European Space Policy Institute

CASE FOR SPACE

SPACE APPLICATIONS MEETING SOCIETAL NEEDS

Report 7, October 2007

coordinated by
Catherine Doldirina, ESPI

Short Title: ESPI Report 7, October 2007
Ref.: C/20490-001-P11 + BMVIT
Editor, Publisher: ESPI European Space Policy Institute
A-1030 Vienna, Schwarzenbergplatz 6
Austria
http://www.espi.or.at
Tel.: +43 1 718 11 18 - 0 Fax - 99

This report was funded, in part, through a contract with the European Space Agency (ESA) and the Austrian Bundesministerium für Verkehr, Innovation und Technologie (BMVIT). The German Aerospace Center (DLR) supported the project through funding a workshop in Bremen.

Price: 11 EUR
Printed by ESA/ESTEC
Layout and Design: M. A. Jakob/ESPI and Panthera.cc

Table of Contents

Europe Mosaic by ENVISAT, ESA

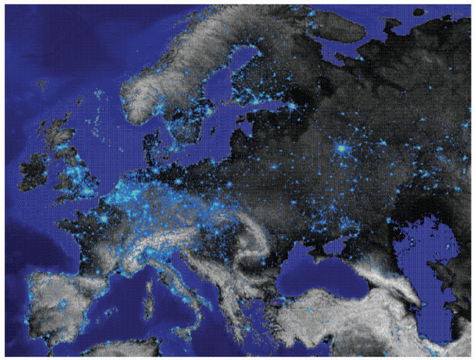
Executive Summary: The Flyer

The Executive Summary is presented in the form of a Leaflet that contains a short description of the issues raised in the Report, mentions other issues of interest for future research and application, outlines the benefits of the space applications' use, and lays down views with regard to required actions.

THE SETTING:

THE IMPORTANCE OF SPACE UTILISATION

- The 2007 European Space Policy acknowledges that space is a strategic tool for independence, prosperity, industrial development, technological advance and scientific progress.
- Space is a public good, with beneficial impacts on everyday life, whose applications support European and global sustainable development in areas such as knowledge gathering and dissemination, population studies, mobility, resource prospecting and management, the environment and security.
- Space applications can both solve problems and create new opportunities in our changing society.
- Space is essential to implementing European sectoral policies, and to providing the European contribution to global commitments to deal with issues which have local repercussions.
- Space technology drives innovation and the creation of new jobs in numerous industries.
- Space applications are supporting the elaboration of new global standards and ethics thanks to their ability to observe and monitor Earth as a whole; they also support good governance at international, national and regional levels.
- The worldwide space industry is worth around € 174 billion and growing as an increasing number of countries (especially China and India) come to realise its importance. In 2006 the European space manufacturing industry had a turnover of € 5 000 billion and provided jobs to 29 000 people. In 2004, aerospace was the second highest export category in the EU (23%) after electronic communications. Lastly, at € 80 000 value added per person employed in 2002, apparent labour productivity in the EU's aerospace equipment sector was well above the EU average in manufacturing of € 45 000.



ACTION IS NEEDED

IN EUROPE TO:

- develop and maintain an operational space infrastructure that meets the demands of European society.
- cope with fragmented institutional markets at both European and national levels.
- create dedicated and effective bodies with clear roles and responsibilities as well as the authority to federate respective institutional markets.
- increase capacity building.
- support the 'integration' of the European space industry (through greater interaction with terrestrial industry).
- combine and integrate climate change research efforts.
- transform 'goodwill' disaster management actions into obligations to provide satellite-related services in times of natural and human-made disasters.
- support the United Nations system's use of space applications to meet global needs.
- foster the application and promote the industrial advantages of dual-use technology.
- promote the integration of space systems at local and regional levels.
- sustain a competitive European space industry.
- create educational and outreach projects to raise public awareness of the ubiquitous benefits of space technology and engender a more technology-friendly environment.

E S P I
European Space Policy Institute
Palais Fanto
Schwarzenbergplatz 6
(Entrance: Zaunergasse 1-3)
A-1030 Vienna

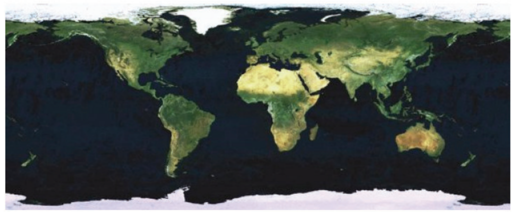
Phone +43 1 718 11 18 0
Fax +43 1 718 11 18 99
www.espi.or.at

Photo credit: ESA

ESPI
European Space Policy Institute

CASE FOR SPACE

SPACE APPLICATIONS MEETING SOCIETAL NEEDS



Summary of a study report addressed to European decision-makers

September 2007

SERVING SOCIETY

The challenges facing European (and global) society cannot be met without using space technology. It is indispensable in areas such as:

Food management for the growing world population

The GMES Global Monitoring for Food Security service element will reduce uncertainty about food supply by 10-15% for 854 million undernourished people worldwide; satellite-based precision agriculture helps maximise crop production.

Securing the supply of energy

ESA's Environmental Information Service for Solar Energy Industries will reduce the operational costs of solar energy plants; its Envisat Monitoring and Forecasting Services for Offshore Industry can track potentially disruptive eddies and severe weather in near-real time; SPOT satellites aid the oil companies in geo-exploration and prospecting, especially underwater; improved weather forecasting allows energy companies to better balance supply and demand.

Improving healthcare

Satellite monitoring of air quality/dust clouds provides early warning to allergy and asthma sufferers; satellites can identify malaria-free areas with 96% accuracy and are providing mosquito control in Europe, as well as monitoring disease vectors; satellite-based early warning of extreme cold or heat (35 000 heatwave-related deaths in Europe in 2003) saves lives; European e-health pilot projects have shown a 1:3 cost–benefit ratio; research on astronaut health (breathing patterns, ageing) contribute to advances in medical techniques.

Multipurpose and multiscale land management

Satellites contribute to cadastral systems; satellite data are useful for cartographic applications; high resolution image products like those from TerraSAR-X enable the analysis of agricultural area utilization and thereby support the distribution of EU subsidies.

Urban planning and management

(Use of) GIS and spatial information databases aids urban planning; Atlas Project; communication satellites supply traffic congestion early warning (in London the cost is € 4.5 million weekly) .

Adapting to new patterns of production and employment

Space provides new job creation (e.g. in space-borne data analysis, information value-added services, navigation-related fleet management and container ship tracking); stimulation of technological innovation via spin-offs (e.g. ground-penetrating radar, materials and textile design and manufacture, anti-vibration technology) .

Ensuring communications and access to information

Satellites provide telephony—Insat connects 75% of India's population—real time broadcasts (Olympic Games, news coverage), video conferencing, faster, more secure banking and financial transactions; satellites are bridging the regional and digital divide by providing broadband internet access to 25 million remote homes in Europe, e-learning is extending education to sparsely populated, rural areas.

Preserving the past

Remote sensing has uncovered new archaeological sites (space-based radar discoveries at Angkor Wat and in Egypt); ESA–UNESCO 'Open Initiative' assists developing countries to monitor their World Heritage Sites.

PROTECTING THE ENVIRONMENT

Space applications are a crucial tool for solving current and future environmental problems:

Understanding climate change and Earth systems through

satellite-enabled continuous and global measurement of sea levels and melting of ice caps, and monitoring of ozone holes, etc.; GMES-guided adaptation to climate change could save up to € 28 billion per year; GMES will provide the European contribution to the worldwide GEOSS.

Extreme weather

Eumetsat is using new satellite technology to increase the frequency and precision of meteorological forecasting.

Ecosystem change

Satellites are monitoring and tracking the major factors in ecosystem change (alteration in habitats and of wildlife migrations, spread of invasive species, pollution) and provide effective modelling of future developments.

Sustainable marine management

through measurement and monitoring of rising sea temperatures and oxygen deficiency in European seas; assessment of habitat change, over-fertilisation (eutrophication), algal blooms and (over)fishing; pollution control (Envisat component of the European Maritime Safety Agency's (EMSA): oil spill monitoring service; satellite-based mapping of European coastal waters aids spatial planning, safety at sea and international security.

Deforestation and forest management

Remote sensing complements ground-based observations to provide consistent, repeatable, cost-effective data on vegetation cover, pinpointing general deforestation, forest fires and illegal logging—a 5% reduction in deforestation could provide economic benefits of up to € 11 billion.

Freshwater scarcity

Space observation systems monitor water quantity and quality in lakes, rivers, wetlands, coastal areas and groundwater; they aid 3-D reservoir planning and drainage basin management; with telecommunications systems they provide multi-hazard early warning, and preparedness and response assessment of water stored in glaciers and ice-caps.

Enforcing Europe's domestic environmental regulations and international obligations

Remotely sensed data aid the implementation of EU Natura 2000, Water Framework and Plant Health Directives, and provide verification of the Convention on the Prohibition of Military or any other Hostile Use of Environmental Modification Techniques, as well as of nuclear non-proliferation and testing treaties; evidence from ESA's ERS satellites was admitted in court in prosecution of a Singaporean oil tanker.

The influence of space weather on Earth's environment

Space-based research has enhanced our knowledge of solar ultra-violet, visible and heat radiation, and magnetic activity and of their influence on our climate and effect on crucial technologies.

Learning about our world by understanding the cosmos

Europe is a leader in space science through missions such as Mars Express, Venus Express, Rosetta, Cassini-Huygens and the Herschel space observatory, which, when launched in 2008, will be the largest telescope in space.

MANAGING RISKS

Space is a valuable instrument for reducing risk in the following fields:

Understanding and communicating the conditions for natural disasters

Satellite data can improve our understanding of earthquakes by monitoring changes in the Earth's electromagnetic field; communications satellites have doubled the warning time for tropical cyclones and hurricanes from 24 hours in 1990 to 48 in 1999.

Assessing the risks of natural disasters

High-resolution satellite imagery can be used for flood insurance risk management (e.g. the Italian SIGRA project), tsunami tracking and wildfire risk assessment.

Management and mitigation of natural and human-made disasters

Satellite positioning systems provide faster response and a complement to or even substitute for terrestrial infrastructure where this is lacking; GMES disaster management services could provide benefits of up to € 80 million per year; telemedicine allows in situ treatment of survivors using expertise from around the world.

Transport of hazardous goods

Satellite positioning and communications services ensure wireless monitoring, e.g. via the EU Standardised Hazardous Goods Transport Alerting (SHAFT) project.

Air and road traffic management

Signals timing enabled by navigation satellite ensures fewer delays in civil aviation take-off and landing and greater safety; Meteosat supplies cloud warnings every 15 minutes, while navigation services for air traffic control will permit shorter polar flights—and thus lower CO2 emissions—and cost savings of up to € 30 000 per flight; satellite radio navigation can cut road travel time by 10-20%; Galileo will provide the infrastructure to mitigate the negative impacts of road transport.

Search and rescue

The COSPAS-SARSAT location system has assisted in the rescue of some 21 000 persons from air crashes, shipwrecks, etc and has also saved the lives of numerous mountaineers, rock climbers and yacht crews, thereby also saving coastguard and mountain rescue teams millions of euros.

Movement of refugees and illegal immigrants

As above, positioning systems aid the search for refugees and illegal immigrants stranded at sea in the Mediterranean and elsewhere; remote sensing data assist decision making on the sites of refugee camps and the monitoring of their size and conditions.

Trafficking of illegal goods

Satellites transmit data and imagery in real time between surveillance aircraft and surveillance centres.

Mass events

Satellites continuously transmit positioning data to secure timely traffic management measures and provide accurate weather forecasting.

(Inter)national security

By increasing transparency ,satellite observations reduce the incentive for and risk of surprise attacks, verify compliance with truce agreements and peace treaties and thereby help keep the peace; space-based intelligence gathering can track terrorist movements; communication satellites contribute to transmission of information.

I. Introduction

Space services are unique as answer the societal challenges that Europe and the world are facing in the field of climate change and environment, ageing population, health issues, global competition, terrorism and other threats, and the acceptance of technological advances. The **main goal of this Report**, funded by the European Space Agency (ESA) and the Austrian Bundesministerium für Verkehr, Innovation und Technologie (BMVIT), with additional support from the German Aerospace Center (DLR), is to assess the benefits of **space applications for societies' needs**, in particular, with respect to the improvement of the quality of life as well as for the political and geopolitical positioning of space-faring nations and regional ensembles. For this purpose, the Report discusses various success stories of space-faring nations and their strengths and weaknesses; finally, a set of positions within the framework of Europeans nations and institutions is proposed.

The space industry today **is worth** around **US$115 billion**[1] and could amount to **US$1.5 trillion by 2020**.[2] However, it still requires significant public funding and the **Case for Space** needs a vigorous and articulated advocacy. **Decision makers** in governments and legislative bodies at the national and regional levels should be **fully informed** of the relevance and attractiveness of space research and applications. For this reason, the Report uses a perspective centred on the user. It aims at complementing similar national efforts undertaken by the United Kingdom[3], and underway in France, Germany and Italy with a different scope.

The Report was shaped by the participants of a workshop from the space and users' sectors that addressed the relevance, adequacy and comparative advantages of space applications to societal challenges in a long-term perspective.[4] This workshop had been prepared by an expert meeting[5] at the beginning of the research work. Thus, it takes into account the following aspects:

- Because of the difficulties involved in an economic study, the data on return on investment will be presented only as a reference to existing studies;
- The merits of a traditional approach which deals with access to space (space sciences, earth observation, navigation, positioning, timing, and tele-communications) are recognized, yet it appears preferable to strengthen the relevance of space tools in relation to the issues of a sustainable economy, global threats, climate change, population and technology issues. A qualitative assessment is provided in a few cases.

The Report, therefore, concentrates on the topics that are of immediate importance or of great impact for people's life on Earth:

- **Life of citizens** and their problems – Capabilities of space solutions;
- **The environment**, its change and the impacts of this change – The role of space in approaching these issues;
- **Risk management** – The support of satellites' for the handling of disasters, tracking refugee flows and making transport safer.

There are a number of milestones that constitute a point of departure for the present study. It is strongly suggested that these should guide all decisions taken with regard to space.

First of all, it must be borne in mind that the 2007 European Space Policy[6] regards **space as a strategic tool** for independence, prosperity, industrial development, technological advance and scientific progress in Europe. Furthermore, **space supports sustainable development** in Europe and around the world in the fields of knowledge, population, mobility, resources, environment, and security. **Space technology** is an **engine for innovation** in numerous industries and a **driver for the creation of new jobs**. For instance, EU Commission expects Galileo to create around 150.000 jobs.[7]

Moreover, **space applications** encourage the development of new global standards and ethics through a universal earth view and observation; they also **support good governance** at the international, national and regional level.

For these reasons, the **space component has to be integrated into the decision-making process** in the relevant areas.

According to the Organisation for Economic Co-operation and Development (OECD)[8], **the**

most promising space applications for the period until 2030 are:

- Telecommunication services – telemedicine, distance learning, e-commerce, and multimedia entertainment;
- Earth observation applications – environment applications, land use management, exploration, natural disaster prevention and management, and treaty monitoring;
- Satellite navigation applications – fleet and traffic management, location based services, and search and rescue.

Last but not least, satellites offer unique advantages over terrestrial infrastructures: they deliver **global data** (providing **spatial variability**) and they secure **data continuity** (providing **temporal variability**) with regard to **any** (even the most remote) geographic areas. Therefore, they can perfectly complement or even substitute traditional *in situ* data, which are very costly, provide only local measurements, and are limited in time.[9]

Based on the factual background highlighted above, this Report advocates the broadening the use of space applications. Its **methodology** is as follows:

1. Each of the selected themes presents three to four sub-topics;
2. Each sub-topic highlights the issues at stake; the current terrestrial methods applied are outlined, and the added value of space applications' use in the selected fields is explained;
3. As a conclusion, a shortlist of recommendations for the required actions is developed;
4. The Report is supplemented by a Leaflet that serves as the Executive Summary and contains a short description of the issues raised in the Report. It mentions other issues of interest as well as potential research and applications; it outlines the benefits of the space applications, and presents the guidelines for action required.

Thus, space applications contribute to greater transparency and accountability of decision-making in an international, national and regional context. **Space technologies enable people to observe, locate and communicate with ever increasing speed and precision.**

II. The Themes

1. Challenges Faced by Citizens and Space-Based Solutions

1.1. Theme Overview

Contemporary European and other **societies are experiencing a phenomena** that our (even near) ancestors had never seen: unprecedented population growth and the entailing issues; an ageing society; digital divide and access to information; increased mobility; urbanisation and growth of big cities. This list could even be much longer. Changes in the earth's **climate are impacting people's lives** as well. To mention just a few potential implications: increased heat-related mortality (especially in Europe, due to high number of elderly people);[10] malnutrition, and disorders in agricultural management. **All these issues need to be addressed** by political decision-makers to make the lives of citizens easier, and more adequate to the state of present technological development.

To attain these objectives, space technologies can and should be used. For instance, use of **remote sensing data** is spreading from such research (and application) areas such as demography, archaeology and anthropology to international relations, law and policy, as well urban studies.[11] In order to be more illustrative, the Report does not address all of the above mentioned issues citizens are being confronted with, but rather concentrates on the added value of space applications with regard to the following issues:

- Population growth and food management (including land use),
- Health issues,
- Energy supply.

1.2. Population Growth and Food Management

1.2.1. Introducing the Issues

According to the official United Nations (UN) estimates, the number of inhabitants on the planet will increase by **2.6 billion** by 2050.[12] But already today, **854 million people** worldwide are **undernourished**. This figure includes 820 million in developing countries.[13] The UN Food and Agriculture Organisation (FAO) Report reveals that **under nourishment** causes **additional medical** costs in developing countries of around **US$30 billion per year**, a sum that exceeds the amount committed so far to the Global Fund to Fight AIDS, Tuberculosis and Malaria over five times.[14] This raises the issue of **food (in)security**. Article 25(1) UN Universal Declaration of Human Rights[15] recognises and Article 11(1) International Covenant on Economic, Social and Cultural Rights[16] reaffirms the **right to a standard of living** adequate for health and well-being that includes **adequate food**. Therefore, this right should be enforced globally. In this context, space is an important support, because **information obtained, derived and transmitted using space-based systems provides** an independent and autonomous **mechanism for monitoring the proper realisation of adequate policies** and compliance with international commitments.

Furthermore, **70%** of poor and unsecured **people** live in rural areas and **rely on agriculture for** their **livelihoods**. That is why the benefits of space applications can help to solve the problems of an increasing population, which will be illustrated by the example of agriculture and land management.

According to a study by the Food and Agricultural Organisation (FAO) (based on satellite imagery), the estimated **maximum amount of cultivable land is 2.8 billion hectares**: almost twice as much as the currently used 1.5 billion hectares.[17] The expansion of cultivable land will be limited due to the constraints of ecological fragility, degradation, toxicity, incidences of diseases, and lack of finance and infrastructure.[18]
Consequently, there is a need to **change the modes of agricultural production**, which is very much dependant on **climate and annual weather patterns.** They include temperature, rainfall, and soil moisture that change and thereby affect plant physiology and decrease predictability of plant pests and pathogens patterns.[19] The weather impact is fully substantiated by numbers: the **agricultural losses from El Niño** alone in the USA amount up to **US$2.6 billion** a year.[20]

> "Everything that has ever happened in all of human history has happened on that blue dot. All the triumphs and tragedies, all the wars and all the famines, all the major advances. That is what is at stake - our ability to live on planet Earth, to have a future as a civilization."
>
> *Al Gore, Former US Vice President and Nobel Peace Prize, 2006*

1.2.2. Traditional Methods Used to Increase Agricultural Production

Nitrogen and phosphorus fertilizers are the most widely used chemicals to achieve bigger harvests. The amount used has been constantly growing since the 1960s. But their **effectiveness is declining,** because of diminishing returns. Today only 30% to 50% of applied nitrogen and around 45% of phosphorus fertilizer is absorbed by crops.[21] Moreover, **these chemicals are detrimental to natural ecosystems and dangerous for people**.
Intensive agriculture leads to gradual **degradation of natural resources** (soils, forests, marine fisheries, air, and water) and eradicate species living in the wild, which in turn diminishes agricultural production capacity.[22] For instance, 43% of birds' species living in Europe are highly endangered, because of the agricultural methods used.[23]

1.2.3. Space Applications' Value

The deployment of space applications represents a new way to increase the supply of agricultural products required by the increasing world population's demand. The **agricultural benefits** of improved El Niño forecasts that only use of data from meteorological satellites could amount to US$450-550 million a year.[24] Thanks to the development of the forecasting techniques based on satellite data it is possible to forecast El Niño already six months in advance. Furthermore, remote sensing is actively used to monitor crop production as well as to measure leaf area indices, to identify soil properties by their spectral signature, to evaluate crop productivity and to forecast yield, and provides a valuable data source for crop simulation models. It is also used for improved water management, especially of irrigation systems. Both remote sensing and positioning services can be used for **precision farming**, a fairly common practice in the USA, which is advancing in Europe, and will be more widely introduced in the developing countries. Information and communication systems enable farmers to make the best decisions regarding timeframes for planting seeds as well as for harvesting products, or using the right amount of pesticides and fertilizers. In addition, accurate geo-information could ease access to loans and insurance products that protect livelihood (weather-based and commodity risks instruments, and land registration system).

These measures are particularly significant due to the fact that agriculture is still an important growth engine for a number of European and other economies. For instance, in the enlarged **European Union, the rural areas** represent 92% of the territory and 56% of the population; they **generate 45% of the Gross Value Added** (GVA) and provide **51% of the employment**.[25]

The last tool to be mentioned in this section is **Global Monitoring for Food Security** (GMFS). It is a Service Element of the EU / ESA Global Monitoring for Environment and Security (GMES) initiative. It aims to establish an **operational service for food security** to serve policy makers and operational users by providing accurate and timely spatial information on the variables affecting food security.[26] For rural development analysis, a detailed geographical breakdown is needed.

1.2.4. Political Incentives to Develop Space Applications

Article 7 Sixth Community Environment Action Plan sets the goal to achieve a **better understanding of the threats to the**

environment and human health to take action to prevent and reduce these threats, *i.a.* by **substituting dangerous chemicals** with safer ones or safer alternative technologies not entailing the use of chemicals, with the aim of reducing risks to people and the environment. It should be one of the main objectives for governments to provide any possible assistance (including awareness and access) to farmers and land developers who are in **need of relevant information products** and services in order to use their property in the most sustainable way. Last, but not the least: very high resolution (VHR) **satellite images** can **ensure** that **subsidies** within the framework of Good Agricultural and Environmental Conditions (GAEC), as outlined within the cross-compliance framework, are **distributed** in a **fair** and **timely** manner.[27] High resolution image products like those from TerraSAR-X enable the analysis of agricultural area utilization and thereby support the distribution of EU subsidies.

1.3. Health Issues

1.3.1. Introducing the Issues

One of the most striking impacts of **climate change** on human health is its influence on biological behaviour of **vector organisms and the geography of the diseases they spread**. The changed transmission patterns will increase vulnerability of people who were never previously exposed to the risk of contracting this disease, as, for example, the vulnerability of the Europeans towards cholera and malaria. This risk may be lowered by the level of material resources, effectiveness of governance and civil institutions, quality of public health infrastructure, and access to relevant local information on extreme weather threats.[28]

According to the estimates based on global and regional mathematical models, the proportion of the world's population living within the potential **malaria transmission zone** is projected to **increase** from around 45% in the 1990s to around **60% by 2050**.[29] The **threat** is apparent, as even now there are more than 300 million acute phases of the illness, and about **2.7 million people die** from this disease each year. **The value of interventions** – such as vaccination initiatives, residual house spraying and mass drug administration, as well as relocation of human populations away from infected areas[30] **to control malaria** epidemics depends on the **timely information** about their outbreaks.

> "Pandemics are very different from natural disasters and other international emergencies, which usually affect only limited areas or regions of the world."
> "Pandemic influenza and other emerging diseases are a particular challenge. The conditions of our highly mobile, interconnected, and economically interdependent world have made these diseases a much larger menace than in the past."
>
> *Dr Margaret Chan, Director-General of the World Health Organization, 2007*

1.3.2. Traditional Methods of Pandemics Prediction

The traditional methods widely used to predict outbreaks of e.g. cholera or malaria are **community-based or regional studies**, which presuppose direct medical inspection of people living in potentially affected areas. **Public health surveillance** is the ongoing systematic collection, analysis, interpretation and dissemination of data concerning health-related events for use in public health action to reduce morbidity and mortality and to improve health in the affected populations. As there is or might be lack of medical personnel in the most affected areas, this procedure may be **too slow or too risky if** the epidemic has already started.

1.3.3. Space Applications' Impact

i. Mapping Risk Environment

Mapping health risk environments can be done by using landscape epidemiology. To this end, remote sensing data provides information on the vector habitat to which disease spatial distribution is related. The integrated analysis of **data on land cover, habitat and human population** provides information on the spatial distribution of the disease.[31] Depending on the disease, the ability for remote sensing to accurately predict the actual distribution of disease vectors can be very high. For instance, **malaria-free areas were predicted with 96% accuracy**. Areas where transmission only occurs near water and intense malaria transmission areas were predicted with 90% and 87% accuracy, respectively.[32] The value of precision in forecasting possible routes of malaria spread that space applications are able to provide cannot be underestimated, as **40% of the world**

population is at risk of malaria infection.[33] **Remote sensing** has also the potential to contribute to the creation of a global warning system for increased plankton production and associated **cholera outbreaks**, as there is a proven correlation between the seasonal rise in sea surface temperature and sea surface height and the subsequent outbreaks of cholera.[34]

Finally, **tick-borne diseases** that are spreading much wider in warming Europe can be combated with the help of satellite applications. For instance, in Russia, Google Earth mapping service is being used to aggregate the areas of the tick-borne diseases with geo-data.[35]

ii. Health Early Warning Systems

Remote sensing data are helpful for setting up diseases' early warning systems, which include three main components: **continuous surveillance** of a disease; disease **risk modelling**; and **forecasting** future risk using the first two components.[36] Without remote sensing data these systems will not be as precise as necessary. New remote sensing technologies for monitoring and measuring with a **high degree of accuracy**[37] such ecological variables as soil moisture, vegetation cover, climate, weather, and sea surface temperature on a global scale will inevitably play an important role in disease early warning systems.[38] **Weather-derived predictions**, based on meteorological satellites' data, thanks to their accuracy and speed are a good **alternative to** traditional **early detection systems**.[39] The following satellite-based services can be used for the maintenance and deployment of disease early warning systems:

- **Satellite earth observation** for the environmental monitoring in order to produce and maintain an environmental database, as well as risk maps for water, air, and vector-borne diseases;
- **Satellite communication systems** for the real-time transmission of relevant data to or from any country and any centre, as well as to alarm appropriate institutions, stakeholders, decision-makers and the media.[40]

1.3.4. E-Health

The World Health Report 2006[41] presents an estimated **shortage of** almost **4.3 million doctors** and medical personnel worldwide in the near future. Africa will be hit the worst, as it is a region with 24% of the global burden of diseases, but only 3% of health workers commanding less than 1% of world health expenditure. To **combat** this challenge **efficiently,** the use of **telemedicine**, and thereby the deployment of **satellite telecommunication systems'** capabilities is a logical, and in the long run, a **cost-effective tool**. Telehealth, telemedicine, or e-health is usually defined as "the use of information and communication technology (ICT) to deliver health services, expertise and information over distance, geographic, time, social and cultural barriers."[42] Telemedicine is useful for providing more accurate explanations and diagnoses. It is also **economically beneficial**, as it helps to avoid costly transfers to specialist centres, providing instead teleconsultations in remote areas. A European study on telehealth implementation on just 10 sites comes up with an estimated **annual benefit of €400 million. This benefit is four times the amount of investment which amounts to around €100 million**.[43]

1.3.5. Political Incentives to Develop Space Applications

Article 152 of the **Treaty establishing the European Community** lays down that "a **high level of human health protection** shall be ensured in the definition and implementation of all Community policies and activities." It further states that both national and Community actions "shall be directed towards improving public health, **preventing** human illness and **diseases**, and **obviating sources of danger** to human health". It is, therefore, an obligation of the European decision-makers to deploy the best options to achieve these objectives. And as **space** is one of them it, **has to be taken into account**.

1.4. Energy Supply

1.4.1. Introducing the Issues

Due to population growth and the global industrialisation process, the need for **new sources for the supply of electricity** over the next 50 to100 years is obvious. The alternatives are either a **drastic collapse of living standards** in the developed world (ranks first) or a radical reduction in the number of humans on the earth.[44] Already today, **one-quarter** of the world's population has **no access to electricity**. About 80% of lives in India and sub-Saharan Africa: These are areas where alternative energy sources could be widely used.[45] In these countries, solar power – an alternative energy source that is gaining importance in Europe – could be used. The **solar energy market** that uses (solar cell) technology originally developed for space exploration: in has an annual turnover of €600 million in Germany and €1000 million in the rest of Europe.[46] Its estimated growth is €1500 million by 2030. In addition to the shortage of electricity, **global oil demand** will reach **99 million barrels** (mb/d) **per day** by 2015 and 116 mb/d by 2030 up from 84 mb/d in 2005.[47] These facts and figures illustrate that there is demand for more efficient energy resources management.

1.4.2. Conventional Methods of Energy Resources Exploration

Precise, long-term irradiance data is needed to select the optimal geographic spots to build **solar plants**, but **only a few high quality ground-based measuring facilities** are available at present. Furthermore, *in situ* measurements require the use of complicated devices, are expensive and limited in coverage – they would only cover **a 30 km** radius around the 200 solar-energy-measuring stations. Building just one measuring station **costs** no less than **€20,000** and they have to be built only on already planned areas. This requires additional monitoring.[48] With regard to the assessment of the potential energy yield of a prospective **wind farm**, the traditional way is to use **data from a meteorological mast**, which provides only **point-measurement data**, and entails service work for its installation and operation amounting to yearly **€750,000**.[49] For safe, cost-effective and environmentally responsible decision-making regarding **deep-water drilling operations, the** monitoring of eddies is of vital importance. The industry traditionally **deploys surface drifters**, which are **costly** and provide **incomplete information**.

1.4.3. Value of the Satellite Applications

In order to provide the necessary services to end-users who plan, construct and operate solar energy power plants, as well as to those operating conventional power plants, ESA developed a project called **"Environmental Information Services for Solar Energy Industries"** (ENVISOLAR). Its services are based on **data** from Meteosat Second Generation 1 **weather satellite**, which provides a **new image every 15 minutes** and thereby overcomes the insufficiency of terrestrial monitoring.[50] Wind-farming greatly benefits from the **satellite measurements of ocean winds**, as they provide a more **comprehensive** and spatially resolved **view** of wind climatology and the **entire probability distribution**. Earth observation (EO) data provide wind investors and engineers with synoptic **information that is not available from any other source**, and helps them get a first overview of many prospective sites (even very remote) without leaving their office, much more cheaply than travelling many miles to the site.

To **show eddies** from the main current in **near-real time,** the *Ocean Numerics* company develops detailed synoptic maps of sea-surface height under ESA funded **Envisat Monitoring and Forecasting Services for Offshore Industry** (EMOFOR) project.[51] Furthermore, **satellites** can assist in accurate quantification of how much water is and will be available (e.g. from precipitation or snow melting) to efficiently manage the **production of hydropower energy** and determine the market price of electric power. Only satellites are able to **provide real-time measurements of weather-related parameters controlling the hydrological cycle** (e.g. snow melting conditions) and terrain conditions (digital elevation model, land cover, etc.) affecting the river run-off.[52] EO services cover large areas and therefore are best suited for operational applications.

In the light of the examples mentioned, it is clear that **space data** are an indispensable means of monitoring **renewable energy sources**. Their use will, as a result, increase the **benefits** of the development of renewable resources with the have following dimensions:

- **Economic** benefits from the more efficient use of energy;
- Decreasing dependence on oil imports enhances national **security**;
- **Environmental costs** entailed by conventional energy uses are avoided;
- Renewable energy market growth generates **additional income and jobs**.[53]

1.4.4. Political Incentives to Develop Space Applications

The main drivers to increase the production of electricity generated from renewable energy sources in the EU Member States should be linked to the key priorities of **European energy policy**, namely, security of supply and reduction of greenhouse gas emissions. Adherence to these principles will facilitate the achievement of the Lisbon long-term strategic goal to transform the internal European market into one of the most competitive and dynamic markets capable of sustainable development. Furthermore, the use of satellite services will make compliance with the **European Directive on the promotion of electricity produced from renewable energy sources in the internal electricity market** easier and cheaper[54] that defines as a target in Article 3 an indicative share of 22.1% of electricity produced from renewable energy sources in total Community electricity consumption by 2010.

1.5. Summary

The challenges facing European (and global) society cannot be met without using space technology. It is indispensable in areas such as:

Food management for the growing world population
The GMES Global Monitoring for Food Security service element will reduce uncertainty about food supply by 10 to15% for 854 million undernourished people worldwide; satellite-based precision agriculture will help to maximise crop production.

Securing the supply of energy
ESA's Environmental Information Service for Solar Energy Industries will reduce the operational costs of solar energy plants; its Envisat Monitoring and Forecasting Services for Offshore Industry can track potentially disruptive eddies and severe weather in near-real time; SPOT satellites aid oil companies in geo-exploration and prospecting, especially underwater; improved weather forecasting allows energy companies to better balance supply and demand.

Improving healthcare
Satellite monitoring of air quality/dust clouds provides early warning to allergy and asthma sufferers; satellites can identify malaria-free areas with 96% accuracy and are providing mosquito control in Europe, as well as monitoring disease vectors; satellite-based early warning of extreme cold or heat (35,000 heat wave-related deaths in Europe in 2003) saves lives; European e-health pilot projects have shown a 1:3 cost–benefit ratio; research on astronaut health (breathing patterns, ageing) contribute to advances in medical techniques.

Multipurpose and multi-scale land management
Satellites contribute to cadastral systems; satellite data are useful for cartographic applications; high resolution image products like those from TerraSAR-X enable the analysis of agricultural area utilization and thereby support the distribution of EU subsidies.

Urban planning and management
(Use of) GIS and spatial information databases aids urban planning; Atlas Project; communication satellites supply traffic congestion early warning (in London the cost is € 4.5 million weekly).

Adapting to new patterns of production and employment
Space provides new job creation (e.g. in space-borne data analysis, information value-added services, navigation-related fleet management and container ship tracking); stimulation of technological innovation via spin-offs (e.g. ground-penetrating radar, materials and textile design and manufacture, anti-vibration technology).

Ensuring communications and access to information
Satellites provide telephony — Insat connects 75% of India's population — real time broadcasts (Olympic Games, news coverage), video conferencing, faster, more secure banking and financial transactions; satellites are bridging the regional and digital divide by providing broadband internet access to 25 million remote homes in Europe, e-learning is extending education to sparsely populated, rural areas.

Preserving the past
Remote sensing has uncovered new archaeological sites (space-based radar discoveries at Angkor Wat and in Egypt); ESA–UNESCO 'Open Initiative' assists developing countries to monitor their World Heritage Sites.

2. Environmental Challenges and Space-Based Solutions

2.1. Theme Overview

The **4th Assessment Report Summary** [55] prepared by the Working Group II of the Intergovernmental Panel on Climate Change (IPCC) confirms the findings of the IPCC 3rd Report prepared back in 2001[56] in that climate projections anticipate **major changes in** the intensity, distribution and frequency of severe **weather**, decreased **sea ice** leading to open ocean passageways in Arctic, the continued shrinking of mountain **glaciers**, and a continuation of the trend of record **temperatures**. The Report stresses that many of these changes are being largely caused by **human activities**. These environmental changes are creating and will create different **"problematic zones"** which have to be handled with care. These include, to name just a few, climate change, ecosystems' change, deforestation, water shortage, weather forecasting, marine environment.

> "Paleoclimate information supports the interpretation that the warmth of the last half-century is unusual in at least the previous 1300 years. …Further warming will induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century."
>
> *R.K Pachauri, IPCC Chair, 2007*
>
> "The global environment continues to suffer. Loss of biodiversity continues, fish stocks continue to be depleted, desertification claims more and more fertile land, the adverse effects of climate change are already evident, natural disasters are more frequent and more devastating, and developing countries more vulnerable, and air, water and marine pollution continue to rob millions of decent life."
>
> *Johannesburg Declaration on Sustainable Development, 2002*

The diversity of the climate change variables and the necessity to integrate the multiple stresses influencing natural and human systems calls for the establishment of a more holistic approach to **environmental observation and modelling**.[57] The ability to characterize and/or reduce uncertainties in climate change prediction is a critical element for supporting energy and conservation policies related to global warming.[58]

This Report will concentrate on the following topics, as they represent the **key environmental factors that affect sustainability in Europe**:

- Climate change and weather forecasting;
- Deforestation and forest management;
- Fresh water management;
- Changes to ecosystems: marine environment.

2.2. Climate Change and Weather Forecasting

2.2.1. Introducing the Issues

Climate changes represent reflections of variations within the earth's atmosphere, as well as processes in oceans and ice caps, and of human activity. External factors that shape the climate are often called climate forcings and include variations in solar radiation, the earth's orbit, and greenhouse gas concentrations.[59] To highlight the last forcing one should mention that the manufacturing industry emitted the equivalent of **910 million tonnes of carbon dioxide** in 2000, making it the second major emitter of greenhouse gases, after the electricity, gas and water supply sector (1.091 million tonnes of carbon dioxide equivalent).

Because of **climate change, Europe** is **facing processes** like retreating glaciers, longer-lasting seasons, shift of species ranges, and health impacts due to **heat waves** of unprecedented magnitude. Negative impacts will include a higher risk of inland **flash floods**, and more frequent coastal flooding and **increased erosion**.[60] Furthermore, in the global perspective, the process of **climate change** may have a **severe impact on the human civilization**: the disasters that accompanied El Niño in 1997-98 caused more than **30,000 deaths**, displaced hundreds of millions of people and cost nearly US$100 billion.[61] Taking into account the complexity of the factors that influence the climate, anticipatory and **precautionary adaptation** to its change is more effective and **less costly than** forced, last-minute, **emergency adaptation or retrofitting**.[62] As the socio-economic impact from climate change grows, there will be both a change in research emphasis and a greater need **to survey and understand the processes on and within our planet.** Therefore, this demands greater investments in climate research.[63]

"Climate change will affect the basic elements of life for people around the world – access to water, food production, health, and the environment. Hundreds of millions of people could suffer hunger, water shortages and coastal flooding as the world warms."

Stern Report on the Economics of Climate Change, 2006

"Only from space can a transparent and coherent picture of environmental change be provided to convince nations and individuals of this urgency."

Long-Term Space Policy Committee Second Report, European Space Agency (ESA), 2000

2.2.2. Insufficiency of Terrestrial Monitoring

Climate change research has considerable potential to help us better anticipate adverse health outcomes, specifically those related to heat mortality, changes in patterns and the nature of vector-borne diseases, and air quality.[64] The investment in the **observation of the climate change** on earth and other environmental issues will contribute to the monitoring and production of forecasting products for fields related to the environment: energy, agriculture, water, world economies, etc.[65]

***In situ* monitoring** on land, in the atmosphere and throughout the oceans has territorial limitations and follows the so-called **inductive approach**, according to which a global picture is supposed to emerge from the synthesis of individual results. Inherent to this approach are **omissions**, **duplications** or **wrong assessments** that lead to a dissipation of resources and the loss of time.[66] For this reason, it is **virtually impossible** to conduct an adequate **global** or even regional environmental **study**.

2.2.3. Space Applications' Contribution

The use of **high resolution satellite imagery** has the following **advantages** in comparison to *in situ* data in climate change monitoring: **coverage**, **continuity** and **quality**. The first gives an exhaustive view of vast areas at the same time and is not limited by administrative restrictions; the second ensures that data for the same area is acquired at a high rate of repetition without weather-related restraints; and the third is secured as the data is recorded in various wavelengths, visible and non-visible.[67] The data provided by satellites is very accurate. For instance, in glacier map areas, the maximum error of omission and commission is 5%.[68]

Stakeholders believe that the **impact of GMES information** in support of climate change policy would be a reduced level of scientific uncertainty and a consistent improvement of concerted international action to reduce the impact of climate change through better adaptation. This was estimated to result in a reduction in damage costs in the range 0.1 – 0.5%. It represents a yearly **economic value of between €5 and €28 billion,** starting around 2025 if the average of all four IPCC emissions scenarios (SRES 2000) is taken as a representative baseline for carbon emissions and a conservative estimate of the social cost of carbon.[69] Another good example is the use of the **Scanning Imaging Absorption Spectrometer for Atmospheric Chartography Instrument**[70] aboard ESA's Envisat (the first space sensor capable of measuring the most crucial greenhouse gases) by scientists from the Institute of Environmental Physics at the University of Bremen to produce **greenhouse gas-related maps**.[71]

2.2.4. Political Incentives to Develop Space Applications

The Renewed EU Sustainable Development Strategy[72] sets out that "**sustainable development** means that the needs of the present generation should be met without compromising the ability of future generations to meet their own needs", and is an **overarching objective** set out by the Treaties on the European Union and European Community.[73] Therefore, an important obligation of decision-makers is to ensure that human consumption of natural resources corresponds to the earth's ecological capacity to regenerate them. The climate change problem is global, but has diverse regional implications, as the reaction of different ecosystems to the same variables may be different. Therefore, **the local and**

regional authorities have to engage in relevant activities. This would fulfil the requirement of Article 5 (3) **Sixth Community Environment Action Programme**[74] which encourages regional climate modelling and assessments both to **prepare regional adaptation measures** such as water resources management, conservation of biodiversity, desertification and flooding prevention, and to support the efforts to raise awareness among citizens and business.

2.3. Deforestation and Forest Management

2.3.1. Introducing the Issues

Forests are extremely important for the life of every society and for humanity on the whole, as they are a **key-element of nature conservation**, of the **carbon cycle**, as well as a critical factor of the **hydrological cycle**.[75] They represent the basis of life on earth as they perform important ecological functions; they play a role in the regulation of the climate and water resources, and are habitats for plants and animals. Forests also provide some essential goods like wood, food, fodder and medicines, as well as services like recreation.[76]

> "Long detailed reports don't have the same influence as a good map, especially in places where many people who live there still cannot read. There's a big difference between just telling local people about a problem like deforestation and actually showing them it on a map."
>
> *Alain Retiere, UNOSAT, 2003*

Activities like **deforestation** especially on steep slopes lead to erosion, reduce the moisture absorptive capacity of the land, and **increase vulnerability to flash floods** that are becoming more and more frequent in Europe and destroy houses and cultivated fields. In 2001, **22.4% of all trees** assessed by the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) in Europe were classified as moderately or severely **defoliated** or **dead**.[77] Another "burning" problem of the forests worldwide is fire. According to the EU Commission, **each hectare of forest lost** to fire costs Europe's economy between **€1000 and €5000**. The forest losses from wildfires are huge: the latest fires in Greece and France in July 2007 destroyed, respectively, more than **4,200**[78] and **800**[79] hectares of forests.

2.3.2. Shortcomings of Terrestrial Monitoring

Existing methods of terrestrial forest monitoring are, i.a., large-area experiments, long-term research centres, field stations, periodic unstaffed sample sites.[80] The ability to establish **terrestrial monitoring sites** depends on the level of a specific country's economic development, which differs greatly between, for instance, African and European countries. Direct methods are accurate but labour intensive and therefore, used only to a limited extent. They consist of two steps, leaf collection and leaf area measurement. One of the main methods to measure biomass – destructive sampling – is "expensive, time-consuming, and infeasible at the country level".[81]

Today, it is hard to talk about terrestrial methods of forest monitoring alone, as **satellite monitoring** is a common tool to conduct it. The benefits of space technologies are widely recognized in this field of application, first of all, because they complement the inability of terrestrial monitoring to give a view of vast forest-covered territories as well as to monitor forests that are located in isolated places (as, for example, the rain forests in Brazil or Africa). In such cases neither terrestrial nor aerial monitoring is economically viable. Furthermore, terrestrial monitoring can easily provide biased (falsified) information, which is precluded when satellite data is used.

2.3.3. The Added Value of Space Applications

First, **satellite** imagery can cover **vast territories** (1000s to 10.000s of km² on just one image), cover the same area **regularly** and record the information in different **wavelengths**, thereby **tracking the state of forest resources**. Secondly, the regular use of satellite-borne data together with the *in situ* data can contribute to the creation and maintenance of **mapped changes of the earth forest** cover, which will facilitate continuous forest monitoring and management.

Satellite data are appropriate for the rapid identification of the location of deforestation areas and trends in deforestation dynamics. Some algorithms, which use satellite data, generate low commission errors (resulting from actions taken), and in the cases reported, **identified** more than **80% of deforestation polygons** larger than 3 ha.[82] When referring to the economic analysis and using the lowest end of the range of assumptions, a **5% impact on reducing deforestation** (i.e. the lowest estimated impact from stakeholders) produces **economic benefits** within the range of €1 - €4.4 billion per annum starting from around 2025, or approximately **€2.7 - €11 billion** in present value terms.[83] Finally, space technology is one of the most efficient tools for combating forest fires, especially when such a unique mechanism as infrared monitoring is deployed.

With regard to leaf area index estimation on a global scale, **satellite-based methods are the only cost-effective approach**. Satellite long-wavelength radar is a perfect tool for mapping several forest biomes.[84]

2.3.4. Political Incentives to Develop Space Applications

The **European Commission**, together with the **Member States** and relevant international organizations, is working towards **establishing a European Forest Monitoring System** that will be based on existing forest databases and monitoring systems and will cover a wide range of forest variables.[85] The system will be a bottom-up approach based on the **active role of national authorities**.[86] It is, therefore, the objective and responsibility of EU Member State national and local governments to monitor forests the best possible, which means to deploy satellite services and make full use of satellite-based information.

> "Prediction is a difficult art when addressing the complexity of Earth processes how do we account for phenomena as diverse and poorly understood as seismic fault dynamics, climate variation or the ecological intricacy of a wetland? Observations are the only means for deciphering nature's complexity".
>
> *José Achache, GEO Secretariat Director*

2.4. Changing Ecosystems: Marine Environment

2.4.1. Introducing the Issues

Water covers more than two-thirds of the earth's surface (over 335 million square kilometres). **Oceans** provide people not only with transportation routes, food, livelihoods, culture and recreation, but also **play a crucial role in regulating the earth's atmosphere and climate**.[87] It is, therefore, of great importance to know the oceans better and to manage them in a sustainable manner. For Europe, one of the most important sea is the **Mediterranean Sea**. Its shores, unfortunately, account for **8.3%** of global **carbon dioxide emissions** that are constantly increasing as well as for the **lack of supervision of** more than **80%** of the **landfill sites** in south and east Mediterranean countries, and for **30% of international shipping traffic**,[88] which is subject to little supervision.

Another phenomenon that impacts areas of every European sea is **eutrophication** – nutrient enrichment of watersheds. It is affected by more intensive farming efforts, industrial livestock production, construction of inadequate sewage systems and rising fossil fuel use. Of the four regional seas analysed within the European Lifestyles and Marine Ecosystems Project (ELME), the Mediterranean and the Black Sea clearly had the least reliable ecological data available.

For example, the Black Sea and Mediterranean **lack a long-term spatially comprehensive plankton monitoring system**, a programme which could provide early warning signals of environmental change.[89]

The problem of the poor state of the marine environment is aggravated by **unsustainable fishing**. For instance, a considerable proportion of the catch in EU-managed waters is made from stocks that are already below their safe biological limits. This is particularly noticeable for stocks of highly valued species (white fish).[90] Disappearance of traditional stocks facilitates the intrusion of alien species and thereby contributes to furthering the potentially **irreversible changes** to marine ecosystems in Europe and elsewhere. The constant monitoring of the marine environment and the livestock is therefore required in order to predict negative changes and develop mechanisms to prevent them.

2.4.2. Shortcomings of Terrestrial Monitoring

A **serious shortage of reliable, comparable and long-term data** (for crystallizing trends) for the key indicators of the environmental quality of oceans, including risks to marine life and human health, are being reported.[91] The

remoteness and inaccessibility of the high seas, open oceans, and the seabed, as well as the fact that they are not under any national jurisdiction, severely restricts knowledge about them.[92] For example, instruments designed for chemical and nutrient monitoring of oceans cannot be placed deeper than 25 meters, which reduces the area of possible measurements.

What is even more challenging is the **inability** of existing ***in situ*** **monitoring** to **support the ecosystem approach** of ocean studies, as it cannot fully reflect the interrelatedness between the biological, physical and chemical aspects of the marine environment. The interrelatedness and interdependence of all the variables influencing the ocean environment is precisely the issue that needs to be tackled in order to be able to understand, preserve and manage oceans in a more sustainable way.

2.4.3. Value of Satellite Monitoring

Remote sensing technologies allow a **more frequent and detailed coverage** of the oceans, especially of their remote parts. Satellites, particularly the European **Envisat**, are being used to measure such variables as sea surface temperature ocean colour, waves and wind, as well as oil slicks.[93] **Satellites supplement other devices** (such as remotely-operated vehicles and free drifting data collecting floats), as they are able to reveal the physical three-dimensional nature of the ocean environment, while keeping a focus on surface processes.

Satellite monitoring, as well as **positioning services** can contribute to quantifying or modelling illegal, unregulated and unregistered (IUU) fishing, thereby overcoming current lack of data in this regard. Geographic Information Systems (GIS), whose completeness would be unthinkable without satellite data, provide a very useful tool to further analyse and present the geographical gaps in coverage of oceans. Space technologies are indispensable for marine species protection. For instance, **satellite tracking** of basking sharks has revealed that they spend about 80% of their yearly activity outside the UK 12nm coastal limit. It is, therefore, clear that by limiting biodiversity protection to the limit of the UK's marine jurisdiction, adequate protection of the full range of this species within UK waters is impossible.[94]

2.4.4. Political Incentives to Develop Space Applications

Sustainable management of the world's oceans is of major concern for the international community to ensure the livelihood of millions of people. In Point 38 Plan of Implementation of the **World Summit on Sustainable Development** (WSSD),[95] world leaders agreed in that the use of satellites to monitor oceans and their resources has to be increased. There is an **urgent need to provide a global overview of the global marine environment** based on science and responding to the needs of policy makers for reliable information that would allow them to take any necessary and timely action. As the satellites techniques do provide a global overview, they should be actively used to meet this goal.

2.5. Summary

Summarising this chapter, it is worth stressing that space applications are a crucial tool for solving current and future environmental problems:

Understanding climate change and earth systems through
satellite-enabled continuous and global measurement of sea levels and melting of ice caps, and monitoring of ozone holes, etc.; GMES-guided adaptation to climate change could save up to € 28 billion per year; GMES will provide the European contribution to the worldwide GEOSS.

Extreme weather
Eumetsat is using new satellite technology to increase the frequency and precision of meteorological forecasting.

Ecosystem change
Satellites are monitoring and tracking the major factors in ecosystem change (alteration in habitats and of wildlife migrations, spread of invasive species, pollution) and provide effective modelling of future developments.

Sustainable marine management
through the measurement and monitoring of rising sea temperatures and oxygen deficiency in European seas; assessment of habitat change, over-fertilisation (eutrophication), algal blooms and (over)fishing; pollution control (Envisat component of the European Maritime Safety Agency's (EMSA): oil spill monitoring service; satellite-based mapping of European coastal waters aids spatial planning, safety at sea and international security.

Deforestation and forest management
Remote sensing complements ground-based observations to provide consistent, repeatable, cost-effective data on vegetation cover, pinpointing general deforestation, forest fires and illegal logging—a 5% reduction in deforestation could provide economic benefits of up to € 11 billion.

Freshwater scarcity
Space observation systems monitor water quantity and quality in lakes, rivers, wetlands, coastal areas and groundwater; they aid 3-D reservoir planning and drainage basin management; with telecommunications systems they provide multi-hazard early warning, and preparedness and response assessment of water stored in glaciers and ice-caps.

Enforcing Europe's domestic environmental regulations and international obligations
Remotely sensed data aid the implementation of EU Natura 2000, Water Framework and Plant Health Directives, and provide verification of the Convention on the Prohibition of Military or any other Hostile Use of Environmental Modification Techniques, as well as of nuclear non-proliferation and testing treaties; evidence from ESA's ERS satellites was admitted in court in the prosecution of a Singaporean oil tanker.

The influence of space weather on earth's environment
Space-based research has enhanced our knowledge of solar ultra-violet, visible and heat radiation, and magnetic activity and of their influence on our climate and effect on crucial technologies.

Learning about our world by understanding the cosmos
Europe is a leader in space science through missions such as Mars Express, Venus Express, Rosetta, Cassini-Huygens and the Herschel space observatory, which, when launched in 2008, will be the largest telescope in space.

3. Risk Management and Space-Based Solutions

3.1. Theme Overview

Risk management is used as an overarching concept and **includes** disaster management, measures with regard to security – transport, maritime and societal security, – as well as a general reduction of vulnerability. Risk is a concept that refers to a likely negative impact to human life and health, material assets, or intangibles that may arise from a process, activity or an event. The ultimate objective of risk management is to **bring the probability of damages caused as close to zero as possible**. A higher level of society's development and level of well-being makes it more vulnerable to external factors that may destroy or diminish it. Therefore, risk management becomes more important, and has to operate with more precise risk analyses and measures of coping with it. The main elements of risk analysis and management are: **knowledge of risks** as a reliable basis for decision-making, **effective communication, co-ordination** between authorities, as well as a strong culture of **preparedness**.
There are **different and multiple risks** to which societies are vulnerable: various disasters, terrorism, health risks, societal risks, risk to lose strategic infrastructure, armed conflicts, globalisation, etc.[96] Because of their different nature and therefore, different paces of coping, not all of them will be addressed in this Report. Taking into account the importance and the magnitude of possible negative impacts on the life of European society and of the world, the following issues will be dealt with in this section:

> "Declare the following as the nucleus of a strategy to address global challenges in the future: …to implement an integrated, global system, especially through international cooperation, to manage natural disaster mitigation, relief and prevention efforts, especially of an international nature, through Earth observation, communications and other space-based services, making maximum use of existing capabilities and filling gaps in worldwide satellite coverage…"
>
> The Space Millennium Declaration, UNISPACE III, 1999
>
> "Space Technology, for its part, has yielded a number of 'spin-off'' benefits that have tangibly improved our daily lives and that are helping us to address a range of daunting challenges including environmental protection and disaster prediction."
>
> *Kofi A. Annan, Former UN Secretary General, 2005*

- Natural disasters' understanding and management (including handling of mass events);
- Refugee movements;
- Traffic risk reduction.

3.2. Disaster Management

3.2.1. Introducing the Issues

Throughout its history, humanity has been facing disasters of different natures and dimensions. The number of **people** injured, left homeless or hungry in the course of disasters tripled to **2 billion** during the last 10 years. The number of persons vulnerable to disasters grows by 70 to 80 million per year.[97] **Direct economic losses** increased five times to **US $629 billion** in the 1990s.[98] Natural **disasters of meteorological and hydrological origin** have the most devastating effect: from 1992 to 2001 they caused the death of **600,000 people** and an economic loss of **US $446 billion**.[99] Alone in 2002, floods killed more than 100 people and caused billions of euros of economic loss in Europe.[100] According to a World Health Organisation (WHO) Bulletin,[101] in **2003 weather-related events caused the death of 38,210 people**, left 892,312 homeless and 157,920 injured. Overall, the number of people affected by the disasters amounted to 70,274,114 and the **economic loss to US $35,193 million**.

Effective **early-warning systems**, appropriate **emergency preparedness** measures as well as **vulnerability mapping** are a key to preventing and/or mitigating the effects of disasters. **Data collection and effective dissemination** processes are crucial for any risk management activity, as they allow both decision-makers and the public to understand the country's vulnerability to various hazards, and to take appropriate actions to reduce them.[102] This requires the constant input of resources.

3.2.2. Limited Effectiveness of Terrestrial Solutions

The biggest problem in managing disasters on the spot is often the **absence or non-availability of the terrestrial infrastructure** due to the damage caused by a disaster. In addition, **terrestrial monitoring** of the disaster cycle stages, other than immediate damage prevention or mitigation (preparedness and reconstruction), is **territorially limited** and therefore cannot give a full picture of the anticipated losses or losses caused.

Furthermore, a systematic study of disasters is a relatively young science; therefore, the **quality of the data available for risk estimation is considerably lower** than that available for assessing other types of risks like medical risks or engineering failures.[103] The **lack of appropriate and timely geo-information**, **timing** localisation, and **working telecommunication** systems affects the **efficiency of** international and regional efforts in major **aid operations**.

3.2.3. Necessity to Use Space Applications

Navigation, timing, broadcasting, communication by satellite, and earth observation for monitoring natural disasters and humanitarian aid, are only a few examples of the important **benefits** that disaster management systems owe to **space applications**.[104] For instance, **space telecommunications** help to deliver and **exchange the necessary information faster** and therefore, **facilitate response actions**, which is extremely important to mitigate damage from disasters. **Satellites' capabilities** are today **indispensable** for proper disaster management. Moreover, **satellite data can be used for all phases of disaster management**: prevention, anticipation, response and post-crisis. Just a few examples clearly illustrate this.

Use of satellites to provide advance information about **tropical cyclones** has **doubled the warning time,** from 24 hours in 1990 to 48 hours in 1999, while the warning time for tornadoes improved from around 8 minutes or 9 minutes to 17 minutes.[105]

Regarding **earthquake prediction,** satellite monitoring of pre-seismic changes is an attractive alternative to a terrestrial station network, as it is cheaper.[106]

Space saves lives: Operation of the **Cospas-Sarsat System** from 1982 to 2006 has provided distress alert information that **rescued over 20,531 persons** in 5,752 distress situations.[107] COSPAS-SARSAT System's cost and **benefit ratio** alone for the USA was **11 to 1** in 2004.

Another example: after the set-up of the **Environment Vigilance Map project in France** to assess and disseminate information on disasters (including space-based information), the floods in December 2003 caused the death of only **7 people**.[108] The benefits are striking if compared to the death of **92 people and €15 billion** damage due to the storms in France in 1999 when the system was inactive.

For Europe, the benefits of **Global Monitoring for Environment and Security** (GMES) deployment are extremely important. GMES services can **reduce mortality and morbidity by 0.3-0.7%** for humanitarian crises, which yields **economic benefits** of approximately **€80 million per annum**.[109] Further impacts of GMES would be a **reduction in flood costs** of approximately **1.5%** as well as a **1% reduction of damages from forest fires** due to improved risk assessment. This draws an **economic benefit of** around **€145 million** per annum.[110]

Effective international cooperation for the sake of disaster management requires participation in the **International Charter on Cooperation to Achieve the Coordinated Use of Space Facilities in the Event of Natural or Technological Disasters.**[111] The Charter's two main objectives are: **supply of data** for the anticipation and management of potential crises as well as the **facilitation** of participation in the organisation of the emergency or reconstruction and subsequent **operations** by **using data** and **information** from **space facilities**.

3.2.4. Political Incentives to Develop Space Applications

As acknowledged by the international community in the Charter "Space and Major Disasters", **space technologies** (particularly, earth observation, telecommunications, meteorology and positioning technologies) **are to be applied in the management of disasters**. Furthermore, according to the **Hyogo Framework for Action 2005-2015**: Building the Resilience of Nations and Communities to Disasters[112] adopted within the framework of the UN International Strategy for Disaster Reduction by 168 countries in 2005, **disaster risk reduction is a national and local priority** with a strong institutional basis for implementation and should be oriented at the reduction of the risk factors and strengthening disaster preparedness. In this context, the most important requirement for attaining achieve this goal is the **availability of relevant information and its timely analysis**.

3.3. Refugee Movements

3.3.1. Introducing the Issues

Global warming is now considered to be certain by a vast majority of scientists and caused almost definitely by anthropogenic factors. A **major consequence** will be **forced human migration** and about **150-200 million** additional so-called **environment refugees** by 2050 are forecasted.[113] These refugees will increase the number of traditional refugees that amounted to **9.9 million** in late 2006, as well as **23 million** other displaced persons[114] – victims of conflicts, especially in Europe. The increase makes the issue of illegal immigration a cause of greater concern in the European Union. According to a recent research report by the German Federal Ministry for Migration and Refugees, the **contribution of illegal migrants** to the German shadow economy could amount to approx. 13% at present, which would translate into an **annual loss in tax revenues and social security** contributions of just under **€18 billion**.[115]

> "When a disaster strikes, updated geographic information is a key element in the refugee relief process, as the scenario is often chaotic and takes place in areas not familiar to many of the relief staff. Refugee operations also tend to take place in areas where updated geographic information does not exist, which further adds to the complexity of such operations."
>
> *Einar Bjørgo, Nansen Environmental and Remote Sensing Center, 1999*
>
> "If we have to send a team of experts to access all the villages, it would be far more costly and sometimes impossible. The imagery was very useful [in Kosovo] because some of the areas were still under fighting or there were land mines"
>
> *Jean-Yves Bouchardy, UNHCR's Geographical Information Unit, 2000*

The question of **migration** in general needs a **twofold course of action**:

- Set up of the system coping with the increasing amount of people who migrate (e.g. from one country to another, or within one country) that includes **infrastructure planning** etc., in the long-term perspective;
- **Emergency response and disaster management** in the short-term perspective.

3.3.2. Shortcomings of Terrestrial Monitoring

Monitoring refugee movements **from the immediate vicinity** (normally by peace-keeping forces) **may cause an escalation** of the conflict that initiated the movement. No one likes to feel that they are being watched, especially when engaged in illegal/criminal activities. Furthermore, it is not safe for those who monitor such situations and the migration flows they cause. Additionally, in emergency situations it is difficult to direct migration flows using terrestrial means.

3.3.3. Efficiency of Space Applications

Satellite-borne data and information can be used to monitor and possibly plan refugee movements, camp establishment and large-scale aid activities. Space applications could help such agencies as the UN High Commissioner on Refugees (UNHCR) in their projects, for instance in assisting Afghani refugees to come back to their country. **Remote sensing** satellites can be used as an alternative source of **information over no-fly zones**. Thanks to high resolution satellite imagery, human rights advocates can now document abuses anywhere in the world – even in countries that are sealed off from on-the-ground researchers, as for instance, in the case of atrocities in Darfur, Sudan.[116] Benefits of using high resolution satellites imagery, as well as other satellite capabilities are being analysed within the **Geospatial Technologies and Human Rights Project** (GaTHR).[117]

3.3.4. Political Incentives to Develop Space Applications

EU States have agreed to set up a **Common European Asylum System** (CEAS) by 2010, for which satellite technology (information and services) can be used. Satellite information can be utilized to improve the monitoring of the EU external border, which is one of the priority policies in the framework of **policy priorities in the fight against illegal immigration of third-country nationals**.[118]

3.4. Traffic Risk Reduction

3.4.1. Introducing the Issues

Transport plays a big role in the European countries' economies. All types of transportation in the European Union are increasing. The five major economies, France, Germany, Italy, Spain and the UK, **each** recorded over **150 million tonne-kilometres**, and accounted for just over three-quarters of total national transport in 2005.[119] Road freight performance reported by EU and Norwegian freighters haulers (excluding freighters from Greece and Malta) in 2004 was 1 677 billion tonne-kilometres. In the EU-25 **maritime ports**, **3,393 million tonnes of goods** were **handled** in 2003 (i.e. 7.4 tonnes per EU-25 inhabitant). Air passenger transport in the enlarged European Union went up by 8.5% in 2005 compared to 2004, to more than 700 million.[120] The world number of air passengers in 2003 amounted to 1.6 billion people.[121]

Approximately seventy European companies operate some **250 different service pipelines**, which, at the end of 2004, had a **combined length of 35,383 km**, slightly shorter than that for 2003. The volume transported in 2004 was 847 Mm^3 of crude oil and refined products, which is 4% higher than in 2003.[122] The increase in transportation volumes and intensity requires the establishment of a comprehensive approach with regard to traffic management and security. Inefficient management can lead to unnecessary and undesired difficulties and losses.

According to the Community Road Accident (CARE) Database, there were about **1.3 million car accidents in the EU-25 in 2004**, in which about **1.8 million persons** were casualties, of which some 285,000 were seriously injured and 43,358 lost their lives.[123] Regarding economic loss, the **weekly £3 million** damage from traffic jams in London is a vivid example.[124]

The financial implication of the **weather on aircrafts accidents** is a persistent problem around the world. Weather is a factor in roughly **23% of all aviation accidents,** and annually costs the US an estimated **US$3 billion** for accident damage and injuries, delays, and unexpected operating costs.[125]

The globalisation of trade has raised the issues of providing **maritime security** and resolving **transportation**. This a particularly important topic, as the dependence on transportation for increasing economic prosperity makes roads, routes and transportation means **critical infrastructure** that need extra protection from external risks. In addition, the significant increase in air transport requires the use of satellite navigation services to guarantee growth and safety.

3.4.2. Shortcomings of Terrestrial Monitoring

Sustainable mobility implies an optimal trade-off between economic, environmental and social requirements in the field of transport. An efficient transport system means high-quality and cost-effective transport services for EU companies and for society.[126]

3.4.3. Space Applications' Solutions

With regard to **marine transportation**, it has been agreed at the Sub-Committee on **Radiocommunications and Search and Rescue** (COMSAR) of the International Maritime Organisation (IMO) that the setting up of the Long Range Identification and Tracking system (LRIT) for ships and their **position based on satellites** could be managed by regional data centres.

At EU level, such a regional system will be built on the existing SafeSeaNet system.[127]

In the field of **aviation transportation industry** space is of great help for efficient flight management. It is becoming easier to identify dangerous clouds and give prior warning to those in need using tools such as **Meteosat Second Generation satellite,**[128] which provides different images of clouds every fifteen minutes, and **Radar network,**[129] which provides images every five minutes, and is of great help to the aviation services industry. Only space applications (satellites monitoring space weather, telecommunication and positioning satellites) can help to achieve the anticipated **economic benefits** of polar flight routes amounting to **€22,000 to €30,000 per flight**. Consequently, shortened flights will improve **fuel efficiency** and **reduce CO2 emissions by around 20 million tonnes**, making US$4.3-6 billion savings.[130]

In a few years, Europe's satellite navigation programme, **GALILEO**, will provide the technological infrastructure needed to further reduce the negative impact of road transport. The monitoring and management of **traffic fluidity** will be significantly improved when a great number of cars are equipped with satellite navigation receivers and guidance systems. Deployment of satellite technology to enhance **security on the European roads** is proving to be a **service in high demand**. This support the activities of **EUROWATCH**, a company that, thanks to GPS use, provides drivers' connection to police 24-hours a day in a number of European countries.[131] Moreover, the **European satellite navigation project GALILEO**[132] will significantly contribute to the monitoring and management of traffic fluidity. For example, if the average speed of the cars equipped with **GALILEO** navigation receivers on a given road sector drops significantly, a control centre can anticipate a traffic jam and suggest that approaching vehicles choose a different route.[133] Furthermore, the system will make tracking of goods, wherever the transportation means used.[134]

The GALILEO system is extremely important for Europe, as it risks losing out on an effective tool to manage transport modes until it achieves **independence in the field of satellite radio navigation**. Several studies have concluded that the potential benefits to transport operators and clients due to reducing travel time by using of Intelligent Transport Systems (ITS) amount to 10%-20%.[135] In addition to the fact that such systems will provide public administration with rapid and detailed **information on infrastructure and maintenance needs**.[136]

3.4.4. Political Incentives to Develop Space Applications

Providing road safety and security is the obligation of European decision-makers that has its roots in the fundamental **right of the EU citizens to live and work in safe conditions**. Therefore, if space technology can contribute to the fulfilment/protection of this right, it must be considered when making decisions in this regard. The European Commission, furthermore, points out the need to adopt a long-term plan on **information and communication systems** and provide the necessary regulatory framework for implementing such systems, including licensing procedures, performance requirements and the existence of adequate radio frequencies.[137]

Aside from the limited scope of the road security and safety issue and with regard to the protection of the roadway systems as critical infrastructure assets, it is clear that **satellite data and information** are an important tool that contributes to adherence to Common Foreign and Security Policy and the Hague Programme.

3.5. Summary

Space is a valuable instrument for reducing risk in the following fields:

Understanding and communicating the conditions for natural disasters
Satellite data can improve our understanding of earthquakes by monitoring changes in the earth's electromagnetic field; communications satellites have doubled the warning time for tropical cyclones and hurricanes from 24 hours in 1990 to 48 in 1999.

Assessing the risks of natural disasters
High-resolution satellite imagery can be used for flood insurance risk management (e.g. the Italian SIGRA project), tsunamis tracking and wildfire risk assessment.

Management and mitigation of natural and human-made disasters
Satellite positioning systems provide faster response and a complement to or even substitute for terrestrial infrastructure where this is lacking; GMES disaster management services could provide benefits of up to € 80 million per year; telemedicine allows in situ treatment of survivors using expertise from around the world.

Transport of hazardous goods
Satellite positioning and communications services ensure wireless monitoring, e.g. via the EU Standardised Hazardous Goods Transport Alerting (SHAFT) project.

Air and road traffic management
Signals timing enabled by navigation satellite ensures fewer delays in civil aviation take-off and landing and greater safety; Meteosat supplies cloud warnings every 15 minutes, while navigation services for air traffic control will permit shorter polar flights—and thus lower CO2 emissions—and cost savings of up to € 30,000 per flight; satellite radio navigation can cut road travel time by 10% to 20%; Galileo will provide the infrastructure to mitigate the negative impacts of road transport.

Search and rescue
The COSPAS-SARSAT location system has assisted in the rescue of some 21 000 persons from air crashes, shipwrecks, etc and has also saved the lives of numerous mountaineers, rock climbers and yacht crews, thereby also saving coastguard and mountain rescue teams millions of euros.

Movement of refugees and illegal immigrants
As above, positioning systems aid the search for refugees and illegal immigrants stranded at sea in the Mediterranean and elsewhere; remote sensing data assist decision-making on the sites of refugee camps and the monitoring of their size and conditions.

Trafficking of illegal goods
Satellites transmit data and imagery in real time between surveillance aircraft and surveillance centres.

Mass events
Satellites continuously transmit positioning data to secure timely traffic management measures and provide accurate weather forecasting.

(Inter)national security
By increasing transparency, satellite observations reduce the incentive and risk of surprise attacks, verify compliance with truce agreements and peace treaties and thereby help keep the peace; space-based intelligence gathering can track terrorist movements; communication satellites contribute to transmission of information.

III. Need for Action in Europe

In this chapter a compilation of the needs for action is given. These needs result from the sectoral analysis within the Report. They are presented as a **roadmap for strengthening the framework conditions to use space for answering societal needs.** The analysis of each of the chosen three themes has clearly shown that there is a need for action in order to make the best of space applications services for societal, environmental and risk management issues.

The **issues range from shaping the legal environment and supporting international activities to initiating precise programmatic actions**. To adapt the best implementation policies, the needs (and actions) have to be considered not as isolated issues, but taking into account their interrelationships, as the same actions may meet different needs. To achieve success, the following recommendations are made:

- **Develop and maintain an operational space infrastructure that meets the demands of European society.**

This issue relates, above all, to GALILEO project and the GMES initiative: a concern, which also applies to national projects. Their successful launching and further implementation will be of a tremendous value for Europe. Therefore, they have to be further developed in order to yield the expected benefits. From the political and strategic perspective, the essence of the benefits is the provision of **access to independent information to support the European presence in international actions**, as well as for securing **European autonomy in critical technologies and capabilities**.[138] As regards the economic aspects, it will foster applications and the industrial advantages of dual-use (technologies): will **improve the business options of European enterprises** engaged in space applications.

- **Cope with fragmented institutional markets at both European and national levels.**

The initial action to take with regard to the functionality of the institutional markets is to **create dedicated operative bodies** with clear role definitions, responsibilities and the authority **to federate respective institutional markets**. Such bodies, with clear governance mechanisms and funding schemes, should be created at the national levels in the Member States of the European Union. Their work has to be coordinated by an authority at the EU level in order to ensure a harmonised regulatory action in this sphere.

- **Increase capacity building.**

One of the most important actions that would facilitate the development of the space application markets is the increase of capacity building **among the experts** (i.e. producers of the space application services), as well as **among the users**, who have to be aware of the benefits of space technologies for their businesses and must be able to fully deploy them in their work. To achieve this aim, effective educational projects for both communities have to be launched and maintained. **Carrying out educational projects and rising awareness** among the general public about space and the benefits of space technology would be another useful action in this regard, as it will create **a more technology-friendly environment in Europe.**

- **Support the "integration" of the European space industry (through greater interaction with terrestrial industry).**

The actions referred to above – educational projects – will also help to facilitate the "hybridization" of the European space industry – making it more opened to interaction with terrestrial industry. Furthermore, for the purpose of cooperation between the industries, it has to be promoted through the **research of existing demands and offers**, and by the **development of business plans for new strategic activities** (such as, for example, the joint project of EADS Astrium and Infoterra "TerraSAR"). This process will inevitably generate **new markets** for space application products and services.

- **Combine and integrate climate change research efforts.**

To ensure the best environmental monitoring of climate change in order to provide timely and effective adaptation measures, Europe has to federate the efforts of climate change research. As Article 2 Sixth European Community Environment Action Programme[139] states, protection, conservation, restoration and development of the functioning of natural systems should be carried out both in the European Union and on the global scale. For this purpose, a **global partnership** for the environment and sustainable development should be developed. The first measure to be taken in this direction in Europe should be to secure the **establishment of a European (regional) coordinating authority** that would harmonise climate change research in each of the European States, thereby providing a synthesis of data for a full and detailed environmental picture of the regional ecosystems with their interconnections.

- **Transform "goodwill" disaster management into obligations to provide satellite-related services in times of natural and human-made disasters.**

The good will efforts regarding disaster management, such as the International Charter "Space and Major Disasters" or UN SPIDER, need to **be transformed into binding obligations to provide satellite-related services** in order to achieve a global partnership for reducing vulnerability to natural and man-made disaster risks. European nations and the European Union should act as advocates for such a process, with their international partners.

- **Support the United Nations system's use of space applications to meet global needs.**

Europe needs to **use its space technologies and capabilities** to support the UN in using space systems for global needs, as it will help it to adequately position itself in the world. Such a stance will show other international relations' players the European space capacities, and will serve as a good advertising tool for the commercial marketing of space applications' products and services. Analyses have brought some separate points with regard to benefits, and the EU now has chances to help, e.g., OOSA, specialized agencies, and to participate in UN regional activities.

- **Promote the integration of space systems at local and regional levels.**

In order to promote the **intensive use of the potential benefits of space applications,** the use of space systems should be integrated on local and regional levels in the European Union. Therefore, decision-makers at all levels have to be engaged in this process by raising space awareness among user communities. In doing so, due regard should be given to development of a sufficient terrestrial infrastructure, necessary hard and software, etc, as the **integrated infrastructure can be of critical importance**.

- **Sustain a competitive European space industry.**

Another objective for European policy-makers should be to sustain a competitive European space industry in the world market. The European space industry as well as companies delivering space applications' services has to be **active in their cooperation with developing countries** in order to be more competitive and **to find new markets** for their products and services. In the ever globalizing business world, this path is the right one to follow.

- **Implement measures that address the exchange, sharing, access, use, and liability for interoperable spatial data and spatial data services.**

Taking into account the importance of access to information for developing a space applications services sector (e.g. GALILEO and GMES), the **issues of accuracy and reliability of information as well as of integrity of satellite systems** have to be addressed. This requires the implementation of measures that address the exchange, sharing, access, use, and liability for interoperable spatial data and spatial data services across the various levels of public authorities and across different sectors. Therefore, **data generation and storage mechanisms have to be established and maintained, and their interoperability ensured**.

Endnotes

[1] *See* at http://www.royalsoc.ac.uk/news.asp?id=6289.
[2] EADS Astrium estimations.
[3] UKspace Case4Space Summary Report, EADS Space: Hertfordshire, 2006.
[4] The workshop took place on June 4-5, 2007 in Bremen with special funding by DLR.
[5] The expert meeting took place on March 4, 2007 at ESA Headquarters in Paris.
[6] Adopted by the Council of the European Union and the Council of the European Space Agency on May 25, 2007.
[7] Latest info *see* e.g. at http://www.dw-world.de/dw/article/0,2144,2582904,00.html.
[8] OECD Report Space 2030: Exploring the Future of Space Applications, 2004, at 117, 119, 121.
[9] Space for Wind Energy, Energy in Focus 6 (2006), available at http://www.energy-focus.com/issue6/pdfs/RENEWABLES/ESA148.pdf.
[10] At least 35,000 people died as a result of the record heat wave in Europe in August 2003, info available at www.newscientist.com.
[11] De Sherbinin A., Balk D., Yager K., Jaiteh M., Pozzi F., Giri C., Wannebo A., Social Science Applications of Remote Sensing, October 2002, available at http://sedac.ciesin.org/tg/guide_frame.jsp?rd=RS&ds=1.
[12] *See* press release POP/918, available at http://www.un.org/News/Press/docs/2005/pop918.doc.htm.
[13] State of Food Insecurity in the World, FAO Report, 2006, available at http://www.fao.org/docrep/009/a0750e/a0750e00.htm.
[14] State of Food Insecurity in the World.
[15] Adopted and proclaimed by UNGA Res. 217/A/(III), December 10, 1948.
[16] UNGA Res. 2200/A/XXI, 152 signatory countries.
[17] *See* Makinde M.O., Webster R., Khumal N., Keetch D.P., Role of Agricultural Biotechnology in Hunger and Poverty Alleviation for Developing Countries, 2007, available at http://www.europa-bio.be/GreenManifesto/South%20African%20REPORT%20-%20FINAL.pdf. See also Greenland D.J., Gregory J. and Nye P.H. 1998, in Feeding a World Population of More Than Eight Billion People. Waterlow J.C., Armstrong D.G., Fowden L. and Riley R. (Eds), Oxford University Press, at 39-55.
[18] Fischer G., Shah M., van Velthuizen H., Climate Change and Agricultural Vulnerability, International Institute for Applied Systems Analysis, 2002, available at http://www.iiasa.ac.at/Research/LUC/JB-Report.pdf.
[19] Climate Change 2001, IPCC Working Group II: Impacts, Adaptation and Vulnerability, available at http://www.grida.no/climate/ipcc_tar/wg2/350.htm#911.
[20] As during 1997-98 El Niño, more info at http://www.spacedaily.com/news/pacific-02g.html.
[21] Tilman D., Cassman K.G., Matson P.A., Naylor R., Polasky S., Agricultural Sustainability and Intensive Production Practices, *Nature* 418 (2002), available at http://www.nature.com/nature/journal/v418/n6898/fig_tab/nature01014_F1.html.
[22] Pinstrup-Andersen P., Pandya-Lorch R., Rosegrant M. W., The World Food Situation: Recent Developments, Emerging Issues, and Long-Term Prospects, 2020 Vision Food Policy Report International Food Policy Research Institute, 1997.
[23] Unwin B., Half of all bird species' threatened by intensive EU farming, *Independent*, November 8, 2004, available at http://findarticles.com/p/articles/mi_qn4158/is_20041108/ai_n12821865.
[24] *See* OECD Report Space 2030: Tackling Society's Challenges, at 59, based on NOAA source.
[25] Rural Development in the European Union, Statistical and Economic Information Report, European Commission, August 2006, available at http://ec.europa.eu/agriculture/agrista/rurdev2006/RD_Report_2006.pdf.
[26] GMFS Cost and Benefit Analysis, available at http://esamultimedia.esa.int/docs/GMES/GMFS_C2_Ph2_V2[1].1_12_11_04_Approved.pdf.
[27] Satellite images aid implementation of agricultural reforms, 13 April 2007, available at http://www.eomd.esa.int/stories/story270.asp.
[28] Woodward A., Hales S., Weinstein P., Climate change and human health in the Asia Pacific region: who will be the most vulnerable? *Climate Research* 11 (1998), 31-38.
[29] Climate Change 2001, IPCC Working Group II: Impacts, Adaptation and Vulnerability, available at http://www.grida.no/climate/ipcc_tar/wg2/350.htm#911.
[30] Liang S.Y., Linthicum K.J., Gaydos J. C., Climate change and the monitoring of vector-borne disease. Medical Student JAMA 287:2286 (2002), available at http://jama.ama-assn.org/cgi/content/full/287/17/2286.
[31] Curran *et al.*, Landscape Epidemiology and RS/GIS, 2000, available at http://geo.arc.nasa.gov/sge/health/landepi.html.
[32] *See* Social Science Applications of Remote Sensing.
[33] Anderson E., Automated Mosquito Identification: Tools for Early Warning of Vector-Borne Disease Outbreaks, 3rd International Conference on Early Warning, March 2006, available at http://www.ewc3.org/upload/downloads/Symposium_MegaEvents_08_Anderson_125.pdf.
[34] Contributions of Land Remote Sensing for Decisions about Food Security and Human Health, Workshop Report, 2007, available at http://books.nap.edu/openbook.php?isbn=0309102952.
[35] Info available at http://www.cnews.ru/news/top/index.shtml?2007/05/14/249764.
[36] Meyers M.F. et al., Forecasting Disease Risk for Increased Epidemic Preparedness in Public Health, Advances in Parasitology 47 (2000), at 309-330.
[36] Info available at http://www.cnews.ru/news/top/index.shtml?2007/05/14/249764.
[37] Microbal Threats to Health: Emergence, Detection, and Response, 2003, available at http://books.nap.edu/openbook.php?isbn=030908864X.
[38] Under the Weather: Climate, Ecosystems, and Infectious Disease, 2001, at 91, available at http://books.nap.edu/openbook.php?isbn=0309072786.
[39] Teklehaimanot H. D., Schwartz J., Teklehaimanot A., Lipsitch M., Weather-based prediction of *Plasmodium falciparum* malaria in epidemic-prone regions of Ethiopia, *Malaria Journal* (2004), 3-44, available at http://www.malariajournal.com/content/3/1/44.
[40] Presentation of Del Marlleo M., available at http://www.medetel.lu/download/2006/parallel_sessions/presentation/0407/Lleo.pdf?PHPSESSID=cd5c3b0a078c5d0b5d0c121a4bcc0d05.

41 Working Together for Health, available at http://www.who.int/whr/2006/en/.
42 Jennett P., Socio-Economic Impact of Telehealth: Evidence Now for Health Care in the Future, available at http://www.ahfmr.ab.ca/grants/docs/state_of_science_reviews/Jennett_ES.pdf.
43 Stroetmann K. A., Jones T., Dobrev A., Stroetmann V. N., eHealth is Worth It: The Economic Benefits of Implemented eHealth Solutions at Ten European Sites, available at http://ec.europa.eu/information_society/activities/health/docs/publications/ehealthimpactsept2006.pdf.
44 Dinerman T., Space Solar Power: Why Do We Need It and What Do We Need to Get It? *The Space Review* (2007), available at http://www.thespacereview.com/article/868/1.
45 World Energy Outlook, International Energy Agency (IEA) Report, 2002.
46 Sunshine mapping from space means brighter solar energy future, available at http://www.esa.int/esaEO/SEM4Q82DU8E_index_0.html.
47 World Energy Outlook, IEA Report, 2006, Executive Summary.
48 Neugebauer O., Dem Sonnenschein auf der Spur, *Financial Times Germany*, July 29, 2005, available at http://www.envisolar.com/factsheets/Artikel_Financial_Times.pdf.
49 Space for Wind Energy, Energy in *Focus* 6(2006), available at http://www.energy-focus.com/issue6/pdfs/RENEWABLES/ESA148.pdf.
50 Sunshine mapping from space means brighter solar energy future, available at http://www.esa.int/esaEO/SEM4Q82DU8E_index_0.html.
51 *ESA Bulletin* 125(2006), available at www.esa.int.
52 Eye in Sky, *ReFocus*(2005), available at http://www.eomd.esa.int/files/docs/131-176-149-30_2005819151822.pdf.
53 More info at http://home.um.edu.mt/ietmalta/rescue.htm.
54 2001/77/EC, adopted on September 27, 2001.
55 Available at http://www.ipcc.ch/SPM13apr07.pdf.
56 The reference to the 3rd Report is made due to the fact that the full text of the 4th Report is not yet available, accessible at http://www.ipcc.ch/pub/reports.htm.
57 For more information *see* GOALS (Global Ocean-Atmosphere-Land System) for Predicting Seasonal-to-Interannual Climate: A Program of Observation, Modeling, and Analysis, US National Research Council, National Academy Press, 1994; Capacity of U.S. Climate Modeling to Support Climate Change Assessment Activities, US National Research Council, National Academy Press, 1998.
58 *See Climate Change Science: An Analysis of Some Key Questions*, US National Research Council, National Academy Press, 2001.
59 For more info *see* e.g. Hansen J., Climate Forcings in the Industrial Era, available at http://www.giss.nasa.gov/research/briefs/hansen_05/.
60 Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability, IPCC Working Group II 4th Assessment Report, Summary for Policymakers, available at http://www.ipcc.ch/SPM13apr07.pdf.
61 OECD Report Space 2030: Tackling Society's Challenges, 2005, at 59.
62 Burton I., The Growth of Adaptation Capacity: Practice and Policy, in Adapting to Climate Change: An International Perspective, Smith, J.et al. (eds.). Springer-Verlag, 2006, at 55–67. *See* also Stern Review on the Economics of Climate Change, October 2006, available at http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm.
63 Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, available at http://books.nap.edu/catalog/11820.html.
64 To be adopted soon as a fourth GMES core service by the GMES Advisory Council.
65 *See* Earth Science and Applications from Space.
66 Experimental study of regional and global terrestrial environmental processes using spaceborne hyperspectral and infrared sensors, available at http://sergio.montenegros.de/public/fire_reagent.pdf.
67 Inventory and Monitoring of Shrimp Farms by Radar Satellite Data, Pilot study in Sri Lanka, available at http://www.fao.org/sd/eidirect/EIre0084.htm.
68 Assessing the Status of the Development of Standards for the Essential Climate Variables in the Terrestrial Domain, Secretariat of the Global Terrestrial Observing System (GTOS), 2007, available at http://www.fao.org/gtos/doc/pub49.pdf.
69 Socio-Economic Benefits Analysis of GMES, PricewaterhouseCoopers, 2006, available at http://esamultimedia.esa.int/docs/GMES/261906_Executive_Summary_final.pdf.
70 Shortly called SCIAMACHY. More info at http://envisat.esa.int/instruments/sciamachy/.
71 Which is in line with Article 5 (1)(i)(c) Community Environment Action Programme on improving monitoring of greenhouse gases. More information available at http://www.spacemart.com/reports/First_Greenhouse_Gas_Animations_Produced_Using_Envisat_SCIAMACHY_Data_999.html.
72 10117/06, adopted on June 9, 2006.
73 Latest consolidated version from December 29, 2006, OJ C 321 E/3.
74 Decision No 1600/2002/EC of the European Parliament and of the Council of 22 July 2002, available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002D1600:EN:NOT.
75 EC Regulation 2151/2003 of November 17, 2003 concerning monitoring of forests and environmental interactions in the Community (Forest Focus).
76 FAO Forest Resources Assessment Programme, more info at http://www.fao.org/docrep/006/ad650e/ad650e00.htm.
77 State of Europe's Forests, MCPFE Liaison Unit Vienna and UNECE / FAO Report, 2003, available at http://www.unece.org/trade/timber/docs/sfm/europe-2003.pdf.
78 *See* http://www.phantis.com/news/read.html?newsID=2007070483907.
79 *See* http://www.adetocqueville.com/200707161503.l6gf3bg17860.htm.
80 See, Tschirley J.B., Norse D., Food and Forestry: Global Change and Global Challenges, available at http://www.fao.org/gtos/ppt/gctekey.ppt#271,6,Slide 6.
81 Assessing the Status of the Development of Standards for the Essential Climate Variables in the Terrestrial Domain.
82 Morton D. C., Rapid Assessment of Annual Deforestation in the Brazilian Amazon Using MODIS Data, *Earth Interactions* 9(8), abstract available at http://ams.allenpress.com/perlserv/?request=get-abstract&doi=10%2E1175%2FEI139%2E1.
83 Socio-Economic Benefits Analysis of GMES, fn 57.

[84] Assessing the Status of the Development of Standards for the Essential Climate Variables in the Terrestrial Domain.
[85] Communication from the Commission to the Council and the European Parliament on an EU Forest Action Plan, COM(2006) 302 final.
[86] Future European Forest Monitoring System, Position Paper, Steering Committee of Cost Action E43, March 2007, available at http://www.aisf.it/biodv/PPT/COSTE43PositionPaper.pdf.
[87] Global Marine Assessments, UNEP-WCMC Survey, 2007, available at http://www.unep.org/dewa/assessments/EcoSystems/water/Survey07final.pdf.
[88] For all data *see* A Sustainable Future for the Mediterranean, Executive Summary, 2006, available at http://www.planbleu.org/red/pdf/red_resume_uk.pdf.
[89] European Lifestyles and Marine Ecosystems: Exploring Challenges for Managing Europe's Seas, 2007, available at www.elme-ue.org.
[90] EU Commission data, December 2005, available at http://www.europa-eu-un.org/articles/en/article_5459_en.htm.
[91] *See* Feasibility Study for Establishing a Regular Process for the Assessment of the Marine Environment, available at http://www.unep.org/dewa/assessments/EcoSystems/water/MarineAssessment/reports/germany_report/IOC.ppt#276,21.
[92] A Survey of Global and Regional Global Marine Environmental Assessment and Related Scientific Activities, available at http://www.unep-wcmc.org/marine/GMA/docs/GMA_Review.pdf.
[93] More info at http://www.bnsc.gov.uk/content.aspx?nid=5676.
[94] Biodiversity Protection and Conservation in the Marine Environment, available at http://www.wcl.org.uk/downloads/2005/WCL04_Biodiversity_WP4_25Aug05_final.pdf.
[95] Adopted on September 4, 2002.
[96] *See* European Security Strategy, adopted on December 12, 2003.
[97] Living with Risk – A Global Review of Disaster Reduction, available at www.unisdr.org.
[98] World Disaster Report 2002, International Federation of Red Cross and Red Crescent Societies, available at http://www.ifrc.org/publicat/wdr2002/index.asp.
[99] Living With Risk: A Global Review of Disaster Reduction Initiatives. 2nd ed. Geneva, UNISDR, 2004.
[100] More info at http://ec.europa.eu/information_society/activities/policy_link/documents/factsheets/env_osiris.pdf.
[101] Volume 53, No.3, July 2004.
[102] Words Into Action: Implementing the Hyogo Framework for Action, UNISDR Draft document, available at http://www.unisdr.org/eng/hfa/docs/words-into-action-consultation-draft.pdf.
[103] Vulnerability and Risk Assessment, 1994, available at http://www.undmtp.org/english/vulnerability_riskassessment/vulnerability.pdf.
[104] European space industry and examples of space applications, MEMO/07/154.
[105] The Impact of Disasters on Long-Term Food Security and Poverty Alleviation – Policy Implications, FAO Committee on Food Security, 29th Session, available at http://www.fao.org/DOCREP/MEETING/006/Y8936e/Y8936e00.HTM.
[106] Molchanov O., Main Results of Recent Joint Japan -Russia Research on Seismo-Electromagnetics and Related Phenomena, Earthquakes, Ground-based and Space Observations Workshop, June 2007, available at http://euro-seismic.oeaw.ac.at/index.php?option=com_docman&task=doc_view&gid=32.
[107] Info available at http://www.cospas-sarsat.org/Status/saves.htm.
[108] Carriere J.-M., Meteorological Vigilance: An Operational Tool for Early Warning, International Conference on Early Warning, March 2006, available at www.ewc3.org/upload/downloads/Symposium_MultiHazard_07_Carriere_060.pdf.
[109] Socio-Economic Benefits Analysis of GMES, fn 57.
[110] Socio-Economic Benefits Analysis of GMES, fn 57.
[111] Rev.3 (25/4/2000).2. Known as International Charter „Space and Major Disaster".
[112] Final Report, World Conference on Disaster Reduction, CONF.206/6.
[113] Stern Review on the Economics of Climate Change, 2006, at 77, available at http://www.hm-treasury.gov.uk/media/D/8/Part_II_Introduction_group.pdf.
[114] UNHCR 2006 Global Trends Report, available at http://www.unhcr.org/statistics/STATISTICS/4676a71d4.pdf.
[115] More info at http://www.goethe.de/ges/pok/prj/mig/en2285523.htm.
[116] *See* at http://www.eyesondarfur.org/satellitetech.html.
[117] A project within the Science and Human Rights Programme of the American Association for the Advancement of Science, with major funding from the MacArthur Foundation, and support from the Open Society Institute, more info at http://shr.aaas.org/geotech/index.shtml.
[118] Commission Communication, July 19, 2006, COM/2006/0402 final.
[119] Data for 1999-2005, Eurostat Report Trends in Road Freight Transport, available at http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-07-027/EN/KS-SF-07-027-EN.PDF.
[120] Eurostat press-release, January 2007, available at http://epp.eurostat.cec.eu.int/pls/portal/docs/PAGE/PGP_PRD_CAT_PREREL/PGE_CAT_PREREL_YEAR_2007/PGE_CAT_PREREL_YEAR_2007_MONTH_01/7-19012007-EN-AP.PDF
[121] One Sky… Global ATW – the Way Forward.
[122] See at http://www.concawe.be/DocShareNoFrame/docs/1/KCDCKANCMCEJFIPFAFMBNPCIVEVDE69YBDE3BY2YG3BY/CEnet/docs/DLS/Rpt063-2006-01514-01-E.pdf.
[123] EU Road Safety 2004: Regional Differences, Eurostat 2007, available at http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-07-014/EN/KS-SF-07-014-EN.PDF.
[124] See at http://www.eccj.or.jp/ambassador/eng/27/4/4_1.html.
[125] See Malala R., The Impact of Weather on Aircrafts Accidents, South African Weather Service, available at http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p48_s2a_07_malala_v.pdf.
[126] See Indicators Needs For a Transport Policy Information System, Best Conference, 2001, available at http://bestransport.org/conference03%5CPanagopoulou3b.PDF.
[127] Improving European Integration in Maritime Reporting, Monitoring and Surveillance, Background Paper 2006, available at http://ec.europa.eu/maritimeaffairs/pdf/SEC(2006)_689%20_4b.pdf.
[128] *See* at http://www.esa.int/esaEO/GGGGEHCM8EC_index_0.html.
[129] *See* at http://www.dwd.de/en/Technik/Datengewinnung/Radarverbund/Radarbroschuere_en.pdf.

[130] Integrating Space Weather Observations & Forecasts into Aviation Operations, American Meteorological Society & SolarMetrics Policy Workshop Report, 2007, available at http://www.ametsoc.org/atmospolicy/documents/space%20weather%20&%20aviation%20report.pdf.
[131] *See* at https://secure.eurowatchcentral.com/article.aspx?rno=44.
[132] *See* at http://www.galileo-solutions.com.
[133] The Socio-Economic Benefits of Roads in Europe, March 2006, available at http://www.erf.be/files/2808_ERF_SEBS_030306_Final.pdf.
[134] European Transport Policy for 2010: Time to Decide, White Paper, 2001.
[135] The Socio-Economic Benefits of Roads in Europe.
[136] Keep Europe Moving – Sustainable Mobility for Our Continent: Mid-term Review of the European Commission's 2001 Transport White Paper, 2006.
[137] *See* European Road Safety Action Plan, EU Commission Communication COM(2003) 311 final.
[138] Socio-Economic Benefits Analysis of GMES, fn 57.
[139] Adopted on July 22, 2002 by Decision No 1600/2002/EC

Mission Statement of ESPI

The mission of the European Space Policy Institute (ESPI) is to carry out studies and research to provide decision-makers with an independent view on mid- to long term issues relevant to the governance of space.

Through its activities, ESPI contributes to facilitate the decision-making process, increasing awareness on space technologies and applications with the user communities, opinion leaders and the public at large, and supporting students and researchers in their space-related work.

To fulfil these objectives, the Institute supports a network of experts and centres of excellence working with ESPI in-house analysts.