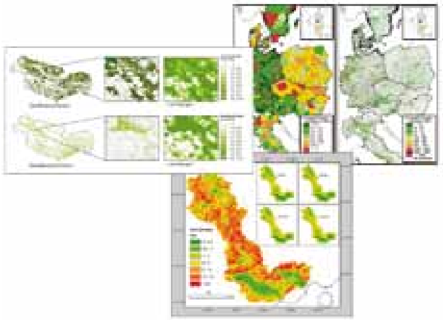

Figure 3: geoland2 core information service examples. Upper left: Forest indicators. Lower right: Spatial planning indicators – population density. Mid-low: Agricultural indicator – soil erosion

> **Land Carbon:** The Land Carbon Service aims to set up pre-operational infrastructures for providing global and regional (France, Hungary, the Netherlands) variables related to the terrestrial carbon cycle, in near-real-time (NRT), for describing the continental vegetation state (leaf area index and biomass), the surface fluxes (carbon and water), and the associated soil moisture. These variables are produced daily by models able to assimilate satellite data. This land data assimilation system is being implemented gradually. Past time series of observations, associated to atmospheric re-analysis, serve as a reference climatology for the NRT products. Combining these bottom-up to the top-down carbon flux estimates (the latter are produced by the GMES atmospheric service) reduce the uncertainties in the quantification of terrestrial biospheric sinks and sources of carbon. The added value of LAI complementing soil moisture has been demonstrated (15-year climatology for France study, 2003 heat wave analysis). Demonstration of positive impact of LAI seasonality information for ECMWF medium-range weather forecast. Collections of daily products (net ecosystem exchange, gross primary production, ecosystem respiration) being prepared for release in 2010.

> **Natural Resource Management of Africa** (NARMA): The thematic focus is on natural resource management in a seasonal as well as multi-annual perspective to facilitate decision making processes and medium term planning exercises. The service under development is deployed according to two axes: one part is technological and the other is the human interface between the processed data and the end users. The technological part of the service offers an integrated computer-based solution between data (typically low resolution data, with high acquisition frequency) received from Core Mapping Services and satellite application facilities via GEONETCast receiving stations and the end user. This NARMA service is packaged in the so called "e-station", which automates the final steps of data post-processing adjustable to the specific geographic and thematic areas to be covered, and provides a multi-user web-based reporting environment. geoland2 services has become part of the operational "e-station" operated by all sub-Saharan countries within the framework of AMESD (African Monitoring of the Environment for Sustainable Development). The project will also provide support to the EC for the preparation of "country environmental profile" (CEP) documents for about 40 African, Caribbean and Pacific Group of States ACP countries. Both service elements have been successfully demonstrated in 2009 and will be implemented in 2010.

> **Global Crop Monitoring:** The Global Crop Monitoring Core Information Service provides objective, near-real-time assessments of crop conditions and yield forecasts in support of European policies in the fields of agriculture, trade and food security. Benchmark the Biophysical Parameter Service products and promote standards for derived vegetation anomaly products. This service tests the use of bio- parameters as yield indicators or as information on phenology and further develops the direct ingestion of these parameters in crop growth models. In addition first Crop Area Estimates for 2009 over China were provided in support of JRC/MARS campaigns.

> **Spatial Data Infrastructure** (SDI): The Spatial Data Infrastructure (SDI) task supports the Core Mapping and Core Information Services in the dissemination of products and services to users. For this INSPIRE is considered as the baseline, to ensure an easy integration into the context of the European Spatial Data Infrastructure. The enhanced SDI Expert portal was released in July 2009. A broad range of geoland2 demonstration products have been integrated and are available for metadata search and inter-active use on the web-map server and for download through the expert portal.

CONCLUSION

In the last decade an impressive number of EC, ESA and national projects have developed GMES Land Information Services in close collaboration with international, European, national and regional/local end-user organisations. These projects have demonstrated the added value of such services in supporting the implementation of European Directives and International Policies.

From this "bottom-up" consolidation of geo-information services, a set of common geo-information parameters has been identified to support a broad range of down-stream services. These will be established as the GMES Land Monitoring Core Service (LMCS).

The purpose of the geoland2 project is to further elaborate the LMCS specifications and validation approach, as well as to verify a viable production system by setting up a pre-operational prototype production environment ready for operations.

LAND MONITORING

The LMCS is expected to expand from delivering only relatively "simple" core "mapping" parameters (such as land cover, land use or bio-physical vegetation information) towards the provision of core "information" relevant on a pan-European up to global scale (such as water quality information across catchments basins or sustainable development parameters). This will ultimately allow an assessment of policy impact, serve as a harmonisation back-drop to national/local reporting and as a common reference for sector-specific analysis.

A range of downstream service applications derived from the LMCS are being developed in geoland2 that use local in-situ data and/or local models, and that support reporting on global, national and regional level and have been consolidated and demonstrated by FP6 and GSE projects. The primary focus of the downstream services is to serve legally mandated organisations (agencies) in implementing their daily duties. Further down-stream applications are expected to address commercial and/or export spin-off use of GMES skills and data.

A core service that can be used to address multiple purposes is expected to substantially stimulate the downstream services market and to offer excellent opportunities for growth, in particular for established SMEs serving regional/local markets or specific down-stream market sectors.

The expectation is that a future operational implementation will rely on competitive market rules. The LMCS is expected to be procured on Global and European level, while downstream services will follow the subsidiary rule and rely on national/regional/local public customers. Commercial and export opportunities to exploit European GMES skills are expected to ensue beyond the current scope and timing.

To build a trusted market offer, sound and accepted validation approaches, transparent and commonly agreed service standards need to be established.

LAND MONITORING

geoland2

European Area Frame Sampling - Hot Spot Monitoring

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Space Research Center PAS, Poland, Specto Natura Ltd., United Kingdom, Joint Research Center, Italy, ITUK, United Kingdom, IGiK, Poland, AGI, Lithuania, Resac, Bulgaria, DFD, Germany, SYKE, Finland

ABSTRACT

A means of providing detailed mapping of selected sites ('hot spots') is an important component of the Land Monitoring Core Service (LMCS), as outlined in the GMES: Next Steps (GAC-13-02) document. Accordingly, suitable EO data requirements are being formulated as part of the GMES Data Warehouse Requirements (the new centralised, ESA-managed data procurement mechanism) from 2011.

The European Area Frame Sampling (AFS) component of geoland2 has been established to address these needs and to support a wide range of internal and external users. AFS approaches monitor the landscape features of interest at a set of specific sites rather than 'whole territory', as these features would be too expensive or challenging to monitor comprehensively. The design of the sample scheme is optimised to:

> increase representivity,

> improve the quality of the estimates derived from the sample sites and,

> understand the uncertainties present.

WORK PROGRAMME

European Area Frame Sample Design

The European AFS within geoland2 was designed initially to deliver statistically robust estimates of land cover and land cover change for features with fine spatial detail (0.25 ha) from ~4m very high spatial resolution (VHR) EO data. Although descoped from its initial concept for EO data supply reasons, the design as it now stands is still a valuable asset, representing a well distributed set of 114 sample sites covering 8 biogeographic regions, 19 Member States, coastal zones, urban areas and land above 1200m. The European AFS (figure 1) therefore provides a biogeographically and politically relevant set of sites for both the calibration / validation of other geoland2 products and also the demonstration of the capabilities of VHR EO data at the pan-European level.

Figure 1: The current European Area Frame Sampling (AFS) scheme containing 114 biogeographically and politically representative sample sites overlaid on the CORINE Land Cover map. The AFS is scalable and can be adapted to respond to changing requirements and specific incidents / issues ('hot spots'); Specto Natura Ltd.©

PRODUCTS AND USERS

The European AFS portfolio is made up of a number of products from the sampling design itself, through collections of pre-processed VHR images (including multi-date composites) to information products such as land cover maps. The main information product will be a generic land cover product delivering a set of 10 basic classes aligned with the nomenclature recorded by LUCAS, with a minimum mapping unit of 0.25 ha. Where EO data availability allows, for instance the addition of ~20m high spatial resolution (HR) inputs, enhanced land cover information will be derived with up to 20 land cover classes.

The products will now be described in term of their envisaged end use:

1. The AFS provides a well distributed collection of large area (~ 225 km^2) samples to validate the High Resolution (HR) Layer products, produced elsewhere within geoland2 from ~20m imagery. A number of the sample sites have been selected specifically to cover portions of the geoland2 transects where the HR layers are being developed. The VHR imagery could be used directly for manual comparisons. More effectively, the land cover information products produced for each sample site can be adapted to validate the HR layers automatically. For instance, urban, water and forest masks could be generated for comparison to parts of the imperviousness, water and forest layers respectively (figure 2).

2. Similarly, a number of sample sites (~40) are associated with Urban Atlas (UA) areas. Therefore the European AFS could provide both VHR imagery and tailored information masks to support UA validation activities.

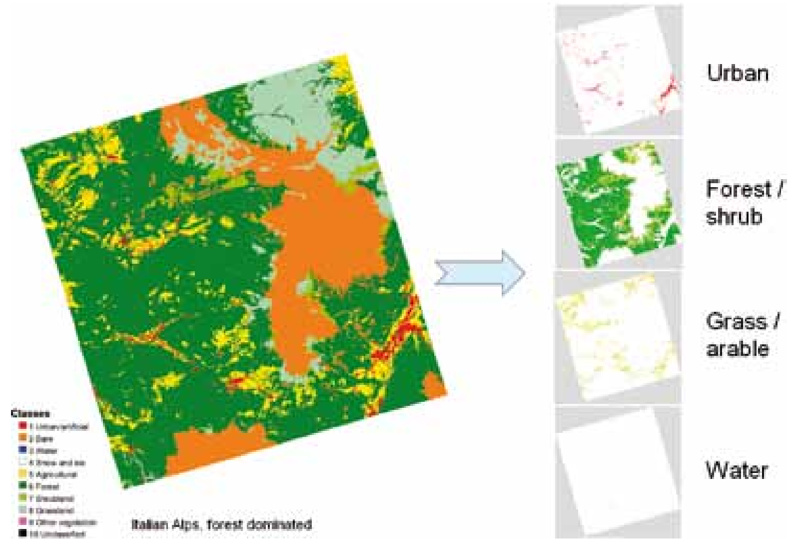

Figure 2: An example of the generic land cover product for a single sample site and the subsequent conversion to masks suitable for the validation of the HR layers, ITUK and Specto Natura Ltd.©

3. The European AFS sample design and products were selected to align closely with the LUCAS requirements and to support its activities in a number of ways. The sample sites were selected to address specific deficiencies in the LUCAS scheme, by including certain islands not visited by LUCAS surveyors and land above 1200 m (~ 12 sites) where EO derived products could provide additional information. The land cover products use a nomenclature aligned to LUCAS, to allow the provision of added value to LUCAS results and also to calibrate LUCAS results against other products and validate LUCAS results against an independent dataset. Further added value could be provided by the EO-derived products through the provision of information which it is not possible to record in the LUCAS approach, such as landscape pattern and habitat connectivity and the conversion of the mapping to other nomenclatures.

4. The European AFS will also demonstrate the capabilities of VHR EO data for monitoring a number of "hot spots" on a regular basis. The AFS sample sites were selected to cover NATURA 2000 sites (74 sample sites have one or more N2000 sites present), areas of high nature value (HNV) farmland (~20) and wetlands (~25). The information products will provide both generic and enhanced land cover data to support monitoring of these sites, which can be converted to match some of the EEA indicators (figure 3).

5. The European AFS can be easily extended to cover other "hot spot" situations, with the existing sites providing long term background or control information. For instance, the recent Hungarian toxic waste release site could be set up as a new sample site for future monitoring. The impact of the release and subsequent clean-up / recovery could then be compared to sample sites in the region or with similar biogeographical conditions.

6. geoland2 is developing a toolbox of change detection methods to support monitoring activities in general, and to allow existing monitoring to benefit from the outputs of the LMCS. As the EO data for each AFS sample site is compiled over time, indicators of change and change products can also be derived (figure 4).

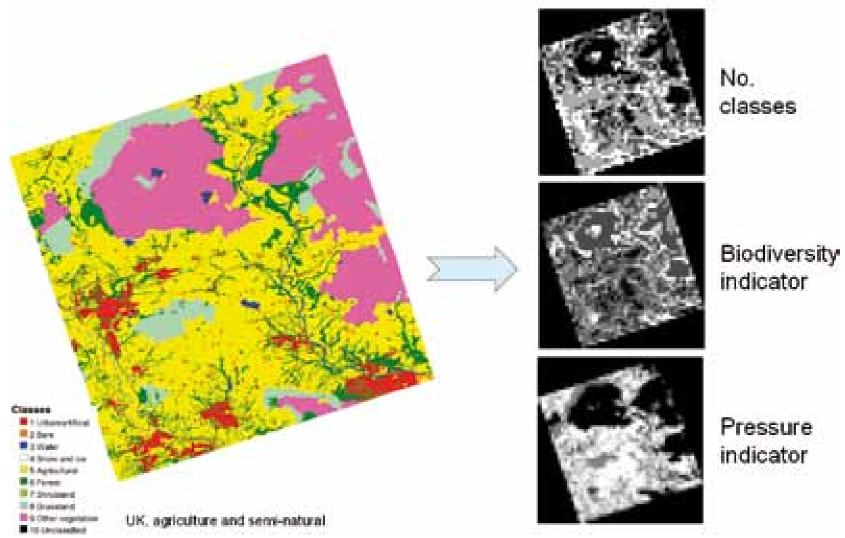

Figure 3: Examples of enhanced land cover products in the form of spatially detailed indicators derived from the generic land cover product within a single sample site. The 'no. classes' is an indicator of landscape heterogeneity, the 'biodiversity indicator' weights the area of land cover classes depending on their possible biodiversity value and the 'pressure indicator' highlights the areas of intensive land use such as urban and arable. IGiK and Specto Natura Ltd.'

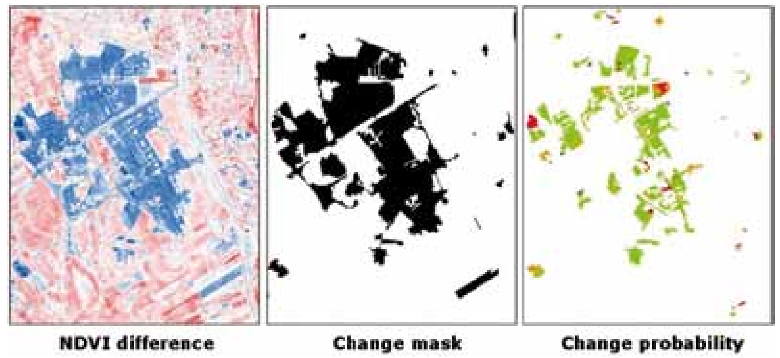

Figure 4: Examples of different ways of estimating change from VHR EO data. The normalised difference vegetation index (NDVI) difference shows expansion of vegetation in red and reduction of vegetation in blue. Such products can be thresholded to produce masks or further processed to produce change probability indicators, SRC '

PARTNERSHIPS AND COLLABORATIONS

SATChMo is primarily seen as a European level service and close relationships are being developed with the European Environment Agency in terms of the local component of the GMES Initial Operations (GIO), DG-Environment in terms of hot spot monitoring and Eurostat in support of the LUCAS survey. The sample sites also demonstrate the opportunity to provide a useful data and information source to Member States and the spatial scales involved are in line with their requirements.

Towards the future, SATChMo is now working with some of the new FP7 projects which aim to develop downstream services which can build on the capabilities of the AFS and generic land cover products and provide support to development of more enhanced land information products. One example is the Multi-scale Service for Monitoring NATURA 2000 Habitats of European Community Interest (MS-MONINA) project which will develop a pan-European, multi-scale approach to habitat monitoring and assessment that reflects the specifics and the variety of habitats in the different biogeographical regions, and guides the specifications of the service chains for the assessment biodiversity.

CONCLUSION

In summary, the current European AFS within geoland2 is an important and effective demonstrator for what will be possible, given sufficient EO data within GIO. The European AFS bridges the gaps between more conventional in-situ / site-based monitoring and full territorial EO-based products with limited spatial detail. Each of the sample sites contributes to a localised framework for integrating ancillary information and regional statistics in a realistic landscape structure, allowing the extraction of robust results, indicators of condition, measures of uncertainty and evidence for causal relationships between policy, processes and outcomes.

As this is only a demonstrator activity during the life of geoland2 (to 2012), longer term the European AFS would need to be scaled-up within the context of GIO, towards the levels envisaged by earlier projects such as FP5 BIOPRESS. Much of the technology is already proven and is only restricted by the realistic availability of VHR EO data described in the GMES Data Warehouse Requirements document (which covers the period 2011-2014). It is clear that the European AFS can provide the necessary links between other LMCS products in terms of validation and calibration. It can support activities within and beyond the LMCS at the European and regional levels and, in some cases, nationally where particular "hot spots" are concerned. The European AFS is therefore a powerful multi-use EO data and product strategy, which complies with the INSPIRE principles of collecting once and using many times.

geoland2

Continental component of the Land Monitoring Service

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Infoterra GmbH, Germany, GAF AG, Germany, Indra Espacio, Spain, GISAT, Czech Republic, Specto Natura, United Kingdom, Geoville, Luxembourg, Geoville, Austria, Ioanneum Research, Austria, ETC-LUSI, Spain, Planetek, Italy, Joint Research Center, Italy, ROSA, Romania, VTT, Finland, Geoapikonisis, Greece, AUTh, Greece, AGI, Lithuania, Eurosense, Belgium, EFI, Finland, Metria, Sweden

ABSTRACT

The overall context is defined by the European Commissions communication on GMES, where "land information services" are one of three key fast tracks to be implemented.

In the current setup of the continental LMCS, geoland2 will support two main elements:

> Continuation of Corine Land Cover (CLC) change mapping to assure European-wide harmonised time series on Land Cover/Land Use (LC/LU) changes.
> Production of a set of 5 quantitative high spatial resolution thematic LC layers (HR layers) and changes layers. These layers shall comprise at present pixel-based information on impervious areas, forests, grasslands, wetlands, and small water bodies.

Euroland will answer these requirements by focusing on development, prototype implementation and demonstration of operational processing lines taking benefit from common processing elements, e.g. image data pre-processing, common indices production. The resulting processing chain shall develop the capacity to efficiently produce European wall-to-wall coverages of the 5 quantitative HR layers in a quality and cost effective way. It is expected that the HR layers will:

> Support the European LC/LCC mapping and monitoring activities, such as the CORINE Land Cover 2012 update, by offering production tools and manuals together with HR layers.

> Allow MS to thematically enrich existing national LC/LU data bases.

> Allow the direct use of the information for further value-adding and downstream applications on European level (e.g. environmental indicators, to be demonstrated by the CIS).

> Support the production of Very High Resolution (VHR) Urban Atlas update products for Europe's major cities.

The HR layers shall offer high spatial resolution, quantitative pixel-based information of more or less complex nature on particular themes. However, also discrete thematic information will be provided as secondary layers, such as built-up areas, forest / non forest areas, grasslands, wetlands and water bodies. As each of the HR layers will be made up of one or more sub components, primary and secondary products can be provided for all HR Layers, according to implementation priorities at European and Member States level. For instance, a primary layer for the HR Forest layer is crown cover density map validated to 1 ha Minimum Mapping Unit from which a secondary product such as a forest/non forest map can be produced using a MS-specific forest definition. Similarly, the imperviousness map from the HR Imperviousness layer can be extended to a secondary product such as a built-up mask using established limits for imperviousness in built-up areas.

WORK PROGRAMME

Euroland comprises activities of the type "System Design and Pre-Operational Demonstration". In the first two years of the project, processing lines and production architecture based on the critical review of existing user needs carried out in previous GMES projects were developed. The process includes R&D activities to design the production lines and to implement new elements for service evolution. The steps followed are to set up, test and demonstrate pre-operational prototypes which are ready for operational implementation.

PARTNERSHIPS AND COLLABORATIONS

The European Environment Agency is recognised as the main responsible organisation for the 5 GMES High Resolution Layers (HRL) for land monitoring in the GMES Initial Operations (GIO) stage. Given its role in the consolidation of the methodology for the 5 HRL, the geoland2 Euroland task recognises the European Environment Agency (EEA) and its collaborative networks as the one key user organisation that is addressed.

ACHIEVED RESULTS

The HR layer service specifications are based on a long-term consultation process with EEA and a broad user base of national and environmental users. The Euroland team is focusing on investigating all technical and practical issues of service concept evolution raised by the GMES Bureau and the project reviewers, e.g. on dynamic change monitoring, data integration, product and service specifications as well as pan-European roll-out requirements. This is intended to better support the required assessment of the maturity of individual HR Layers prior to the finalisation of the GIO Implementation Plan. A more regular exchange and further direct meetings with the mentioned entities and other key stakeholders are envisaged in order to converge towards accepted HR Layer products and services.

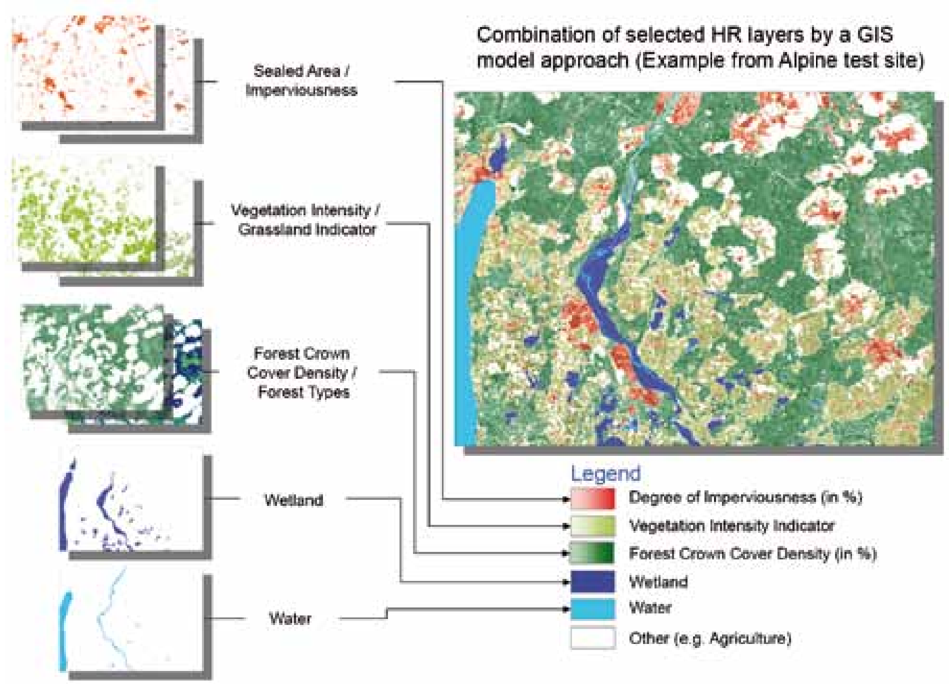

Figure 1: Example for the 5 HR layers (Alpine test site):

Left: individual layers, right: demonstration of all layers combined based on a GIS model approach. As several layers are partially overlapping (e.g. wetlands and forest) the borderlines between the layers may vary according to user needs

LAND MONITORING

IMPERVIOUSNESS LAYER

Based on the positive experience of the utility of the Fast Track Service Precursor Sealing Layer, EEA approached Euroland to produce an Imperviousness Layer update. The reason for this update is the rapid increase of the urban areas at European level and the EEA's need to report by the end of 2010 whether this trend is still on-going and, thus, would require political action. This trend can not be tracked and analysed with current CLC time series due to the relatively coarse spatial resolution and extended time interval. As such, there was an urgent demand to demonstration the capacity of Euroland to produce rapidly an imperviousness layer update.

The analysis of user requirements led to the following service specification for the update:

> Raster dataset on changes in core land cover data for built-up areas in full spatial resolution (20 x 20 m) with the associated metadata. The dataset will be delivered for each of the 38 EEA member countries participating in the regular Corine Land Cover dataflow and as a seamless European dataset.

> Re-construction of full spatial (20 x 20m) and 1 ha European layers after conclusion of the enhancement.

> Raster data set with the identification of updated areas (20m, European projection only).

Technically feasible change detection methods have been benchmarked in year 1 of geoland2. After consolidating the service specification with EEA a highly automated change detection method has been developed and has been implemented in the production units.

The method is pre-stratification-based on the reference year 2006 (Image2006 + CLC + FTSP Sealing Layer 2006). An automated comparison of pixel values of Image2006 and Image2009 extract the change indicator layer which is followed by a visual inspection of the identified change information.

FOREST LAYER

The layer design as addressed and explored by geoland2 consists of a complex HR Forest Layer with geometrically consistent and synergistic pixel-based Forest Type and Forest Crown Cover Density information at high thematic/quantitative accuracy. These two components are considered "primary products". As a secondary product, customised national / regional Forest Area maps may be derived directly by member states, applying individual Forest definitions (in terms of crown cover density thresholds) and integrating local databases. This is expected to bring specific benefits to member states by enabling them to make full use of pan-European Forest products towards their national needs and vice versa. It will for example allow the performance of a flexible conversion of national forest information to be in line with international reporting requirements, which often differ in the definition of the applicable threshold for forest crown closure (e.g. Corine Land Cover, Food and Agriculture Organization). Another secondary product will be Forest Area Change (in terms of afforestation, deforestation and clear cuts) by making use of semi-automated spectral change monitoring procedures in combination with actual Forest Area maps.

The Euroland Forest Team has developed, integrated, tested and demonstrated this processing chain in different demonstration sites covering all major European forest ecosystems, in order to define a technically and scientifically sound well-tested and documented processing chain which allows effective pan-European operational mapping of the HR Forest Layer. In the first year of geoland2, HR Forest Layer demo products have already been mapped for five of these demo sites based on Image2006 EO data, and the results have been validated and published via the geoland2 SDI and web portal. These products were demonstrated and user utility assessments carried out with national users in early 2010. VHR data as well as the SATChMo AFS data will be used as independent spatially detailed validation data for the forest layer.

GRASSLAND LAYER

Although Europe annually acquires a huge amount of agriculture information from member states, i.e. from the Integrated Administration and Control System (IACS) and the national Land Parcel Information Systems (LPIS) there are still significant gaps in knowledge on grasslands as expressed by EEA. Hence, the research question to geoland2 is: Can an EO based method be found to answer this demand for arable / grassland distinction and a further grassland characterization?

The primary layers for the grassland HR layer focus on the temporal behaviour of soil or vegetation indices (e.g. NDVI, green fraction, soil fraction, etc.) during the growing season (seasonal variability). These primary layers include three products: a vegetation dynamics/seasonality indicator, a bare ground indicator (at one point there was bare ground) and a vegetation roughness indicator (spectral, e.g. canopy shade factor). Natural grassland shows a comparably constant seasonal development since the building of green biomass is solely influenced by phenological trends. For managed grassland the loss of biomass due to grazing or hay-cutting involves a significantly higher variation of biomass during the year. Arable land shows the most dynamic temporal behaviour, ranging from bare soil in the beginning of the season (for many crops), through a constant and comparably fast evolution of biomass during the growing period to a rapid decrease of the vegetation cover - or even the appearance of bare soil - in and after the harvesting season. The vegetation dynamics/seasonality indicator will describe these phenological variations among the different classes, e.g. through combining multi-date NDVI or green fraction. The bare ground indicator characterizes the appearance of bare soil at one point during the growing season. The vegetation roughness indicator is an indicator of the canopy roughness and will discriminate flat canopies like crops or managed grassland from rough canopies like trees, shrubs and unmanaged grasslands.

The generation of the secondary layers is based on the combined analysis of the seasonal development of the primary layers. The resulting thematic products include a basic classification discriminating between arable land and grassland, an enhanced grassland classification assigning the intensity of management (e.g. pasture, natural grassland) and a demonstration of a landscape structure indicator describing the spatial fragmentation of the landscape. For the differentiation of natural and managed grasslands the synergy of Very High (VHR), High (HR) and Medium Resolution (MR) and the potential of time series by MR data like MODIS and MERIS data are aspired. For the derivation of three to five important dates to discriminate these classes depending on the geographic location, the seasonal behaviour and start of the growing season of different landscapes will be analysed with MR data (MODIS). The approach is then to derive the geometry of agricultural parcels from HR and VHR data supported by already existing information systems, e.g. European LPIS, and combine it with the seasonal information of the three to five HR data takes (such as AWiFS, DMC or LISS III). Reference data (e.g. LUCAS or CORINE) will be used to assign the seasonal trends to specific crop and grassland classes. The differentiation of crops and grassland in difficult terrain (e.g. the Alpine region) will be carried out through analysing the SRTM-DEM concerning slope and height. Furthermore, the classification will include different geographical regions with different seasonal behaviour and start of the growing season. Therefore, a map with European's ecoregions will be included in the analysis.

Both, primary and secondary layers will be provided with a spatial resolution of 20m whereas the thematic products will be generalized to a 1 to 5 ha MMU.

WETLAND LAYER

Wetland areas may be characterised by vegetated, bare and water surfaces, but more likely a combination of all three. During the year, wetlands will display dramatic changes in surface characteristics as the vegetation growth and hydrologic season's impact on the site. Vegetation growth will tend to obscure water and other surfaces as it develops during the summer months. Winter storms and spring melting of snow will tend to increase inundation levels. Both of these processes may not be wholly natural as wetlands are often managed, as flood alleviation schemes, and wetland areas are used for grazing and harvesting reeds or peat.

The primary layers for the wetland HR layer may be related to the temporal extent of water surfaces and the proportions of vegetation, water and bare surfaces. For each of the EO data takes the NDVI, biophysical parameters and the original spectral data could be used to perform a simple classification into water, vegetation and bare ground for the areas identified as wetlands. A secondary product could then use the proportions of water from each EO data take to establish the period(s) of significant inundation or in-situ information from existing wetland data bases. Besides that, the RAMSAR nomenclature needs to be carefully analysed, as well as considering a package of wetland 'indicators' which may be derived starting for instance from a set of temporally varying biophysical indicators or fractional abundance maps different land cover types occupying the wetland. Here, SATChMo experience could support this approach, as some of the current SATChMo sites also include wetland elements.

Hence, for highly dynamic wetlands the EO data situation is similar to the previously discussed grassland layer, with the difference that no legal obligation for mapping of wetlands exists. However, a similar approach by integrating existing international (e.g. RAMSAR, MEDWET) and national wetland databases, as well as CORINE Land Cover data should be feasible. But it is clear that none of these databases provide the information and detail which is expected from a pan-European wetland layer.

By only using EO data the detection and mapping of all European wetlands would prove to be very difficult, inaccurate, and time consuming. Therefore, in a first step, a methodology should be developed to make use of the existing databases to establish a homogeneous pan-European mapping and monitoring of wetlands. Thereby, the identification/localization should take benefit of the existing information, while the actual mapping has to be based on EO data. In this context Euroland will closely cooperate with SATChMo.

WATER LAYER

Freshwater ecosystems in Europe are rich in biodiversity but at risk. They provide essential ecosystem services to humans, such as cleaning water, preventing floods, producing food, providing energy and regulating freshwater resources. Numerous pressures affect European freshwater ecosystems. Biodiversity has suffered from pollution and degraded water quality. In addition many inland water bodies endure

LAND MONITORING

too little water (due to water scarcity and drought), too much water (due to floods), and modification by artificial structures. As a result, freshwater biodiversity is at risk. Restoring and preserving natural freshwater ecosystems has multiple benefits and should be encouraged. It requires close coordination between nature protection, water uses, energy production and spatial planning.

According to EEA there is the need to recognise and monitor small water bodies across Europe as there the highest changes occur which shall include the monitoring of coastal water areas.

This HR layer comprises the CORINE Land Cover Class 5, i.e.

> Inland Waters – permanent as well as temporary (Optional) Marine waters (t.b.d. by EEA)
> Layer indicating water basins and stream courses
> Generally the CORINE Land Cover class descriptions are used to delineate water areas and to separate them from each other and from other classes
> If multitemporal satellite data (such as Image2006) is used, water will be mapped "high water", this means that the maximum extent of the actually visible water is mapped, e.g. in the case of a reservoir

The product will be delivered as a pixel layer, validated to 1 ha MMU. However, there are still a range of open questions on the service specifications which need to be discussed with member state experts and the EEA; e.g.:

> Which is the preferred season to be used (this may vary significantly between Northern and Southern Europe)
> Shall an averaged water layer be produced (i.e. using all available seasons and averaging the water levels of each season)
> How to deal with coastal zones; i.e. differences in water levels due to intertidal changes (e.g. shall we simply map what we see at one point in time)?

As the spectral response of water bodies in most cases allows a highly automated detection such an approach can be applied to any available seasonal coverage.

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CONCLUSION

The expected benefits are that on European level operational HR layers will allow the creation of pan-European environmental indicators. In addition, they can contribute to a better understanding of land cover changes and ecological and environmental trends to mitigate impacts of global warming and environmental degradation. On member state level they can support national mapping and monitoring activities for instance by providing additional quantitative land cover information to upgrade or further attribute existing national land data bases. However, while the service specification of the two layers "Imperviousness" and "Forest" are already consolidated, the other remaining layers (grassland, wetland, and water) are still under discussion between European and member state experts and users.

geoland2

The Biogeophysical Parameters Service

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ABSTRACT

The European GMES initiative provides a political framework for future implementations of Services Centres in charge of products and services related to environmental applications. The project geoland2 constitutes a major step forward in the implementation of the GMES Land Monitoring Core Service (LMCS), and addresses the 3 components (local, continental, and global) of the LMCS.

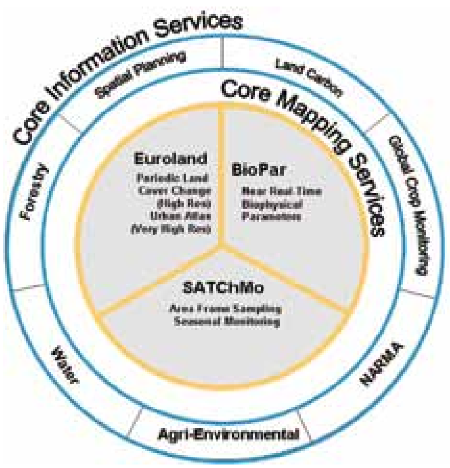


Figure 1: The geoland2 structure

Building upon the results of preceding projects funded by the European Commission and the European Space Agency, geoland2 is the last brick towards the implementation of fully mature GMES Land Services, consisting of Core Mapping Services (CMS) and Core Information Services (CIS) (Figure 1). The CMS produces "basic" geo-information on the land state covering a wide variety of thematic content, spatial scales from local to global, and update frequency from 1 day to several years, on the basis of Earth observation data. Besides being a valuable information source by their own, the mapping products are input for the CIS focusing on water quality, spatial planning, forest management, agri-environmental issues, food security, carbon cycle analysis. These CIS offer specific information for European environmental policies and international treaties on climate change, food security, and sustainable development.

The Bio-geophysical Parameter (BioPar) CMS aims at setting-up operational infrastructures for providing regional, continental, and global variables describing the vegetation state, the radiation budget at the surface, and the water cycle, both in Near Real Time (NRT) and off-line mode. Built to answer the needs of CIS, and other CMS, considered as representative of a large community of users (institutional users, future GMES services, international scientific community, ...), the BioPar portfolio includes parameters identified as Essential Climates Variables (ECV) like Leaf Area Index (LAI), Fraction of Absorbed PAR, Albedo, Land Surface Temperature, Burnt Areas, or Soil Moisture. These variables are at high resolution (~10 m) of some risk areas across Europe, at medium resolution (300 m) over the whole Europe, and at low resolution (from 1km to 10km) at the global scale. In complement of the continental and global products provided in NRT for monitoring activities, the available EO data archive will be processed with the same methodologies so that to get consistent long times series, necessary for anomalies detection. All BioPar products (demonstration products, on-demand products, NRT products) are made available freely progressively through the SDI Expert Portal (http://www.geoland2.eu/core-mapping-services/biopar.html).

WORK PROGRAMME

The concept of BioPar relies on research and development activities, shared in 3 topics (vegetation, radiation, water), and on demonstration operations, shared in NRT and off-line processing. In particular, the R&D activities focus on parameters as LAI, FAPAR, albedo, burnt areas or soil moisture, which have been identified by the WMO/GCOS in the context of UNFCCC as Essential Climate Variables (ECV). The research teams define the retrieval algorithms based upon existing and validated methodologies, improve them to match as well as possible the user requirements, and initiate innovative actions to adapt them to the technical specificities of the next generation of sensors in order to ensure the continuity of the service. Effort will be put on the compatibility between historic and current products so that long-time series are available after the reprocessing of available EO archives. Independent teams perform the product validation, following the standards defined by the Land Product Validation (LPV) sub-group of CAL/VAL group of CEOS (Committee on Earth Observation system). The development teams implement the algorithms in processing lines, and generate test data sets for user evaluation. The pre-operation centers perform the pre-operational production at regional, European and global scales, in NRT and in offline mode. Finally, the resulting biogeophysical parameters are disseminated by the Spatial Data Infrastructure Expert portal, in a format in accordance with the INSPIRE directive.

Product	NRT / Off-line	Spatial Resolution	Spatial	Temporal	Sensor
Continental Vegetation					
LAI, FCover, FAPAR, DMP, NDVI, Phenology	NRT	1 km	Global	10-days	VGT
Times series of vegetation products	Off-line	4 km	Global	10-days	AVHRR + VGT
Burnt areas + seasonality	NRT	1 km	global	Daily	VGT
MERIS FR biophysical variables	NRT	300 m	Europe	10-days	MERIS
HR biophysical products	Off-line	10 m	Pilot Areas	4 times/year	SPOT, RapidEye
Energy Budget					
Downwelling Shortwave Surface Flux Downwelling Longwave Surface Flux	NRT	~5 km	Global	hourly	ΣGEO + AVHRR
Land Surface Temperature	NRT	~5 km	Global	hourly, daily, 10-days	ΣGEO + AVHRR
Surface Albedo	NRT	1 km	Global	10-days	VGT
Surface Albedo	NRT	~5 km	Global	10-days	ΣGEO + AVHRR
Water cycle					
Water bodies + seasonality	NRT	1km, 250 m	Africa	10-days	VGT, MODIS
Soil Moisture + Freeze/Thaw	NRT	0.1°	Global	Daily	ASCAT
Time series of soil moisture products	Off-line	25 km	Global	Daily	ERS-1&2 Scatt

Table 1: The BioPar CMS Portfolio

Most of the products of the BioPar portfolio (Table 1) are delivered in NRT in the sense of few days (less than one week), as requested by the final users who need to know the surface conditions within a few days of delay in order to react appropriately in case of anomaly, and to anticipate and manage the potential resulting problems. Detecting anomalies by comparing the current observation with a reference requires having consistent long time series. BioPar will provide such time series for some Essential Climate Variables (LAI, FAPAR, Albedo, soil moisture) taking advantage of existing EO data archive, and developing sensor-independent methodologies.

PARTNERSHIPS AND COLLABORATIONS

The BioPar CMS is a joint venture of 13 partners: HYGEOS, CNES, INRA, Météo-France, and Spot-Image SA (France), Université Catholique de Louvain (UCL), and VITO (Belgium), Institute of Meteorology (Portugal), Vienna University of Technology (Austria), EOLAB (Spain), University of Leicester, and ECMWF (United Kingdom), and Igik (Poland).

BioPar takes benefit of several European initiatives, funded by EC, ESA, or Eumetsat, carried out for many years to map the biophysical parameters from EO data at continental and global scales. BioPar goes further in the visible integration of R&D projects (ESA/Globcarbon, FP5/Cyclopes, FP6/geoland, GBA2000), and aims to extend (FP6/VGT4Africa) or to complement (EUMETSAT/LSA SAF, FP7/DevCoCast) the operational services. BioPar has close relationships with the EC initiatives at JRC, MARS FOOD and the ACP Observatory, by providing products to the Global Crop Monitoring CIS, and NARMA (Natural Resources Monitoring in Africa) CIS, respectively. Thus, the BioPar products are disseminated by EUMETCast to African users of the AMESD (African Monitoring of Environment for Sustainable Development) project, a partnership between the African Union Commission, and the EU.

The BioPar teams are also strongly involved in the international bodies, like the CEOS and its CAL/VAL LPV sub-group, especially to set-up the measurement protocols to collect reference data (VALERI project lead by INRA), to guaranty the access to reference data (International Soil Moisture Network website hosted by Vienna University of Technology), to define standard procedure to validate the EO-derived land products (i.e. GOFC-GOLD Fire implementation group attended by University of Leicester). Finally, some scientific collaborations are in progress to assess the quality, and the usefulness of BioPar products (i.e. global LST evaluated by USDA, soil moisture used by the "Global Monitoring of soil moisture for water hazards assessment" project).

ACHIEVED RESULTS - LAI, FCOVER, FAPAR, NDVI DERIVED FROM SPOT/VEGETATION SENSOR DATA

The leaf area index (LAI) is defined as half the total foliage area per unit of ground surface. The FCover is the fraction of ground unit covered by green vegetation. The FAPAR is defined as the fraction of photosynthetically active radiation absorbed by green vegetation for photosynthesis activity. The instantaneous FAPAR value at 10:00 solar time is used as a very good approximation to the daily integrated value under clear sky conditions. The Normalized Difference Vegetation Index (NDVI) corresponding to the SPOT-5/VEGETATION-2 sensor characteristics for its Red (B2) and Near Infrared (B3) bands is also provided.

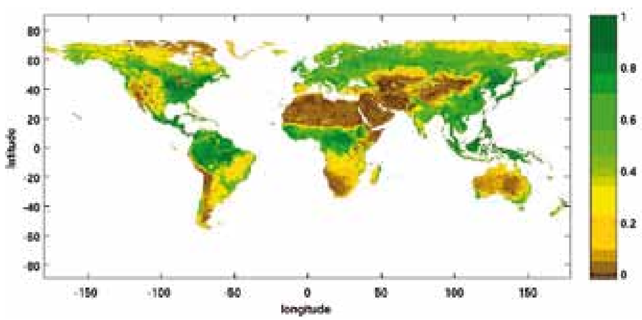


Figure 2: FCover derived from SPOT/VEGETATION, August 2004

The algorithm is based on already existing LAI, FAPAR, and FCover products to capitalize on the efforts accomplished and get a larger consensus from the user community. Following the published literature on products validation (Weiss, et al. 2007; Garrigues, et al. 2008), the best performing products were selected and combined to take advantage of their specific performances while limiting the situations where products show deficiencies. The selected products are re-projected onto the VEGETATION plate-carrée 1/112° grid, smoothed through time and interpolated at the 10 days frequency. Then the products are combined, and eventually scaled, to provide the fused product that is expected to give globally the 'best' performances. The fused products are generated for few years over the BELMANIP2 set of sites that is supposed to represent the possible range of surface types and conditions over the Earth (Baret, et al. 2006). Neural networks are then calibrated over this set of sites to relate the fused products to the corresponding atmospherically-corrected and directionally-normalized top of canopy SPOT/VEGETATION reflectances (Baret, et al. 2010).

Such methodology has been defined by INRA, and the processing line has been adapted by CNES, based upon an existing chain developed previously by Medias-France in the framework of the FP5/CYCLOPES project. CNES has also generated two years of global, 10-daily products (example on Figure 2). The processing line will start soon to run in NRT at VITO. These vegetation products are being validated by EOLAB (Camacho et al., 2010) according to the protocol defined by the Land Product Validation (LPV) group of CEOS (Morissette et al., 2006). The methodology is being to be adapted to the historical AVHRR surface reflectances made available by the NASA/LTDR (Long Term Data Record) project. The archive from 1981 will be processed to get a long time series (about 30 years) of vegetation variables fully consistent with the SPOT/VEGETATION products.

THE SET OF BIOPHYSICAL VARIABLES DERIVED FROM THE FR MERIS SENSOR DATA

The MERIS Full Resolution (FR) biophysical products, and the High Resolution (HR) biophysical products, contain a set of variables including estimates of the green, brown & soil cover fractions, the LAI, the FAPAR, the chlorophyll content, a canopy shadow factor, and the water & snow cover fractions.

The baseline vegetation model developed for processing the MERIS data uses the SAIL/PROSPECT model as core component (Jacquemoud et Baret, 1990). This model was upgraded and completed in order to include the contribution of brown vegetation, the modelling of "rough" canopies, the computation of vegetation cover fractions in reference directional conditions, and the computation of FAPAR from the SAIL model. Then, to restore the heterogeneous nature of the MERIS pixels, a further modelling step is applied consisting in having a composite canopy model made of two components: 1) a main canopy component made of predominantly green vegetation, that may have all range of conditions from crops to forest/shrub canopies; 2) a second canopy component made of low brown vegetation, primarily designed to model either senescent crops/grasslands or bare soil conditions. Another important component of the developed model is the soil modelling, the soil reflectance being an input of the SAIL model. This scene model is then coupled with a model of the atmospheric transmission from Earth surface level to the sensor (Verhoef and Bach, 2003). The detection of water and snow covers is done through additional modelling of the corresponding surfaces which are combined, as linear mixture, with the standard land model.

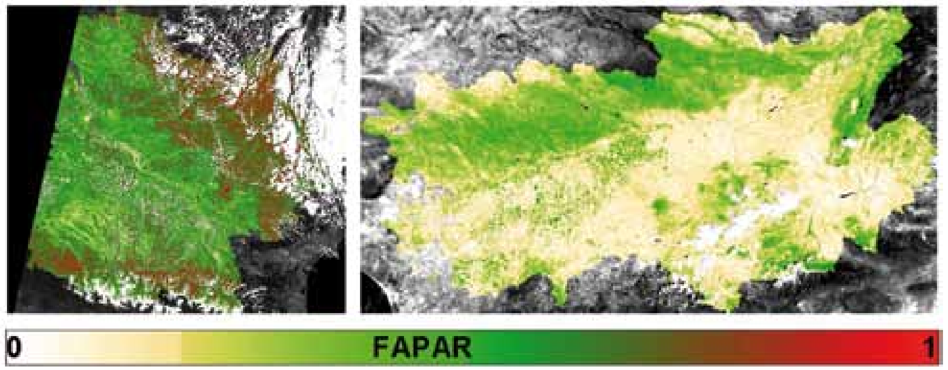


Figure 3: FAPAR over the Adour-Garonne river basin for May 2008 (left), and the Guadalquivir river basin for May 2006 (right) derived from MERIS FR data

Spot Image SA has elaborated the methodology above, developed the processing line, and ran it in off-line mode. Today, the existing MERIS FR (300m resolution) products covers some river basin across Europe (Rhine, Seine-Normandie, Guadalquivir, Adour-Garonne, Nemunas, Moselle-Sarre, Motala-Ström, Sventoji, Strymonas-Struma) for years of major interest for the final users (Figure 3). The production in NRT covering the whole Europe should start in the next weeks. These products are being validated by EOLAB, jointly with the products derived from SPOT/VEGETATION data. High resolution products have also been generated from SPOT and Rapid-Eye data acquired in 2009 and 2010 at different stages of the vegetation development over some high risk areas (Figure 4).

Figure 4: FSoil over Bulgaria for March, June and September 2010 from HR SPOT data

SOIL WATER INDEX (SWI) DERIVED FROM ASCAT/METOP SENSOR DATA

The Soil Water Index is defined as the soil moisture content (in percent) in the soil profile. The retrieval algorithm uses an infiltration model describing the relation between Surface Soil Moisture (SSM) and profile soil moisture as a function of time. The algorithm is based on a two-layer water balance model (Wagner et al., 1999) to estimate profile soil moisture from SSM retrieved from scatterometer data. The remotely sensed topsoil represents the first layer and the second layer extends downwards from the bottom of the surface layer. In this model, the water content of the reservoir, whose depth is related to a characteristic time length (T), is described in terms of an index, which is controlled only by the past soil moisture conditions in the surface layer. A computational adaptation of the original SWI algorithm has been made based on a recursive formulation proposed by Albergel (2008). In this method, a gain factor is introduced that relates the past SWI measurements to the current measurements. The SWI processing algorithm uses ASCAT-25km SSM product as input to generate daily global SWI images, calculated for five different T values (1, 5, 10, 15, 20, 40, 60, 100) together with the respective quality flags.

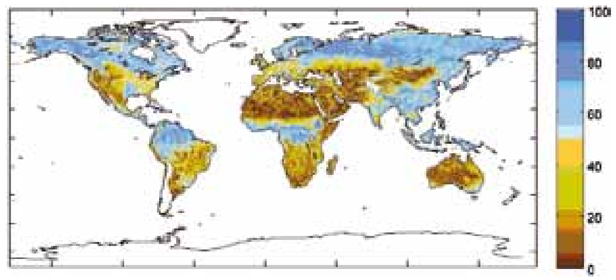


Figure 5: Global SWI (%) derived from ASCAT/Metop data for T=10 on 15th July 2007

The retrieval algorithm is defined by Vienna University of Technology, the processing line is developed by CNES which has also generated the SWI products over the period from 1st June 2007 to the present (Figure 5). The processing line is running in near real time at the Institute of Meteorology of Portugal. The SWI products are being validated by Météo-France and ECMWF using in-situ observations, and operational, analyzed products from models running at global and regional scale. A second version of the product is planned in the project life, including a more accurate detection of the freeze and thaw conditions of the surface.

THE SURFACE ALBEDO DERIVED FROM THE SPOT/VEGETATION SENSOR DATA

The albedo is the fraction of the incoming solar radiation reflected by the land surface, integrated over the whole viewing directions. The BioPar albedo products include the directional albedo calculated for the local solar noon, and the hemispheric albedo, integrated over the whole illumination directions for 3 broad bands: [0.4, 0.7μm], [0.7, 4μm], and [0.3, 4μm]. The coefficients resulting from the inversion of a 3-kernels linear model on the atmospherically corrected reflectances acquired during a period of 30 days are then combined with the pre-computed values of the directional kernels integrated over angular domains to estimate albedos. Finally, the broadband albedos are derived by linear relationships of spectral ones.

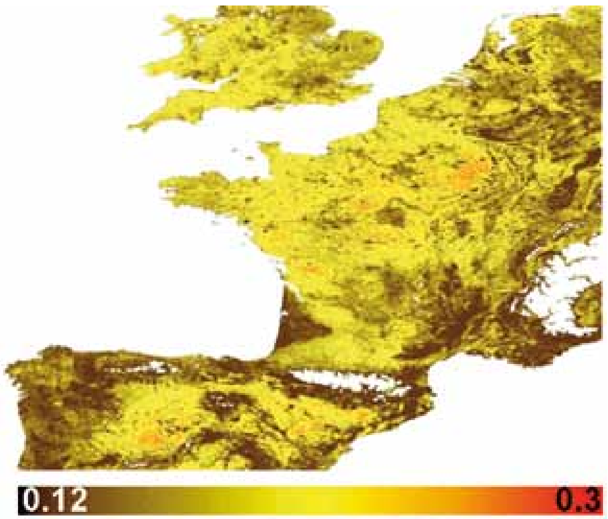
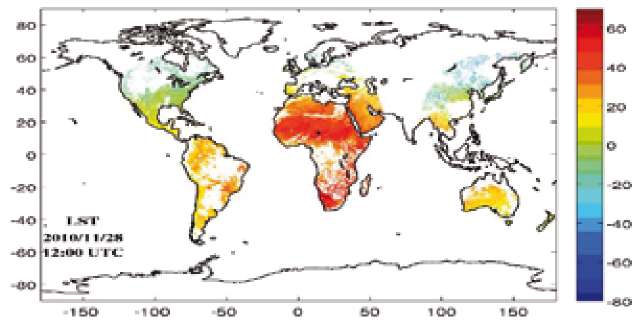


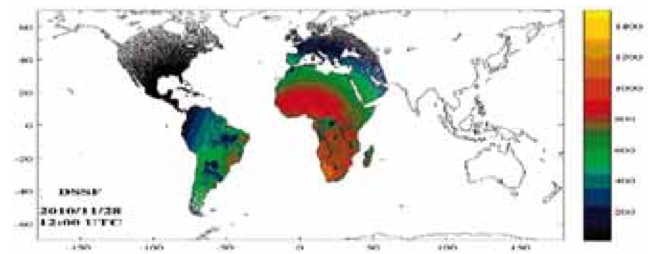
Figure 6: SPOT/VGT Albedo on April 2004

This algorithm and the processing line have been previously set-up in the framework of the FP5/CYCLOPES project (Baret et al., 2007) by CNRM, and Medias-France, respectively. CNES has adapted the existing chain to the geoland2/BioPar specifications, and generated two years of global, 10-days products (Figure 6). The processing line is running in NRT at VITO. These SPOT/VEGETATION albedo products are being validated by EOLAB according to the protocol defined by the Land Product Validation (LPV) group of CEOS. An inter-comparison with the other BioPar albedo product, derived by merging geostationary and polar sensors data, will be performed.

DOWNWELLING SURFACE FLUXES AND LAND SURFACE TEMPERATURE FROM GEOSTATIONARY SENSORS

The Downwelling Shortwave Surface Flux (DSSF), Downwelling Longwave Surface Flux (DSLF), and Land Surface Temperature (LST) are generated by the fusion of geostationary and polar sensor data. The DSSF represents the short-wave fraction of the solar irradiance (0.3-4 µm) reaching the soil background. The DSLF is defined as the irradiance reaching the surface in the thermal infrared part of the spectrum (4-100 µm). The LST is the radiative skin temperature of land surface. The albedo variables are the same as those retrieved using SPOT/VEGETATION data (§4.5). The Institute of Meteorology of Portugal is in charge of the algorithm definition, the processing lines development, and the production in near real time of the 4 products. These radiation variables correspond to an extension of those currently produced on an operational basis by the Satellite Application Facility on Land Surface Analysis (Trigo et al., 2010). While the latter are restricted to EUMETSAT sensors, geoland2 products make use of non-European geostationary satellites to increase area coverage (Freitas et al., 2010). The global DSLF, DSSF, and LST are available from August 2009 to the present (Figure 7). The production of hourly products is continuing in NRT.





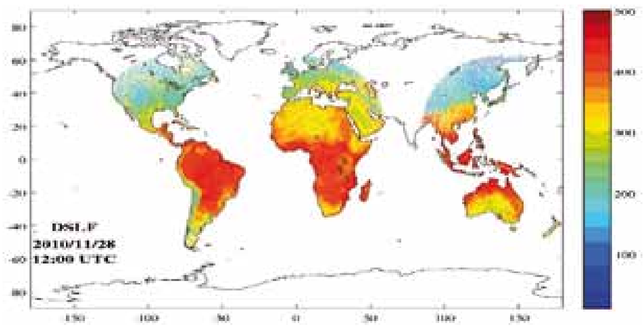


Figure 7: LST (°K), DSSF and DSLF ($W.m^{-2}$) from merging GOES, MSG, and MTSAT data

WATER BODIES & BURNT AREAS PRODUCTS

The burnt areas products are running in NRT at VITO since April 2010 (Figure 8). A new product is available every 10 days. The University of Leicester is working on the extension to the global scale, and on the improvement of the algorithm developed previously for the L3JRC project (Tansey et al., 2008). In particular, seasonality metrics (start, end and timing of maximum burning) will be added. Further, in the project life, the methodology will be adapted to AATSR sensor data.

Figure 8: Burnt areas detected over Africa in September 2010

The small water bodies product results from the fusion of two existing algorithms: the first one (Gond et al., 2004) was developed in the framework of VGT4AFRICA by the Joint Research Centre and is suited to arid and semi arid condition; the second one was developed for GlobalWatch project and was further developed in the context of Desert Locust prevention FAO product (Pekel, 2009). Both methods rely on different thresholds for the NDVI, the Normalized Difference Water Index (NDWI), the Hue (from RGB to HSV transformation) and the reflectance in the middle infra-red of SPOT/VEGETATION data. The product includes also information about the seasonality, i.e. the date of filling and the date of drying. The Université Catholique de Louvain (UCL) is in charge of the methodology, whereas the processing line is developed and will run in NRT at VITO. In a second step, the detection algorithm is being adapted to MODIS data (250m resolution) to identify smaller ponds (D'Andrimont et al., 2010).

CONCLUSION

At mid-term of the life project, BioPar has provided most of demonstration products which are under evaluation by the users of the CIS, and other CMS, by independent thematic validation team, and by external experts of the scientific community. Progressively, the pre-operational implementation of services starts, the NRT products become accessible freely through the SDI Expert portal (http://www.geoland2.eu/core-mapping-services/biopar.html), and the reprocessing of available EO data archives begins to get consistent long time series.

These efforts are focused on the implementation of the GMES Land Monitoring Core Service, and BioPar CMS intends to bring a main brick to build the Global component of the LMCS. Through a global systematic monitoring service, the Global component of the LMCS aims to provide near real time bio-geophysical parameters at global scale, addressing primarily the 13 terrestrial ECVs, and describing the vegetation state and dynamic. The principal scope of the Global component of the LMCS is to deliver information products and services on the status and evolution of land surfaces to feed a range of downstream services applications set-up to support specific EU policies at international level and European commitments under international treaties and conventions, such as the three Rio conventions on Climate Change, Desertification and Biodiversity.

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SubCoast

Monitoring and forecasting subsidence hazards in coastal areas around Europe

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ABSTRACT

The objective of the GMES-downstream service SubCoast (www.subcoast.eu) will be to develop a service for monitoring the extent and impact of subsidence in coastal lowlands and demonstrate its capability in various pilots for a variety of settings around Europe. The service will be designed to appropriately determine the effects of subsidence on current and future flood risk in coastal lowlands, monitor the integrity of coastal barrier systems and infrastructure and assess the impact of subsidence due to natural or man-made causes (groundwater pumping and oil/gas production) on land use and hydrology. SubCoast will be built on the heritage of GMES Service Element Terrafirma and use the full capability of PSI as an earth observation technology for large scale subsidence mapping. Necessary R&D will be focused on possible augmentation of data sources and the improvement of retrieval algorithms. Subsequent validation efforts will make full use of the Terrafirma Validation Test site and other current validation initiatives. A distributed data and information system will be set up which facilitates the accessibility and operability of EO-data, in-situ data (including geoscientific data) and model results for the selected areas. SubCoast will orient its services along existing guidelines established in previous GMES-projects and in line with relevant directives at European Level. End-user involvement will be realised by establishing a user federation which holds the most directly involved regional, national and European stakeholders.

BACKGROUND

Coastal lowland areas are widely recognised as highly vulnerable to the impacts of climate change, particularly sea-level rise and changes in runoff, as well as being subject to stresses imposed by human

modification of catchment and delta plain land use[1]. Utilisation of the coast increased dramatically during the 20th century, a trend that seems certain to continue through the 21st century. It has been estimated that 23% of the world's population lives both within 100 km distance of the coast and <100 m above sea level, and population densities in coastal regions are about three times higher than the global average.

Rates of relative sea-level rise can greatly exceed the global average in many heavily populated coastal lowland areas due to subsidence. Natural subsidence due to autocompaction of sediment under its own weight often worsens by sub-surface fluid withdrawals and drainage. This potentially increases inundation hazard, coastal erosion, habitat disruption and salt water intrusion, especially for the most populated cities on these coastal lowland areas. Aside from regional environmental effects of subsidence there are direct costs related to subsidence and soft soil conditions experienced in coastal lowland areas. Failure of constructions, infrastructure and water defence structures bring high maintenance costs with them and add up to substantial financial damages in these areas. Typically, rates of subsidence vary over various spatial scales and depend strongly on local geological conditions and human activity.

Therefore, both from a viewpoint of imminent adverse effects from climate change in coastal lowland areas as from the perspective of a sustainable management of infrastructural assets in these areas, there is a need of:

> Adequate data and information to assess spatial variations in subsidence in coastal lowland areas in relation to sea level rise and its impact on flood risk.

> Adequate data and information to assess geographical and temporal variations in subsidence and its impact on the geomorphological, ecological and hydrological systems in coastal lowland areas in order to anticipate necessary adaptive measures.

> Monitoring of the rate of settlement and movement of water defence structures and engineered constructions in order to detect any significant weaknesses in these structures in time.

1 IPCC, 2007: Summary for Policymakers. in: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

WORK PROGRAMME AND MILESTONES

SubCoast aims at connecting local, national and European policy requirements, together with existing GMES Services and auxiliary data-streams with a dedicated service for monitoring the extent and impact of subsidence in coastal lowland areas around Europe and globally to a level where sustainable information services can be delivered. Based on the experience of four pilot services, focussed on the needs and specifications of end-users in specific coastal lowland settings, and on extensive validation of these services, a product portfolio will be developed which can be delivered by the consortium throughout Europe and eventually worldwide, supporting GMES ambition as a European initiative for Global environmental monitoring.

Central to the SubCoast is the development of pilot-services since these will be both the testing environments for the proposed services as well as the deliverers of primary derived output to share with the stakeholders and end-users. The pilot services implement the concept of the SubCoast-downstream service and the appropriate validation procedures for the most important coastal lowland setting around Europe. The main concept is that the different pilot services should have the capability of testing the different functions of the downstream-service and demonstrate its viability for the most important issues related to subsidence in a coastal lowland setting. In SubCoast four pilot areas have been chosen to test the services. Two of these areas are at a regional scale, one on a national scale and one at European scale so as to demonstrate the service capability to various stakeholders operating at various levels: Rhine-Meuse-Delta, Southern Emilia Romagna, Baltic Coast and a pilot to integrate information at a European scale.

Figure 1: Pilot areas for service testing in SubCoast

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The project work plan consists of six work packages:

WP 1 – Scenarios, Impacts and User Requirements, aims at connecting local, national and European policy requirements by taking into account user needs, existing guidelines, climate scenarios, and impact analysis from a broad stakeholder consultation. As the Project is strongly user driven, the outcome in this work package will feed into WP 2 and WP 3. In **WP 2 – Data Provision Service**, a dedicated data provision service is built incorporating links to the existing GMES-services and auxiliary data-streams consisting of terrestrial data and taking into account a possible outlet to GMES Emergency Response Core Service.

Figure 2: Subcoast-webportal - Assessing and Monitoring Subsidence Hazards in Coastal Lowland Areas around Europe

In **WP 3 – Service Implementation and Validation via Pilots**, the dedicated data provision service is further developed in four European pilot services, focussed on the needs and specifications of end-users in specific coastal lowland settings. By validating these services on the different regional settings and integrating in-situ data and space systems, a service portfolio will be developed. For each pilot service developments will be tailored for ready take up in existing work processes of involved end-users.

WP 4 – Service Sustainability and Market Development, is focussed on developing and implementing an economic model for service provision which justifies the investment. It will also research the viability and added value of implementing new satellite datastreams, thus supporting GMES ambition as a sustainable European initiative for Global environmental monitoring. The results of the pilot services will be disseminated in **WP 5 – Dissemination**, through publications, newsletters, flyers and a web portal, thus giving the SubCoast the added value of relating its services with stakeholder related issues.

PARTNERSHIP AND COLLABORATION

All pilot services have actively involved end-users:

Pilot	End-users
Rhine-Meuse Delta	> Ministry of Transport, Public Works and Water Management/Rijkswaterstaat
Southern Emilia Romagna	> ARPA Emilia Romagna
Baltic	> Maritime Office in Gdynia > Department of Regional and Spatial Development of Pomorskoie Voivodeship > Coastal Research and Planning Insitute, Klaipeda University
European	> European Environmental Agency > UK Environmental Agency

SubCoast will use data to extend services towards a European initiative aimed at delivering data and information on extent and impact of subsidence in coastal lowland areas around Europe. Other relevant partnerships and collaborations which are brought in through partners involved in national and European programmes e.g. OneGeology, the effort to build a digital geological map, and which is of use in SubCoast's effort to work on a strategy for integration of subsidence assessments along Europe's coastal lowlands.

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ACHIEVED RESULTS

The SubCoast Downstream service integrates leading GMES-services in the field of earth observation and interferometric SAR-analysis with state-of-the-art geoscientific models for coastal lowland areas both on a regional scale as well as on a European scale. Subsidence in these areas is of major interest regarding the imminent issues rising from climate change, such as sea level rise and flooding. Progress beyond the state of the art is envisaged for the following outstanding issues:

> Facilitating user take up by integrating earth observation into end-users models

This asks for an integrative approach where the service is extended from basic PSI-products towards end-products which readily answer the most relevant issues related to subsidence in coastal lowland areas such as relative sea level rise, flood risk, coastal erosion, salt water intrusion. Many of these processes take place over relatively long time scales (decadal to centennial). Models used for predicting trends are therefore sensitive to initial conditions. The assimilation of high resolution earth observation data sets into state-of-the-art geoscientific models will therefore be a major improvement both in terms of service delivery, meeting end user requirements, as well in terms of technological advancement.

> Supporting user uptake by integrating data streams

Earth observation datasets and data-centres are organised around the mapping and monitoring of components typical for part of the coastal environment, such as land use, infrastructure, sea level, ground water level. Clearly, broad access to data-sets (satellite, in-situ, surveys, Core data) will contribute to a better monitoring of the impact of subsidence and rational decisions towards the development of future scenarios and strategies. The synergistic use of models and EO-data means an important step forward in the predictive capabilities the science community has so far. Data-assimilation is starting to become a widely used strategy for model updating but is not yet standard. SubCoast specifically addresses this topic over all models and develops strategies to make the best of synergistic use of geoscientific models and EO-data.

> Developing PSI-services beyond state-of-the-art

Two outstanding issues relate to the current state-of-the-art in PSI-processing. Firstly, current sensors like ASAR and SAR are nearly at the end of their lifetime. This makes it necessary that new sensors will be explored for continuous service delivery in the advent of Sentinel 1, GMES operational SAR-platform. Apart from extending service delivery, new sensors like TerraSAR-X, Radarsat 2 and Cosmo Skymed will also make new PSI-products possible. Notably, the extension of Line-of-Sight-displacements towards displacements in the local, earth bound coordinate system will be possible, which will be a great benefit for end users to determine the actual processes contributing to the local ground movement. This will be especially important when addressing structural deficiencies in infrastructure and water defence works, thus contributing to flood safety. Secondly, current PSI-products are mainly restricted to single scenes or parts of it whereas for subsidence issues in coastal lowland areas, large area overviews are demanded. A multi-scene PSI-processing will enable to detect trends on the scale of the coastal area facilitating the comparison of areas at risk in a regional reference system.

CONCLUSION

SubCoast develops a user-centered downstream GMES-service for delivering data and information on extent and impact of subsidence in coastal lowland areas around Europe and demonstrates its viability in various pilot services for a variety of geographical settings and applications.

In order to achieve these goals, SubCoast has been structured around the following topics:

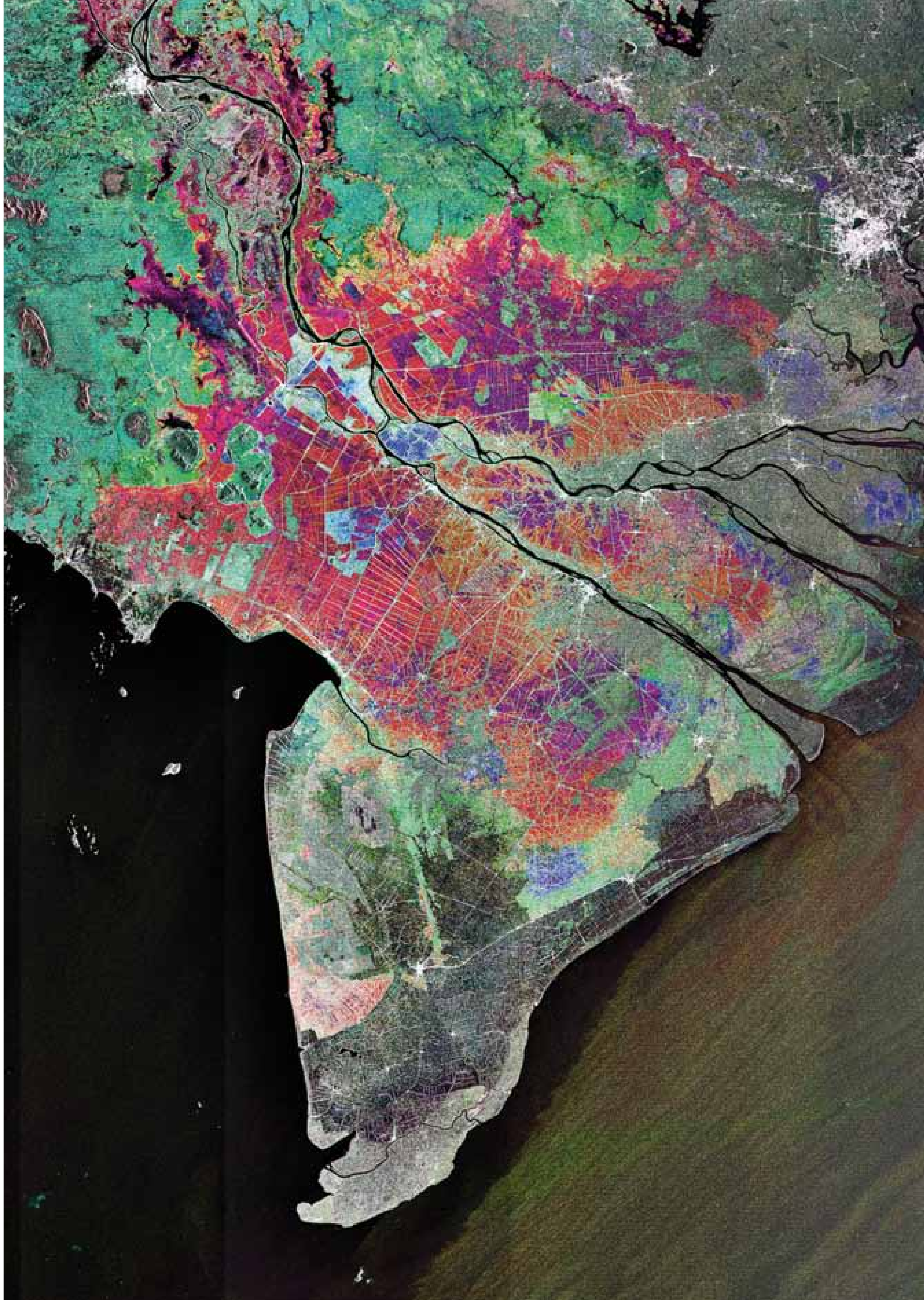
> Deriving indicators of environmental and economic impact made by subsidence by making use of state-of-the-art scenario and impact models.

> Developing a coordinated data provision service for necessary terrestrial and satellite data, and input data streams from GMES-Services and functioning as a portal for SubCoast-services.

> Testing the SubCoast-concept through dedicated pilot services making our approach viable and supportive.

> Demonstrate via a user federation, which holds the most directly involved regional, national and European stakeholders, how the SubCoast-products will be integrated into current user practices and their working environment.

> Build service sustainability by developing a service delivery model which will transform the project into an operational downstream service and includes arrangements to ensure quality, standards and feedback as input to service improvement.



Marine monitoring

Listen to ocean stories

MyOcean

Ocean monitoring and forecasting core services

The European MyOcean example

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ABSTRACT

Since OceanObs 1999, ocean monitoring and forecasting core services have reached an initial level of maturity. A world-wide network of operational oceanography centres now provide real-time ocean information using space-based and in-situ observations and assimilative models.

In 2005, Europe defined the "Marine Core Service" as a new pan-European service aiming at delivering to any interested party, and particularly downstream service providers, core information on the ocean (currents, temperature, sea surface height, ice coverage and thickness, primary ecosystems, etc.) recognized as common denominator data required to develop added-value services.

MyOcean is the first implementation project of this integrated pan-European Marine Core Service for ocean monitoring and forecasting. This 3-year project started in 2009 and involves 61 partners in 29 countries.

MyOcean users are service providers involved in four application areas: marine safety, marine resources, marine and coastal environment and weather, and seasonal and climate prediction. They form a wide and diverse community but share a common interest for generic ocean-state information as an input to their own services.

MyOcean has already opened a first marine core service for ocean monitoring and forecasting, and provides access to a range of observation-based and model-based products. This is based on a "system of systems" organization interconnecting different centres in Europe to form a single pan-European capacity with five thematic assembly centres dealing with observations, seven monitoring and forecasting centres dealing with assimilative models and a single service desk to ensure the easiest possible access for users. This operational oceanography service relies on remotely-sensed data and in-situ observation networks and the long-term sustainability of both components.

What are the main choices made in Europe to define MyOcean? What is the market, the service offer, the production capacity and the organization that will drive the implementation of a Marine Core Service in Europe? What is required upstream from observation networks to run such a service? What is required downstream from this service by operational oceanography users to develop further their mission? This paper will attempt to answer these key questions.

OCEAN MONITORING AND FORECASTING CORE SERVICES, INTRODUCTION

Ocean forecasts are provided on a regular basis by more than a dozen operational oceanography centres in the world. Forecasts are produced by routine assimilation of real-time, remotely-sensed and in-situ data into numerical models. Some of them describe the global ocean as a whole while others are at a regional scale.

Europe, Australia, the United States, Canada, Japan, and now China, are fully committed to the development and consolidation of an operational ocean monitoring and forecasting capacity. Both space-based and in-situ (e.g. the international ARGO programme) oceanography programmes are gathering a wider range of countries in this global earth-observation endeavour for the ocean; this large international cooperative effort is actively coordinated through GOOS and GEOSS.

Systems such as Mercator (France), FOAM (UK), TOPAZ (Norway) and MFS (Italy) in Europe, and Bluelink in Australia, HYCOM and ECCO in the United States, Concepts in Canada, and the systems run at JMA/MRI/JMASTEC in Japan, and SOA/NMEFC in China are today international references for ocean monitoring and forecasting core services. The GODAE Ocean View international initiative (see Bell M. J, et.al. and http://www.godae.org) provides up-to-date references of existing monitoring and forecasting systems at the international level.

THE EUROPEAN MARINE CORE SERVICE AND THE MYOCEAN PROJECT

Europe acknowledged the need and opportunity for a global ocean monitoring and forecasting capacity at an early stage, and took the necessary steps to initiate the necessary preparations.

Leading European countries for oceanography such as France, the United Kingdom, Norway and Italy have been involved in international coordination efforts for more than a decade to foster development of new systems, services and skilled teams in marine core services. The GMES MERSEA projects (from 2003 to 2008; see Desaubies, Y. (2005 and 2009), and J.A.Johannessen et al.) made a real difference at the EU level to start the integration of the different national facilities for ocean monitoring and forecast production into a single pan-European system, and provided Europe with a new and valuable focal point for international coordination.

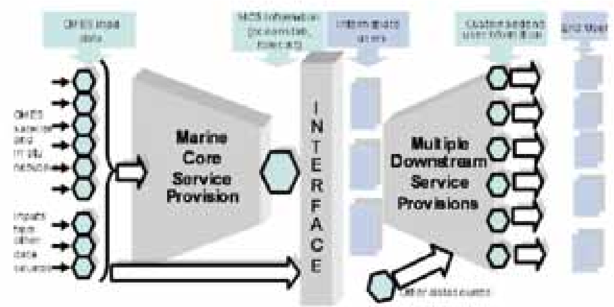

Figure 1: The GMES value-adding chain for the marine information services, positioning the Marine Core Service

In October 2005, the European Commission held a workshop devoted to the marine component of the GMES program, which defined the "Marine Core Service" and took actions for its implementation. The MCS Implementation Group, set up by the Commission to supervise and validate the implementation of this new Service, proposed this definition (see Ryder, P.): "The MCS is conceived as one part of a processing chain which operates on observational and other forms of data to help create tailored information services to meet a wide range of end-user needs. Almost all such end-user services relating to the marine environment require access to information about the state and dynamics of the oceans and seas. The MCS provides that information to intermediate users who combine it with other forms of information and data (e.g. socio-economic data) to provide customised downstream services for the end users. The implementation of the overall chain needs to have some flexibility; as components of downstream services are developed to serve multiple uses, it may be more efficient for them to be provided as part of the MCS". Figure 1 illustrates this segmentation of the value-adding chain, and the role taken by the "core" service in this chain.

The Marine Core Service GMES program provides a multi-year framework to develop the expected ocean monitoring and forecasting capacity for Europe.

MyOcean (see [1]) is the first implementation project of this initiative. Co-funded by the European Commission under the 7th Framework Programme (FP7), MyOcean covers the 3 year period (2009-2011) with a total cost of € 55 million, of which € 34 million is funded by the European Commission. The objective of MyOcean is to deliver a service, the assessment of this service and an overarching organization driven by user needs.

As a marine core service, the MyOcean objective is to provide users with the best generic information available on the state of the ocean. MyOcean is committed to develop and run a pan-European service based on a worldwide capacity for ocean monitoring and forecasting, using data assembly, modelling and assimilation systems. The service is intended to serve any user requesting generic information on the ocean, and especially downstream service providers who will use this information as an input to their value-added services to end-users. These "intermediate users" cover a wide range of downstream sectors, both in the marine field and other connected fields (e.g. climate, natural resources, etc.). The MyOcean service consists of the provision of "core" information on the ocean, defined as the common denominator data requested by these service providers for their different and specific sectors. It corresponds to the main variables needed to depict the ocean state: temperature, salinity, currents, sea level, ice coverage and thickness, primary ecosystem variables, etc. MyOcean provides this information for the daily state of the ocean (real-time), its short-term evolution (forecast for the coming days, up to 10-14 days), and its history over the past 20-50 years (hindcast and reanalysis). Users can access the information through a centralised service desk.

MyOcean gathers 61 partners spread over 29 different countries. This represents a pan-European team of some 350 experts working together on a common objective. All maritime nations of the European Union are represented in MyOcean, and the team welcomes as well some non-European associate nations. The project gathers a wide variety of skills and experience – research and development, operations and service, technical and industrial development, user applications, quality assessment and management – to contribute to the project activity. Each partner has been assigned a specific role. A group of around 20 "core partners" is committed to implement and provide the MyOcean service. These core partners play a key role: Europe's leaders for operational ocean monitoring and forecasting are involved and committed. Another third of the consortium (~20 partners) provides the scientific and industrial support needed for the quality control of the user requirements captured by the MyOcean organization and the experience of the partners is presented below. This experience will grow throughout the implementation of the project. The final third (~20 partners) forms a European network devoted to setting up and developing links with the user community.

The MyOcean objectives and the composition of the consortium can be found on http://www.myocean.eu.

MYOCEAN USER REQUIREMENTS

The MyOcean market consists of "intermediate users": service providers serving specific end-users who need core information about the ocean as an input to their activities.

Users of MyOcean are the service providers requiring core information on the ocean to run their activities: they are called intermediate users since they are the essential intermediates between the core service and the end-users. They have different statuses, running operational or research activities in the marine sector, but open to a wide variety of application areas. They include national public agencies, such as national weather services and marine institutes, European agencies such as the European Environmental Agency and the European Maritime Safety Agency, private companies providing services on a specific market niche, research laboratories, and environment policy conventions (e.g. HELCOM, OSPAR, UNEP/MAP). Their common denominator is that they are in direct contact with the end-users, and that they need upstream core information on the ocean. MyOcean has invited a number of intermediate users to join the project to foster service and market development. Users of the MyOcean service also add value to the core ocean information to meet their own end-users needs.

MyOcean has segmented the market into four areas to cover the whole spectrum of requirements and structure the marine core service offer and has built a network to manage the user requirements. The four market areas help define the core service required by coherent groups of users. These four areas of benefit are: (i) the "marine safety" area; (ii) the "marine resources" area; (iii) the "marine and coastal environment" area, and (iv) the "weather, seasonal and climate prediction" area. MyOcean is organized to capture and manage user requirements throughout the project, to specify service evolution. A network of reference users in Europe has been organized amongst the 60 partners of the project to cover the European territory (Figure 2).

This network is tasked to link with the main users of the four market areas, and to organize and feed the users' requirement reference documentation. A core user group, composed of a small selection of users, serves as an advisory group for the project coordination (see below).

The general requirement is to have access, on a systematic and guaranteed basis, to reliable and categorised information on the physical and biogeochemical state of the ocean, based on the combination or assimilation into 3D ocean general circulation models of remotely-sensed and in-situ observations. Variables expected are for the physical part: sea level, sea surface height, temperature, salinity, currents, surface wind and waves, sea ice (extent, concentration, thickness, motion) and for the biophysical and biogeochemical part: attenuation of solar radiation, chlorophyll, dissolved inorganic matter (O_2, pCO_2, ...), dissolved nutrients and primary production. Global coverage is required with a focus on European seas, and a capacity to solve meso-scale dynamics as well as to provide reliable information for multi-year global trends. Real-time information is required (operational monitoring and forecasting) as well as multi-decadal reanalyses of the ocean state. Users have also expressed requirements to receive fully assessed information and indication of product quality.

Figure 2: MyOcean network of reference intermediate users involved in the project, spread over 29 countries

Segmenting the application field in four areas allows a better understanding of MyOcean user expectations: In the "marine safety" area, users are service providers involved in marine operations, oil-spill combat, ship routing, defence, search & rescue... and all marine activities involving offshore operations. The European Maritime Safety Agency, marine meteorology of the national weather services and Navies are users in this area. Their first requirement is for "real-time and operational" ocean core information (hindcast, nowcast, forecast), mainly for the surface layers of the ocean and the mesoscale circulation (eddies, fronts, etc.). These users are also users of marine weather wind & waves information. They need systematic and routine information, with the possibility to request a rapid environment assessment. High-resolution (both temporal and spatial) limited-area coverage, but with a worldwide capacity, is also required. In the "marine resources" area, users are service providers involved in the evaluation and monitoring of marine resources such as fish stock management. The International Council for the Exploitation of the Sea (ICES) and national marine institutes are some of the users identified in this area. These users require information related to ocean physics and primary ecosystems, with fully assessed analyses of the present situation and long-term trends over the last 10-20 years. They require an excellent estimation of the physical state of the ocean (such as vertical speed) to enable efficient coupling with ecosystem modelling. Long-term simulations, trends and anomalies, with global and basin-scale views to cover large marine ecosystems areas, are required. Realistic monitoring at higher resolutions is expected. In the "marine and coastal environment" area, users are service providers involved in coastal monitoring and environmental assessment activities. The European Environmental Agency and the national environmental agencies are natural users identified here, as well as environmental policy conventions such as UNEP/MAP in the Mediterranean Sea, OSPAR in the Atlantic, HELCOM in the Baltic Sea, and any institutes or companies running coastal monitoring systems. These users require three-dimensional depictions of the ocean state and its variations, boundary conditions to force coastal monitoring systems, and reference and standard indicators on the ocean environment status. They are particularly demanding with regard to high-resolution information for coastal areas; sea level information, remote-sensed ocean colour and surface temperature, and high-resolution 3D model information, required for environmental assessment activities.

In the "weather, seasonal and climate prediction" area, users are mainly services involved in weather forecasting, but also services monitoring polar ice extent evolution and the global environment for climate. The European Centre for Medium-range Weather Forecasting and national weather services in Europe are users in this area, as well as groups involved in international initiatives such as the International Polar Year; and any private or public entities involved in services linked to the exploitation of climate and seasonal forecasting information. These users require global ocean analyses and multi-decadal past trends with coupled ocean-ice models.

THE MYOCEAN SERVICE OFFERING

MyOcean offers to users a reliable and easy access to valuable ocean core information. The MyOcean service offer is driven by quality and simplicity: quality of the ocean information provided to users, and simplicity of the access to information. Providing clear and easy access to the ocean core information available in Europe is considered by MyOcean partners as the first priority. This is why the primary investment is on the inventory of the "core products" available (the portfolio) and on the service tools and organization (the desk). In the initial definition of MyOcean, the aim to facilitate user access to information as far as possible has been a strong driver, forcing technical and organisational decisions (a single desk) and legal / economic decisions (open and free data policy).

MyOcean delivers "regular and systematic reference information (processed data, elaborated products) on the state of the oceans and regional seas, at the resolution required by intermediate users and downstream service providers, of known quality and accuracy, for the global and European regional seas". This mission, as defined by the Marine Core Service Implementation Group of the European Commission, drives the MyOcean service definition. The information provided concerns the physical state of the ocean (temperature, salinity, currents, density, sea level, ice coverage and concentration, etc.) and primary ecosystem variables at the mesoscale, in accordance with the user requirements presented above. The service is provided daily, on a global scale, through a "global ocean" component with higher resolution information for the European seas provided by "regional seas" components. The information is based on the combination of space-based and in-situ observations, and 3D ocean models with data assimilation. MyOcean offers a real-time service consisting of nowcasts (real-time analyses) and forecasts (1-2 weeks), and a reanalysis service describing past events and trends over the past 20-25 years. This is compliant to users' first requirements described above.

The MyOcean products are all openly accessible and delivered free of charge. This data policy has been designed to be as simple as possible to ensure easy user access to products. The products are made available without any restrictions on their use (e.g. commercial) other than uncontrolled redistribution or reselling without adding value. The only commitments made by users signing the licence agreement are to acknowledge MyOcean as the source of data and to respond to enquiries aimed at assessing and improving the service. The MyOcean 3-year project is seen at European level as a full-scale demonstration of the value of this open data policy. The MyOcean catalogue describes the list of products offered to users by the production centres. This document is indeed the cornerstone of the service offer and drives the entire production chain. The products available from MyOcean are defined in its service portfolio, which describes the products (geographical coverage, depth level, spatial and temporal resolutions, temporal extent, and quality flag), their quality and delivery characteristics (timeliness, format, user standards) and dissemination mode. The goal is to set up a simple and single portfolio for the whole pan-European MyOcean marine core service, with reference definitions shared by users, producers and stakeholders, and regularly updated. 111 standard product lines have already been made available through this catalogue six months after the project kick-off: all geographical areas are covered by assimilative models, which ensures access to monitoring and forecasting model information on the global ocean and in European regional seas; all observed variables are covered by data centres which ensures access to remote-sensed sea level, ocean colour, sea surface temperature, ice, wind and in-situ data. All products have been gathered and made accessible through a single "Online Queryable Catalogue", which can be accessed at http://www.myocean.eu. Every product is described by a "product-ID" providing all relevant information on content and format; interested users are then invited to contact the service desk.

The MyOcean "service desk" is a single entry point to access the product and service portfolio. This service desk consists of a secured web portal, which includes a self-service facility (with a user

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registration form and user query form), the service portfolio, access to product documentation, a visualization service, user outreach and feedback questionnaires and knowledge management resources. Email contact is ensured through: servicedesk@myocean.eu.org. The MyOcean service desk also has a service desk call centre (24/7), an operations service desk support team, an integrated IT service desk tool, change management, access rights management and knowledge management tools. The MyOcean service provision is governed by Service Level Agreements (SLAs) with the MyOcean users. The ITIL international standard for service organization has been chosen to drive the MyOcean service definition and organization.

THE MYOCEAN PRODUCTION

The MyOcean production capacity is based on a "system of systems" organization interconnecting different centres in Europe. This system-of-systems architecture has been chosen for its ability to involve the best European centres (to retrieve from them the best information for users) and to define a clear and high-quality industrial and service organization (to provide an operational service). The functional architecture is organized to allow operations of the Marine Core Service based on physically-spread infrastructures (see Fig. 3). Functions cover all requirements in terms of production and service. Common functionalities have been distributed via common sub-systems to allow interoperability, standardisation and economies of scale.

The system functional architecture is broken down into 14 sub-systems: 12 production units and 2 central components. The production units are either "Thematic Assembly Centres (TACs)" dealing with observations or "Monitoring and Forecasting Centres (MFCs)" dealing with model & assimilation. The 2 central components manage the information produced and provide the portal to users. They support all the TACs and MFCs, by ensuring common standards and interfaces leading to cost-effective economies of scale and the interoperability required by users. The physical architecture is spread across seven countries (Denmark, France, Italy, Norway, Spain, UK, Ukraine), centres being linked with WIS/GTS network, Internet protocols and in some specific cases with EuMetCast.

The 12 production units represent the pillars of the MyOcean organization; each of them has a specific mission to conduct in the overall service organization. A MyOcean 'production unit' has its own internal organization, run under the responsibility of a leading entity, but has to address R&D activities to prepare service evolution, system development and integration, service operations and assessment of the production. Each production unit is run by a leading entity with the potential involvement of other entities and operational service commitments.

a) The Thematic Assembly Centres (TACs) are the MyOcean Production Units dealing with the observation-based information; they are committed to provide the products based on observation data that are required by the MFCs for assimilation or validation, and the ones identified in the MyOcean products portfolio for dissemination to users. They provide hindcast (past) and nowcast (real time) information. They retrieve the observations from observation agency data centres with primary processing, and ensure the final processing and validation steps. Five Thematic Assembly Centres (TACs) have been created:

> The "Sea Level" TAC

> The "Ocean Color" TAC

> The "Sea Surface Temperature" TAC

> The "Sea ice and Wind" TAC

> The "In situ data" TAC

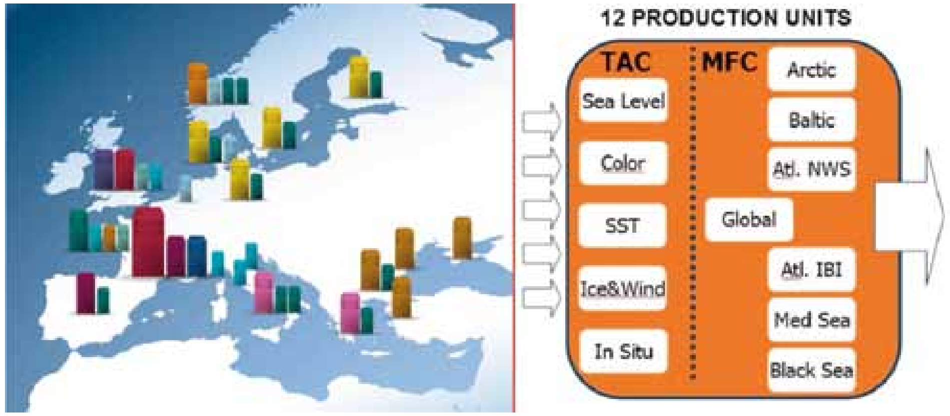

Figure 3: The MyOcean production "system of systems" composed of 12 production units

b) The Monitoring and Forecasting Centres (MFCs) are the MyOcean Production Units handling model-based information. They are committed to provide the products based on model data identified in the MyOcean products catalogue for dissemination to users. They provide hindcast (past), nowcast (real time) and forecast (future) information. They use the information provided by the TACs, and some additional ancillary data, run assimilative models and ensure the ocean state monitoring. Seven Monitoring and Forecasting Centres (MFCs) have been created, one for the global ocean and six for European regional seas:

> The "Global Ocean" MFC, which deals with the whole global ocean
> The "Arctic" MFC, which deals with the Artic polar region
> The "Baltic sea" MFC, for the Baltic Sea
> The "NWS" MFC, for the North-West-Shelves region in the Eastern-North Atlantic
> The "IBI" MFC, for the Iberian-Biscay-Irish region in the Eastern-North Atlantic
> The "Mediterranean Sea" MFC for the Mediterranean Sea
> The "Black Sea" MFC, for the Black Sea

Overall, these 12 production units (5 TACs and 7 MFCs) maintain appropriate capacities and mechanisms to ensure that the products are state of the art, and characterised and delivered to the right standards. They set up appropriate mechanisms and activities to ensure the maintenance and the long-term evolution of the service.

OBSERVATION REQUIREMENTS

Ocean monitoring and forecasting services are critically dependent upon remote-sensed and in situ data, either for assimilation into ocean circulation models or direct combination into data-based products. As for operational oceanography in general, the main requirement for the European MyOcean Marine Core Service is to have a long-term, continuous and near real time access to the core operational observations of sea level, temperature, ocean colour, sea ice, wave and winds. Long-term continuity and the transition from research to operational mode remains a major challenge. MyOcean requirements are common to international requirements as presented by GOOS and its international GODAE initiative (see for instance Clark C. (2009), and P.Y. Le Traon, et al. (2006)).

Regarding remotely-sensed data:

> In addition to meteorological satellites, a high precision (AATSR-class) SST satellite is needed to give the highest absolute SST accuracy. A microwave mission is also needed to provide an all weather global coverage.
> At least 3 or 4 altimeters are required to observe the mesoscale circulation. This is also useful for significant wave height measurements. A long-term series of a high accuracy altimeter system (Jason satellites) is needed to serve a reference for the other missions and for the monitoring of climate signals.
> Ocean colour is becoming increasingly important, in particular in coastal areas. At least 2 satellites are required.
> Two scatterometers are required to globally monitor the wind field with high spatial resolution.
> Two SAR satellites are required for waves, sea-ice characteristics and oil slick monitoring.

Regarding in-situ data, there is a wide consensus on the initial system to sustain both for climate and operational oceanography objectives. This in-situ observation network includes:

> Argo, a global array of profiling floats measuring temperature and salinity profiles as well as deep ocean currents. Argo is the primary source of data on the ocean interior. It constitutes a cost-effective system for basin-scale, real-time global observations in the upper 2000 m.
> Data from ships of opportunity: XBTs for the measurement of temperature profiles down to ~450-750m, sea surface temperature and salinity from TSGs.
> Surface drifters: low-cost and lightweight platforms that passively follow the horizontal flow at the surface. They also provide precise sea surface temperature measurements.
> Moorings: at present the only technology to provide a complete long-term suite of physical, air/sea interaction and biogeochemical quantities, like chlorophyll, oxygen, CO_2, oxygen, nutrients. These data are essential for validation and assessment purposes.
> The global Tide Gauge Network which provides long term reference and validation sea level data.
> Data from research vessels which deliver complete suites of multidisciplinary parameters from the surface to the ocean floor. The information collected is of high accuracy, quite necessary for various validation tasks, deep ocean and carbon observations but very sparse, with intermittent spatial coverage and at high cost of operations.

MYOCEAN GOVERNANCE

The MyOcean organization (see Fig. 4) is designed to make the transition from the current organization, mainly driven by R&D needs and challenges, to an organization that will preserve its innovation capacity through R&D but at the same time support a sustainable, reliable and efficient operational activity at European level. The MyOcean pan-European service organization is driven through a Board for the strategic issues, and an Executive Committee for the technical and service management aspects. Two advisory bodies provide support: one dealing with user issues and the other with research and development. The work is broken down into 18 work packages, 14 of them being run as business units in charge of the 14 sub-components of the systems (the 5 Thematic Assembly Centres, 7 Monitoring and Forecasting Centres, the management information system and the data portal).

The MyOcean Board is the acting governing body supporting the coordinator in the steering and strategic management actions and decisions. It is composed of the coordinator P. Bahurel (Mercator Océan, France), six senior scientists and managers – M. Bell (Met Office, UK), F. Jacq (CLS, France), J. A. Johannessen (NERSC, Norway), P.-Y. Le Traon (Ifremer, France), N. Pinardi (INGV, Italy) and J. She (DMI, Denmark). The Board has two main roles: (i) a strategic role to explore any management, strategic, legal and organizational issues that could contribute to feed the GMES Marine Core Service long term roadmap, such as agreements with external providers or major users, links with international programs and national initiatives and preparation of the next Marine Core Service management organization; (ii) a steering role, supporting the project coordinator in the project coordination and making important decisions on priorities (e.g. evaluation of progress objectives/achievements). The Board is tasked to develop and maintain international relations with other services and centres in the world. It reports to the General Assembly, which is the ultimate decision-making body of the consortium, composed of one institutional representative appointed by each of the 60 partners.

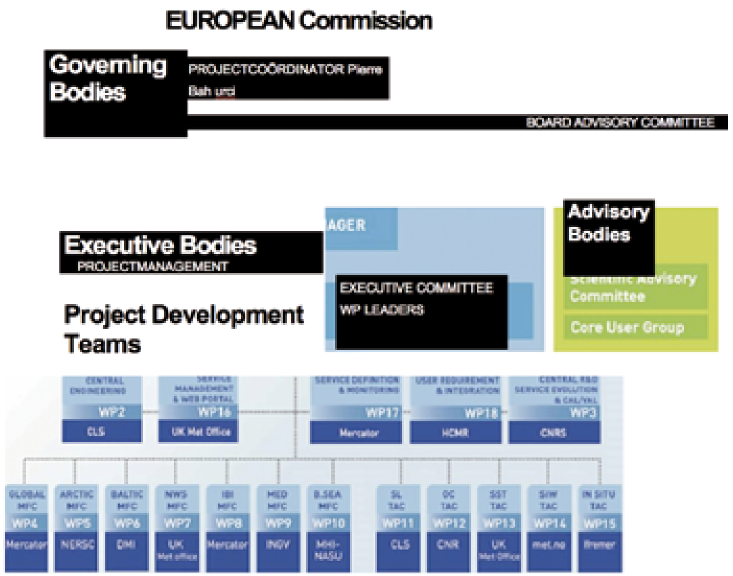

Figure 4: The MyOcean project organization

The MyOcean Board is advised by the MyOcean Advisory Committee, composed of high level representatives of GMES Stakeholders. These directors of European agencies and organisations provide a strategic vision and help to align the direction of the project in full compliance with the requirements of GMES stakeholders, in order to assure the sustainability of the Marine Core Service. The Committee is co-chaired by the project coordinator and the chairman of EuroGOOS. Two other advisory bodies are supporting the coordinator and the partners. The Core User Group consists of a dozen representatives of the User community, and provides recommendations on the service evolution, and feedback on the present situation. It supports any analysis regarding a new service line (new products, new requests, etc.), and helps in setting up efficient links with the user community as a whole. The Core User Group is involved in the organization of the User Forums. The Scientific Advisory Committee is composed of senior scientists and provides support on scientific strategy. It deals with the scientific quality of the service provided and makes recommendations to ensure a state-of-the-art production capacity, encouraging transfers from the research community to the MyOcean team. The Scientific Advisory Committee is the reference committee to select new research investigation actions and teams through the Open Call process planned in MyOcean.

The overall management is achieved through and by the Executive Committee, chaired by the project manager, and composed of the 18 work-package leaders. The Executive Committee drives the overall service and development activity and is responsible for the budget / technical / scheduling objectives set by the project. The Executive Committee's main role is to implement the decisions of the governing bodies and to monitor the work. It proposes the annual work plans and budgets, and any changes required to meet project objectives within the available resources and considers re-allocation of work and funding amongst tasks and partners. The Executive Committee drives the production, service and quality activities. The Project Manager – F. Adragna (Mercator Océan, France) – supported by the Project Office team is in charge of the daily management of the Project. The MyOcean project management team can be contacted through myocean@mercator-ocean.fr.

CONCLUSION

Since OceanObs 1999, ocean monitoring and forecasting core services have reached a first level of maturity. A network of operational oceanography centres throughout the world has been formed: this network forms a valuable capacity to provide users with a reliable depiction of the ocean based on space and in situ observations and assimilative models.

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In Europe, MyOcean is undoubtedly the most important initiative for the implementation of an ocean monitoring and forecasting service. MyOcean has already played a leading role in its preparation phase in fostering European collaborations towards this objective, and will, in the coming years, be the natural framework to build the sustained Marine Core Service required for the development and sustainability of oceanography services.

MyOcean specifications rely on a thorough analysis of the stakeholders' expectations, the market demand and the science and production capacity in Europe. MyOcean is able to rely on the participation and commitments of the best ocean centres in Europe, and the involvement of experienced scientists and managers in oceanography. MyOcean is a European service, open to the rest of the world. It provides a worldwide service for ocean monitoring and forecasting which is fertilized in its science / operation / service / governance organization by international collaborations. MyOcean represents the first embodiment of the European Marine Core Service, providing a first range of ocean monitoring and forecasting products based on ocean models and observations. Anyone can access this information, which is designed to serve adding-value downstream service providers.

This first public-good service is critically dependent upon a reliable and sustained satellite and in-situ observation network for oceanography.

Throughout the world, teams running ocean monitoring and forecasting core services are now facing a two-fold challenge: their transition to an operational status to secure their service to users, and their response to new societal needs. These societal needs are now quite diverse, and are not limited to open ocean forecasts. Innovation in ocean monitoring and forecasting core services will remain an important driver for the coming years.

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EAMNet

Europe Africa Marine Network

Steve Groom, Plymouth Marine Laboratory

ABSTRACT

EAMNet is a project funded by the European Commission and aims to build a network linking Earth Observation (EO) information providers, user networks and centres of excellence in Europe and Africa in the area of coastal and marine observations, and contributing to sustainable development in Africa. The project started in March 2010 and is undertaking capacity building and maintenance, building upon existing infrastructure and expertise in Africa. The overall aim is to improve the exploitation of EO data for coastal and oceanic monitoring and contribute to the setting up of an Africa-wide observation system (GOOS-Africa). The project will provide an interface between European GMES-related core and downstream services and R&D projects (notably MyOcean) and African initiatives (e.g. AMESD) with the GMES-Africa initiative. It will also provide further links with GEO. Specifically, EAMNet will:

> Promote exploitation of existing and new marine EO data streams produced in Europe and Africa (e.g. MyOcean, OSI-SAF and DevCoCast) and disseminate the data using fast and reliable systems (GEONETCast).

> Harmonize and contribute to the evolution and improvement of the application of these data.

> Improve the coverage of the marine GEONETCast reception network.

> Contribute to existing training courses undertaken in AMESD, DevCoCast and other initiatives.

> Develop EO specific modules within the MSc courses of three African Universities.

> Coordinate R&D activities in Africa with GMES projects in Europe and promote best-practice through targeted exchange of personnel and open fellowships.

> Connect the African and EU marine communities by co-organizing yearly symposia (in parallel with the alternating AARSE and AMESD meetings), maintaining a web site and publishing a regular newsletter.

> Identify the requirements of the African stakeholders for the provision of GMES services.

> Contribute to the implementation of the Action Plan for GMES and Africa Partnership resulting from the Lisbon Process on "GMES and Africa" and planned to be endorsed at the next EU-Africa Summit.

INTRODUCTION

The Europe Africa Marine EO Network (EAMNet) is a project funded by the European Commission (EC) under the Space theme of the 7th Framework Programme (FP7) that is constructing a network linking Earth Observation (EO) information providers, user networks and centres of excellence in Europe and Africa. It is focussed on coastal and marine observations for use for sustainable development in Africa and in support of GOOS-Africa, the African component of the Global Ocean Observing System, that is constructing an Africa-wide ocean observing system. The project aims to extend to Africa the Global Monitoring for Environment and Security (GMES) initiative being developed to provide reliable and timely, sustained services based on EO data. Indeed, recognising the potential GMES role in Africa, the "Lisbon Declaration on GMES and Africa" initiated the Lisbon Process on "GMES and Africa". GMES and Africa is explicitly mentioned in the First Action Plan for implementation of the Africa-EU Strategic Partnership under Partnership 8, which make reference to the outcome of the event "Space for Development – the Case of GMES and Africa".

The project started in March 2010 and held its kick-off meeting and first co-located meeting in Addis Ababa in October 2010. This paper gives the background to the project and presents some preliminary results.

EAMNET WORK PROGRAMME

EAMNet consists of six work packages (WP) as follows:

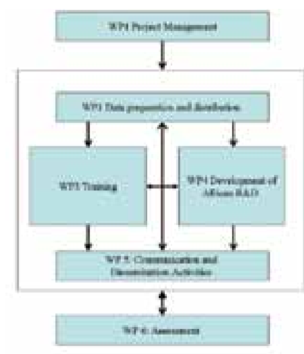

Figure 1: work package overview

The Data preparation and distribution mechanisms WP will improve the coverage and availability of GMES data for use in Africa. First, EAMNet will monitor available GMES data including from existing FP7 projects such as DevCoCast (GEONETCast for and by developing countries and MyOcean) and the OSI-SAF (Ocean and Sea-Ice Satellite Application Facility), recognising that these data streams will evolve considerable over the next few years. This task will consider data currently distributed either via the GEONETCast system towards Africa or available via the web (GEONETCast is a system through which data are transmitted via digital video broadcast over satellite channels to low-cost receivers, in this case in Africa). Second, EO data processing will be undertaken to complete the 1-km coverage of ocean colour and sea-surface temperature data over African coastal waters started in DevCoCast regions (see Fig. 3). Third, the GEONETCast reception station network for marine institutes and Universities will be improved by installation of 5 additional receivers at key sites to support acquisition, processing and dissemination of EO data and derived information. Finally, free and open-source tools to utilise these data will be made available with clear instructions for installation and use.

The Training WP will contribute to, build upon and extend existing training courses planned by the Joint Research Centre of the European Commission (JRC), the African Monitoring of Environment for Sustainable Development (AMESD) project, DevCoCast and in the Agulhas and Somali Current Large Marine Ecosystem (ASCLME) area, involving training in remote sensing and GIS for marine and coastal management. This will provide a cost effective way of undertaking training on GMES data without duplicating existing activities. The project will also contribute to the regional workshop to be run by the Partnership for Observation of the Global Oceans (POGO) agreed to be held in concert with the project. EAMNet participants will contribute GMES Africa specific material and presentations at the POGO course. A second task will be to design and implement marine-EO specific modules for use in university courses in Ghana, Tanzania and South Africa. Through wider dissemination of course materials and "training of trainers" these modules will deliver skilled professionals who are well prepared to serve the African needs, for example, of the AMESD programme and to meet the wider needs of sustainable development. This will ensure the provision of skilled experts in Africa in the longer term.

The Development of African R&D WP will organise and run personnel exchanges targeted at young/mid-career researchers within the partnership focussing on specific topics of high relevance to GMES and Africa such as coordinating GMES R&D activities in Europe and Africa, dissemination of best practice and developing African "champions" who will promote GMES data. EAMNet will also offer 1 to 3 month fellowships open to any African researcher visiting any marine science institute or university in Africa or Europe to undertake a project relevant to the aims of EAMNet and GOOS-Africa.

The Communications and Dissemination WP will establish and operate different communication and dissemination events, platforms and media to ensure that partners inside the network can meet and communicate with each other and to provide important wider engagement. The different communication and dissemination activities aim at engaging different target audiences at different levels. The co-organization of yearly EAMNet meetings with major conferences in Africa will provide marine-focussed sessions and a workshop to promote EAMNet results and wider GMES activities. The meetings will enable researchers external to the project to meet with partners and, hopefully, be inspired by the EAMNet activities. The distribution of a 3-monthly electronic newsletter will target named researchers and technologists to promote EAMNet data and resources and wider GMES activities focussed on Africa. The establishment of a website/portal will provide access to data and information by anyone. Finally, EAMNet will liaise with external bodies such as the Group on Earth Observations (GEO) where these can add value to the activities of the project.

The User Assessment WP has provided input to the EU-Africa action plan for GMES Africa, and will provide continuing advice to update the plan; this WP will also guide the development of EAMNet, and finally will assess of the efficacy of the different component projects in term of implementing the action plan and providing long-term sustainable capacity.

Finally, the above WPs are underpinned by the Project Management WP to ensure the efficient management of EAMNet.

PARTNERSHIP

EAMNet is comprised of ten partners, four in Africa and five in Europe, with one international organisation (EUMETSAT): see Table 1 and Figure 2. However, through the open fellowships and installation of GEONETCast receivers the project will have an impact on many other African countries and institutions.

Beneficiary name	Country
Plymouth Marine Laboratory (coordinator)	UK
University of Cape Town	South Africa
Institute of Marine Research	Portugal
Danish Meteorological Institute	Denmark
The European Organisation for the Exploitation of Meteorological Satellites	Germany
Natural Environment Research Council – National Oceanography Centre Southampton	UK
Institute of Marine Sciences University of Dar-es-Salaam	Tanzania
University of Ghana	Ghana
MeteoFrance - Centre de Météorologie Spatiale	France
National Institute of Oceanography & Fisheries	Egypt

Table 1: EAMNet partner list

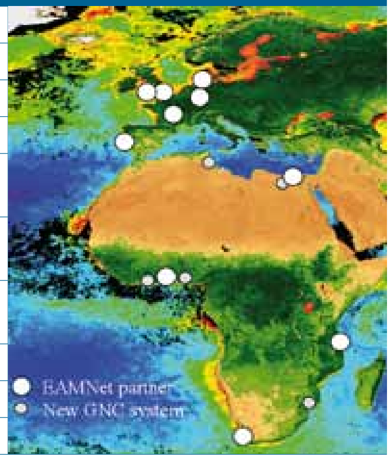

Figure 2: Partner sites and planned locations for new GEONETCast systems

RESULTS

EAMNet has been in operation for only 10 months at the time of writing (January 2011) but has already started to have an impact. A number of results are presented below.

FELLOWSHIPS

The fellowship programme is already "up and running" with the first call for open fellowships in autumn 2010 and applications are currently under review. The response was good with an over subscription for available places. Likewise, the targeted fellowships between members of the consortium have been planned with the first exchanges starting in February in South Africa and the UK. Topics to be investigated include "Using ocean data for fisheries resource management", "Impact of Climate Change and Variability on Coastal Panaeid Shrimps abundance in Rufiji Delta, Tanzania", "Eddy Variability and their influence on the Primary Productivity in the Mozambique Channel" and "Investigation of Transport and Dispersion Pattern of Suspended Particulate Matter in estuaries of Tanzania".

DATA PORTAL AND DATA DELIVERY

EAMNet has been providing EO data on ocean colour including phytoplankton chlorophyll-a concentration and turbidity and on sea-surface temperature in both near-real time, typically within 8 hours, and 7-day composites which give good coverage. These data can be accessed via the EAMNet data portal (see Fig. 3) while transmission has started via the GEONETCast system for near-real time data with other data to follow. The EAMNet data portal provides a single point access to data from the data production centres in UCT South Africa and PML, UK as well as other international data providers such as NASA USA and the JRC. The PML ocean colour data use the same processing stream as being developed in the FP7 MyOcean project. Data are available for the entire coast of Africa, and also areas of the western Indian Ocean provided on behalf of the Oceans and Coastal theme of the AMESD project. Fig 4 shows an example phytoplankton chlorophyll-a 7-day composite for 13 to 19 January 2011 for the Mozambique channel.

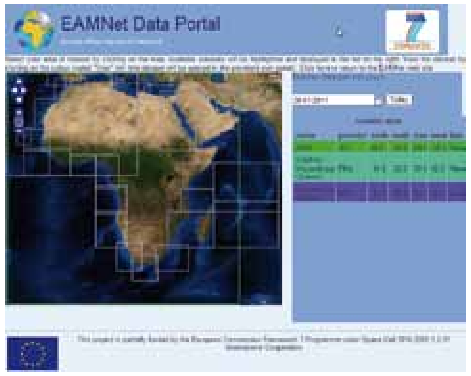

Figure 3: EAMNet data portal.

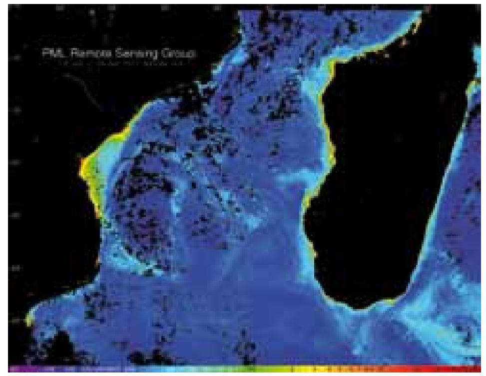

Figure 4: Example chlorophyll-a 7 day composite image 13-19 January 2011.

PUBLICITY

Dissemination and communication are obviously very important in a networking project and EAMNet has accomplished this through a number of routes. The web site (www.eamnet.eu) provides the most widely visible portal to information about the project and headline information will soon be available in French, Portuguese and Arabic. EAMNet has also produced a newsletter roughly every three months providing more specialist information on the project: these are available through the web site and e-mail lists.

AFRICAN ASSOCIATION FOR REMOTE SENSING OF THE ENVIRONMENT (AARSE) 2010 CONFERENCE

EAMNet has arranged to synchronise its internal project meetings with major African conferences, notable the AARSE biennial meetings. The 2010 conference was held in Addis Ababa in October and EAMNet assisted with organisation of the dedicated Marine and Coastal sessions which attracted approximately twelve speakers and a number of posters. This was considered a success and it is expected that a special issue of an international peer-reviewed journal will be produced on the basis of the papers. EAMNet also participated in a booth in the conference and provide information leaflets on the project.

CONCLUSION

Although EAMNet has only been in operation for ten months it has already started to have an impact. The project has provided daily coverage in near-real time of EO data covering the entire coast of Africa and has also made links with AMESD to extend the data coverage to the western Indian Ocean. EAMNet also contributed to the AARSE 2010 conference by supporting the organisation of the Marine and Coastal session and supporting speakers. With the first fellowships about to start and the first MSc training to be undertaken in 2011, and installation of new GEONETCast systems imminent, the project is creating the links and building the infrastructure to ensure a longer term legacy.

Atmosphere monitoring

Something is in the air

MACC

Monitoring atmospheric composition and climate: Developing the GMES Atmosphere Service

Adrian Simmons

European Centre for Medium-Range Weather Forecasts

ABSTRACT

MACC (Monitoring Atmospheric Composition and Climate) uses the modelling and data assimilation approach of numerical weather prediction to monitor the composition of the Earth's atmosphere and predict air quality with a focus on Europe. It provides data that are important for understanding climate and validating and improving the models used to predict climate change. Information important for protecting health and for efficient use of solar power generation is also supplied. MACC is developing core operational atmospheric environmental services for Europe's GMES (Global Monitoring for Environment and Security) initiative.

WORK PROGRAMME, METHODOLOGY, MILESTONES

In its objective to monitor the atmospheric composition and climate, MACC uses the modelling and data assimilation approach of numerical weather prediction to monitor the composition of the Earth's atmosphere and predict air quality with a focus on Europe. It provides data that are important for understanding climate and validating and improving the models used to predict climate change. Information important for protecting health and for efficient use of solar power generation is also supplied. MACC is developing core operational atmospheric environmental services for Europe's GMES (Global Monitoring for Environment and Security) initiative.

Figure 1 gives an overview of the process by which MACC uses satellite and in-situ observations to produce a set of products. MACC's main components are:

> Acquisition and pre-processing of observational data, and provision of estimates of surface emissions of key species.

> Global and regional processing chains that include not only the data assimilation and modelling systems that provide the basic monitoring and forecasting products, but also systems that provide derived products.

> Interface to downstream-service providers and other users.

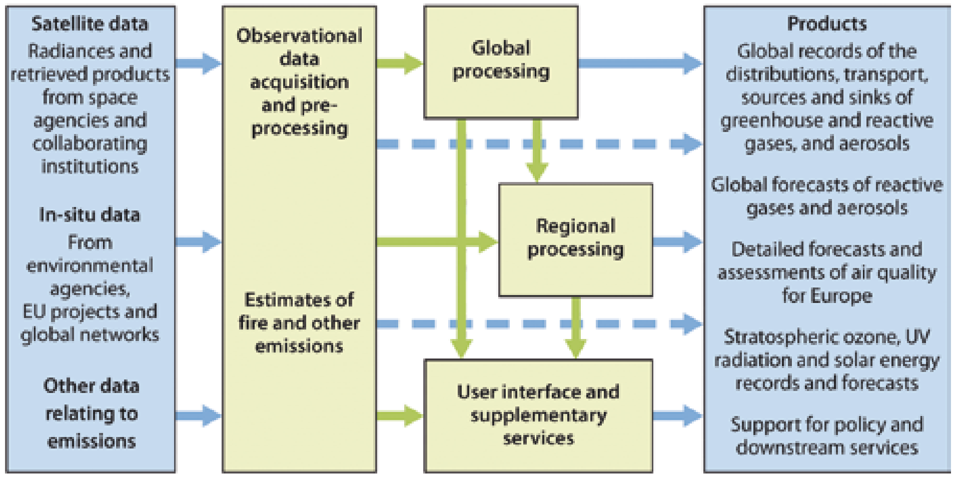

Figure 1: An overview of the MACC processing system

With respect to input data, MACC utilizes data from the many satellites that supply information on atmospheric dynamics, thermodynamics and composition. The data are provided either by space agencies or by other institutions that extract or 'retrieve' data on physical or chemical variables from the raw satellite measurements. MACC itself undertakes some of the required satellite data retrieval for atmospheric composition. The satellite data are complemented by extensive *in situ* data from ground-based and airborne meteorological instruments and by a more limited amount of *in situ* data on atmospheric composition.

ECMWF's primary task for MACC in this area is the acquisition, pre-processing and archiving of the composition data that are used for global assimilation and validation in conjunction with ECMWF's holdings of meteorological data. Support is also provided to facilitate the flow of near-real-time and validated retrospective European air-quality data to the regional forecasting and assessment component of the project.

MACC also acquires and updates data related to the emissions of chemical species and particulate matter into the atmosphere. A sub-component led by ECMWF is devoted to estimating the highly variable emissions from fires, whose location and intensity are identified from satellite observations, currently from the SEVIRI and MODIS instruments operated respectively by EUMETSAT and NASA. MACC runs its fire-emission system both routinely in near-real-time to provide data for aerosol and reactive-gas forecasting and retrospectively to provide records for use in extended reanalysis and case studies. An example of significant variation in fire activity is illustrated in figure 2, which shows substantially lower global biomass burning in 2009 than in previous years. This was mainly due to a known reduction in deforestation in Brazil last year, although relatively wet weather in Siberia also contributed.

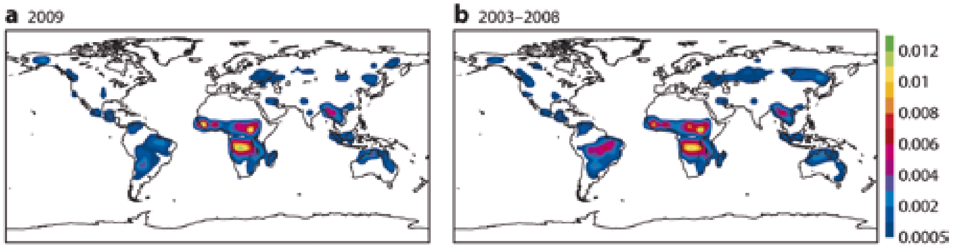

Figure 2: Fire radioactive power density (Wm-2) averaged for (a) 2009 and (b) 2003–2008. Global biomass burning was lower in 2009 than in previous years mainly due to reduced deforestation in Brazil. Note that, in addition to biomass burning, the maps exhibit minor features associated with gas flares such as those near the Persian Gulf

A core task is the global monitoring and forecasting. The global component of MACC operates and refines the analysis and forecasting systems that provide the basic monitoring and forecast products for atmospheric composition. It also provides derived products related to the radiative forcing of climate, inferred corrections to sources and sinks, surface UV radiation and resources for solar power generation. Additional observational data are used for validating products.

MACC's integrated data assimilation and forecasting system for atmospheric composition and weather is based on incorporating greenhouse and reactive gases (including carbon dioxide, methane, carbon monoxide, ozone and nitrogen dioxide) and several types of aerosol (dust, sea-salt, organic and black carbon, and sulphate) into ECMWF's Integrated Forecasting System (IFS). Chemical production and loss of the reactive gases are taken at present from one of three coupled chemistry transport models maintained by partners in the project: MOCAGE from Météo-France, MOZART from Forschungszentrum Jülich (Germany) and TM5 from KNMI (The Netherlands). Development of the modelling and data assimilation components within the IFS, operation of production streams, dissemination of results and basic validation are the main tasks of ECMWF in MACC. Model development currently includes incorporation of chemistry and related modules from the transport models into the IFS to eliminate the overheads of the coupled approach.

The integrated global system is run daily to provide monitoring and four-day forecasting of the reactive gases and aerosols. It has been operated routinely and quite robustly in research mode since the summer of 2008, although this has entailed running rather more than a day behind real time. Soon, however, the global system will be moved under the control of ECMWF's operational supervisor, which will substantially improve the timeliness of products. Horizontal resolution will be increased at the same time, from T159 to T255 (125 km to 80 km) for the IFS. Full 24×7 operational support cannot be provided at this stage, but is expected to start in 2012 under a new funding regime.

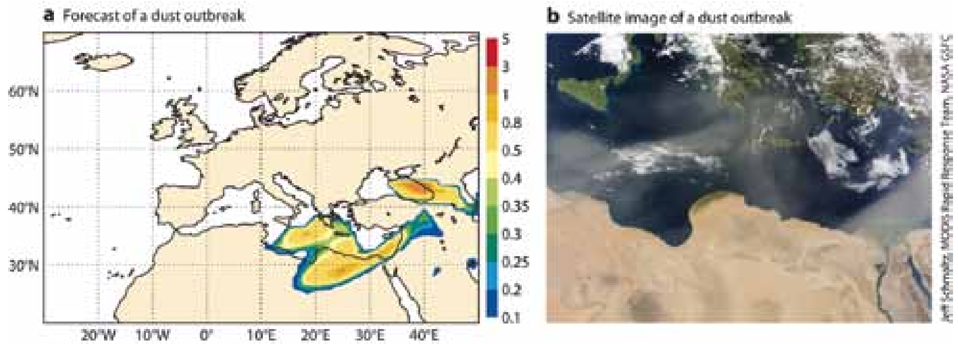

Figure 3: (a) Dust outbreaks from North Africa into the eastern Mediterranean on 18 February 2010 captured in a 33-hour forecast from the global MACC system. (b) The corresponding image from the MODIS instrument on NASA's Terra satellite. The forecast product is a prototype warning index based on scaling the dust aerosol optical depth by a measure of the deviation from climatological conditions. (Image credit: Jeff Schmaltz, MODIS Rapid Response Team, NASA GSFC)

To illustrate the type of service that can be provided by MACC, figure 3 shows a prototype dust warning index. Fine dust and other particulate matter are generally damaging to health, and severe dust storms can cause major disruption to transport and other aspects of daily life. Determining the origin of air pollution episodes and distinguishing between natural and man-made sources of pollutants is important for establishing and implementing policies to improve air quality and protect health. Transport of dust from Africa is a significant factor causing European regulatory thresholds for particulate matter to be exceeded.

The integrated MACC system is also run retrospectively by ECMWF. A production stream for monitoring greenhouse gases is run routinely about six months behind time to enable use to be made of data that arrive with a lag of several months. In addition, there is a continuing programme of reanalysis for the period from 2003 onwards when satellite data on atmospheric composition has been at its best.

GEMS carried out a reanalysis for 2003–2007, and this has been extended by MACC until April 2009. An example showing interannual differences in aerosol and carbon monoxide due to Siberian fires was presented in *ECMWF Newsletter No. 120*. MACC has now started a second reanalysis for the period, using higher horizontal resolution and other improvements to the data assimilation system and input data, including emissions.

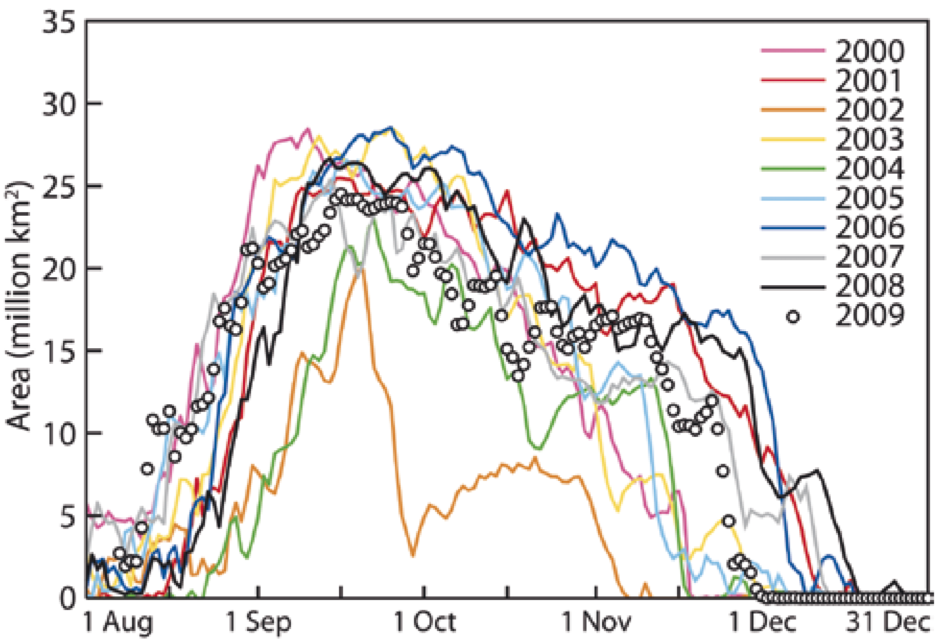

Figure 4: Area of the southern hemisphere with total ozone less than 220 Dobson Units. These records produced by partner KNMI for 2000 to 2009 are based on assimilating data from the GOME and SCIAMACHY instruments on ESA satellites. Their production is being continued in MACC

Three specialised global analysis systems for stratospheric ozone are operated by partners BIRA-IASB (Belgium), DLR (Germany) and KNMI as part of their contributions to MACC. The systems are based on assimilating data from a series of satellites into chemical transport models, and are of relatively low cost. They are run primarily to extend the data records that were established by running them during the PROMOTE project, but they also provide reference points for the performance of the newer integrated MACC system. Figure 4 presents an example of the inter-annual variability of the ozone hole that forms over the Antarctic each winter.

Regional forecasting and evaluation forms another major work package. MACC's regional processing component comprises an ensemble of higher-resolution chemical analysis and forecasting systems run over a common European domain by seven partners. The core ECMWF system provides the meteorological fields required by the regional systems, and the global MACC system provides chemical and aerosol boundary conditions. Forecasts are produced daily for three days ahead. Retrospective analyses of validated air-quality measurements are also produced, providing a description of the background European levels of pollutants that are characterised by the influence of long-range transport. This enables evaluation of interannual variations in air quality and the effects of changes in emissions.

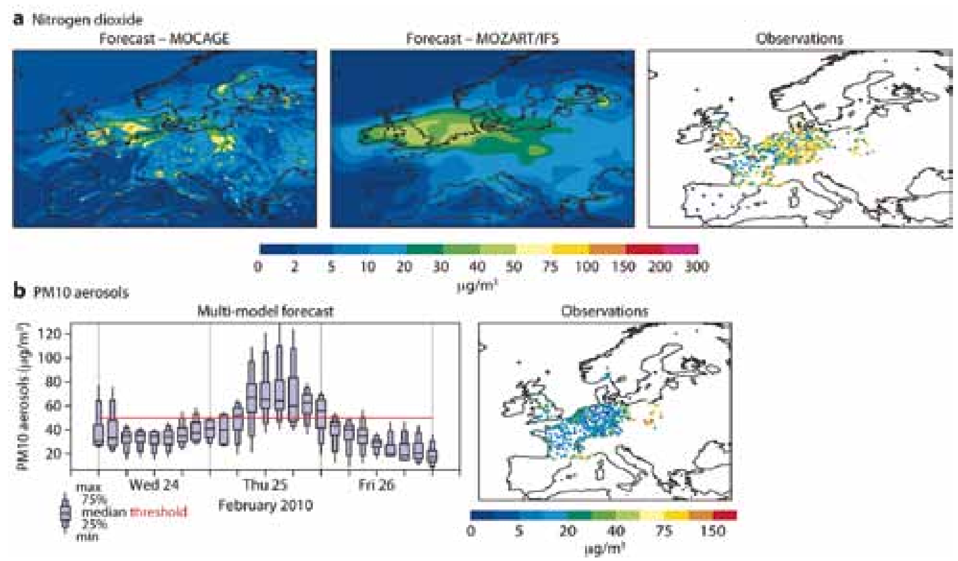

Figure 5: (a) Nitrogen dioxide distributions for 18 UTC on 25 February 2010 from the 42-hour forecasts from the MOCAGE regional model (left), the MOZART/IFS global model (centre) and the measured values (right). (b) The spread in multi-model forecasts of PM_{10} (particulate matter with sizes up to 10 microns) for Warsaw over the three-day period commencing 00 UTC on 24 February 2010 (left) and the measured values of PM_{10} at 12 UTC on 25 February (right)

Figure 5a illustrates the detailed forecasts of air quality that can be provided by a high-resolution regional model and figure 5b shows an example of how the concept of the Epsgram developed for medium-range ensemble weather forecasting has been extended to shorter-range regional prediction of pollutants.

The user interface and policy support is an important aspect of the work. The final component of MACC provides the interface to intermediate service providers and end users, runs service-chain test cases and supports the development of policy for the control of atmospheric pollution. Boundary conditions from the global system may be used not only to support MACC's regional component, but also to drive other European models or models for other regions of the world.

MACC includes a service-chain test case that uses regional modelling to study links between dust outbreaks and the occurrence of meningitis in the Sahel region of Africa. Other test cases evaluate the capability of MACC's core service lines to support downstream services for urban air-quality forecasting and other types of health warning.

Policy support is undertaken in liaison with the European Environment Agency, national and regional environment agencies and other interested bodies. It includes agreements on data exchanges, preparation of scenarios and predictive tools to be run on demand in extreme situations and provision of agreed input to assessment reports.

Examples of the support MACC provides for international measurement and modelling initiatives are shown in box B.

Box A. The objectives of GEMS and PROMOTE

GEMS: Global and Regional Earth-system (Atmosphere) Monitoring using Satellite and In-situ Data (GEMS) – to develop a comprehensive data analysis and modelling systems for monitoring the global distributions of atmospheric constituents important for climate, air quality and UV radiation, with a focus on Europe.

PROMOTE: Protocol Monitoring for the GMES Service Element: Atmosphere – to provide a sustainable and reliable operational service to support informed decisions on the atmospheric policy issues of stratospheric ozone depletion, surface UV exposure, air quality and climate change.

Box B. Support for measurement and modelling initiatives

MACC supports the American HIPPO observational campaign by providing near-real-time forecasts of carbon monoxide, ozone, and aerosol. HIPPO is measuring cross sections of a comprehensive suite of atmospheric trace gases approximately pole-to-pole, from the surface to the tropopause, five times during different seasons over a three-year period. Its data will be used to evaluate and improve MACC's global analysis and forecasting system.

MACC supports the AQMEII coordinated evaluation of European and North American regional air quality modelling. AQMEII promotes exchange of information on practices, inter-community activities and identification of research priorities, with a focus on policy needs. MACC is providing boundary data on atmospheric composition for comparisons of regional model performance over North America and Europe.

ATMOSPHERE MONITORING

PARTNERSHIPS AND COLLABORATIONS

MACC began on 1 June 2009, when it took over from the FP6 EU-funded GEMS project. MACC also continues a number of activities developed within the GMES Service Element project PROMOTE under funding from the European Space Agency (see box A).

MACC is undertaken by a 45-partner consortium drawn largely from the participants in GEMS and PROMOTE, and like GEMS is coordinated by ECMWF. Eleven of the partners are national meteorological services from ECMWF Member and Co-operating States.

ACHIEVED RESULTS

MACC's products relating to atmospheric composition are made freely available. Graphical products, datasets and reports can be downloaded from the project's main website (www.gmes-atmosphere.eu) or from partner websites for which the main site acts as a portal. Other forms of dissemination are under development. Training can be provided and user feedback is encouraged.

CONCLUSION

MACC is engaged in an ongoing process of consolidating and refining its analysis and forecasting systems, completing the migration of components from GEMS and PROMOTE, and establishing supplementary new services. It continues to expand its capability to monitor the quality of its products on a systematic basis. Also MACC is developing its interaction with users to ensure that their requirements are known and met, and that their feedback on products is received and acted upon. This will include a focus on the downstream-service projects that are being established under GMES to provide much of the delivery of targeted services to end users. MACC in turn provides feedback on the quality of the input data it uses, and helps to define the requirements for new observing systems, in particular the GMES Sentinel satellite missions. Bringing all this to fruition also requires funding to be secured and governance arrangement to be put in place for sustained future operation.

MACC is unique worldwide in the breadth of what it is doing and in the integration of its activities. Its success derives from its ability to use the expertise and infrastructure of the many members of the consortium, and builds upon the pioneering work of GEMS and PROMOTE. Meeting future challenges will require continued effective cooperation between national meteorological services, environmental and space agencies, universities and research institutes within Europe, and continued interaction with the wider international community engaged in observation and research in atmospheric composition.

MACC

Wildfire monitoring in the GMES atmospheric services developed by the MACC project

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E.C.M.W.F., Forschungszentrum Jülich, Free University of Amsterdam, King's College London

ABSTRACT

The MACC project is implementing atmospheric monitoring and forecasting services for the global and European domains as part of the GMES programme. Smoke plumes are monitored by assimilating observations of aerosol optical depth and various trace gases. Biomass burning is monitored in real time by assimilating observations of fire radiative power (FRP) from five satellite-based instruments. The global monitoring capability is demonstrated with a near real time fire and smoke analysis for South America, where a threefold increase of biomass burning has been detected in 2010 compared to 2009. Furthermore, an anomalously flat diurnal cycle has been recorded for the Russian wildfires of July and August 2010. This can be interpreted as a characteristic of peaty soil burning, which entails particularly large emissions. The global aerosol service was able to forecast, with three days lead time, the air quality threshold transgression in Finland that resulted from the Russian fires.

WORK PROGRAMME, METHODOLOGY, MILESTONES

The local and regional air quality is during wildfire episodes obviously dominated by smoke. On a global scale, biomass burning is a significant source for various aerosols and reactive and greenhouse gases: For example, fires are the dominant source of organic matter, which is the dominant anthropogenic aerosol in terms of average aerosol optical depth. Fire emissions also contribute approximately 40% of the carbon monoxide emissions and the carbon emission rate of open vegetation burning amounts to 25–45% of the corresponding rate due to fossil fuel consumption, globally.

Monitoring Atmospheric Composition and Climate (MACC) is the current pre-operational atmospheric service of the European GMES programme. MACC provides data records on atmospheric composition for recent years, data for monitoring present conditions and forecasts of the distribution

of key constituents for a few days ahead, including smoke plumes from biomass burning, cf. Simmons et al. "Monitoring Atmospheric Composition and Climate: Developing the GMES Atmosphere Service" in this book.

While smoke plumes from fires are observed and consequently represented in the analyses of MACC, a priori information on the vertical distribution of the atmospheric constituents and the speciation of aerosols is still required [Benedetti et al., 2009, Engelen et al., 2009, Inness et al., 2009]. Therefore, and for continued generation of smoke plumes in the forecast, various species emission fluxes are required by the atmospheric model as surface boundary conditions.

These fluxes are derived from observations of the actual fire distribution since biomass burning varies strongly on all time scales from hours to decades and beyond [Kaiser et al., 2006]. FRP satellite products are particularly suitable for emission monitoring because they are available in near real time in principle and in practice, as hot spot products, and provide quantitative information on the amount of burning biomass, even more accurately than burnt area products. For retrospective analysis, MACC combines the well-established GFED3 inventory [van der Werf et al., 2010] with Fire Radiative Power (FRP) observation by the MODIS instruments [Justice et al., 2002]. For real time applications, MACC assimilates FRP from the MODIS [Justice et al., 2002], SEVIRI [Roberts and Wooster, 2008] and GOES-East and -West [Xu et al., 2010] Imager instruments [Kaiser et al., 2009].

FRP products for the SEVIRI and MODIS instruments are obtained in real time from the EUMETSAT LandSAF, Lisbon, and NASA and NOAA, respectively. Additionally, MACC is running a unique real time FRP production chain for the GOES satellites. All products are subsequently merged, observation gaps are filled with data assimilation, FRP is converted to the emission fluxes of 25 smoke constituents.

PARTNERSHIPS AND COLLABORATIONS

The team working on fire emission estimation in MACC comprises world-leading experts in the fields of satellite fire products (King's College London), fire emission modelling (Free University of Amsterdam, Forschungszentrum Jülich) and data assimilation (E.C.M.W.F.). Collaboration with Instituto de Meteorologia, Lisbon is additionally aimed for in order to make use of their expertise developed by hosting the EUMETSAT LandSAF and satellite processing for the GMES Geoland projects.

In order to maintain a close collaboration with the scientific community and promote the MACC products for scientific use, partners from the MACC fire team have convened an Exploratory Workshop funded by the European Science Foundation (ESF) in 2009 [Kaiser et al., 2010] and a fire-related session at the European Geosciences Union (EGU) General Assembly 2010. The global FRP product is already used by the UN's Global Fire Monitoring Centre (GFMC), Freiburg, Germany. Further contacts include the European Forest Fire Information Service at JRC, the Naval Research Laboratories, Monterey, US, and INPE-CPTEC, Brazil.

ACHIEVED RESULTS

MACC has been producing global daily maps of observed FRP in real time, i.e. with a time lag of six hours, throughout its life time. The maps are currently based on observations aboard the satellites Meteosat-9, Aqua and Terra and the methodology is continuously being improved through validation. An example is shown in Fig. 1, left plot, which highlights the widespread burning towards the end of the dry season in southern hemispheric Africa and South America. Individual large boreal forest fire events are visible in Siberia and Canada. The real time fire emission fluxes are being used by the global MACC production system to constrain forecast of aerosol and the lagged monitoring of greenhouse gases. The real time fire emission fluxes of reactive gases, namely carbon monoxide, are currently being used for the support of scientific investigations into the global transport patterns of reactive gases, cf. Fig. 1, right plot.

The retrospective fire emission fluxes of aerosols, reactive gases and greenhouse gases are being used throughout the global MACC reanalysis of 2003 to the present. Combining the real time fire observations with those of previous years allows assessments of the severity of the various fire seasons even while they are still ongoing. For example, Fig. 2, left plot, shows the FRP that has been observed over southern hemispheric America since 2003. The signal is dominated by biomass burning in the Amazon. It appears to display a negative trend since 2005 that is overlaid by two very strong fire seasons in 2007 and 2010. The trend may be an indication of reduced deforestation. A comparison with the El Niño index reveals that the two strong fire seasons coincide with strong transitions of El Niño to La Niña atmospheric states.

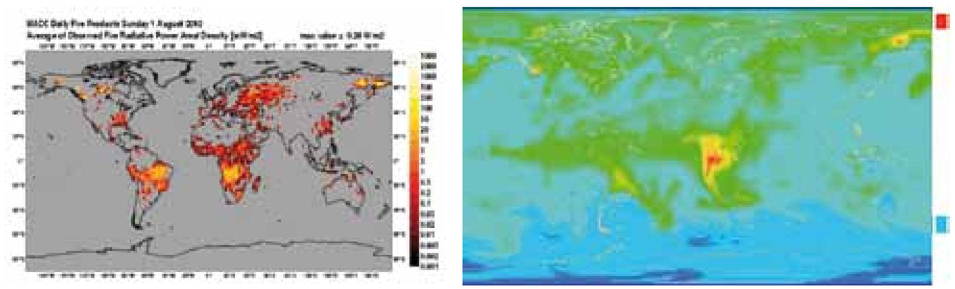

Figure 1: Merged Fire Radiative Power (FRP) Observations (left) and resulting simulated carbon monoxide distribution at about 3 km altitude (right) on 1 August 2010

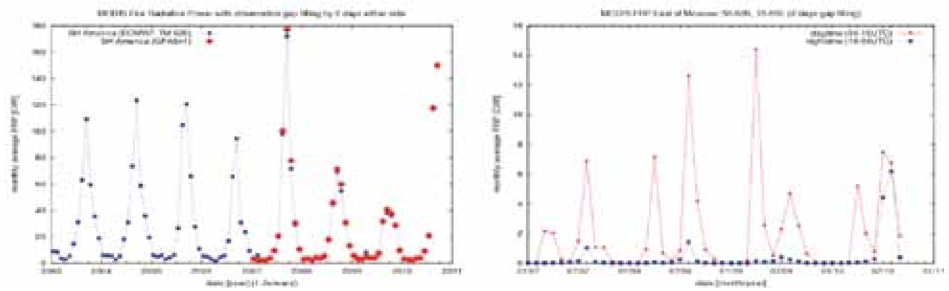

Figure 2: Observed FRP over Southern Hemispheric America (left, 2003– 2010) and East of Moscow (right, 2007–2010, for daytime and nighttime)

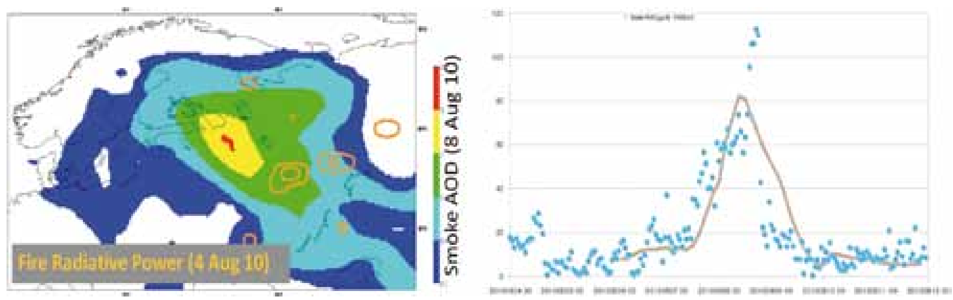

Figure 3: Observed FRP and simulated AOD over Northern Europe (left) and observed PM_{10} (symbols) and 3-day forecast of PM_{10} (line) in Virolahti, Finland (right, µg m-3) during the Russian fires of Summer 2010. FRP contour lines at 50 and 500 mW m-2

Following anomalously high temperatures, large wildfires devastated parts of Russia to the east of Moscow in July and August 2010. Because of the dry conditions, peaty soil fires developed, which emitted large quantities of smoke. The FRP and the aerosol optical depth of the smoke were observed by NASA's MODIS instruments and used in the global real time forecasting system of MACC. Fig. 3, left plot, shows the distributions of fires on 4 August and of smoke on 8 August as represented in MACC. The time series of in-situ observations of PM_{10} in the right plot of Fig 3 shows that the air quality of Virolahti in Finland was affected by smoke around 8 August, which caused a transgression of the EU threshold of 50 µg(PM_{10}) m-2 for the 24-hour average. The 3-day forecasts of PM_{10} at Virolahti that was produced by the global MACC system matches the in-situ observations well, thus highlighting the ability of MACC to monitor and forecast the global distribution of aerosols with an accuracy that allows local air quality applications. The excellent accuracy is primarily attributed to the combination of data assimilation of aerosol optical depth observations with the accurate representation of atmospheric transport in the IFS.

MACC advised the European Environmental Agency (EEA) on the potential impact of the Russian fires on European air quality and answered a specific query by the French Ministry of Ecology concerning forecasts of the Russian smoke plumes by showing that the EU member states, except Finland, would be hardly affected by the smoke. MACC also published a news item on its web server that listed its products providing information on the Russian fires and smoke.

The space-borne fire observations used in MACC show that the diurnal cycle of the Russian fires was flat, which is in sharp contrast to that of previous years' fires, which virtually extinguished at night, cf. Fig. 2, right plot. Thus the characterisation as "peaty soil fire" can be done remotely and in real time using the satellite observations processed in MACC.

CONCLUSION

The fire service within the MACC project is providing real time and retrospective services for the monitoring of the global distribution of biomass burning and its smoke emissions. These services are a vital input for the atmospheric services of MACC and also used by users outside MACC.

For retrospective studies, the fire emissions are calculated from a combination of the GFED inventory with FRP observations. For real time applications, MACC is running the first Global Fire Assimilation System (GFAS) based on Fire Radiative Power (FRP) observations. It ingests fire products from the satellite-based MODIS, SEVIRI and GOES Imager instruments. The system is also unique in that it uses observations of no fire occuring to avoid ad hoc assumptions on the diurnal cycle of fires. Thus it is able to characterise the diurnal cycles of the observed fires. Observation gaps are filled with a data assimilation technique in the upcoming version.

The real time fire monitoring over South America records an increase of biomass burning by a factor of about three for the biomass burning season 2010 when compared to the previous year. Like the comparable fire season in 2007, it coincides with a transition from El Niño to La Niña. This demonstrates the global monitoring capability with short response times of the MACC system.

During the catastrophic Russian fires in summer 2010, the MACC near real time system was able to forecast the resulting transgression of a European air quality threshold in Virolahti, Finland, with three days lead time. This proves the applicability of the global MACC systems for regional air quality applications, in addition to the regional MACC services. MACC's fire assimilation system is able to identify the fact that peaty soils were burning in Russia from the observed diurnal cycle of the fires. This has been shown to be the distinctive feature of this summer's fires that made them produce large amounts of smoke.

All MACC fire services are publicly available, see http://www.gmes-atmosphere.eu/fire. This research was supported by the EU Seventh Research Framework Programme (MACC project, contract number 218793). We thank the Finnish Meteorological Institute for making the PM_{10} in-situ observations from Virolahti available.

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ATMOSPHERE MONITORING

MACC

An 8-year time series of global atmospheric composition: the MACC reanalysis

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E.C.M.W.F.

ABSTRACT

The Monitoring Atmospheric Composition and Climate (MACC) project is currently running an 8-year reanalysis of atmospheric composition covering the years 2003 - 2010. This reanalysis combines satellite data from various sensors with a state-of-the-art atmospheric transport/chemistry model to provide a consistent time series of 3-dimensional fields of gases, such as ozone, carbon monoxide, nitrogen dioxide, carbon dioxide, methane, and aerosols. For many users such a consistent time series is much easier to apply for their purposes than the individual, sometimes patchy, data sets that exist from various satellite instruments. Issues such as inconsistencies between satellite instruments are dealt with within the reanalysis and lower the burden for users. The MACC reanalysis has now processed the period 2003 – 2006 and will process another four years before the end of the project. While the reanalysis is still running, first users have already registered and downloaded data and the expectation is that the number of users will grow considerably when the full reanalysis has finished and has been validated.

WORK PROGRAMME, METHODOLOGY, MILESTONES

The Monitoring Atmospheric Composition and Climate (MACC) project is the current pre-operational atmospheric service of the European GMES programme. MACC provides data records on atmospheric composition for recent years, data for monitoring present conditions, and forecasts of the distribution of key constituents for a few days ahead. MACC combines state-of-the-art atmospheric modelling with Earth observation data to provide information services covering European air quality, global atmospheric composition, climate, and UV and solar energy. A key component of the project is an 8-year global reanalysis of atmospheric composition. The last few decades have shown the large value of meteorological reanalyses with for instance the current ECMWF reanalysis (ERA-interim) having already more than 5000 registered external users (Paul Poli, personal communication, 2011). Also, the paper "The ERA-40 re-analysis" (Uppala et al., 2005) has been identified by Thomson Reuters Scientific's Essential Science Indicators as one of the most highly cited papers in the field of Geosciences.

ATMOSPHERE MONITORING

The important value of a reanalysis is the combination of various sources of observational information (in-situ, aircraft, satellite) into one estimate of the atmospheric state at any one moment using the constraint of a state-of-the-art atmospheric model providing a 4-dimensional picture of the atmosphere for periods ranging from a few years to several decades. While this picture is obviously not perfect, it has been estimated with great care, taking into account the uncertainties in both the model and the observations, and it allows users to work with a single estimate instead of having to deal with several, often inconsistent, estimates from various observing networks.

While several meteorological reanalysis data sets exist from various numerical weather prediction centres, the number of reanalyses for atmospheric composition is limited. So far, most focus has been on stratospheric ozone records. MACC is providing the first comprehensive reanalysis of atmospheric composition for the period 2003 – 2010 based on the initial effort undertaken in its predecessor project GEMS (Global and regional Earth-system (Atmosphere) Monitoring using Satellite and in-situ data; Hollingsworth et al., 2008). Satellite data from various satellite sensors are used to constrain CO_2, CH_4, O_3, CO, NO_2, and aerosol, while many other chemical gases are provided from the underlying chemical transport model. The aim is to provide a consistent time series of global atmospheric constituents.

ACHIEVED RESULTS

The MACC reanalysis is currently half-way through the planned period of 2003 – 2010. It has processed various satellite data sources, which are listed in Table 1 and Table 2, to constrain various atmospheric constituents. Satellite data listed in Table 1 are actually assimilated, while satellite data listed in Table 2 are only being monitored.

The latter means that the observations are routinely compared to the model forecast, but the information is not used to adjust the model. The data listed are only the top of the iceberg, because the MACC reanalysis also assimilates all available meteorological observations. This amounts to about 5 million individual observations every 12 hours.

Table 1: Satellite data of atmospheric composition assimilated in the MACC reanalysis

Instrument	Satellite	Provider	Version	Species	Type	Period
GOME	ERS-2	RAL		O_3	Profiles	20030101-20030531
MIPAS	Envisat	ESA		O_3	Profiles	20030127-20040326
MLS	AURA	NASA	V02	O_3	Profiles	20040808 -
OMI	AURA	NASA	V003	O_3	Total column	20041001 -
SBUV	NOAA-16	NOAA	V8	O_3	6 layer profiles	20040101 -
SBUV	NOAA-17	NOAA	V8	O_3	6 layer profiles	20030101 -
SBUV	NOAA-18	NOAA	V8	O_3	6 layer profiles	20050604 -
SCIAMACHY	Envisat	KNMI		O_3	Total column	20030101 -
MOPITT	TERRA	NCAR	V4	CO	Total column	20030101 -
IASI	METOP	LATMOS/ ULB		CO	Weighted column	20071001 -
SCIAMACHY	Envisat	KNMI	V1.1	NO_2	Tropospheric column	20030101 -
MODIS	AQUA	NASA		AOD	Total column	20030101 -
MODIS	TERRA	NASA		AOD	Total column	20030101 -
SCIAMACHY	ENVISAT	SRON		CH_4	Total column	20030101 -
AIRS	AQUA	NASA		CO_2	Radiances	20030101 -
IASI	METOP	EUMETSAT		CO_2	Radiances	20070101 -

Table 2: Satellite data of atmospheric composition monitored in the MACC reanalysis

Instrument	Satellite	Provider	Version	Species	Type	Period
OMI	AURA	KNMI	Col. 3	NO_2	Tropospheric column	20041001 -
OMI	AURA	NASA	V003	SO_2	Total column	20040817 -
SCIAMACHY	Envisat	BIRA		SO_2	Total column	20040104 -
OMI	AURA	NASA	V003	HCHO	Total column	20040827 -
SCIAMACHY	Envisat	BIRA	V2	HCHO	Total column	20030101 -
TANSO	GOSAT	JAXA		CH_4	Total column	20090601 -
TANSO	GOSAT	JAXA		CO_2	Total column	20090601 -

The model that is used in the data assimilation system is the ECMWF Integrated Forecasting System (IFS) meteorological model, which was extended in GEMS and MACC to include the main atmospheric constituents of the MACC system (O_3, CO, NO_2, SO_2, HCHO, CO_2, CH_4, and aerosol). This model is coupled to a full chemistry transport model (the MOZART CTM) that simulates the relevant chemical processes (Flemming et al., 2009). The IFS model runs at a resolution of 80 km at 60 vertical levels and the CTM runs at a resolution of 125 km at 60 levels. Great care has also been taken in prescribing the surface fluxes, both anthropogenic and natural, for the various gases. More details about the global data assimilation system can be found in Benedetti et al. (2009), Engelen et al. (2009), Flemming et al. (2010), Inness et al. (2009), Mangold et al. (2010), and Morcrette et al. (2009).

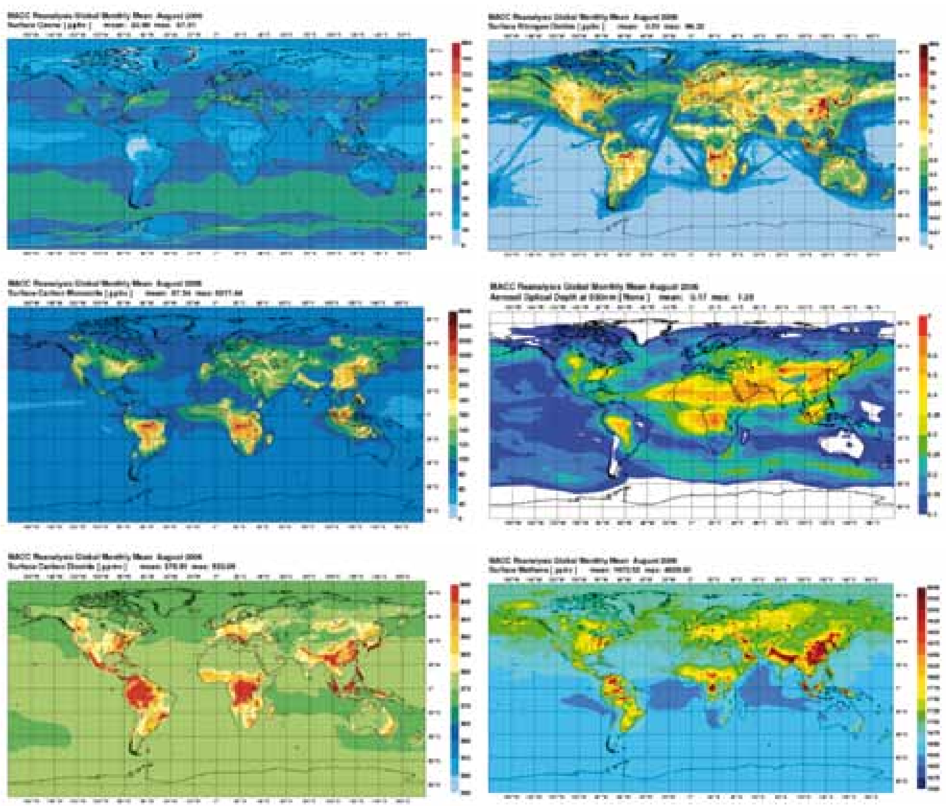

Figure 1: Monthly mean results from the MACC reanalysis for August 2006. Shown are surface O_3, surface NO_2, surface CO, aerosol optical depth (AOD). Surface CO_2 and surface CH_4 concentration

Monthly mean results for August 2006 are shown in **Figure 1**. Figures like these immediately show the global distribution of various chemical gases and potential relationships between them. Also, by comparing different years it is possible to study changes in both natural and anthropogenic emissions. Extreme events can be put in better perspective by easily comparing them to more common situations. An example is shown in **Figure 2**, which shows the effect of large wildfires in Siberia in 2003 on the concentrations of CO and aerosol relative to more normal conditions in 2005. Such a comparison makes it immediately clear that a period of strong wildfire activity can have a significant impact on the air quality over a large region.

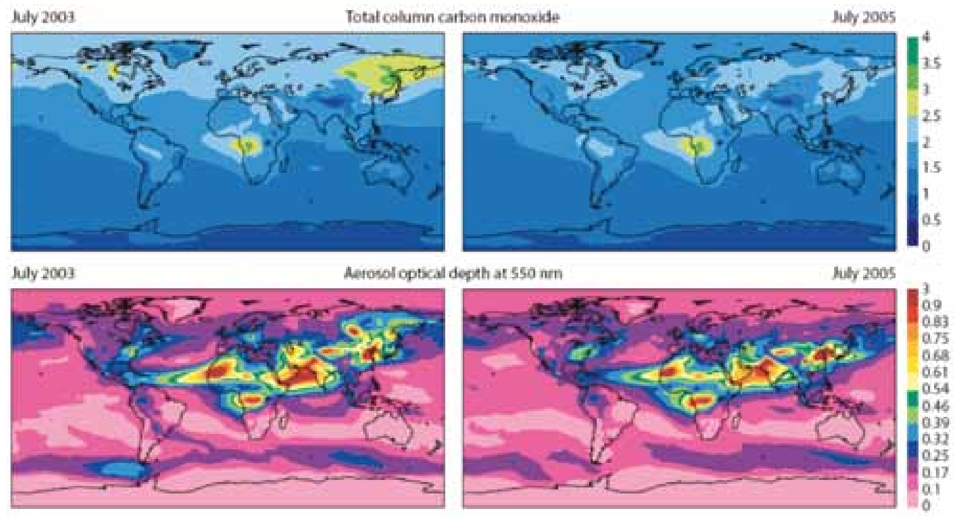

Figure 2: Effect of strong wildfire emissions in Siberia in 2003 compared to 2005. Shown are total column carbon monoxide concentrations on the top and total aerosol optical depth at the bottom, both for July 2003 and July 2005

While a reanalysis tries to account for the various error sources as carefully as possible, it is difficult to provide clear uncertainties on the final product. Therefore, it is crucial to validate the results with independent reliable observations. Ground-based observations have an advantage here, because they are easier to calibrate against laboratory standards than satellite data. **Figure 3** shows an example of the validation that MACC carries out. Shown is the root-mean-square error of aerosol optical depth (AOD) for the GEMS (F026) and MACC (FBOV) reanalyses as well as a run without data assimilation (EXLZ) relative to independent observations from the AERONET network. It is clear that both reanalyses, which assimilate observations from the MODIS instrument, improve over the experiment without data. Also, the RMS error is small (less than 0.1) compared to absolute values which can go up to 3 or higher (see for instance **Figure 1**).

Figures showing monthly mean distributions of the key gases are available on the MACC web site (http://www.gmes-atmosphere.eu/services/gac/reanalysis/) and the underlying data are available from the MACC data server (http://www.gmes-atmosphere.eu/data/).

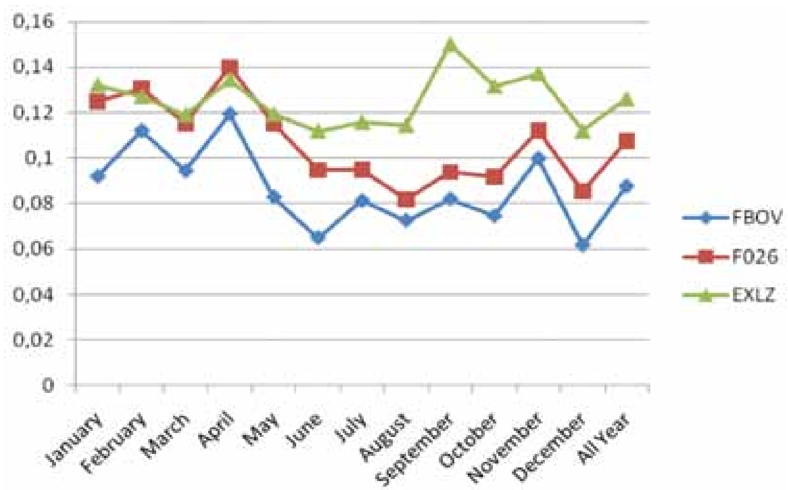

Figure 3: Validation in terms of root-mean-square error of the GEMS (red) and MACC (blue) aerosol optical depth results against independent observations from the AERONET network. Also shown are the results from a model simulation without data assimilation (green)

CONCLUSION

One of the key components of the MACC Global Services is an 8-year reanalysis of atmospheric composition. The MACC reanalysis is a good example of collaboration within Europe with many MACC partner institutes involved. Experience in assimilating huge amounts of observations is combined with experience in accurately simulating atmospheric transport and chemistry; experience in estimating surface emissions and natural sources and sinks is combined with experience in validating large data sets. This way, a well-documented and consistent data set is being generated that will be very useful for various user communities.

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MACC

Quantitative simulation of Eyjafjallajökull 2010 eruptive matter dispersal

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ABSTRACT

The eruption of the Eyjafjallajökull volcano on Iceland from April 14-May 23, 2010 demonstrated the need for skilful simulation and forecast of emitted constituents. In the frame of GMES (Global Monitoring for Environment and Security) activities, the simulation of dispersion of volcanic emissions is a typical, yet extremely challenging task. On the one hand, comprehensive limited area chemistry transport models like those engaged in MACC are theoretically best suited to simulate the transport, dispersion, chemical transformations, particulate matter modifications, and sedimentation of volcanic gas phase and fine particle emissions. On the other hand, the extremely poor predictability of eruptions with respect to time, height distribution, composition, and duration renders the problem as a very special, far from being solved challenge. In addition, special requirements are invoked by aviation security. During the first days of the Eyjafjallajökull eruption, London VAAC (Volcanic Ash Advisory Centre) model simulations have been the basis of flight ban decisions on a zero tolerance basis. Models from other VAACs and various R&D models across Europe were set up to provide further simulations. However, experiences of the last months demonstrate, that there is a substantial lack of combining sophisticated atmospheric chemistry and particle modelling capacities with the wealth of new earth observation data for improved eruption plume dispersion predictions. Reliable information for the declaration of flight ban areas of possibly different levels of severity could hardly be achieved due to the lack of quantitative information of measurements.

The present paper presents the results of a first quantitative simulation of the Eyjafjallajökull emission dispersal, seeks to identify weaknesses, and proposes actions, to achieve substantial progress from combining existing developments, hoping to achieve better volcanic ash cloud forecasting infrastructure. In this study the underlying model is the EURopean Air pollution Dispersion-Inverse Model (EURAD-IM), developed and operated at the University of Cologne and also operated at ECMWF, University of Aveiro, and Research Centre Jülich.

The experiences with adapting the system and application indicate that even sophisticated and comprehensive Eulerian reactive chemistry and aerosol models can be quickly adapted to simulate volcanic emission dispersion. The main weaknesses for getting better simulation skills emerge from a crucial lack of knowledge on the variability of emission heights and plume composition in terms of particle diameter spectrum, its composition, and exhausted gases. The results indicate, that the EURAD-IM, as many other models, was able to simulate the horizontal distribution of the ash plume quite skilfully, also visible upon comparison with satellite data. In addition, while many models were unable to demonstrate a useful vertical positioning of the ash cloud, it could be shown that with available information a satisfying degree of compliance with lidar data, especially with the ceilometer data from DWD, could be achieved. Quantitative information was available by in-situ data, first obtained from the Zugspitze (German Alps) observatories. With available particle number and SO_2 concentration levels, the EURAD-IM simulation could be scaled and good compliance was achieved. In summary, it turned out that in-situ and lidar and ceilometer information was most valuable. The application of satellite data is strongly dependent on the viewing characteristics: atmospheric column information from space-borne sensors need completion by height information. The optimal combination of instruments still needs to be identified, and will be different for different types of volcanic eruption parameters.

WORK PROGRAMME, METHODOLOGY, MILESTONES

Special events like biomass burning, mineral dust outbreaks, and, most erratically, volcanic emissions are difficult to simulate. Yet, they are an important objective of GMES activities. While the former two processes are introduced to the MACC system, eruption simulations and forecasts of the dispersion of volcanic gases and aerosols are typically beyond the scope of operational systems.

The present paper describes the simulation set up at RIU shortly after the outbreak on April 14th, 2010, and measure taken to satisfy the need for quantitative simulations. The EURAD-IM as underlying model is run with 15 km horizontal resolution as its standard configuration in MACC. The European continental scale model EURAD-IM, displayed ash plume simulations for over a month. This model proved to be easily adapted to volcanic ash and gas eruption modelling, including full gas phase chemistry, aqueous phase chemistry, as well as aerosol dynamics and chemical formation, dry and wet removal, and cloud interactions. For variational inverse modelling, adjoint components of principal process modules are available and applied for source strengths inversion with air quality conditions (Elbern et al., 2007). It is clearly desirable for ash quantification to determine/distinguish, which fraction of remotely sensed aerosol is secondary inorganic. This, however, requires an observing network, which is usually unavailable apart from well furnished flight missions. Due to a coupling with a meteorological model (MM5 or WRF), consistent vertical winds are available. A remarkable coincidence between modelled and lidar observed height levels could be demonstrated. After in-situ observations were available from GAW Zugspitze observatory, quantitative simulations could be provided.

Further details of the system set-up are as follows: The forecast of position and extension of the volcanic ash plume of London VAAC includes an estimate of the plume height. This information was updated every six hours. Further informations about changes of plume height were published by the Iceland Meteorological Office (IMO) in its status report regarding the progress of the Eyjafjalla eruption. Both information sources have been used for our volcanic ash dispersion forecast to achieve an estimate of eruption height reflecting the current conditions as accurate as possible.

A numerical model of one-dimensional homogeneous volcanic plumes (Plumeria, Mastin (2007)) has been used for a first estimate of eruption rates. Taking into account a vent height of 1660 m, a vent diameter of 50 m, and plume height of 9.5 km, the model estimates an eruption rate of about 2.5·105 kg/s. We have assumed that about 99% of the erupted matter is rapidly deposited in the vicinity of the volcano, so that the initial eruption rate of total particulate matter has been set to 2.5·103 kg/s. This eruption rate has been scaled during the continuation of eruption according to plume height estimations published by VAAC or IMO.

The erupted volcanic ash is vertically distributed over all model layers between vent and top of plume. In doing so, 70% of the erupted matter is assigned to the upper half of vertical plume extent. We have assigned 90% and 10% of erupted matter to the coarse particle and accumulation mode, respectively.

PARTNERSHIPS AND COLLABORATIONS

The present work is mainly performed as a partnership between RIU and the German weather Service, but about to be extended to further lidar groups and flight mission participants. The in situ data from Zugspitze proved to be of high value, allowing to scale the simulation and to introduce quantitative data. This must be expanded to other in-situ observations as additional data basis. Since injection height information is of critical uncertainty, any observation of ash plume heights is highly valuable. Lidar data, despite being very sparse, is therefore of special importance. The ceilometer network of DWD serves this need, as a main branch of the ash plume reached continental Europe at the German coast. Spaceborne lidar by calypso may complement the height information, as do flight missions from various countries. Data of nadir looking satellite instruments could mainly confirm the horizontal position

of high concentration distribution, while little information can be gained for the vertical position. Remote sensing based information of concentration levels is critical as well, as model based a priori information is less reliable, due to the exceptional nature of volcanic emissions.

ACHIEVED RESULTS

In this study the first week (April 14 to 22, 2010) of the eruption was simulated, which covers roughly the time span of the flight ban over Europe. During this time the ash plume was observed and simulated to arrive at northern Germany at 16^{th} and descended continuously on its way southbound. The southern German ceilometer station Klippeneck displays this situation in Fig. 1 (left), showing the descend of the ash plume from 4 km height at 17^{th} midnight down to boundary layer height of 2 km, and ensuing boundary layer mixing at about 18:00 UTC. The corresponding EURAD-IM simulation is given in the right panel, demonstrating an excellent agreement with the ceilometer data.

The ash plume reaches the Alps at the same date, while splitting east and west bound.

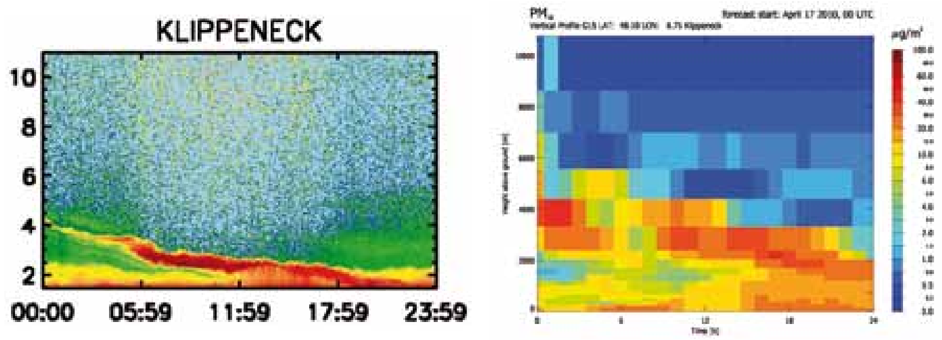

Figure 1: Observed DWD ceilometer reflectances for station Klippeneck (left panel) and corresponding simulated PM_{10} concentrations (right panel) for April 17, 2010. Time axes are given in UTC. Colour scale of ceilometer gives relative reflectances only. Model results are given in $\mu g/m^3$

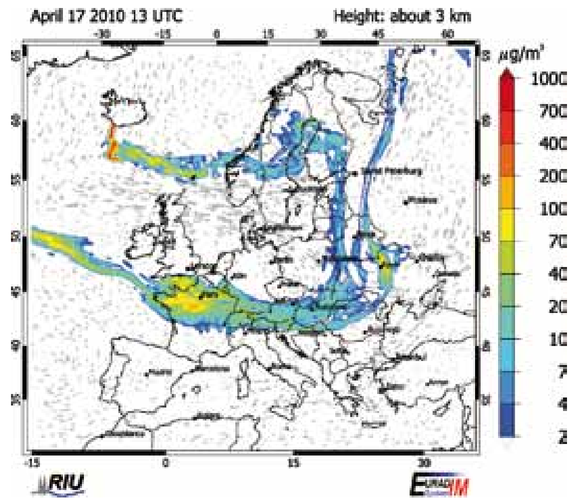

Figure 2: Dispersal of Eyjafjalla volcanic matter 3 km above surface for April 17, 2010, 13:00 UTC

This situation is displayed in Fig. 2. After an anticyclonic recirculation over France, parts of the original ash cloud had a second encounter with the central Alps at 19th. The absolute values of the volcanic emission rates have been scaled upon comparison with in-situ data, starting from the Plumeria model estimates. The scaling station is situated on mount Zugspitze (47°25' N, 10°59' E) at an altitude of 2650 m above sea level. After scaling, the final result is given in Fig. 3. With the arrival of the ash cloud at April 17th, 2010, at approximately 9 UTC the PM_{10} values at Schneefernerhaus, Zugspitze, increase rapidly for both, modelled and observed concentrations. Also, the decrease after the second filament encounter of ashes passed the station on April 19th is represented very well by the model. In summary, the model skill is surprisingly high, given the poor knowledge of the initial volcanic emission parameters.

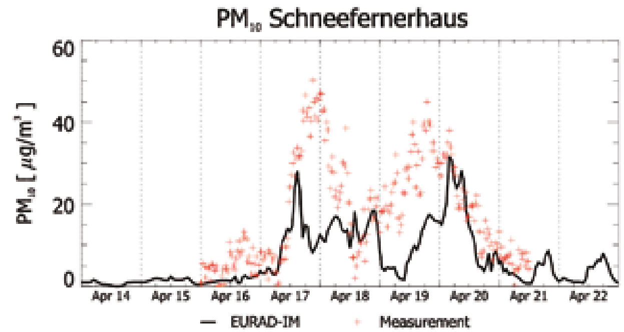

Figure 3: Comparison of model results (black line) and PM_{10} observations (red crosses) at Schneefernerhaus on Mount Zugspitze, from April 14 to 22, 2010. Courtesy S. Gilge (DWD)

CONCLUSION

Experiences so far gained from our simulations can be comprised as follows:

> Need for eruption profile and composition.

> From the volcanic emission source, the most important information is needed by the temporally varying emission height profile. Further, the plume composition is requested in terms of particle size distribution and particle composition. SO_2 and other trace gas concentrations are further needed to calculate the contribution of secondary components.

> Estimates of the needed volcanic plume characteristics will always be uncertain enough to look for additional information further downstream of the injection location. The exploitation of further observations of the ash plume is therefore mandatory.

Need for early assessment of small particles:

> Nevertheless, observations as close as possible to the eruption site allow for a longer and better forecast for areas downstream. Already at this point it is of special importance to learn about the mass and height levels of ash particles with sedimentation velocities which are small enough for medium and long distance transport. In the aerosol community parlance, coarse mode and accumulation mode particles are of key importance, after fallout of larger particles, which are only of local interest.

ATMOSPHERE MONITORING

Need for comprehensive models and observational data:

> Today's remote sensing retrievals are rarely able to identify aerosol size and composition unambiguously. However, the discrimination of volcanic ash from other particles like sulphate or other water soluble particles, evolving from co-emitted gas phase precursors, is vital for identifying reasonably small flight ban areas.

> Advanced chemistry transport models (CTMs) include a rich variety of processes, many of which are concerned with atmosphere surface interactions. Nevertheless, for future applications, sophisticated modules for aerosol modelling are required to simulate all relevant aerosol processes. These include simple sedimentation, but also aerosol dynamics, that is the interaction and accretion of aerosols of different sizes and formation of secondary aerosols from emitted gas phase precursors. For the better interpretation of remote sensing data, interaction processes with clouds, most prominently wet removal, but also vertical redistribution, and aqueous phase chemistry must be included in the modelling.

> It must be stated, that volcanic ash cloud forecast models are not furnished with a sophisticated data assimilation system as meteorological forecast models are. This is mainly due to two specific characteristics:

1. Ash cloud simulations are predominantly driven by the volcanic emission source, which is hard to estimate quantitatively, and
2. Observations of the transported ash cloud are provided as provide mostly remote sensing data.

> Both characteristics pose a combined numerical optimisation problem of source inversion and chemical data assimilation, a discipline, which only recently gained some attention in the realm of GMES (Global Monitoring and Environmental Security).

Need for data assimilation:

> Basically, advanced data assimilation systems can be adapted to make all relevant information of observing systems available for forecast improvements. Of primary importance are those systems which are able to give information about plume height and mass concentrations. To reliably determine the latter quantity is an especially difficult task for remote sensing retrievals. Therefore, near source airborne in-situ measurements (say < 400 km distance) are of special value, as they allow to scale emission estimates by absolute values at an early stage of transport, with larger particles already deposited. Ash layer height assimilation can be achieved by MISR and CALIPSO, if cloud cover and orbital position allow. Ground and aircraft based lidars are of special value, as they continuously record height levels. Indirect height levels can also be achieved by total column or AOD satellite retrievals (e.g. OMI, SEVIRI), which ideally combine with lidars.

> Data assimilation is therefore the appropriate method to combine different remote sensing measurement geometries and principles. Observation operators of all useful instruments and their adjoint should be made available. Clearly, efforts must be made to make all data available in near real time.

> A special aspect of this assimilation strategy is to perceive, that ash cloud and probably SO_2 or sulphate concentrations analyses can not only be used as initial values for a subsequent forecast, but also for an emission source inversion. Improved emission source estimates provide a special benefit for better forecasts, although the starting point is more in the past. The full problem to be solved is therefore a combined inversion-data assimilation task.

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MACC

The MACC stratospheric ozone service

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ABSTRACT

MACC - Monitoring Atmospheric Composition and Climate - is the current pre-operational atmospheric service of the European GMES programme. MACC provides information services covering European Air Quality, Global Atmospheric Composition, Climate, and UV and Solar Energy. One of the services provided by MACC is the stratospheric ozone service. The service combines state-of-the-art stratospheric chemistry and meteorology modelling with Earth observation data of ozone and other constituents relevant for the ozone layer by means of data assimilation techniques. This results in real-time analyses and forecasts of the stratospheric ozone concentrations. Retrospective analyses are produced from 2003 for the three-dimensional distribution of ozone and related species, and for the 30-year period 1979-2008 for the total column amount of ozone. These detailed datasets provide important information for scientific studies, for the public and policy makers, and assessments like the WMO/UNEP Scientific Assessment of Ozone Depletion (WMO, 2007) and Antarctic ozone bulletins (WMO, 2010).

WORK PROGRAMME, METHODOLOGY, MILESTONES

The stratosphere is the atmospheric layer between 15 and 35 km altitude which contains large amounts of ozone that protects us from harmful ultraviolet radiation. In 1984 a rapid decline of ozone over Antarctica - the ozone hole - was discovered, and man-made chlorofluorocarbons (CFCs) were identified as the reason for the ozone loss. The Montreal Protocol was introduced which drastically reduced the production of CFCs, and a recovery of the ozone layer is foreseen this century. However, dedicated monitoring/analyses systems are still needed to quantify the recovery in the coming decades. MACC (http://www.gmes-atmosphere.eu/; Hollingsworth et al., 2008) is one of the major projects to provide such detailed analyses.

MACC combines the information from several dedicated stratospheric chemistry models and data assimilation systems. These are:

> The ECMWF weather model (IFS) coupled to the MOZART and TM5 chemistry-transport models (Flemming et al., 2009; contribution from Jülich, KNMI and ECMWF).

> The BASCOE 4D-Var system (Errera et al., 2008; contribution from BIRA-IASB).

> The SACADA 4D-Var system (Elbern et al., 2010; contribution from DLR in collaboration with University of Cologne).

> The ozone column analysis system based on the TM model (van der A et al., 2010; contribution from KNMI).

The stratospheric ozone service (http://macc.aeronomie.be/) provides:

> Real time analyses of the ozone layer, based on the latest real-time satellite data.

> Forecasts of the ozone distribution.

> A re-analysis of atmospheric composition and ozone starting in 2003 (including data from the ENVISAT and EOS-Aura satellites).

> A multi-sensor re-analysis of the total column ozone, from 1979-2008.

Below we will highlight a few results from the stratospheric ozone service.

ACHIEVED RESULTS

Data assimilation is a powerful tool to combine our knowledge of atmospheric processes with the available measurements. Figure 1 shows an example of a monthly averaged ozone profile (partial pressure in mPa) for October 2008. Clearly visible is the ozone destruction between 30 and 200 hPa. This is not well described by the model alone (orange), but with the information from satellite sensors assimilated (blue), the analysis becomes very close to the independent ozone sonde in-situ observations (red) from Neumayer Station in Antarctica (Flemming et al, 2010; Inness et al., 2009). Included in this analysis is data from the Microwave Limb Sounder (MLS), the Ozone Monitoring Instrument (OMI), the Solar Backscattering Ultraviolet radiometer (SBUV-2) and the SCanning Imaging Absorption spectroMeter for Atmospheric CartograpHY (SCIAMACHY) satellite instruments.

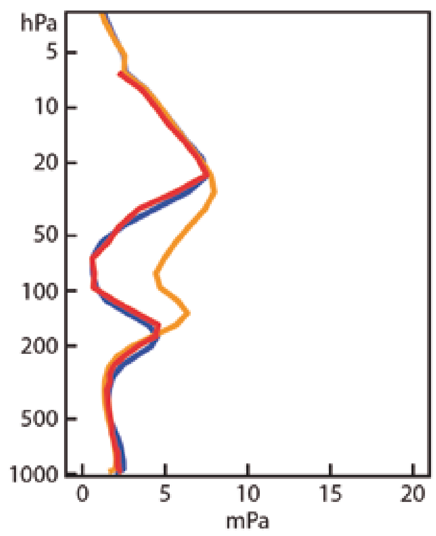

Figure 1: monthly averaged ozone profile (partial pressure in mPa) for October 2008

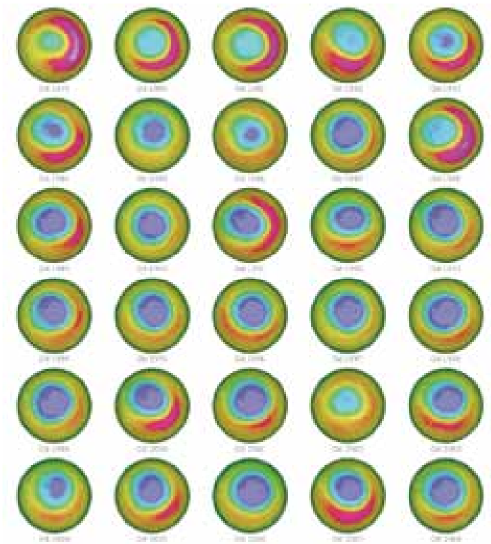

Figure 2: mean column amount of ozone in southern hemisphere, October, for all 30 years

A coherent total ozone dataset for the period 1979 to 2008 has been created from the available ozone column data measured by polar-orbiting satellites over the last thirty years (van der A et al., 2010). One prominent example drawn from this dataset is the mean column amount of ozone in the Southern Hemisphere in October for all 30 years, shown in figure 2. The appearance and deepening of the ozone hole during the 1980s is clearly visible.

Fourteen total ozone satellite retrieval datasets from the instruments TOMS (on the satellites Nimbus-7 and Earth Probe), SBUV (Nimbus-7, NOAA-9, NOAA-11 and NOAA-16), GOME (ERS-2), SCIAMACHY (Envisat), OMI (EOS-Aura), and GOME-2 (Metop-A) have been used in the 30-year analysis. The approach consists of two steps:

> A bias correction scheme is applied to all satellite retrieval datasets, using independent ground-based total ozone data from the World Ozone and Ultraviolet Data Center as reference. With these corrections spurious trends are removed from the individual datasets, bringing them well in line with each other.

> Data assimilation is applied to create a global dataset of total ozone analyses. A chemistry-transport model provides a detailed description of (stratospheric) transport and uses parameterisations for gas-phase and ozone hole chemistry. The multi-sensor dataset results from a 30-year data assimilation run with this model and with the 14 corrected satellite datasets as input, and is available on a grid of 1×1½ degree, four times each day, for the complete time period (1978–2008).

This multi-sensor total ozone dataset is available for trend studies as well as detailed analysis of past events. It is a source of information for research, assessments as well as education.

As a second example of the products provided by the stratospheric ozone service we will discuss the development of last year's ozone hole (WMO, 2010).

In 2010 the onset of the ozone destruction in the ozone layer over Antarctica only started to become visible during September, whereas under normal conditions the first signs already become visible about halfway through August. The MACC analysis based on observations by the SCIAMACHY instrument on the ENVISAT satellite show that the amount of ozone decreased steadily towards October, but the destruction continued to lag behind that of previous five years (see figure 3). At the beginning of October the amount of ozone destruction was still 40-60% less than in a typical year.

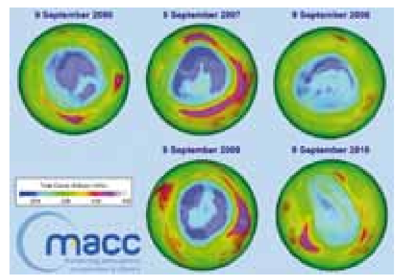

Figure 3: ozone hole over Antarctica of years 2006 to 2010

Such a large change in ozone observed in 2010 cannot be attributed to the slow decrease of stratospheric chlorine of 0.5-1% per year, but turns out to be caused by unusual meteorological conditions. In July and August 2010 a phenomenon known as a Sudden Stratospheric Warming occurred in the stratosphere above Antarctica: a sudden fast warming in the ozone layer. From historical satellite observations we know that Sudden Stratospheric Warmings have occurred before. In 2002 there was a particularly large warming that caused the ozone hole to split and disappear already in September. In 1988 there was a sudden stratospheric warming in July and August comparable to 2010. Small temperature increases

ATMOSPHERE MONITORING

in the Antarctic stratosphere in July and August of only a few degrees do have a large impact and may lead to a significant decrease of the destruction of ozone as observed. Such events therefore cause a large variability in ozone concentrations and complicate efforts to determine if the expected ozone hole recovery has started.

In October the situation changed and the ozone loss became more comparable to previous years. Ozone destruction usually ceases in October after which the ozone hole starts to fill up in November, early December. The 2010 ozone hole was very persistent and a large area of ozone destruction was observed until mid December. This is demonstrated in figure 4, which shows the area with little ozone (ozone column amount less than 220 Dobson units).

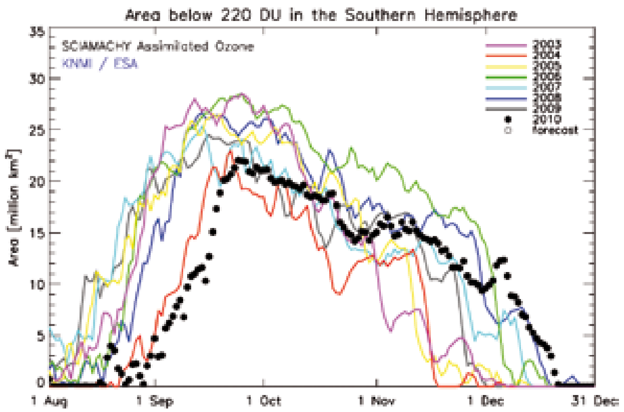

Figure 4: highlighted area of little ozone, less than 220 Dobson units

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CARBONES

A re-analysis of carbon fluxes and pools over Europe and the globe

Creating a carbon baseline

Pascal Prunet, Andrzej Klonecki, Cédric Bacour

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ABSTRACT

The increasing atmospheric concentration of greenhouse gases is the main driver of the ongoing climate changes. Since the beginning of the industrial revolution, CO_2 concentrations have increased by 30%, N_2O by 20% and CH_4 by 300%. These changes are caused by human activities, especially through fossil fuel combustion and modifications of global vegetation related to land-use change. The fossil fuel emissions are still increasing, as a result of the very rapid increase of economic activities, in particular in developing nations such as China. This increase is larger than the most pessimistic GIEC scenarios. On average, only half of the CO_2 from anthropogenic emissions has remained in the atmosphere until now. The land and oceans have sequestered the other half, in approximately equal proportions. However, the apportionment of carbon fluxes between ocean and land varies in time and space, and continental sources are particularly heterogeneous.

The present quantification of CO_2 sources and sinks, as adopted by governments and institutions through Kyoto protocol negotiations, is based on inventories of forest biomass and on energetic statistics. This pragmatic quantification is too simple to correctly represent the atmospheric signatures of CO_2 variability. The inventories allow estimating the fluxes only at decadal time scales, and are not adapted to detect rapid changes, to characterize ecosystem vulnerability, or to implement an appropriate management of carbon stocks and CO_2 fluxes. Furthermore, most ecosystems are not covered by the inventories, which are plagued by serious measurement and sampling biases. As a result, there is now a strong need for detailed information of CO_2 fluxes and carbon pools, under the form of well resolved maps and their variabilities. This need is expressed both by the members of the climate modelling community who want to understand and quantify the carbon cycles at global and regional scales, and also by policy makers and citizens who want to make well-informed decisions on CO_2 emissions at regional and local scales. Accurate measurement of regional CO_2 fluxes is identified in the GEO (Group on Earth Observation) 2009-2011 work plan as an essential climate variable.

Indeed, information on CO_2 fluxes and variabilities at regional scale is fundamental for the validation of Earth system and climate models in order to:

> Have realistic flux estimates for model benchmarking.

> Improve the modelling of ecosystem water and energy balance.

> Evaluate the impact of extreme events on CO_2 fluxes and ecosystem adaptation to climate change.

> Detect "hot spots", i.e. vulnerable regions of the carbon cycle and of the climate system (permafrost, tropical forests, gas hydrates) which may release significant amounts of CO_2 in the future.

A novel approach for quantifying and understanding CO_2 surface fluxes is proposed in this project by developing a Carbon Cycle Service called CARBONES. CARBONES is a global information system that addresses the quantification and understanding of the global distribution of CO_2 fluxes, carbon pools and underlying processes, in a comprehensive and accurate way. It benefits from in situ data infrastructures (ICOS, FLUXNET, global CO_2 networks, biomass and soil inventories) as well as space-based information of land and oceanic surfaces biophysical properties and atmospheric composition. CARBONES will deliver the first ever consistent, high spatial- and temporal-resolution information on the state of the Carbon Cycle, with associated uncertainties and attribution to controlling processes.

METHODOLOGY

The CARBONES re-analysis system is based on a pivotal triad of advanced process-based models of the carbon cycle: in the atmosphere (LMDz General Circulation Transport Model), in the land ecosystems (ORCHIDEE biosphere model) and in the oceans (PISCES ecosystem and carbon-cycle ocean model). These models, which describe the complex biological, chemical and physical processes which regulate the exchange of CO_2 over each point of the globe, are optimized with the help of a full-fledged 4D-var assimilation system (see Figure 1 for schematic representation) by using long-term *in situ* and satellite observations. Four "observation pillars" are used to constrain the 20-year reanalysis of the carbon cycle:

1) Long-term satellite monitoring of ocean colour and land greenness, measuring respectively phytoplankton and vegetation activity.

2) Eddy covariance networks with online measurements of CO_2, heat and water fluxes.

3) Long-term air-sea flux shipboard and fixed stations records.

4) Atmospheric CO_2 concentration networks.

In addition, the CARBONES service uses as an input gridded climate and weather data, as well as land cover and vegetation maps.

The key output of CARBONES will be a calibrated 20-year re-analysis of spatial and temporal variations of carbon fluxes and pools over the globe. Such a product, which does not exists at present, meets the strong demand from IPCC climate modellers for testing and improving their simulations of the future evolution of the coupled climate-carbon cycle system.

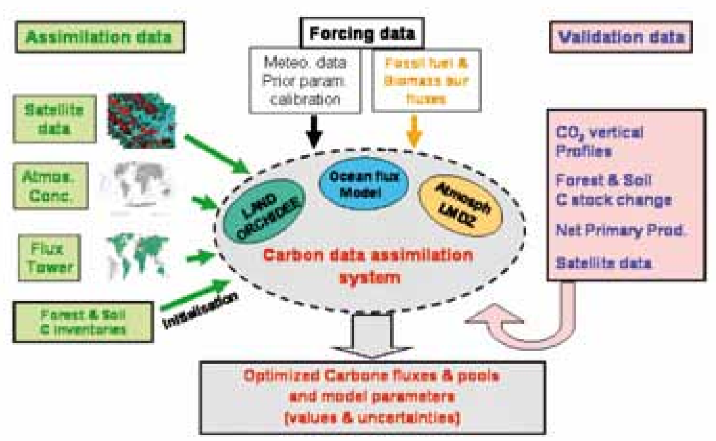

Figure 1: Schematic view of the carbon cycle data assimilation system.

Special emphasis is placed on evaluating the carbon fluxes and pools over Europe and the North Atlantic, by taking advantage of the wealth of carbon observations recently collected by EU funded projects, such as CARBOEUROPE and CARBOOCEAN. The combination of these data sets with process-based atmospheric, land and ocean models will allow us to obtain fluxes at the high spatial (50-100 km) and temporal (3-hourly) resolutions necessary to capture details and rapid changes in the carbon cycles at regional and local scales. Moreover, the system also integrates tropical deforestation fluxes and global fire emissions data as well as the very high-resolution anthropogenic emission inventories over Europe, and moderate-resolution inventories over the rest of the globe.

PARTNERSHIPS AND COLLABORATIONS

The following organisations constitute the CARBONES consortium:

> NOVELTIS (Coordinator), SME, France

> Commissariat à l'Energie Atomique (CEA)- Laboratoire des Sciences du Climat et de l'Environnement (LSCE), France

> Thales Alenia Space, France

> CLIMMOD, SME, France

> Met Office, UK

> University of Stuttgart, Germany

> Max Planck Institute for Biochemistry, Jena, Germany

> ALTERRA- Dienst Landbouwkundig Onderzoek, the Netherlands

> Cambridge Environmental Research Consultants (CERC), UK

> Atomic Energy Authority Technology (AEAT), UK

> Federal Institute of Technology (ETH), Zurich, Switzerland

> University of Aberdeen, UK

> Peking University, China

> European Forest Institute (EFI), Finland

In order to provide an integrated view of the Carbon cycle, CARBONES collaborates with existing FP7 projects by adopting a consistent integration of space-based information on CO_2 atmospheric composition (MACC), land surface biophysical state (GEOLAND) and ocean bio-geochemical and dynamic state (MYOCEAN).

The regularly updated surface fluxes dataset (and related information on pools and processes) provided by CARBONES will also be of significant added-value for core service information, and can be used as to capitalise on the carbon-cycle-related aspects of the Core Services for calibration and improvement of the Earth system and climate-coupled models.

PROJECT OBJECTIVES

CARBONES aims to provide a calibrated 20-year re-analysis of space and time variations of carbon fluxes and pools over the Globe, consistent with all available *in situ* and satellite data. It will provide significant added value to GMES Core Services with respect to climate users needs. The CARBONES products will be tailored to be used by the IPCC climate modellers for testing and improving their simulations of the future evolution of the coupled climate-carbon cycle system.

The CARBONES project also addresses the following complementary key objectives:

1. Interfacing with and integrating Cores Service data, in order to provide:
    - > Closure of the carbon cycle by coupling slow pool changes and fast flux changes.
    - > Independent benchmarking of core service data and methods using *in situ* derived global carbon cycle products.
    - > Value added to core service data.
    - > Attribution of carbon cycle changes to processes in relation to climate change.
    - > Integration of relevant ocean-land-atmosphere core service data into a single, coherent carbon-cycle analysis.
2. Interfacing with and adapting existing Carbon Cycle in-situ data infrastructures.
3. Implementing state-of-the-art process-based models and assimilation methods through the integration of the CARBONES information system.
4. Developing an interactive visualisation/mapping interface of the carbon cycle, designed to meet Climate Modellers needs and dedicated for experimentations.
5. Developing tools and analyses for the specification of future satellite missions (MTG, post EPS, etc.) related to Carbon Cycle monitoring.
6. Generating a 20-year re-analysis of carbon fluxes and pool maps using available in situ and satellite data.
7. Regularly updating the carbon fluxes and pool products by using available Core Service data.
8. Validating the CARBONES information system against existing European fluxes monitoring programmes.
9. Analysing user needs and potential downstream applications: exchanges with climate modelling groups for product definition and service design, identification of possible downstream services and institutional/commercial end-users of a CARBONES operational service.

The CARBONES data products and diagnostics will be made publicly available through a tailored user-friendly web interface, allowing climate modellers, other science communities and the general public to understand and easily visualize the living carbon cycle over the past 20 years. With new information and methodological developments regularly being available in particular through the MACC, GEOLAND and MYOCEAN Core Services, towards the end of the project, a regular 3-monthly update of carbon fluxes and pools will be applied to the CARBONES system. As such, the CARBONES service will lay the foundation of a future global operational verification system of CO_2 fluxes.

CONCLUSION

The CARBON Environmental Service (CARBONES) will provide the first multi-decadal reanalysis of the global carbon cycle and a service to provide a rolling update of this analysis. This service will include the "essential climate variables" (defined by the Global Climate Observing System) of atmospheric carbon dioxide, leaf area and biomass in various categories. This reanalysis will combine the primary long-term observations of the terrestrial and oceanic carbon-cycles (atmospheric concentrations, remotely-sensed land surface and ocean characteristics and in situ ecological measurements) using data assimilation techniques. Moreover, the CARBONES service will provide a well-founded baseline for predicting future responses of the carbon-cycle to climate change. It will also act as a benchmark during the period of overlap for services such as the Atmospheric and Land Service. The primary users for the reanalysis are climate modellers who need an initial condition for their predictions and, for the same reason, scientific groups calculating changes in carbon stocks. Thus a benefit will be an independent global check on reporting of carbon inventories for the United Nations Framework on Climate Change.

Access to the results of the CARBONES reanalysis will be provided by a flexible and user-friendly web-interface. The techniques used for the reanalysis will also be used, in conjunction with the core services, to provide a rolling update on the state of the carbon cycle. This possibility will evolve towards an operational, integrated, carbon-cycle monitoring capacity as a potential downstream service.

ATMOSPHERE MONITORING

EURO4M

European reanalysis and observations for monitoring

Tracking changes in the European Climate

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ABSTRACT

The EURO4M (European Reanalysis and Observations for Monitoring) project is a 4-year EU research project funded under the Space theme of FP7 and started in April 2010. The overall goal of EURO4M is to develop and deliver the best possible and most complete gridded climate time series and climate-monitoring services covering all of Europe. EURO4M has 4 specific objectives:

> Generate datasets consisting of time series of climate observations and reanalyses of past observational data.

> Produce innovative and integrated high-quality climate data products for research and practical applications.

> Reach out to the user community, stakeholders, policy-makers and the general public with data products and climate services.

> Evolve into a future GMES (Global Monitoring for Environment and Security) service on climate change monitoring that is fully complimentary with and supportive of existing core services.

More detailed information can be found on the project website: http://www.euro4m.eu

WORK PROGRAMME, METHODOLOGY, MILESTONES

The EURO4M project combines observations from satellites, ground-based stations and results from comprehensive model-based regional reanalyses. Climate variability and change can be better understood and predicted using these three building blocks to monitor the European climate.

Surface *in-situ* climate data provide information, often with high precision and temporal resolution. Even in the satellite era, surface observations contain essential information that cannot be provided by other platforms. In the implementation plan of the Global Climate Observing System (GCOS), a number of Essential Climate Variables (ECVs) were defined for the atmospheric, oceanic and terrestrial domains. EURO4M considers those ECVs that form primary input to the GMES services and the societal benefit areas defined by the Group on Earth Observations (GEO). The atmospheric in-situ climate variables EURO4M focuses on are: air temperature, sea surface temperature, precipitation, snow cover, air pressure, surface radiation budget, wind speed and direction and water vapour. Issues such as data archaeology, homogeneity of the records and spatial interpolation are addressed within the project in order to provide reliable and state-of-the-art high-resolution monitoring for Europe.

Within EURO4M, satellite-derived monitoring products are considered in connection with monitoring products derived from surface observations. However, over the oceans and sparsely populated areas, satellite instruments are often the only data source. EURO4M will further develop and integrate the EUMETSAT-SAF (Satellite Application Facility) products and methods for climate monitoring. In this respect, reprocessing of existing satellite products in order to derive homogeneous long-term datasets is an important effort. Synergy exists between EURO4M satellite products and developments related to the ESA Climate Change Initiative. EURO4M will use satellite products to verify the reanalysis datasets, to support satellite inter-calibration activities, and to derive climate indices. Additionally, satellite-based solar irradiance datasets are developed which can be used for the efficient planning and monitoring of solar energy systems (Figure 1).

A reanalysis of past weather can be achieved by combining observational datasets from surface stations, radiosondes (weather balloons) and satellites with a comprehensive Numerical Weather Prediction (NWP) model. The great benefit of using modern data assimilation methods is that it provides a complete picture of the atmosphere, covering the whole of the 3-dimensional domain, including not only the observed variables but also those that are not directly measured.

EURO4M delivers new state-of-the-art regional reanalysis methods and datasets for Europe. Some of these datasets cover most of the last 20 years whereas the potential of other more advanced systems are demonstrated for shorter periods. The spatial resolution of the data assimilation systems and the use of precipitation and surface data will also be improved within the project. In order to further enhance the resolution of the regional reanalyses to the local scale, EURO4M also performs 2-dimensional downscaling. These high-resolution reanalyses employ regional variations given by observational statistics and physiographic factors such as the land-sea mask and orography.

The EURO4M website (http://www.euro4m.eu) provides links to the observation datasets and the reanalyses datasets of several atmospheric Essential Climate Variables (ECVs) which have been developed so far as part of EURO4M. More datasets will become available during the remainder of the project.

PARTNERSHIPS AND COLLABORATIONS

The EURO4M project is a collaborative effort of 9 European partners (see title page for list). Special arrangements have been established with key international organizations, such as the EEA (European Environment Agency), as a prime user of EURO4M data and products. Other links include ECMWF (European Centre for Medium-Range Weather Forecasts), EUMETNET (the network of European meteorological services) and GCOS (Global Climate Observing System).

Within EURO4M, a Climate Liaison Team (CLT) actively solicits user requirements and feedback. Through their mediation, the results of EURO4M feed directly into applications and impact assessments relevant to European societal and community needs. Sustainable links between EURO4M and GMES are established by actively involving GMES core and downstream services, in line with the user-driven objective of GMES. The CLT also trains users in the handling of EURO4M products and services through workshops, e-learning modules, podcasts and user guides covering different skill levels.

SCIENTIFIC AND TECHNOLOGICAL RESULTS

The high-resolution datasets that are produced by the EURO4M project allow us to place observed high-impact weather and extreme events in a long-term historical context. The innovative and tailored products (Figures 1-3) improve climate-change information services for society and support adaptation to a changing environment. Whilst EURO4M provides time series showing the changes in climate over time, the project also allows near real-time reporting during emerging extreme events.

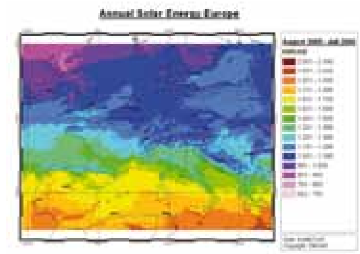

Figure 1: Map of calculated solar energy in a typical year (source: DWD, CM-SAF)

EURO4M products are disseminated through regularly issued Climate Indicator Bulletins (CIBs). These bulletins focus on user groups interested in, for instance, disaster prevention, health, energy, water resources, ecosystems, forestry agriculture, transport, tourism and biodiversity at European, national and local levels. These user groups do not have to access and process the terabytes of raw observation data or reanalysis data. Instead, the CIBs provide them with simple, effective and timely knowledge abstractions from EURO4M data and activities. The bulletins are flexible user-driven products that respond to current environmental and climatic events. The first bulletin will be issued in the first quarter of 2011 and will focus on European temperature.

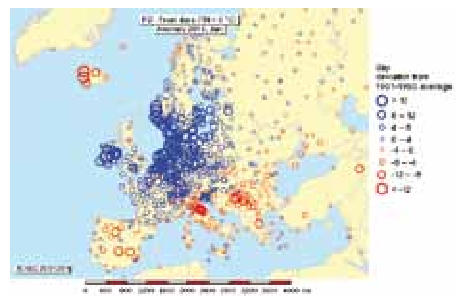

Figure 2: Observed number of frost days in January 2010, when the minimum temperature was below 0°C. Large parts of Central and Western Europe show 10 more frost days in January 2010 compared to the long term average (Source http://eca.knmi.nl)

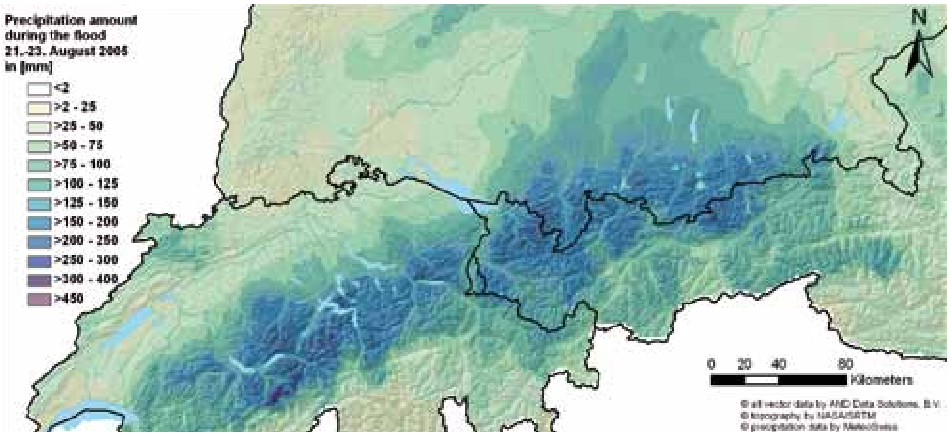

Figure 3: High resolution precipitation map based on observations in August 2005, when more than 150 mm of rain fell within 3 days over parts of Austria, Germany and Switzerland (Source: MeteoSwiss)

CONCLUSION

EURO4M contributes to establishing a data archive of systematic observational data related to the climate system. The climate change time series will be based on the optimal combination of regional observation datasets of Essential Climate Variables (ECVs) and model-based regional reanalysis. A continuous record of ECVs will be developed, coherent with UNFCCC requirements. EURO4M contributes to the consistency of such data, as well as to a sustainable and transparent access to such data for scientific and operational climate communities.

High quality, high-resolution data products from EURO4M will provide the information basis for new generations of research initiatives and wider societal, industrial and environmental user applications. The EURO4M system has the potential to evolve into a future GMES service on climate change monitoring that is fully complimentary to and supportive of the existing operational services.

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ATMOSPHERE MONITORING

MONARCH-A

Monitoring and assessing regional climate change in high latitudes and the Arctic

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ABSTRACT

Climate change can only be understood through improved knowledge of the coupling between the dynamic processes in the atmosphere, the solid Earth, the hydrosphere, the cryosphere, the biosphere and the anthroposphere. These components are interlinked by forcing and feedback mechanisms at a broad range of temporal and spatial scales, and usually with distinct regional characteristics. The Arctic and northern hemisphere high-latitude regions, in particular, are susceptible to climatic and environmental change. Rapid decreases in Arctic Sea ice concentration (Drobot et al., 2008; Johannessen, 2008) and decreases in sea surface carbonate saturation caused by human-produced CO_2 (Orr et al., 2005) are two striking examples. Quantitative uncertainties in changes in high-latitude and Arctic Sea level, permafrost and surface albedo are other examples. The European citizen has a right to know the consequences of such changes for Europe. However, this cannot adequately be provided today. The scientific rationale, uniqueness and timeliness of the MONARCH-A project must be seen in this perspective.

The ultimate goal of MONARCH-A is consequently to generate a dedicated information package tailored to a subset of multidisciplinary Essential Climate Variables (ECVs) and their mutual forcing and feedback mechanisms associated with changes in terrestrial carbon and water fluxes, sea level and ocean circulation and the marine carbon cycle in the high latitude and Arctic regions.

Adopting an Earth-system approach, MONARCH-A will execute systematic provision of tailored information and products to assist climate-change research, and generate and make avaiable reliable, up-to-date scientific input for the definition and implementation of European and international policies and strategies on climate change and society. The information package will be based on generation of time series of observation datasets and reanalyses of past observational data enabling adequate descriptions of the status and evolution of the high-latitude and Arctic region Earth-system components.

WORK PROGRAMME, METHODOLOGY AND MILESTONES

The MONARCH-A approach (Figure 1) will be organized around four main activities, notably: (i) changes in carbon-water interaction, (ii) changes in sea level and ocean circulation, (iii) changes in marine carbon cycle and (iv) synthesis and interaction with the scientific community on climate change research. 11 multidisciplinary Essential Climate Variables (ECVs) relevant for high-latitude and Arctic regions will be generated and made available in the information package. Arranged according to the GCOS ECVs domain they include:

> Terrestrial: river discharge, snow cover, ice sheet mass balance and permafrost.
> Oceanic: sea ice drift and sea ice volume, sea level, current, ocean colour and CO_2 partial pressure.
> Atmospheric: near-surface wind field.

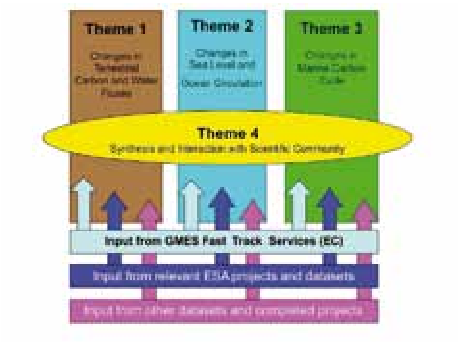

Figure 1: Illustration of project structure with the three (vertical) themes focusing on generating selected multidisciplinary Earth system ECV while the fourth (horizontal) cross-cutting theme will include synthesis and interaction with the user community. Products from major information platforms including the GMES Fast Track Services, ESA relevant projects and data archives and other national and international datasets and projects will be pulled in as marked by the arrows (Copyright MONARCH-A)

Quantifying and reducing the uncertainty in climate predictions is a critical element in IPCC considerations to ensure that society can use the predictions to take informed decisions on mitigation and adaptation strategies. This presents a major challenge in climate modelling and prediction. Quality control of the model fields through regular and consistent validation and inter-comparison against independent observations is therefore mandatory, as is implementation of realistic initial conditions. Cox and Stephenson (2007) have shown that the major element of uncertainty in predictions up to 30 years is the lack of adequate information on initial conditions, i.e. lack of quality observations.

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In order to reduce the uncertainty in climate predictions over such a multi-decadal period, the primary need is for more and better observations, scientific research, feedback mechanisms and process understanding, as also emphasized by IPCC (2007) and Hawkins and Sutton (2009).

PARTNERSHIPS AND COLLABORATIONS

The MONARCH-A project consortium brings together several partners with significant experience and knowledge, as briefly indicated below.

Partner	Expertise, Experience and Knowledge
P1-NERSC	Developing multi-satellite ocean and sea ice remote sensing algorithms. Developing coupled ocean – sea ice models, data assimilation system (TOPAZ) and reanalyses.
P2-USFD	Developing terrestrial carbon and water models, and analyzing satellite data for land-surface processes and exploiting them in Dynamic Vegetation Models. Innovative data assimilation methods in terrestrial carbon and water models.
P3-UHAM	Developing reanalyses in coupled ocean-sea ice models; developing and running ocean and coupled assimilation experiments; analyzing the quality of ocean and climate models; developing the ocean and sea-ice remote sensing algorithm.
P4-CNRS	Applying space techniques to study solid Earth and surface fluid envelopes, large-scale continental hydrology, sea level variations at global and regional scales, gravitational field and temporal gravity variations.
P5-NIERSC	Expertise in understanding the behaviour of aquatic ecosystems in response to global change; bio-optical retrieval algorithms; monitoring of harmful algae bloom events; primary production assessment for ocean and inland waters.
P6-UiB	World-class expertise in analyzing inorganic carbon in the ocean and producing global carbon and other relevant datasets obtained from different measuring platforms. Delivered state of art system for measuring sources and sinks of carbon in the ocean.
P7-DTU	Expertise in the field of geodesy and developing Earth observation methodology for both marine and Arctic GMES services. Strong focus on climate changes in Greenland on sea level, ice-sheet mass balance and sea-ice extent.
P8-IFREMER	The CERSAT repository at IFREMER offers expertise in retrieval algorithm developments, calibration/validation of satellite sensors, data analysis and merging techniques. A fast and flexible reprocessing capability is also being developed.

EXPECTED SCIENTIFIC AND TECHNOLOGICAL RESULTS

As the length of existing ECV data records increases, in some cases now to around 20-30 years, and they gradually become of better quality and accuracy, adequate validation and adaptation to better initialization are becoming feasible. In this context, the expected advanced achievements from the

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Earth-system approach undertaken in MONARCH-A, with its focus on high latitude and Arctic regions, will lead to progress beyond the state-of-the-art. In particular, the generation of refined and consistent multidisciplinary time series of:

> Land: vegetation cover, river discharge and lake levels
> Cryosphere: snow cover, permafrost, ice sheet elevation change, sea ice drift and sea-ice volume
> Ocean: sea level, current and colour
> Atmosphere: near surface wind field and CO_2 partial pressure

integrated with existing complementary information on land cover, fire, sea-ice extent and concentration, sea-ice thickness, sea surface temperature and sea level will provide tailored information and products to assist climate change research to incorporate the refined and consistent ECVs.

For the ocean carbon cycle, satellite observations constrain primary production – through ocean colour and chlorophyll related transfer functions (with the possibility to quantify air-sea gas exchange and detect blooms of specific species), through surface wind-speeds and their variability, sea state/white capping, sea surface temperature and ice cover which influences biological production and gas exchange. It is also hoped that new reliable atmospheric CO_2 column measurements from space (GOSAT) can be obtained, although this will not be possible for the sea surface for which in-situ measurements are required. Furthermore, for the carbon budget, the export production rather than the primary production is critical. Though export production can be roughly estimated from primary production, models need to be used to fully account for a correct quantification of the biological carbon pump.

Through re-analyses, an adequate and consistent description of the status and evolution of high-latitude and Arctic regions will be provided in the context of terrestrial carbon and water fluxes, sea level and the ocean circulation and marine carbon cycle. It will focus on changes over the last 30 - 50 years. This will ensure new scientific input for the definition and implementation of European and international environmental and societal policies, including climate adaptation strategies addressing European, national, regional and local levels. It is therefore expected that the MONARCH-A project will provide important new quantitative scientific knowledge and information consistent with GCOS -107 (2006) to:

> Characterize the state of a subset of dominant multidisciplinary ECVs and their variability in high-latitude and Arctic areas.
> Monitor the forcing of the high-latitude climate system, including natural and anthropogenic contributions, at regional and local scales.
> Support the attribution of the causes of high-latitude climate change.
> Support the prediction of high-latitude climate change.
> Enable advanced understanding of the two-way connections between global and regional climate change.

CONCLUSION

MONARCH-A will contribute to establishing a data archive of systematic observation data related to the climate system, for a continuous record of essential climate variables including river discharges, snow cover, permafrost, ice sheet and glaciers, sea level, current, ocean colour, sea-ice drift, surface wind, and CO_2 partial pressure coherent with UN Framework Convention on Climate Change (UNFCCC) requirements and the ECVs identified in the GCOS 2^{nd} Adequacy Report to UNFCC in 2003. All data and results from the MONARCH-A project will be subject to a sustainable and transparent access for global climate scientific and operational communities. Elements of the achievements may also be relevant for the IPCC AR5.

The outcome form MONARCH-A is also expected to contribute to improving the structure and coordination of entities involved in the processing and delivery of climate change relevant dataset, in order to avoid dispersion and duplication of activities and to pave the way for a sustainable provision compliant with the requirements of climate analysis communities. Project output will also underpin many of the societal benefit areas as defined by GEOSS, in particular:

> Reducing loss of life and property from natural and human-induced disasters.
> Understanding, assessing, predicting, mitigating and adapting to climate variability and change.
> Improving water-resource management through better understanding of the water cycle.
> Improving the management and prediction of terrestrial, coastal and marine ecosystems.

The project may also lead to socio-economic benefits in the following policy areas:

> Europe as a global partner (climate-change adaptation, global environment protection, humanitarian response).
> Preservation and management of natural resources (air quality, marine environment, forest ecosystem management, civil protection).
> Sustainable growth (efficient delivery of public services).

Finally, it is worth underlining that the MONARCH-A project is expected to be highly relevant for the complementary ESA Climate Change Initiative which started in 2010 for a period of 6 years.

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PASODOBLE

Local and Regional Air Quality Services for Europe

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ABSTRACT

There is a profound relationship between human health and air pollution. In Europe, particles in the air are estimated to reduce the lifetime of the average citizen by eight months. Therefore monitoring, assessing and forecasting air pollution is fundamental to increase the quality of life and prosperity.

In the context of Europe's GMES Monitoring system for Environment and Security, PASODOBLE seeks to provide information and support for regions and cities that are affected by air pollution. By combining the capabilities of space-based data, in-situ measurements and modelling, PASODOBLE is developing and demonstrating its services, named Myair, in 4 thematic lines:

> Health community support for hospitals, pharmacies, doctors and people at risk,

> Public forecasting and assessment for regions, cities, tourists and sporting events like the Olympic Games in London 2012,

> Compliance monitoring support on particulate matter for regional environmental agencies,

> Local forecast model evaluation support for local authorities and city bodies.

Building on the achievements of the ESA GMES Service Element PROMOTE, PASODOBLE is currently developing user-driven and sustainable downstream services in more than 30 regions and cities throughout Europe (www.myair-eu.org). From 2010 to 2013 existing user requirements are analysed and improved service designs for new and continued air quality monitoring and forecasting services proposed. The project links global satellite and modeling capacities down to specific local

applications according to user needs. Interacting with over 30 users in 16 countries, multiple cycles of delivery, use and assessment versus requirements are applied.

PASODOBLE works towards a harmonized European framework for sustainable downstream air quality services. By developing a generic and modular service infrastructure, including quality management, it will increase the implementation efficiency for new services in the future. PASODOBLE combines local action and work towards European harmonisation by integrating and promoting best practice tools.

European citizens will benefit from Earth Observation, since Myair services provide a solution to mitigate the harm from air pollution by directly reaching residents who are most vulnerable, allowing them to change their behaviour or to take relief mediation in time. By raising awareness, reducing health costs and diminishing morbidity, it will improve quality of life and sustainability of prosperity.

WORK PROGRAMME, METHODOLOGY, MILESTONES

PASODOBLE means "double step" and this is the philosophy which will be followed (Figure 1): It takes a first generic step from the GMES Core Services, space and in-situ components to the Downstream Service Cluster; and a second generic step from the Downstream Service Cluster to the users and market.

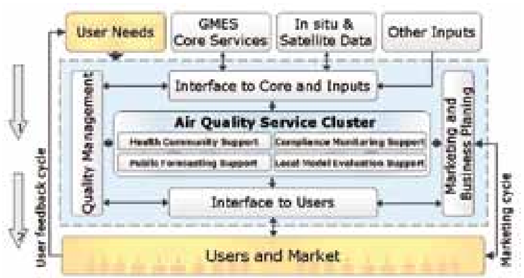

Figure 1: The PASODOBLE project and its relationships within the wider community

PASODOBLE is linking global satellite and modelling capacities down to specific local applications throughout Europe according to user needs. It is combining daily observations from satellite, measurements from ground-based networks and chemical transport modelling by means of data assimilation. Building on the outcome of MACC it is following a nested chain from European down to national, regional and local levels. In order to achieve the final goal of improving the daily live of European citizens it is integrating all relevant data and knowledge together with participating users.

Currently over 30 users from 16 countries in Europe are involved to stipulate their requirements and to assess and evaluate the services in two cycles. The users comprise national, regional and local environmental agencies, city bodies, health actors like hospitals, pharmacies and medical researchers, the tourism industry and sporting event organizers.

PASODOBLE comprises an initial phase of requirement analysis, service design, development and implementation, followed by two full annual demonstration and evaluation cycles in which each service and the generic framework with regard to user needs will be assessed. The research and technical development in PASODOBLE is facilitated and strengthened by two generic interfaces to data inputs and the users and two cross-cutting activities for quality management and marketing and business planning.

Finally, PASODOBLE is also a very passionate dance. Accordingly, it is the challenge for, and the commitment of, the PASODOBLE consortium to analyse and serve the user requirements, to demonstrate the value of the services and the proposed service infrastructure, to assess and develop the markets and to stimulate the development of sustainable and self-supportive services.

PARTNERSHIPS AND COLLABORATIONS

In order to realise the objectives, a significant majority of European key players in the development of user-specific air quality services has joined forces in PASODOBLE. The consortium consists of 22 partners from 13 countries and comprises SMEs, industry and research institutions, key users, experts and networks. This mixture assures both, closeness to the market and commitment to European excellence and added value:

> DLR, Deutsches Zentrum für Luft- und Raumfahrt, DE
> ACRI – ST, FR
> AEA Technology, UK
> AUTH, Aristotle University of Thessaloniki, EL
> BMT - ARGOSS, NL
> IASB, Institut d'Aeronomie Spatiale de Belgique, BE
> BAS, Bulgarian Academy of Sciences, GPhI, BG
> CERC, Cambridge Environmental Research Consultants, UK

- > CGS, Carlo Gavazzi Space, IT
- > CHU, Centre Hospitalier Universitaire Nice, FR
- > MUW, Medical University Vienna, AT
- > EMA, European Medical Association, INT
- > FMI, Finnish Meteorological Institute, FI
- > KNMI, Koninklijk Nederlands Meteorologisch Institut, NL
- > NILU, Norsk Institutt for Luftforskning, NO
- > FRIUUK Rheinisches Institut für Umweltforschung, DE
- > TASF, Thales Alenia Space France, FR
- > TNO, Nederlandse Organisatie v. Toegepast Natuurwetenschappelijk Onderzoek, NL
- > VITO, Vlaamse instelling voor technologisch Onderzoek, BE
- > Nowcasting International, IE
- > Outdoor Concepts, DE
- > RIVM National Institute for Public Health & Environment, NL

PASODOBLE collaborates with established initiatives and boards like the GAS implementation group, the Forum for Air Quality Modelling in Europe (FAIRMODE) and national GMES fora. Compliance with and contribution to INSPIRE and SEIS is also a key element of the project.

EXPECTED SCIENTIFIC AND TECHNOLOGICAL RESULTS

PASODOBLE focuses on regions and cities that are affected by air pollution (Figure 2). Currently user-driven and sustainable Myair services in more than 30 regions and cities throughout Europe are developed combining the capabilities of space-based data, in-situ measurement networks and modelling. Complementary to the GMES Core Atmosphere service (MACC), high resolution modelling up to street level resolution is applied to capture strong gradients of air pollutants where the majority of European citizens live. The main expected achievement will be to improve information for the public, people at risk, tourism and sports, to support the health community and to deliver policy relevant data and advice to local authorities and regional agencies.

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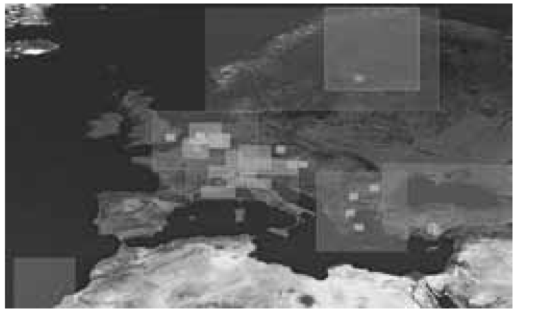

Figure 2: Regions covered by PASODOBLE-Myair Services

Over the past decade epidemiological studies have measured increases in mortality and morbidity associated with air pollution. There is further a profound relationship between well-being and air pollution levels. The health community support services are aiming at packaging existing air quality data to increase its uptake in health care community, developing information products together with the health community, establishing information-dissemination mechanisms to increase support among specialists, and cooperating with local, regional and European users. The services are useful for authorities as well as people at risk to have daily and intuitive information about the levels of air pollution. The developments will offer a solution to mitigating the harm from air pollution by directly reaching residents who are most vulnerable, allowing them to change their behaviour or to take relief mediation in time.

Informing the public on air pollution levels is demanded in the European Air Quality Directive [6]. Therefore a dedicated service line aims at improving existing air quality services. On the one hand it follows a thematic integration of data on air pollutants, meteorology, aero-allergens and UV radiation towards intuitive and understandable indices. On the other hand it follows a region-wise harmonisation of services with respect to state-of-the-art methodologies on nesting and data assimilation, validation protocols, INSPIRE and SEIS compliance and HARMO. Specific services are dedicated to support road traffic management in the Netherlands, harbour management in Antwerp and Rotterdam, tourist navigation and information services in the Black Forest in Germany, and the Olympic Games in London 2012.

A special effort will be made to link the MACC "core" and PASODOBLE "downstream" service components into stable processing chains. Complementary to the GMES Core Atmosphere service and building on the results of the European Model Ensemble, high resolution modelling and monitoring up to street level resolution is applied to capture strong gradients of air pollutants like particulate matter or nitrogen dioxide where the population density is highest. An air quality assessment study for Brussels shows that more than 342 000 citizens were exposed to annual mean nitrogen dioxide concentrations exceeding the European threshold of 40µg/m³ in 2005 (Figure 3). NO_2 is an atmospheric pollutant with adverse health effects which is regulated by the European Air Quality Directive. In order to capture the strong concentration gradients of NO_2, high resolution air quality modelling at 1km*1km as well as high resolution satellite and in-situ observation is needed to accurately estimate human exposure.

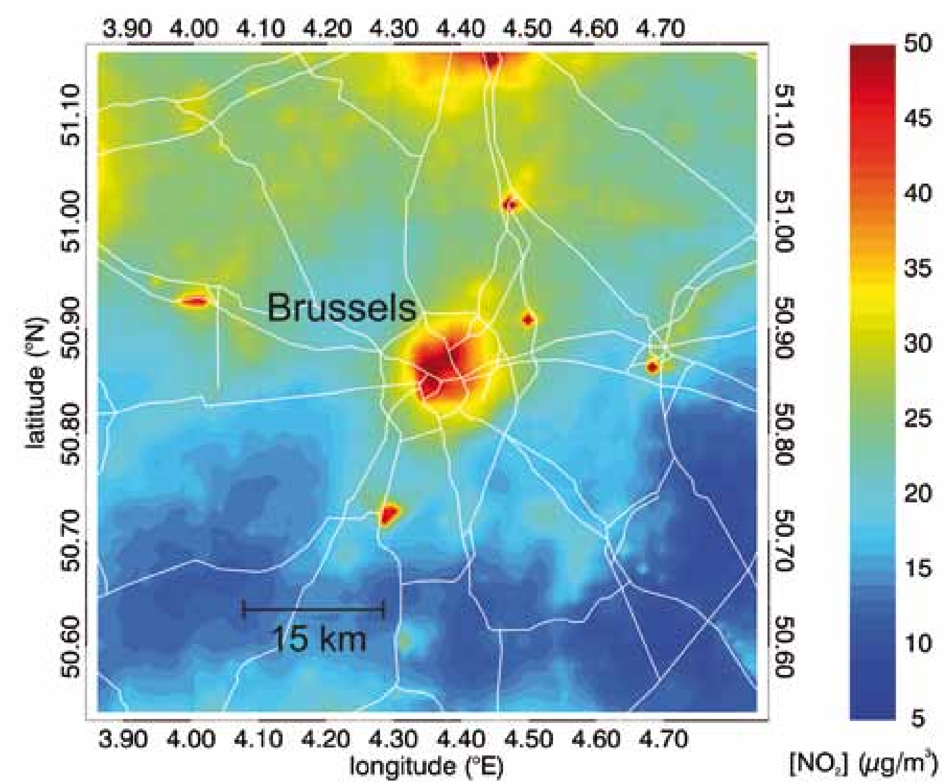

Figure 3: High resolution NO_2 assessment for Brussels and the year 2005

The compliance monitoring service line aims at supporting regional agencies with AQ Directive compliance duties through provision of complementary GMES-based services with regard to particulate matter: Based on various satellite-borne instruments and different retrieval schemes currently a mapping tool for annual exceedance monitoring and spatial forecasting of possible exceedances in the near term is developed. It will allow for a fast quantitative understanding of possible natural explanations (mineral dust) for an exceedance.

Imagine a city that wants to set up an air quality forecasting and public information system to improve quality of life for their citizens. Will they know how to proceed to get an effective and efficient solution which delivers the best objective measures and values? The Local Model Evaluation Service is developing a web-based toolbox as a service in order to set standard criteria and protocols for performance evaluation, to standardize interfaces and to support accountability/apportionment studies. The service will be tested with seven local city authorities. The evaluation of model output utilizes satellite and in situ data and builds on the evaluation methodologies and recommendations of HARMO and FAIRMODE.

Finally an online User Interface is being developed offering modular tools to access and analyse the data of the Downstream Services. It will comprise a state-of-the-art visualisation tool using web coverage, feature and map services with OGC compliance, Google Earth and export functionalities for data and metadata, analysis tools for calculating human exposure and comparisons with in-situ data as well as data fusion tools.

Overarching all specific methodological developments, the project is working on integrating and promoting best practice tools and harmonization approaches for local air quality services. Here it will take into account the directives CAFÉ (Clean Air For Europe), INSPIRE (Infrastructure for Spatial Information in the European Community (INSPIRE) and SEIS (Shared Environmental Information System) and develop and offer tools for automated validation and metadata creation.

CONCLUSION

PASODOBLE aims at developing local and regional air quality services to improve information for the public, people at risk, tourism and sports, to support the health community and to deliver policy relevant data and advice to local authorities and regional agencies. In addition PASODOBLE is developing a generic and modular service infrastructure. By combining local action and work towards a harmonised European infrastructure for local air quality applications, PASODOBLE will facilitate and strengthen the development of quality-assured state-of-the art services and increase the implementation efficiency for new services in the future. Hence it will stimulate the development of downstream services addressing new regions, new cities or additional service providers.

Nearly all European research projects dealing with air quality are currently focussing on continental and regional scales with spatial resolutions less than 10km*10km, which are too coarse to resolve the strong gradients of air pollutants (e.g. NO_2)). PASODOBLE is concentrating on the local and urban scales where the majority of citizens live and deals with spatial resolution up to street level.

One key ingredient to build innovative and successful air quality downstream services is the availability of Earth Observation and in-situ data for e.g. improving the forecasts and monitoring particulate matter from space. In this context the upcoming Sentinel 4 and 5 missions are important. Besides the continuity issue, especially at regional and local levels a higher spatial resolution of the air pollutant observations is essential. Regarding these sensors of the next generation, the presented downstream services will also benefit from a better temporal resolution and a better radiometric sensitivity with respect to the boundary layer. It needs to be emphasised that continuity and sustainability of in-situ and Earth Observation data availability is crucial for the success of the downstream services.

Based on the concept and methodology of PASODOBLE, we conclude that European citizens will benefit from Earth Observation, since Myair services provide a solution to mitigating the harm from air pollution by directly reaching residents who are most vulnerable, allowing them to change their behaviour or to take relief mediation in time. By raising awareness, reducing health costs and diminishing morbidity, Myair services will improve quality of life and sustainability of prosperity in Europe.

ACKNOWLEDGEMENTS

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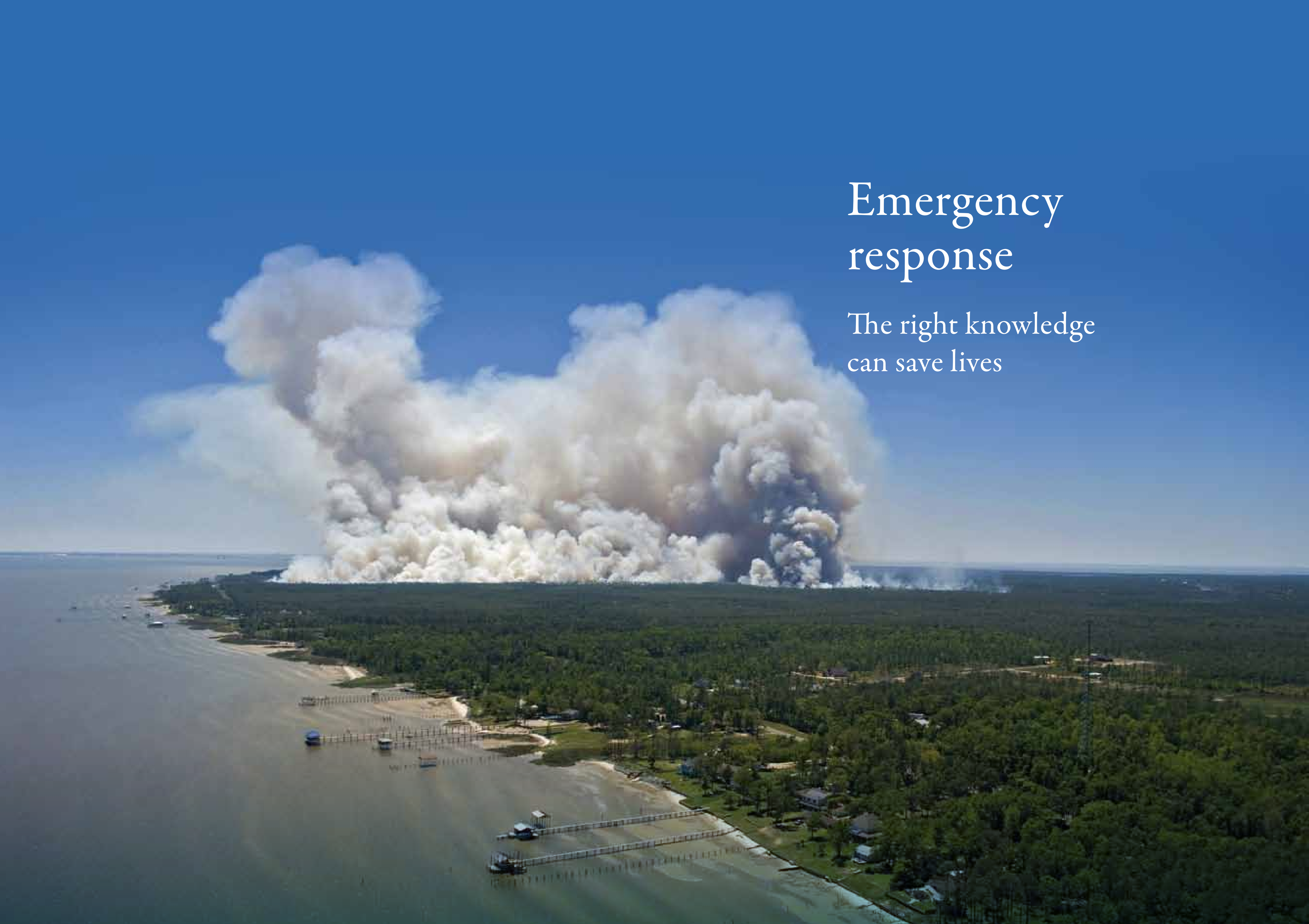

Emergency response

The right knowledge can save lives

SAFER

En route for a SAFER world with the GMES Emergency Response Service

David Hello, Gil Denis

SPOT Image, Toulouse, France

ABSTRACT

Every year, fires, floods, earthquakes and volcanic eruptions, landslides and other humanitarian crises claim the lives of thousands of citizens in Europe and around the world. With climate change, the frequency or intensity of such events may even increase. With the SAFER project, co funded by the European Commission[2], GMES Emergency Response Services are moving one step closer to full-scale operational deployment. SAFER is a large European project funded in the frame of the GMES initiative.

Started in January 2009, the SAFER project is preparing and paving the way for operational implementation of the GMES Emergency Response Service, reinforcing the European capacity to provide efficient support in case of natural crises and humanitarian disasters. SAFER has already delivered services at full-scale in response to real emergency situations, in Europe or abroad, as well as during specific exercises. Recent activations results demonstrate the performance and the validity of the model. This first return of experience brings useful knowledge for the future operations in Europe and worldwide.

PROVIDING MORE EFFECTIVE RESPONSE TO EMERGENCIES

Efficient emergency response is highly ranked on the political agenda. Recent major disasters in Europe, in Africa and worldwide (either natural, man-made, or complex humanitarian crisis) such the forest fires near Athens in Greece, the Klaus storm in France and the earthquake in Italy have stressed again the need to improve the European disaster response capacity.

2 SAFER project has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 218802 (GMES services)

EMERGENCY RESPONSE

The role played by the European Union in emergency response and disaster relief is two-fold: the first mission is to protect lives and assets of European citizens. The second one, as part of the European solidarity, is to provide effective disaster and humanitarian assistance in other parts of the world.

In December 2007, the European Parliament and the European Council recommended to strengthen the Community's Civil Protection mechanism and the Cooperation between Member States in order to improve the effectiveness of emergency response in case of major disasters.

In a similar way, the European Parliament and the European Council have signed in December 2007 the European Consensus on Humanitarian Aid for improved delivery of assistance.

Figure 1: The crisis cycle and the response

SIMILAR NEEDS INSIDE AND OUTSIDE EUROPE

Disasters have more and more a cross-border nature. Their mitigation requires coordinated responses. Key criteria are speed, effectiveness and cost-efficiency and require a managed, coordinated and integrated response. The same instruments – in particular civil protection assets – are deployed by the Community and Member States to respond to the same needs within the Union and beyond EU borders, either as a stand-alone disaster response contribution or as a complement to humanitarian aid.

A CLEAR BUT CHALLENGING EXPRESSION OF NEEDS

Accurate and comprehensive information makes better decision-making. The users needs, expressed both by civil protection and by actors in charge of humanitarian assistance have been reported and further detailed in 2006 by the GMES Emergency Response Service (ERS) GMES implementation group and confirmed in September 2008 during the Lille conference. The targeted crisis situations are:

> Meteorologically-driven hazards (e.g. storms, fires, floods),
> Geophysical hazards (e.g. earthquakes, tsunamis, volcanic eruptions, landslides and subsidence),
> Man-made disasters, either deliberate or accidental (e.g. urban fires, chemical incidents on industrial sites),
> Humanitarian disasters.

FAST DELIVERY FOR DECISION MAKERS AND IN-FIELD OPERATIVES.

The key service requirements to be implemented by SAFER are:

> Geographical scope: inside and outside Europe.
> Includes reference mapping, assessment (rapid mapping) and situation mapping, crisis follow-up products, from data acquisition to delivery to the final users. Specific thematic products, depending on the type of event (floods, volcanoes, etc.) can bring additional specialised information.
> Reference maps shall be delivered in less than 6 hours. This requirement can only be met by preparing and maintaining in advance a "library" of reference maps on the world areas subject to natural or humanitarian crises.
> Optimised operational processes, including anticipation of data acquisitions.
> Information delivery to decision-makers and to in-field operatives.

The most challenging requirement is the end-to-end service delivery time: the first reference maps shall be delivered within six hours and the assessment maps shall be available in less than 24 hours for Europe and the Mediterranean basin (36 hours elsewhere).

EMERGENCY RESPONSE

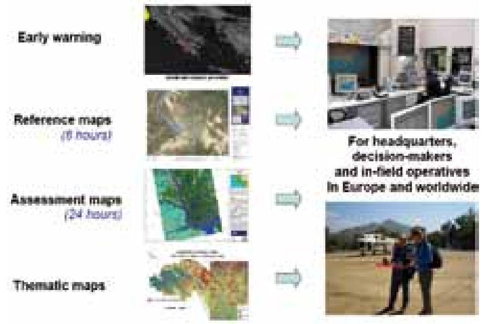

Figure 2: The SAFER product portfolio

SAFER, FROM BEST EFFORT TO OPERATIONAL SERVICES

The main objective of SAFER is to prepare the implementation of operational versions of the GMES Emergency Response Core Service. SAFER is a key contribution for the transition from pre-operational demonstrators to a fully operational and independent emergency response capacity in Europe. SAFER aims at reinforcing the European capacity to respond to emergency situations: fires, floods, earthquakes, volcanic eruptions, landslides, humanitarian crisis. The main goal of SAFER is the upgrade of the core service and the validation of its performance with 2 priorities:

> The first priority is the short term improvement of response when crisis occur, with the rapid mapping capacity after disastrous events, including the relevant preparatory services (reference maps). For validation purposes, the project will deliver, as early as 2009 a full scale service for real events or during specific exercises. The main performance criterion is the response time. Work addresses technical, operational and organisational issues.
> The second priority is the extension to core service components before and after the crisis. It targets the longer term service evolution, through the provision of thematic products, to be added in the portfolio of services. The main criterion is the added-value of products with risk-specific information.

EXPECTED RESULTS AND IMPACT

The main expected impact of SAFER is the integration on the service side. This action is mandatory in order to reach the critical mass and meet the targeted quality and performance of the GMES Emergency Response Service.

Closer to the operational stage, SAFER, in particular with the "full size – real conditions" validation activities, is a key instrument to foster the dialogue between the actors currently involved in rapid services and define enhanced operational processes and the related service level agreements.

As for the other GMES services, SAFER will demonstrate that efficient and shared solutions can be set up at European level, with a good balance between the mutualisation of resources and the subsidiarity principle.

A user-driven pre-operational service:	– Service delivered as early as 2009, with an incremental Service Level Agreement defining the levels of performance. – Validation by users with the support of an independent entity (The Joint Research Centre of the European Commission).
A rapid mapping capacity:	– Gradual increase of activations: 30-45-60 events per year. – Reference maps available in less than 6 hours (targeted performance) – Anticipation of new acquisitions, based on events monitoring, to speed-up mapping.
A more complete information content:	– Reference mapping prepared in advance. More than 7 M km^2 covered. – Progressive enrichment of the service with thematic maps (assets and population maps, risk maps, historical damage maps) for the different types of hazards.
An end-to-end support service:	– Focal point, as single point of contact available 24/7 to manage service delivery. – Service gateway for efficient access. – Geo-information delivered up to the intervention field ("in-field" GIS solutions).
Preparing a fully operational service:	– Service development and validation according to standard processes. – Set-up of service infrastructure to allow seamless integration between service partners and with end-users. – Written procedures and methods. Quality organisation. Training courses for users.

Table 1: SAFER expected results

PRODUCTS AND SERVICE EXAMPLES

Figures 3 and 4 are samples of products which have been delivered for validation purposes. The satellite image on figure 3 is a Spot 5 high resolution image which has been used for the assessment of the damages caused by the severe fires near Athens in August 2009. The map on figure 4 is a reference map to be delivered between 6 and 24 hours after the alert. On this particular map, based on Express maps, SPOT Image added some specific layers describing the impact on the earthquake in Afghanistan in April 2009. Figure 5 is a map produced by SERTIT for SAFER in rush mode during the activation after the Corsica fires near Aullènes.

Figure 3: High resolution Spot 5 image acquired after the Greek fires near Athens – Overview and details (August 2009). This image is the input data for the rapid mapping activity

THE CHALLENGE OF THE TIMELINESS PERFORMANCE: THE OPERATIONAL ORGANIZATION OF THE SERVICE

The experience of the previous projects shows that, for a reactive and time-critical service as targeted in SAFER, an "operational coordinator" of the service is necessary.

This operational coordinator must ensure the end-to-end management of an operation (a crisis response support), coordinating all the actors that will contribute to the service (data acquisition, value-added provision of different types), and the interface to the users.

This need is recognized in the GMES Emergency Response Service Implementation Group report which states: "The GMES Emergency Response Service focal point represents an expert layer able to harmonize and coordinate the activity of the providers consortia and of European agencies and centers, to receive through the national or European focal points user information requests and to decide and finalize effective operational steps (e.g. to perform the negotiation with a mission plan to acquire new data, to verify the suitability of the actual available input dataset, etc.)

One of the operational innovations brought by the SAFER service organization is the ability to anticipate reference maps production and data acquisitions when early signs of an upcoming crisis occur (in example hydro-meteorological forecasts for flood, etc.), or when the first information regarding the effective start of a crisis arrives.

This anticipated activity allows to work in "hidden time", and thus to improve the delivery delay with respect to the effective user request.

The role of the SAFER focal point also appears in the functional architecture as depicted in the GMES Emergency Response Service Implementation Group report, shown below in figure 5.

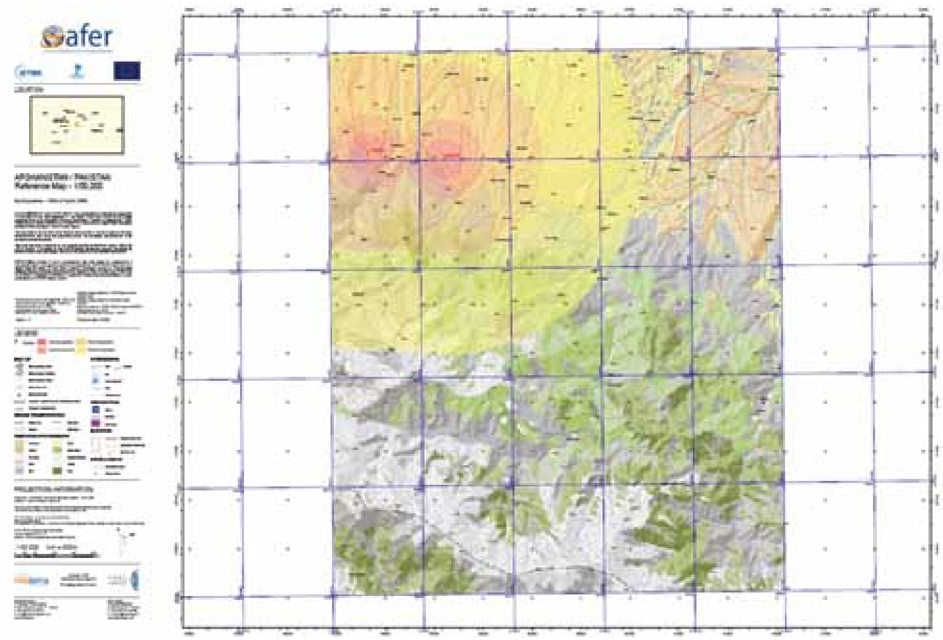

Figure 4: Reference map of Afghanistan produced by Infoterra / SPOT Image for SAFER. Based on Expressmaps with additional layers describing the impact of the earthquake

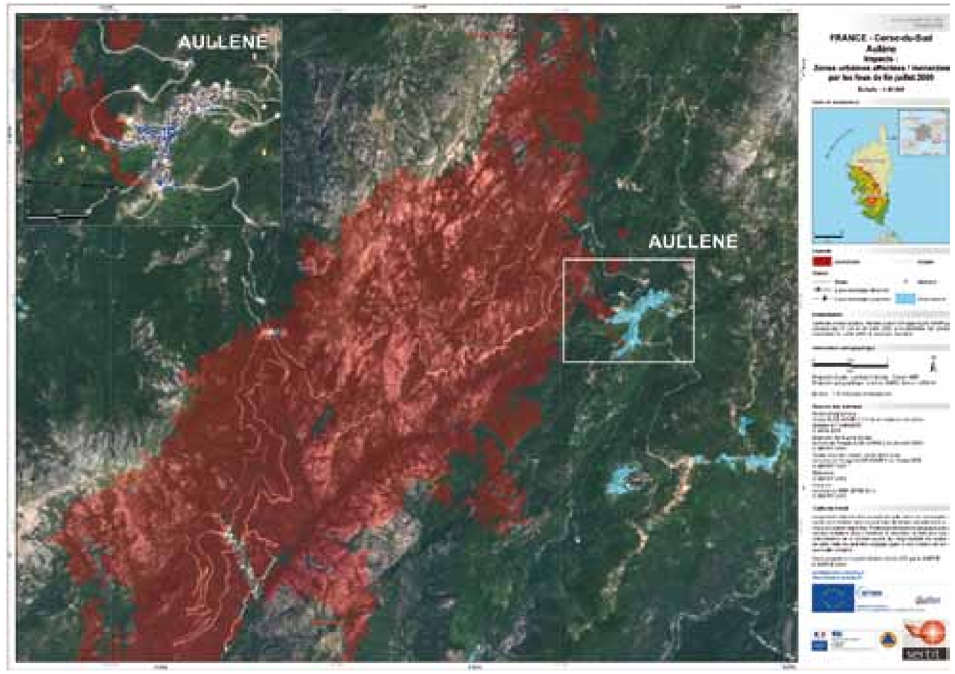

Figure 5: SAFER organization and operational model

Figure 6: Assessment map produced by SERTIT after the fires in Corsica (Aullènes, July 2009)

SAFER IMPLEMENTATION: A EUROPEAN CONSORTIUM WITH A WIDE EXPERTISE

The SAFER consortium, coordinated by SPOT Image SA, includes 54 partners from 16 countries (29 private organisations and 25 public institutions). With users such as European civil protection authorities or international UN agencies, SAFER is built around a core team of European industry and research institutes that have gained experience in this area within the framework of both the EC's Sixth Framework Programme for Research and Technological Development and ESA programmes (including PREVIEW, RISK-EOS, RESPOND, TERRAFIRMA, LIMES and BOSS4GMES).

A wide network of scientific partners and service providers extend the European dimension of the project, in particular to the EU New Member States. The total budget of this three year project is € 40 M with a € 27 M grant funded by the 7th Framework Programme for Research and Technological Development of the European Commission.

The main European service providers (Infoterra / SPOT Image, Sertit, Telespazio), space agencies (CNES, ROSA, DLR), small and medium enterprises (Keyobs, Magellium, etc.) and research teams (UNIFI, CNRS, INGV, LATUV)) are involved. SAFER is therefore one of the largest projects launched at European level in the frame of the GMES initiative.

FIRST OPERATIONAL RESULTS ON REAL EVENTS

First operational use of SAFER started in early 2009 with the decision to activate the service after the two earthquakes in l'Aquila and in Afghanistan. A large operational exercice was also organised in France (Richter 65 in Lourdes) with the French Civil Protection.

Because of the intensity and frequency of the wild and forest fires, SAFER service activity increased during the summer 2009, with four major activations between mid-July and end of August: fire in Marseille (France), fire in Corsica (France) and Sardigna (Italy) and the large fires near Athens in Greece.

Reference and assessment maps, have been produced and delivered by SAFER in rush mode to the end users (French, Italian and Greek civil protections).

Since April 2009, SAFER has been activated 35 times for disaster event both in Europe and outside Europe and for the need of both the Civil Protection community and the Humanitarian Aid community (mainly United Nations bodies).

During these emergency situations, the SAFER operational model has been successfully implemented and validated: SPOT Image, as focal point operator, is in charge of operational management and a network of European service providers (mainly SERTIT and DLR for the work performed during the summer) produces the geo-information. This model includes the interface with the GMES data access component (earth observation data provision coordinated by the European Space Agency). Some activations have been performed in close partnership with the International Charter Space and Major Disasters, using a cooperation agreement defined between SAFER and the Charter board.

Among the main lessons learnt, it is worthwhile mentioning:

> The importance of early warning and anticipation of the activation by the users. This is a key success factor in order to save time in the mobilisation of earth observation capacities and to meet users' expectations for fast delivery of information. SAFER implements an "anticipated activation" mechanism, based on daily monitoring of alert and early warning signals. This is an efficient solution for the anticipation of the official request of the users.

> The benefits brought by a well-specified operational model, with clear responsibilities, interfaces and procedures. Even with a networked organisation, if the decision–making process is defined and applied, the distribution of the work among a set of service providers has no impact on the end-to-end performance. Even in rush mode, this model can provide an efficient solution in order to implement "online" quality control in the operational loop, before dissemination of the information products.

> The means for the dissemination of the information products not only to the headquarters but also up to the final users (in-field). Even if this issue is mainly depending on internal organisational and operational rules at civil protection level, some tools can be helpful for a more efficient distribution of the SAFER products.

During the summer, the French civil protection in Corsica has exploited a set of mobile terminals and a risk management equipment developed by Astrium Services and Infoterra (ELISEO system). It includes communication, navigation and real-time mapping functions, this tool improved the efficiency of the geo-information products for field operations.

Figure 7: ELISEO system used for distribution of information products to in-field operatives. Operational validation in Corsica (August 2009)

In order to be fully exploited by the various users not only in rush mode during the crisis itself but also after the event for the detailed assessment of damages (e. g. for the ministry of agriculture or ministry of environment), the information products shall be interoperable and designed to allow:

> Easy integration by the users in their GIS tools and working environment.
> Flexible combination of information layers in order to fulfil various needs (e. g. burnt area boundary overlaid on a reference map or on a detailed land use map).
> Last transfer to in-field operatives and integration in the field equipment, i. e. with multilayered vector representation and efficient use of the bandwidth of the communication channels.

CONCLUSION

During the next three years, SAFER project will be one of the main instruments of the European Commission in order to implement operational GMES services for the emergency response.

The first operational results highlight the validity of the service concept and of the organisational model. The next step will be the confirmation of these lessons with a wider set of users and crisis situations.

In order to achieve the successful transition from a research and project-driven logic to sustainable operations, the main identified challenges are:

> Setting up an appropriate organisation and management structure at European level with four requirements:
> Political engagement
> Link with users at European, national and regional level
> Clear mandates to service operators and selection of a main operator entity for the operational service management
> Pan-European organisation and activation rules for non European users.
> Defining the right balance between mutualisation of resources at European level and subsidiarity at regional / member state level. For SAFER, it includes also the long term plans for the cooperation with the International Charter Space and Major Disasters.
> Securing long term public funding for the operation of the GMES Emergency Response Service.
> Guaranteeing continuity of Earth Observation sources, at European level but also and perhaps mainly at national (institutional and commercial) level: emergency response services require mainly high resolution optical and SAR images and this capacity is firstly provided by national missions.

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SAFER

GMES Emergency Response - Two years of EO-based Rapid Mapping

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ABSTRACT

Within the 7th research framework programme of the European Commission the SAFER project aims at developing and providing a pre-operational version of the GMES Emergency Response Service (ERS). A main component of this is the rapid mapping service called Emergency Mapping. Within this service satellite-based information products are generated covering natural or man-made disasters, like for the Haiti Earthquake, the Poland, Romanian and Pakistan floods, the Xynthia storm in France and the alkali mud flow in Hungary (examples are shown in this paper).

Overall, the Emergency Service's main objective is to set up a pre-operational service based on precursor projects' services and user collaboration to set in motion the basis for future operational environments in the GMES Initial Operations (GIO) and further on in a fully operational context. Besides the regular service provision which increased from 22 activations in year 1 to 51 in year 2, the service focuses on further improving the service structure, the portfolio and the technical background to target improvements in response time and the quality of the crisis map products. In total more than 600 crisis products were generated during the first two years of GMES Emergency Mapping.

Following the project's initiation process and the setting up of the SAFER Emergency operational model, service provision is well structured and performs smoothly, benefiting from the long lasting experience of the initially involved service providers. Lessons learned during the first year were immediately analysed and resulting improvements have already been implemented.

EMERGENCY RESPONSE

WORK PROGRAMME

Embedded in the GMES Programme the Emergency Response project SAFER provides Rapid Mapping based on earth observation data (EO data). The main aim during the three years project lifetime is to tailor the future European Emergency Response service. One of the most important aspects is to include the complete set of users from European Member States and provide services to their requests. Based on the user feedback the service will be adjusted towards the user needs. The general approach of SAFER is described in figure 1 below. On the left side the user community is visualised. The user requests are channelled through the National Focal Points. On the right side the service segment is displayed. The satellite data is provided to the SAFER service providers and transferred into crisis information products. These are delivered to the users requesting the service.

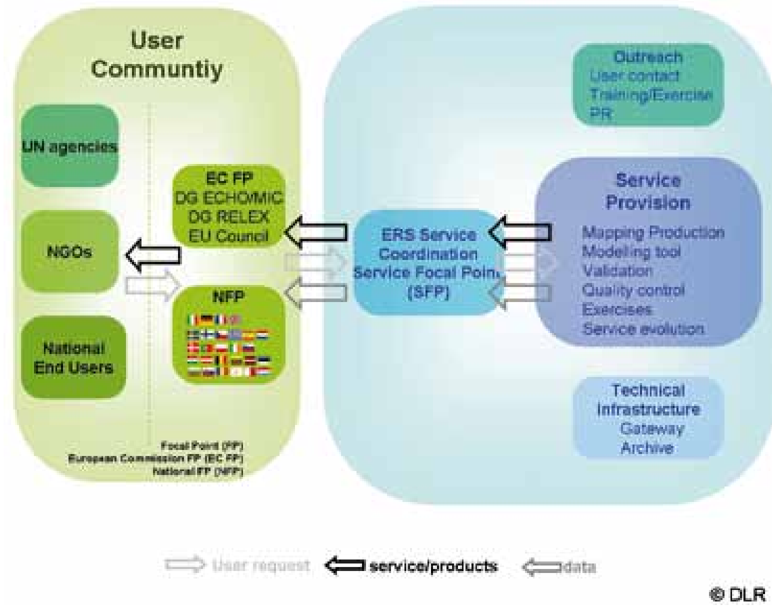

Figure 1: General operational structure of the GMES Emergency Response Service SAFER (copyright DLR)

One of the general aims of the project is to speed up the delivery time of the first crisis product after the initial user request. Other important aspects are the standardization and harmonization of the service to ensure a common and high level of quality of the products and services. A qualification process is set up to include new partners that have to ensure the same quality of service before fully being integrated into the service providers group. Even if the frame of the project is the research environment, the focus of the Emergency Response service is laid on the service provision. At the beginning of the project it was planned to serve 30 activations in year 1, 45 activations in year 2 and 60 activations in year 3. These figures were derived from statistics of the International Charter "Space and Major Disasters". For each activation the project allocated a specific volume of effort that was also derived from the Charter activations. The unit is called "Rapid Mapping Unit (RMU)" and reflects the effort that is needed to generate an analysis product out of a pre- and a post-disaster satellite image including the associated services like documentation or metadata generation and the 24/7 availability. Usually, a "standard activation" is fully covered with 4 RMUs. Now, after two years of SAFER it turned out that the service is much more recognized and requested than initially planned. After a 3 month set-up period at the start of the project the service delivered products for 22 activations in year 1. Taking the missing 3 months into account it was more or less the presumed number of activations for year 1. In year 2 we already served 51 activations, instead of the planned 45. And in year 2 we had some very impressive natural catastrophes with a huge humanitarian impact like the Haiti earthquake in January 2010 or the floods in Pakistan in July and August 2010 where the users requested much more service from GMES Emergency Response (see examples given below).

METHODOLOGY

The system is being set up in an attempt to meet and deliver on user requests; they are at the heart of the procedure. Starting with the portfolio through to user feedback, users are consulted and their requests are heeded to throughout. The upgrading of the whole chain is being undertaken in order to achieve the high standards of timeliness and robustness that they demand. This though is a complex issue with uptake, technological integration and requirements varying greatly on the user's side.

The activation of the service is very easy. The registered users only have to contact the 24/7 hotline of GMES Emergency Response and send the filled Service Request Form. After a confirmation of the validity of the request the user is continuously updated about the status of the service provision and will be provided with the information defined by him in the Service Request Form. A more detailed description of the service is provided on the SAFER website (www.emergencyresponse.eu).

The GMES Emergency Mapping or Rapid Mapping service is a partnership. At the heart of this partnership is a collaboration that has been welded together over time between the two senior partners, the DLR and SERTIT. e-GEOS is in the process of qualification whereas the European Union Space Centre mostly works on collaborations between SAFER and G-MOSAIC, a more security related

Framework Programme 7 project which is less operationally orientated. Those RMSPs regularly meet at least twice a year to discuss lessons learned from past activations and to decide on operational improvements to further optimise the service provision. Additionally, the "background" service covering the evolution of the service like improving the quality of the products, standardizing the product formats, harmonizing the extraction methods or widening the service portfolio. Recently the service portfolio comprises rapid reference maps, disaster extent maps and damage assessment maps, each in overview and/or detailed map scale. The products can be ordered in many different product formats such as jpg (default), tiff, geotiff, pdf or geopdf with metadata following ISO and INSPIRE standards. The user can also chose between several delivery methods, ranging from email delivery or ftp services of the digital product formats to courier of printed out hard copies. Currently, also shapefiles of the different information layers can be requested and will be provided after signing a respective user license.

The service providers try to provide the products with the best quality possible within the short time frame that is given. Therefore, a set of procedures has been implemented to ensure the quality of the SAFER products. First of all, the project defined some thresholds for the thematic accuracy of the products. This was based on the experience of precursor project validation work. The SAFER services and products are regularly validated against those standards. Additionally, an ISO conform quality assurance mechanism has been implemented which checks the service performance with respect to the key parameters like conformity to the given procedures and timeliness. And last but not least, each product undergoes an operational, internal quality check by the Service Providers following common procedures.

MILESTONES

The main milestones of the project are the Annual Review meetings and the semi-annual Progress Meetings. Besides that, the project has set up an evolution process which ensures a continuous improvement of the service. Therefore, the project consists of three evolutionary versions: V0, V1 and V2. V0 is the fundament of the service and represents the "best of" of the precursor Rapid Mapping Service as provided in the GMES Service Elements RISK-EOS and RESPOND. V1 started after 18 months, V2 after 30 months respectively, and provide improved services to the users. The improvements are prioritised to ensure that the most important services are implemented first. And if the development of some improvements is time consuming they are started timely to include the final result within the project duration. One of the targets of the project is to decrease the duration until the first crisis product is provided to the user. The aim for the RMSP group is to reduce the time for processing and analysing of the satellite data and generating the requested crisis product from recently 8 hours to 6 hours. Statistics from year 2 show that there is a significant trend to reach this aim as we already deliver the products within approx. 7 hours after data reception. Even more important is to reduce to reaction time of the complete chain which also includes the service frontend (SAFER Focal Point), the satellite data provision and other parts of the chain like the Gateway as the envisaged interface between all players. Data provision is a critical aspect, as the work of the RMSPs depends on a timely provision of the satellite data. At the moment the data provision needs further improvements. The crisis data is often delivered to the RMSP 48 hours after user request or even later, although some enhancements are visible in the past. But we are still far away from the goal to provide the first crisis product within 24 hours after user activation. This is the main challenge for the service evolution as it is a requirement defined by the users which has to be fulfilled.

MAIN OPERATIONAL ACHIEVEMENTS

During the first 2 years of the project, the emergency mapping teams gathered much experience, shaping the future ERS services. After setting up the service, SAFER provided Emergency Mapping services for more than 70 activations (with more than 650 products in total), some of them were very challenging and provided a lot of information to further adjust the recent service structure and the products. In this section a state of play along with examples from some of the activations are presented.

The fifty activations that occurred in 2010 disguise some exceptionally large activations with many user requested areas of interest (AOIs). This is not always borne out in the statistics as they weren't broken down to regional, local separate activations. In this light January 2010 (figure 2 below) seems to be a quiet month, with only 2 activations, but the Haiti Earthquake was mapped during that period and given the user requests, detail of mapping and number of areas mapped this activation could be considered the equivalent of close to 10 smaller activations such as the Mozambique floods.

Worldwide, plain flooding represents 50% of activations, with flash floods, earthquake damage, hurricane/storms, fires, technical accidents, volcanoes, humanitarian crises and user requested exercises making up the remainder, each approx. 5%. A large proportion of the service's activities have concerned Europe, but events of Asia, Africa, Caribbean or Pacific islands were also covered.

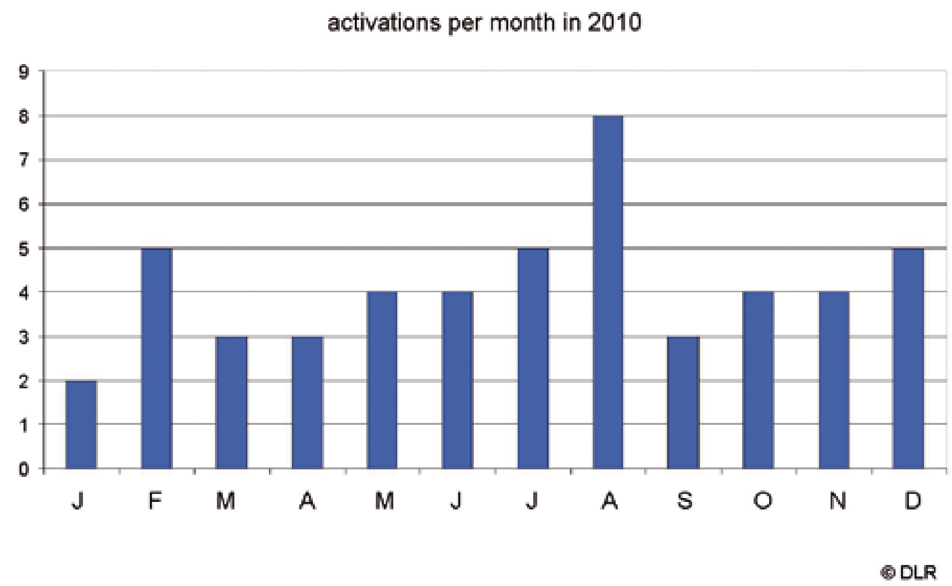

Figure 2: Activations compiled on a monthly basis (copyright DLR)

Some highlights of the year include the publication 36 hours after the Haiti Earthquake of the first earthquake damage estimate map (see figure 3), the Polish, Romanian and month-long Pakistan floods (see example for one of the various products SAFER generated during the Pakistan flood event in figure 4), the Xynthia storm in France and the alkali mud flow in Hungary to support disaster management. The experienced operators, adapting to novel situations, also produced new highly appreciated products, complementary to the portfolio, such as the spontaneous gathering area maps elaborated for the Haiti event showing where people gathered out in the open away from building structures.

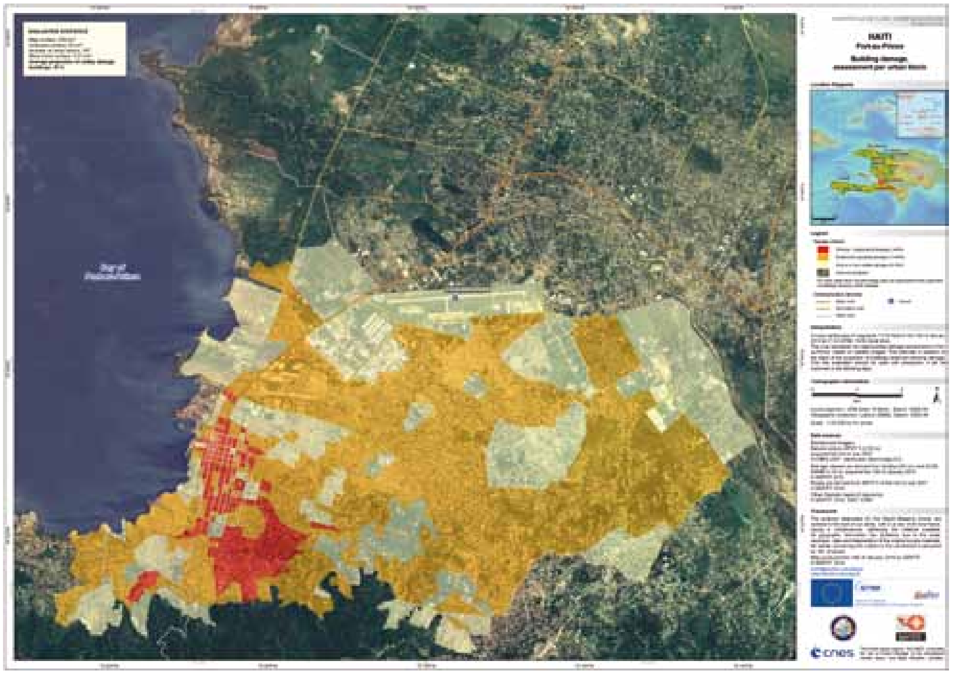

Figure 3: First damage assessment product worldwide delivered 36 hours after event, produced by SERTIT within SAFER an within the context of an International Charter "Space and Major Disasters" activation (copyright SERTIT)

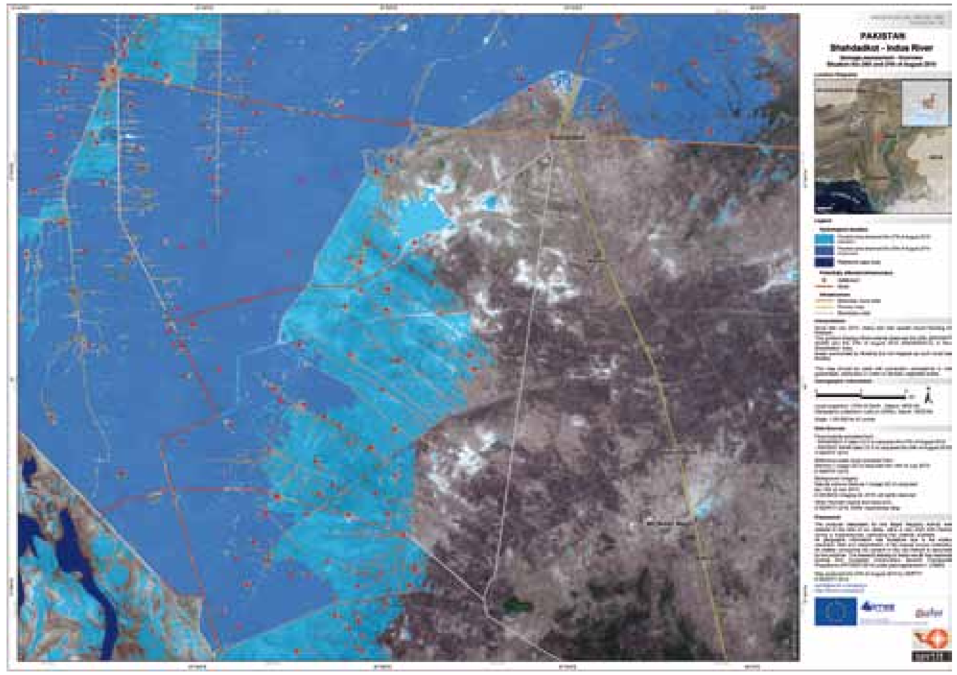

Figure 4. Flood Extent dynamics between August 24th and August 27th – Sindh Province, Shahdadkot city with impact analysis. The product delivered 8 hours after EO data acquisition (August, 27th), (copyright SERTIT)

Another example shows the technical accident in the vicinity of Kolontár, Hungary in 2010. On October the 4th 2010, a reservoir dam holding waste of an aluminium plant near the village of Kolontár collapsed after a period of heavy rains all over central Europe. The toxic mixture of aluminium deposites and mud run through several villages like Kolontár and contaminated the human settlements as well as the agricultural fields along the run-off channel. Seven humans lost their lives, more than 150 were injured. The pH-value of the alkali mud was so high that all the fishes in the small riverine in which the mud emerged were killed. It was the largest ecological disaster in the history of Hungary. The consequences of this contamination will affect the region for decades.

Figures 5a. and 5b. Two of the GMES Emergency Response products generated in the frame of the activations for the collapsed dam of an aluminium plant in Hungary 2010 (http://www.zki.dlr.de/article/1655), (copyright DLR)

EMERGENCY RESPONSE

Figures 5b.

CONCLUSION

After over 10 years of Rapid Mapping experience, it is well established that Crisis Mapping is a "power exercise" which consists in deploying at any moment, in a very short amount of time, an important integrated capacity of trained engineers, expert analysts, computers, software, communications media etc … This cannot be improvised, and supposes a structured approach for establishing these significant means. Hence, whereas the activity level, which seems to be close to over 4 activations a month or 1 a week, could seem constant, it actually varies considerably with the Rapid Mapping group handling close to 10 equivalent activations a month, 5 in parallel.

The last two years of GMES Emergency Response service has shown that it is more and more requested by the users resulting in more activations than planned. It is a good sign that the users include this new source of information into their well established operational chains to support the crisis management.

Nevertheless, we still have work to do to generate a common understanding of the possibilities and limitations of the EO based services. Once this is realized one of the major aspects, the control of the service volume, can be better handled. At the moment users often request the complete set of the portfolio which was not the initial intention of such a varied service. With a restricted budget it thought necessary to customise the service to user demand to the Emergency Response service, instead of an "all inclusive" wish list. The user group is very heterogeneous. Some are experienced some not. The role of the user in general is very important since they do not only activate the service but also they provide valuable feedback after each activation which is needed to further evolve the service to the real user needs. In terms of the service the European Community's users are more aware and happy with the 2010 service and this trend is confirmed by the other user communities, in terms of fit to portfolio, capacity, availability and punctuality. In 2010, user demand from within Europe has greatly increased. The service could still improve but what is clear at this stage is the service fulfils its role mostly through the presence of a limited number of polyvalent experienced players and this keeps response times low and quality high. In the coming years the mutual understanding will be further increased which will be of benefit for the user who will give a timely and highly individualized service as well as for the service provider who can concentrate on the needs that are most relevant to support the crisis management.

SAFER implemented some very valuable improvements to standardize and harmonize the service delivery in the last two years. Thus, the recent Emergency Mapping service is already the "next generation" of Rapid Mapping provided in the past GMES Service Elements. In the next year of SAFER the performance and standardization will be continuously improved by further optimising internal processes, including the Gateway as interface and using a common data model and extraction guide to further harmonize the products to a more consistent service. Also the data provision announced some valuable improvements for year 3 which will also positively affect the timeliness of the complete service. These are some promising facettes of the service evolution which will increase the users benefit.

In general, the recent service has laid the basis the future GMES Initial Operation phase (GIO) which builds the bridging link to the final GMES Emergency Response Operations.

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SAFER

Emergency Support Mapping in the Emergency Response Service: Information products to support ALL phases of the crisis cycle

Alex Irving and Jacquie Conway

Astrium GEO

ABSTRACT

The objective of this paper is to describe the Emergency Support Mapping component of the Emergency Response Service (ERS), the products produced within this component, to explain the rational for Emergency Support mapping and why it is and should continue to be, such an integral part of the current (SAFER) and future ERS, and to present user driven success stories highlighting the benefits of this service to actors involved in all phases of the crisis cycle, from preparedness/prevention before an event, through the emergency response phase during an event, to the recovery phase after an event.

This paper will describe the types of products produced in the Emergency Support component of the ERS, and how these products may be used for each phase of the disaster cycle. Although Emergency Support mapping mainly operates in the two phases "pre" and "post" the actual crisis event, it is important to note that it supports ALL three phases, with products produced in the Preparedness/Prevention phase (i.e. Geographic reference maps) being directly used during the Emergency Response phase to improve the timeliness of providing baseline information to emergency response actors during the critical time at the beginning of a crisis event.

The decision where to map (produce the information products) is user driven. It is driven by both direct user demand ("activation" in emergency support mode) for preparedness planning and recovery activities and by pro-active identification of vulnerable areas together with the user in support of emergency response activities.

Users comprise civil protection agencies, UN agencies, the Red Cross entities and humanitarian NGOs. Current user map requests within the pre-operational ERS (i.e. SAFER), include locations in the Caribbean, South America, Africa, Central and South-East Asia as well as inside Europe itself.

The Emergency Support mapping component within the pre-operational ERS (SAFER) has set an important precedent for emergency and security related GMES services by establishing a data model based on a proven and internationally recognised military template (Multinational Geo-spatial Co-Production Program (MGCP). The original military specification has been simplified to allow for ease of data capture taking into account user requirements, such as the categorisations of road types "hard-paved" etc. but at the same time maintaining key criteria to ensure compatibility across sectors. The currently adopted specification and data model allows for multi-use of Emergency support products by both Emergency and Security services.

WORK PROGRAMME, METHODOLOGY, MILESTONES

It is commonly accepted that disaster risk management is a cyclic activity), with three major phases: *Preparedness/Prevention*; *Emergency Response*; and *Recovery*. Satellite derived geographic information can be used in support of all three phases. Emergency Support mapping operates within the Preparedness/Prevention and Recovery Phases but supports *all* three phases. Figure 1 below illustrates the types of products produced and how these products may be used for each phase of the disaster cycle. Although Emergency Support mapping operates in the two phases highlighted in Figure 1, it is important to note that it supports ALL three phases, with products produced in the Preparedness/Prevention phase being directly used during the Emergency Response phase.

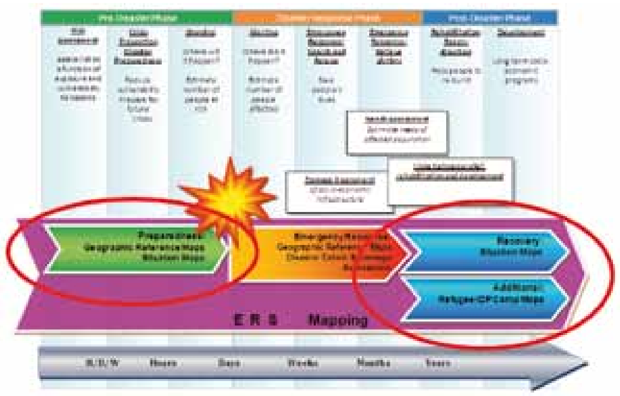

Figure 1: The product types and their "uses" within the three phases of the disaster cycle

EMERGENCY RESPONSE

The types of products produced in each phase within the Emergency Support mapping component of the ERS are as follows:

> Preparedness/Prevention

Preparedness products in the form of Geographic Reference Maps, provide an overview of an area that is or might be at risk. Information content includes basic topographic features from the following themes: transport; hydrography; population; industry & utilities and physiography. The capture of these core topographic features provides the essential canvas against which more specific map applications can be applied, either within the service or by the user themselves. Pre-disaster Situation Products contain additional thematic information for example on land cover, building density and vulnerability.

> Recovery

Recovery products provide additional thematic information for the analysis of the post-emergency situation. Medium or long term monitoring with satellite images can help to follow reconstruction works or observe possible changes in land use and resources.

Post-Disaster Situation products contain, basic reference information and can also include: Detailed needs assessment, Detailed damage assessment, Flood duration statistics, Reconstruction monitoring and Humanitarian situation assessment etc.

> Additional

Additional products feature in the Recovery part of the Emergency Management Cycle, and focus on the various aspects of Refugee/IDP Camps, such as population density and statistics, risk analysis, vulnerability classes and status and condition of resources. They include maps based on contemporary Satellite data and those enhanced through contextual information provided direct from the field.

All categories are available as Overview: small scale (large area coverage) and Detailed: large scale (small area coverage) products.

The work programme and product production is dependent upon user input and service provider production experience and therefore needs to be flexible. This flexibility applies to both selection of areas to be mapped and to the development of the service.

> Site Selection

For *Preparedness/Prevention* products, a pro-active identification of vulnerable areas in close consultation with users is undertaken. This can either be a direct user request ("activation"), for the users current key logistical planning and risk assessment activities, for a Pre-disaster situation map focusing on key infrastructure features such as, roads, harbours, or population statistics, or a vulnerability assessment to produce a geographic reference map in preparation for future potential risk assessment activities or crisis events.

Pro-active identification of areas uses multiple data sources together with user input to assess the vulnerability to natural hazards such as cyclones, floods, landslides, earthquakes, volcanoes and drought. Examples of these data sources include global vulnerability indices produced by the Center for Hazards Risk Research (CHRR) at the University of Columbia in the US and the emergency database EM-DAT maintained by the Centre for Research in the Epidemiology of Disasters (CRED) at the University of Louvain in Belgium, also websites engaged in early warning for disasters (e.g. Humanitarian Early Warning System (HEWS), Famine Early Warning System (FEWS)) and others that address wider issues of disaster preparedness and *recovery* (e.g. ProVention, Preview, and the JRC ACP Observatory for Sustainable Development).

User site selection is highly variable, as seen from the distribution of Figure 2 and covers all map types (see Figure 3: User activations according to Map type 3).

Figure 2: Locations of User activations in SAFER.

Another key criterion in the identification and selection of areas to be mapped is the existence of and access to existing mapping.

Once a vulnerable area has been identified a thorough process is undertaken to identify whether there is suitable accessible geographic data that can be used for Emergency Support purposes. This is to ensure efficiencies by avoiding unnecessary duplication of mapping. The process involves:

> contacting national mapping agencies and organisations involved in precursor projects;

> an extensive search of the Internet

> accessing online map archives (commercial and non-commercial), and looking for any geographic data associated with the area of interest.

When existing maps are identified, an assessment of the age and the quality of the map is made. Access to suitable data is often subject to licensing and usage restrictions, and if these cannot be accommodated then new map data is created from recent imagery and ancillary reference material. Mapping will also be created if identified mapping is found to be too old or of insufficient quality for the needs of the ERS.

Recovery and Additional mapping is completely driven by user demand, i.e. Activation in Emergency Support mode for situation mapping and monitoring of a crisis hit area any time from 4 weeks after an event. This mapping primarily supports relief agencies in their reconstruction and rehabilitation activities allowing them to monitor and evaluate progress.

> Data Model and Specifications

The specifications for geographic reference mapping underlie Preparedness and Recovery mapping and are based upon a simplified data model that is derived from a military specification applied to a global military mapping programme called Multinational Geo-spatial Co-Production Program (MGCP). MGCP is seen as a successor to the Vector Smart Map (VMAP) programme initiated in the early 1990s. Global coverage of basic topographic features (categorised according hydrography, physiography, population, transport, industry and utilities) are freely available as VMAP level 0 (1:1M scale) datasets and with limited coverage at level 1 (1:250 000 scale). These widely available datasets have often been used by humanitarian organisations and international NGOs as core datasets for mapping. Adoption of an MGCP-based data model for the ERS allows for a high degree of feature and attribute correlation between the ERS product and older VMAP data and current MGCP-compliant datasets in use by security-related GMES projects such as G-MOSAIC (www.gmes-gmosaic.eu).

Attribution of features (especially Transport) have focused upon logistics and attributes considered of importance to humanitarian and civil defence, for example road type (hard-paved/unpaved (loose surface), density of built-up areas, identification of open areas in urban areas (potential locations for temporary housing of/aid distribution for refugees/IDPs). It should be noted that the data capture and initial attribution is dependent upon firstly, the type of satellite imagery, and secondly, any ancillary data sources. Very high resolution optical imagery[3] would be used for any Detailed scale maps (1:5 000 – 25 000) and high resolution optical imagery[4] used for Overview scale maps (1:25 000 – 500 000). Ancillary data sources could include existing reference data provided by users, topographic maps, free online data sources (e.g. toponymy databases).

In the Additional theme Refugee/IDP mapping has been based solely upon a combination of geographic reference mapping specifications and ad hoc user requirements, but recently service provider Metria has developed a geodatabase based on a UNHCR data model that will enable improved integration with UNHCR refugee and camp management databases. Further development will address integration of key elements with the Emergency Support geodatabase.

> Key Production Milestones

Emergency Support map production experienced delays in EO data supply at the start which meant little production was completed in 2009. Subsequent improvements to EO data supply assisted the rapid increase in map production that has characterised Emergency Support's progress during 2010. In 2009 there was a limited number of activations (17) 8 of which came from users and 9 that were pro-active. In 2010, the ratio between user and pro-active activations increased in favour of user activations with 59% of activations (this includes completed, in production and scheduled activations) coming from users, 22 % pro-active activations (the remaining 19% addressing a specific cost-verification exercise). Figure 3 provides a picture of all activations during 2010 according to map type and source.

3 Resolution <=1m GSD. Examples would include (but not be limited to) satellites such as WorldView (1&2), QuickBird, GeoEye-1, Ikonos.

4 Resolution = 5m. Current primary source is RapidEye data.

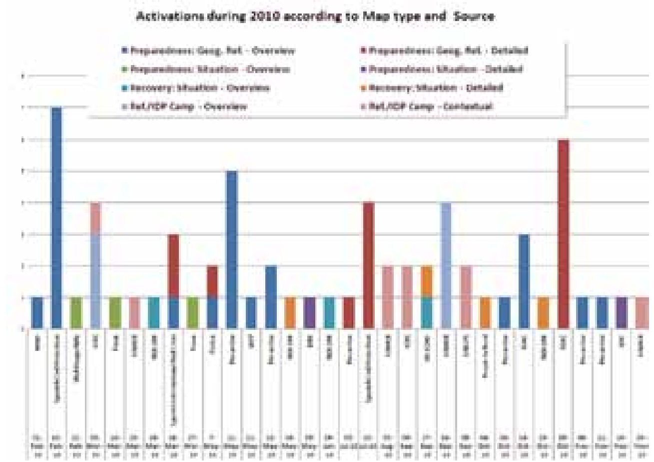

Figure 3: User activations according to Map type

PARTNERSHIPS AND COLLABORATIONS

All map activations (65) requested by users were produced in close collaboration with the users themselves. External collaboration with other GMES projects included the very successful partnership between SAFER and G-MOSAIC in the provision of evacuation maps plans requested by SAFER user Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK)[5] for several locations hosting the FIFA World Cup in South Africa during the first half of 2010. G-MOSAIC was represented by the European Union Satellite Centre (EUSC), also a partner in SAFER and SAFER by Deutsches Zentrum für Luft- und Raumfahrt (DLR).

5 The German Federal Office of Civil Protection and Disaster Assistance (BBK).

EMERGENCY RESPONSE

ACHIEVED (OR EXPECTED) SCIENTIFIC AND TECHNOLOGICAL RESULTS, POSITIVE FEATURES, PROBLEMS ENCOUNTERED

User feedback has been highly positive overall, most of which has come from *Preparedness* and *Recovery* Situation products with a single response from a recent *Additional* Refugee/IDP activation. Examples of activations, the products produced and user feedback are described below:

> Preparedness

Background: On 4th January 2010, a landslide occurred in the Hunza valley, Gilgit-Baltistan province of northern Pakistan. The initial disaster buried the village of Attabad, destroying 26 homes and killing 20 people. As the weeks passed, the problems compounded because the landslide did more than destroy a village. It also blocked the Hunza River, creating an 11 km long lake that inundated several other villages and submerged 5 km of the Karakoram Highway, the major trading route with China.

User request: In early March 2010, Focus Humanitarian Assistance Pakistan (FHAP) contacted SAFER-partner MapAction and initially required flood modelling expertise to help identify when the landslide dam would be overtopped and the modelling of the extent of the destructive flood wave downstream in the event of a probable dam breach. All products were to be provided in GIS-compatible layers for local analysis. This request was followed later by an additional request for maps to assist local emergency response teams in recovery activities.

***SAFER Response:* Flood modelling expertise was drawn from SAFER R&D partners Geomer and Infoterra GmbH who prepared the following:**

- > A calculation of the filling rate of the lake with a predicted 'burst' date was initially produced.
- > Simulation of the failure scenario showing the affected areas and wave progression – in the case of dam failure the resulting wave is expected to reach a height of 40m progressing at 2m/sec
- > Maps overlain with the simulation details (see Figure 4)

Preparedness situation maps were produced by Infoterra Ltd. and comprised a set 17 of situation maps featuring the newly formed lake, time of wave, time of high water, as well as safe areas provided by the user (see Figure 5).

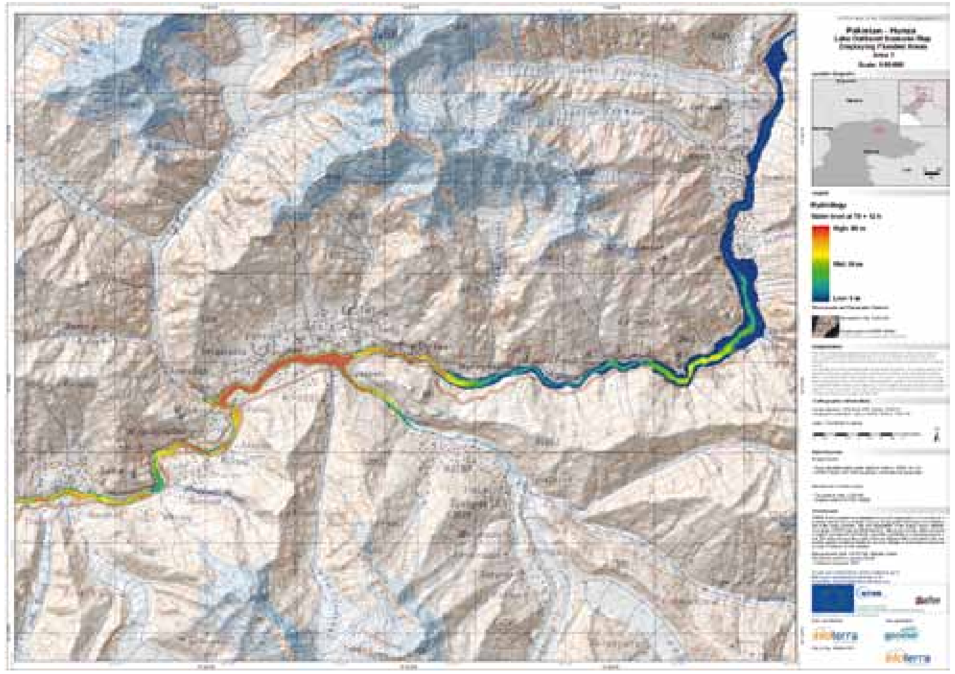

Figure 4: Map showing results of modelling dam breach and flood wave progression

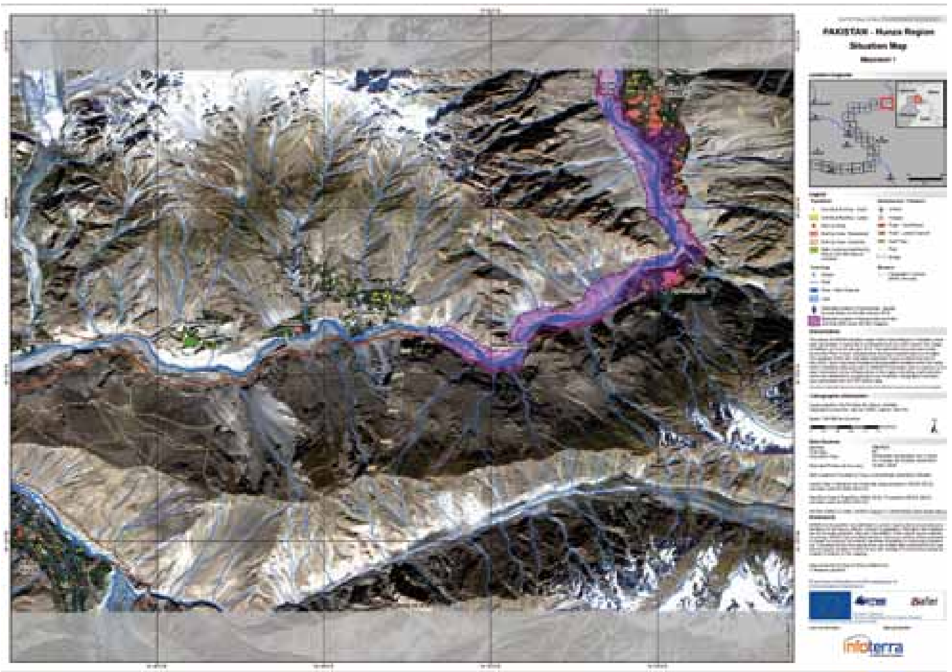

Figure 5: One of seventeen Preparedness: Situation maps showing landslide, flood extents and safe areas

User Feedback: FHAP provided the following comments in their feedback on the SAFER response: "The maps and other products provided by SAFER were of great use for us. Hunza Landslide on 4th of January 2010 developed a Lake in Hunza River which becomes a huge threat for up and downstream areas. In such time SAFER Team provide technical assistance to develop flood models and different Dam Breach scenario maps which helped us a lot in contingency planning.

Overall, the performance and timely support of SAFER teams was great, and we'll expect to be connected in future for joining hands to work for disaster risk reduction.

Last but not least, FOCUS Pakistan is grateful to SAFER for its support and assistance."

> Recovery

The National Directorate-General Disaster Management (NDGDM) of Hungary has made 4 requests for Recovery Situation products all of which have received positive feedback. These include maps and

EMERGENCY RESPONSE

GIS-compatible data to identify (1) extensive subsoil ponding and flooding in the vicinity of Jász-Nagykun-Szolnok and Hajdú-Bihar counties, (2) further rising aquifer levels in the Borsóhalmi region, (3) flood extents in Borsod region and (4) the downstream passage of toxic sludge resulting from the collapse of the alumina tailings reservoir wall on the outskirts of Kolontár. Products were used in the planning of emergency recovery operations and for damage assessment. Examples of products are featured in Figure 6 and Figure 7.

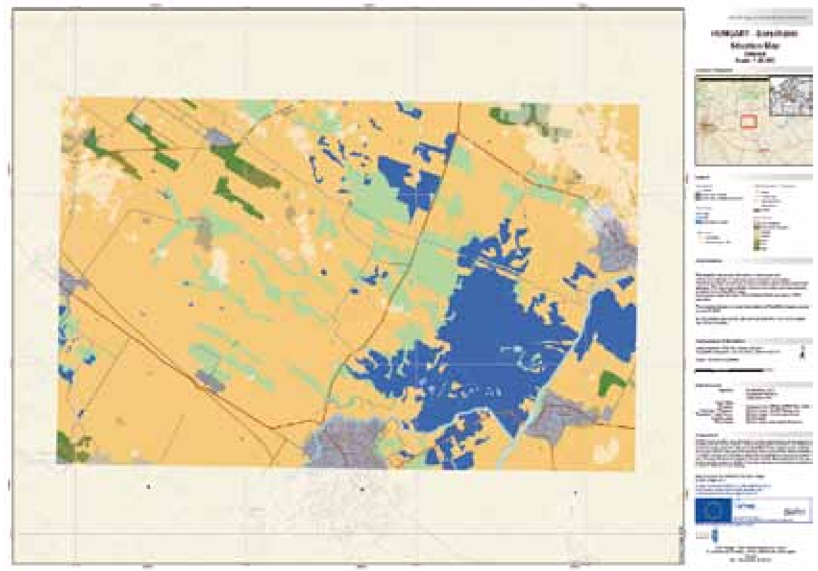

Figure 6: Example of Recovery: Situation map showing flood extents in Jazbereny, Hungary

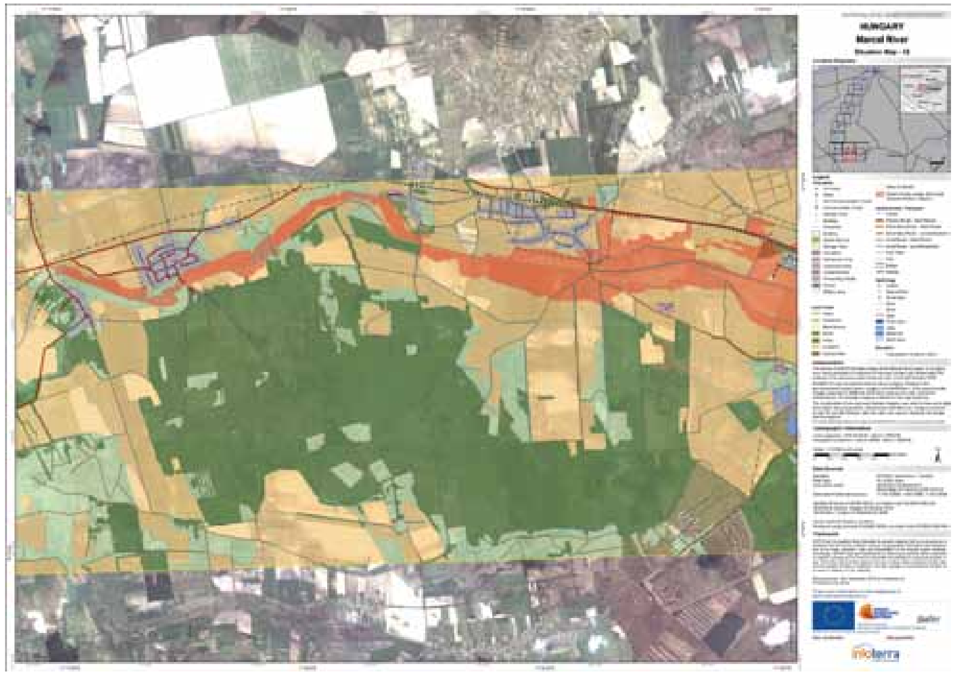

Figure 7: Recovery: Situation map showing location of toxic sludge from tailings reservoir at Kolontár, Hungary

User Feedback: For all products the results from the User Feedback Forms that address 'Usability' and 'Quality and Precision' show user satisfaction to predominantly be very high.

This level of user satisfaction is summarised by the user's response to the provision of 13 maps used for damage assessment and recovery operations in the aftermath of the Kolontár reservoir collapse: "First of all thank you for the final files matching our purposes completely."

> Additional

Background: The Afgoye Corridor is an area described as the world's largest concentration of displaced people, lying north west of the Somali capital Mogadishu it covers an area of over 170 km^2.

User Request: UNHCR required GIS-compatible vector data that would show new settlements and major infrastructure changes.

SAFER Response: Metria used their specialist expertise in the identification of refugee and IDP settlements to extract the required information from newly acquired very high resolution optical imagery. No map sheet products were requested, reflecting, in part, the common use of GIS in larger humanitarian organisations. Deliverables included shapefiles and 2 brief 'movie' created from the satellite imagery of a flyover along the corridor.

User Feedback: UNHCR were highly satisfied with the Usability and Quality of the data provided by Metria and this was reflected in the high ratings featured in the User Feedback Form.

> Summary of positive features and problems encountered

After a slow start in 2009, the uptake of the Emergency Support Service by users in 2010, the collaborative approach between service providers and users to define the product requirements leading to a robust data model, the extensive map production programme and the positive feedback on the products generated can be seen as a success for the Emergency Support Mapping Service.

Problems encountered include delays in EO data supply (which have now been overcome), and extended production times. The latter is a direct consequence of adopting a rigorous approach to data capture and internal quality control (QC). The data capture and QC process is subject to ongoing review and amendment and will be a prime component of the next internal workshop.

CONCLUSION

Emergency Support Mapping provides essential geodata for humanitarian and civil defence agencies, for emergency response mapping and for planning activities (Preparedness/prevention and Recovery). It provides the "backbone" for Emergency and Security Service provision.

Emergency Support (non-emergency mode) mapping plays an important and integrated role in the disaster emergency response phase and in the preceding and subsequent phases of preparedness and post-disaster recovery, rehabilitation and development and is thus key to an efficient and effective future GMES Emergency Response/Security Service.

SAFER

Response to Eyjafjallajökull and Merapi Volcanic Eruptions

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ABSTRACT

After PREVIEW FP6 Project's conclusion, the WP30210 within FP7 GMES SAFER (Services and Applications For Emergency Response) Project has the main objective to refine and consolidate the Earthquake & Volcanoes (E&V) services that were just tested in previous activities and to provide operative services to Users, the Civil Protection Authorities. Here we mainly report objectives and results for the specific tasks related to Eruptive volcanic parameters (WP30211). Four specific products related to the volcanic events which will contribute to the monitoring of the phenomena and mitigation of the eruption effects are expected within the end of the Project. They mainly concern: SAR displacement, high temperature events (HTE), Ash detection, SO_2 concentration and flux, and Ash dispersion models. In particular, here we mostly focus on the activity performed in the occasion of FP7 GMES SAFER activation during two major volcanic eruptions that occurred in 2010. The first activation was for the Eyjafjallajökull eruption in Iceland between April and May 2010, and the second one was solicited in the occasion of the eruption of Mount Merapi (Indonesia) in October-November 2010. Here we present the results of both remote sensing and modeling activities performed during these two events.

SAFER WORK PROGRAMME, METHODOLOGY, MILESTONES

The FP7 GMES Services and Applications for Emergency Response (SAFER) project aims at implementing preoperational versions of the Emergency Response Core Service.

SAFER is specifically addressed to reinforce European capacity to respond to emergency situations: fires, floods, earthquakes, volcanic eruptions, landslides, humanitarian crisis. The overall objectives of the activities in geophysical activities included in WP3 are to develop, upgrade, and validate thematic or crosscutting services and to qualify the most mature ones to be implemented in the pre-operational service provision.

The thematic products and services have been developed in line with the recommendations given by the Implementation Group Report.

They extend the core services (a) by specific expertise coming from the different thematic fields, or (b) by extending the service to cover the entire crisis cycle. These contributions will thus expand beyond the emergency response part of the disaster cycle and cover forecasts and early warning services as well as vulnerability analyses and assets mappings.

The geophysical WP3 activities to large degree take into account and further develop the products and services initiated and implemented in the EU FP6 project PREVIEW (Spinetti et al, 2009). The services previously developed are suited to be provided over large areas (e.g. pan-European), to be transferable from one region to another and to fulfill the criteria of Emergency Response "core" (vs. down-stream) services. The earthquake and volcanoes services provide forecasting of volcanic ash dispersion, the estimation of lava flow effusions rates, ash detection, SO_2 concentration and flux of volcanic eruptions, the mapping of surface deformations and sources in volcanic areas, and the mapping of damages under different earthquake scenarios.

PARTNERSHIPS AND COLLABORATIONS

The SAFER consortium brings together the main European actors involved in the emergency response (users, service providers, scientific teams). SAFER assembles a highly skilled and experienced European network of partners. The SAFER consortium includes key representatives of the main ongoing projects, either integrated projects for EC or GSE projects for ESA, ensuring thus the optimal capitalization of experience. In particular the Earthquakes and Volcanoes work is lead by INGV and supported by NILU and ENS for the generation of volcanoes related activity products and by GAMMA, Eucentre IGAR and Telespazio for the generation of earthquake related activity products. Moreover, the SAFER project has activated collaborations with the Tectonic platform of Terrafirma ESA Project. Indeed SAFER has focused the application of Advanced InSAR (A-InSAR) techniques to the Vrancea region (Romania) to make an analysis of slow movements in a high seismic risk area in Europe. This activity stems from SAFER service evolution as it is related to disaster preparedness efforts. As the Terrafirma project is specifically addressed to such topics this link with SAFER might be strengthened in the next years.

RESULTS

SAFER has been activated to perform activities to mitigate the risk and to support the emergency by satellite services and numerical simulations during two major volcanic eruptions occurred in 2010. The first activation was for the Eyjafjallajökull eruption that occurred in Iceland when explosive activity started on April and ended in May 2010. The second activation was for the eruption of Mount Merapi in Java Indonesia in October-November 2010. In the following the results of both remote sensing and modelling activities performed during these two events are described.

EYJAFJALLAJÖKULL ERUPTION PRODUCTS

The April-May 2010 Icelandic eruption has had a tremendous unprecedented impact on civil aviation in Europe and beyond resulting in billion Euro economic loss and large social impact, especially during the 14-20 April week. On 14th April at 8-9 GMT the eruption started to produce a sustained column reaching a maximum height of about 11 km a.s.l. and a volcanic ash cloud spreading all over Europe. Since the onset of the eruption the INGV staff was part of the permanent *coordination* group that was set up during the emergency by the Italian Civil Protection Department in order to monitor the air-space over the Italian territory.

SATELLITE RETRIEVAL MAPS

Satellite images, from which volcanic cloud quantitative parameters were estimated, came from polar satellite MODIS and MERIS acquired during different phase of the eruption.

MODIS data, free available from NASA, has been used during the week 14-20 April with approximately one day of delay to estimate the presence and the loading of volcanic ash in the North Europe area and the aerosol optical depth (AOT) over Italian territory (Figure 1 and Figure 2). The ash detection in the TIR spectral range is carried out by using the Brightness Temperature Difference (BTD) (Prata, 1989). To reduce the water vapour effects on BTD a correction procedure has also been applied (Corradini et al., 2008; 2010). The ash mass is computed using the formula suggested by Wen and Rose (1994). MERIS provide medium-spectral resolution of 300m of full spatial resolution data operating in the visible and near-infrared (VNIR) spectral range. The aerosol optical depth (AOT) over Iceland area has been calculated (Spinetti et al, 2007; 2008) showing the densely volcanic aerosol drifting S-SE direction on 11 May 2010 (Figure 3).

EMERGENCY RESPONSE

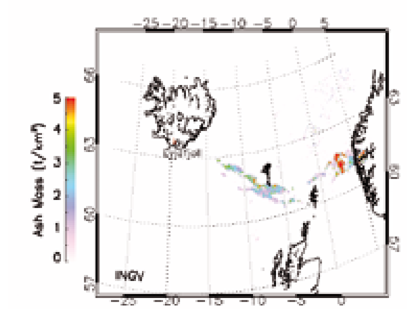

Figure 1: Terra-MODIS volcanic ash mass on 15th April 2010 11.35 GMT over North Europe. The figure shows the ash emitted on 14th April spreading from Iceland to Norway

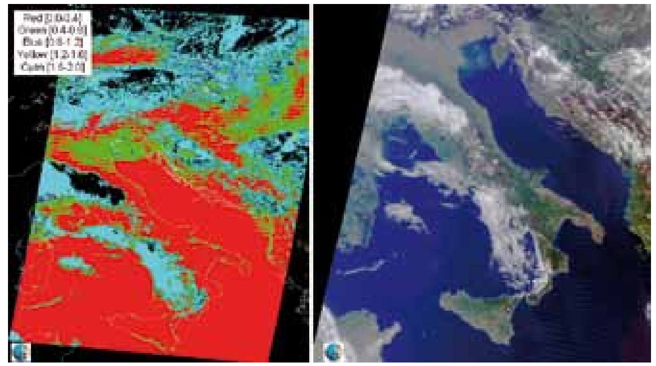

Figure 2: Terra-MODIS on 21th April 2010 9.35 GMT over Italian territory. Right panel shows the MODIS image in RGB composition. Left panel the corresponding AOT showing high values in the Pò Plane (Green color) where airspace was closed

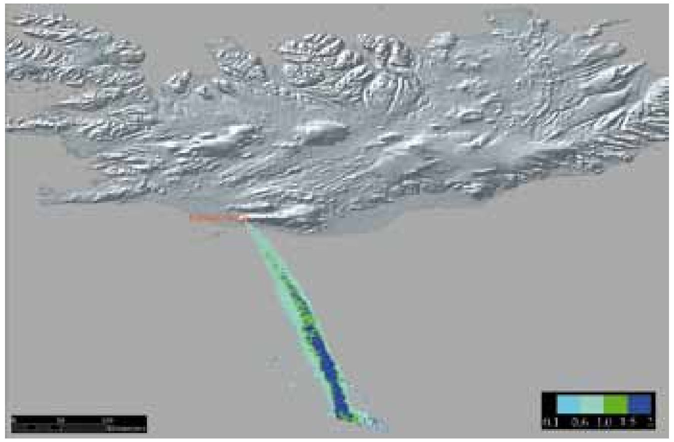

Figure 3: MERIS derived AOT map on 11th May 2010 12.55 GMT over South Iceland. The figure shows the volcanic plume traveling in S-SE direction

VOLCANIC ASH FORECASTING MAPS

The VOL-CALPUFF code (Barsotti et al., 2008) was used to simulate the ongoing activity and to provide forecasting maps of volcanic ash concentration at different atmospheric levels. During the volcanic crisis, as soon as the 72-hours weather forecasting data were downloaded from the NOAA website, the numerical procedure was executed once per day. Further in order to simulate a quite reliable activity and to update the model input data, each day an accurate check of all the available information regarding the eruption intensity and column height on the web was done. Due to the wide extension of the area interested by ash presence we choose to define a 6000X4000km domain extending from 35N to 65N. The standard map produced by the model shows areas interested by those concentration values adopted as new threshold for aviation security by VAACs at International level. They are 2x10-4 g/m^3 and 2x10-3 g/m^3, respectively (Figure 4).

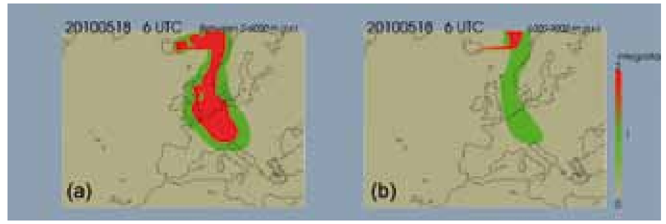

Figure 4: Forecasting maps produced with VOL-CALPUFF model for 18th May 2010 at a specific instant. They show ash presence at two different altitudes: (a) between 0-6000 m a.s.l. and (b) between 6000-9000 m a.s.l. The red area corresponds to ash concentration of 2x10-3 g/m^3 and the green one to 2x10-4 g/m^3

MERAPI ERUPTION PRODUCTS

On October 26th, 2010, Merapi Volcano (Indonesia) started its eruptive activity characterized by multiple pyroclastic flows that killed hundreds of people living in the surroundings.

SATELLITE RETRIEVAL MAPS

Thanks to the activation of a DAP (Data Access Portfolio), satellite images from the data basket of SAFER have been processed and analyzed applying DInSAR (Differential Interferometry SAR) to detect surface displacements (Massonet et al., 1994). Being the Merapi a case-study for another FP7 project named MIA VITA (MItigate and Assess risk from Volcanic Impact on Terrain and human Activities), the derived information have also been delivered to the Indonesian CVGHM (Center for Volcanology and Geological Hazard Mitigation). In particular, we have received Radarsat-2 scenes, pre and post-eruption images, and COSMO-SkyMed data. The analysis of the deformation has been performed in the period from March to October by using Radarsat-2 and COSMO-SkyMed.

Both results confirm a large movement up to 10 m of the Southern flank along SW direction and possibly a subsidence. The crater summit rupture and a new emerging dome have also been detected by exploiting the COSMO-SkyMed very high resolution images (Figure 5).

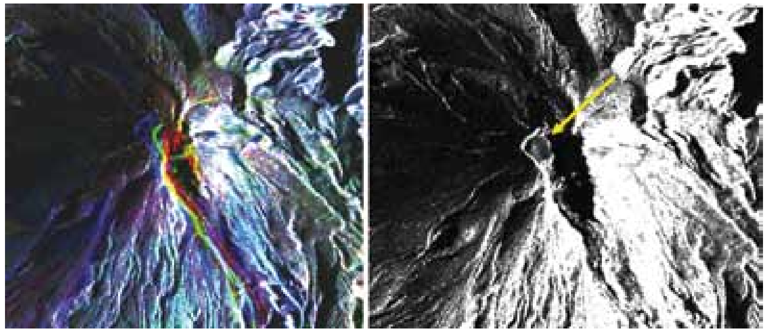

Figure 5: Left image: Multi-temporal analysis in RGB component: R= 1/5/2010, G=31/10/2010, B=8/11/2010. Evolution of the opening from 1st May 2010 (red line), 31th October 2010 (green line) and 8th November 2010 (blue line), after the big event on 5th November. Right picture: Onset of a new dome (yellow arrow)

Even considering the not ideal weather conditions, due to geographical position and season, a systematic analysis has been done based on infrared data MTSAT, AVHRR and MODIS, focused on the identification of the volcanic plume content.

Using MTSAT geostationary data, provided by "Earthquake Research Institute & Institute of Industrial Science U-Tokio", the presence of volcanic ash has been detected in the night between the 3rd and 4th November 2010 IR channels. The technique enables the discrimination of the weather clouds with respect to the ash clouds content (Figure 6). NOAA-AVHRR images, degraded 4 km of spatial resolution, between 24th October to 4th of November 2010 and MODIS images, 1 km of spatial resolution, between 29th October to 4th of November, have been processed for ash detection. A total of 31 images haven't revealed any evidence of ash, probably due to meteorological clouds higher than ash cloud and strong presence of water vapor. SO_2 has been reveled using MODIS bands as shown in Figure 7.

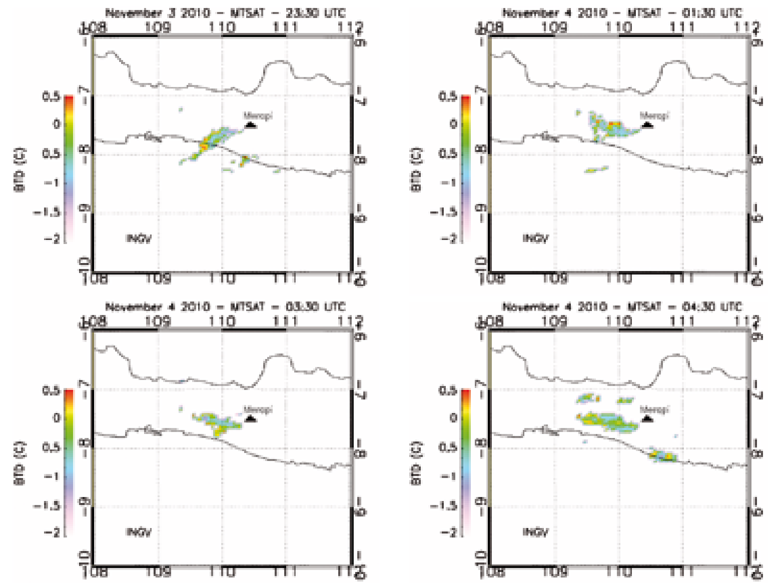

Figure 6: MTSAT elaboration for volcanic ash identification from 3rd November 23.30 GMT to 4th November 04.30 GMT

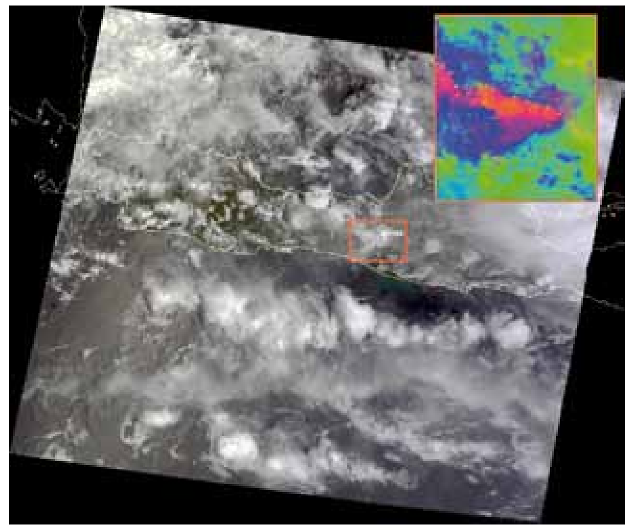

Figure 7: MODIS data on 4th November 2010 03.20 GMT on true colour showing the high presence of clouds in the Java region. Insert panel de-correlation stretching zoom showing contaminated SO_2 release from Merapi

VOLCANIC ASH FORECASTING MAPS

As soon as the eruptive activity shifted to the generation of sustained plumes accompanied by an abundant release of ashes (this occurred since 5th November), the VOL-CALPUFF code was applied to produce forecasting maps of ash dispersal at regional scale. By using weather forecasting data available over Indonesian domain (GFS – dataset from NOAA/NCEP web server) the code was applied to simulate the impact on air and the ground of two plausible explosive events characterized by different eruptive intensities and defined on the basis of the volcano history. In particular we referred to Scenario1, characterized by a 15km column height and an estimated erupted mass equal to $0.26x10^8$ m^3, and Scenario2 with 20km column height and $1.3x10^8$ m^3 erupted volume, assuming a six hours emission duration for both of them. An almost uniform fine grain-size distribution was adopted as initial condition. Under these assumptions, the model produced maps of both aerial ash concentration (each six hours) and the cumulative ground deposition. Figure 8 shows forecasting ash concentrations in atmosphere at different altitudes a.g.l. as produced for Scenario 2 on November 8.

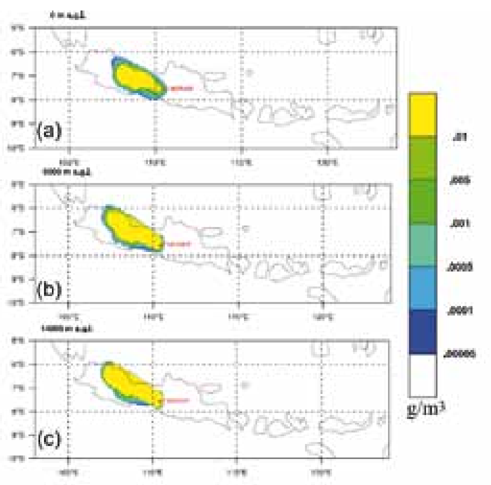

Figure 8: Ash concentration maps produced on 8th November 2010 for Scenario 2 (20km column height assumed). Three altitudes are reported: (a) at ground level, (b) at 6000 m a.g.l. and (c) at 14000 m a.g.l

CONCLUSION

The activation of SAFER for both the Eyjafjallajökull eruption in Iceland between April and May 2010, and Mount Merapi eruption in Indonesia between October and November 2010 has successfully demonstrated the possibility to react and provide products to Users. In the case of the Eyjafjallajökull eruption three newsletters were issued and the first one, issued on 15th April just the day after the explosive activity starts, has been published on the EC website. An official document (newsletter) compiled by the SAFER team was released also during the Merapi activity.

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Security

Keeping Europe safe

G-MOSAIC

Developing Geospatial Intelligence Applications in GMES

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e-GEOS S.p.A.

ABSTRACT

Geospatial intelligence applications are those remote sensed services whose objective is to provide information to the decision making, supporting the operational activities to contrast instability phenomena threatening the world security.

This paper is aimed at showing the main steps toward the development of geo-spatial application for Security within the context of GMES, focussing on G-MOSAIC, a 36 months project that was launched at the beginning of 2009 and funded in the framework of the FP7 for R&D GMES initiative.

In particular this article will introduce the "S" in GMES, with an overview on the political context beyond the Security in Europe and the priority areas addressed by the European policies. Based on those priority areas and the related Security domains, the G-MOSAIC service portfolio has been designed and will be presented in this article. Finally an overview on the running pre-operational scenarios put in place during G-MOSAIC execution will be given, in terms of geographic areas, scope and services deployed.

WORK PROGRAMME

In the framework of the GMES initiative, G-MOSAIC is a collaborative project led by e-GEOS, aimed at identifying and developing pilot services in the context of Security. In particular G-MOSAIC provides services to support Intelligence/Early Warning activities (outside a crisis regime) and Crisis Management Operations (during the different phases of a crisis: preparedness, intervention, post crisis assessment).

G-MOSAIC Services are designed and tailored to meet the needs of those institutions whose mandate is to take part in the peace-keeping and peace-making process under a global perspective:

> General EU Administration, such as the EU Council, the General Directorates and the Agencies
> Member States and National Administration. Including Ministries of Foreign Affairs (and related Crisis Units), Ministries for Internal Affairs acting on Security thematic in cooperation with the European entities on the basis of the subsidiary principle
> The Civil Organizations, ONGs, and the United Nations Agencies

PARTNERSHIPS AND COLLABORATIONS

In order to achieve the goals, G-MOSAIC objectives require a heterogeneous team working together to provide for the project excellent skills concerning the following expertise areas:

> Satellite based Information Services
> Socio-economic, political Themes
> Information Services Infrastructures
> Innovative EO products Research
> Security Systems
> Economic models
> Architectural Models

The Consortium composed of 36 partners is thus made of a balanced share of participation from:

> big industrial groups and European operational institutional entities, that ensure that security related users trust in the proposed services reliability, capacity to handle security issues;
> research actors that guarantee the innovation and the high technological level of the developed products and service chains;
> operational public bodies that are involved in security related activities at European level and
> SMEs bringing in their contributions in non EO information handling, in specific technologies or for the architectural design.

The project was launched at the beginning of 2009 and will last 36 months. In June 2010 a big user workshop was organized at Ispra on the premises of the Joint Research Centre. The audience had a wide range, with users coming from several countries within and outside Europe, ranging from EU entities to National authorities and NGOs.

Currently G-MOSAIC counts around 40 user organizations involved at different level (committed with signed letters, informally involved as observers, etc), that can be grouped in different segments related to the Security dimension:

> 4 EU Entities
> 8 EU National Ministries
    > 3 Ministries of Defense
    > 3 Ministries of Foreign Affairs
    > 2 Ministries of Home Affairs

SECURITY

- > 2 Intelligence Centres
- > 4 Armed Forces
- > 13 International Organizations
- > 8 National Civil Organizations
- > 3 Cartographic Centres

ACHIEVED RESULTS

The European Security Strategy (ESS) is a fundamental document for the European consensus on a long term approach to international cooperation and crisis management.

From a doctrinal viewpoint, the ESS recognises that "preventive engagement can avoid problems for the future", states that "with the new threats, the first line of defence will often be abroad" and then it goes to note that "none of the new threats is purely military; nor it can be tackled by purely military means".

The ESS recalls that Europe's security is compromised, directly or indirectly, by global challenges such as disease, poverty, competition for natural resources and energy dependence, and is confronted by a number of key threats:

- > Terrorism, in particular catastrophic terrorism that acts worldwide and makes use of limitless violence to cause massive casualties.
- > Proliferation of Weapons of Mass Destruction (WMD), in particular in combination with international terrorism.
- > Regional conflicts, which become themselves a source of other threats like extremism, terrorism, state failure, organized crime and WMD proliferation.
- > State Failure often due to bad governance, creating the conditions for other threats like organized crime and terrorism.
- > Organized Crime.

The European Commission and the General Secretariat of the Council have worked together to identify the following areas for action, meeting EU policy requirements:

> Support to EU External Action

Europe needs to improve its ability to detect and monitor trans-regional security threats and to improve its response capacity to emerging crises.

Detection and monitoring of trans-regional security threats, enhancing risk assessment and early warning requires improving crisis prevention tools, preparedness and response capacities.

> Maritime Surveillance

In October 2007, the Commission adopted an Integrated Maritime Policy for the European Union (Blue Book), addressing the need for a coherent policy encompassing all areas related to seas and oceans, ranging from maritime governance to quality of life in costal areas. Interoperability at a European level is necessary to meet the challenges and threats relating to safety of navigation, marine pollution, law enforcement, and overall security.

> Border Surveillance

In February 2008, the European Commission presented a Communication on the creation of a European Border Surveillance System EUROSUR8, with the main objective of preventing unauthorised border crossings, reducing the number of illegal immigrants loosing their life at sea and increasing the internal security of the EU by contributing to the prevention of cross-border crime. The Communication focuses in particular on the surveillance of maritime external borders and contributes to the framework set by the EU Integrated Maritime Policy.

The European Security policies and related priority areas are part of the GMES program, as put in evidence in the EC Action Plan (2001), where it is written that "the GMES initiative aims to respond to the growing concerns amongst policy makers on sustainable development, global climate change, and conflict resolution".

GMES projects entirely dedicated to exploit the satellite capabilities to support security thematic are the following:

- > LIMES, which ended in May 2010, aimed at prototyping innovative security applications both in land and maritime domain;
- > G-MOSAIC started in 2009 and is more focussed on consolidating a user base and concentrating on pre-operational aspects of the forthcoming security services delivery in the field of EU External Action, including contractual models and Service Level Agreements.
- > MARISS, which started in 2007, is entirely dedicated to the maritime domain.

SECURITY DOMAINS AND SERVICE PORTFOLIO

G-MOSAIC has been designed after having reviewed the available technologies and service elements – the so called "building blocks" - as to build up a pre-operational service portfolio aimed at supporting different thematic domains.

Such portfolio is composed by the following services, within the different domains reflecting the European areas of interest and related priorities mentioned above:

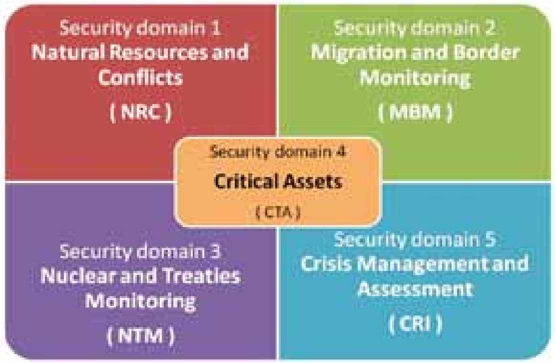

Figure 1: Security domains of G-MOSAIC

> Conflict Related to Natural Resources
    > Exploitation of natural resources
    > Population Pressure
    > Land Degradation
    > Illegal Mining
    > Illegal Timber Logging
    > Illicit Crops
> Migration and Border Monitoring
    > Migration routes and border crossing
    > Coastal surveillance

> Nuclear and treaties monitoring
    > Nuclear facilities and key site surveillance
> Critical Assets
    > Critical Asset Monitoring
    > Critical Asset event assessment
> Crisis management and assessment
    > Contingency Plan Preparation
    > Rapid Geospatial Reporting
    > Damage Assessment for Post Conflict Situations
    > Support Reconstruction Missions After Conflicts Assessment

These domains are complemented by the Maritime one, which is not within the G-MOSAIC scope even if actually within the scope and mandate of many Security Users.

G-MOSAIC SCENARIOS

In order to demonstrate the effectiveness of the G-MOSAIC service portfolio and its applicability to a whole GMES Security concept, a series of scenarios have been put in place with the cooperation of the Users, who participate by providing requirements, context data and information, service assessment. Those scenarios are aimed at integrating different services within the context of specific geographic or thematic boundaries.

Here is a short description of the G-MOSAIC scenarios with some example of products delivered up to now.

EASTERN EUROPE

Security, in particular with regard to border issues, is not just a military issue. Various (civil) risks can threaten the security of communities and nations, such as the destruction of ecosystems, illegal migration and conflicts with respect to border crossing and shared assets. The Service Case "Eastern Europe" provides support to situation awareness concerning different types of border areas ("blue" and "green" border) and critical assets (harbour) along the EU's external frontier.

The objectives are to provide support to situation awareness, monitor activities along borders and critical infrastructure and assets.

> Border area monitoring services have been delivered in the border areas between Poland and Ukraine, Russia and Estonia, Bulgaria and Black Sea.
> Critical Assets Monitoring services have been delivered in the harbour of Burgas and Varnas in Bulgaria, the Lviv Stadium in Ukraine and the Gdansk Stadium in Poland.

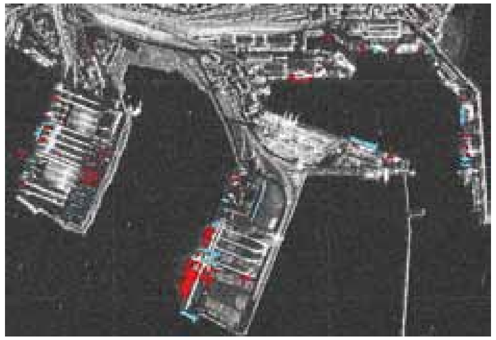

Figure 2: Change detection analysis, Burgas harbour, Bulgaria

DEMOCRATIC REPUBLIC OF CONGO

The Democratic Republic of Congo (DRC) is the third largest country (by area) in Africa located in west-central Africa. The DRC has been at the centre of what could be termed Africa's world war (1998-2003). An UN- supported peace agreement in 2002 and the formation of a transitional government in 2003 brought an end to the five year conflict. Despite the signing of peace accords in 2003, fighting continues in the east of the country and DRC continues to be ranked high in the failed state index (ForeignPolicy, 2009)

The overall scope of the service case is to:

> monitor population dynamics and environmental changes linked to conflicts;
> provide information related to population, natural resources and conflicts at local and regional level;
> improve existing surveillance and situation awareness services for monitoring illegal activities and borders.

The following services are embedded in the service case:

> Exploitation of Natural Resources
> Critical Assets Monitoring
> Border Monitoring
> Illegal Mining
> Illegal Timber Logging

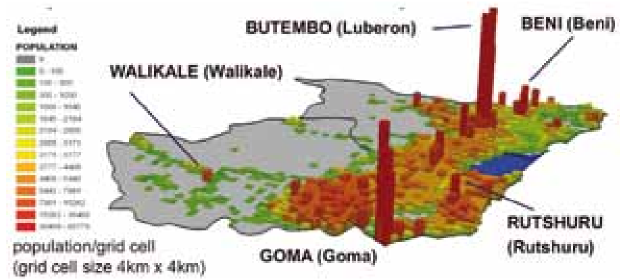

Figure 3: Population distribution map

SOUTHERN AFRICA

This scenario is focussed on Zimbabwe, Mozambique and Swaziland concentrating on the exploitation of natural resources, land degradation and population pressure in support of intelligence and early warning as well as contingency planning information and rapid mapping for crisis management operations.

Spatial indicators are established to investigate the link between environmental and social factors and conflict. Environment and natural resources can play a role in the onset, duration, and termination of conflicts. In other words, conflicts where environmental factors play a role are preceded by key events. The presence of a certain pattern of sequencing events opens the possibility to develop conflict early warning systems.

In Zimbabwe the link between land degradation, population pressure and conflict is investigated with respect to:

> the timeline of conflict development,
> the intensity of conflict,
> scenarios for conflict resolution.

In Mozambique and Swaziland, resource use conflicts are studied. Extensive agriculture activities in the headwaters affect water availability and quality in downstream areas. Indicators will be validated for conflict intelligence and early warning.

The G-MOSAIC services deployed within these scenarios are the following:

> Land degradation
> Population pressure
> Contingency Plan Maps on the city of Harare

ILLICIT CROPS

Drug abuse is a well known world wide phenomenon with UN Member States committed to reduce significantly both the supply of and demand for drugs by 2008, as expressed in the Political Declaration on the Guiding Principles of Drug Demand Reduction.

The production of poppy or opium plant was introduced in Peru some years ago. Currently, there are poppy plantations in the departments of San Martín, Amazonas, Huanuco and Cajamarca (Cortegana, one of the study areas within this service).

Colombia is the world's biggest coca grower and is responsible for 62% of the world's supply of cocaine. Nariño is located in the South-western part of Colombia, at the border with Ecuador. The geographic features of the region include high elevations, as well as coastline. This department has the highest amount of land under illicit cultivation with 24% of the total coca cultivation in the country. The departments of Surbol, jointly with Nariño, Putumayo and Guaviare are the one's where most of the area under coca cultivation can be found in Colombia.

The overall scope of the service case is to monitor and evaluate illegal crop plantations in different sites in order to use this information as a tool for decision makers (poppy in Peru and coca in Colombia). The main goal is to use the Illicit Crop service to locate and quantify the number of plots and hectares with illicit crop cultivation in both countries. The results will be compared then with the reports published by local and/or international organizations.

NUCLEAR AND NON PROLIFERATION MONITORING

The Nuclear and Non-Proliferation Monitoring service case supports efforts for preventing and combating the proliferation of Weapons of Mass Destruction (WMD), verifying the compliance with the relevant treaties. This service case comprises two activities:

> Monitoring of Nuclear areas.
> Monitoring of Conventional weapons.

The objectives are:

> Monitoring of Nuclear areas that are known areas of the world used as storage of nuclear armament, decommission of nuclear material or nuclear facilities will be monitored.
> Monitoring of Conventional weapons at military sites around the world will be monitored to do an analysis of installations, activities, armament, etc.

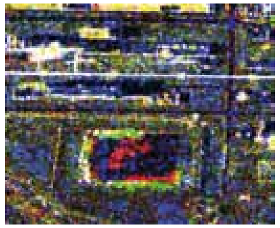

Figure 4 Change detection analysis on nuclear plant obtained by SAR multi-temporal combination

Two service chains are involved in the pre-operational activities:

> Monitoring of nuclear decommissioning sites - the activity in a selected nuclear decommissioning site will be analyzed using VHR SAR data.
> Continuous surveillance of nuclear facility – the activity in a nuclear complex will be analyzed using VHR optical and SAR data.

CRITICAL ASSETS

Critical Assets comprise a wide variety of elements, either manmade structures or natural, whose disruption, destruction or alteration may cause problems for the security of the States and citizens. EPCIP is the EU programme for the protection of such infrastructures ([COM (2006) 786, 787]).

The perception of criticalities varies across countries, time and relevance of economic activities. Critical assets are rather different in African, South American or Asian contexts to those defined for Europe or North America; differences lay in volume, concentration, maintenance, construction materials, assigned security buffers, etc.

Nature can often be aggressive, dangerous, risky or disastrous. Therefore natural critical assets are also monitored. Monitoring of criticalities is often performed within critical timeframes.

EO data are particularly adapted for remote regions with outdated ground information. Products are mainly derived from VHR/HR optical and SAR data, supported by MR and LR processing. VHR EO allows for detailed analysis at infrastructure level; HR EO allows for areal analysis; MR/LR EO allows for trend and NRT analysis.

> Man-made critical assets: objects associated with property and economic activities, mostly coincident with civil engineering critical infrastructures.
> Natural critical assets: natural hazards leading to natural and humanitarian chaos and geomorphologic elements subject to become critical.

Critical assets can be monitored within critical timeframes, image provision allowing:

> Critical Assets Monitoring (CAM) Service: monitoring critical assets to control infrastructures and prevent possible events or actions that may threaten citizens security.
> Critical Assets events assessment (CAE) service: post crisis assessment to support follow up activities, after the detection of security breaches.

PLANNING AND PREPAREDNESS

Within the context of crisis management and assessment operations, the service provided in this scenario aims at providing a global picture when a crisis is triggered. "Crisis" indicates wars, civil conflicts or natural disasters provoking humanitarian emergencies.

A crisis situation requires intervention aimed at preserving peace, the security of EU Member States citizens and, in general, strengthening international security.

The Planning and Preparedness operational scenario answers to user needs related to a "pre-crisis" situation in providing information for:

> planning civil evacuations,
> preparing operational plans for strategic missions.

A typical situation could be the evacuation of EU citizens where satellite based geospatial analysis can improve the preparation of evacuation plans.

The services deployed are the following:

> Contingency plans, aimed at producing city maps, derived from an optical satellite orthoimage with geo-spatial information in support of emergency planning for evacuation and intervention for the greater city area.
> Multitemporal coherent analyses, based on SA, false colour composite images focusing on land use and land cover changes.
> Detailed Land Cover and City Maps, produced from very high resolution satellite orthophoto, IR band, 50 cm spatial resolution.

CRISIS MANAGEMENT

This scenario is focussed on rapid geospatial response in case of a crisis. The service products include both basic cartography information and analysis layers. In order to improve the timeliness of response, the service products are predefined with the intention to cover possible needs for crisis management services when activated in the context of a crisis. Within 72h after data reception, the users receive an assessment of the situation of the crisis area.

The objectives are:

> to provide the user with fast and reliable information about the situation post event in an area,

> to introduce research geospatial techniques into an operational workflow,

> to produce geospatial intelligence information beyond the geographical nature of data.

The services delivered are:

> Reference mapping: All the information based on pre-event data that could be valuable (e.g.: landmark buildings, areas suitable for a particular purpose...),

> Assessment analysis: All the information based on post-event data reporting the situation during the first moments of the crisis,

> Secure Information: Allow the user to control the flow of information ensuring the confidentiality of data.

Figure 5: Damage assessment, Tlachuano, Haiti

POST CRISIS ASSESSMENT

Directly after a crisis or catastrophe fast information about damages to infrastructure and affected areas is needed for immediate relief and to assess the general situation. This analysis is expected rapidly, tolerating a higher error margin. A more detailed analysis with much higher accuracy has to be conducted for a more intense assessment to plan consequent recovery operations.

SECURITY

During the rehabilitation and reconstruction phase, the developments need to be monitored. Especially a supervision of an appropriate utilization of the allocated funds is of interest to the donor community. Both analyses are carried out in the Service Case "Post crisis assessment".

The damage and reconstruction of buildings and infrastructure is only an example, the categories to be monitored will be reviewed on a case by case basis. The long-term objective concerns the assessment and monitoring of factors such as environmental degradation, which has been proven to play a crucial role in the development of conflicts. For conflict resolution and peace building the reconstruction of societies requires interdisciplinary spatial information. One specific aspect is the availability of land for agricultural production and water resources to support society.

The overall scope of the service case is to:

> Damage assessment for post conflict situations: e.g. assessing and analysing actual damage to infrastructure and destroyed buildings.

> Monitor reconstruction after conflicts: e.g. assessing the effect of reconstruction missions by analysing new buildings in formerly destroyed areas.

> Assess and monitor environmental factors playing a crucial role for conflict development as well as for conflict resolution and the peace building process.

The following service chains are embedded in the service case:

> Damage assessment for post conflict situations.

> Support of reconstruction missions after conflicts.

CONCLUSION

Satellite based geo-spatial information is an important tool to support the authorities involved in Security and Stability processes and related activities.

The European needs in terms of Security Services are linked to the policies addressing the role of Europe and Member States in the global security picture, including the terms for participation in the peace-keeping and peace-building operations.

The GMES program is aimed at promoting and funding the spatial research to stimulate the set up of operational services tailored to the needs of the user communities involved in both the decision making process and in-field operations.

As part of the initiatives funded within GMES, the G-MOSAIC project has the purpose of consolidating a pre-operational service portfolio matching user needs, thus bridging the research activities with the future operational phase of the Security services.

To this end there is the need to understand in deep the operational scenarios in which users are involved, as to design and implement end-to-end service chains covering all aspects of operations: input data procurement, operational workflow, architecture, management of operations, contractual issues and Service Level Agreements.

SECURITY

G-MOSAIC

An Experience on Rapid Mapping inside GMES

The approach of the Rapid Geospatial Reporting Service of G-MOSAIC

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European Union Satellite Centre

ABSTRACT

RGR (Rapid Geospatial Reporting) is a Rapid Mapping Service orientated to provide users with relevant geo-spatial information in the context of a crisis happening anywhere in the world at any given time. It aims to cover the whole chain of geo-information creation in rapid mode, taking benefit of the collaborative workflow schema of the service and a thorough understanding of the end-users needs.

It is enclosed in the G-MOSAIC (GMES Services for Management of Operations, Situation Awareness and Intelligence for Regional Crisis) project. This GMES (Global Monitoring for the Environment and Security) Project is aimed at developing and delivering pilot security related services. G-MOSAIC is a project within the 7th Framework Programme (7FP 2009/2013) co-funded by the EU Commission and framed in GMES.

This paper will put an accent on the main characteristics of the service and the philosophy behind it.

WORK PROGRAMME

G-MOSAIC project focuses on GMES Security Dimension, including regional crisis, therefore addressing global challenges linked to external security, in line with the European Union's External Action.

The scope of the RGR service is to support efforts for the management of a crisis situation, both for planning evacuations or deployments and to assess the assets status in the area.

The RGR service deals with the immediate reaction to a crisis (within the first hours of a short crisis, or longer for an on-going one). The RGR service will provide enough data for decision makers in order to make a first assessment on the delivery of people or material to the area. Although each crisis scenario is different the key factor of this service is the time response. Standard data schemas have been prepared, as well as all possible beforehand information that does not relate to any particular AOI (Area of Interest), as a crisis may happen at any location, but the RGR products may considerably vary from one activation to another to adapt itself to the specific event and to the user needs.

This service is 24 hours and can be activated at any time. The service products are produced on a continuous basis. The delivery starts few hours after the arrival of imagery.

In case of complex emergencies (OCHA definition: "humanitarian crisis typically characterized by extensive violence and loss of life, massive displacements of people, widespread damage to societies and economies, and hindrance of humanitarian assistance by security risks and political and military constraints."), synergies with other GMES Services will be put in place as described in the following section.

PARTNERSHIPS AND COLLABORATIONS

G-MOSAIC as part of GMES is related to other projects, either past or present. G-MOSAIC inherits the knowledge of previous projects (such as LIMES) and expands its previous achievements. Also, in some cases, G-MOSAIC shares common goals with other projects currently on going, such as SAFER (Services and Applications for Emergency Response).

The experience has proven that emergency and security events cannot in many cases be dealt with in a separate manner.

The European Union Satellite Centre (EUSC), the coordinating body of G-MOSAIC project's RGR service, has been fostering a proposal to implement a synergy between the GMES Emergency and Security on-going projects (namely, the "Proposal for Synergies G-MOSAIC – SAFER"). Both projects and the EC have been carrying on their mutual collaboration, recognising it as an absolute necessity and priority.

SAFER's pre-operational capabilities in the provision of Reference and Rapid Assessment Mapping can be exploited to provide a fast and reliable base to G-MOSAIC, which can add value to the product by including layers of information specifically security-related, such as e.g. gathering areas, helicopter landing sites, infrastructures analyses and so on. Conversely the Civil Protections and all SAFER users can take advantage of the additional layers of information produced by G-MOSAIC. This approach has the advantage to both optimize the resources available by the two projects and provide the user with a coordinated and as-fast-as-possible response and with the highest quality assurance. This is believed to be able to supply the best support to in-field operations.

Several entities are brought together in the context of the G-MOSAIC project, as well as in the RGR Service. The partners that currently participate in the RGR Service are E-Geos, SPOT, INDRA, GMV, PLUS Z-GIS and the EUSC, coordinator of the service.

The approach for the provision of the service focuses on the high specialization of several partners. The reaction of the RGR Service is centralized and coordinated by the EUSC. This approach has several advantages:

> *Homogenizes production.* Final products are seamless and homogenous among different activations because the integration and design of production are centralized.

> *Maximizes knowledge specialization.* Each partner contributes to the service provision from its specific field of expertise.

> *Increased expertise sharing.* By working a cooperative way, partners are aware of the overall view of the service, serving as a good background for synergic growth of expertise among partners.

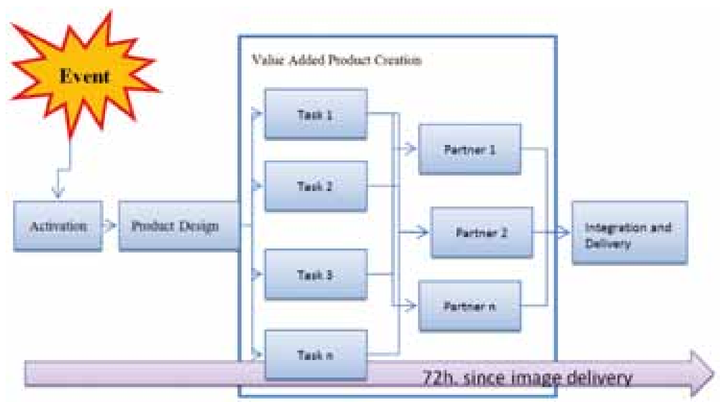

Figure 1: Multi-Partner approach

ACHIEVED RESULTS

The service can be subdivided in components that represent the different phases of a complete workflow of geographic information (Figure 2).

Figure 2: Service Components

DATA ACQUISITION

Since the essence of the service is to react to particular events, EO (Earth Observation) data are the most comprehensive and fast data source for RGR's goals, being the basis for work of the RGR service. Nonetheless, any information previously available will need to be confronted with after event information.

Because of the nature of EO, the acquisition phase is the less operational of the whole chain. This is due to the fact that several elements outside the chain of work can affect this process.

> *Atmospheric Conditions:* Optical sensors cannot capture data through clouds.

> *Capture Conditions:* As the satellites orbit, they capture imagery as they pass by the AOI. Furthermore, if a comparison between imagery from the same satellite is needed, then the "revisit time" (time between two passages of a given satellite over the same spot) needs to be taken into consideration.

> *Political Restrictions:* Covering for information anywhere in the world implies that some events might happen in locations where the commercial distribution of satellite imagery is not allowed or somehow restricted.

> *Distribution:* The quantity of vendors involved in the procurement increases the complexity of the process. Each vendor covers a certain number of sensors, and a service like RGR can potentially need all available in the market.

In order to tackle these potential problems, the RGR service relays on GSCDA (Ground Segment Coordinated Data Access) service of the ESA (European Space Agency) for the acquisition of satellite imagery. This service offers one centralized point of contact for satellite imagery procurement using a multi-mission approach that can help minimizing all these potential problems. One central point of contact can reach off-line agreements with distributors, ensuring the provision of all sensors in the market.

The RGR coordinator is in charge of connecting the requirements of the different partners responsible for the provision of the service and the data procurement order.

Beyond the acquisition of satellite imagery, there are other EO possibilities that in given occasions can become a very useful source of information. For example, whenever available, pre event photogrammetric flights can provide with an increased spatial resolution.

GENERATION OF VALUE ADDED PRODUCTS

The generation of Value Added Products is the core of the RGR Service. With the input provided in the data acquisition phase, products are generated attempting to meet user needs. Requirements are read and products designed accordingly, trying to match quantity and quality of data to the deadline.

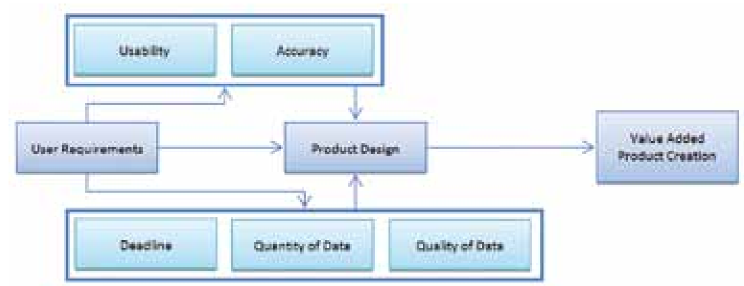

Figure 3: Value Added components schema

In an emergency situation, the requirements gathering become an exceptionally relevant phase, precisely because of its scarcity. Users demanding such service are under the stress of responding fast to a given event. Requirements are far from a description of the products but rather a description of the action the user needs to perform. This is the reason why in Figure 3 some requirements were represented outside the User Requirements. *Quality constraints, Accuracy,* etc. are concepts that will be rarely specified by a user who is in a rush. The RGR service offers specialized expertise coordinated to meet the user needs rather than a set of standard pre-defined products.

As an example, in the first moments of Haiti Earthquake, several users contacted the RGR service and the EUSC in request for the service with different requirements. These requirements are summarized in Table 1.

User	Requirement
Spanish Red Cross	Deliver Help in the field
United Nations (UN), Italian MoD, Italian MoFA	Assess the extent of damage and support operations in the area
UN	Assess the accessibility and damage extent in surrounding areas such as Leogane and Jacmel
Dutch MoD	Assess whether airport and harbour in Port-Au-Prince are operational for landing or docking

Table 1: Haiti User Needs

The analysis to be performed, the density of data, the geometries to be used, the layers of information to be created… all this fall in the side of RGR service. And this process is what is known as *Product Design*.

The *Product Design* is essentially the matching of the user needs with the production requirements. It affects from the definition of layers to the actual creation of data. Product Design must balance *Quantity*, *Quality* and the *Time constraints*. *Time* is, in the case of crisis response, a major limitation that cannot be negotiated. For this reason products need to be designed balancing enough quantity to cover the AOI with enough quality.

The products are designed trying to maximize accuracy and usability. Scalability, instead, is sacrificed in order to reduce production time and thus increasing quantity of data produced.

SECURITY

With the requirements mentioned in Table 1, gathered and centralized, several products were designed to respond to these needs (Table 2).

Product	Description
Port-Au-Prince Damage Assessment	Map Series and Overview mapping based on manual interpretation representing the spread and intensity of Damage
Port-Au-Prince Trafficability	Map Series representing the status of roads and streets by segments. Along with this, location of spontaneous gathering areas in the product to provide help for delivery of help
Port-Au-Prince Airport Report	Detailed briefing note on the operational status and features present in the airport
Port-Au-Prince Harbour Report	Detailed briefing note on the operational status and features present in the harbour

Table 2: Some of the G-MOSAIC RGR Haiti Products

But Product Design goes beyond the definition of the product. The highest impact, what will make the difference between a useful or a useless product, will lie at the technical level on how the product is produced.

We could take as an example the Chile earthquake of February 2010. RGR was required to provide information for the area of Concepción and Talcahuano. The area was impacted by two destructive events. After the earthquake (8.8 M_w) the coastal area of the north was impacted by a tsunami. For this reason, damage in the area was very unevenly spread. Using the same techniques for damage assessment in both areas would not have been the best approach for the following reasons:

> The earthquake affected mainly an urban area, and for that reason related to a transportation network, and organized in built up plots, while the area affected by the tsunami affected industrial or touristic areas.

> The nature of damage of the tsunami was highly heterogeneous and intense (boats pushed in the land, flooded areas, damaged infrastructures…) while the damage of the earthquake was homogeneous and not that strong (collapsed or damaged buildings).

Any method trying to represent both in the same way would loose representation of damage. Therefore, RGR decided to provide the user with two different damage assessments, one for the earthquake (Figure 4) and one for the tsunami (Figure 5). As it can be seen, the final products represent the same concept (damage) in a different way.

Figure 4: Urban Block damage assessment orientated to represent the damage of the earthquake produced by RGR.
© Digitalglobe 2010 provided by e-Geos under EC/ESA GSC/DA

Figure 5: Detailed Damage assessment in coastal area, orientated to represent the damage of the tsunami produced by RGR.
© Digitalglobe 2010 provided by e-Geos under EC/ESA GSC/DA

QUALITY CONTROL AND INCLUSION OF OTHER SOURCE OF DATA

Quality Control inside a rush mode process is a tough issue. A quality related process aimed to quantify the adequacy of a dataset to given conditions must meet some requirements that may jeopardize production in a rush environment:

> To be *external* to the production chain and to be *quantitative*. Regardless of how streamlined the process is, a relevant quantitative process will require an overlap of analysis. If a parallel group of resources is available, product will increase usability by increasing area of coverage or by deepening the density of data,

> To be *objective*. Any objective procedure will disregard the particularities of an emergency.

Most product design decisions must be taken at the moment of the activation, because it is impossible to predict where the meaningful information will be, or what data it will be feasible to create. In an emergency procedure, products to be released are engineered in the moment of the activation in order to fulfil user requirements. The availability of inputs and requirements is never guaranteed in such short time frames.

Quantitative external validation is not suitable as a quality control of rush mode environment, so an alternative to ensure the quality of the product must be applied. *In-line quality control*, orientated to the procedures rather to the products, can still be applied. In a nutshell, *Product Design* encompasses the decisions related to all the steps of the production orientated to meet the requirements of the user, and *In-line quality control* refers to internal quality control orientated to the processes rather than to the products.

Data Extraction, defined as "The process of analysing input data and outputting a dataset" can either be Manual, Automatic or Semi-automatic. Regardless of the modality of the process, Data Extraction needs extraction criteria. Definition of extraction criteria (whether parameters for an automatic algorithm or instructions to an operator) can be a very lengthy process whenever time allows. In the context of a rush-mode activity, extraction criteria must take into consideration:

> *Quantity of Data:* Good extraction criteria in a rush-mode situation will be designed to increase the quantity of data generated.

> *Quality of Data:* Extraction criteria must be *Error Minimization Orientated*. This means that, in order to achieve an acceptable level of quality, the criteria must preference the safest way, sacrificing if necessary density of data.

> *Time:* Extraction criteria will always take into consideration the deadline.

For this reason, the requirements for the extraction criteria need to be clear enough to avoid misunderstandings or classification confusion, detailed enough to avoid missing information and light enough to ensure production rates are met.

An example of this can be seen in the creation of a damage assessment product for Haiti. This product would be designed following the next premises:

> Relevant information for the user is the damage distribution connected to the transportation network.
> Each urban plot will be classified with a value representing destruction.

This method provided good results in the beginning of the operations, but is still improvable. This method has major flaws that could be improved:

> *Lengthy:* Requires the operator to search for highly destroyed buildings and then make an averaged decision about each parcel regardless of the size, which is also subjective and too error prone.
> *Inflexible:* Once the data is created, it cannot be modified but by the same method used for the data extraction.

Instead, Figure 6 and Figure 7 propose a different approach to obtain the same product. After first testing on the methodology used previously, the extraction criteria was changed.

Figure 6: Port-Au-Prince, with identified destroyed buildings. © Digitalglobe 2010 provided by e-Geos under EC/ESA GSC/DA

SECURITY

Figure 7: Port-Au-Prince Damage Assessment derived from point layer of destroyed buildings - © Digitalglobe 2010 provided by e-Geos under EC/ESA GSC/DA

The operator was given the very basic instruction of extracting destroyed or highly damaged buildings. After that, the final product for extraction would be what can be seen on Figure 6, a cloud of points represented damage. This, of course, is not a good product, as it is not finalized. The final user would need to process mentally the distribution and intensity of damage.

For this reason, another step is taken to create a proper representation. Each parcel will have an assigned ratio of damage obtained from the relation of destroyed buildings and surface.

This method has several advantages:

> *Accurate:* By simplifying the instructions, the error is reduced.
> *Fast:* Once destroyed buildings are localized, no further decision needs to be made.
> *Flexible:* Each parcel will have a different damage ratio value. This way, representation of damage can be changed depending on the clusters present in the dataset without altering the manual extraction.

As seen, an internal quality control focused on the process defined by the Product Design has the highest impact in quality, while still being feasible.

SECURITY

DISTRIBUTION

Distribution can make the difference between a successful activity and a useless dataset, regardless of its technical quality.

The philosophy of the RGR service is to maximize the distribution of datasets created during activation as long as security related constraints allow. This is done through three different approaches:

> *Format of delivery:* To its users, RGR provides not only with cartographic products, but also with any mid-level product, such as vector or raster datasets, increasing the usability of the service, as the user will be able to reuse and combine this information.

> *Mean of delivery:* Redundancy in delivery is the best way to ensure information reaches all necessary places. Project website, G-MOSAIC Common Portal application for user or FTP is the ways to access the information.

> *Community:* Whenever the situation allows, information is also made public beyond the users activating the service (like in the case of Haiti or Chile).

Although GMES cannot deal with classified information, the RGR Service, according to the policies adopted in the G-MOSAIC project, can guarantee a minimum level of confidentiality and can treat the activations as "G-MOSAIC restricted" if needed. This basically means that a "need to know" policy will be adopted which implies that nobody but the project partners involved in the service provision and the coordinator (and upon request the European Commission) will be informed about the task, the area of interest and the requester.

The project infrastructure and the GSC-DA were designed taking into account specific recommendations to guarantee the possibility to limit the access to the information upon user request. It addresses procedures and architecture aspects.

Several requests have successfully been treated with the "G-MOSAIC restricted" clause.

Users are continuously feeding back the operational chain of RGR. They expressed their satisfaction with the service, as it can be seen in this example:"...I would like to stress the fact that the activation of the G-MOSAIC project has been a great opportunity to successfully test how a GMES (EC-FP7 funder project) can efficiently contribute, in the operational domain of Rapid Service Provision, to having the "end-user perspective" fully met during the disastrous earthquake that has severely affected to the peoples in Haiti." - Kyoung Soo Eom, Chief Cartographic Section, UN.

CONCLUSION

The activities and the philosophy of the RGR (Rapid Geospatial Reporting) Service of G-MOSAIC have been described and illustrated with several real/practical examples.

> Service Orientated. The RGR service understands that the information created during a crisis has a contextual value for that crisis. The accent of value is on the service itself, on the availability to react in short time, providing the appropriate information to support decision-making.

> User needs driven. The RGR service is at all times driven by the user needs. The communication with the user is continuous during the activation and the products are designed on-line to perfectly fit the user needs.

> Centralized Approach. Synergistic knowledge. With the help of a central point of view, the specialized knowledge of each partner obeys always to a common Product Design that allows a true synergy of different fields of expertise.

> Integrated in GMES. The RGR Service plays an active role in coordination with other projects and service of GMES through an approved guideline for synergistic approach on complex emergencies.

> Confidentiality. The RGR Service integrates protocols to keep information confidential whenever requested by the user.

The characteristics of the philosophy of RGR affect every aspect of the service, from general policy implementation to technical issues. The RGR service is on its way to create a sustainable service of excellence, contributing to support decision-making and operations in the rush situations. It is an example of pre-operational service that could be straightforward transferred into an operational service.

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G-MOSAIC

Use of Earth Observation and ancillary data for Sub-national Conflict Analysis

A Case Study in the North Kivu Province of the Democratic Republic of Congo

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ABSTRACT

In the last decade there has been an increased focus on security of individual people (UNDP 1994). At the same time, a number of studies have examined the potential role of environment and natural resources in starting or prolonging conflicts. Both approaches depend on information about environment, demography and conflicts which is mainly available at national level. Although there is a consensus that civil conflicts should be studied at subnational level, statistical and spatial datasets at subnational level are only available for a limited number of regions. Our study draws upon earth observation (EO) and geographical information systems (GIS) to study the relationship between natural resources and conflict in the Kivu Provinces of the Democratic Republic of Congo (DRC). EO and GIS can provide relevant information to examine potential links between population, environment, natural resources, and conflict. First, we present a theoretical framework for environmental conflict onset developed within the G-Mosaic[6] project; secondly, we describe preliminary results of our analysis of the links between population, environmental and resource factors and lastly, we draw some tentative conclusions.

WORK PROGRAMME AND METHODOLOGY

> Conflict analysis using earth observation data

This study examines natural resources and conflict at sub national level, using theoretical assumptions about environmental conflict, statistical and spatial data and models as well as earth observation (EO).

6 European Community's Seventh Framework Programme (FP7/2007-2013, grant agreement N°218822).

Theoretical models make assumptions about how and why conflicts may arise and why they may continue or recur. Statistical models compare sets of countries over a period of time using statistical information about their economic performance and developmental status and compute the probability of a conflict occurring as a result of such long-term performance factors. Conflict datasets are collections of information about conflict events, actors and locations, which can be used to monitor conflicts in the short term. EO technology can provide accurate, georeferenced, quantitative and relevant information to better localise where people are situated at a given time. Population distribution models integrate demographic data from statistical sources with land use information derived from EO data. EO data can also be used to monitor the changes in the natural environment which might be relevant for the cause of a conflict. All these elements can be combined in a system for monitoring natural resources and thus help to prevent conflicts related to lack of these resources.

Some statistical models have been built to assess quantitatively the risk of conflict both on the global and on the regional level. At the global scale Burnley et al. 2008 provided a tool to predict the risk of conflict at country level using existing open source global datasets. The model uses national statistical data reflecting the political, economic, social weakness or strength of a country, and capacities to manage conflict. According to this model, the DRC is at high risk of conflict in the future. However, as contemporary wars are mainly country-internal conflicts, any statistical study of wars that applies country-level statistics is "potentially flawed" (Buhaug and Rod 2005). Unfortunately statistical and spatial datasets at subnational level are only available for a limited number of regions. Stephenne et al. (2009) proposes a data driven methodology to assess probable regional drivers of instability in the Caucasus region. The statistical model built at this regional level predicts the risk of conflict at the level of district within the Caucasus region.

EO provides a source of geospatial features that are used in natural resource assessment and population density estimations. Satellite imagery is used to produce grid-based and raster datasets for socio-economic and environmental indicators. Datasets of physical factors that relate to security like land cover, natural resources and population can be built or improved using these EO data. GIS tools combined with satellite imagery can provide a continuous spatial representation of variables such as density of population, distribution or ethnicity, land cover or natural resources among different layers. GIS provides both the structure to build grid based datasets and the tools to integrate and overlay different datasets and to produce spatial indicators. A growing number of studies use GIS-layers generated from physical and socio-economic data to define the determinants of violence at local level, such as illegal mining of gemstones and the illegal cultivation of illicit crops.

> G-Mosaic Environmental Conflict Model and Indicators

The G-Mosaic theoretical model outlined by Maas and Alklin (2009) assumes that population pressure, due to population growth and density may be associated with conflict. It also assumes that resource depletion due to environmental degradation leads to resource scarcity which can lead to national/local conflicts over resources IF national/local resource management is poor. The main assumptions used are: conflict might be greater in more populated areas or near locations where natural resources such as land and mine sites are being exploited. Our study planned to derive a time series of EO data on the exploitation of natural resources, population numbers and environmental degradation. A time series of the EO data can be used to test if changes precede or are associated with conflict events. Similar approaches have been used in other global level studies, such as Raleigh & Urdal (2007), which uses land degradation and water availability data to investigate conflicts related to resource scarcity. The time series information is used to test if changes in indicator values precede or are associated with conflict events taken from the Armed Conflict Location and Event Dataset - ACLED[7].

Accordingly, we defined three indicators: Exploitation of Natural Resources (ENR), Population Pressure (PP) and Land Degradation (LD). The indicators are designed to monitor exploitation of natural resources such as minerals (ENR), concentration of population within a region (PP) and changes in the land cover classes agriculture, natural vegetation and forest (LD). Table 1 shows the variables derived from EO data and obtained from other sources.

Variables	Description
Conflict intensity	Number of conflictive events in any given district or grid cell at any given day
Conflict	Existence of conflict in a given district or grid cell in a given day
Land degradation	Existence of change in land cover LD in a given district or grid cell or defined polygon
Land degradation intensity	Value for change in land cover LD in a given district or grid cell or defined polygon
Extraction of natural resources	Existence of mine location within a grid cell, district or defined polygon
Population	Number of individuals within a grid cell, district or defined polygon, categorised into high and low

Table 1: EO and Non EO Variables

7 www.acleddata.com

> Conflict situation in the Democratic Republic of Congo

The DRC is still suffering the impacts of extended, intensely violent conflict. Most known deposits of strategic mineral resources are found in the East and South of the country. In Eastern DRC, control over areas with mineral deposits has changed hands several times between different armed movements and army units (UN 2009). Monitoring and management of natural resources is often inadequate or nonexistent in conflict areas of the DRC. Therefore, more detailed and better information is needed on the legal and illicit exploitation of natural resources and any relationship between natural resources and conflict.

Our study focuses on the two Kivu provinces in Eastern DRC.

> Population estimation

Population is an essential dataset and given the absence of up-to-date census data we make use of existing estimations. The large scale population dataset LandScan™ [8] is the georeferenced dataset most widely used for such applications. However, a specifically adapted methodology was developed within G-Mosaic in order to obtain population estimations at the same scale as LandScan, using datasets without copyright restrictions. The technique combines EO and socio-economic information using specific assumptions about spatial patterns. Based on the disaggregation of CIESIN Gridded Population of the World v3[9] (GPW), population distribution has been calculated and mapped for North Kivu province.

The G-Mosaic population distribution is derived via a disaggregation of modelled population figures for 2010 from the GPW. This disaggregation is done following a weighted procedure that is determined by Land cover information (derived from EO data) and location, area and type of villages. Total population figures are projected in a one square kilometre grid. The model results in a GIS grid database where each cell contains a number of inhabitants. The input data are:

- Landsat data from 2005-2009
- Gridded Population of the World v3 – modelled figures for 2010 (CIESIN, CIAT)
- Land Cover classification from 2000 ("Carte de l'occupation du sol de la République Démocratique du Congo, UCL-Geomatics (Louvain-la-Neuve, Belgique) 2006".)
- Ancillary data from RGC (Le reférentiel géographique commun en RD Congo www.rgc.cd): Point layer populated areas based on GPS, satellite and existing maps, roads, rivers and lakes

8 Global developed by Oak Ridge National Laboratory, http://www.ornl.gov/sci/landscan.
9 Center for International Earth Science Information Network (CIESIN), Columbia University; and Centro Internacional de Agricultura Tropical (CIAT).

A visual comparison between the G-Mosaic population map and the LandScan dataset shows the differences between the datasets (Figure 1).

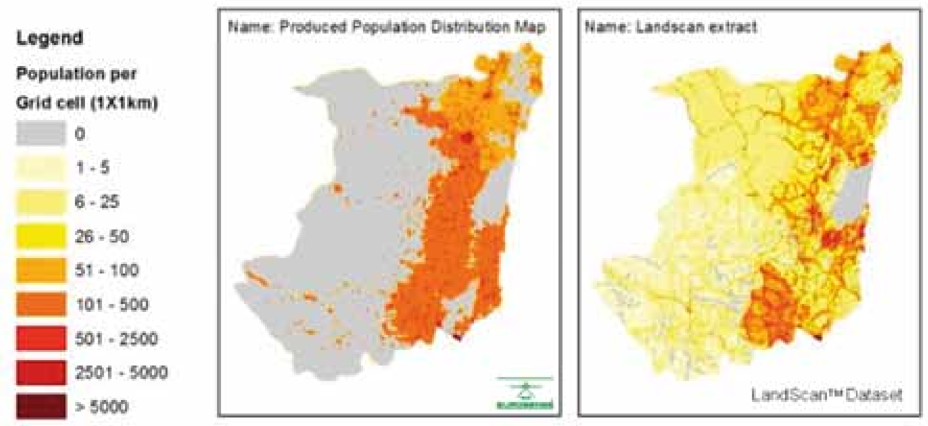

Figure 1: Comparison of the G-MOSAIC population map (left) and the Landscan dataset (right)

The different approaches followed clearly result in different products. The G-MOSAIC population map assumes that in the western part of the province only the village areas extracted from the point layer are inhabited. Areas covered by dense forest are assumed to be difficult to access and are therefore considered not inhabited in the G-Mosaic population map. While the processing chain of LandScan puts an important weight on the road layer, the modular method proposed by Eurosense in G-Mosaic does not include such a dataset but focuses on a hierarchy of populated areas (villages, small and bigger towns) to derive the pattern of population distribution.

The different census population data used as input for both models can have a large influence on the final results. The population figures of both models are in the same range, both on province level as on territory level. The most recent population census data that could be found is from 2005. According to these data the total population of N-Kivu was estimated at 7.460.642 people. (Source: Union de Congolais pour la Défense de la Patrie et du Peuple (UCDP). The population estimation of the UCDP is based on the assumption that registered (potential) voters as of 2005-12 represent exactly 33% of the population in each province.

Further validation is necessary to determine the accuracy of the dataset. However, the lack of good validation data for these regions is a real difficulty. The absence of reliable and actual regional population census data hampers both calibration and validation of the G-Mosaic population model. Nevertheless, we know that the G-Mosaic population model takes into account the known populated places, the delineation of large populated places based on satellite imagery and the population density linked to Land Use classes. Based on this knowledge together with the observed correlation with the LandScan dataset, we can assume that, in expectation of more detailed and reliable validation data, the G-Mosaic population map can be accepted as a usable product for the area.

> Environmental Degradation

The measurement and detection of changes at the land surface potentially reflecting land degradation is performed using multitemporal medium resolution EO data for two dates in time (2003 and 2008). Given the context in DRC described earlier we are focusing on changes in specific land use and land cover classes.

We use a semi-automatic method, which combines object based segmentation of landscape elements and pixel based change detection. The class definition aims at providing a link to the widely used Africover classification schema (FAO 2003). The results from land cover classification and change detection are aggregated based on the direction of change (de- or increase) and the major land cover classes (agriculture, forest and shrub or grassland). Figure 2 shows the result of this analysis performed for three territories in the area of interest.

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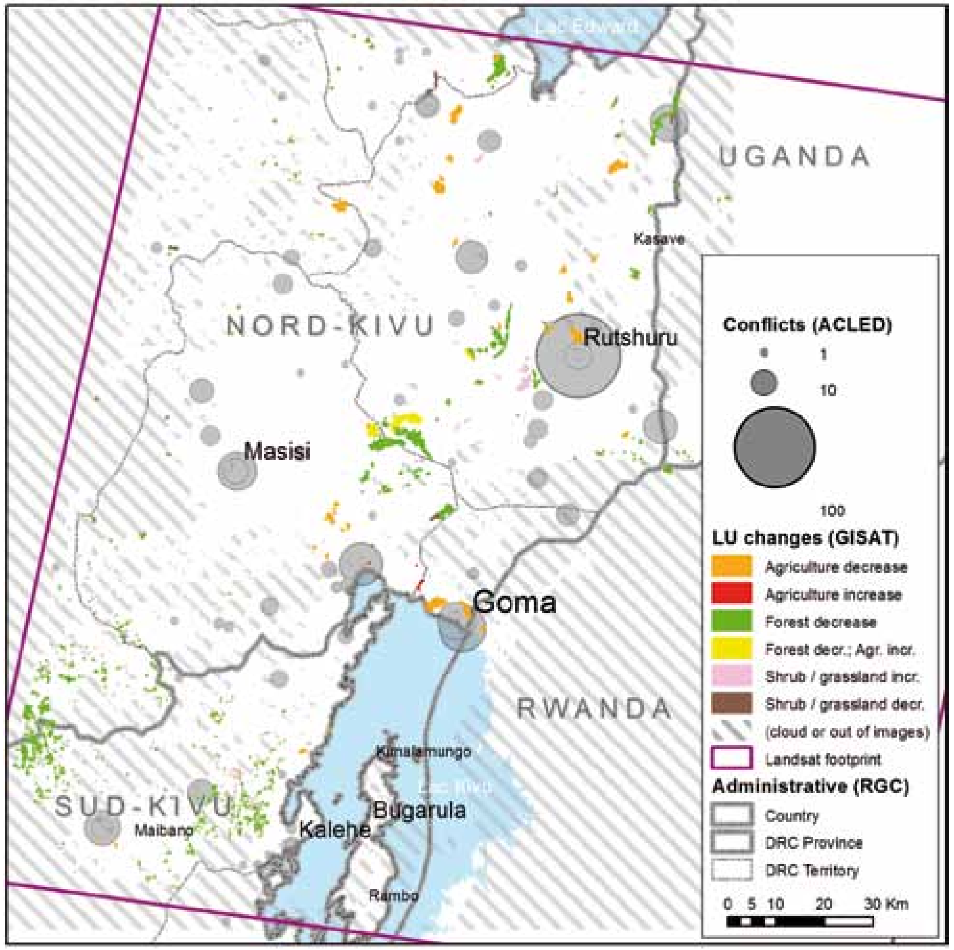

Figure 2: Land use changes and conflict intensity in three Kivu territories. Note the hatched area under cloud coverage

Using the EO information on location and intensity of environmental changes, we are able to show local clusters of land degradation. The largest clusters are caused by deforestation. While some of these degradations are induced by natural events, the other clusters might have evolved due to human activities. Another important degradation refers to loss of agricultural land by either reforestation of natural vegetation or urbanization in the two bigger cities Rutshuru and Goma. The analysis is hampered by the lack of adequate EO data and missing reference information. Furthermore, it is affected by the strong cloud coverage in the study area, which is typical for tropical climates. Unfortunately, this cloud coverage affects the results and reduces the area for which geo-spatial information on environmental degradation is available.

> Conflict Event Data and Link to environmental and population data

A visual assessment was made of the proximity of conflict events to the areas where EO-detected changes to natural vegetation (forest and agriculture) had occurred. Contrary to the model assumptions no effect was observed (Figure 2). The same applies for the mine site locations that show no particular link to the occurrence of conflicts. The analysis of the landuse/landcover change surface versus number of conflict events does not show a clear relationship between land degradation and the number of conflicts. More specifically, we do not find the expected correlation between the number of conflicts at a given location and the surface of landuse/landcover changes around this position. The conflicts are not occurring, where a high rate of landuse/landcover change has been observed. However, as expected, conflicts have a higher occurrence in the populated east of Kivu (Figure 3).

SECURITY

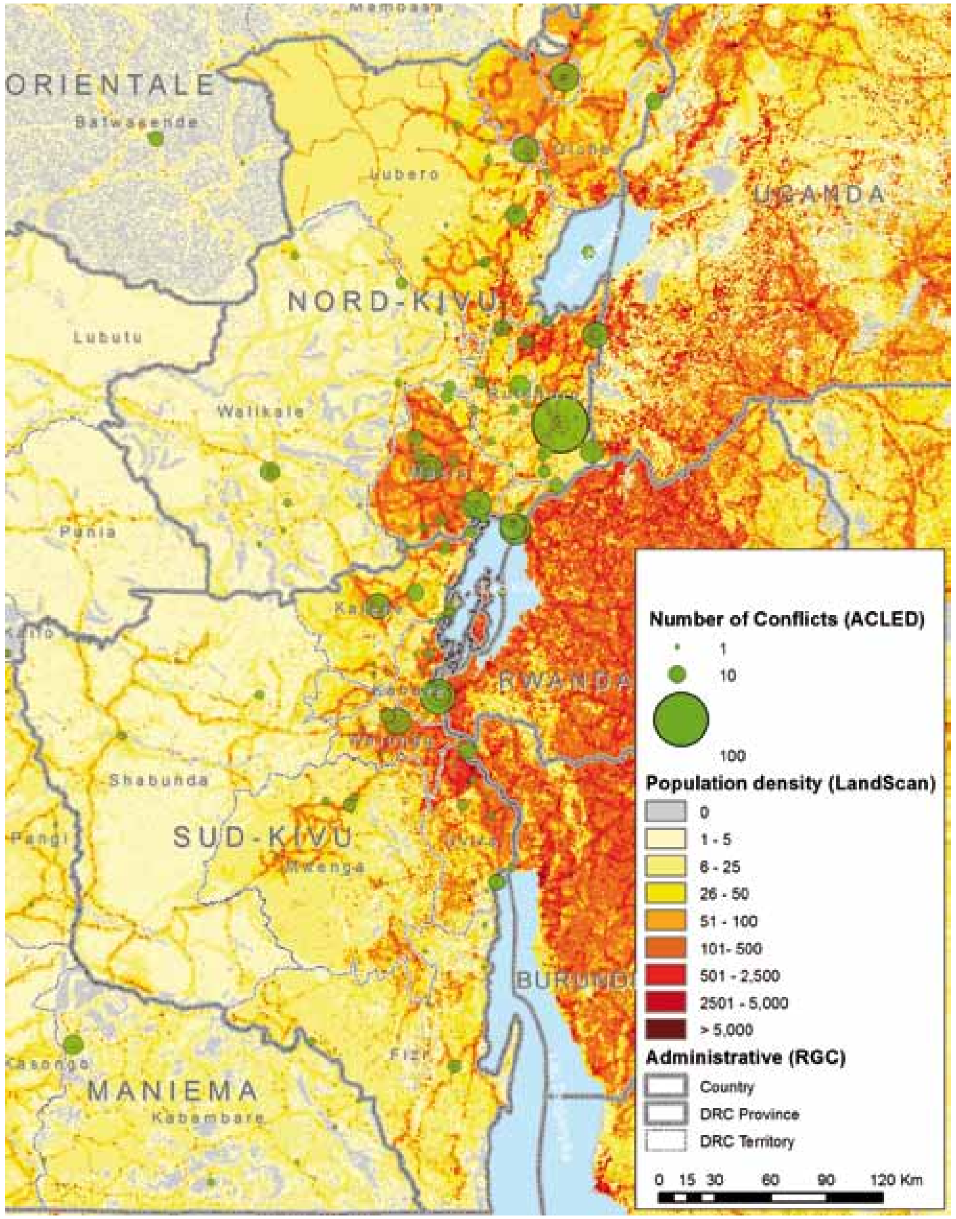

Figure 3: Population density (LandScan 2008) and conflict intensity in Kivu

While the EO data provided some missing information about extent of agricultural cultivation and deforestation, the analysis did not show any link between conflict locations and the other model variables (i.e. Land cover changes, mining positions, population density). Reasons for this are manifold: there is not enough data (both in time and in space domains), to establish a link between changes in the natural environment and conflict. The effects of environmental changes on conflict events might lag behind with respect to the event itself, and could be revealed with more, frequently updated EO information. As well, the land use changes in a period of five years are compared with continuous conflict information. Conflict information for a few, discrete point locations is compared with spatially continuous land use change information. Field level data would have been useful, but were difficult to obtain in the case of Eastern DRC. Additionally, the analysis was performed over a small area. The analysis should be extended over a larger area, showing all the changes within shorter periods of time extracted from cloud free satellite images.

CONCLUSION

This study used satellite data to investigate where and how resources are exploited in remote, insecure areas. From the data analysed it has not proved possible to find direct links between environmental degradation and conflict or to properly test the indicators, due to data quality and availability problems. However, the approach still holds promise. Even though initiatives exist to map and monitor natural resources, in eastern DRC information about mining sites (activity levels/production) is still incomplete and infrequently updated due to insecurity and problems to access the areas concerned. This need can be usefully addressed by remotely sensed data. Since the amount of information derived from the satellite data in our study was limited, partly by problems of persistent cloud cover, in future, other sources might be used, like advanced radar satellite imaging, which is not affected by cloud cover. In future, the exact relation of conflict events to EO outputs could be further analysed. A higher temporal resolution of EO data would improve more time series of data for each year in the dataset.

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G-MOSAIC

Change detection and damage assessment based on the new generation radar satellites for G-MOSAIC pilot services

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ABSTRACT

Within the GMES initiative, several projects focus on supporting the European Union Common Foreign and Security Policy (CFSP) and the Common Security and Defence Policy (CSDP). Two of them are GMOSS (2004-2008) and, addressed in this paper, G-MOSAIC (2009-2011). GMOSS was the predecessor of G-MOSAIC. An important issue in GMOSS was to connect the information needs following from the CFSP security priorities to Earth Observation (EO) technology. The aim of G-MOSAIC is to go a step further and develop geospatial information products and pilot services for the EU external relations policies (CFSP/CSDP) and security end-users. Pilot services to which TNO contributes, are developed in Cooperation with DLR, e-GEOS, GMV, Infoterra, Joanneum Research, JRC, and others. Key technology that is discussed is radar change detection. Output products give information on vessel traffic, harbour activities, transhipment of goods, timber logging, earthquake damage, and reconstruction after crisis. Present radar EO systems turn out to be well suited to monitor different activities due to different scattering mechanisms, and irrespective of cloud cover.

WORK PROGRAMME, METHODOLOGY

Synthetic aperture radar: Since 2006 a new generation of radar satellites is operational, succeeding the successful generation of ERS, JERS, Envisat and Radarsat-1. Representatives of the new generation are TerraSAR-X, Cosmo-SkyMed, Radarsat-2, and ALOS PALSAR, see Table 1. Most important properties of these satellites are a higher resolution (1-10 m) combined with polarimetric imaging, and continued all-weather coverage, that make them pre-eminently suitable for security applications.

Synthetic Aperture Radar (SAR) is an active instrument, it transmits a signal to the earth and the returned scattering shows the characteristics of the illuminated surface. The radar wavelength determines the ability to penetrate vegetation and soils; the longer the wavelength, the deeper the

penetration. The polarisation determines the observed scattering mechanism. In general there are three scattering mechanisms:

> Double-bounce scattering from wall-ground or other orthogonal structures that function as an efficient radar reflector. Dependent on the size of such a structure, the backscatter can be quite strong. Double-bounce is visible in HH and VV.

> Rough-surface scattering. This type of scattering is diffuse and often weaker than double-bounce. Rough-surface scattering is visible in HH and VV.

> Volume or canopy scattering. This type of scattering occurs when the radar waves penetrate a medium such as vegetation canopies. The longer the wavelength, the deeper the penetration, and the stronger the radar return. Volume scattering is visible in all polarisations, but because double-bounce and rough-surface are not, HV and VH (referred to as cross polarisations) exclusively show volume scattering.

Platform	Launch	Band 1)	Polarisation 2)	Resolution	Status
Seasat	1978	L	HH	25 m	Ended 1978
ERS 1	1991	C	VV	30 m	Ended 2000
JERS 1	1992	L	HH	18 m	Ended 1998
ERS 2	1995	C	VV	30 m	Operational
Radarsat 1	1995	C	HH	10 m	Operational
Envisat	2002	C	Dual pol	30 m	Operational
ALOS PALSAR	2006	L	Quad pol	10 m	Operational
Radarsat 2	2007	C	Quad pol	3 m	Operational
TerraSAR-X	2007	X	Dual pol	1 m	Operational
Cosmo-SkyMed	2007	X	Dual pol	1 m	Operational

1) L-band = 23 cm; C-band = 5 cm; X-band = 3 cm

2) Dual pol selectable from HH/VV, HH/HV, and VV/VH; Quad pol HH, HV, VH, VV

Table 1: Overview of past and present radar EO satellites.

Radar change detection: Radar change detection is a technology that detects the differences between two or more radar acquisitions of the same area, in time. First radar change detection studies, coherent and non-coherent, date back to the early nineties. Coherent change detection takes into account the amplitude and phase of the radar image, while non-coherent change detection only considers the amplitude. For both, the imaging geometry of the acquisitions has to be the same, sometimes referred

to as repeat-pass geometry. Because co-registration for coherent change detection is more demanding, chosen was to apply non-coherent change detection.

An important issue in non-coherent radar change detection has always been the reduction of speckle noise. The chosen speckle filtering method showed good results applied to medium-resolution SAR imagery (ERS, Envisat, Radarsat-1) in the past. Output is a vector change layer.

Radar damage assessment: Damage assessment can be considered as an application of change detection. A distinction can be made between detailed damage assessment that focuses on damages at building-level (e.g. applying the method chosen in Section 3.1), and grid-based damage assessment. The latter is based on the average difference or correlation per grid-cell, or a combination.

RESULTS

Pilot services that make use of radar change detection technology and that are addressed here, are coastal and harbour surveillance, illegal timber logging, damage assessment, and reconstruction monitoring. Up to now several geospatial information products were produced to evaluate the pilot services.

One product shows the activities that take place in the harbour of Burgas, Bulgaria, based on detailed change detection applied to TerraSAR-X images. Relocated ships, cranes, trains, sea-containers, and goods are visible (see Figure 1 - left).

Another product shows vessel movements in Radarsat-2 images, in and outside the port of Rotterdam, The Netherlands. The image is enriched with data from AIS transponders (Automatic Identification System) mounted on the larger ships, to give an overview of the vessel traffic. Correlation of non-stationary objects in radar and AIS has to be compensated for an azimuth shift caused by the Doppler processing of SAR images.

A third product shows areas of timber logging in the Democratic Republic of the Congo (DRC) based on change detection applied to ALOS PALSAR images. Comparing these loggings with the concession areas will show if these loggings are legal or not. Especially in this product the volume-scattering properties of long-wavelength cross polarisations are used, see Figure 1 (middle).

A fourth product is a damage assessment of Port-au-Prince, Haiti, after the earthquake on 12 January 2011, based on TerraSAR-X and Cosmo-SkyMed images. Two assessments were done, one grid-based with cells of 200 m, and one detailed assessment at building level. Results were compared with the Post

Disaster Needs Assessment (PDNA) of UNITAR/UNOSAT, JRC, and the World Bank. The grid-based damage assessment shows the best results, mainly in the more regular structured areas such as the city centre, that return more double-bounce scattering. Damage in the shanty areas is less visible, see Figure 1 (right).

A fifth product shows reconstruction activities in Banda Aceh, on Sumatra, Indonesia, after the tsunami on 26 December 2004, based on TerraSAR-X images.

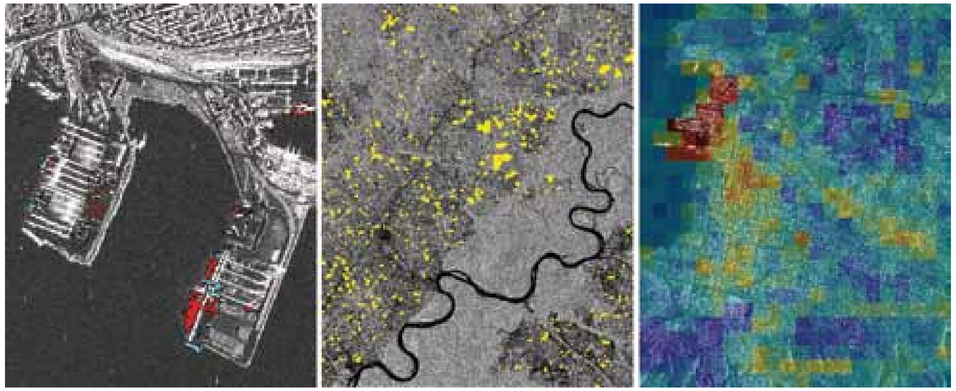

Figure 1: Harbour activities in Burgas, Bulgaria (left), timber logging in DRC (middle), and grid-based damage assessment in Port-au-Prince, Haiti (right). © Infoterra GmbH. © JAXA/METI. Data were provided by the European Space Agency

CONCLUSION

In this paper the high-resolution radar and change detection technology that is used in several G-MOSAIC pilot services is discussed. With these pilot services different information products were generated for intelligence and crisis management. The products give information on vessel traffic, harbour activities, transhipment of goods, timber logging, earthquake damage, and reconstruction after crisis. Present radar EO systems turn out to be well suited to monitor different activities due to different scattering mechanisms, and irrespective of cloud cover. Correlation of non-stationary objects in radar and other data has to be compensated for an azimuth shift caused by the Doppler processing of SAR images. Due to the scatter mechanisms in urban areas, damage in the shanty areas is less visible than in the more regular structured areas such as the city centre.

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GEO-PICTURES

Seeing emergencies from different angles

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ABSTRACT

The objective of GEO-PICTURES (GP) is to provide powerful humanitarian and environmental emergency management for global use, represented by concrete needs from the United Nations, EU Civil Protection Mechanism and Government of Amazonas, as largest environmental areas of concern in the world. Targeted for use in emergencies, GP is designed to save lives and mitigate disaster effects on environment. In emergency situations striking humanity, environment and the civil public, it is of paramount importance to communicate, from field, what has happened and where as quickly and accurately as possible so that appropriate actions can be taken. One cannot rely on an existing infrastructure except satellite communications for global coverage. GP provides near-real-time input of pictures, video and sensors worldwide. UN, with specific expertise in rapid mapping produce real-time situational maps with a combination of space & terrestrial image and sensor information. Completely new, and a missing link in operations, this provides a significant contribution to larger and medium scale emergency management all over the world, and specifically in areas with poor communication infrastructure after the disasters.

GEO-PICTURES combines state of the art in satellite communication, navigation and earth observation, based on a core technology with geo-image and -sensor communication at up-to-date satellite earth observation. A main challenge is high-resolution image communications without broadband infrastructure. An innovation award winning core concept (AnsuR ASIGN) forms an excellent basis for enhancement, further integration and direct use in operations. GEO-PICTURES allows a large number of accurate field observations to be transferred via optimized protocols to a control center. Geo-observations include photos, video, audio and sensors that measures temperature, moisture, wind etc; helpful in emergency/disaster management and for improving interpretation of space based remote sensing data.

GEO-PICTURES will also design small lightweight equipment based on the latest mobile technology; in particular the open Linux based platform Android. This will give disaster management experts an all-in-one tool for rapid damage assessment, in addition to the dedicated camera/computer/communication unit solutions, while at the same time allowing for a modular integration of GEO-PICTURES components into existing systems. It is an excellent basis for crowdsourcing, where the public contribute in-situ observations. The consortium also works with small Unmanned Aerial Vehicles (UAV) as a platform for observations. GEO-PICTURES can be used for disaster management worldwide, and the solution as in an early form already contributed to disaster management in Haiti after the recent Earthquake and environmental emergency in Nigeria. The novel emergency management platform will be developed in Oslo with several partners, and form a seamless solution hosted by United Nations (UNITAR/UNOSAT) on the CERN campus in Geneva.

WORK PROGRAMME, METHODOLOGY AND MILESTONES

GEO-PICTURES is the only project funded under the call the FP7 Space Call *"SPA.2009.1.1.03 Integration of SatCom / SatNav with GMES for prevention and management of emergencies"*, that is part of the *"(9.1.1) Space-based applications at the service of European Society / Integration, harmonization, use and delivery of GMES data"*. A main objective is to provide users with all the required in-situ and space-based information in a timely, seamlessly integrated, secure and user-friendly way for managing disasters and emergencies, while building on current initiatives and proven concepts and realistic user requirements from experienced field assessment experts. The targets are, via research, development, integration and other suitable activities, to obtain:

> *Observations*, in terms of complete solutions for collecting and sending geo-referenced in-field assessment input with high quality digital photos, video, sound and various sensors.

> *Decisions* via operational servers for seamless *integration* of in-situ with suitable EO/GMES data, and possibilities for global web-access, for rapid emergency management. Dedicated solutions for United Nations, EU Civil Protection Mechanism and the Government of Amazonas (Brazil).

> *Distributions and actions*, with efficient, optimized solutions for making in-situ field data, GMES data, expert advice and other relevant information rapidly available in field.

> *Optimized solutions for satellite and mobile* links. Holistically optimized protocols for rapid input via mobile satellite communication systems.

> *Optimized image compression*, management and transfer mechanisms for the target applications.

> An overall *network architecture* and service provider solution for the specific use cases.

> Secure a *lasting and sustainable impact* by a high degree of trials, training, dissemination and direct use during the project development of incrementally improved solutions.

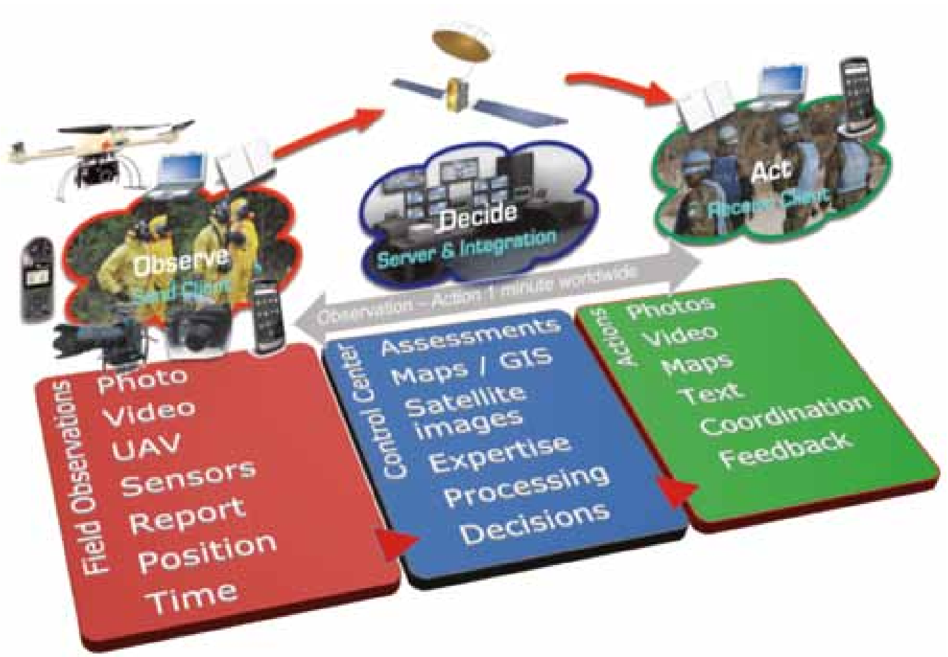

Figure 1: The steps for emergency management: Observe, Decide, Act.

GP follows iterative development; the systems will grow in complexity and features, but even the first versions early in the project is used in live trials and demos with users. GP is user driven by identified needs for the United Nations, EU Civil Protection Mechanism and the Government of Amazonas, but also significantly inspired from the novel technological options possible. There is clear focus on a useful practical solution in the development and demonstration of value-added services meeting user needs. In addition to the management, the work packages of GP is divided into 4 main categories. These are:

1. WP 2 – Getting it all on the right track

> Define user aspect requirements so these can be mapped to technical requirements and system design performed. Where user requirements are collected via a broad approach to users worldwide before the technical requirements are defined. The user requirements, along with the contract with the EC, becomes like "commercial requirements", and development shall in principle be done that answer to these.

> From user aspect requirements, map these to technical requirements and prepare for system design. Starting with the baseline system. All requirements are to be SMART: Specific-Measurable-Attainable-Realizable-Traceable (Time-Bound for development).

> Perform system design. Use of social media in emergency management. Consider design choices, e.g. Android operated smart-phones or iPhones are to be decided). Integration with Twitter for social media, in addition to the Virtual OSOCC for professional integration with emergencies worldwide, and an online GIS system for mapping and geographic data feeds.

Figure 2: The Android Solution

2. WP 3 – Putting it all together

> Perform the required project research early in the project. May continue until the end of the project for study topics.

> Do development. A main task in the project is the actual S&T development. Several sub-projects and individual activity lines will be defined.

> Conduct complete integration and lab-test of the developed units, also including user guidance. As a web-based system, location is free, but good Internet connection required.

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3. WP 4 - Getting the user feedback!

> Verification of achieved objectives is key. In GEO-PICTURES the verification of achieved objectives will in addition to a technical review be done during several live in-field exercises and continuous dialogue with the user community.

> Key performance indicators shall be tested. Key technology issues, new features and functions have special attention. Robustness and interoperability with field users equipment. Tests by technical experts and non-technical users /no special connection to the project.

4. WP 5 - Making it known and last!

> In-field UN and EU civil protection training and exercises. Events in Amazonas. New routines for first responders. Impact on national, European and global level. Publications, disseminations, papers, articles and material in relevant forums. Validate project technology, with sufficiently many field trials with expert and users. Collect feedback for final phase of development and future work plans. Standardization, use policy and influencing.

Micro-drones (UAV) help obtain project objectives. These can fly up to an hour on batteries, lifting cameras high up. Used in the right way, this technology is also easy to use. While smaller systems are somewhat subject to wind and the local flying conditions, they are less dependent on clouds. Having sub-cm resolution, it is better resolution than satellites. With a weight of a few kilograms, they are small, easy to take around and offer environmentally friendly operations.

The micro-drones can be used both as a very high camera tripod, lifting the camera to places and angles otherwise not obtainable, or as a very low "satellite", capturing photos that can be ortho-rectified and used for small scale rapid mapping. Microdrones allow oblique angle imagery, highly useful in earthquake damage assessments. Thus these systems can not only be used to merge the in-situ and remote sensing observations, but also as an excellent complement to these. The images in Figure 3 show the result of initial test with the UN in Geneva. Photos are taken with a remote controlled Android smart-phone, transferred in real time to a server, providing access to the information from anywhere to anywhere.

Figure 3: Geo-referenced live transferred assessment photos from a small UAV, using an Android mobile phone. Geneva 2010

The project runs over 24 months. It started March 2010. The major milestones have been the use of GP solutions for several UN missions, including earthquake damage assessment in Haiti and floods in Pakistan. Spin-off products have been created as well for various damage assessments. While there will be several larger and smaller user situations for test during the project, a larger trial where the solution is integrations part of the exercise will be planned towards the end of the project.

PARTNERSHIPS AND COLLABORATIONS

9 partners collaborate to GEOPICTURES:

> *AnsuR Technologies* (ART/NO), SME, coordinator and major development partner for robust image and in-situ communications and data distribution. Project initiator.

> *United Nations*, UNITAR/UNOSAT (UNOSAT/CH), representing UN users and responsible for development of online GIS server for rapid mapping and in-situ data integration.

> *Universitat Autònoma de Barcelona* (UAB/ES), represented with three research groups in wireless and satellite communication, mapping/geography and image coding. Key contribution in holistic system optimization, in general as well as in particular in Amazonas.

> *Kongsberg Satellite Services* (KSAT/NO), is responsible for rapid access to space data, both booking of new observations (post-disaster) and search of existing data (pre-disaster).

> *Johanniter-Unfall-Hilfe e.V.* (JUH/DE) represents the EU Civil Protection, does training and planning, and develops equipment sets for European Civil Protection. Defines equipment lists (SW, HW), tests and disseminates within EU Civil Protection.

> *State University of Amazonas* (UEA/BR) does research into environmental in-situ sensors based on satellite systems. Specifically targeting flooding scenarios.

> *Secretary of Science and Technology of the State of Amazonas* (SECT/BR), is responsible for users i Brazil, as well as policy impact and overall coordination in Amazonas.

> *Disaster Management Advice & Training*, DMAT Consulting e.U. (DMAT/AT) is a professional and highly experienced disaster management SME, and contributes particularly to development of a all-in-one unit based on smart-phones.

> *Associacao Brasileira de Telecomunicacaoes* (ABT/BR) is supporting SECT in technical matters.

Via the different project partners there are plenty partnerships and collaborations. These include other EU projects, other UN organizations such as UN/OCHA, partners like Google, Inmarsat, other TELECOM partners in Brazil, as well as both the organizations INPA for forestry and INPE for satellite observations. There are several national civil protection organizations involved from e.g. Brazil, Austria, Switzerland, Germany and Norway. These are also involved in UN Disaster Assessment and Coordination (UNDAC).

ACHIEVED RESULTS

GEO-PICTURES has proven to be an excellent basis for a complete end-to-end solution, combining state of the art in several areas into a new beyond-state-of-the-art solution and developing new state-of-the-art progress in each of the areas represented by the participants and the work packages. A major innovation of GEO-PICTURES lies in the holistic combination of modular elements into a complete system, which in turn is so strongly linked to the identified emergency management needs. As such the system comprises a clear technical and scientific progress beyond state-of-the-art in itself. However, several of the individual building blocks independently demonstrate that while being a very user driven project, the technological improvements are impressive enough in their own right. State-of-the-art in satellite communication, emergency communications, image coding and communication, robust communications adapted to unknown channels, satellite-mobile synergies, rapid mapping, access to GMES data, GIS management for emergencies to mention some, add to the clear leap envisioned in state-of-the-art in the management of humanitarian and environmental emergencies.

GP results include the benefit of a large user feedback via an online survey that is active throughput the project. There has been a large dissemination activity in the UN, including global meeting and demos at the INSARAG (International Search and Rescue Advisory Group) in Abu Dhabi in March 2010, and three live missions in Haiti (twice) and Pakistan. With Johanniter-Unfall-Hilfe e.V., GEO-PICTURES is used at main trainings several times a year (EU Assessment Mission Courses, EU Modules Basic Courses, EUTAC trainings). AnsuR has also sold a version to the Norwegian Civil Protection after a few months of the project. Further, the "European Earthquake Center", EMSC, and AnsuR have entered a partnership where the mobile version of GP is to be used for geo-referenced visual input right after disasters.

Figure 4: GEO-PICTURES used in Haiti

Figure 5: GEO-PICTURES from flood damage assessment in Pakistan 2010

With GEO-PICTURES, state-of-the art is improved in:

> Global emergency management, operations and use through an integrated solution.
> Image coding and real time audio-visual communications over mobile satellite systems.
> Efficiency and reliability for use through new protocols.
> Rapid access to and choice of latest and previous GMES data for emergency management.
> Field validation of remote sensing analyses.
> Environmental management the rainforest.
> Flood monitoring and surveillance.
> Pre- and post disaster management.
> International collaboration on integrated satellite applications.

Major *challenges* are related to real user situations. *Making GEO-PICTURES advanced is simple - making it simple is a main challenge*. Most users are not professionally trained for applications such as GP. In the field they have other actives of large concern, and if they cannot get things to work right away they may not spend more time on it during that mission. The technology *must* therefore *always work* which is different than to prove it *can* work. For the first trials, it is of great advantage to get collaborative users and technical support.

CONCLUSION

Near real-time availability of visual in-situ assessments during emergencies are difficult to obtain due to lack of proper communication and integrated solutions. This is identified as a missing link in emergency operations. Availability of such information—combined with updated GMES data—will change the way the world manages and prevents humanitarian and environmental emergencies. A target of GEO-PICTURES is an integrated service platform, hosted at CERN in Geneva for the United Nations, in collaboration with the UN Office for the Coordination of Humanitarian Affairs (UN OCHA). The project will have major impact. The European Commission has agreed on procedures for direct interaction and collaboration with OCHA and UNTIAR/UNOSAT. Thus, the integrated service platform is in line with both EU and UN policies on coordination and collaboration during major emergencies.

With the prominent users directly involved both as users, service provider and system integrator for the service platform of GEO-PICTURES, we secure a high level of impact, attention and long-term strategic commitment to the project.

The practical use cases for GEO-PICTURES are Large Humanitarian Disaster Management, Civil protection cases and a broad range of environmental emergency prevention and management. In all three cases the management of the scenarios include monitoring in the surveillance pre and post disaster phases, and rapid response including rapid damage assessment and support for rescue operations during emergencies. GEO-PICTURES has already proven a significant potential to contribute to:

> *Large humanitarian disasters* can be flooding, tsunamis, earthquakes, mudslides, wars and refugee issues, complex emergencies and more. United Nations is the main organization in the world for managing global and regional humanitarian disasters. The UN's UNITAR/UNOSAT provides rapid mapping services, training and research in the area of satellite solutions focusing in particular on developing countries and has a long history of working with European partners.
> *Civil Protection cases*, managed by the EU Civil Protection Mechanism, facilitating cooperation in civil protection assistance interventions in the event of major emergencies, may require urgent response actions. This also applies to situations where there may be an imminent threat of such major emergencies. Community cooperation in the field of civil protection aims to better protect people, their environment, property and cultural heritage in the event of major natural and manmade disasters occurring both inside and outside the European Union.
> *Environmental Disaster Management* as managed by the Amazonas Government and United Nations. There is an increasing level of awareness around the enormous consequences of environmental disasters and issues like global warming. Amazonas faces a large number of potential environmental emergencies such as flooding risks and large reduction of rainforest including illegal deforestation. This comes in addition to several civil security challenges. The Government of Amazonas and the Amazonas State University are part of the project and will input requirements and support the development of solutions to combat the challenges above and run trials with GEO-PICTURES in order to integrate it into permanent systems.

The United Nations includes a number of the key target user groups, including emergency, rescue, peacekeeping and other categories, requiring support in all areas of the world, including some of the most difficult environments to work in. UN also includes the prominent ITU (International Telecommunication Union). Developing GEO-PICTURES for the UN will enable the technology to also serve a variety of other use cases. Especially the United Nations Disaster Assessment and

Coordination (UNDAC) teams and the EU Civil Protection Mechanism assessment and coordination teams will be one of the most important users of the results of the project.

The overall objective of GEO-PICTURES will be achieved, providing the end-emergency-users – in terms of United Nations, European and world-wide civil and environmental protection agencies, search-and-rescue teams and other life-guarding bodies with all the required information in a seamless, integrated, timely, secure and user-friendly fashion for prevention and management of emergency situations using the latest developments in GMES, communications and navigation technologies.

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NEWA

New European watcher

Fulvia Verzegnassi

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ABSTRACT

The space sector is a strategic asset contributing to the independence, security and prosperity of Europe and its role in the world. For Europe to have non-dependent access to critical space technologies is therefore a conditio sine qua non for achieving its strategic objectives. "Non-dependence" refers to the possibility for Europe to have free, unrestricted access to any required space technology. The project's focus is on the expected medium-term impact for Europe to develop or regain the capacity to operate independently in space, for example by developing in a timely manner reliable and affordable space technologies that in some cases may already exist outside Europe or in European terrestrial applications. There is a need to identify EU-shared, sustainable Roadmaps for Space Technologies Development to:

> Study new European capabilities for future Earth observation missions (e.g. detection of moving objects).

> Evaluate space and qualification of critical technologies, in view of the utilization of commercially available technologies.

> Address the strategic challenges related to space technologies, to complement current efforts of the space community and to contribute to the European Space Programme.

> Demonstrate complementarity and possible synergies with national agency and ESA funded activities.

> Improve the coordination of civilian and military programmes and exploit associated synergies.

The New European WAtcher (NEWA) project aims to strengthen European space-based Reconnaissance & Surveillance (R&S) capabilities by providing a technological assessment of current/planned capabilities and building the European dimension for the development and establishment of space-based NEWA solutions for moving object detection and identification. The focus will be on space radar assets in support of security-related applications (border surveillance, law enforcement, etc). The main steps for the NEWA project are the identification of the technological gaps preventing the establishment of space-based EU R&S capabilities, the identification of the state-of-the-art techniques and/or innovative concepts, and the definition of the mid-term technological goals and an EU-shared sustainable roadmap.

SECURITY

CONCEPTS AND OBJECTIVES

The future of space technology at EU level is dictated by several policies covering space and related applications (Security, Defence, Sustainable Development, etc.), which are defined by on-going Technology Programmes (GMES, ESA Technology Programmes, ASI and CNES developments, etc.). Synergies are sought in a number of application fields, since the capabilities offered by space assets can be exploited efficiently and simultaneously by different users. Space systems enable global Situational Awareness (SA) and provide the intelligence and information upon which decision makers rely, both at national and EU level. As a critical enabler for security and defence operations, space systems are vital to the EU, both in peacetime and during crises.

The development of the space sector at EU level – and related applications – should be based on the following factors:

> Development of a coordinated and coherent approach to international relations in space.

> Exploitation of synergies between civilian and military programmes – of course, in full compliance with the respective scopes of action.

> Definition of the appropriate R&D effort in space technology through synergies with the initiatives of ESA or other European, national or regional entities.

The NEWA project is largely based on the aforementioned steps and focuses specifically on the space radar technologies that would allow the development of the space-borne moving object detection system for EU security. The possibilities opened by NEWA have been widely discussed in the international community in view of the significant added value it would bring to security-related applications in terms of intelligence information gathering for the surveillance of both EU and non-EU territory.

Recent technical and technological findings have demonstrated the availability of some of the components required by NEWA – at least for non-space platforms – while the development of current space radar systems tends to include NEWA-related capabilities through the upgrading of flying sensors.

NEWA will deliver a common roadmap based on the characterization and understanding of the EU and global scenario, and the identification of the required technological developments. The collection of user requirements, technological assessment and benchmarking of state-of-the-art NEWA-related solutions, cost-benefit analysis and predictive evolution of techniques and technologies will represent the project's key tools for achieving the stated goals.

CONSORTIUM AND ORGANISATION

The project methodology aims to ensure optimal use of the knowledge, expertise and experience of the partners. The organisational breakdown structure is presented in Figure 1.

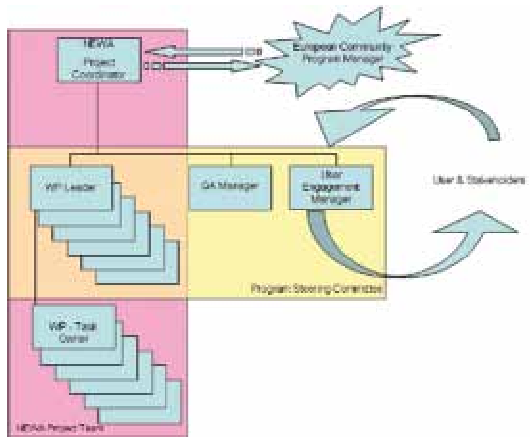

Figure 1: Organisation breakdown structure

The consortium has substantial pre-existing know-how in areas relevant to the NEWA project, which will be exploited to the full and considered as "background" knowledge.

The NEWA project is sub-divided into several work packages, each being led by the consortium member with the most relevant experience, as indicated in Table 1. A schematic representation of the inter-relations between the work packages is given in Figure 2.

NEWA Consortium Roles	
Company	**Role**
TASI	Main Investigator and Coordinator
	MTI Techniques Assessment
	Roadmap
IAI	User Engagement
	Policies & Analysis
E-GEOS	GMES Liasons
VEGA SPACE Ltd	Operational Scenario Analysis
FRS	International Policies
TSA	Identification of Gap fill
INDRA ES	Technologies Assessment
UPC	Processing Technologies Review

Table 1: Distribution of main project work packages across the consortium members.

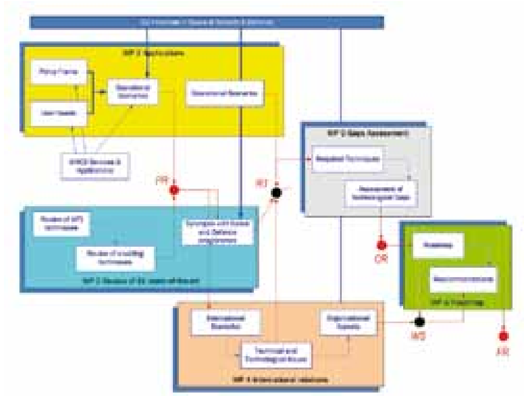

Figure 2: Schematic representation of logic flow between NEWA work packages

SECURITY

EXPECTED SCIENTIFIC AND TECHNOLOGICAL RESULTS

The Earth Observation (EO) applications addressed by NEWA (see Figure 3) are in line with GMES programme and will take into account the main results, achievements and analysis performed within GMES, at global or thematic level.

The GMES initiative includes an Earth observation component that is crucial to monitoring the environment, preventing and managing natural or industrial catastrophes, anticipating conflicts and managing crises. Security (related to natural, technological or humanitarian risks) is a challenging component of GMES that has received relatively little attention until now.

Past experience in GMES shows that security represents one of the main application fields for GMES EO-based geo-information services, and a space-based moving object detection capability is one of the most important applications for monitoring activity in this context (ship detection, land border monitoring, etc.).

It is, by definition, a complex topic, where multi-level integration is required and different sub-domains often overlap significantly. In this context, the project focuses its efforts on services that aim to reinforce the European capacity to predict and respond to crises and emergencies associated with natural and man-made disasters.

Figure 3: NEWA application areas

Over the last 10 years, GMES has created a portfolio of products intended to support European citizens faced with natural or man-made problems or crisis situations, through EO-based capabilities. GMES projects have allowed a rationalisation of the main needs thorough analysis, system design and tests, and through an incremental approach. These projects are also defining a solid framework for security services and a basis for the next steps of development. The first generation projects, such as MARISS or LIMES, are supporting the definition of the service in each part of the service chain: the evaluation of the service need identifies gaps and the main constraints that will need to be addressed to achieve truly operational services for users. It is also the phase in which the GMES community has to clarify the mid- and long-term objectives and initiate the required approach to reach these. Within NEWA, the team will analyse the past GMES projects and results, from the gap analysis to the service chain consolidation, providing the elements for NEWA development in line with GMES future planning and implementation based on a path from the short term (access existing services and infrastructure) towards the longer term (including the use of second-generation infrastructures and the definition of future service implementation). This activity will be performed mainly for the security domain, but it will also consider the overall and transverse input from other services and applications in order to be in line with the overall GMES framework and policies.

Moreover, NEWA is complementary to ongoing initiatives at EU and national levels and allows the identification of possible synergies with national agencies and ESA-funded activities, as well as relevant harmonised European space technology roadmaps. Coordination with on-going EU programmes will be ensured and findings from such initiatives will be fully exploited by NEWA.

Even if military programmes are under the sole control of the individual EU or ESA Member States, there are jointly driven initiatives for intelligence and surveillance satellites like Cosmo-Skymed (France, Italy), Helios II (France, Spain, Italy, Greece, Belgium, Germany) or SAR-Lupe (Germany). These joint endeavours are unlikely to be extended to EU programmes, but an EU-wide surveillance network (BOC13, E-SGA14) integrating these systems is under development. With its "civil" systems, the EU is in fact willing to use similar means to address comparable global challenges, such as environmental disasters, ocean monitoring or migration movements with GMES. NEWA is expected to improve coordination of civil and military programmes and better exploit synergies.

SECURITY

ENABLING TECHNIQUES

Radar techniques offer unique capabilities for long-range object detection and surface imaging, independently of solar illumination and meteorological conditions (see Figure 4 for an example of the type of imaging possible).

Figure 4: Typical picture of a moving target on the ground

In the case of security applications, most objects of interest (targets) are dynamic, inducing a Doppler frequency shift in the reflected signals or echoes. Typical cases of this are ground vehicles, ships, aircraft, missiles, intrusion and illegal activities, population migration, etc. In addition, many hazardous situations are intrinsically dynamic, such as volcanic or seismic activities, landslides, land subsidence, avalanches, dangerous sea states, oil slicks, tsunamis, etc. In all these cases, since the background scene is static, it is possible to design fixed or adaptive radar Moving Object Indicator processing techniques to:

> Enhance moving target detection;
> Reject static objects in a radar scene (clutter);
> Estimate the target radial speed;
> Obtain accurate high-resolution images of the moving target for identification or classification purposes.

Arguably, the most critical technical challenge faced by space radars is the development of data processing algorithms that can distinguish between moving targets and the surrounding background clutter. Identifying such targets from space is especially difficult: from the point of view of an orbiting satellite, the ground is moving at about 15 000 miles per hour, so distinguishing a vehicle that is moving only a few miles per hour faster than that is a difficult task.

Conventional radar Moving Target Identification (MTI) techniques are based on Doppler spectrum filtering. A typical MTI filter for ground-based radar has a notch response, usually at zero Doppler, resulting in a strong cancellation of the static objects or clutter. In this way, a well designed MTI can achieve signal-to-clutter improvements of the order of 40-50 dB. An additional and complementary technique is that of Moving Target Detection (MTD), which is essentially a set of filters able to further increase the target detectability and estimate its Doppler frequency, which is directly related to the target velocity. Velocity ambiguities caused by aliasing when sampling the scene at constant Pulse-Repetition Frequency (PRF) and blind velocities are two well known limitations of MTI and MTD. In the case of EO applications, the radar is typically installed in an airplane or satellite. The relative motion of the radar over the observed surface, necessary to form high resolution Synthetic Aperture Radar (SAR) images, causes a range- and azimuth-dependent Doppler shift, creating a space-frequency coupling that hampers the adoption of conventional MTI filters. One of the key innovative solutions for NEWA is Digital Beamforming (DBF). The concept of DBF is to obtain digital channels directly sampling the antenna element signals (see schematic representation in Figure 5). The availability of these channels gives the radar platform a considerably increased flexibility with respect to analogue beamforming. The flexibility stems from the possibility of generating antenna patterns with a programmable data processor instead of with dedicated (and costly) HW devices (e.g. TRM). In fact, with the data processor, it becomes possible to simultaneously synthesize many different patterns which act on the stored digitized signal, enabling different functions. As an example, it would then be possible to perform Space-Time Adaptive Processing (STAP) MTI processing, disturbance/jammer nulling, Direction Of Arrival (DOA) processing, interferometry and multi-target tracking.

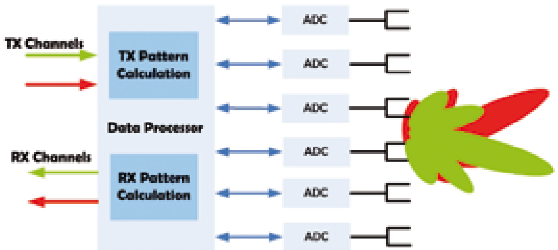

Figure 5: Digital Beamforming Scheme

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ENABLING TECHNOLOGIES

The production of space radar satellites would also require that several hardware challenges be overcome. Nine specific challenges have been identified:

Challenge 1 – Large-aperture, phased-array antennas (example shown in Figure 6) are required for synthesizing narrow antenna beams for clutter spectra reduction and performance maximization in slowly moving object detection. Such antennas must also be capable of surviving the launch and deployment phases.

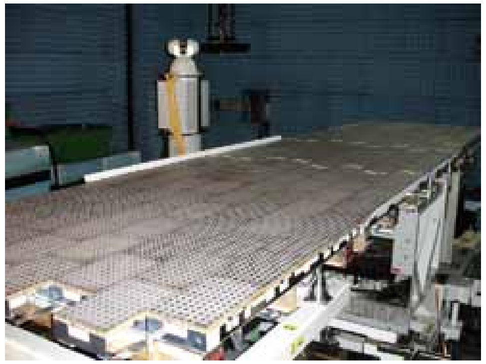

Figure 6: Example of a SAR antenna

Challenge 2 – Multi-channel receivers are nowadays feasible only on non-space platforms due to reliability, costs, volume and weight constraints. Systems with up to tens of receiving digital channels have flown on surveillance airplanes. The possibility for implementing systems with up to tens of channels on a space platform is the key challenge to be addressed.

Challenge 3 – Satellites are typically powered by solar cells and backup batteries (for use when the Earth's shadow blocks out direct sunlight). The space radar designs require solar arrays to be smaller and lighter than those of current-generation satellites with similar power requirements, necessitating the development of more-efficient solar cells. Spacecraft batteries also present a technical challenge.

Challenge 4 – In SAR imagery, the resolution of an image is directly related to the bandwidth of the radar signal, which in turn is limited by the system's Analogue-to-Digital Converters (ADCs). These converters change returning radar signals from analogue into digital form for processing. The space

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radar designs in this analysis would require ADCs capable of sampling an incoming signal at a rate of some gigahertz, with 8 to 10 bits of precision. ADCs of that type are just beginning to become available for use in space.

Challenge 5 – Capability of on-board processing capabilities are required by real-time applications, where objects are first detected and then the observation modality is changed in order to better illuminate the surrounding Area of Interest and the object itself.

Challenge 6 – RF components performance becomes critical in MTI applications due to the requirement on response time, isolation, amplification for high sensitivity, etc.

Challenge 7 - To detect moving targets, a Ground Moving Target Indicator (GMTI) radar must be able to distinguish the Doppler shift of a target from that of the surrounding terrain. That task is more difficult when the radar is mounted on a satellite that is moving at high speed relative to the ground. To overcome this problem, STAP techniques have been introduced, in which the statistical properties of the radar returns from the surface terrain (referred to as ground clutter) are first estimated and then mathematically removed from the incoming signal, leaving only the targets.

Challenge 8 - Space radar satellites for NEWA will generate large amounts of raw data, particularly in GMTI mode. Because the algorithms needed to turn these data into usable intelligence are complex, much of the data processing will have to be performed on the ground rather than on the satellites. Thus, the space radar system will need a substantial communications downlink capability.

Challenge 9 – Life-cycle and costs are the final two drivers in the assessment of NEWA concept feasibility.

CONCLUSION

It is expected that a large range of applications will benefit from MTI technology availability, in addition to those explicitly related to defence. Most of the identified downstream applications are in line with the ongoing efforts in the context of GMES. In the field of maritime surveillance, MTI can provide additional information to support vessel identification and tracking. Vessel identification is currently performed using focused SAR images based on different extraction algorithms; this information is complemented, when available, with AIS (Automatic Identification System) information either from ground-based or space-based systems (the latter is currently under development – AISSat-1). MTI would improve the information extraction through clutter suppression of space-based radar data. The benefit increases as the size of the vessel decreases, since it is in this case where conventional techniques have difficulties to detect vessels. The specific case of illegal immigration is of significant interest and some such scenarios have been presented.

NEWA's contribution to EU monitoring and support capabilities is largely based on the improvement of the monitoring of moving objects. NEWA technologies will enable a new kind of monitoring capability, with key features such as detection of metal moving objects (size of a car), near real-time response and a good revisit time thanks to constellation deployment. These features could apply to significant operational scenarios for EU security that shall be detailed and refined over the course of the NEWA project. Existing planned space observation systems can provide advanced information to monitor an area, but lack movement analysis capabilities. Furthermore, classic radars systems cover some key areas (air, sea) but leave certain aspects unmonitored. Monitoring capabilities is a core topic for key EU policies such as border control, external policies (humanitarian aid, EU emergency and crisis response capabilities), international treaty enforcement, infrastructure protection (trains) and warning capabilities. NEWA will provide a clear value-added based on its near real-time response capabilities for those policies, fostering the level and the quality of global information for the EU. Monitoring could be improved through a "real-time" operational system, which is currently lacking Europe, and could reduce the gap between the capabilities of the EU and those of other countries. Quality and response time are enabling factors for information, and therefore enabling factors for the efficiency of EU policies. NEWA technologies could contribute to the improvement of key EU policies, mainly security related, providing a better protection of EU citizens. Furthermore, NEWA technologies can contribute to the reinforcement of EU capabilities as a global player fostering the operational aspect of external policies.

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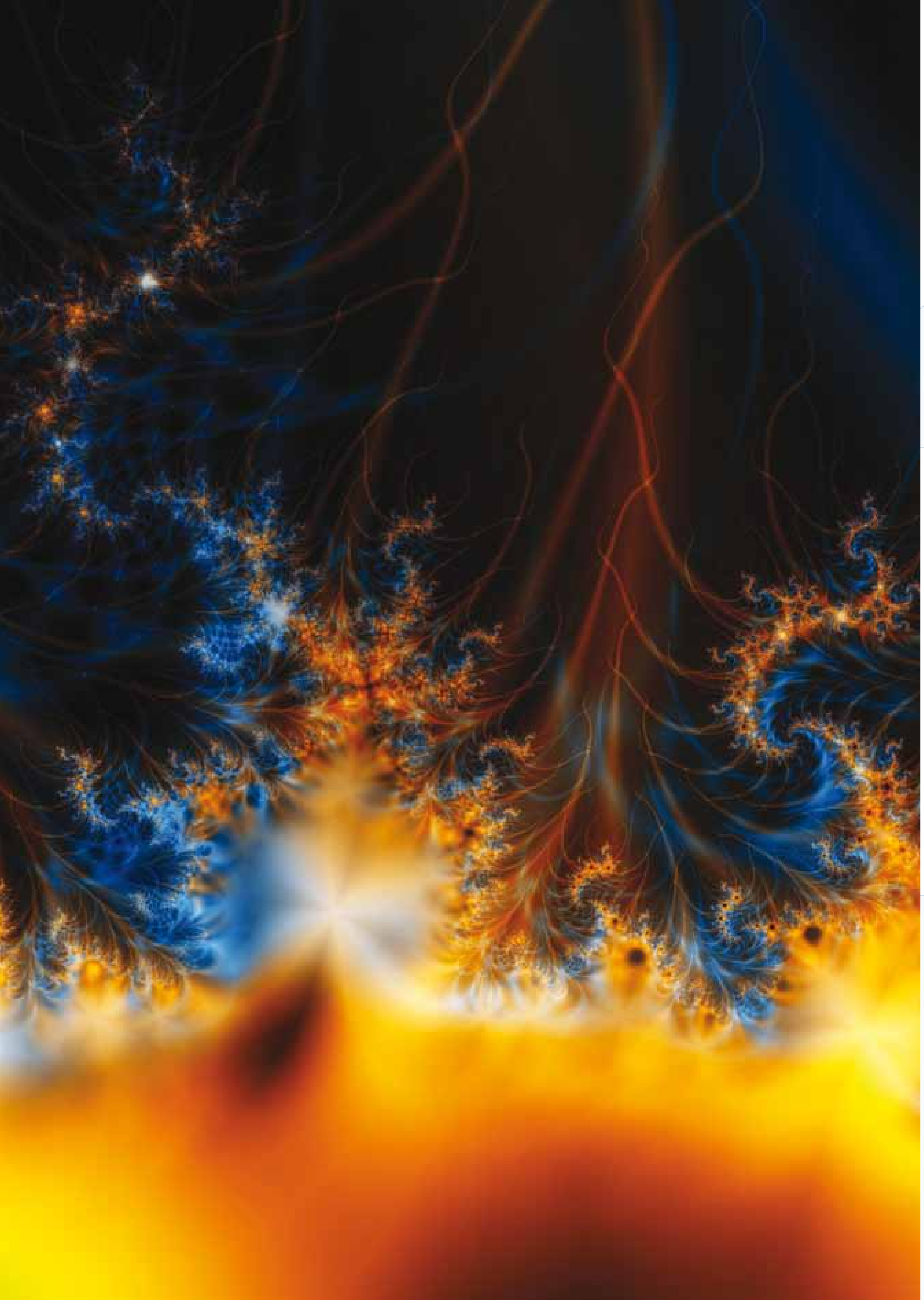

Part II Strengthening Space Foundations

Space science and exploration

Europeans share a common passion for space

HAMLET

Human model MATROSHKA for radiation exposure determination of astronauts

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ABSTRACT

The exploration of space as seen in specific projects from the European Space Agency (ESA) acts as groundwork for human long-duration space missions. One of the main constraints for long-duration human missions is radiation. The radiation load on space travellers is a factor of ~100 higher than the natural radiation exposure on Earth and it might further increase due to solar particle events should humans travel to Mars. In preparation for long-duration space missions, it is important to evaluate the impact of space radiation in order to secure the safety of astronauts and minimize their radiation risks. To determine the radiation risks on humans one has to measure the radiation doses to vital organs of the human body.

One way to realize this is the utilization of the ESA facility MATROSHKA (MTR), which houses a human phantom and is operated under the scientific project lead of the German Aerospace Center (DLR). The facility was launched in January 2004 and is just performing its fourth experimental phase - now inside the Japanese Experiment Module (JEM). The MATROSHKA project is dedicated to determining the radiation load on astronauts when staying within or outside the International Space Station (ISS). The MTR phantom is equipped with over 6 000 radiation detectors to determine the depth dose and organ dose distribution in the body. It is the largest international research initiative ever performed in the field of space dosimetry and combines the expertise of leading research institutions around the world, thereby generating a huge pool of data of potentially immense value for research.

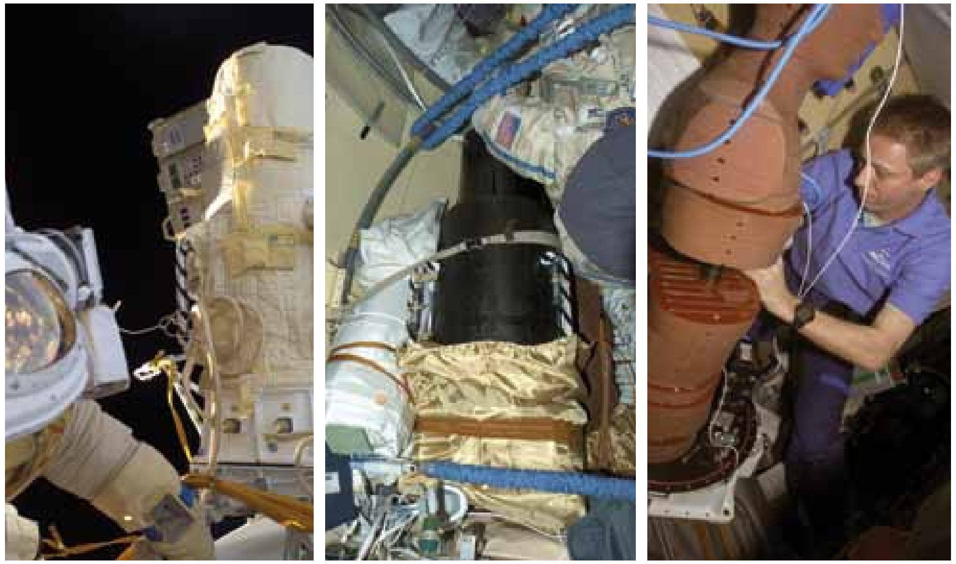

Figure 1: The MATROSHKA facility: (a) outside ISS exposure (simulation of a spacewalk) MTR-1 experiment phase; (b) inside ISS exposure MTR-2A experiment phase; (c) European astronaut Thomas Reiter removing the radiation detectors after the experiment phase MTR-2A for read out and data evaluation on ground. © NASA

Aiming at optimal scientific exploitation, the FP7 project HAMLET intends to process and compile the data acquired individually by the participating laboratories of the MATROSHKA experiment. Based on experimental input from the MATROSHKA experiment phases as well as radiation transport calculations, a three-dimensional model for the distribution of radiation dose in an astronaut's body will be set up. Based on a solid experimental and theoretical basis the model is essential for realistic radiation risk estimates for future human interplanetary space exploration. Data received up to now from the MTR experimental phases (MTR-1, -2A and -2B) are already implemented in the database along with relevant experimental and scientific background data.

WORK PROGRAMME, METHODOLOGY, MILESTONES

HAMLET – Mission Statement: The aim of HAMLET (http://www.fp7-hamlet.eu) is the effective scientific exploitation of data obtained from the ESA MATROSHKA project. This will be achieved by bringing together leading European scientists in the field of space dosimetry to increase and enhance the output of the project and present it to the European scientific community as well as the public audience.

MATROSHKA (see Figure 1) is a mannequin equipped with more than 6 000 radiation sensors to allow assessment of the exposure of a simulated astronaut's torso to cosmic radiation on board the ISS. The mission is currently performing its fourth experimental phase in the Japanese Experiment Module Kibō and, up to now, already generated a huge pool of data of potentially immense value for research.

To ensure the optimal scientific exploitation of the data generated within the MATROSHKA experiment, the collaborative FP7 project HAMLET (1 September 2008 – 31 August 2011) brings together European experts to process and compile the acquired data and develop a three-dimensional model for the distribution of radiation dose in an astronaut's body. In particular, the project objectives are (1) the processing, compilation and combination of dosimetric data for the MATROSHKA experiment; (2) the characterization of the applied radiation detector response to a well-defined subset of the space radiation environment and harmonization of experimental protocols; (3) the survey and detailed exploitation of available literature on cosmic-ray dosimetry and phantom experiments on board the ISS; (4) the development of a 3D Voxel model of the MATROSHKA phantom to facilitate the calculation of organ doses and thereby assessing the effective dose, which is a prerequisite for radiation risk estimations; (5) radiation transport calculations using the Monte Carlo transport code PHITS; (6) the launch of a dedicated HAMLET website and build up of a database structure for archiving MATROSHKA dosimetric data and (7) the organization of HAMLET Public Outreach Events to inform the public audience about the status of the project.

Within the HAMLET project these goals are embedded in five dedicated work packages (WP), with corresponding milestones and deliverables, namely: WP1: Data Processing and Compilation; WP2: Detector Characterization; WP3: ISS Space Data Intercomparison; WP4: Experimental and Calculated 3D Radiation Model; WP5: Dissemination of Results

PARTNERSHIPS AND COLLABORATIONS

Over the past decades, Europe has acquired significant expertise in space radiation dosimetry, radiation biology, the development of instrumentation for radiation measurements in space as well as particle transport codes. The HAMLET consortium under the coordination of DLR, Cologne, Germany (Table 1) brings together acknowledged European experts in these particular fields of science to stimulate the dialog, catalyse new interactions among leading universities, research institutions and space agencies around the world and thereby strengthen the European leadership in space life sciences.

Table 1: HAMLET expert consortium.

Beneficiary name	Acronym	Primary investigator(s)	Country
German Aerospace Center	DLR	G. Reitz, T. Berger	Germany
Vienna University of Technology	TUW	M. Hajek	Austria
Christian Albrechts University zu Kiel	CAU	S. Burmeister	Germany
Atomic Energy Research Institute	AERI	J. K. Pálfalvi	Hungary
Institute of Nuclear Physics	IFJ PAN	P. Bilski	Poland
Chalmers University of Technology	CHALMERS	L. Sihver	Sweden
Health Protection Agency	HPA	L. Hager, R. Tanner	United Kingdom

To complete the identified tasks it is necessary to collaborate with the international partner organisations within the MTR experiment, most notably the Japanese Aerospace Exploration Agency (JAXA), the National Aeronautics and Space Administration (NASA) Lyndon B. Johnson Space Center (JSC) and the Oklahoma State University (OSU). The need for further cooperation has become evident in order to conduct the extensive ground-based experiment programme at high-energy accelerator facilities for detector intercomparison, calibration and detector response studies. Dedicated research projects at the National Institute of Radiological Sciences (NIRS) in Chiba, Japan (Research Project #20P240), and the GSI Helmholtz Centre for Heavy Ion Research in Darmstadt, Germany (Research Project #AO-08-IBER), have become major fundaments.

ACHIEVED RESULTS

Based on the work packages a short summary of the major achievements and results will be given.

> WP1: Data Processing and Compilation

The experimental data acquired by the participating laboratories from passive i.e. thermoluminescence (TLD) and nuclear track etch detectors (PNTD), radiation detectors during the MTR-1 mission outside the ISS and the MTR-2A mission inside the ISS have been processed and compiled (see Figure 2). They provide an essential input for the development of the three-dimensional dosimetric model as well as a benchmark for radiation transport codes. In-depth evaluation of dose and linear energy transfer (LET) spectra from real-time radiation sensors, such as the dosimetry telescope (DOSTEL) and the silicon scintillation devices (SSD) used in the MTR-1 experiment complement the results achieved so far.

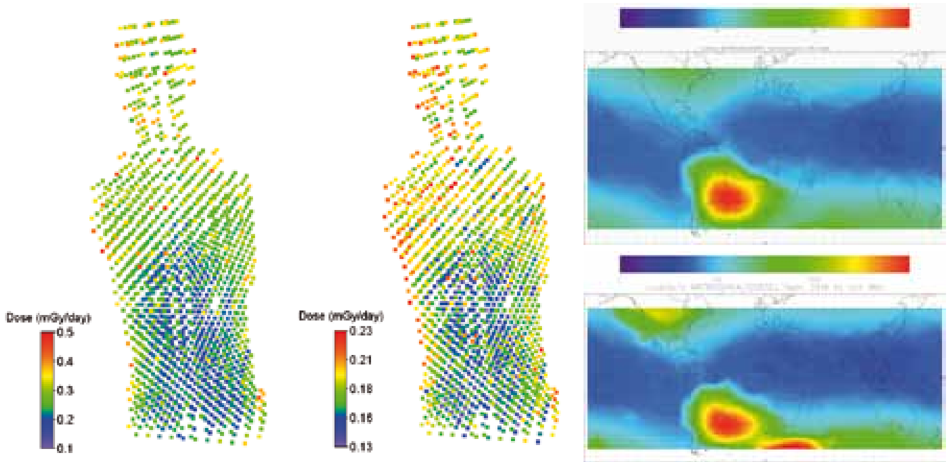

Figure 2: Absorbed dose distribution for the MTR-1 (a) and the MTR-2A (b) experiment measured by ~4 800 thermoluminescence dosimeters distributed in the MATROSHKA torso; (c) active dosimetry telescope DOSTEL count rates over the orbit of the space station highlighting passage for different time periods as well as the change in radiation environment conditions over time and orbit of the space station. © HAMLET Consortium

> WP2: Detector Characterization

In order to combine the individual data sets, which have been acquired using different detector types and evaluation methods, active and passive radiation sensors have to be characterized in ground-based radiation fields available from high-energy particle accelerators (see Figure 3). Therefore the HAMLET consortium submitted two research proposals for "Ground Based Detector Research" to the National Institute of Radiological Sciences (NIRS), Chiba, Japan and the European Space Agency (ESA), Noordwijk, The Netherlands. Both proposals were accepted after a peer review process. First experiments with monoenergetic beams of fully ionized helium, carbon, silicon and iron nuclei at the Heavy Ion Medical Accelerator (HIMAC) at NIRS and the Heavy Ion Synchrotron (SIS) at the GSI Helmholtz Centre for Heavy Ion Research in Darmstadt (Germany) permitted the investigation of the detector response to a small, well-defined subset of the space radiation environment. Due to an international cooperation of DLR with NASA it was further possible to irradiate detectors with protons of energies up to 450 MeV – to simulate a solar particle event - at the NASA Space Radiation Laboratory (NSRL) at the Brookhaven National Laboratory (BNL), Brookhaven, USA.

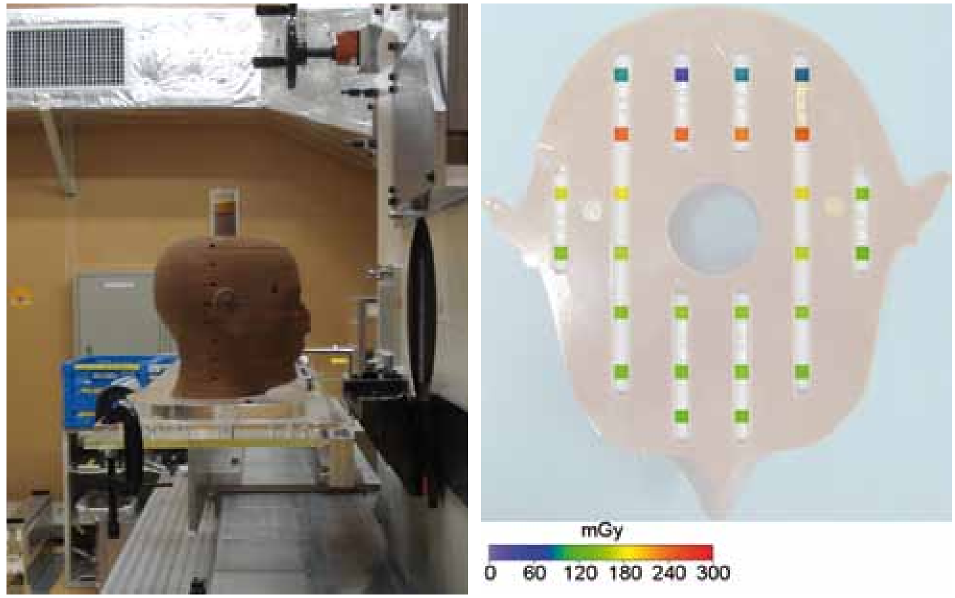

Figure 3: (a) The phantom head equipped with passive radiation detectors at the beam exit of the Heavy Ion Medical Accelerator (HIMAC) at NIRS, Chiba, Japan (left); (b) the dose distribution inside the phantom head measured with thermoluminescence detectors after irradiation with 150 MeV/n Helium ions. ©HAMLET Consortium

> WP3: ISS Space Data comparison

Although the MATROSHKA experiment represents the most extensive effort so far in quantifying the radiation exposure of astronauts, harmonization of the available dosimetric data requires the inclusion of all dosimetric data collected in this field. Therefore a publication database has been set up on the HAMLET webpage (see Figure 4). The directory structure has been adapted to the tasks defined above: (a) phantom experiments on ISS, (b) active radiation monitoring on ISS, and (c) passive radiation monitoring on ISS. The collected papers have been distributed to the particular experts of the HAMLET consortium for purposes of evaluation and comparison. The web database is updated in regular intervals to account for the extensive literature survey still being in progress. A further source of valuable knowledge is provided by the web-based proceedings of the annual Workshops for Radiation Monitoring for the International Space Station (WRMISS), available under http://wrmiss.org/. Authors of papers to be considered in the present survey have been contacted for their permission to use the experimental data.

Figure 4: http://www.fp7-hamlet.eu/index.php/literature

> WP4: Experimental and Calculated 3D Radiation Model

For this work package two computer tomography (CT) scans of the MATROSHKA phantom were performed. The data from the CT scans are thereby the prerequisite to build the Voxel model of the phantom called NUNDO (Numerical RANDO). A computer program OrDoCal (Organ Dose Calculation) was developed for the interpolation of point doses over the whole phantom volume and for calculation of the organ doses based on the data input from WP 1. Using this software the data obtained within the MTR-1 and MTR-2A phase of the experiment were analyzed and a 3D dose distribution within the phantom was calculated (see Figure 5). Based on the constructed Voxel Phantom NUNDO first preliminary radiation transport calculations have been performed using the heavy ion transport code PHITS.

SPACE SCIENCE AND EXPLORATION

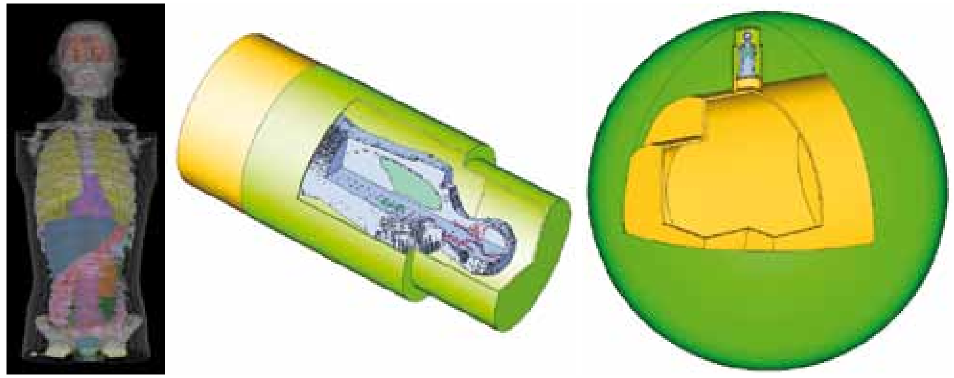

Figure 5: (a) Three-dimensional numerical model to calculate organ doses; (b) modelling of the MATROSHKA facility in PHITS code geometry; and (c) setup of the MTR facility outside the ISS for radiation transport calculations. ©HAMLET Consortium

> WP5: Dissemination of Results

The Public Outreach of HAMLET was optimized by installation of the HAMLET web page under http://www.fp7-hamlet.eu. The scope of this page is not only to inform the public about the project itself, but rather provide a comprehensive but concise overview of the space radiation environment, detector instrumentation, radiation transport models and associated topics, and highlight the expertise of the participating institutions. An image gallery serves as an online repository of digital images pertaining to the MATROSHKA experiment and HAMLET activities.

The science achievements of the HAMLET project are disseminated publicly through a web database. Following the definition of a unified structure for the experimental data provided by the individual participants, a front end of the web database has been designed which allows for convenient and reliable uploading of the processed dosimetric data under http://www.fp7-hamlet.eu/index.php/database. The data archive currently contains absorbed dose rates measured under extravehicular activity (EVA) conditions during the MTR-1 experiment by miniature luminescence detectors at about 4 800 sites within the anthropomorphic phantom body. The user is graphically assisted in navigating through the torso. The database disseminating count/dose rates as well as linear energy transfer (LET) spectra measured by active instruments has been set up and tested internally and will be online after the peer reviewed publications of the data.

Dedicated Public Outreach Events (see Figure 6), hosted and organized at the bases of the participating institutions, shall further increase the awareness of the public audience to the significance of radiation exposure for the future development of human spaceflight.

Figure 6: The HAMLET Public Outreach Events: (a) 1st Vienna, Austria (April 2009); (b) 2nd Oxford, UK (January 2010); (c) 3rd Budapest, Hungary (October 2010). © HAMLET Consortium

The 1st HAMLET Public Outreach (PO) Event was held on 1–2 April 2009 at Vienna University of Technology. The keynote lecture on radiation risk in human spaceflight was given by Prof. Dr. Jürgen Kiefer, from 1970 to 2002 Professor of Biophysics at Justus Liebig University Giessen, Germany. The event was acknowledged also by the Vienna City Council for Cultural Affairs and Science Policies and included a space-art Exhibition that attracted considerable audience. The 2nd HAMLET PO Event was held on 21 January 2010 at St. Catherine's College in Oxford, organized by HAMLET partner HPA followed by the 3rd HAMLET Public Outreach at the 12 October 2010 organized by HAMLET partner AERI at the Budapest University of Technology, Hungary. The events attracted attendees with scientific and academic background but also students and an interested public audience. The HAMLET PO Events were advertised trough press releases, magazine articles, leaflets and posters. In addition TV and radio interviews documented the public interest.

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CONCLUSION

Quoting Seneca "Per aspera ad astra" – the way for humans to the stars is not an easy one. Besides all the other obstacles one has to solve for living in space – such as the influence of microgravity on the human body, the psychosocial problems due to different cultures living in confined spaces also the radiation environment is a limiting factor, especially when looking for longer human presence in space or even going to the Moon or Mars. The risks due to exposure to cosmic radiation have to be determined as accurate as possible in order to enable a safe and secure human presence in space. One way to determine this risk is given by measuring the radiation load inside human-like phantoms, as performed within the MATROSHKA experiment. The HAMLET project uses the data generated by the MATROSHKA experiment for the development of a 3D model of the dose distribution inside a human body, simulating an astronaut´s space walk – as well as in different parts inside the ISS – simulating an astronaut moving inside the space station. This 3D model will be verified and benchmarked using highly complex Monte Carlo transport codes. Further on, an extensive ground based program is performed at various heavy ion accelerator facilities around the world to determine the response and to characterize the applied radiation detectors used within the MATROSHKA project. This data – as well benchmarked against radiation transport codes – is used to verify the accuracy of the developed 3D dose distribution model. The outcome of all the work performed within HAMLET will contribute to a better radiation risk assessment for long duration space flight, thereby securing the future presence of humans in low Earth orbit and beyond.

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SPACE SCIENCE AND EXPLORATION

PRoViScout

Planetary Robotics Vision Scout

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Joanneum Research, Graz; SciSys Ltd., Bristol; University of Leicester; DLR, Berlin; CSEM, Zurich; TraSys, Brussles; Aberystwyth University; Czech Technical University Prague; GMV Madrid; MSSL/Univesity College London, Holmbury St. Mary; University of Strathclyde; JPL, Pasadena

ABSTRACT

The EC FP7-SPACE Project ProViScout will demonstrate the feasibility of vision-based autonomous sample identification & selection as well as terrain hazard analysis for a long range scouting/exploration mission on a terrestrial planet along with the robotic elements required. It will bring together major groups currently working on planetary robotic vision, leading experts in planetary surface operations, and experienced planetary scientists, consisting of research institutions all over Europe, NASA-JPL in the US, and the industrial stakeholders involved in mission design, vision, navigation and data exploitation for robotic space missions, convening to a final end-to-end demonstration. The main PRoViScout objectives can be summarized as follows:

> Populate a robotic vision on-board processing chain (PRoViSC) with representative components available at the proposing institutions, with minor adaptation and integration effort.

> Address and merge a representative set of sensors (including a novel zoom 3D-Time-of-flight camera) to fulfil important scientific objectives and prove the general applicability to the approach in different mission scenarios.

> Include the search for scientifically interesting targets as an essential component for mission success into the navigation chain by Autonomous Tasking (Goal based planning and re-planning).

> Compile a PRoViScout Demonstrator on a mobile platform that combines sensors, processing and locomotion on-board ready for an integrated outdoor demonstration.

> Integrate a monitoring function (PRoViM) to understand the behaviour of the system.

> Demonstrate the feasibility of long-term vision-based scouting making use of a representative outdoor test bed and the PRoViScout Demonstrator platform.

In the context of ProViScout, robotic planetary space missions are defined as unmanned missions performing in situ exploration of the surface and (if applicable) atmosphere for any planetary objects outside the Earth. Most such missions involve a means of mobility provided by either a surface vehicle ('rover') or by aerial vehicles (balloons, aerobots etc.). Mobile systems are among the most critical of all space missions in requiring a rapid and robust on-site processing and preparation of imaging data to allow efficient operations for a maximum use of their limited lifetime, throughout the envisaged mission duration and beyond. In the future the number and variety of such platforms will require more autonomy than is feasible today, particularly in the autonomous on-site selection of and access to scientific and mission-strategic targets.

ProViScout will provide the building blocks on board of such future autonomous exploration systems in terms of robotics vision and decisions based thereupon. PRoViScout will help develop a unified and generic approach for robotic vision on-board processing, namely the combination of navigation and scientific target selection by addressing all relevant existing approaches to this topic and integrating them into a framework ready for and exposed to field demonstration. The explicit implementation or adaptation of vision processing components will be realized in the Project scope to the extent necessary to complete the processing chain for this purpose. PRoViScout offers real research challenges (rather than mainly integration and trials), and inherently it has potential Earth based applications that do not and will not emerge over the next few years without such efforts. Mutual benefits are guaranteed by the proposers' involvement in major relating European initiatives such as ExoMars PanCam, Eurobot, EC-FP7 PRoVisG and the UK national CREST Project Autonomous Robot Scientist.

WORK PROGRAMME, METHODOLOGY, MILESTONES

PRoViScout is realized in seven Work Packages (WPs) with 4 Tasks (T) each on average:

WP1 MANAGEMENT: This work package – as a kind of standard project component - includes the administrative (Task 1.1), financial (T1.2), technical (T1.3) and scientific (T1.4) management of the project.

WP2 CONSOLIDATION: To formulate the Road Map, WP2 summarizes the status of knowledge about the topics covered in PRoViScout and states the requirements in terms of science (T2.1) and operational aspects (T2.2). System requirements for the final demonstrator are formulated (T2.3), the demonstration scenarios and target missions are collected (T2.4), and relevant computer vision in terms of recognizing scientific targets is addressed (T2.5).

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WP3 SCIENCE TARGET SELECTION: This work package addresses the science selection element of the architecture and will include: Geological and Morphological classification implementation (including aerial) (T3.1), Organics and Biological classification implementation (T3.2), and the low-level selection of interesting targets coupled directly to the Pan-Tilt control of the Rover vision system (T3.3). Pattern Recognition and Learning to train and select the image primitives of scientific targets detected from T3.1 and T3.2 is implemented in T3.4.

WP4 PROVISC & ON-BOARD SYSTEM: This is the main system integration work package that enables an operational vision-based navigation and control of the rover for an end-to-end demonstration. Multi-spectral panoramic camera, the 3D-TOF sensor, high resolution camera and WALI, a novel Wide Angle Laser Imager (T4.1) and the AU Rover (T4.2) are adapted. The Navigation and Mapping Module (T4.3) as well as the Decision Module (T4.4) are plugged in. All modules are integrated into a Software Framework (T4.5) executable on a processing unit on board of the Rover. Supporting 3D Vision functionalities such as calibration, vision data fusion and 3D reconstruction are covered in T4.6.

WP5 PROVIM: The monitoring and visualization of the rover operations and its decisions is realized in this WP, with the monitoring of operations and decisions (T5.1), visualization and rendering of special components (T5.2), and the backend interface to the www (T5.3).

WP6 SIMULATION & TESTING: All simulation and testing, except the final public test, takes place in this Work Package. A simulated data base is provided by T6.1 in order to have ground-truth whenever needed. Special attention is paid to the feasibility of merging aerial / aerobot with ground – based data, which is performed in T6.2. A sequence of laboratory tests (T6.3) should ensure the proper function of individual components and the interfaces between them. A contribution to the international series of AMASE field-tests at the Arctic region is covered by T6.4. Mars Exploration Rover (MER) 3D vision processing (T6.5) is used to verify the methodology using real comprehensive data from a planetary surface, to show the benefits of the autonomous science selection approach and its applicability in planetary environment. An internal test with all components integrated (T6.6) should verify the whole Software – and Hardware suite.

WP7 EXPLOITATION: T7.1 is concerned with the academic and public dissemination of PRoViScout results, closely synchronized with the European Spacemaster Initiative. One major Project output is the integrated public test (T7.2). Spin-offs are evaluated in T7.3, and the external PRoViScout web-site is compiled and maintained in T7.4.

The entire PRoViScout effort is planned with about 210 Person Months. It comprises 6 milestones (MS; Table 1) of which one has been successfully achieved by paper submission (Jan 10th, 2011).

Table 1: List of Milestones and technical reviews

MS no	MS title	Means of verification
MS1	Requirements & Design Review	Agreement among Partners
MS2	Science & Target Selection Review	Agreement among Partners
MS3	Rover Readiness Review	Rover platform ready for components integration
MS4	Module Integration Campaign	Major vision & processing components integrated on Rover
MS5	PRoViM in the web	www part of PRoViM is reachable
MS6	Integrated Test	Test in representative environment has been conducted

PARTNERSHIPS AND COLLABORATIONS

In addition to the 11 PRoViScout Beneficiaries (Table 2) the Consortium is supported by the Machine Learning and Instrument Autonomy group of JPL (Robert Granat), acting in the Steering Committee together with scientists from some of the PRoViScout Partners. The tasks are well balanced between the academic, research and industrial partners.

Table 2: PRoViScout Beneficiaries

www.PRoViScout.eu © PRoViScout	> Joanneum Research Institute for Information and Communication Technologies (JR), Austria > SciSys UK Ltd. (SSL), United Kingdom > German Aerospace Center (DLR), Germany > Aberystwyth University (AU), United Kingdom > Czech Technical Unviversity (CTU), Czech Republic > GMV (GMV), Spain > University of Leicester (ULEIC), United Kingdom > Swiss Center for Electronics and Microtechnology (CSEM), Switzerland > TraSys (TRS), Belgium > University College London (UCL), United Kingdom > University of Strathclyde (UoS), United Kingdom

ACHIEVED & EXPECTED RESULTS

The search for traces of life – past or present – is at the centre of Europe's ongoing Planetary exploration programme. In the near future, robots with life science sensors will explore the surface of Mars and drill below its surface to look for signs of life, supported by recent data from Europe's Mars Express mission. Yet mobility at the surface of another planet is a challenge. Mars is a harsh and cold environment. Transmission time to Earth currently stands at some 15 minutes. In consequence, real-time remote control is impractical making overall scientific progress slow.

PRoViScout addresses this challenge. The project will demonstrate a novel, autonomous exploration system (Figure 1). To make robotic rovers more independent and efficient, instead of waiting for instructions from Earth, PRoViScout implements an on-board vision-based identification and planning system. It will be able to identify objects of interest and interpret their relevance to various mission goals. Rovers will "see" important scientific or navigation features in the terrain and task themselves to gather more detailed data about previously unseen targets, whilst carefully prioritising and allocating their limited resources and keeping track of possible hazards.

By paper submission PRoViScout has been running for 9 Months. Beside the written deliverables (design documents and, reports, partly available at the PRoViScout website) the main results achieved so far are as follows:

> All requirements from science and operations have been collected and reported. This includes the definition of the target scenario planned for the field test during the final Project phase.

> System design has been finished. All interfaces between the components (rover, vision system, Hardware trade-offs, navigation system, decision module, execution control, and monitoring system) have been defined, and the main functions as well as distributed and shared data have been identified & reported in a design document.

> A new 3D-Time-of-Flight (3D – TOF) camera has been designed by CSEM (Figure 2, left), which is able to zoom and integrates RGB high-resolution images.

> Preliminary tests to extract scientifically interesting image parts from training & classification indicate that an automatic system is able to detect meaningful targets.

> Candidate field test sites in Morocco, Tenerife, Wales and Iceland were investigated, assessed and discussed. The major result is a strong preference of Tenerife, due to accessibility, logistics, locomotion, climate and scientific aspects.

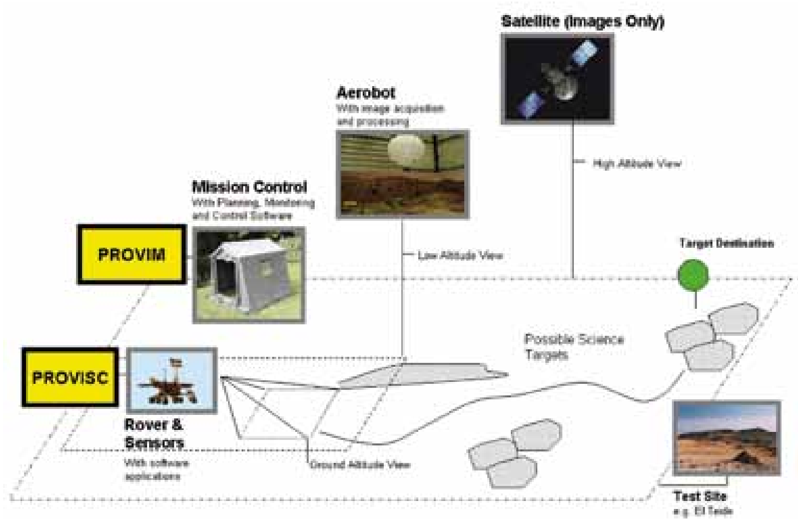

Figure 1: PRoViScout scenario during field testing. The Rover, equipped with active and passive vision sensors will receive a local map obtained by satellite and/or aerobot imagery. The map contains waypoints indicating interesting targets. On its autonomously selected path through the terrain the system observes its environment and looks for scientifically interesting targets. Once found a target, it assesses the costs to reach the target and decides upon changing its original plan to obtain close-ups. Mission control receives high-level data only, getting an insight into the decisions of the systems and main parameters involved (images taken, costs, decision reasoning, various visualizations). © SciSys

In early 2010 an assessment of scientifically interesting areas at Clarach Bay (Aberystwyth, UK) took place (Figure 2, right). The resulting report is publicly available via the PRoViScout download area. In January 2011 an aerobot test has been planned, to verify the concept of a tethered aerobot for Rover mapping & science target selection support. The definition of relevant training samples to test pattern recognition methodologies for automatic identification of scientifically interesting targets is ongoing, see Figure 3 for an example. Key parameters for the operational scenario of the final field test have been assessed, and some recently implemented components have already been verified in simulated environment (Figure 4). Independently, components such as 3D reconstruction of the rover's environment or specific target recognition have started to develop.

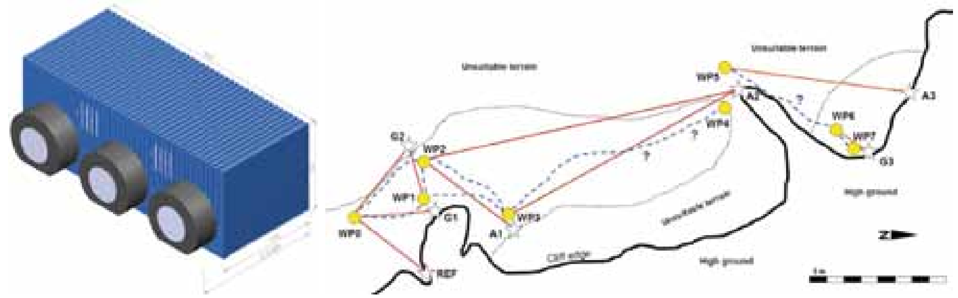

Figure 2: Early achievements of PRoViScout requirements definition & design work. Left: Dimensional layout of the zoom RGB 3D-TOF camera. © CSEM. Right: Example for waypoints and a globally planned rover trajectory in the area of Clarach Bay (Aberystwyth, UK). © Univ. Leicester

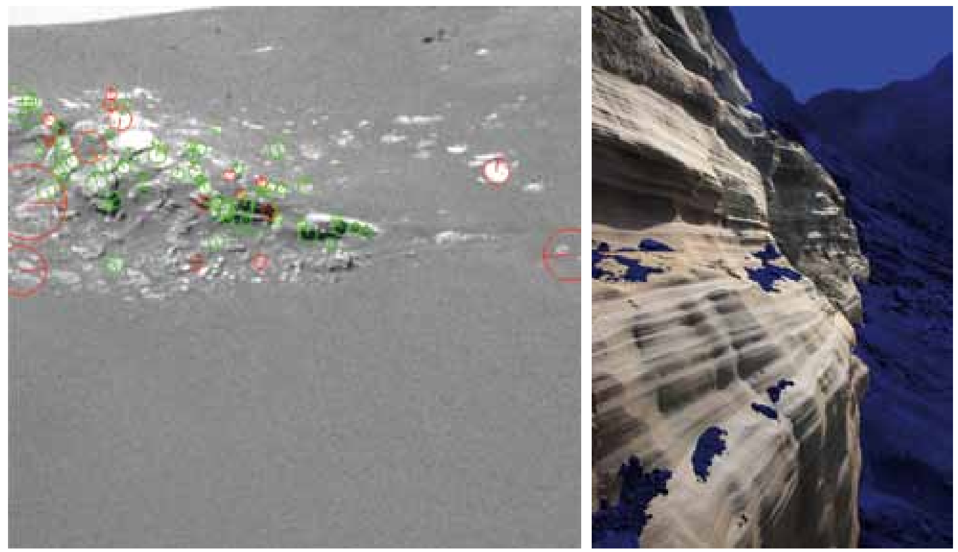

Figure 3: Left: Classification result for an image captured on Mars: A binary classifier was trained on extracted SIFT keys from images with geological structures. These structures where manually labeled by experts into an interesting and one background class. Here, green keys indicate some interesting regions while red keys denote background. The scale of the region is indicated by the diameter of the circle, while the line starting in the centre of the key point location signals the orientation based on image gradients around the key point. © NASA-JPL/JR. Right: Training image (one out of several tens), with interesting areas kept coloured; other areas are marked dark blue. © DLR

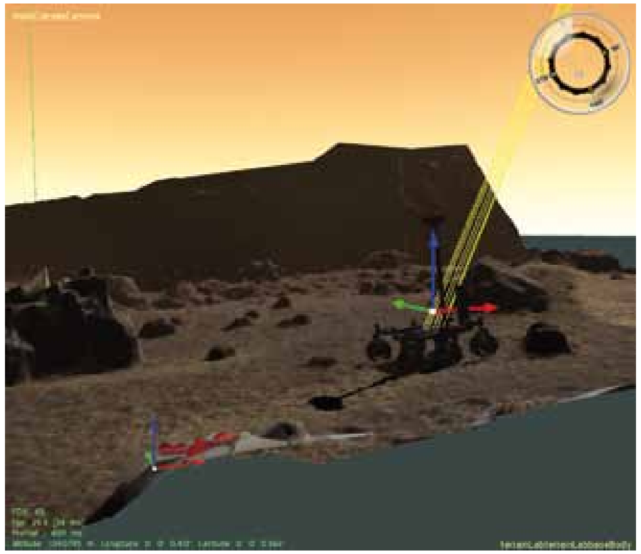

Figure 4: Visualisation of the robotic system inside its environment as planned during the field test, considering the terrain, the sun position, real-time shadows, the display of system key parameters and a rover simulation. © TraSys

CONCLUSION

ProViScout supports the development of more autonomous space vehicles. Vision based sample identification enables such rovers to act more independently, which is needed for more efficient scientific mission outcomes. The PRoViScout project objective is to increase the amount of quality science data that remote planetary rovers can deliver on behalf of Earth based science teams. This will be obtained by prototyping intelligent technologies which increase their autonomy and therefore exploration efficiency.

The major project goal is a field test that demonstrates the ability to autonomously traverse terrain whilst "keeping an eye open" on potential scientifically interesting targets passed on its way – and change the global plan in favour of additional observations. The first year of the Project has paved the way to such a system by identifying the key parameters of a scenario, specifying the system components and their interfaces, and already detailed designing and implementing major components such as a novel 3D-Time-of-Flight sensor, and aerobot mapping strategies.

PRoViScout will effectively increase the amount of data returned per Euro spent on European space missions thereby ensuring good value for European Taxpayers.

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ACKNOWLEDGEMENT

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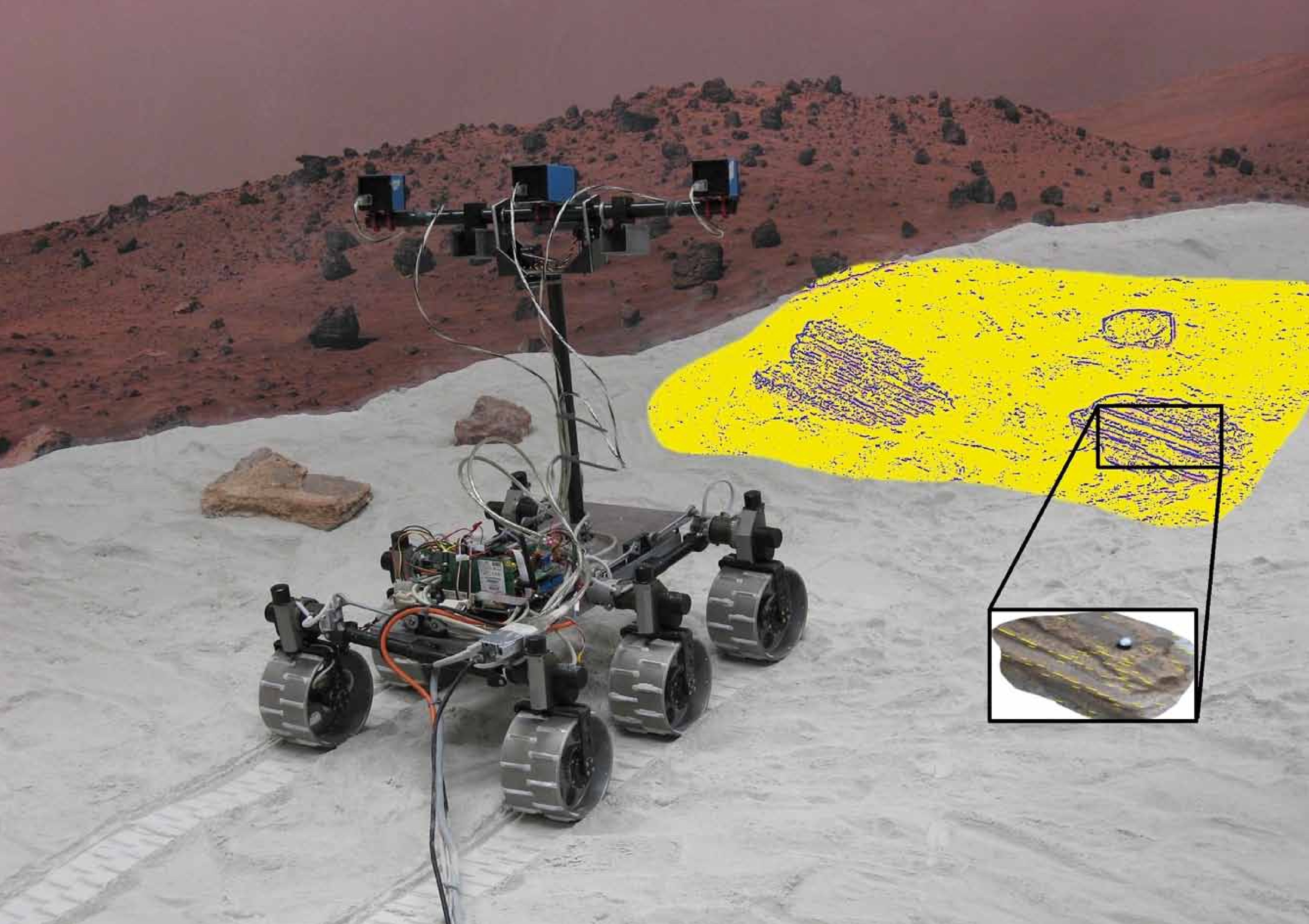

PRoVisG

Planetary robotics vision ground processing

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ABSTRACT

The EC FP7-SPACE Project PRoVisG brings together major EU and US research institutions and stakeholders involved in space robotic vision and navigation to develop a unified approach to robotic vision ground processing. It is a Collaborative Project in the frame of FP7-SPACE -2007-1, having started in October 2008 with a duration of 39 Months until December 2011. State-of-art computer vision is collected inside and outside Europe to better exploit the image data gathered during past, ongoing and future robotic space missions to the Moon and the Planets. This will lead to a significant enhancement of their scientific, technologic and educational outcome.

The main PRoVisG objectives can be summarized as follows:

> Integration of a Planetary Robotic Vision ground Processing chain (PRoViP) with representative components available at the proposing institutions, with minor adaptation and integration efforts.

> Integration of a Planetary Robotic Geographic Information System (PRoGIS) that provides access to comprehensive PRoViP vision data processing chains as well as visualization of the context, history, vision meta data and products of complete robotic planetary missions.

> Include funds to issue Announcements of Opportunity (AOs) to European vision groups to submit results from consortium-provided test data for specific algorithms. Key groups within the consortium will perform an evaluation of such submitted algorithms and produce as well as compare their own results on this set of test data.

> Organise workshops as well as sub-workshops in major computer vision conferences to present the results, their evaluation and the winners of the PRoVisG "prize", and a summer school in 2010 and 2011.

> Hold a field test at a representative site (e.g. caldera of Tenerife) at the end of the project period, attached to a Summer School, in order to demonstrate the elaborated processing framework & GIS to the academic and public society.

> Address specific needs in terms of Sensors and sensor arrangements. The Swiss Beneficiary CSEM developed a new panoramic stereo sensor; its benefits will be verified in the course of the PRoVisG project, together with a 3D Time-of-Flight sensor.

The integration of PRoViP and PRoGIS is currently ongoing. PRoVisG Partners have contributed with high-level vision processing algorithms. An Announcement of Opportunity is in preparation to involve the international computer vision community in planetary robotics vision with a contest for point cloud production from multiple images. Field tests using the Astrium Rover Bridget were already successfully conducted to test the integrated vision processing tools, and show their applicability to relevant conditions. A project web page and several tens of publications, as well as a Summer school in 2010 and 2011 complete the set of dissemination activities.

WORK PROGRAMME, METHODOLOGY, MILESTONES

PRoVisG is realized in seven Work Packages (WPs) with 4 Tasks (T) each on average:

WP1 MANAGEMENT: This standard work package includes the administrative (Task 1.1), financial (T1.2) and technical management (T1.3) of the project.

WP2 SPECIFICATIONS & REQUIREMENTS: We outlined the full scenario on the basis of mission cases (T2.1) for intermediate and final versions of the PROGIS prototype and defined specific use cases – leading to a Requirements Definition Document (RDD). The PRoGIS and PRoViP requirements were collected from the scientific (T2.2) and operations (T2.3) point of view. Additional requirements came from MER mission experience (T2.4).

WP3 INTERFACES: A number of component interfaces were covered, starting with a description, adaptation (T3.2) and calibration (T3.5) of the sensors and robotics components (T3.4) in a vision-system relevant manner. The data structures, procedures and functions of on-board systems were taken into account (T3.1), and some specific 3D data structures (e.g. overhangs, caves) were addressed here (T3.3). To enable an open architecture of the PRoViP the access of 3rd party processing components was settled here as well (T3.6). Beside these data- and processing – related interfaces a strategic action was covered: The functional items of the joint European/US development of a Stereo Work Station are linked here (T3.7).

WP4 PROCESSING CORE (PROVIP): The collection of existing standard product generation functions fills default processing chains (T4.1). To cope with the mission- and scientific requirements specific surface modelling functions had to be added (T4.2). The whole field of site data fusion (T4.3) brings different resolutions and viewpoints into one context, sensor fusion (T4.4) covers the integration of different sensors and sensor signatures. A task foreseen for innovative methods (T4.5) allows the implementation or adaptation of new methods of immediate relevance to planetary robotics vision.

WP5 PROGIS OVERLAY: The functional specification and interface implementation of the PRoGIS processing overlay (i.e. calling PRoViP functions) takes place in T5.1. The PRoGIS implementation itself consists of the GIS data base & core (T5.2) and the Web-GIS overlay functionality (T5.3). Specific add-on-product generation is covered (T5.4), some visualization & rendering functions will be implemented to meet the scientific requirements (T5.5), and the incorporation of global context from orbiter data is realized here (T5.5).

WP6 EVALUATION: The evaluation has four aspects: 1) To search for European solutions of planetary robotics vision processing on a competitive basis (within e.g. sponsored workshops) contains the announcements and maintenance of such calls (T6.1) and the evaluation of the results (T6.2). 2) MER data processing testing (T6.3) will demonstrate the PRoViP abilities for existing mission data. 3) Testbeds tests (T6.4) will show the PRoVisG applicability under realistic and real-time conditions, and a task dedicated to MER Mapping & Mobility (T6.5) shows a direct impact on the usability of PRoVisG results for mission operations. 4) A special task will be dedicated to the assessment of compliance with the requirements settled during the specifications phase (T6.6).

WP7 DISSEMINATION: Dissemination and exploitation of the results is a five-stage process: Workshops placed in larger-scope congresses ensure the interfacing to related actions ongoing in planetary research and robot vision (T7.1). A field test campaign raises public attention and serves as major milestone of the project (T7.2). A PRoVisG web site (T7.3), two dedicated summer schools, the contribution to public events and the compilation of an "education kit" (T7.4) cover the educational and PR aspects. In view of future industrial usability of selected PRoVisG results T7.5 collects Spin-Off and other exploitation activities.

The entire PRoVisG effort is planned with about 350 Person Months. It comprises 6 milestones (Table 1) of which three have been successfully achieved by paper submission (Dec. 21st, 2010).

Table 1: List of Milestones and technical reviews

MS no	MS title	Means of verification
MS1	Requirements Definition Review	Meeting minutes: Agreement on requirements
MS2	Interfaces Review	Meeting minutes: Agreement on interfaces
MS3	PROVIP Demonstration & Review	Successful demonstration
MS4	PROGIS in the web	Web access & test successful
MS5	Requirements Assessment Review	Review document states positive result
MS6	TUB Summer school	Held, participants number sufficient

SPACE SCIENCE AND EXPLORATION

PARTNERSHIPS AND COLLABORATIONS

In addition to the 13 PRoVisG Beneficiaries (Table 2) the Consortium is supported by the Instruments and Science Data Systems Section of JPL (Bob Deen, Veljko Jovanovic) and by the Leicester Space Research Centre (John Bridges), acting in the Steering Committee together with scientists from some of the PRoVisG Partners. The tasks are well balanced between the academic, research and industrial partners.

Table 2: PRoVisG Beneficiaries

Partners are located in Europe and the USA **www.PRoVisG.eu** © PRoVisG	> Joanneum Research Institute for Information and Communication Technology (JR), Austria
	> Aberystwyth University (AU), United Kingdom
	> Deutsches Zentrum für Luft- und Raumfahrt (DLR), Germany
	> Ceské vysoké ucení technické v Praze (CTU), Czech Republic
	> SciSys UK Ltd. (SSL), United Kingdom
	> Astrium Ltd. (ASU), United Kingdom
	> Technische Universität Berlin (TUB), Germany
	> University College London (UCL), United Kingdom
	> The Ohio State University (OSU), United States
	> University of Surrey (UNIS), United Kingdom
	> Centre Suisse d'Electronique et de Microtechnique SA - Recherche et Developpement (CSEM), Switzerland
	> Centre national d'études spatiales (CNES), France
	> University of Nottingham (UNOTT), United Kingdom

ACHIEVED & EXPECTED RESULTS

By paper submission PRoVisG has been running for more than 2 years. Beside the written deliverables (design documents, reports and manuals, partly available at the PRoVisG website) the main results achieved so far are as follows:

- A catadioptric stereo sensor (Figure 1, left) and attached software (calibration, navigation & 3D reconstruction) for data exploitation were developed and delivered to the PRoVisG Consortium.
- A set of collected functions from PRoVisG Partners, partly to be integrated into PRoViP, and partly to be made available via remote procedure calling, among them
- Shape-from-shading (SFS) by AU

> High dynamic range (HDR) by DLR
> Multi-view stereo reconstruction by CTU
> Rock modelling and segmentation by OSU
> Wide baseline stereo by DLR
> Super Resolution by TUB
> Digital Elevation Model (DEM) generation workflow by JR.
> 3D reference data and images were collected by CTU for an international contest on 3D reconstruction. Publishing of the contest data & definition is still ongoing at paper submission.
> Data processing of various planetary & related data was performed to prove the ability of PRoVisG tools to exploit planetary vision data on highest level. See Figure 2 for an example of combining different cameras' data with various resolution.
> Dissemination of the Project was higher than initially expected. The PRoVisG website has been visited several thousand times. Press response to field tests and demonstration activities was tremendous and some TV appearance took place as well. A PRoVisG Podcast was prepared, and PRoViSG was released on Wikipedia. Some tens of papers funded in the frame of PRoVisG appeared in computer vision and planetary science conferences.
> PRoVisG participated in the AMASE 2010 Expedition to the Arctic area of Svalbard. The ExoMars PanCam Team was supported with 3D vision processing components.
> One major achieved result was highly intensified Cooperation between the European PRoVisG institutions and US Partners Ohio State University and JPL.
> The joint development of a stereo work station for enhanced interactive viewing of stereoscopic data by JPL and UCL lead to the decision to emphasize this activity in terms of effort and work power. During paper submission the generation of an open-source version is under discussion.
> The contribution by OSU was found highly relevant in terms of their expertise collected during MER Mission navigation and mapping. Reference data provision, important parts of PRoViP and PRoGIS design work as well as strategic comments and support during meetings proved their participation to be most useful.

In July 2010 a field test was held in Aberystwyth, hosted by AU, making use of the ASU Rover Bridget. It was mainly used to find exploitation modes of the catadioptric stereo sensor by CSEM and to verify the PRoViP processing chains implemented so far. After calibration of the various vision sensors mounted on Bridget (Figure 1), the field test data exploitation resulted in the immersive 3D reconstruction of a part of the Clarach Bay area (Figure 3), documented in a YouTube video.

Despite some outstanding results, a set of shortcomings and possible problems for the project impact were detected:

> The software & tool contributions by individual PRoVisG participants were highly heterogeneous, apparently due to missing standards in the area of 3D computer vision. One impressive example was a simple internal "contest" for stereo processing of some Clarach Bay July 2010 data: The disparity maps from 5 different institutions arrived in 5 different formats and data interpretation schemes. However, the documentation provided after request allows an objective evaluation of the contest. Similar heterogeneity applies to the software items listed above, raising PRoViP integration effort above the estimated amount. It was therefore decided to focus on a few most important contributions to be integrated into PRoViP.
> A general observation applying to academic institution was the late availability of personnel during project start, which caused some delay during the first months of the Project.
> Due to loss of relevant personnel, a planned underwater test had to be postponed. The same problem applies to the expected addressing of Rover locomotion issues in connection with 3D vision. Both topics are not expected key results of the project, but they were planned as further added-value items. Valid replacements are currently under discussion.

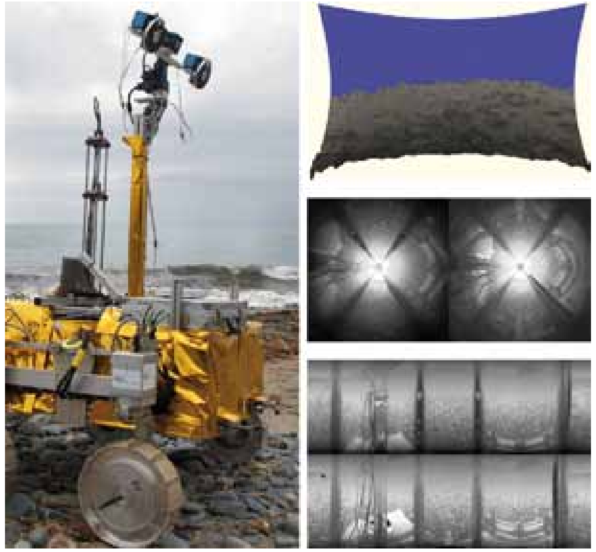

Figure 1: Left: CSEM Catadioptric sensor & 3D-Time-of-Flight (3D-TOF) camera mounted on ASU Bridget Rover during field test at Clarach Bay, Aberystwyth, July 2010 © Joanneum Research. Right: (top) 3D-TOF distance image (grey coded), (middle) catadioptric sensor images and (bottom) reconstructed panorama from catadioptric sensor © CSEM

One major result under test during the Conference is the PRoGIS, a web-based GIS that allows the access to the most important PRoViP functions, and presents them together with spatial context in a web browser. A final field test at Tenerife in late Summer 2011 has been designed, based upon the experience at Aberystwyth in July 2010. It will collect representative data to be utilized during a following Summer School in Berlin.

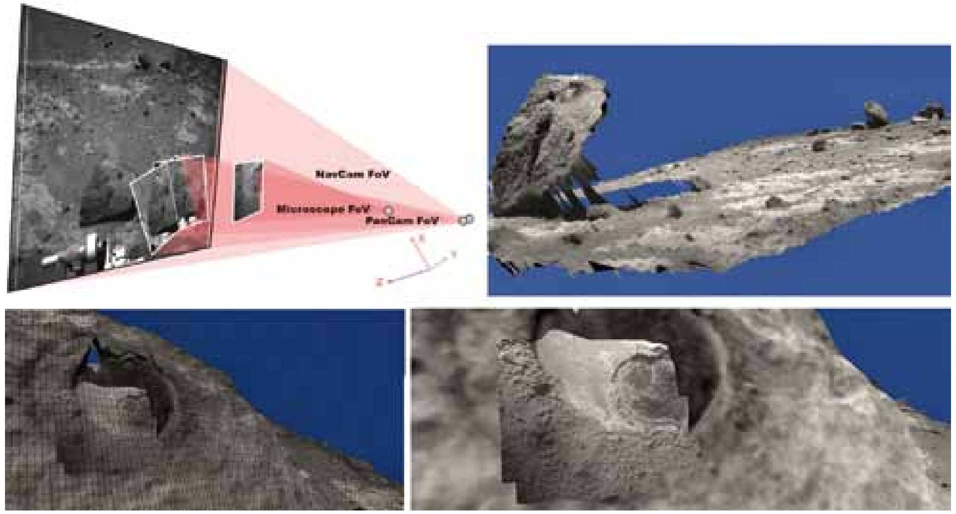

Figure 2: Fusion of three levels of scaling using MER image data. Top left: Visual Fulcra (fields-of-view) from image orientations of NavCam and PanCam Stereo pairs, and Microscope. Top right: Rendered overview of fusion between PanCam DEM, NavCam DEM and Microscope image texturing the PanCam 3D result. Lower row: Close-up rendering of the fusion result, with and without triangular grid overlaid. The resulting vrml data set allows interactive 3D zooming into the MER APXS instrument drill hole. Source: Courtesy NASA-JPL[10]. Processing: PRoVisG. © Joanneum Research

10 Data was captured between Sol 2095 to Sol 2121, when the Opportunity Rover stayed in the same position at 'Marquette Island', and captured a great amount of different image types, such as PanCam, Front Hazcam, Navcam, and Microscopic Imagers.

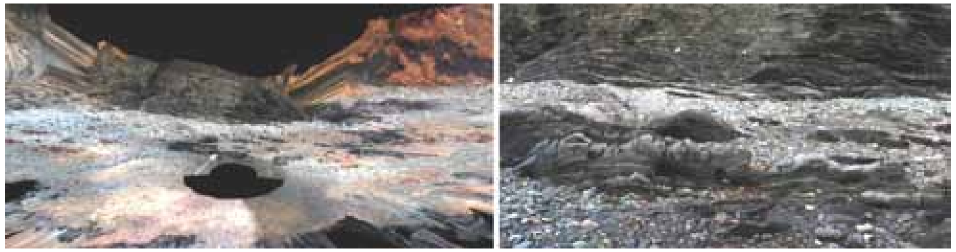

Figure 3: Rendering of 3D reconstruction using ExoMars PanCam – simulating stereo, 20 pairs. Left: Whole area in viewer. Right: Close-up at the marked position in the overview. A high resolution video showing real-time rendering of this area is available at YouTube. Credits: VRVis, Vienna. © Joanneum Research

CONCLUSION

PRoVisG shows that a medium-scale Cooperation of vision experts and planetary scientists is possible. The Project is in line with planning and impact expectations. Some drawbacks have been found due to missing standards in this relatively new area of computer vision application: although the effort to integrate methods from different providers into a unique framework is larger than expected, the objectives of the Project will be achieved within the given time frame until end 2011.

ACKNOWLEDGEMENT

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SPACE SCIENCE AND EXPLORATION

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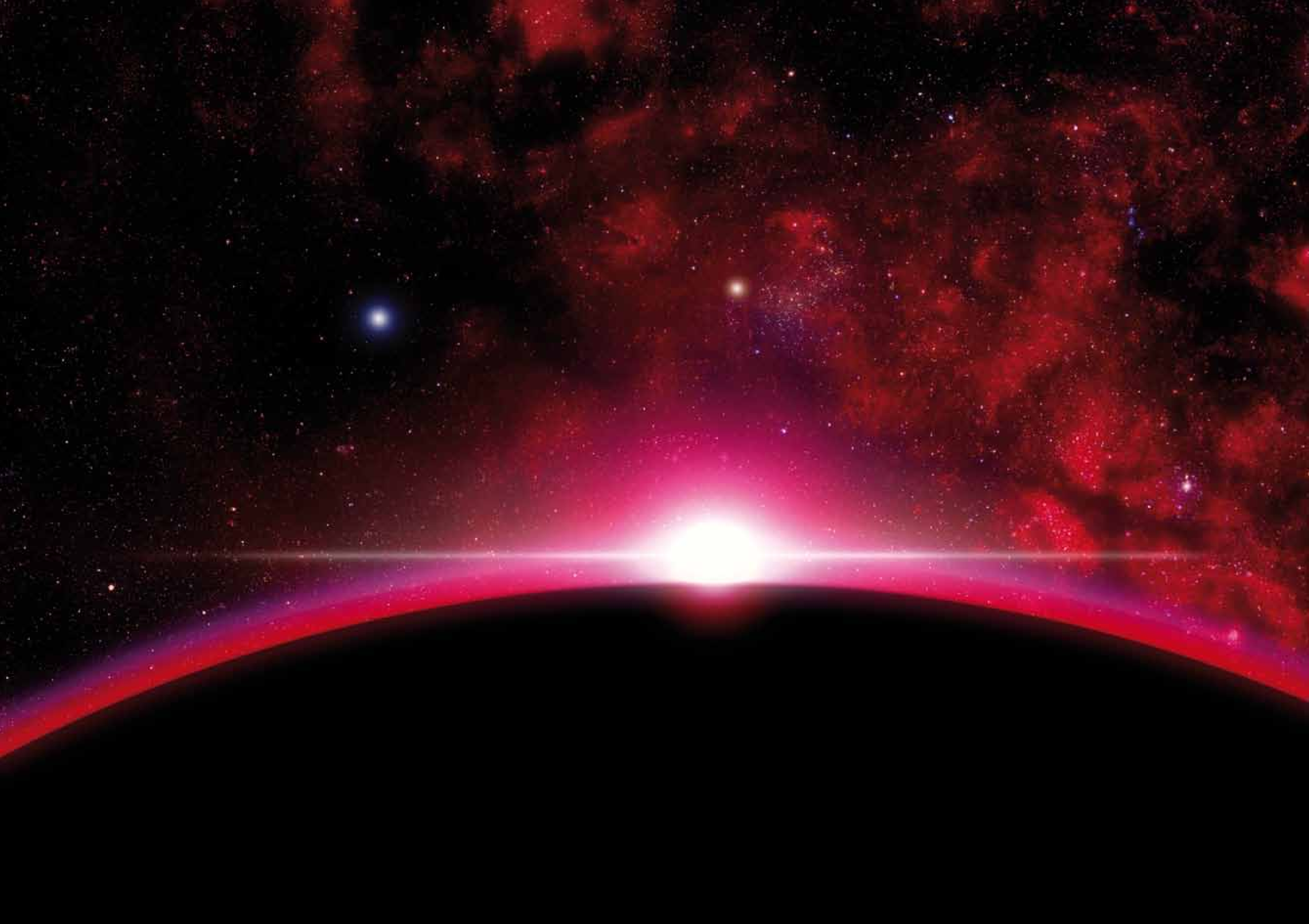

SOTERIA

Solar-terrestrial investigations and archives

Giovanni Lapenta (Coordinator)

Katholieke Universiteit Leuven

ABSTRACT

SOTERIA, a FP7 Space Science project, aims at improving our understanding of the space weather phenomena through collaboration between experts in different fields of solar, space and geophysics. The main goal is to make better use of existing data and provide better databases, which will go beyond the present state-of-the-art in regard to details, time-resolution and improved methods of accessing it.

We live in an era when the concept of environment is enormously extended: it is not bound to the accessible terrestrial sites, oceans and atmosphere, but it also comprises the extraterrestrial environment including the Sun. What we observe in this expanded and dynamic environment is called Space Weather. Influences of the Sun on the Earth come through the solar spectrum of radiation, which provides us with light and heat, and through other changing features of the solar activity. Some of the most important and impressive phenomena of the solar activity are shown in Figure 1 depicting sunspots (regions of intense magnetic fields on the solar surface) and coronal mass ejections (CMEs). CMEs carry tremendous amounts of plasma and energy through the solar system, and those which hit the Earth can, in some cases, lead to dramatic consequences. When a CME reaches the Earth, complex series of events in the magnetosphere and ionosphere are triggered, with effects down to the lower atmosphere and on the ground.

The studies conducted by SOTERIA involve the analysis and processing of the relevant data from 18 satellites, including several ESA and other European satellites. The study is complemented by a large set of data from European ground-based observatories. SOTERIA includes also considerable effort in utilizing and developing theoretical and simulation models for interpreting the space weather data.

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Figure 1: Major sunspot group passing central meridian: this image shows an active Sun, only two years after the last maximum of activity, with a major sunspot group passing central meridian. This whole-disk CCD image was taken on Jul. 29, 2002 with the Uccle solar telescopes (ROB, Brussels), one of the ground-based synoptic instruments that will support Work Package 2 of the SOTERIA project

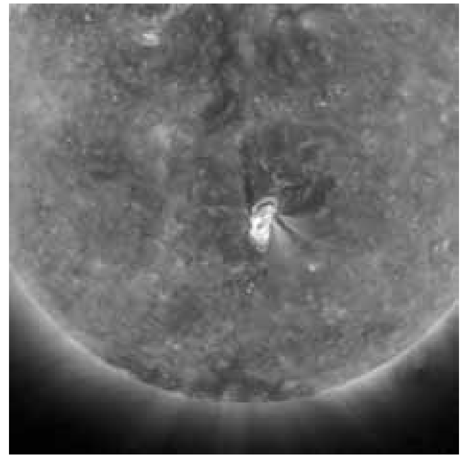

Figure 2: Close-up view of an active region observed by Proba-2's SWAP instrument on 3 April 2010. This eruption caused vast amounts of charged particles that reached the Earth the following Monday, 5 April. Proba2 (proba2.oma.be) is a key contributor to the Soteria project

WORK PROGRAMME AND PROGRESS

The activities of SOTERIA cover all aspects of the complex processes of space weather in the Sun-Earth connection. The work is organised into 6 work packages (WP):

> **WP1: Management.**

> **WP2: Photosphere and Chromosphere.**

Starting at the source of the space weather events, the first activity area focuses on the solar photosphere and chromosphere, that are the lowest visible strata of the Sun. The activities developing there are largely determined by what happens under the visible surface, in the interior of the Sun, an area that can currently be explored by helioseismology, a discipline that uses wave activities on the visible surface to detect the underlying structures (similar in principle to the seismology studies done on the Earth for example to detect underground oil reservoirs). SOTERIA collects all the available type of information on the photospheric and chromospheric features of the Sun relevant to space weather. Global changes in the solar activity are characterized by an 11-year cycle. The last cycle has finished recently with its lowest level of activity, and now the new cycle is to begin with an increasingly active phase coming, making the study of space weather even more urgent. Significant puzzlement is currently stirring the community due to the apparent delay in the start of the next phase of increased solar activity, an issue where the historic data collected as part of the SOTERIA project will prove valuable.

> WP3: Solar Corona.

The next layer of the solar atmosphere is the corona, visible by the unaided eye during solar eclipses as a crown around the Sun, giving it its name. SOTERIA focuses on bringing to bear the full range of observational tools on the ground and on satellites, including new and planned missions, and of theoretical and simulation tools to advance our ability to understand and predict the dynamic processes of the solar corona, such as the streamers, the flares and the eruptive evolution of solar arcades leading to the so-called CME, coronal mass ejection.

> WP4: Heliospheric Evolution.

The solar wind emanating from the Sun carries with it the solar magnetic field and the disturbances caused by the dynamic events on the Sun. The interaction of this complex medium with the planets and especially of course with the Earth is at the core of the study of space weather. The SOTERIA project uses dedicated existing tools, observational and theoretical, to understand this interaction. A catalogue of events covering some of the most common and most interesting occurrences in the space weather is created and a large collaborative effort is made to investigate with all tools available (some of which are in collaboration with American institutions, such as the Community Coordinated Modelling Center of NASA) and by all teams with expertise in this field within SOTERIA. But we also are developing new tools to harness the expertise of some SOTERIA partners in other areas of environmental forecasting (such as the meteorological predictions or the ocean modelling). We are developing a new statistical approach to couple observational data into theoretical simulations (the so-called data assimilation) to improve the predictive capability.

> WP5: Irradiance.

Of course the solar influence on the Earth and space is not limited to the solar wind, also the light comes from the Sun! An accurate estimation of the effects of solar events and natural solar cycles is key in our understanding of the Sun-Earth connection, with implications also for the complete understanding of the mechanisms constraining the climate. In SOTERIA, we focus on the variability and the origin of the UltraViolet radiation, which is likely to play a major role in the Sun-climate connection, and also develop models to understand its impact on the upper atmosphere.

> WP6: Dissemination.

The main goal is to provide better databases, which go beyond the present state-of-the-art in regard to details, time-resolution and improved methods of accessing it. The complete data coverage of Soteria can be found on the Soteria wiki: www.soteriaspace.eu/wiki/index.php/WP6_VO_Action_Plan. A key aspect of the dissemination activity is related with the Soteria Virtual Observatories (VO) named SODA (Soteria Data Archive), available from the SOTERIA web page. With the start of the HELIO FP7 network Soteria will seek further integration with the HELIO's VO, an activity further promoted by the creation of a specific infrastructure funded by the EC-FP7 project CASSIS.

Finally SOTERIA puts the largest emphasis on making all the models and all the observations described above available not only in their raw format but in a more organized common frame that maximizes the value of data previously scattered and presented incoherently. As part of this effort, SOTERIA does not only rely on state of the art internet-based software tools (including both software tools developed by the USA research efforts and by other European efforts such as the FP7 project HELIO) but will also organize outreach for the general public and training for scientists, in collaboration with other European efforts, funded by COST and international institutions such as the UNESCO International Center for Theoretical Physics, targeting especially to reach young scientists in developing countries.

PARTNERSHIPS AND COLLABORATIONS

The team of the SOTERIA project is coordinated by Giovanni Lapenta of the Katholieke Universiteit Leuven and includes scientists from institutions in 8 EU countries (Belgium, Denmark, Germany, Austria, Hungary, France, Poland, Finland) and in 3 non-EU countries (Switzerland, Croatia and Russia). The institutions involved are: Katholieke Universiteit Leuven (Coordinator), Universitaet Graz, Schweizerisches Forschungsinstitut für Hochgebirgsklima und Medizin in Davos, Konkoly Observatory, Centre National de la Recherche Scientifique, Koninklijke Sterrenwacht van Belgie, Observatoire de Paris, Space Research Centre, Polish Academy of Sciences, KFKI Research Institute for Particle and Nuclear Physics, Technical University of Denmark, University of Oulu, Georg-August-Universität Göttingen Stiftung Öffentlichen Rechts, Hvar Observatory (Faculty of Geodesy, University of Zagreb), Noveltis Sas, P.N. Lebedev Physical Institute and Informatique Electromagnetisme Electronique Analyse numérique.

Full information about the partners and contact information is available on the web site for SOTERIA: www.soteria-space.eu.

EXAMPLE OF RESULTS

The results of Soteria are vastly larger than what can be reported here. The interested reader is referred to the Soteria web page for more details. We summarise here three main results in the form of three figures.

Soteria has contributed to improving our understanding of origins, propagation and impact of space weather events.

Soteria monitors the evolution of the Sun, of the interplanetary space and the Earth space environment with state of the art observational tools on the ground and in space.

The Sun's surface (photosphere) is far from being uniform and steady but rather is very dynamic with the most prominent features being Sunspots, shown in Figure 1, obtained from ground-based observations from the Royal Observatory in Brussel. The active regions are the source of major space weather storms, including solar flares and coronal mass ejections that produce highly energetic particles. Figure 2 reports one of these active regions observed by the mission Proba2, one of the most important components of Soteria.

Soteria has developed many new results, models and simulation that led to better understanding and prediction of the formation, evolution and propagation to the Earth of these space storms.

SOTERIA includes also a considerable effort in utilizing the existing and developing improved theoretical and simulation models for interpreting the space weather data. As an example of the modelling activities, Figure 3 shows the simulation of one region of plasma formed in Sun atmosphere (the solar corona) and propagating towards the Earth. In this process enormous amounts of energy and matter are released with dangerous effects for technology and humans in space. In the case considered a flux rope is formed and is subsequently rendered unstable by the kink instability.

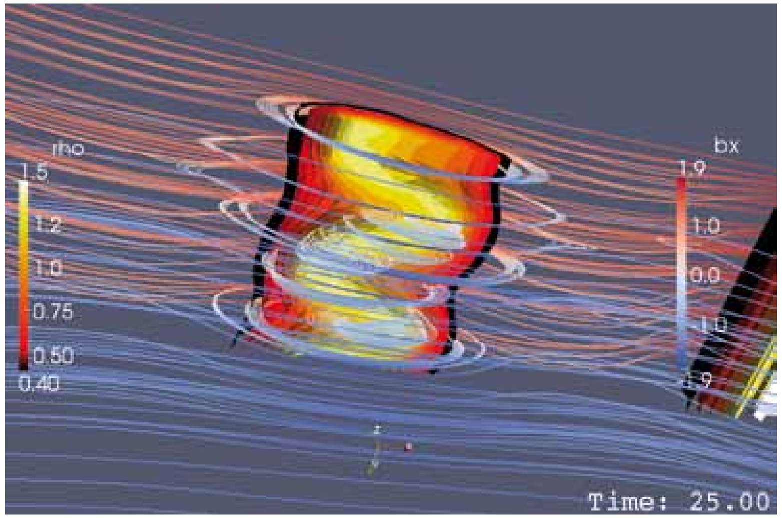

Figure 3: Simulation of magnetic reconnection, the process of magnetic field annihilation and energy release into the space environment. A complete list of the modelling tools and efforts can be found on the Soteria wiki: www.soteria-space.eu/wiki/index.php/Modelling and on the Data Assimilation menu on the main Soteria web page www.soteria-space.eu

CONCLUSION

Soteria has concluded its second year of operation and has commenced its third and final year. All the tasks planned for the first two years have been achieved and the work is well underway to reach in time and even beyond the original expectations all the goals that were set for the project. But in the opinion of the Consortium, the success of Soteria, one of the first FP7 space projects to start and the very first space weather-related project ever funded by the EC reach far beyond the technical area. Soteria has succeeded to bring together in a spirit of generous collaboration and even friendship 16 groups and institutions from different countries far from each other and in many cases with no previous background of collaboration with each other. Soteria is building a legacy of technical excellence and of better understanding of space weather processes that is leading already to better forecasting tools. And Soteria has formed a network of expert people and state of the art infrastructures upon which Europe can build its future in space weather research.

ULISSE

USOCs knowledge integration and dissemination for space science experimentation

Luigi Carotenuto on behalf of the ULISSE Consortium

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ABSTRACT

Preservation and exploitation of scientific data is a key element for further progress of science and for its application to improve daily life conditions.

The ULISSE project is aimed at improving preservation, valorisation and exploitation of data produced by European experimentation in space. Particularly the project intends to prepare the exploitation of the huge amount of scientific data that will be produced in the coming years by European experiments on board the International Space Station, the largest space platform that is approaching its full operational capability.

ULISSE is based on a distributed infrastructure: a middleware platform integrates the distributed resources (as data and tools) for the provision of services to the users. The USOCs (User Support and Operation Centres) are a network of scientific space facility operations centres and act as focal points in the distributed architecture. ULISSE services consider different types of users: main focus is on the scientific community, but also space industries, space agencies, decision-makers, educational bodies and the general public are taken into account. Surveys of user needs and of available datasets have been performed. ULISSE will provide scientific and technical data obtained in space experiments concerning almost all scientific disciplines, as Life Sciences, including Biology, Space Medicine and Exobiology, Biotechnology, Space Science, Plasma Physics and Space Environment, Technology, Material and Fluid Sciences.

A special effort is devoted to standardize the representation of the information to generate a common knowledge among the communities interested in space science experimentation. To this perspective, ULISSE has produced a metadata standard and the related data inventory and is creating a knowledge representation, using Topics Maps technology; the resulting database is comprehensive of the different scientific disciplines in order to improve cross-disciplinary information mining and sharing. Additional tools and applications for data management, visualization and integration are going to be developed.

ULISSE is collecting and harmonizing existing constraints and limitations to data distribution stated by data owners, typically the space agencies that fund or coordinate the space experiments. ULISSE, with the support of the European and national space agencies, will identify and implement reference rules for data distribution in compliance with the existing data policies.

As a first step, ULISSE will make available data from previous space experiments on the International Space Station as well as data from other space platforms, like sounding rockets, Foton capsule, Space Shuttle, etc. These datasets, coming from a wide ensemble of experiments, represent a relevant resource that ULISSE brings to a new life, and are being exploited for testing and demonstration purposes. The first session of the ULISSE demonstrator has been held on the occasion of the 7th Space Weather Week in Nov. 2010. Further sessions will follow in 2011.

The project includes specific dissemination activities: scientific as well as non-specialist publications, public events and educational activities on space research. In this way the project contributes to increasing the involvement of specialized communities and the awareness of general public on the results and benefits of space activities.

WORK PROGRAMME, METHODOLOGY, MILESTONES

The ULISSE activities have been decomposed into three main phases, each one year long. Three main milestones are foreseen at the end of each phase.

The first phase consists of surveys and analyses and was concluded with the definition of the scenario for ULISSE development, as first milestone. To this aim, a survey of user needs was performed; the survey was based on interviews of potential users and collection of questionnaires. Main services for data exploitation were identified on the resulting basis. In parallel, the data provider partners (i.e. the partners that are custodian of scientific repositories) performed a survey of available datasets, collecting also the corresponding limitations to data access policies imposed by the data owners, if any. Moreover, each data provider contributed to the preliminary definition of the ontology for its discipline and activity field, during a series of thematic workshops. The scenario definition was completed with the analysis of sustainability of the initiative after the completion of the current Grant.

The second phase consisted mainly of the development of the middleware, of the networking and of the initial set of tools. The phase included also the description of the datasets through the metadata standard and it was concluded with the execution of the first session of the ULISSE demonstrator as a second milestone. This session focused on the demonstration of the capabilities of ULISSE through the preliminary implementation of a subset of services and tools.

The third phase is aimed at completing the development of the platform and tools and at implementing a final demonstration session (third milestone). At the demonstration sessions further suggestions and comments from potential users will be solicited and integrated in the evaluation.

The project started at the beginning of 2009 and will be completed at the end of 2011. The time evolution of the project activities is shown in Figure 1.

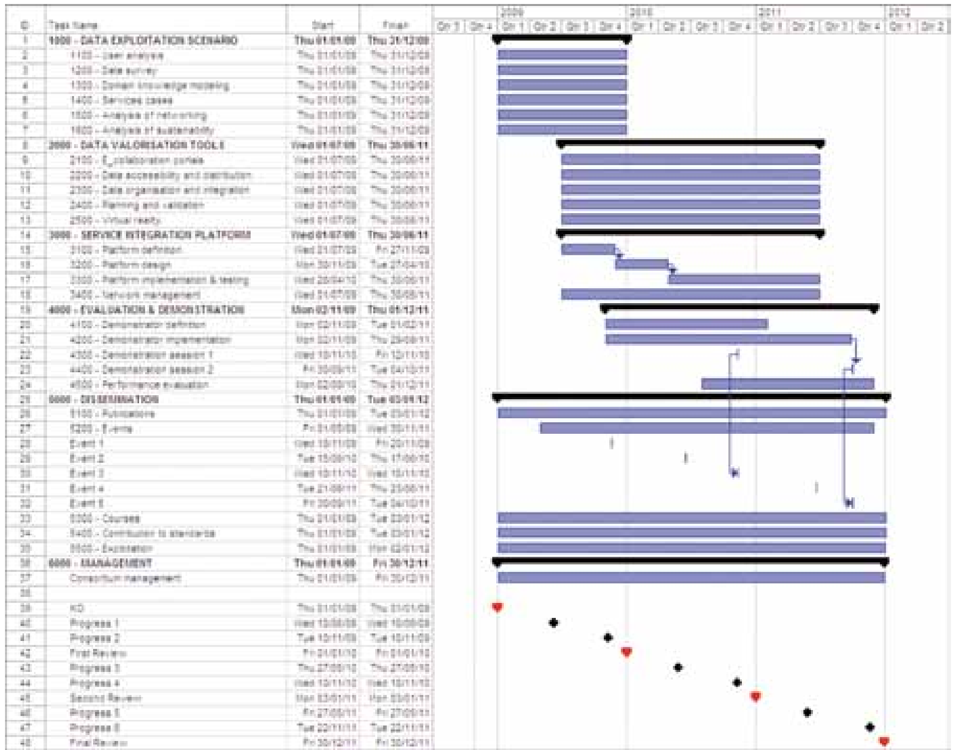

Figure 1: time evolution of the project activities

PARTNERSHIPS AND COLLABORATIONS

The ULISSE project is conducted by a network of research centres, space agencies and companies with a wide experience in the space field. Team composition, main expertise and role in the project of each partner are sketched in Table 1.

SPACE SCIENCE AND EXPLORATION

The ULISSE network stems from the network of the European USOCs. They have been established in various European countries with the support of national space agencies and are coordinated by the European Space Agency to conduct the operations for European scientific experiments on board the Columbus and other modules of the International Space Station. Fig. 2 shows the ULISSE network and the European data infrastructure for the International Space Station. USOC and space research centres host scientific repositories and act as data providers and expert of their specific scientific domain. Some partners are mainly involved in developing tools and infrastructure components.

Name	Main expertise	Role in ULISSE		
Telespazio	USOC, operations, space services & SW	data provider	system developer	Coordinator
B-USOC	Space Res. Centre, USOC	data provider		
CNR-ISTC	ICT Res. Centre	tool developer		
MEDES	Medicine Res. Centre	data provider	dissemination	
Space Application Services	operations, space services & SW	knowledge manag.	SW developer	
CADMOS - CNES	Space Agency, USOC	data provider	tool developer	
Univ. Rome "La Sapienza"	ICT Res. Centre	tool developer		
DAMEC	USOC	data provider		
NLR	Space Res. Centre, USOC	data provider	tool developer	
MUSC - DLR	Space Agency, USOC	data provider	demonstration	
ETH Zurich	Biology Res. Centre, USOC	data provider	system developer	
N-USOC	Biology Res. Centre, USOC	data provider		
SRC PAS	Space Res. Centre	data provider	dissemination	
Univ. Politecnica Madrid	USOC	data provider	demonstration	
Weum	SW	system developer		
ELGRA	Research Association	scientific advice	dissemination	

Table 1: ULISSE team composition and expertise

Figure 2: ULISSE network and European ground infrastructure for International Space Station experimentation

ACHIEVED RESULTS

The relevance of preservation of scientific data in repositories that can be accessed by the user community with the support of tools for data exploitation has been recognized by the European Community as a key element to sustain and improve knowledge development and applications of research findings. The need for data preservation and exploitation is particularly relevant for space experimentation, due to the large costs and long preparation of a space experiment and its scarce repeatability.

Figure 3: The International Space Station (courtesy of ESA)

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Figure 4: The Columbus module (courtesy of ESA)

ULISSE is aimed at ensuring the preservation in the long term and at the exploitation of the data obtained by European experiments on the International Space Station (ISS) and on other space platforms.

The ISS (Figure 3) is one of the largest and more complex space programmes: it has reached its full operability and in the next 10 years will produce a very large quantity of data. Europe participates, through the European Space Agency, in the ISS programme with Columbus, the European module that allows experiments in a pressurized laboratory and on external pallets exposed to the outer space conditions (Figure 4). Columbus hosts experiments related to almost all scientific disciplines, as for example astronomy, radiation physics, astrobiology, space technology, atmosphere and environment on external pallets; biology, plant or human physiology and medicine, material science, fluid science and fundamental physics in the pressurized laboratory.

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Such a wide range of disciplines represents a challenge and an asset of ULISSE at the same time. To pursue data exploitation by adequate tools a representation of data and of the related scientific domains is necessary. Therefore, an original metadata standard has been defined to capture the information on space experiments and their datasets, starting from the standard ISO19115 and ISO19139. An instance of the Geonetwork tool (Figure 5) has been customised for the management of the ULISSE metadata, allowing creation, editing, search and user management functionalities on the metadata repository that is being created.

A knowledge base is being created using Topic Maps technology (standard ISO IEC 13250). Topic maps contain semantics and knowledge, allowing the description of complex concepts using topics and relations among them. Topics maps have been created based on ontologies for the different disciplines (Figure 6) defined in dedicated workshops and then merged together in a centralized knowledge base. Also metadata have been ingested from Geonetwork to the knowledge base. The ScienceCast tool has been implemented to support knowledge browsing and management.

A number of distributed repositories have been integrated with the middleware using SITools, a tool for providing controlled access to data files according to the data policies. The ULISSE architecture is expandable and other distributed resources (repositories and/or tools) can be integrated easily when they will become available in the future.

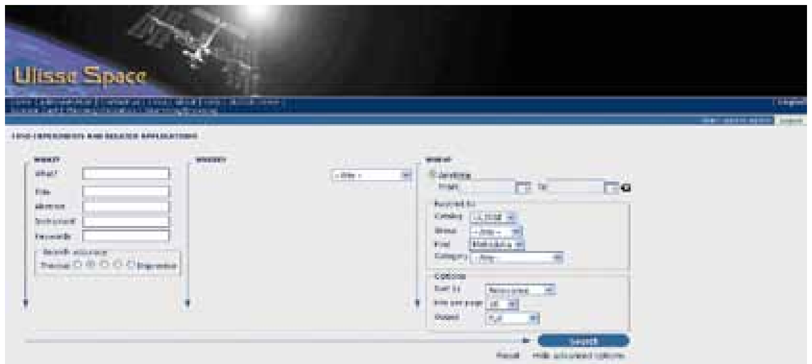

Figure 5: Search window of the Geonetwork tool for ULISSE metadata management

An E-collaboration portal (Figure 7) is being developed using Drupal as recognized open source CMS (Content Management System). This tool provides facilities for creating and editing articles without a need for specific background. The content editor supports individuals and communities of users to easily publish, manage and organize a wide range of contents on a website. The portal aims at disseminating and promoting space research related to ULISSE fields towards the general public.

A tool for planning and validation of scientific experiment activity sequences has been implemented; the tool supports the automatic definition of a schedule of activities for scientific payloads and its validation with respect to the list of identified rules and constraints. The issue of integrating planning and validation technologies has been addressed in.

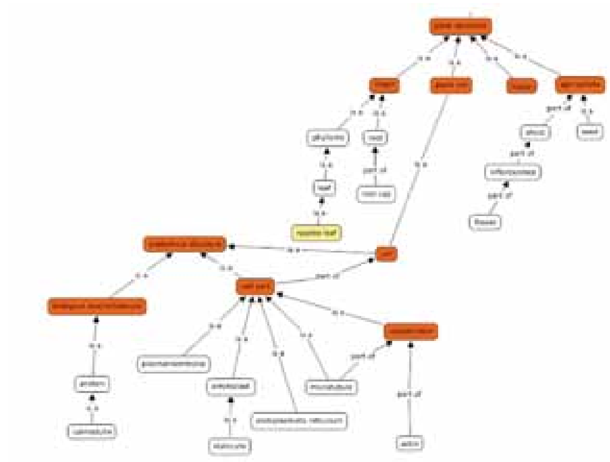

Figure 6: Example of topic map for plant biology

Figure 7: Layout of the ULISSE promotional portal

SPACE SCIENCE AND EXPLORATION

Already networking, knowledge and metadata management, controlled access to data according to data policy and scheduling and validation of payload operations were being demonstrated together with the collaborative portal functionalities at the 7th Space Weather Week in November 2010.

Other tools are under development. 3D visualization will provide enhanced user interfaces. A data organisation and integration tool will allow the comparison of instrument data generated within a single facility, to correlate experiment data with system data or data from other instrument facilities.

Demonstrator sessions of the complete ULISSE functionalities will be held on the occasion of the ELGRA Congress in Brussels in September 2011.

CONCLUSION

ULISSE is a unique instrument for preserving, valorising and providing access to scientific data from multi-disciplinary space experiments, complemented by detailed metadata, domain knowledge representation, semantically enriched interdisciplinary functionalities and other tools for data exploitation and dissemination.

Moreover, while preparing the systematic storage, preservation and exploitation of scientific data coming from future experiments on ISS, ULISSE is playing a pathfinder role with respect to data policies implementation, with the support of the European and national space agencies.

The above achievements of ULISSE can be exploited for the valorisation of other scientific data repositories. To this aim, the ULISSE consortium is pursuing the further extension of the current network, investigating possible collaborations with other FP7 research projects and research centres in Eastern Europe; some opportunities are already under evaluation.

For the above reasons ULISSE will generate the following benefits:

> Maximize the scientific return from space missions;
> Promote possible applications (both in space and on ground) of space experiment results and technologies;
> Contribute to a closer connection between space and ground scientific communities;
> Increase the public awareness about space research results and benefits;
> Contribute to formation activities in the space field.

Further information is available at the ULISSE website and in a recent review paper presented at the last IAC Congress (see Kuijpers, E., et al.).

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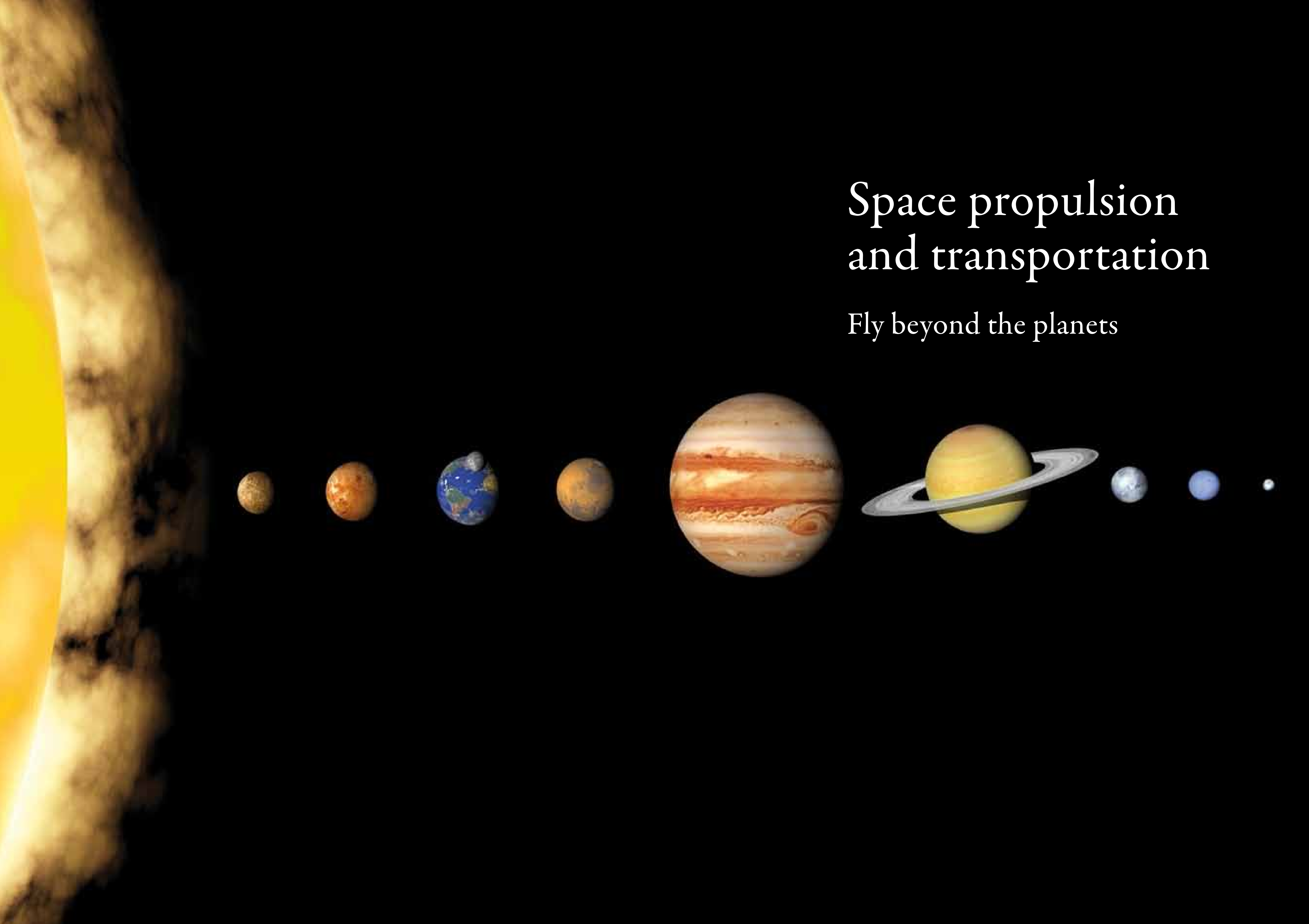

Space propulsion and transportation

Fly beyond the planets

AEROFAST

Aerocapture for future space transportation

Francine Bonnefond, Thierry Salmon, Hélène Requiston

Astrium space transportation

ABSTRACT

Aerocapture is a flight manoeuvre that takes place at very high speeds within a planets atmosphere that provides a change in velocity using aerodynamic forces (in contrast to propulsive thrust) for orbit insertion.

Interest in developing aerocapture technology stems from the solar system exploration needs: sample return missions, in-situ missions and future manned missions require spacecraft to enter and manoeuvre in a planet's atmosphere in order to meet their mission objectives. Until now the combination of the mission requirements for the current exploration missions and technology integration difficulties have slowed the development of aerocapture technology and prevented any prototype flights to date. This transportation technology becomes really attractive with respect to propulsion when the delta-V necessary for orbit insertion becomes greater than 1 km/s, which is the case for the here above mentioned future missions.

Aerocapture technology is at TRL (technology readiness level) 2 to 3 in Europe. In order to use the aerocapture technology for operational missions while mitigating future development risks, the TRL of such a technology must reach the level 6. TRL6 shall be reached through a flight demonstration preferably performed with the Martian conditions in order to prepare for the future MSR missions (first potential missions to use the aerocapture technology).

In order to prepare for such a mission demonstration it is proposed in the frame of the FP7 to reach a TRL 3 to 4 for this technology. Aerocapture is very much a system level technology where individual disciplines such as system analysis and integrated vehicle design, aerodynamics, aerothermal environments, thermal protection systems (TPS), guidance, navigation and control (GNC), instrumentation need to be integrated and optimized to meet mission specific requirements. Objectives of the project are as follows:

> OBJ1: Define a project of aerocapture demonstration (planet to be assessed),

> OBJ2: Make a significant progress in space transportation by increasing the TRL of the planetary relative navigation and the aerocapture algorithm up to 5.

> OBJ3: Build a breadboard to test in real time the pre-aerocapture and aerocapture GNC algorithms,

> OBJ4: Demonstrate/prototype the thermal protection system for such a mission,

> OBJ5: Define on-board instrumentation for aerocapture phase recovery.

Innovative thermal protections are currently under analysis and testing in order to optimise the front shield, required for aerocapture (see Figure 1). Figure 2 shows a sample before and after testing. Several formulations (different resin/cork ratios, new resins and different percentages, plasticizers, reinforcement fibers, low density fillers) are tested.

The emphasis is on the GNC non real time and real time simulations. The test bench for the real time testing is currently under definition and implementation. The status and progress of these main objectives will be detailed during the conference.

WORK PROGRAMME, METHODOLOGY, MILESTONES

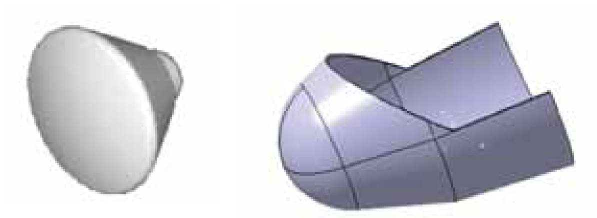

Figure 1: Two different shapes for the aerocapture system are currently under assessment from the system and design point of view: ARD-like (sphere-conical shape) and a biconic shape

Figure 2: Sample of thermal protection before, during, and after testing

Over the whole period of 30 months the AEROFAST project will fulfil the five objectives mentioned above. The work break down structure is shared out of five work packages (WP) in order to fulfil the objectives of the project. The first WP is dedicated to the overall mission definition and set of requirements, as well as to the different system analyses. The WP2 concentrates on the vehicle itself and its architecture, budget and lay-out. WP3 intends to finds attractive solutions for thermal protection systems. WP4 ensures the design and establishment of the real time test bench with focus on relative navigation. WP5 deals with on-board instrumentation during the aerocapture phase. A sixth WP deals with management dissemination and exploitation.

The project started on January 2009 and is expected to finish mid of 2011. The different main milestones are shown in Table 1.

Table 1: Project milestones

Milestone	Milestone name	Status	Delivery date
M1	KOM – kick-off meeting	held	January 2009
M2	PM1 – 6 month review	held	July 2009
M3	SRR – system requirement review	held	January 2010
M4	PM2 – progress meeting 2	held	July 2010
M5	TRR – test readiness review	To be organised	December 2010
M6	NRT QR – non real time qualification review	To be organised	TO+27
M7	QR – qualification review	To be organised	TO + 29
M8	FP – final presentation	To be organised	T0 + 30

PARTNERSHIPS, COLLABORATIONS

As shown in Table 2 AST-F, with its extensive experience in space transportation systems design and development, is the coordinator and deals with the coordination of the overall aerocapture mission and design and vehicle architecture.

SPACE PROPULSION AND TRANSPORTATION

Table 2. The AEROFAST consortium

Beneficiary Number *	Beneficiary name	Beneficiary short name	Country
1 (coordinator)	ASTRIUM-ST SAS	AST-F	France
2	ASTRIUM-ST Gmbh	AST-D	Germany
3	DEIMOS Engharia	DME	Portugal
4	Amorim Cork Composites S.A.	AMORIM	Portugal
5	SAMTECH	SAMTECH	Belgium
6	University of Roma – La Sapienza	UNIROME	Italy
8	STIL-BAS (Bulgarian Academy of Sciences)	STIL-BAS	Bulgaria
9	Institute of Aviation	IoA	Poland
10	Space Research Centre-Polish Academy of Sciences	SRC-PAS	Poland
11	ONERA	ONERA	France
12	KYBERTEC	KYBERTEC	Czech Republic
13	Faculty of Sciences of the University of Lisbon	FCUL	Portugal

Through its involvement in different projects on GNC topics, DME has accumulated a broad know-how and expertise and contributes to the project on all tasks linked to GNC, navigation aspects, as well as on simulator development (real and on real time aspects). FCUL efficiently contributes to the image processing and generation. UNIROME has a good expertise on control and scientific payloads thanks to the development of in-house satellites. AST-D copes with the design of the spacecraft. SAMTECH has a great experience in software development, validation and use in the field of thermal and mechanical analysis. ONERA is well-known over Europe for the different test facilities (large range of Mach number and enthalpies) they offer, as well as for their capabilities to the development and run of software for aerothermodynamics. IoA provides support to AST-F and ONERA in the field of CFD computations. AMORIM is the number one in the world for cork and is in charge of developing new TPS materials based on cork. STIL-BAS and the SRC-PAS are in charge of proposing new and innovative on-board instrumentation. KYBERTEC is in charge of creating the web site and maintaining it during the whole life of the project.

ACHIEVED RESULTS

The frame of the mission has been defined as follows:

> Low cost mission, leading to the choice of Soyuz-like Launch performance,

> Optimized entry conditions at 120 km: Relative velocity: 6377 m/s, Flight Path Angle: -10.04°, Perigee altitude : 24,8 km (optimized to obtain the targeted apogee altitude after the aerocapture phase),

> Main characteristics of the spacecraft:

> Three modules vehicle concept (final satellite, aerocapture system and cruise module),

> Maximum diameter: 3 600 m.

The main manoeuvres are shown in Figure 3.

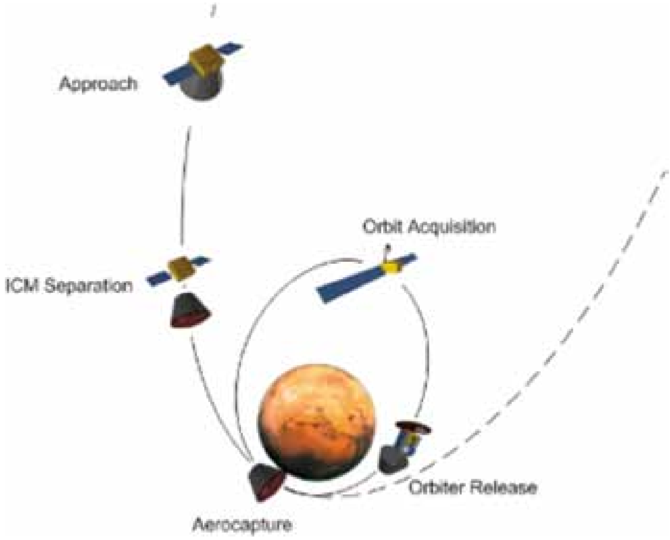

Figure 3: Illustration of three main aerocapture manoeuvres. Pre-aerocapture phase: Hyperbolic path to the upper atmosphere. The challenge is to master the attitude/position of the S/C before the manoeuvre. Main aerocapture phase : From entry point to atmosphere exit. The goalis to reach an elliptical orbit within a narrow corridor. The challenge is to sustain large heat loads. Post aerocapture phase : Transfer to a parking orbit: to target a quasi circular sun-synchronous orbit at a low altitude with an altitude of 345km, and an Inclination of 92.7°.

SPACE PROPULSION AND TRANSPORTATION

Thanks to the choice of the guidance scheme, the AEROFAST entry corridor is as follows (Overshoot ~50 km and Undershoot ~20 km):

The most promising aerodynamic shapes for aerocapture have been assessed within these five possibilities. The selected shapes are the apollo-like and the biconic shapes (Figure 1). More detailed analysis is being conducted; in particular the need of a protection for the rear part of the composite to protect the equipment behind the heat shield is being studied for both shapes (Figure 4, 5).

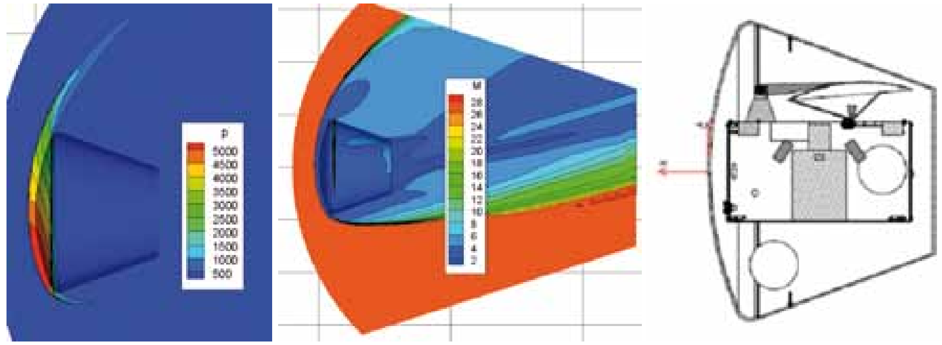

Figure 4: ARD SHAPE - Euler computations and Satellite within Aerocapture system

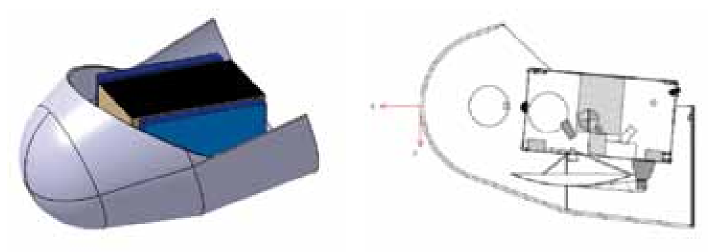

Figure 5: Biconic shape and accommodation

The next steps are:

> Apollo-like shape: Cross-check: AST-F (Euler) / IoA (NS) calculations,

> Biconic shape: Calculations of heat fluxes to assess the need (or not) of a protected cover.

The design of the three modules of the AEROFAST spacecraft has been drafted for the ARD shape: A preliminary design of the AEROFAST composite was performed with the Apollo-like shape for the front shield. This leads to the following results: AEROFAST composite weighs 1162 kg in total with the Interplanetary Cruise Module of 228 kg and the Aerocapture system: 934 kg.

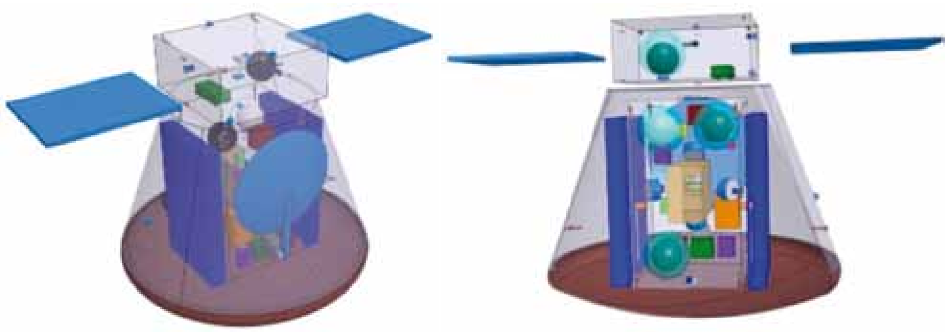

Figure 6: The Apollo-like shaped composite during the cruise phase. Section cut in right-hand view

The assessment of adequate thermal protections for the front shield is performed and, if required, establishment of innovative thermal protections for the aerocapture heat shield is foreseen. A specific focus is put on innovative thermal protections with cork. The objective is to define the ways to increase the qualities of cork-based material through two alternatives: either a superlight material or reinforced material. The superlight material should have a density between 200 and 450 kg/m^3. The analysis is still on-going. Comparison will be performed through synthetic tables with the main qualities and properties. The aim is also to identify the further steps of development for the most promising solutions. AMORIM will also define and manufacture a prototype (sub scale) to show the processes for moulding. The prototype will be manufactured with the most interesting solution in the right geometry (scale to be determined).

The aim for AEROFAST is to improve the AEROCAPTURE transportation technique by means of increasing the TRL up to 3 /4 and thus achieve TRL 4/5 for GNC algorithms. This is achieved through different simulations and test benches (Figure 7):

In an initial stage (to reach TRL 3) through:

> Non-RT Functional Engineering Simulator (AEROFAST_FES), Functional evaluation of both Pre-Aerocapture and Aerocapture GNC algorithms performance in complete and accurate modelling of the "Real World"

> And the IP Laboratory (IP_LAB), Generate real-world images (non-synthetic) to test and assist IP development,

In a later stage (to reach TRL 4/5):

> RT Processor In-the-Loop Test bed (AEROFAST_PIL), Evaluation of both Pre-Aerocapture and Aerocapture GNC performances in real time environment (LEON3/RTEMS),

> RT Hardware In-the-Loop Test bed (AEROFAST_HIL), evaluation of Pre-aerocapture GNC+IP performances and their interaction, both in real time (LEON3/RTEMS) and using representative navigation camera in mock-up (Figure 8).

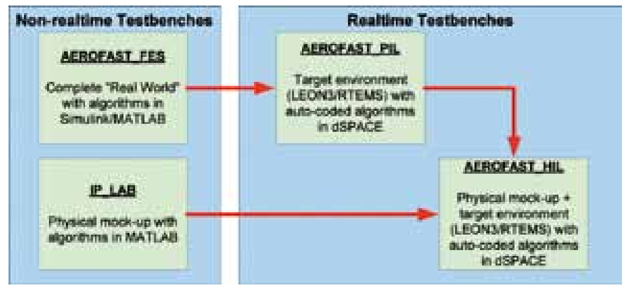

Figure 7

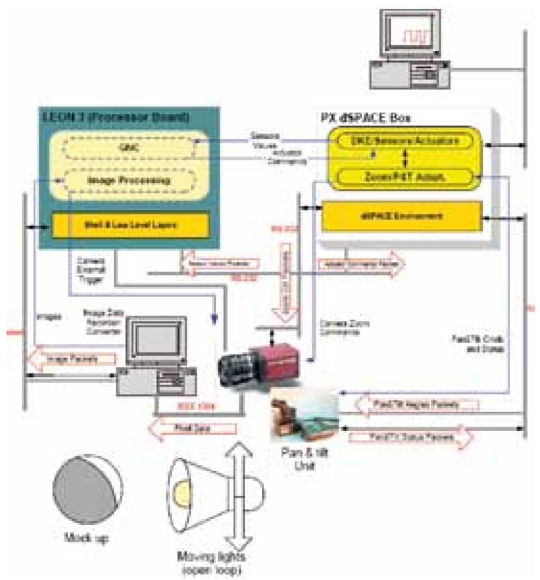

Figure 8: RT Hardware In-the-Loop Test bed (AEROFAST_HIL)

CONCLUSION

AEROFAST is a very motivating project and the whole consortium is fully engaged. The main goal of AEROFAST is to increase the TRL of the aerocapture technology up to 3 to 4 by defining an aerocapture demonstration through the mission and the spacecraft design.

Following a detailed comparison analysis on different potential shapes for the aerocapture system, two options are further deepened: the ARD-like and the biconic-like shapes, from the system and the architecture point of view.

For the ARD-like shape, the finalisation of the CFD computations is foreseen with a cross-check of methods used. For the biconic option the heat fluxes were assessed over the complete spacecraft. This will allow identification of the instrumentation needed during the aerocapture phase: What phenomena shall be observed in the aerocapture path? And add scientific objectives when the spacecraft is on the final orbit.

Concerning the thermo-mechanical analysis the development of a 3D ablation module is currently applied to the ARD shape. The next step consists of the application to biconic shape and optimization of the heat shield.

In parallel to this activity, the aim is also to identify innovative thermal protection systems (TPS) with low density while sustaining high heat loads. These new materials will be modelled in the 3D ablation module in order to improve the optimization of the related heat shields of both options (ARD and biconic).

For what concerns the GNC activities, the on-going tasks consists in improving the navigation sub-system for the pre-aerocapture phase and test all algorithms through real time and non-real time breadboards. For the ARD-like the work is roughly finished, for the biconic S/C, the aerocapture corridor is being defined, as well as the definition of Control requirements.

The project will be finished mid of 2011 and already now a lot of results are on the table and show the nominal progress of activities as well as the nominal achievement of the project and fulfilment of the objectives.

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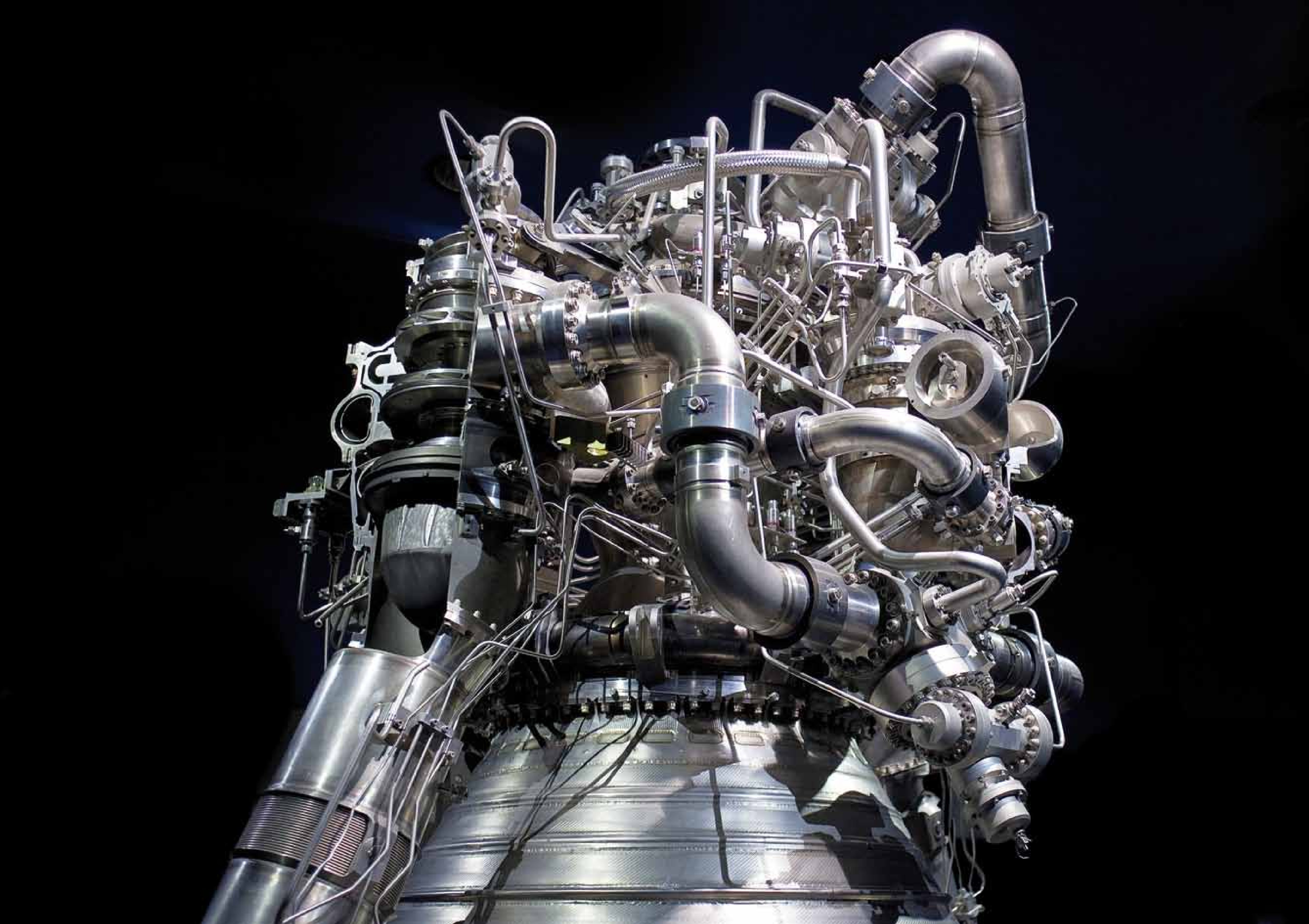

GRASP

Green Advanced Space Propulsion

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ABSTRACT

The possibility of replacing presently used highly toxic propellants by so-called green propellants with a significant lower level of toxicity has captured the attention of research groups as well as of the relevant industry worldwide. And indeed the potential of green propellants seems inspiring. The lower level of toxicity reduces the risk for personnel handling such propellants and therefore allows simplified and more cost efficient handling procedures. A variety of authors have outlined other areas of possible cost reduction when using propellants with a lower toxicity level. This includes a simplification of the propellant logistic and storage, fuelling infrastructures at the launch pads, and propellant procurement to name only some.

Most authors have focused on one particular green propellant in their experimental work and outlined the characteristics and benefits of it. Although very promising results have been reported, green propellants in general have up to now failed to generate a confidence level sufficient for the major industry to initiate first steps to implement them into a commercially available propulsion system.

Contributing to this hesitation is the lack of a comprehensive effort to investigate Green Propellants and to provide industry with information they can use to re-evaluate their future strategy in respect to green propellants. For this reason a European consortium, financed by the European Commission in the 7th Framework Programme (FP7) and consisting of 11 entities from 7 European countries, was established. The project, "Green Advanced Space Propulsion" (GRASP) aspires to provide such an information background.

WORK PROGRAMME, METHODOLOGY, MILESTONES

Presently, chemical propulsion for in-space application relies nearly fully on propellants which are highly toxic and in most cases carcinogenic. This included fuels such as hydrazine, monomethyl hydrazine (MMH), unsymmetrical dimethylhydrazine (UDMH) and oxidizers such as mixed oxides of nitrogen (e.g.MON-3) and nitrogen tetroxide (NTO). Although those propellants have very good performance and, even more important, have an extensive flight history, their handling requires

complex and costly precautions to protect human operators and the environment. One of the goals of GRASP is to encourage the respective agencies (e.g. European Space Agency (ESA)) and industries to look seriously into the possibility to replace those propellants in the long run. Such a switch might be in particular important since over the last decades, the limitations in handling e.g. hydrazine have become more and more restrictive, which is reflected in the development of procurement costs of hydrazine (1990: 17.00 $/kg in 1990 vs.170.00 $/kg in 2006). It was and it is the view of the GRASP consortium that this situation might become even more difficult in the upcoming decade or so due to introduction of efforts such as REACH. This view was recently (October, 2010) confirmed by the action of the European Chemical Agency (ECHA) to place hydrazine on the "Registry of intentions for Annex XV dossiers". Although it is highly improbable that this results in a general ban of hydrazine in the short term, it shows that the use of such propellants introduces at least a certain element of planning uncertainty for agencies and the relevant industry alike.

Although worldwide activities are ongoing to investigate low toxicity propellants offering similar performance and reliability, the relevant industry is only marginal active in this search. The reasons for the lack of involvement of the industry are complicated but considering the cost and in particular the anticipated return of investment associated with e.g. a communication satellite one can comprehend their reluctance to utilize new and, for the most part, unproven technologies. In addition to the financial aspects, the technical complexity and in general the missing, or perceived missing, information and background with regard to green propellants might have been another reason for the industry not to fully embrace the search for propellant alternatives.

The GRASP consortium, funded by the European Union in the 7th Framework Project (FP7), is dedicated to establish a comprehensive and coherent evaluation of the green propellant topic in order to allow industry to better assess the potential of green propellants and the issues related to them. The eleven members of the GRASP consortium are located in seven European countries and include members from industry as well as from academia, research institutes and small/medium enterprises (SME). The project duration is three years (project start in December 2008) and its effort comprises a total of 350 man months.

The GRASP project methodology is somehow simplified depicted in Figure 1. The project is dominated by four assessments which will be conducted in frequent intervals. While the first assessment is solely based on the collection of data and theoretical (performance) calculations, the following three assessments are based mainly on experimental data generated during the project. Basis of the first assessment was a number of 92 propellants. By applying certain selection criteria (toxicity, performance and others), 28 of those propellants were chosen for experimental evaluation. The focus of this first series of the experimental investigation was for some of the propellants the evaluation of fundamental, but up to now unknown, properties (e.g. heat of vaporization or heat of formation), others were investigated with regard to their decomposition properties (e.g. ionic liquids, hydrogen peroxide) or ignition properties (fuels such as ethanol, kerosene, dipentene etc.). The outcome of the experimental investigation and subsequent second assessment was the choice of 6 propellants which are presently tested in laboratory propulsion system. The performance of those six propellants and propulsion systems respectively will be the focus of the third and fourth assessment.

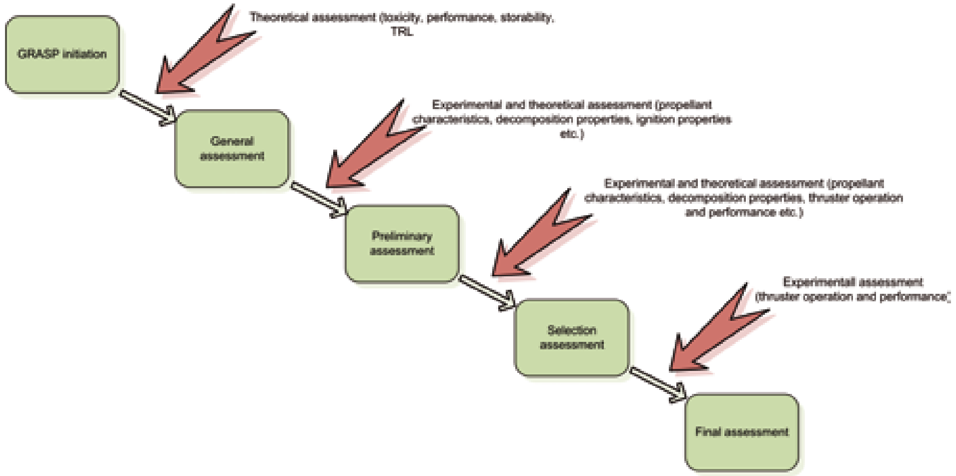

Figure 1: GRASP project assessment methodology

With this stepwise assessment and selection process, the GRASP consortium hopes to provide a comprehensive and consistent assessment which will at the end identify propellants which not only are much less toxic but also, in the near term to most likely candidates for replacing presently used toxic propellants.

SPACE PROPULSION AND TRANSPORTATION

PROJECT STATUS AND ACHIEVEMENTS

In its second project year the GRASP project was largely dedicated to the experimental investigation of selected propellants and catalysts. The groundwork for this experimental assessment was laid out in the first project year during which, from an initial group of 92 different propellants, 28 were chosen as the most suitable green propellant candidate. The experimental assessment consisted of propellant characterization (e.g. determination of density, heat of formation etc.), investigation of transport and storage properties (e.g. gap testing), evaluation of thermal and catalytic decomposition (for hydrogen peroxide and ionic liquids) and many others.

Significant progress was achieved in many aspects. Of particular importance is the fact that some of those advances are not only improving the scientific value of the GRASP effort in general but are expected to have a direct impact on how the research community will conduct and direct their future research, thereby ensuring the visibility and relevance of the GRASP project. In the following only some of the highlights from the second project year of GRASP are listed:

> The assessment of catalytic activity conducted within GRASP is probably the largest coherent effort ever. The test matrix consisted of 52 catalyst variations, including ceramic monoliths, pellets, gauzes, metallic foams with variations of their geometry, nature of carrier material, nature of active catalysts, manufacturing process variations and many others. Even more important, the experimental assessment has identified a number of catalyst types which are very suitable for the envisioned use in a propulsion system. Decomposition efficiencies of well above 95% and a reduction of the transition times down to 1 second and lower are only two of the major accomplishments.

> One of the very promising green propellant candidates, an ionic liquid named FLP-106, has been methodically investigated and important substance properties have been evaluated. The decomposition path for this particular propellant has been investigated in yet unprecedented level of detail, leading to the development and manufacturing of advanced catalysts for ionic liquid decomposition.

> Detailed auto ignition testing of some of the selected fuels (bipropellant system) provided essential information about general ignitability and ignition delays respectively. This information is one of the core properties needed to decide the suitability of a fuel and is therefore of substantial importance for the GRAS consortium as well as for the general research community.

> The parallel to the experimental investigation running establishment of analytic models, describing the decomposition process, lead to several important improvements in the understanding of this complex process. Influence of the thermal aspects but also operational conditions such as feed pressure and catalytic related pressure drops have been investigated. For example it was found that the thermal properties (capacity and conductivity) of the catalyst itself can govern the transition behaviour and determine its suitability as a high performance catalyst. In addition, the models predict, and experimental investigation verified this prediction, a thermal distribution of the decomposition temperature across the catalyst, an effect which was unknown up to this point. Since this impacts directly the test set-up and test analysis which will be used in the future for such tests, such results are seen as an essential contribution to the general research community.

Amongst others, the above allowed the establishment of an advanced second assessment, further down-selecting propellants. A number 6 propellants were identified which will be implemented into 8 different propulsion system including monopropellant, bipropellant and hybrid systems spanning a thrust range between 1 and 200 N. The propulsion tests and assessment of the chosen propellants is presently conducted (see figure 2 and fig. 3)

Figure 2: Examples of investigated propulsion system

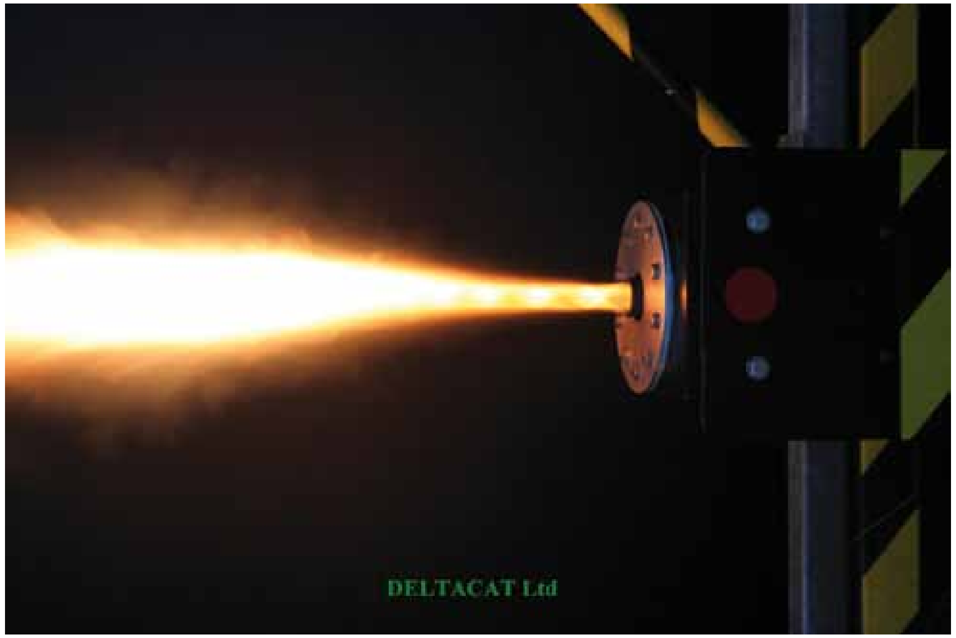

Figure 3: Dipentene/hydrogen peroxide bipropellant thruster (DELTACAT Ltd)

Last but not least, an essential part of GRASP is the dissemination of the green propellant subject(s). Significant efforts were undertaken to disseminate the idea of and the philosophy behind GRASP as well as to inform the research community of the results which were obtained in the framework of GRASP. Twelve publications, participation in several conferences as well as an intensive effort to educate students and prospective students with regard to the topic of green propellants in general and the specifics of GRASP in particular are only some of the efforts of the GRASP consortium.

CONCLUSION

The GRASP project is a comprehensive and coherent effort to shed more light on the potential of green propellants. Starting with a relative large amount of green propellant candidates, GRASP has succeeded to systematically down-select those which are considered to have the highest potential and are most probable to replace the presently used highly toxic propellants. Presently, several propulsion systems (mono-, bipropellant, and hybrid) using those propellants are under investigation. A huge amount of information and data have been collected and generated which is hoped to provide the research community with a guideline for future work but more importantly allows the relevant agencies and industries to make upcoming critical decisions on a well funded basis.

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HiPER

High power electric propulsion: a roadmap for the future

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ABSTRACT

New propulsion technologies will be essential for the performance enhancement and affordability improvements needed by next generation space missions. Although space science and exploration will be the main driving force behind these developments, the novel techniques and methodologies will equally benefit the whole space community, thus generating a very significant impact on Europe's capability to access and exploit space. Moreover, apart from contributing to the expansion of scientific knowledge and expertise in further exploration, space exploration can also benefit society by driving technological innovation for a better tenor of living and by enabling new business opportunities.

In this framework Electric Propulsion (EP) could play a very important role by enabling more affordable and sustainable space-to-space missions. In fact, thanks to the high thrust efficiency and lifetime, modern EP technologies enable mass savings, launch flexibility and long interplanetary journeys with no gravity assist constraints. This also open the way to transferring large payloads through the solar system in a much more affordable way than in the past. Besides, larger payloads can be achieved by increasing the operational power level of the propulsion systems.

HiPER is a 3-year collaborative project partly funded by the European Union aimed at laying the technical and programmatic foundations for the development of innovative EP technologies - and of the related power generation - to fulfill future space transportation and space exploration needs. HiPER involves 20 partners from 6 European Countries under the coordination of Alta. The project's goal is very ambitious, since it not only addresses technologies, but also attempts to consider major technological efforts in the framework of social and political scenarios, both internal to Europe and with respect to non-European partners.

The first two years of activities have been mainly devoted to select mission scenarios which could benefit from the increase of the operational power level of Electric Propulsion systems and to initiate design and development activities of EP technologies and the related power generation. These development activities will be finished during the last year of the programme.

WORK PROGRAMME, METHODOLOGY, MILESTONES

The HiPER project intends to contribute to the implementation of the Space theme of the 7th Framework Programme, namely to the "foundations of space science, exploration, space transportation and space technology", more in detail focusing on the priority of developing new concepts in space transportation and space technologies. Support to research activities related to space transportation and to space science is considered as a fundamental goal for the development of the overall European space strategy.

HiPER's objective will be pursued by conceiving and substantiating a long term vision for mission-driven Electric Propulsion development, considering realistic advances in state of the art of EP related technologies and performing basic research and proof-of-concept experiments on some of the key concepts identified by such a vision. Project's rationale and worklogic is summarized in Figure 1 below.

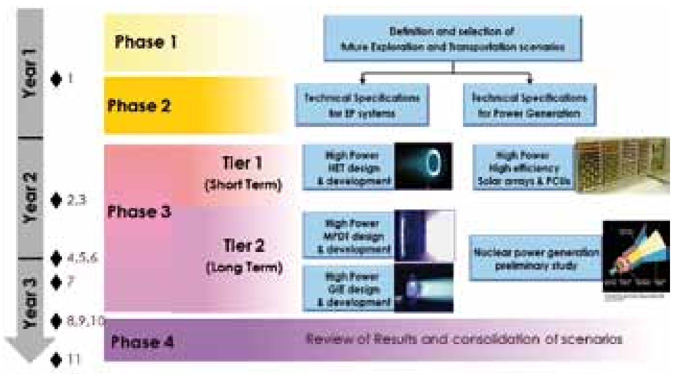

Figure 1: HiPER Project Logic and phases. Major Milestones are numbered and indicated by "♦". © HiPER Team, 2011

Major Project milestones are described below:

> Month 6, Milestone #1: Definition of EP and power generation requirements.

> Month 18, Milestones #2, 3: GIE preliminary design; MPDT preliminary design.

> Month 24, Milestones #4, 5, 6: Solar generator final design; HET final design; MPD High current cathode test finished.

> Month 27, Milestone # 7: Nuclear generator design.

> Month 32, Milestones # 8, 9, 10: HET acceptance test finished; GIE cathode test finished; MPDT final engineering model.

> Month 36, Milestone # 11: Roadmap for future space exploration and transportation scenarios using high powered EP issued.

PARTNERSHIPS AND COLLABORATIONS

HiPER Consortium consists of 20 partners from 6 European countries under the coordination of Alta, well balanced between Research Institutes (Consorzio RFX, CNRS, Fraunhofer Institute, IPPLM), Academia (University of Southampton, Univerity of Stuttgart, Politecnico di Milano), SMEs (Alta, Acta, Aerosekur, Astos, Space Enterprise Partnership, Domaine de Beauregard, KopooS, Tecnalia), Large Industries (Selex Galileo, Rolls Royce, Snecma) and Government Institutions (Onera, CNES).

The composition of the Consortium is reflecting many years of collaboration (and in many cases also competition) by the various partners in the European space market of advanced propulsion and power technologies. This long heritage in mutual interaction is one of the strongest assets of the Consortium, as well as a guarantee that possible issues in the work plan development would be addressed in an effective, constructive and quick way, by involving top level management in the decision making process.

Since the very beginning of the project, the Coordinator - supported by the other partners - has started a series of activities whose goal was to enlarge the HiPER framework to those relevant actors not involved in the team. The idea was to involve major Space entities in the process of definition and assessment of the future scenarios, and in the discussions on how to face with the forecasted technological needs. The plan was discussed with the Commission's Technical Officer and after his approval a letter of invitation was sent to NASA Glenn Research Center (USA), QinetiQ Ltd (UK), EADS-ASTRIUM (UK-D-F) and L3 Communications (USA). More recently, a contact has been established with Swedish Space Corporation for the exchange of information on future scientific exploration scenarios.

ACHIEVED RESULTS

Results achieved so far, and expected outcomes at the end of the project are schematically given in the Table 1. Figures in the next pages give an idea of the achieved results.

Table 1: Results of various work packages

Work Package	Achieved Results	Expected Results
WP 2: Mission Analysis	> Critical review of the past EP missions, lessons learned > Selection of the most promising near-term and long-term mission and transportation scenarios which could benefit from high power EP application > Mission Analysis of selected scenarios > Preliminary requirements and recommendations for high power EP subsystems	> Optimization of selected missions > List of requirements and recommendations for high power EP subsystems
WP 3: Solar Power Generation	> Research activities in the areas of a solar concentrator structure (Fresnel lens, cells technology, light and flexible substrate, memory shape alloy) > Integration on a flexible substrate > Preliminary definition of the Electric Power Subsystem architecture	> Manufacturing of a Solar Concentrator panel prototype 1700 x 1300 mm > Architecture Definition of the Electric Power Subsystem
WP 3: Nuclear Power Generation	> Identification of achievable performance and design characteristics of a nuclear fission reactor for power generation > Identification of the technical developments, management requirements and risk management measures > Preliminary definition of the Electric Power Subsystem architecture	> NEP system Design > NEP radiation shielding Design > Evaluation of the technical challenges to be addressed
WP 4: Hall Effect Thruster	> Erosion studies, thermal modelling and manufacturing process of large diameter HET > Preliminary Design of the 20 kW HET prototype able to provide about 1 N thrust with an Isp of 2500s.	> Manufacturing of a 20 kW HET prototype.
WP 5: Gridded Ion Engine	> Analysis and trade-off of the DS3G architecture > Long lifetime cathode design > Preliminary design of the 25 kW Dual-Stage 3 Grids ion thruster able to provide about 0.45 N thrust with an Isp of 10000 s	> Manufacturing of a long lifetime cathode for a 25 kW DG3G Ion thrusters > Preliminary Design of a 25 kW DS3G Ion Thruster
WP 6: Magneto Plasma Dynamic Thruster	> Characterisation of plasma instabilities in MPD thrusters and identification of design solutions for instability control > Preliminary design of two 100 kW MPDT able to provide about 2.5 N thrust with an Isp of 3000s both in pulse mode and stationary mode. > Development activities of high current multi-channel hollow cathodes > Manufacturing of the 100 kW MPD thrusters and the multi-channel hollow cathode	> Manufacturing of two 100 kW MPD thrusters prototypesl tested in both pulsed and stationary mode > Manufacturing of high current cathodes for the 100 kW MPDTs

Figure 2: Solar Array Concentrator design, © Selex Galileo/HiPER Team 2011)

Figure 3: PPS 20 k ML Hall Effect Thruster, © Snecma /HiPER Team 2011

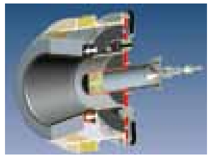

Figure 4: 100 kW AF – MPDT, © Alta /HiPER Team 2011

Figure 5: 100 kW AF – MPDT, © IRS – Stuttgart/HiPER Team 2011

During the implementation of the project, the Coordinator has not faced particular problems in managing the Consortium. Technical Work package leaders have done an excellent management work from their side, thus leaving the Coordinator only administrative, contractual and financial matters. On this side, it has to be noted how FP7 bureaucratic procedures are quite often really difficult to follow, and quite time consuming. The "Participants Portal" system has been proven to be difficult to work with, sometimes, mainly due to the fact it has been upgraded/modified several times last year. On the other hand, REA personnel has always outperformed with respect to the end users requirements, and are a real added value for the Commission funded projects.

A project website was also setup in October 2009, with the main purpose to disseminate HiPER results to a wide audience. From the site it is possible –for partners and REA authorized personnel only- to access the project's Document Management System.

CONCLUSION

During the first two years of activities, the HiPER project has been focusing on the development of future Electric Propulsion technologies and on the development of Solar Electric and Nuclear Electric high power generation. Indeed, the combined use of EP thrusters with high power generation systems can enable a wide range of mission classes. Based on the selection of specific near term and long term mission and transportation scenarios, the impact of the use of EP in future missions has been evaluated and preliminary specifications have been issued for both propulsion and power generation subsystems. The preliminary mission analysis also indicated the need for a significant improvement in power generation subsystem specific mass over the current state-of-the-art. A nuclear power generation technical roadmap was produced in which the achievable performance and design characteristics of a nuclear fission reactor for power generation consistent with the candidate mission requirements were identified. The identification of the technical developments, management requirements and risk management measures necessary to realize these targets were also investigated. In addition, a preliminary definition of the Solar Electric Power Subsystem architecture has been also outlined in order to define boundary requirements applicable to both power generation systems.

As regards high power electric thrusters, activities were mainly aimed at reporting the technological assessment of all electric thrusters concepts studied (i.e. Hall Effect thrusters, Gridded Ion Engines and MagnetoPlasmaDynamic thrusters) and at defining preliminary design specification. Design activities of the HET, MPDT and of hollow cathode prototypes have been almost completed.

During the first two years of the project, initial findings and results have been presented in a number of conferences and meetings, resulting in 12 conference articles.

In conclusion, the HiPER project has demonstrated the possibility of a factual collaboration within a large and to some extent heterogeneous consortium, while at the same time producing excellent technological results.

SPACE PROPULSION AND TRANSPORTATION

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RASTAS SPEAR

Radiation-shapes-thermal protection investigations for high speed Earth re-entry

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ASTRIUM Space Transportation

ABSTRACT

An important step for Space Exploration activities and for a more accurate knowledge of the Earth, universe and environment is to develop the capability to send vehicles into space which select, collect and finally return samples from our solar system, or asteroids to Earth and to perform their analysis. To return these samples, very high-speed re-entry on Earth is today considered as one of the most promising technologies to make both lunar and Martian missions affordable from the cost point of view. The design of a high speed Earth re-entry sample return vehicle requires strong technological bases and relies on a good understanding of the environment encountered during the Earth re-entry.

In the frame of Activity 9.2.1 – Strengthening of Space foundations / Research to support space science and exploration - SPA.2009.2.1.01 Space Exploration, the actions proposed on RASTAS SPEAR project tries to enlarge the basic capabilities on few known topics with low Technology Readiness Level and to strengthen European Industry and Research for coming or future Space Exploration missions or Mars Sample Return (MSR).

The main objective of the RASTAS SPEAR project is to increase Europe's knowledge in high speed re-entry vehicle technology to allow for planetary exploration missions in the coming decades. This will be accomplished by the study and development of innovative, critical technologies which will lead to an increase in knowledge and a reduction of uncertainties and margins used in the design of sample return vehicles. As a result the Technology Readiness Level for high speed re-entry will be increased. The outcome of the project is a European capacity to design lightweight sample return capsules at a considerable lower cost and all this in line (schedule and techniques) with the ESA MSR and Cosmic Vision Programs.

SPACE PROPULSION AND TRANSPORTATION

This main objective can be derived in sub-objectives for RASTAS SPEAR and they are as follows:

Obj 1. To better understand phenomena during high speed re-entry (WP2, 4, 5) enabling more precise capsule sizing and reduced margins

Obj 2. To identify the ground facility needs for simulation (WP2)

Obj 3. To master heat shield manufacturing techniques (WP3) and demonstrate heat shield capabilities

Obj 4. To master damping at ground impact and flight mechanics and thus ensure a safe return of the samples (WP3+4)

WORK PROGRAMME, METHODOLOGY, MILESTONES

Over the whole period of 26 months RASTAS SPEAR project will fulfil the four objectives above-mentioned.

The work break down structure is shared out of five work packages in order to fulfil the objectives of the project. The first WP is dedicated to the overall mission definition and set of requirements, as well as to the different system analyses. The WP2 concentrates on the ground facilities, its current capabilities and necessary improvements to allow close-to-reality simulations.WP3 deals with key technologies necessary to safely bring back samples to Earth. WP4 will take under the magnifying glass the impact of Ablation, and thus shape modification, on Flight mechanics behaviour of the capsule. WP5 wants to show the impact of roughness on heating. A sixth WP deals with management dissemination and exploitation. This is shown in Table 1.

The project started on September 2010 and is expected to finish end of 2012.

Table 1: Detailed list of the work packages.

WORKPACKAGES	TASKS
WP1 **Review of System requirements**	WP1.1: Atmosphere Modelling WP1.2: Trajectories WP1.3: Aerodynamics and Aerothermodynamics WP1.4: Vehicle Design
WP2 **Ground Facilities Improvement**	WP2.1: Analysis of Current Ground Facilities WP2.2: Shock tube technology WP2.3: Ballistic Range Technology WP2.4: Plasma Generator Technology WP2.5: Synthesis
WP3 **Key Technologies for High Speed Entry Mastering**	WP3.1: Choice of TPS+Joints WP3.2: Flow tests with different tiles accommodation (optimisation joints; best materials) WP3.3: Breadboard manufacturing WP3.4: Crushable Structure
WP4 **Ablation-Flight mechanics coupling assessment**	WP4.1: Tools Coupling WP4.2: Ablation coupling assessment WP4.3: Engineering modelling correction by CFD
WP5 **Gas-Surface interactions modelling**	WP5.1: Review of surface roughness and blowing influence WP5.2: Ground Experiment Preparation WP5.3: CFD Modelling WP5.4: Synthesis of WP
WP6 **management, dissemination and exploitation**	WP6.1 – Management WP6.2 - dissemination and exploitation

PARTNERSHIPS AND COLLABORATIONS

Table 2: RASTAS SPEAR consortium

Beneficiary Number	Beneficiary name	Beneficiary short name	Country
1 (coordinator)	ASTRIUM-ST SAS	AST-F	France
2	Centro Italiano Ricerche Aerospaziali	CIRA	Italy
3	CFS Engineering	CFS	Switzerland
4	National Center for Scientific Research "DEMOKRITOS"	DEMOKRITOS	Greece
5	Centre National de la Recherche Scientifique	CNRS	France
6	Institute of Aviation - Instytut Lotnictwa	IoA	Poland
7	Kybertec	KYBERTEC	Czec Rep.
8	Lomonosov Moscow State University	MSU	Russia
9	Office National d'Etudes et de Recherches Aerospatiales	ONERA	France
10	Von Karman Institute for Fluid Dynamics	VKI	Belgium

As shown in Table 2 AST-F with its extensive experience in space transportation systems design and development will be the coordinator and deal with the coordination of the overall project. AST will organise, co-ordinate and manage the different tasks necessary to the fulfilment of the contract, and perform the necessary synthesis of the results by the consortium.

ONERA, CIRA and VKI are well-known in Europe for the different test facilities (large range of Mach number and enthalpies) they offer, as well as for their capabilities to the development and run of software for aerothermodynamics. It is foreseen for IoA to introduce their good knowledge in materials. KYBERTEC will be in charge of creating the web site and maintaining it during the whole life of the project.

MSU, CNRS and CFS Engineering will help to deepen the look on the different topics and bring in their knowledge for Radiation and Bodies Entering Earth atmosphere as well as Computational fluid dynamics (CFD).

Demokritos in charge of the third work package will play an important role firstly for their knowledge in materials and secondly also as integrator of a Capsule Demonstrator.

ACHIEVED RESULTS

RASTAS SPEAR project has just started; this paragraph presents the main expected scientific and technological results.

The entry technology used for the missions like Mars Sample Return mission shall fulfil the main following functions:

> Ensure the entry phase of the ballistic trajectory and sustain the thermal and aerodynamical loads encountered during the entry until the impact,

> Protect the payload from heat and mechanical loads during all the entry until impact on the ground,

> Comply with the planetary requirements, typically ensure sample container integrity until impact and guarantee sealing conditions at any time of the mission and under any circumstances.

The technologies developed for a Martian mission will also be adaptable to all other samples return missions from the Moon, asteroids or even farther planets.

The different technologies used for such a high speed vehicle are classified in the following way:

> Key technologies: Most critical to mission success, they offer the opportunity for meaningful mission pathway differentiation,

> Base technologies: Although necessary and essential, they support current operations and are widespread and shared,

> Critical technologies: Key technologies that need specific attention and a significant development investment due to a low level of Technology Readiness (TRL) (to arrive at the Product Development Review (PDR) a TRL of 6 is required)

For high speed re-entry sample return missions, the different activities are assessed with respect to these three classes of technologies, see Table 4.

Table 4: Earth Return Capsule technology classification

Activities	Technology		
	key	base	critical
Aeroshape stability			X
High speed aerothermal environment			X
Sub-system / equipment :			
Thermal protection	X		
Structure		X	
Crushable material	X		

The Thermal Protection System (TPS) is a key technology for the Earth Return Capsule (ERC). The critical aspect linked to thermal protection is related to the interaction between TPS ablation and aerothermodynamics and as such needs to be further understood. Also the accommodation of the tiles shall be looked at carefully.

The function of the crash protection (i.e. energy absorbing material) is to protect the sample container from the damaging deceleration at impact on ground.

To protect fully the sample container, the crash protection must absorb all the kinetic energy of the object, which depends on the mass m and the impact velocity of the object.

The optimum solution will be the one absorbing energy without generating g-loads beyond the limit of the sample container, while coping with stringent volume and mass allocations.

In order to cope with the very demanding projects like MSR, the goal of this project is to work on the topics often highlighted during phase 0, A or B studies but on which still little knowledge is available. The work will therefore focus on elements for High Speed Re-entry mastering but will not be a redlined project.

As already underlined for these High Speed Sample Return Missions we need to:

> Safely bring down the samples to Earth. RASTAS SPEAR will therefore work on Crushable Structure. Indeed, it allows to circumvent a Parachute System which is complex, and failures during Parachute sequencing can occur. It must be pointed out that for such missions the Parachute System will be activated years after launch of the mission which does not increase probability of success. Crushable structures are therefore the best way to damp the loads on the precious payload

and ensure their survival. For a safe return the different flight phases need to be managed but the behaviour of the capsule during Entry changes with atmosphere density and speed. Also the shape of the capsule changes as high heat loads contribute to ablation changing slightly the shape of the capsule and thus its flight mechanics behaviour. RASTAS SPEAR will highlight this topic and derive information about Ablation and its impact on stability.

> Protect the Payload from heat. To do so RASTAS SPEAR will identify an efficient thermal protection for the front shield. The knowledge on the TPS tiles itself is quite good and this topic is well developed with help from ESA projects, but the problem here is the gap between the tiles. Indeed, for manufacturing reasons the shield is not Unipart but made of several tiles. In-between the gaps must be filled with a resistant material not changing too much its shape and ensuring the integrity of the heat shield during the overall mission. RASTAS SPEAR wants to have a look on this gap material, demonstrate the feasibility of integration but also show by tests its thermal capability. While ablating, the roughness of the heat shield changes. This also changes the heat transfer. RASTAS SPEAR will go a step further and will try to understand the phenomenon. Flow tests under high Mach are necessary allowing the requested measurements and thus compute this. Result: better heat shield lay out and less mass as well as knowledge about Shape-flight mechanics.

> Specify the need of test facilities. Today real in-flight conditions can not be simulated on ground. Especially the radiation is difficult to reproduce. That is why current capabilities of the ground facilities shall be highlighted followed by the expression of improvements to better simulate the flow conditions.

CONCLUSION

RASTAS SPEAR is a very motivating project and the whole consortium will be fully engaged.

The actions proposed on RASTAS SPEAR project try to enlarge the basic capabilities on topics with low Technology Readiness Level and to strengthen European Industry and Research for coming or future Space Exploration missions like Mars Sample Return.

The project does not analyse a specific mission but deals with crucial elements to be well mastered for the design of a Capsule entering in the atmosphere with high speed (more than 10 km/s).

These necessary elements are:

1) To investigate on the available ground facilities and elaborate a proposal to improve these facilities in order to simulate in-flight conditions on ground.

2) To investigate and develop new and innovative methods, materials and systems for joining ablative blocks (tiles) together to produce a complete Thermal Protection System (TPS) for sample-return missions and validate them by tests with Scirocco.

3) To identify and test damping, energy-absorbing systems to allow survival of the Capsule Payload.

4) To analyse the impact of ablation (and thus Capsule shape change) on the flight mechanics.

5) To investigate and test impact of surface roughness on the heat transfer between the flow field and the capsule heat shield. The return on investment for the European Community is a European capability to design carefully a re-entry capsule with focus on mass, and thus on mission cost.

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Space technology

Towards European strategic non-dependence

MIDAS

Millimetre-wave Integrated Diode and Amplifier Sources

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ABSTRACT

The MIDAS project will redress the technology imbalance between the EU and the US in a most significant area of European technology non-dependence, affecting the scientific and commercial exploitation of the sub-millimetre region of the electromagnetic spectrum. Within MIDAS, critical Schottky varactor diodes and the simulation tools for fabricating and designing state-of-the-art sub-millimetre wave components and sources will be developed. Using these, a demonstrator terahertz source will be fabricated, with the aim of generating levels of radio frequency (RF) power previously unavailable within Europe. A small team of complementary expertise has been chosen to undertake the programme, combining world class researchers in the respective fields of circuit simulation, design and fabrication, with the leading SME in Europe supplying terahertz components to the space and commercial arenas. European amplifier technology, combined with optimised Schottky varactors fabricated on diamond substrates, will demonstrate a novel, generic, terahertz source technology, enabling planned sub-millimetre wave space science and Earth observation instrumentation to use wholly European technology. The ability for Europe to exploit the terahertz spectrum, which is recognised to be of key scientific and commercial importance, will be significantly enhanced.

INTRODUCTION

The terahertz (THz) spectral region between microwaves and infrared is of crucial importance to current and future space science, Earth observation and astronomy missions. As well as major international astronomy instruments currently operational or under development (e.g., Herschel's HIFI and the ground based ALMA instruments) a number of cosmological and planetary science proposals have also been submitted to the ESA Cosmic Vision 2015-2025 programme. In Earth observation, passive remote sensing of the atmosphere from space at millimetre and sub-millimetre wavelengths is expected to play a key role in the evolving EU/ESA GMES and Eumetsat MetOp Second Generation programmes; terahertz radio measurements will be directed towards processes linking atmospheric composition and climate, notably including the essential climate variables water vapour and ozone.

Despite these, and other potential applications that span the physical, biological, and medical sciences, the terahertz spectrum has yet to be fully exploited. In part this is because it remains difficult to generate conveniently useful amounts of power at THz frequencies. It is to address this problem, by developing generic integrated Schottky diode and amplifier sources using European technology, that the MIDAS programme is aimed.

Technology in the terahertz region has largely been driven by the requirements of astronomy and atmospheric remote sensing. This has necessitated the development of heterodyne radio techniques for sensitive high resolution spectral measurements. In this context, Schottky diode technology is uniquely important. Low noise Indium Phosphide (InP) front end amplifier technology is generally limited to frequencies below 200 GHz - as frequency rises, gain reduces and amplifier noise deteriorates - and superconducting mixers require cooling. Schottky detector technology, on the other hand, works at all millimetre and sub-millimetre wavelengths and at all temperatures. Most important, Schottky varactor diodes can be used for terahertz power generation through harmonic multiplication from a lower frequency source. With the exception of the 2.5 THz channel of the Microwave Limb Sounder on the AURA satellite, all space missions involving radio receivers above ~100 GHz have used Schottky diode harmonic multiplication as a source of receiver Local Oscillator (LO) power.

Schottky diodes will continue to underpin terahertz receiver development, since alternative detector techniques and techniques for generating power have disadvantages, especially if power and mass resources are limited.

- Quantum Cascade Laser technology (QCL) shows promise, but requires cooling and has not yet been demonstrated to work at frequencies below about 1.5 THz.
- Photonic down conversion, effected through mixing two optical/near-infrared laser beams in a high speed photodiode, is convenient and can provide power levels at ~100 GHz of several milliwatts. However, the efficiency of photonic mixing decreases rapidly with frequency and for the time being there is little prospect of providing sufficient LO power to drive a Schottky mixer at frequencies above 200 GHz.
- Vacuum tube devices and gas lasers can generate large amounts of terahertz power, but are expensive, inefficient and often (at least with respect to space use) limited in their practicability.

SPACE TECHNOLOGY

Consequently, Schottky circuits remain the technology of choice for receiver LO power generation at frequencies between ~150 GHz and 2 THz. However, more power is required than is currently available, if the applications in the terahertz spectrum are to be fully exploited. Current Schottky multiplier chains do not readily realise sufficient power to drive Schottky diode mixers at frequencies ~1 THz, or lower frequency focal plane receiver arrays (as required, for example, by meteorological geostationary sounders) or astronomical imagers. Available transmitter power limits radar applications in the field of cloud physics to long millimetre wavelengths. High bandwidth communication applications that might benefit from moving to higher terahertz frequencies are similarly limited by available power, as are sub-millimetre security imaging applications that use active radio systems.

The MIDAS programme aims to demonstrate, and commercialise, a new European terahertz power capability, by frequency multiplying (using custom designed diode arrays) high power sources at ~100 GHz derived from MMIC amplifiers, that are in turn driven by a frequency multiplied source. Power combining, in hollow waveguide, will be a key feature of both the amplifiers and the high frequency multipliers. This programme, which will ultimately focus on the delivery of a source providing above 100 mW in a frequency band centred on 300 GHz, is particularly timely:

> For the first time, it is possible to source custom Schottky varactor circuits within Europe.

> CAD electromagnetic structure simulators and non-linear analysis programs have demonstrated the ability to optimise circuit designs theoretically, and new high-speed CNC mills and improved lithographic capabilities offer novel options for circuit manufacture.

> Competitive European MMIC power amplifiers are now commercially available.

Improved Schottky terahertz sources are needed not only for future European space instruments. There is also a more general strategic need for the technology. The availability of improved power source technology will improve European competitiveness in a range of emerging markets, from medical and security imaging to non-destructive testing, and is likely to stimulate the appearance of new applications.

WORK PROGRAMME

The aim of the MIDAS programme is to develop and commercialise, using European devices, generic integrated diode and amplifier sources that will allow enhanced power generation in the terahertz band. In order to provide a direction for the work it is intended to demonstrate this new capability by developing a novel integrated diode and power amplifier source, providing powers >100 mW at frequencies around 300 GHz. This is illustrated in the schematic diagram (Figure 1).

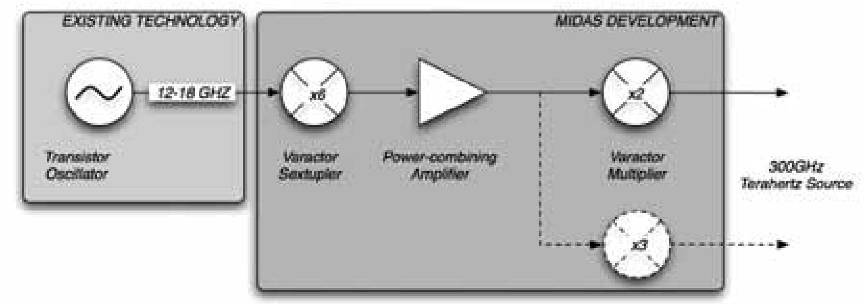

Figure 1: Schematic diagram of ultimate project objectives

The 12-18 GHz transistor oscillator is a straightforward, widely available, microwave component. The oscillator's output will be amplified and sixfold frequency multiplied in the sextupler, which will be a component specifically designed within MIDAS to use European semiconductor devices. The W-band, 75-110 GHz, power amplifier will use foundry MMICs sourced in Europe, and will exploit novel waveguide power combining designs. The varactor multiplier will be a custom GaAs Schottky circuit transferred onto a novel thermally efficient diamond substrates: it will also incorporate waveguide power combining approaches.

In selecting this objective the following considerations were taken.

Power at frequencies around 300 GHz is needed now for planned European space programmes, as an LO enabling sub-harmonically pumped Schottky mixer receivers to operate up to and beyond 600 GHz.

> Varactor multiplication of a power amplified lower frequency source is clearly the preferred method of generating LO power in the terahertz band. As a generic technique it will, in time, allow access to the whole of the terahertz band.

> Although Europe has an excellent reputation in delivering terahertz receiver technology, until recently this has been almost entirely based on Schottky device technology provided by the USA.

> Demonstration of enhanced terahertz power will lead to improved receiver technology and new commercial applications.

In short, the MIDAS programme will address an outstanding technical problem that is currently limiting the exploitation of the terahertz spectral region. In doing so it will bring together and further develop two underpinning terahertz technologies; millimetre wave power amplification and

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Schottky technology. In particular the need for European non-dependence in the area of Schottky diode technology is well recognised, and has been included as one of the key technologies in the work programme for FP7 in Theme 9.

PROGRAMME PARTNERS

A small, close-knit team of complementary expertise has been chosen to undertake the programme.

> The Science and Technology Facilities Council Rutherford Appleton Laboratory (STFC) has set up a fabrication facility that is demonstrating world class Schottky contacts. This proposal will help extend its capability to include varactor diodes.
> The Technical University of Madrid (UPM) has developed outstanding expertise in the physical modelling of Schottky diodes and circuits, and is recognised as a leader in this area within Europe.
> LERMA/Paris Observatory (OBPARIS) is similarly internationally recognised as a world leader in the design of Schottky varactor multiplier chains, and its staff have designed state-of-the-art Schottky circuits subsequently fabricated at JPL for use on Herschel.
> Radiometer Physics GmbH (RPG) is a world leader in terahertz component and system manufacture, and is expert at power amplifier design using MMIC's from European foundries.

All four participants are well known to each other and have previously worked together on European technology development projects. A programme lasting three years and a series of well defined tasks and objectives has been outlined. A number of novel technical developments of increasing technical difficulty are proposed, including the use of transferred diamond substrates for improved thermal performance. Testing at each stage will allow progress to be regularly monitored. It is worth noting that though important in its own right, demonstration of improved source technology by itself not sufficient. In order to be most useful, a fully commercial, generic European capability is required. For this reason the role of RPG Radiometer Physics GmbH, with its facility for commercial evaluation is most important.

CONCLUSION

The FP7 programme MIDAS - Millimetre-wave Integrated Diode and Amplifier Sources was initiated in June 2010 with the central aim of addressing the availability of RF power in the frequency range 150 to 330 GHz. The goal of this programme is to generate of the order 100 mW of power over this frequency band using a combination of Schottky based frequency multipliers and amplifier technologies. This programme will develop novel diode structures, new power combining techniques and advanced simulation tools. Central to the overall concept of this programme is the need to develop theoretical techniques to model the thermal effects of frequency multipliers operating under high-power conditions. The physical diode structures and their associated embedding circuits will also be designed with the aim of reducing the effects of temperature increase at the diode junctions and hence to optimise the power handling and efficiency of these devices.

SATURNE

Microsystems Based on Wide Band Gap Materials for Future Space Transmitting Ultra Wideband Receiving Systems

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Thales Research & Technology France

ABSTRACT

The last Strategic Research Agenda (SRA) of the European Space Technology Platform mentioned a need to support non-dependence on critical technologies from outside Europe for future space applications. In particular, one action under the bullet to reduce critical ITAR dependence is to secure access to high-performance microwave components used in satellite communication/navigation payloads, and earth observations or science instruments such as radars. Future satellite services will require novel types of microwave components to meet the demands in terms of more flexibility (ultra-wide-band (UWB) frequency allocation) and mass reduction. Two technologies are now emerging to face these challenges:

> Wide Band Gap (WBG) semiconductors such as Gallium Nitride (GaN) are expected to play a fundamental role in the development of Intelligent Micro Systems (IMS), yielding unprecedented power performance, efficiency and, along with suitable UWB re-configurable architectures.

> RF-MEMS switches as a complementary low-loss switch technology in order to achieve the re-configurability required for future IMS.

The route towards re-configurability of high power systems requires the merging of these key technologies and functions but they have not been co-integrated so far. Therefore, the main concept of SATURNE is to realize such novel types of microwave functions (re-configurable front-ends) using WBG MMICs integrated with RF-MEMS. The technological trends for transmit and receive front-end systems for many kinds of applications will be considered like:

> Re-configurable and highly power efficient communications satellite payloads with narrow-, multi- or wide-band channel allocation;

> Civilian space applications like environmental monitoring and cartography in X-band.

The SATURNE consortium is confident that the realization of its ambitious objectives will assist Europe to achieve technological leadership in domains that are targeted by ESA.

The main objectives of SATURNE are:

> To prove the feasibility and inherent advantages of using WBG and RF-MEMS based technologies in Intelligent Micro Systems for future space transmitting ultra wideband (UWB) receiving systems. This will be achieved via the integration (monolithic and hybrid) of WBG devices such as GaN based MMICs (LNA and HPA) and RF-MEMS switching networks for the realization of different active subsystems required for IMS.

> The GaN and RF-MEMS based circuits will be used to realize three types of very compact (small size and low weight) antenna breadboards for a proof-of-concept: (1) a smart active antenna made up of several Transmitter / Receiver (T/R) modules, (2) a miniaturized reconfigurable front-end and (3) a frequency-agile T/R module.

WORK PROGRAMME, METHODOLOGY AND MILESTONES

RF-MEMS and Gallium Nitride (GaN) transistors represent a key enabling technology for many applications. Satellite communication and radar systems, for which increasing functionality, better performance at smaller size and power consumption are highly attractive features, will dramatically benefit from a full integration of GaN MMICs and RF-MEMS based technologies onto the same substrate.

Furthermore, much interest is increasingly directed onto the development of improved solid state devices able to guarantee improved radio frequency (RF) output power and efficiency. Increasing RF power per unit device would greatly simplify power combining techniques and permit smaller and lower cost transmitters, for both UWB communication and radar applications. It is worth mentioning that, in order to guarantee that the said enabling technology will be useful for future market application, all the technology processes to be developed for RF-MEMS fabrication must be compliant with those adopted for GaN RF device production. For this reason, all the most relevant universities and companies have been involved in the SATURNE project in such a way as to ensure real production capability and competitive costs for any future requests of SME.The SATURNE project will follow the integration of GaN MMIC and RF-MEMS based functions in different approaches (monolithic and hybrid integration):

MONOLITHIC INTEGRATION APPROACH

The partners involved in the project will join their knowledge and know-how to set up a manufacturing process on AlGaN/GaN heterostructures which is compatible with Microwave Monolithic Integrated Circuits (MMICs) and RF-MEMS devices designed for microwave applications. This will allow for the realization of GaN-based RF-MEMS switches components like SPDT. Cost-effective packaging solutions, which are also very important when we increase the level of integration will also be developed.

1st demonstrator: The development and the integration of the mentioned components (HPA + LNA + SPDT on a single chip) will lead to the demonstration of a smart active antenna in X-band composed of several T/R modules, not only to prove the feasibility of the integration of GaN based RF-MEMS and MMICs but also to measure the performances that can be obtained in term of power handling, size reduction, active antenna efficiency and antenna adaptability.

HYBRID INTEGRATION APPROACH

An intermediate step in terms of integration of both technologies will be realized mainly by TASI and EADS, that are key players in the RF-MEMS and LTCC (Low Temperature Cofired Ceramic) businesses. Here the aim is to prove the feasibility and performance of reconfigurable RF-MEMS based matching networks for GaN power and low-noise transistors by using a hybrid integration approach of both technologies. These will result in the demonstration of a miniaturized reconfigurable front-end.

2nd demonstrator: A miniaturized reconfigurable front-end for the accommodation of wide- or multi-band systems will be developed with a reliability level suitable for space applications. To meet the requirements and offer up-to-date performances, RF-MEMS switches will be integrated on LTCC multilayer substrates. Taking advantage of this approach, a complex topology with monolithic circuits and passive components will be arranged on a small area. In particular the redundancy capability and RF test points will be integrated onto the circuit LTCC board with RF-MEMS switches.

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HYBRID AND MONOLITHIC INTEGRATION APPROACHES

Finally, the last demonstrator will use both approaches and will results on the demonstration of a re-configurable frequency-agile T/R module for a variety of applications.

3rd demonstrator: Re-configurable RF-MEMS based matching networks and high-power SPDT switches will be designed and manufactured on Silicon and on GaN. These circuits will then be integrated with the GaN high-power and low-noise transistors on a LTCC RF-board for the demonstration of a re-configurable frequency-agile T/R module. In addition, ultra-high performance true-time-delay (TTD) units will complete the innovative approach.

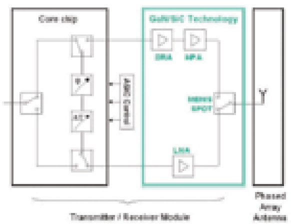
PARTNERSHIPS AND COLLABORATIONS

The SATURNE consortium consists of 3 major industrial partners, 1 innovative SME, and 2 academic groups in total representing 5 European countries:

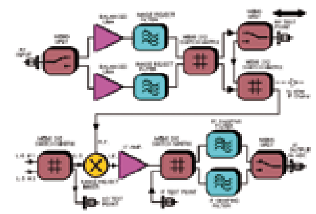
ACHIEVED AND EXPECTED SCIENTIFIC AND TECHNOLOGICAL RESULTS

1. Specifications of the demonstrators

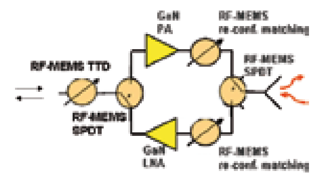
The end user has defined the specifications of the three targeted project demonstrators.



Demonstrator 1: High Power T/R module based on monolithic GaN integration



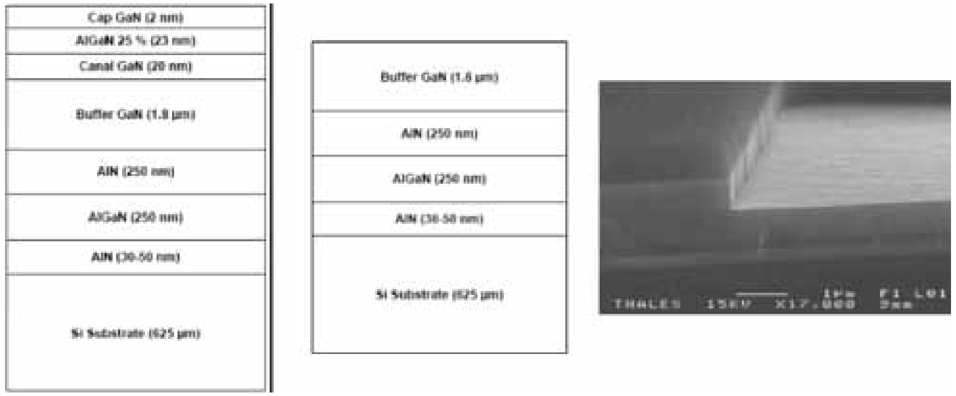
Demonstrator 2: Reconfigurable wideband front end based on hybrid integration (LTCC)



Demonstrator 3: frequency agile T/R module based on hybrid and monolithic integration approaches

Figure 1: SATURNE demonstrators

2. First results of modelling and fabrication of RF-MEMS switches on GaN substrates GaN MMIC technology and MEMS on GaN Substrate are not build on the same substrate level. Initially, for Transistor technology purpose, the GaN on Si/SiC has the structure as given (Figure 2, left):



Characteristics of GaN substrates

Characteristics of GaN substrates after etching

Etched GaN substrate for RF-MEMS and CPW technology compatibility

Figure 2: Characteristics of various GaN substrates

The Top three layers are needed for Transistor technology but will be detrimental to the RF-MEMS technology because of the high density 2D free electron layer generated at the top of the Canal layer. It is then needed for RF-MEMS and CPW technology to get ride of these top layers. For this purpose, 2 means are already available. The first one is to insert charges and render the top layer neutral, the second is to etch the substrate. In the SATURNE project we choose to etch the GaN substrate wherever the Transistor technology would not be needed. The etching need to be done on a thickness of at least 150nm in order to suppress any possibility of remaining 2D electron layer. The final structure of the substrate on which we'll be working for RF-MEMS and CPW technology is presented in Figure 2 (middle and right).

Even though we removed the active layers of the GaN substrate, it is important to verify that basic lumped components such as Resistances, Capacitances and Inductances are still working properly. For this reason we designed, fabricated and then measured test structures. Once the basic test structures featuring resistive, capacitive and inductive components showed proper behavior on GaN Substrates, we then built RF-MEMS switches 3D models, starting with the Single Port Single Throw Shunt capacitive switch and simulated them (Figure 3).

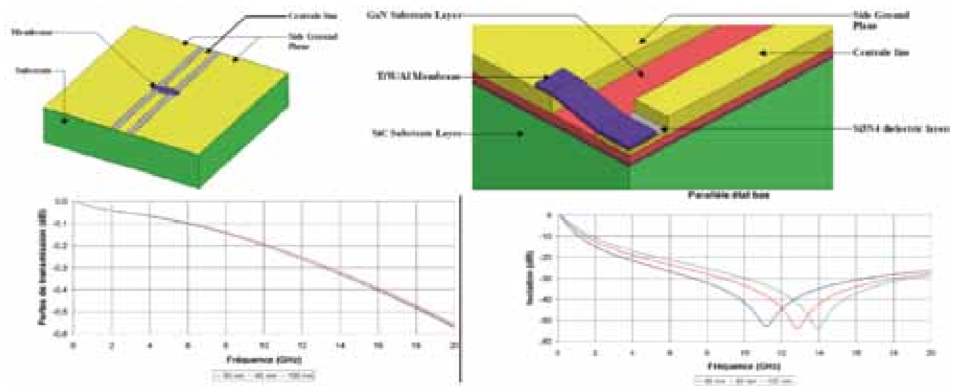
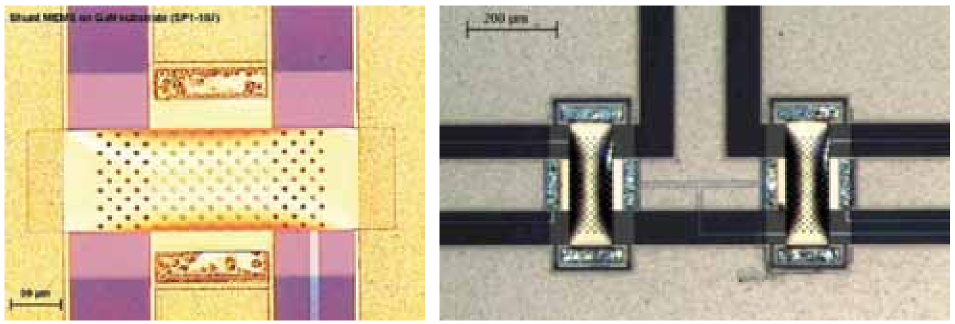


Figure 3: Design and simulation under HFSS of a Shunt RF-MEMS, on GaN substrate, for different dielectric thickness

Once the simulation gave us results in accordance to the specifications, we refined the model with a few more calculations in order to be certain of what we had then we proceeded to the making of masks and the fabrication of the said design. The result is shown in Figure 4:



First fabrication result of a shunt RF switch on GaN substrate

First fabrication result of MEMS-based SPDT on GaN substrate

Figure 4: First fabrication results

CONCLUSION

In conclusion of the above work, a set of rule has been defined for the design of GaN based RF-MEMS to be compatible with the already existing GaN based MMIC Technologies. The first rule of designing GaN based MEMS switches compatible with GaN MMIC technologies is to make sure the substrate surface will be appropriate. The second rule for the GaN based MEMS switches is to have a wave guide, be it micro-strip or coplanar, whose specifications are in accordance to the system's need. Considering the RF-MEMS switches are build on such structures, this is a very important step as it will define some of the RF-MEMS switch dimensions. Last, as the test structures of resistances, capacitances and inductances components showed usual behaviour on GaN Substrate compared to Si/SiO_2 substrate, the designing of RF-MEMS switch on GaN will be able to follow the already existing guidelines of the Si/SiO_2 technologies and be compatible with the GaN based MMIC Technologies.

Based on this work, we expect within SATURNE to confirm the simulations by RF characterisation of the fabricated MEMS components. Once the fabrication of these components will be completed, on one hand reliability test will start and on the other hand, common integration with GaN MMIC will be demonstrated, which reprensent an important milestone toward the realisation of the demonstrators.

TERACOMP

Harvesting science from radio waves

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ABSTRACT

Sub-millimetre wave or terahertz heterodyne receivers are key instruments for many space applications. For example, they are required for monitoring of the earth's atmosphere or detection of molecules that might be tracers of life on other planets or moons. However, key components of these systems are currently supplied from outside Europe and performance as well as mass and power requirements often prohibit the implementation. The TeraComp project aims at developing European industrial level capability to design and manufacture terahertz front-end electronics based on high frequency Schottky diodes, Heterostructure Barrier Varactor (HBV) diodes and mHEMT MMICs for space and other applications. The prototype components will be integrated into a compact 557 GHz heterodyne receiver and evaluated for space instrument applications. The front-end demonstrator consists of a low noise 557 GHz subharmonic Schottky diode mixer, a 275 GHz Heterostructure Barrier Varactor frequency tripler and a 92 GHz mHEMT power amplifiers and a 15 to 92 GHz 6x multiplier as part of the local oscillator chain. This development will significantly contribute to mass and power reduction and it will improve the performance of terahertz heterodyne receivers. In addition, the dependence on critical technologies and capabilities from outside Europe for future space applications will be reduced.

WORK PROGRAMME AND METHODOLOGY

There is a need for compact heterodyne receivers operating in the sub-millimetre wave band above 300 GHz for earth observation instruments and space science missions. The sub-millimetre wave or terahertz domain allows studying several meteorological phenomena such as water vapour, cloud ice water content, ice particle sizes and distribution, which are important parameters for the hydrological cycle of the climate system and the energy budget of the atmosphere. Terahertz molecular line spectroscopy helps to generate and validate models for understanding dynamic processes in our atmosphere. Similar data can be collected from the atmosphere of planets, moons, comets and asteroids, including the search of chemical signatures associated with surface volcanic or even life processes.

A number of future Earth Observation and Space Science Missions planned by ESA will employ terahertz wave heterodyne radiometers based on Schottky mixers. Specifically, the next generation EUMETSAT Polar orbiting weather satellites system (Post-EPS) and the proposed cloud missions, i.e., CIWSIR, call for receivers at frequencies approaching 1 THz. The technology developed in this programme will be appropriate to all these missions. A selection of planned earth observation missions operating at terahertz frequencies is shown in the table below. Missions to the outer planets such as to Titan and Enceladus, the moons of Saturn, (mission acronym: Tandem) or to Europa and the Jovian system (mission acronym: Laplace) are currently being studied at ESA.

Terahertz wave heterodyne radiometers can provide important information about the structure, composition, and greenhouse properties of their atmospheres and identify molecules, which are potential signatures for life and habitability. It should be pointed out that all of these missions have been identified as very important by European scientists but might be put on somewhat lower priority by ESA as we lack European sources for key parts of the instruments and relying on sources outside of the EU/ESA member countries is risky. Therefore, the project complements current efforts of the space community and it contributes to the European Space Programme.

RF band	Characteristics	Mission or instrument
874 GHz		C1WS1R
664 GHz		Post-EPS, C1WS1R
557 GHz	H_2O line	
496 GHz	N_2O, H_2O, O_3, CIO,	STEAM radiometer
448 GHz	H_2O	Post-EPS, C1WS1R
424 GHz	O_2	
340 GHz	H_2O, O_3, CO,	STEAM-r
325 GHz	H_2O line	Post-EPS, C1WS1R

Figure 1: Examples of planned European sub-millimetre / THz wave instruments

At "low frequencies", up to around 300 GHz, discrete (standard) diodes and even HEMT MMIC technology can be used. Monolithically integrated diode circuits (MMICs) are needed at higher frequencies, say >400 GHz, due to transmission line losses and the fabrication tolerances. This program aims to address the lack of suitable technology for the frequency range 400 - 900 GHz that are critical for European projects such as Post-EPS, CIWSIR, Premier etc. Moreover, due to extreme size and weight constraints of earth observation instruments and deep space missions, it is highly desirable and in many cases such as for the Tandem or Laplace missions mandatory to use un-cooled front-end electronics that also operate under low power consumption.

Schottky Diode (SD) mixer technology is the most suitable technology for non-cryogenic receivers operating in the frequency range above 300 GHz. Several ESA missions in the past had to rely on non-European devices due to the lack of a suitable vendor in Europe; this issue will be addressed in this programme through the demonstration of a reliable European source of Schottky devices. Moreover, we will address mHEMT power amplifier technology and Heterostructure Barrier Varactor (HBV) multiplier technology for efficient generation of local oscillator signals.

Project objective is to improve European THz front-end key technologies towards industrialisation and to enable independence in future space programs and instrumentations for scientific missions. Leading European THz groups from industry, institutes and academia will work together with a common goal to demonstrate a state-of-the-art and ultra compact heterodyne receiver front-end module operating in the frequency range 500 – 600 GHz, which could be used in several planned missions.

The following high frequency components constitute the 557 GHz front-end:

> Broadband and low noise Schottky Diode Sub-Harmonic Mixer (SHM) with centre RF frequency at 557 GHz. The MMIC technology will be based on a membrane and beam lead technology.

> Efficient Heterostructure Barrier Varactor Multiplier to 278 GHz (LO source) with an output power of ca 10 mW.

> Efficient W-band power amplifier (LO chain) using mHEMT MMIC technology with an output power of ca 100 mW.

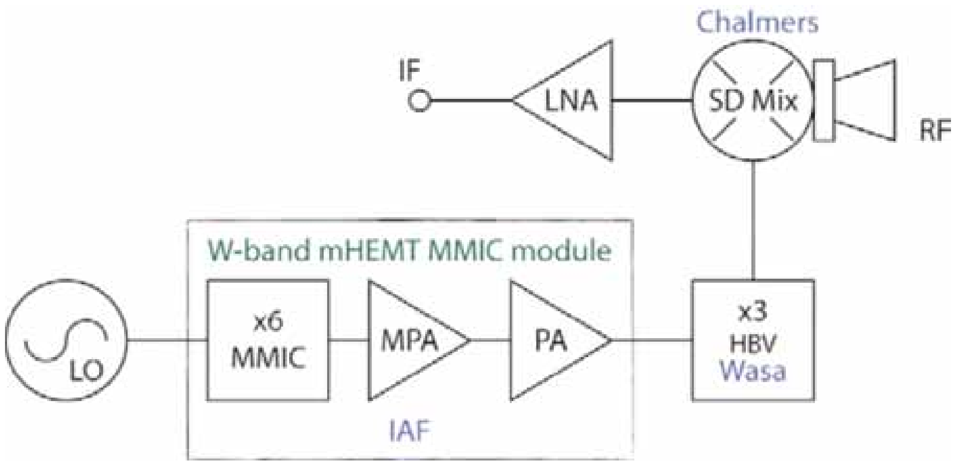

Figure 2: Terahertz Frond-end demonstrator (TeraComp)

The local oscillator chain consists of a high efficiency HBV tripler pumped with mHEMT PA MMIC. The goal is to achieve ultra-low power consumption of the front-end module, low noise temperature for the receiver, and a reliable system by minimising the number of components in the LO chain. Selection of RF frequency has been chosen in order to overlap with planned European missions and complement ongoing ESA projects for mixers and multipliers up to 400 GHz and 664 GHz.

CONSORTIUM

The project is co-ordinated by Chalmers University of Technology (Chalmers) and the consortium consists of the following partners:

> Chalmers University of Technology, Sweden
> Fraunhofer Institute for Applied Solid State Physics, Germany
> Deutsches Zentrum für Luft- und Raumfahrt e.V, Germany
> Technical University of Denmark, Denmark
> Omnisys Instruments AB, Sweden
> Wasa Millimeter Wave AB, Sweden
> Goethe-University Frankfurt, Germany

The consortium offers European leading technology in the fields of Schottky device modelling and fabrication, mHEMT technology, and frequency multiplication using HBVs. The consortium also contains European expertise in the field of millimetre-wave sub-system engineering, production and characterisation.

CONCLUSION

The project TeraComp addresses strategic technology for space terahertz instrumentation and will develop a European industrial capability to design and manufacture terahertz components and electronics. In the long-term, the outcome of TeraComp will play a role in gaining knowledge of the earth atmosphere, the climate system and understanding of the universe. Terahertz electronics will also find dual use applications in ground-based systems and open up for new markets.

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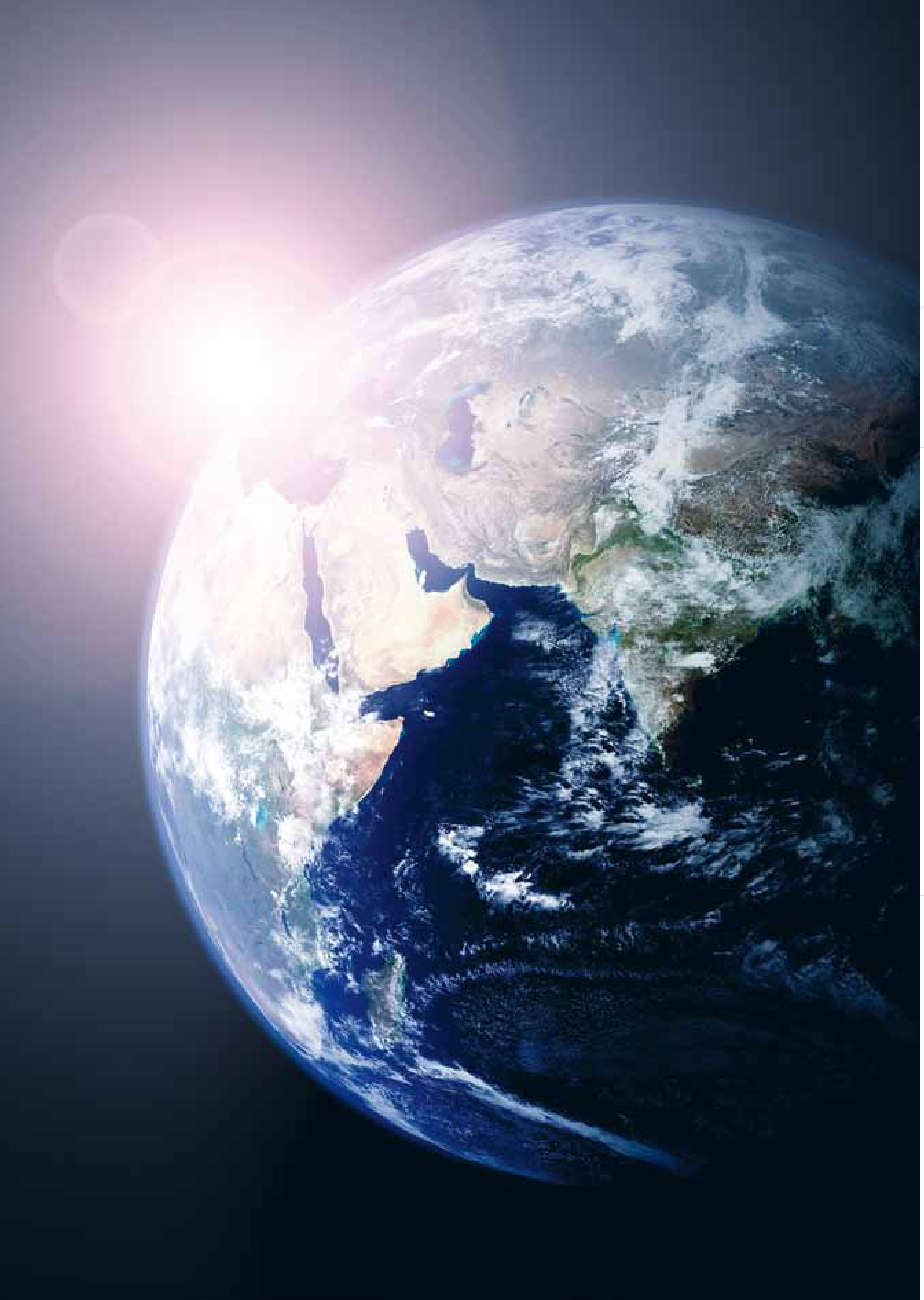

Part III Facilitating Space Research Cooperation

COSMOS

Cooperation of Space NCPs as a Means to Optimise Services

Adrian Klein, Marc Jochemich

German Aerospace Center

ABSTRACT

National Contact Points (NCPs) for Space provide support to those who are interested in Space calls under Framework Programme 7 (FP7). As NCPs are established and funded by national governments their availability and type of support services differs. Since 2008 the European Commission is therefore funding COSMOS. This allows participating Space NCPs to conduct joint activities. On this basis they share good practices, organise events and create a country independent basic support accessible through the project website www.fp7-space.eu.

32 partners from 30 countries are cooperating within COSMOS, coordinated by DLR, the German Aerospace Center. Their joint work has already led to an improved overall knowledge about how to provide good Space NCP services. It eases and accelerates access to know-how for new Space NCPs. Further, COSMOS facilitates joint information days, enhanced personal contacts and improved cross-border matchmaking. Last but not least some particular tasks are addressing specific topics: SME support measures were collected and published on the project website. Within the coming runtime the consortium will finalise a scheme of Space key players representing their interactions. This is supposed to build the basis for an event that will be organised close to the end of the project runtime. The aim is to present EU Space and provide information about and contacts to the according players. It will thus be a big matchmaking opportunity also for 3rd countries.

RESULTS

The exchange opportunity enabled by EC funding via COSMOS is very well received and used by the Space NCPs. Most partners actively participate in joint trainings and all other activities. Moreover the COSMOS consortium organises the official international information days on the yearly FP7 Space calls.

COSMOS offers the chance for improving own skills by learning about how colleagues in other countries do their job. Further on it provides fast access to Space NCP working knowledge for new staff. During the project runtime about half of the partners changed their NCP Space. This is typically weakening national support as newcomers need their time to learn about FP7 and Space. Such negative effects could be mitigated through the COSMOS network.

Just recently the European Commission put Space faring 3rd countries (not being EU member states or FP7 associated countries) in their focus. This aims at joint Space research for mutual benefit. NCPs have knowledge about their countries' Space research scene. They also know how to support participants and how to raise awareness about FP7 Space. This makes NCPs ideal interfaces for 3rd country contacts to be established. Therefore the COSMOS partners have started identifying suitable persons in the Space faring 3rd countries and will support them via a mentoring scheme. As a result more participants from Space faring 3rd countries will learn about FP7 Space funding opportunities and will have improved access to EU Space researchers. At the same time EU researchers will be provided with improved access to potential project partners from those 3rd countries.

An important new issue was just recently raised and will now be addressed. Some partners observed a lack of integration of some of potential participants from their countries, particularly the "new member states" but also some associated countries.

This issue will now be discussed and further investigated. Such activities just make sense in a funded European network.

CONCLUSION

So far it became obvious that funding a network of Space NCPs was an excellent idea. It was a logical step for strengthening the European Research Area through an overall improved support service comprising the organisation of the official information days. As it was intended the network is more than just the single parts. A more balanced and overall improved service but also new services resulted through COSMOS.

It will also in the future make sense to fund an NCP Space network. This was recognised by the European Commission. With the additional objective of broadening the network to Space faring 3rd countries a call for a follow-up project was therefore recently launched. A smooth transfer of the Space NCP service network also to post FP7 Space funding is thus ensured. As mentioned above the extension to 3rd countries is already addressed now within COSMOS. This will surely also help considering the international dimension of post FP7 Space funding.

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> http://www.fp7-space.eu

STAVE

Space Transportation Assets Valorisation in Europe

Michel Pons (Coordinator)

CNES Launchers Directorate, Evry, France

ABSTRACT

STAVE (Space Transportation Assets Valorisation in Europe) is a 24-month Support Action co-funded by the European Commission under FP7.

The consortium is composed of 3 partner countries representing 90% of the European effort in ST: France, Germany and Italy.

The STAVE project is aiming at identifying, evaluating and valorising the skills (research laboratories, universities, research institutes, SMEs, industry) of the New Member States (NMS) of the European Union, in the domain of Space Transportation (ST). This project contributes to the overall objective of maintaining an independent access to Space for Europe.

This team has gathered European ST scientific and technological needs for preparation of the future, in accordance with the existing National and European space agencies roadmaps. These needs have been presented to the NMS through a set of 10 workshops held in the interested countries from December 2008 to May 2009.

The systematic use of the existing networks of NCPs, embassies, agencies and institutional representatives, combined with website information, has enabled the STAVE project to join more than 1000 people representing 800 entities in the 12 NMS for invitation to these workshops.

As a result of this project, a report describing the validated skills of 77 entities has been published widely all over Europe, allowing the classical actors of Space Transportation to better cooperate with these entities which have interesting skills for Space Transportation.

In order to satisfy both the needs of NMS countries entities and Western countries entities, several tables present the skills in different ways.

This report's important added value relies in the technical evaluation which was performed by the 3 agencies' experts about the real capacities of the entities who answered the questionnaire.

This report is available on request michel.pons@cnes.fr or www.stave-fp7.eu

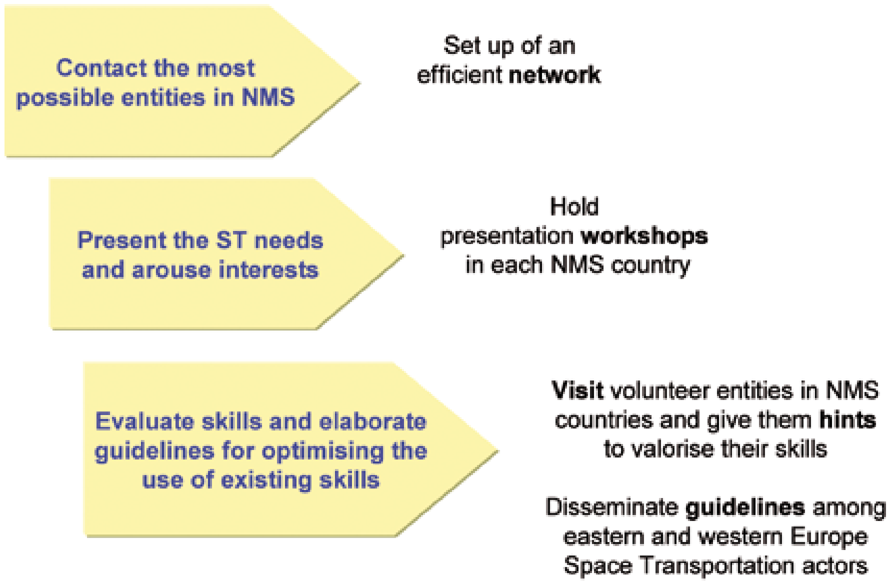
WORK PROGRAMME, METHODOLOGY, MILESTONES

The STAVE project was proposed in order to enhance European capacities for innovation in the domain of Space Transportation in Europe and to take profit of all existing European capacities, contributing to the overall objective of maintaining an independent access to Space for Europe.

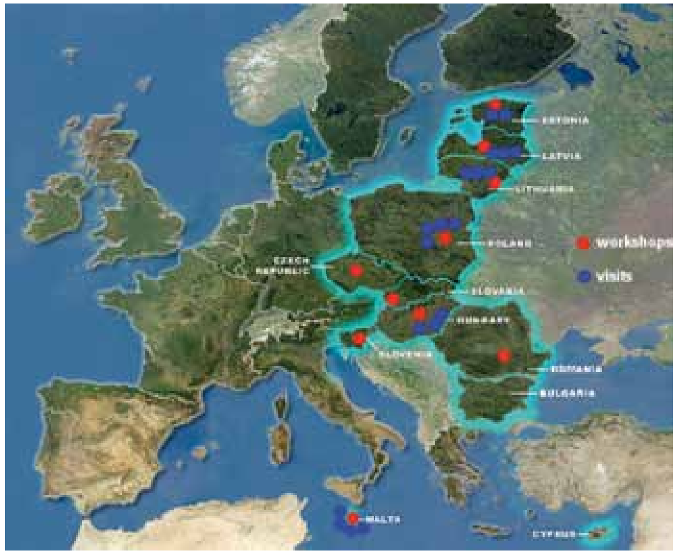
Many technology holders are not necessarily aware of the potential of interest of their technology for Space Transportation.

STAVE work logic was to identify those technology holders, meet them and find out how they could bring added value to the Space Transportation activities in Europe, either by participating to existing programmes or preparing future systems.

The methodology used is illustrated by this chart:



After having held the technical workshops for presentation of the technical needs, each volunteer entity has filled a declaration of skills. These declarations have been evaluated through technical analysis and in some cases, in-situ visits have been established.



Map 1 shows the location of workshops and visits.

The workshops were the opportunity to present the following information:

General Introduction of Space transportation
- Scope (missions, ...)
- Current European launchers
- Future trends (R&T, System demos,...)

Space transportation disciplines
- System definition loop (3)
- Trajectories, GNC, Missions, Flight mechanics (8)

Space Transportation Technologies
- Avionics & Software (5)
- Thrust Vectoring Control (4)
- Propulsion – Solid, Liquid, Components(14)
- Pyrotechnics (6)
- Ground Facilities (6)
- Operations (3)
- Environment, Aerodynamics, Acoustics,.. (10)
- Structures & Materials (7)

Scientific Disciplines
- Classification, Methodologies of Analysis (3)
- Aerospace Sciences (3)
- Propulsion, Enrergy (2)
- Structures, Design & Testing (2)
- Materials, Electronics (5)

Project Phasing
- Technology Readiness Level (TRL) (3)
- Technical Project Phases (2)

Space Transportation Specificities
- Production Rate, Double Source Requirement (2)
- Quality Management (3)
- Reliability, Availability, Safety (5)

Conclusion

Total is 140 slides
Presentation was made available on the web site as a pdf file

PARTNERSHIPS AND COLLABORATIONS

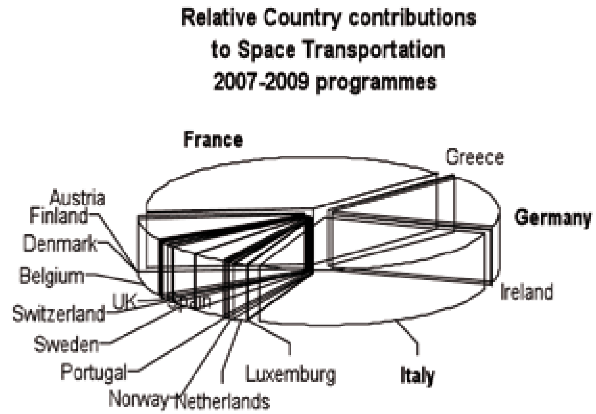
The consortium involves

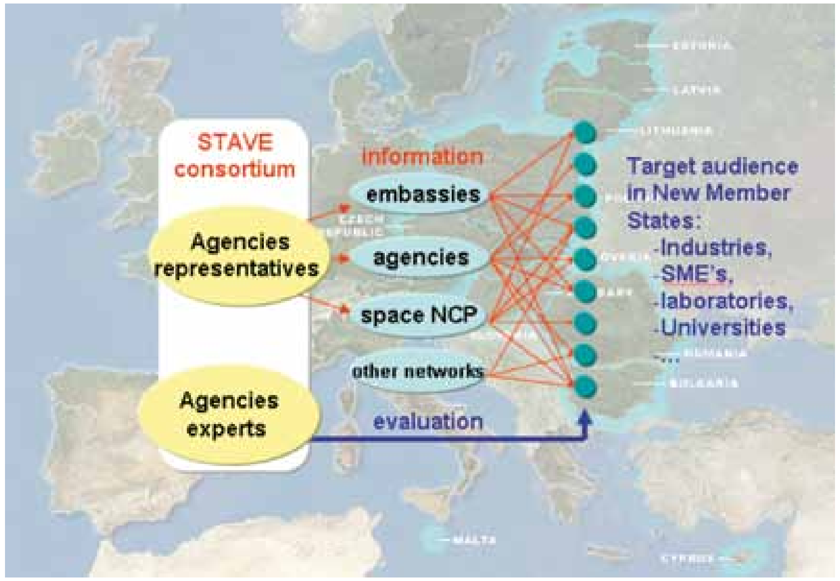
> CNES, the French Space Agency (Michel Pons is coordinator michel.pons@cnes.fr),

> ASI, the Italian Space Agency (Cristiana Cirina responsible for WP2 cristiana.cirina@asi.it)

> DLR, the German Space Agency (Prof W. Koschel for WP3 wolfgang.koschel@dlr.de).

These three European Space Agencies cover more than 85% of the space transportation effort in Europe and are representative of the European needs in terms of Space Transportation. This team gathers representative knowledge of European Space Transportation scientific and technological needs for preparation of the future, in accordance with the existing National and European space agencies roadmaps.





Scheme of the logic used for contacting potentially interested entities.

This consortium achieved an excellent partnership with the network of embassies, NCPs, Space Agencies or ministries, Development agencies from the 12 New Member States, in order to reach as many entities as possible.

Special thanks have to be given to them as they made this project possible.

ACHIEVED SCIENTIFIC AND TECHNOLOGICAL RESULTS

The final result achieved is the establishment of a network of entities who have declared their interest in participating to Space Transportation activities and whose skills have been validated by a team of independent experts.

This network is materialized by a report containing the description of the skills of all entities who participated to the project. This report has been distributed widely in Europe to all participating entities, to embassies, space agencies, NCPs, and also to all the classical actors of European Space Transportation (industry, agencies, research organisms).

This report is not an exhaustive list of the existing capacities, but represents only the result of the STAVE process, in which only those who answered the questionnaire have been evaluated.

It seems that the entities already involved in Space Transportation activities did not feel concerned by this project, already being involved in the domain.

Each of the evaluations has been performed at least by 2 experts.

The information contained in each synthesis report is based on:

> the standard questionnaire which was sent to all entities
> the entities' website, as available at the date of the evaluation
> a complementary in-situ visit when estimated necessary

Each entity has been informed and granted a right of correction of the published evaluation.

These synthesis reports do not pretend to give all details of the evaluated entity, but give a general technical evaluation by independent governmental experts. For more precise information, the coordinates of the person to be contacted is included.

The results are presented in tables, giving a classification of the entities:

Classification table by country

Classification tables by statute:

> Research
> Industry
> Public institution - consultant
> Classification tables by discipline
> System
> Mechanics and structures
> Propulsion
> Miscellaneous

The technical Evaluation Reports are then given for all entities (listed by country).

The expected impacts are :

> In the short term

    > identify existing skills

    > introduce existing skills within the Research projects (2010)

> In the medium term

    > introduce existing skills within development projects (2015)

> In the longer term

    > increase European strengths in Space Transportation

    > introduce existing skills within future large Space Transportation developments (2025)

Problems were found in organizing the workshops, with 2 limitations in the span of the project:

> One difficulty was to reach the entities potentially interested in the project, as very much commercial advertisement is distributed via internet and e-mails. Mails are often considered as spam or simply not read when being sent by unknown people. Therefore, after seeing the lack of answers of the first batches of e-mails, it was requested from our local contact points to make this mailing. Some delay resulted from this draw-back.

> Another difficulty was observed in rising interest among the persons contacted, as in the period considered (end of 2008 – beginning of 2009) the financial crisis gave priority to the very short term activities, needed for survival by many small enterprises. The longer term investment was therefore less a priority. As a consequence, the STAVE project accepted answers even far beyond deadlines, in order to give a chance to entities, which had few resources available for participating in STAVE.

The material organisation of the workshops is not an easy task when you are not in the place (find the venue, adapt the timing with local events and holidays). Thanks to an excellent cooperation with our local contact points, this difficulty was smoothened without too many problems.

As a result, the 10 workshops held were very positive, with many questions and discussions showing the technical interest of the participants in the technical presentation and the possibilities of participation in Space Transportation programmes.

This picture from April 2009 illustrates a workshop, as 2 STAVE experts, Prof W. Koschel from DLR and P. Fortunier from CNES, present slides about solid propulsion.

CONCLUSION

The STAVE project succeeded in making a presentation of Space Transportation technologies and needs for preparation of the future Space Transportation systems in the European New Member States, meeting universities, research laboratories, research organisms, SMEs and Industry.

Among the entities met, some had never been involved in Space activities and discovered that their technologies could be interesting for Space applications.

These entities have declared their interest in participating to Space Transportation activities by filling out a detailed questionnaire describing their skills.

These questionnaires have been evaluated by independent technical experts:

The evaluation forms are gathered in a final report which is made available to all those who wish to establish cooperation in Space Transportation activities.

This report can be obtained on request at
michel.pons@cnes.fr or www.stave-fp7.eu

The participation of these entities in the STAVE project contributes to reaching the European objective (Europe 2020) to take benefit of all existing European capacities for consolidating an independent and affordable European access to Space.

The STAVE project coordinator wishes to thank all those who contributed to this project, and hopes the final report is helpful for establishing an active network.

There has not yet been enough time to assess what long-term effects might effectively come out and therefore any feedback experience or information is welcome in order to widen the impact of this work.

NordicBaltSat

Utilizing the existing and emerging potential of the Nordic-Baltic dimension in critical satellite technologies and applications

Madis Võõras, Kristo Reinsalu

Enterprise Estonia (EE), Invent Baltics (IB), Ventspils High Technology Park (VHTP), Kaunas University of Technology (KUT), Wasat, Swedish Space Corporation (SSC), International Space University (ISU)

INTRODUCTION

Europeans share a common passion for space. The general objective of the NordicBaltSat (NBS) project is to create the necessary conditions for utilizing the existing and emerging potential of the consortium partners in the Nordic-Baltic dimension for continuous and sustainable contribution in major on-going and planned European space programmes.

Since 1975, the European Space Agency (ESA) has led Europe on space missions ranging from low Earth orbit human space flight missions at the International Space Station (ISS) to pioneering journeys to Mars, and further to the moons of Saturn. Following the accession of Poland and the Baltic states to the European Union in 2004, ESA accession is an important next step for the integration of these countries into the European space architecture.

Baltic States (Estonia, Latvia, Lithuania) and Poland, all representing emerging space countries, want to get closer to ESA, primarily as a way to advance their integration into Europe and to create new opportunities for their economies. The joint technology program (JTP) is seen as the heart of the whole NBS project to match the most urgent needs of ESA while creating desired preconditions for emerging space countries to play along in the space market and to speed-up their accession process to ESA. Creation of JTP together with relevant capacity building activities will help to create substantial impact for participating countries on their road to ESA. Other important objectives of NBS project consist of contributing to the shaping of systems of governance in the space field in these countries, as well as public outreach activities fostering dialogue and debate on space science and research with the public at large.

WORK PROGRAMME, METHODOLOGY, MILESTONES

According to the overall strategy of NBS project, there is ongoing need to enhance the potential of emerging space countries around Baltic Sea in order to start to make continuous and sustainable contribution to major on-going and planned European space programs by using different ways of international as well as local cooperation. The project is organized into three core work-packages to reach the project objectives (see Figure 1):

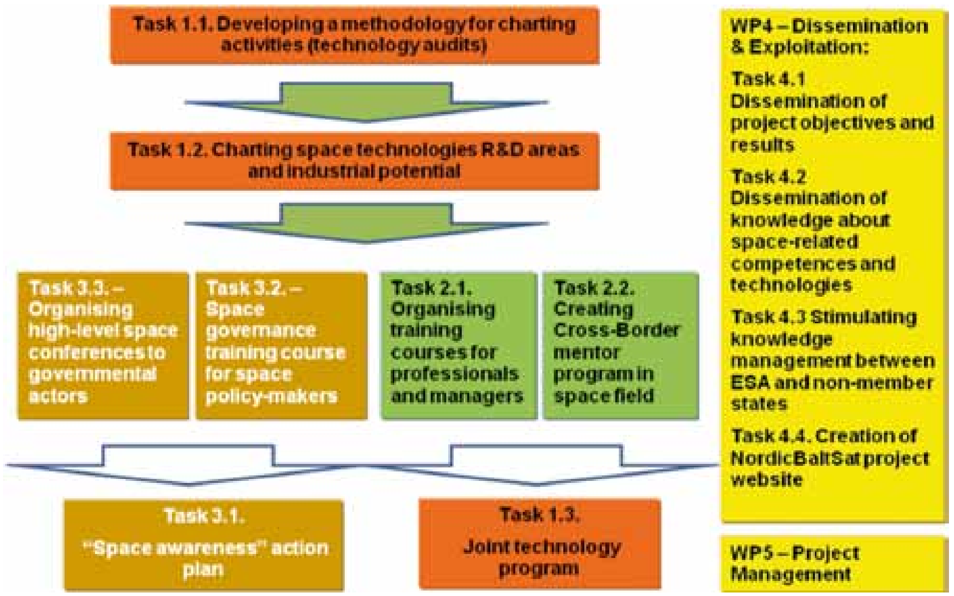


Figure 1: Pert diagram of NBS project

Phase I comprises the charting of space technologies R&D areas and industrial potential in emerging space countries such as Baltic States and Poland.

Phase II comprises three tasks: (1) organizing training courses for experienced professionals and for managers identified in I phase; (2) creating cross-border mentor program in space field with the aim to provide guidance and coaching for companies from emerging space countries by experienced international mentors supplied by Swedish Space Corporation (SSC) and International Space University (ISU), but also by involving other "volunteers" to act as mentors; (3) arranging space governance training course for space policy-makers around Baltic Sea.

Phase III comprises the following tasks: (1) creation of a Joint Technology Programme (JTP) with the aim to determine specific fields and niches for Baltic Sea Region together with suggested measures where emerging space countries want jointly develop space technologies to ensure availability of European sources for critical space technologies; (2) creation of Space Awareness Program (SAAP) for governmental actors; (3) organizing high-level space conference to governmental actors to support implementation of European Space Policy (ESP) and for introducing results of both, JTP as well as SAAP respectively.

PARTNERSHIPS AND COLLABORATIONS

NBS brings together best possible coordinating bodies of national space activities from emerging space countries around Baltic Sea together with space "strongholds" like Swedish Space Corporation (SSC) and International Space University (ISU). Relying on ISU`s extensive experience and know-how being as the world's leading university solely dedicated to the study of space, it will guarantee that all training events will be carried through in highest professional level. When viewing from another angle, SSC which was originally set up by the Swedish Parliament for the technical implementation of Sweden's national space and remote sensing programmes, have all prerequisites in place to be capable to lead successfully the build-up of a Joint Technology Programme (JTP). Since the national programmes have provided the basis for SSC's development into an international business partner for space project, it will help to ensure that program will be prepared according to the needs and hopes both from looking at ESA`s as well emerging space countries point of view.

In order to guarantee ideal basis for NBS' set-up, partners have agreed their dominant joint interests as follows:

> Raise public awareness - There is growing need for raising public awareness to explain that there will be breakthrough of multitude of space technology applications into our everyday life in coming years.

> Space Administration Systems - Emerging space countries should get boost through this project to build up their national space effort administration systems.

> Joint Technology Programme (JTP) - Agreeing on common priorities, finding specific niches will help to create fertile ground for successful participation in ESA programs in future.

All NBS participating countries perceive cooperation with ESA as a powerful tool to create opportunities for their SMEs in high-tech niche sectors and to help further EU integration on national level. At the same time when considering the new realities in the region, it has become more feasible to find solutions to numerous environmental and economic challenges inside the region, which in turn would advance the goals of the European Union as a whole. EU Strategy for Baltic Sea Region has been called into existence with the aim to create a coherent framework to implement existing programs and projects and for the promotion of further integration between countries neighbouring Baltic Sea. In this context, NBS will support also the EU cohesion policy, as the challenges in the Baltic Sea region are common also for NBS partners. Thanks to the European Space Technology Master Plan, which on the other hand supports also an enlargement of the Union by helping the integration of new EU Members States in the space sector along its agreed roadmaps, this situation lays perfect foundations (excellent preconditions) for overall NBS consortia to develop mutually beneficial cooperation with ESA in coming years.

Throughout the project NBS aims to establish long-term relations between firms, institutions and universities from emerging space countries and well-established and well-experienced European space organisations. To this end, a mentorship concept has been introduced. The aim of the creation of cross-border mentor program on space field will be to increase innovation levels and the competitiveness of emerging countries small and medium sized companies by providing them guidance and coaching from experienced international mentors. In general a mentoring process as such is foreseen to facilitate knowledge dissemination between two business persons – the mentee coming from emerging space countries and the mentor, who is expected to have long-term experience working in the space field to come from the ESA member states.

ACHIEVED (OR EXPECTED) SCIENTIFIC AND TECHNOLOGICAL RESULTS, POSITIVE FEATURES, PROBLEMS ENCOUNTERED

In this paper, we have chosen to put more focus on the flow of activities around the preparation of the Joint Technology Programme (JTP). As a first step, already in May 2010 we prepared a specific questionnaire with the aim to capture the interest of more than 150 companies and R&D institutes which already have or might have the potential in the future to be involved in space related activities. In June 2010, we turned to all respondents by starting with following message for introduction:

"NordicBaltSat is a project under European Commission`s 7th Framework programme and in collaboration with European Space Agency, aiming at promoting space industry in Estonia, Latvia, Lithuania, and Poland. Participation in following survey, enhances your opportunities to further present your organisation and to establish direct contacts with the leading space industry companies and organisations across the Europe. Further along, your activities might be included into a joint space technology programme for the Nordic-Baltic region. By filling out the following short questionnaire and marking your technology position in the appended ESA Technology Tree your organisation has the opportunity also to join the training courses for executives and/or mentorship programme that will be introduced in Cooperation with the International Space University (ISU) and the Swedish Space Corporation (SSC). All the above activities are aimed at fostering your future business in the field of space based systems."

Some of the questions were put in the form of just ticking boxes with "yes", "no", or other choices. From our perspective we just wanted to find, in the simplest manner possible, candidate organisations that we believe could participate in, and who believe that they can contribute to space activities in future. Therefore we initially didn`t want to include any explicit references to ESA programmes or technology plans in the first step of the WP 1 survey since we thought that it might complicate matters and risks limiting the perspectives for the people answering the questionnaire.

Customers/stakeholders of the JTP were identified as follows:

> National Space Authorities; with their strategies, industrial policies, and funding without which very little can be achieved in the "upstream" space technology arena

> European Space Agency (ESA); with its technology needs and interest to incorporate further countries and users of data from European systems

> Existing and potential space industry and institutes in the NBS partner countries; as actors and principal beneficiaries of the proposed JTP activities

> European Commission; in the long term, due to its increasingly important role in European space activities, as complementary or superior to ESA

There are also a number of initiatives addressing space technology or related applications in the Baltic region, both from ESA and EC, e.g. the Programme of European Cooperating States (PECS) and ESA Integrated Applications Programme, dedicated Call for Baltics (IAP Call for Baltics). Other strategies for the region (e.g. EU Strategy for the Baltic Sea Region) have also more far-reaching goals which can partly be met by implementing space technology based applications. Although development of downstream applications was originally meant to take place regardless of the JTP (purely on a commercial basis like it happens as usual), preliminary results of NBS survey showed and thereby convinced us that all 4 emerging space countries (Baltic States and Poland) should find their niches also in downstream sector and we cannot exclude this topic from JTP.

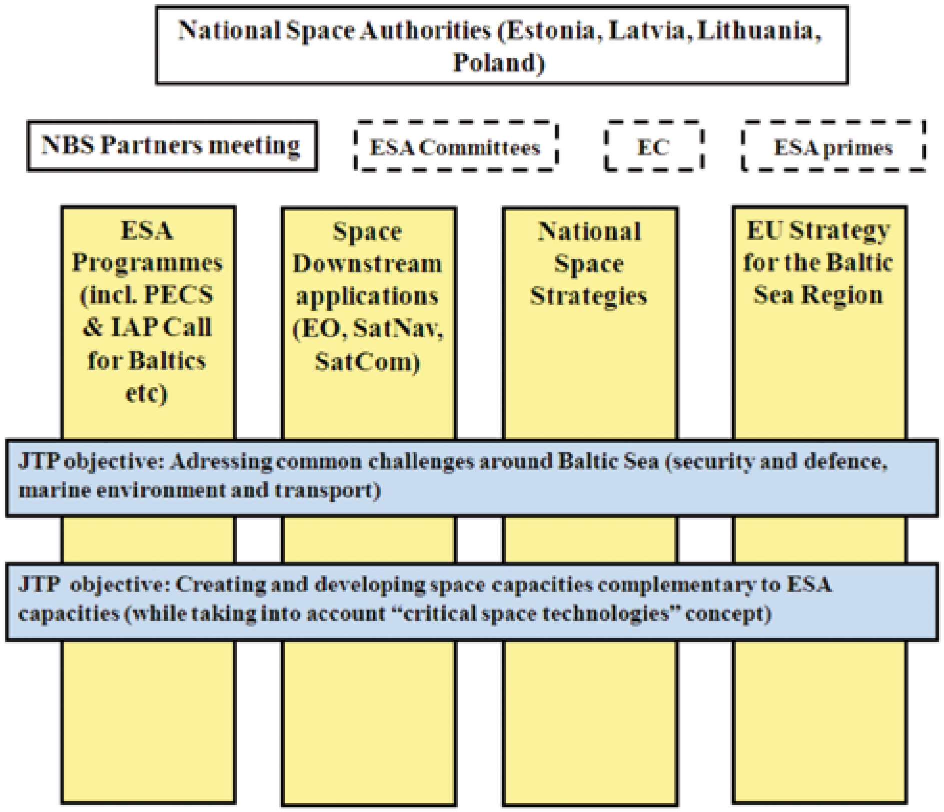


Figure 2: Framework for JTP

Although the general objective of the whole NBS project is very ambitious, our aim is certainly to contribute in a decisive manner towards such development (to achieve continuous and sustainable contribution in major on-going and planned European space programmes). JTP workplan is broken down into more detailed, operational goals as follows:

1. Mapping the capabilities against ESA needs, using results of the NBS survey and ESA technology programmes in to find suitable technology niches for participation.

2. Mapping the capabilities against national space ambitions, using the NBS survey results, national space strategies, and bilateral agreements with ESA.

3. Suggesting national level goals that would enhance the quality of the public sector and also have (ESA and key governmental agencies) business potential.

4. Identifying technology gaps and the development efforts required to fulfil goal 1 and goal 2 here.

5. Identifying common priorities regarding 4 that will enable to find specific niche markets / preferred technology domains strengthen regional cooperation and thereby also the participation in the ESA programmes.

CONCLUSION

The general objective of the NBS project is to create the necessary conditions for utilizing the existing and emerging potential of the consortium partners in Nordic-Baltic dimension for continuous and sustainable contributions to major on-going and planned European space programmes addressing thus exactly the European need for national space programme in emerging space countries. NBS has mission-oriented approach to build a bridge for successful integration into space industry in Europe. As a result of this project and as an overall impact emerging space countries are expected to raise their space capacities in order to access to ESA and to have contribution to European space programmes in future. NBS project aims to: 1) map national approaches to technology strategies for any actions to be taken in harmonising technology developments across the players and; 2) relying on input received from mapping exercise to devise a coherent plan for ESA for space technologies development.

As a response to existing problems (ESA`s need for critical technologies, fragmentation of financing of space technology development) the creation of JTP will be an attempt to coordinate space activities in emerging space countries. This JTP is seen as the heart of a whole NBS project to match the most urgent needs of ESA while creating desired preconditions for emerging space countries to play along in the space market and to speed-up their accession process to ESA. Creation of JTP together with relevant capacity building activities will help to create substantial impact for participating countries on their road to ESA.

In the current paper we tried to focus much more on activities around the preparation of the JTP and its preceding steps. First of all comprehensive methodology for charting was compiled and approved among project partners; secondly each partner was responsible for making its country-specific selection of companies and R&D institutes as potential respondents for NBS survey (see respective link here - http://www.surveygizmo.com/s/295773/nordicbaltsat-charting) and thirdly four different surveys were conducted (in Estonia, Latvia, Lithuania and Poland) and as a result the same number of so-called country reports were produced.

Not only a significant, but also a very crucial part of the work still lies ahead during the first half of 2011 which includes comprehensive analysis based on the country reports (referred above) and also by looking in more depth into the space competencies/technologies matrices across Baltic States and Poland (comparing against each other), which have been produced according to ESA's technology tree approach. A space competences matrix which covers all four emerging space countries would probably enable us to identify in which countries/segments we have higher concentrations of critical mass for different fields in space sector, as well as what fields of expertise are not covered at all and what could be prospective fields of expertise in the future. All this data could be used when making selections between different fields of priorities while preparing the JTP.

SWIFT

GMES – because we need to know

Frédéric Collomb

FDC

INTRODUCTION

The land territories, oceans and atmosphere that constitute our environment have a direct impact on our daily lives.

At global level for instance, the greenhouse gases and aerosols contained in the atmosphere and the major currents that are crossing oceans play a crucial role in the way our climate is changing.

The capacity of our atmosphere to protect us from UV radiations, the quality of the air we breathe or of the water we drink are part of the parameters that affect quality of life and public health.

Urban growth and soil sealing, both resulting from human activities, also modify our environment year after year.

More than ever, the well-being of future generations depends on our ability to establish and implement effective environmental policies. However, this can be achieved only if decision-makers are provided with reliable information about how and why our planet and its climate are changing.

The European Union has already a long track record of successful achievements in gathering and exploiting environmental data. With its Global Monitoring for Environment and Security (GMES) flagship programme, Europe is implementing its own capacity to monitor and permanently forecasts the status of oceans, atmosphere and land territories.

Nevertheless, most people (whatever they are "simple citizens" or decision-makers) are not yet aware of the very active role of Europe in the domain of earth observation and have generally not heard about GMES. *A fortiori*, they do not know either that the scope of GMES is not limited to environmental monitoring but also supports worldwide aid relief, when emergency situations occur (e.g. floods, earthquakes, humanitarian crises) or can even help improve the security of European citizens through applications such as border or maritime surveillance.

It is therefore important to communicate on the GMES programme in order to make sure that all the potential users of GMES, and more generally the public at large, are aware of the products and services offered by GMES.

In 2008, the European Commission launched SWIFT, a 3-year Coordination and Support Action aimed at supporting the European Commission in promoting the GMES programme and its services. The project is currently supervised by the European Research Executive Agency (REA) based in Brussels.

SWIFT includes a number of general communication activities, including the operation of the www.gmes.info website, as well as more targeted actions tailored to the needs of the European Commission or of the projects that are developing the GMES services.

PARTNERSHIPS AND COLLABORATIONS

SWIFT is performed by a consortium of three companies. FDC (coordinator), SQUARIS Consultants and European Service Network (ESN).

FDC is an independent research and consultancy company specialised in the field of space applications (navigation, positioning, earth observation and telecommunications) and based in Vincennes near Paris, France. FDC is certified ISO 9001 since 2004.

FDC has acquired an unchallenged knowledge of Galileo/EGNOS and GMES, the two flagship space programmes of the European Union, through the support given to the European Commission and its Agencies since the very early stages of these programmes. The company has an in-depth experience of institutional aspects, decision-making processes and the industrial environment. FDC performs diverse and complementary activities such as technical studies, political and strategic analysis, functional analysis, system specification, standardisation, user requirements and market surveys, information dissemination promotion and awareness, and project management.

SQUARIS is an independent consultancy located in Brussels, having many years of wide ranging experience in European affairs and an in-depth knowledge of institutional procedures as well as decision-making processes. SQUARIS developed since its creation in 1999 a large range of services addressing commercial companies operating at international level in different industrial sectors and European institutions (DG Research, DG ENTR, DG INFSO, DG MOVE). Among its tasks in EU projects are communication and dissemination activities, monitoring and in-depth analysis of EU legislation and lobbying missions.

Specialising in public sector communication at European level, ESN provides a complete range of web, print, audiovisual and consulting services. ESN mission is to inform debate, facilitate dialogue and influence opinion on behalf of its institutional clients – notably, in the different DGs of the European Commission. From one-off brochures to cross-media international campaigns, and from posters and magazines to thousand-page websites and original online games and animations, ESN helps each client to select and specify the means best suited to their communication objectives, target audiences and budgets.

WORK PROGRAMME, METHODOLOGY, MILESTONES

The GMES programme is coordinated by the European Commission and implemented in partnership with the Member States, the European Space Agency and the European Environmental Agency. The GMES services, which aim to be operational starting from 2014, are currently developed by co-funded FP7 projects that deal respectively with Land Monitoring (geoland2 project), Marine Environment Monitoring (MyOcean project), Atmosphere Monitoring (MACC project), Emergency Management (SAFER project) and Security (G-MOSAIC project). The land, marine and atmosphere services also contribute to Climate Change Monitoring.

Numerous users already exploit the data and information produced by the current pre-operational version of the GMES services. Nevertheless, only a fraction of those who could benefit from a regular use of GMES services are aware of their existence and it is therefore necessary to enlarge the user basis by creating awareness about GMES within all potential user communities, including institutional decision-makers at all levels (European, national, regional, local), potential providers of value-added services based on GMES services and individuals.

Each actor of GMES has a role to play in promoting the programme among these potential user communities. While the European Commission ensures the promotion of the overall programme, the individual projects promote the services they are developing within their user communities.

The approach implemented within SWIFT therefore consists in carrying out communication actions at two different levels: SWIFT supports the European Commission, and more particularly the GMES Bureau, in its general communication activities and SWIFT complements and amplifies the communication activities performed by the five GMES projects.

The actions performed by SWIFT follow a communication action plan which has been agreed with the European Commission in the early phases of the project and is regularly updated at the occasion of the GMES Communication Coordination meetings organised by the project. These meetings are co-chaired by the Research Executive Agency and by the GMES Bureau. They take place every 6 months and are attended by representatives of the projects that are developing the GMES services.

This communication action plan encompasses a wide variety of activities, from general awareness activities (e.g. operation of www.gmes.info or production of videos presenting the programme) to project-specific activities (e.g. promotion of the activations of the Emergency Management service).

ACHIEVED SCIENTIFIC AND TECHNOLOGICAL RESULTS

Figure 1: www.gmes.info website

As far as general awareness is concerned, the most "visible" action carried out by SWIFT is the operation of the www.gmes.info which has become a central source of information on the GMES programme and the achievements made in developing the corresponding services.

The website receives in average 14 000 visitors per month and provides an overview of the GMES programme and services.

It includes a description of each main service (land monitoring, marine monitoring, atmosphere monitoring, emergency management and security) and makes available for download "service portfolio" documents describing with more details the services which are already available today or will be available in the near future. When feasible, the website provides an online access to these services. For instance, most of the services related to the monitoring, analysis and forecasting of European Air Quality, Global Atmospheric Composition, Climate Forcing or UV and Solar Energy are also accessible via the "Atmosphere Monitoring" page of www.gmes.info.

The FP7-funded projects that are currently developing the above-mentioned GMES services are also presented on the website as well as their most recent achievements.

More generally, the website includes a database of GMES-related projects. The current version of the database identifies more than 210 past and current projects which have been funded by the European Commission and ESA. It also includes a library of GMES-related reference documents (e.g. Commission's Communications, European Parliament and Council Regulations, etc.) which are available for download.

SWIFT is very active in the dissemination of GMES-related news either through news items published on www.gmes.info (all news items are available through RSS feeds) or through the electronic newsletter produced by the project every 2 months. Since the beginning of the project, more than 300 news items have been published on the GMES website and 15 newsletters have been released to 1 400 subscribers.

SWIFT also contributes to the promotion of GMES-related events such as workshops, exhibitions or conferences. To date, 140 events have been promoted on www.gmes.info.

The publication of press article is another means to promote GMES. For instance, SWIFT has published two articles presenting GMES in the EU Parliament's Research Review magazine, which is largely distributed to policy makers in Europe (e.g. Members of the European Parliament, European Investment Bank, etc.) and heads of R&D of 500 major global companies. In parallel, SWIFT regularly provides the European Commission with a press review tracing and analysing how GMES is addressed in the press and how the role of European institutions is described.

In addition to general awareness activities, SWIFT provides the GMES projects with a dedicated support that complements their own dissemination activities.

For instance, SWIFT collaborated with the projects in order to harmonise the structure and layout of the descriptions of the products and services they are implementing. This activity led to the production to the portfolio descriptions that are now available to any potential user on www.gmes.info.

Figure 2: GMES Stand at Toulouse Space Show 2010

SWIFT strengthens the promotion of the GMES projects by highlighting their concrete achievements. For instance, releases of a new products or services are announced systematically on www.gmes.info or the SWIFT newsletter. They are also briefly described in dedicated pages of the website.

The volcanic ash plume forecasts produced by the MACC project at the occasion of the Merapi eruption in Indonesia in October 2010 or the release of a new version of the MyOcean web portal in December 2010 are examples of recent project achievements promoted by SWIFT.

In order to support the participation of the European Commission and/or the GMES projects in exhibitions, SWIFT has designed and produced a stand that was used for the first time at the Toulouse Space Show in June 2010. At the occasion roll-ups were also produced to present the projects.

A next major milestone in SWIFT activities is the production of videos presenting GMES. In total, six 2-minute videos will be produced in order to present the programme and its services.

CONCLUSION

The experience gained during the project has confirmed most of the assumptions that motivated the establishment of the SWIFT Coordination and Support Action.

First of all, it has confirmed the need for creating awareness on GMES and in particular the need to inform the potential users of the existing and future services available to them. This is particularly valid for decision-makers at regional and local levels, who have generally not heard about the programme and its benefits. The European Commission is already dealing with this issue notably through the establishment of new Coordination and Support Actions addressing the regional dimension. The need for information is also confirmed by the increasing "demand" noted through the www.gmes.info website: the number of visitors on the website and the number of subscribers to the newsletter have regularly increased over the last 3 years.

However, communicating on a programme like GMES is not an easy task since the scope of the programme covers a wide range of application domains and its outcomes generally do not take the form of concrete devices that the user can take in his hands (by opposition for instance to a satellite navigation device for which any car driver can immediately understand the benefits it brings).

In this context, it is necessary to communicate as much as possible on the products and services offered by GMES and on the concrete benefits they bring rather than on the "concept" which may be too abstract and complex for the users. As far as communication is concerned, it is appropriate to communicate as much as possible on concrete cases which have a link to the "real life" and have a media exposure. The GMES response to emergency situations caused by natural or industrial disasters (e.g. earthquake in Haiti, floods in Pakistan, mud pollution in Hungary, etc.) is a good illustration of this approach. However, this approach should not be limited to emergency management and also applies to most of the other GMES services. The atmosphere monitoring service for instance can be illustrated through the role it can play in the domain of UV monitoring and prevention of skin cancers or in the domain of air pollution alert bulletins. Concrete examples also exist for the services related to marine environment monitoring, land monitoring or security.

Last but not least, considering the wide variety of domains addressed by GMES it is important to coordinate as much as possible the messages to be conveyed and the actions to be performed by the different actors involved in the programme. The coordination mechanism between the GMES projects and the European Commission put in place by SWIFT is a useful component of this necessary global coordination.

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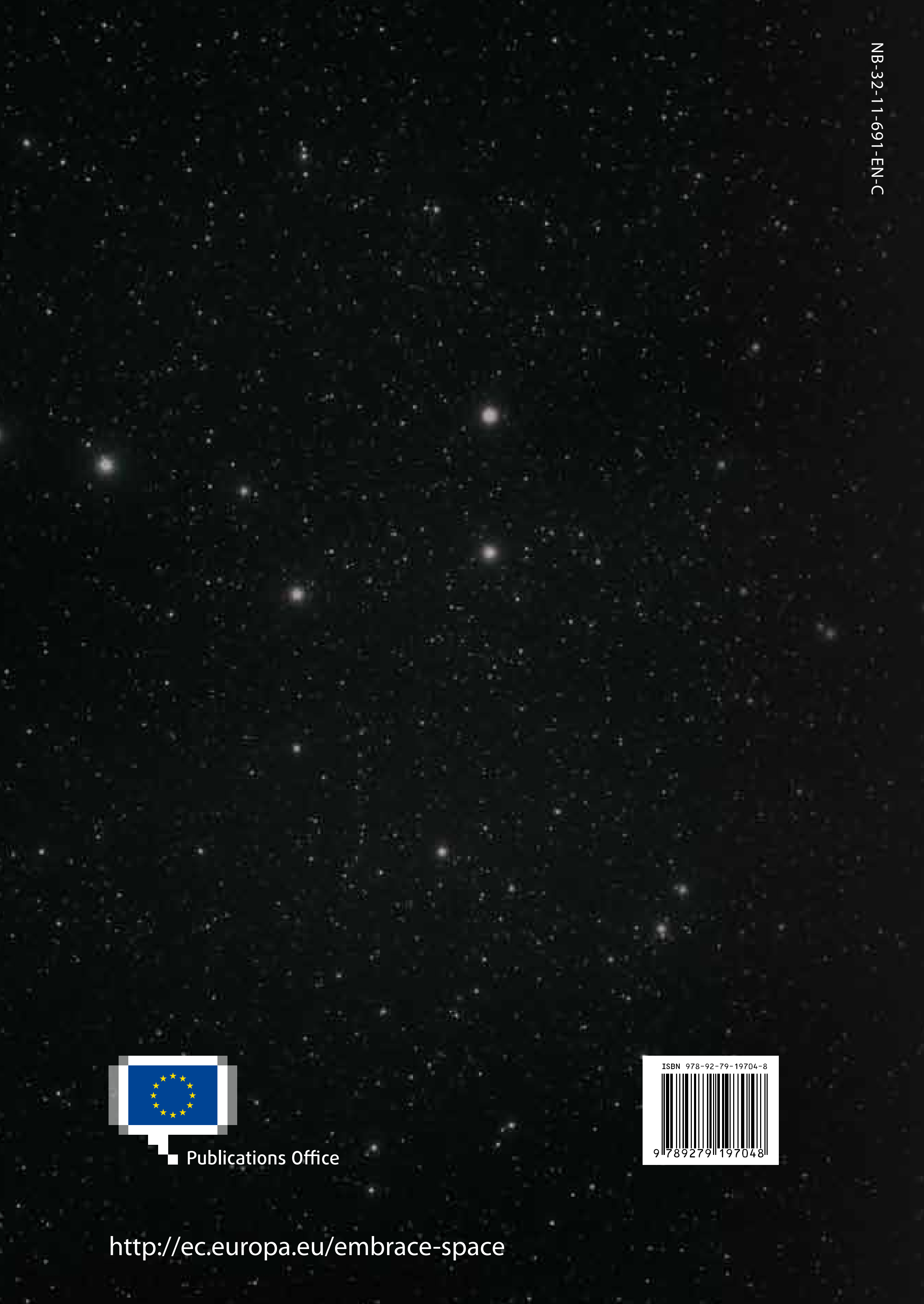

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