Significance of Earth Observation for Switzerland

Report of the

Swiss Commission for Remote Sensing SCRS
Schweizerische Kommission für Fernerkundung SKF

Member of the Swiss Academy of Sciences SCNAT

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SCRS Swiss Commission for Remote Sensing
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I Summary

'Understanding the Earth system is crucial to enhancing human health, safety and welfare, alleviating human suffering including poverty, protecting the global environment, reducing disaster losses, and achieving sustainable development. Observations of the Earth system are critical to advancing this understanding.' [GEO 2006].

Earth Observation (EO) using remote sensing tools and methods offers the possibility for a permanent monitoring of the environment at global to local scales with high temporal and spatial resolution. The data resulting from such observations can be used by many user groups in the most diverse areas (public or private, for research or applied use). Constantly growing user communities are requesting not only continuity of current observations, but also new observations of local, regional and global nature in the various segments of the electromagnetic spectrum.

In Switzerland, Earth Observation data are being used in many fields, such as weather prediction, climate monitoring (e.g. clouds, air pollution, glaciers), landslide detection or topographic mapping. Many of these domains are still at the research level but their potential for operational applications has been proven for many years and is currently being demonstrated. The future operational use of EO data will, of course, depend on its continued availability, and hence on the commitment at international level for a sustainable funding to maintain and operate the observation infrastructure.

The aim of this report is to give an up-to-date overview of Earth Observation activities in, and their significance for, Switzerland. It also provides information about the incorporation of Swiss EO activities into the international framework. All major actors from the field of research and development, from the federal offices and from industry and education are considered.

This report represents the position of the Swiss Commission for Remote Sensing (SCRS). SCRS is the scientific union of remote sensing research institutions within the Swiss Academy of Sciences (SCNAT).

The vision as formulated by the SCRS in this report consists of two elements: 'Earth Observation provides information and knowledge for a sustainable and prosperous development of Switzerland', and – because Earth Observation has become a tool of strategic importance – 'Switzerland remains an attractive and competitive place for Earth Observation in research, application and service development'.

In order to turn this vision into reality, the SCRS recommends:

- to identify relevant niche EO sectors and develop corresponding Swiss core competences;
- to foster training, education and research, and to increase the awareness to EO data;
- to ensure observations according to users' needs, and to make data easily available;
- to create and implement a national EO programme;
- to intensify the international cooperation.

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III Foreword

The Swiss Commission for Remote Sensing (SCRS) expressed at its meeting on 30 June 2006 a strong request for the new edition of the report on the 'Significance of Earth Observation for Switzerland' whose last issues were published in 1987/88 [Koordinationsgruppe Fernerkundung, 1987] and 1995 [CFAS, 1995].

This report describes the state of the art of Earth Observation in Switzerland with remote sensing methods and identifies the benefits for the Swiss users, research community and industry. The report supports decision makers - politicians, research entities and industry - in strengthening and multiplexing their activities on national and international context to support the Swiss needs and potential in the important field of remote sensing and Earth Observation.

This report represents the position of the Swiss Commission for Remote Sensing, the scientific union of remote sensing research institutions within the Swiss Academy of Sciences (SCNAT).

This report was prepared by an author group of the SCRS. I would like to extend my thanks to all those who participated in the preparation of this document. Special thanks go to Dr. M. Borgeaud (Space Center – EPFL), Dr. U. Frei (Space Affairs Division, SER), Dr. F. Holecz (sarmap S.A.), Prof. Dr. K. Itten (RSL – University of Zürich), Prof. Dr. C. Mätzler (IAP – University of Bern), Dr. A. Streilein (swisstopo) and Dr. S. Wunderle (RSRG – University of Bern).

The authors prepared the report on the background of a questionnaire, distributed in 2007 to Swiss entities tackling remote sensing and Earth Observation. Among the inquired entities were several Swiss research institutes (including all Swiss universities), federal offices, service companies and the space industry. The turnaround reached over 45 questionnaires.

The authors incorporated the various viewpoints and contributions in the report with respect to four main actor groups ('Research and Development' R&D, 'Federal Offices, 'Industry' and 'Education') addressing the current 'state-of-the-art', 'benefits' and 'visions'. Therefore this report is broad in scope but it reflects the position of major Swiss actors in Earth Observation rather well, and the significance of EO in politics, economy and society.

Based on findings included in this report, the Swiss Commission for Remote Sensing formulates recommendations to foster and promote the research, development and application of remote sensing and Earth Observation in Switzerland.

Zürich, June 2008 – Tobias W. Kellenberger

1 Introduction

Within living memory, mankind has always had the ambition to survey his habitat, with the aim of understanding how its components relate to each other as well as to their surroundings. Galileo Galilei (1564-1642) outlined the first ideas for flight machines, which would have given us a view of the Earth from above [Galilei, 1632]. For the first time, a technique was introduced for the acquisition of information about an object without being in physical contact with it. Some hundred years later Jules Verne (1828-1905) wrote the tales 'De la Terre à la Lune' and 'Autour de la Lune' which was science fiction [Verne, 1865 and 1869]. Science Fiction has become reality. A large number of satellites with diverse sensors are orbiting the Earth and providing data to improve weather forecasts, map properties of the Earth's surface, improve mapping of remote areas but also to detect changes in our environment.

The European Space Agency (ESA) has recently identified the new scientific challenges for its Living Planet Programme [ESA, 2006]. This programme deals with the most important Earth-science questions that should be addressed in the years to come. It is particularly linked to the new space missions addressing key issues in Earth system science, the infrastructure needed to handle and assimilate the data, and the development of innovative approaches to foster European space expertise in both the instrumentation and the development of modelling activities. Most of the recommendations listed in this document also apply to Switzerland.

It is clear that we are facing a number of challenges regarding our environment, our economies and even our political system, which are driven by:

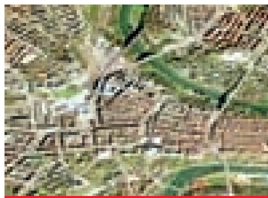
- climate change
- limited resources
- biodiversity changes
- population growth
- natural and man-made disasters

Earth Observation plays a key role in addressing these challenges. For climate change, it has already been proven that satellite measurements are important to complement the other measurement networks (ground-based, in-situ, airborne), in particular on a global scale. Satellite data are among the only means for ensuring global, homogeneous and repetitive observations.

1.1 Why this report?

The aim of this report is to give an up-to-date overview of Earth Observation activities in Switzerland and highlight their significance for our country. It also provides information about the integration of Swiss EO activities into the international framework, and a vision of the future of remote sensing in Switzerland.

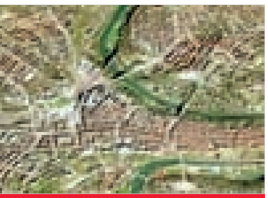
A similar report was published in 1995 [CFAS, 1995]. Since then, both society and technology have faced dramatic changes. The number of Earth Observation satellite and sensor systems has increased. In addition to international satellite programs, an increasing number of national and private entities as well as modestly-sized research institutions are launching their own satellites and Earth Observation systems, gathering an increasing store of observation data sets. Data viewers such as Google Earth, Microsoft Virtual Earth or NASA World Wind is installed on almost every personal computer and students in schools are travelling virtually to the remotest regions of the Earth. Looking at towns, landscapes and regions from outer space naturally draws people's interest. A virtual flight through a big city in 3-D is an everyday occurrence – our perception is changing. Global Earth Observing Systems are in operational use and new international programs have been founded. Service providers are on their way to developing new applications, but most importantly, the international funding structures are changing as well.



Earth Observation data may be simultaneously used by a broad community, from the individual citizen (weather forecast, map products, Google Earth, etc.), industrial users (resource mapping, topographic mapping) and federal and cantonal authorities (security and defence, rapid mapping, hydrology, vegetation analysis, air pollution, land cover and land use, development cooperation, etc.). The benefit of Earth Observation data and products for all these aspects, and even ecological and economic topics, has reached a level of significance that needs to be preserved and extended in the future. Earth Observation does not stop at national borders, as neither the political, scientific nor commercial relations of Switzerland do. The political bodies at all levels - in Switzerland, in Europe and in the world - are in charge of strengthening the environment for Earth Observation and of guaranteeing straightforward and cost-effective access to Earth Observation data for users.

1.2 Remote Sensing and Earth Observation

For clarity, the terms 'Remote Sensing' (RS) and 'Earth Observation' (EO) will be used synonymously in this report. The term 'Earth Observation' means the sensing of the Earth (including atmosphere, cryosphere, ocean, solid Earth and land masses) from spaceborne, airborne and ground based platforms by making use of the properties of electromagnetic waves emitted, reflected and scattered by, or propagated through the sensed objects and medium. Earth Observation with remote sensing methods comprises acquisition, processing, exploitation, modelling, as well as assimilation of data and information.



1.3 Structure of the Report

The report falls into the following main sections:

- In Chapter Two the report outlines the current state of Earth Observation. On the background of the political, scientific, industrial and educational organisation of the national Earth Observation activities, in brief the international network and involvement is given.

- The focus of Chapter Three is on the benefits of Earth Observation for Switzerland, from the viewpoint of the four main sectors 'Research and Development', 'Federal Offices', 'Industry' and 'Education'.

- In Chapter Four, the Earth Observation and remote sensing actors of Switzerland, assembled in the Swiss Commission for Remote Sensing (SCRS) present distinct visions for the future.

- Chapter Five outlines the recommendations, directed to decision makers. The recommendations are formulated with the knowledge about the current state of Earth Observation in Switzerland, based on the actual and potential benefits for our society as well as the strategic importance of EO in particular for environmental and security applications and motivated by the vision of a national Earth Observation strategy.

2 The Current State of Earth Observation

2.1 Relevance of Earth Observation

'The relevance of Earth observation outside the traditional space community has considerably increased over the past decade, even though its importance has not yet been fully appreciated by decision-makers. This is especially true in relation to the environment and sustainable development. Special efforts will be necessary to show that Earth Observation has a vital contribution to make, and careful attention needs to be given to demonstrating exactly how it can contribute to addressing the preoccupations and priorities of the non-space communities.' [CEOS, 2002]

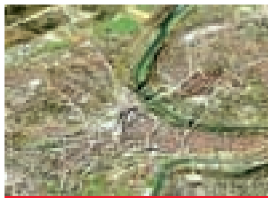
Earth observation is generally understood as the acquisition, measurement and exploitation of data acquired from remote Earth-looking instruments (aircraft- or satellite-based), but also ground-based observations of the Earth system. EO covers a diverse range of remote sensing applications, including weather forecasting, climate and environmental monitoring, vegetation analysis, natural resource exploration, surveillance and numerous scientific applications in the atmosphere, cryosphere, land and ocean domains of the biotic and a-biotic environment. Earth Observation is not limited by national borders. Earth Observation contributes to an improved understanding and monitoring of the Earth system. In many domains EO has already become the most important source of information. It plays an important role in obtaining information on issues related to defence and security. Earth Observation thus supports important government decisions that have significant influence in the fields of environmental protection, land use, coastal monitoring, sustainable development, verification, etc.

Remotely sensed Earth observations have the decisive advantage of offering possibilities for an ongoing global to local recording in good temporal and spatial resolution, as they can be used by the most diverse users in the most diverse areas (public or private, for research or applied use). The user community is undergoing constant growth and keeps placing new demands on Earth Observation of local, regional or global nature, in a broad variety of spectral regions and at various temporal, spectral and spatial resolutions.

2.2 Coordination of Earth Observation in Switzerland

Remote sensing in Switzerland consists of a network of government offices, research and education institutions, trade and industry companies, associations and private individuals.

2.2.1 Political Coordination and Committees



The Federal Council is responsible for the formulation and implementation of the Swiss space policy.

It is advised by the Federal Space Affairs Advisory Commission (Eidgenössische Kommission für Weltraumfragen EKWF). This commission is composed of representatives of all relevant sectors: science and science policy, space industry, operators and users of space systems.

The State Secretariat for Education and Research SER, in co-operation with other federal offices involved in space affairs, is entrusted with the preparation, planning and implementation of the Swiss space policy, which is decided by the Federal Council. For this purpose, the Space Affairs Division (Swiss Space Office, SSO) of the SER is running the secretariat of the Federal Space Affairs Advisory Commission EKWF and chairs the Interdepartmental Coordination Committee for Space Issues (IKAR, see below). The Space Affairs Division of the SER leads the Swiss ESA delegation.

The Interdepartmental Coordination Committee for Space Issues (Interdepartementaler Koordinationsausschuss für Weltraumfragen IKAR) is responsible for the coordination of national space activities and interdepartmental cooperation. It also prepares governmental positions, taking into account the recommendations of the Federal Space Affairs Advisory Commission. It monitors the implementation of governmental decisions relevant for space and ensures a coherent national space policy. IKAR members represent the position of their committee while assuring internal information and coordination.

The Interdepartmental Working Group Remote Sensing (IDA-FERN) coordinates the interests in remote sensing of the federal administration. It

secures information exchange, prevents duplicate endeavours and promotes synergies and new co-operation efforts. The represented federal offices and federal institutions are dealing either with own remote sensing activities or are interested in such.

The Swiss National Point of Contact for Satellite Images (NPOC) is the national information, distribution and archive centre for satellite images. The duties of the NPOC are carried out in common by the Federal Office of Topography (swisstopo) and the Remote Sensing Laboratories (RSL), Department of Geography, University of Zürich (UZH).

2.2.2 Research and Science

In the research and science area, the promotion through the federal government by the Swiss National Science Foundation (SNSF) and SER, Earth Observation is on the one hand represented organisationally in the Swiss Commission on Space Research (SCSR) and on the other hand specially grouped in the Swiss Commission for Remote Sensing (SCRS), both commissions of the Swiss Academy of Sciences (SCNAT). The commission for Remote Sensing includes representatives from Swiss universities (Basel, Bern, Fribourg, Geneva, Zürich) and federal institutes of technology (Zürich, Lausanne), a university of applied science (Muttenz), federal research institutions (Empa, WSL) and the federal offices (representatives of Space Affairs Division of the SER, the Federal Office of Topography (swisstopo), the Federal Office of Meteorology and Climatology (MeteoSwiss), the Interdepartmental Working Group Remote Sensing (IDA-FERN) and both hardware and value-adding industries.
The Swiss Society for Photogrammetry, Image Analysis and Remote Sensing (Schweizerische Gesellschaft für Photogrammetrie, Bildanalyse und Fernerkundung SGPBF) is an association promoting the development of theory and applications in photogrammetry and remote sensing. The association is a national member of the International Society for Photogrammetry and Remote Sensing (ISPRS). The scientific and technical work of the ISPRS is accomplished by eight Technical Commissions. All of them are dedicated to remote sensing issues.

2.2.3 Industry and Trade

Most of the Swiss industries active in the space sector in the context of ESA contracts are members of the Swiss Space Industry Group (SSIG), a division of the Swiss Mechanical and Electrical Engineering industries (SwissMem).

The Swiss Earth Observation Service Providers Society ('Gesellschaft der Schweizer Erdbeobachtungs-Dienstleister' SED) is the Swiss organisation of Earth Observation service provider companies.

2.3 Switzerland and its International Collaboration

Larger European countries such as Germany and France, as well as several smaller countries such as Belgium, the Netherlands, Denmark or Sweden, all have their own national Earth Observation programme. Switzerland does not have a national space agency or a national EO programme. Therefore the EO activities are carried out mostly in the framework of international / intergovernmental organisations or programmes.

European Space Agency
The purpose of the European Space Agency (ESA), founded in 1975, is 'to provide for and to promote, for exclusively peaceful purposes, cooperation in Europe among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems' (Article II of the ESA Convention [ESA, 2003]). ESA is not only active in Earth Observation, but also in areas such as space science, human spaceflight, launchers, navigation and telecommunications. The ESA Earth Observation activities consist mainly of the Living Planet Programme, joint programmes with EUMETSAT, and the GMES Space Component programme. The Living Planet Programme is divided into two main components, (a) a science and research element, which includes the Earth Explorer missions, and (b) the Earth Watch element dedicated to the development of operational missions and applications.
The State Secretariat for Education and Research (SER), Space Affairs Division, is the responsible federal office for the Swiss representation in

ESA. The ESA governing bodies for Earth Observation are the ESA Council, the Programme Board Earth Observation (PB-EO) and the Data Operations Scientific and Technical Advisory Group (DOSTAG).

European Organisation for the Exploitation of Meteorological Satellites

In 1986, the responsibility for the operational meteorological satellites in geostationary orbit, Meteosat, was transferred from ESA to a newly established intergovernmental organisation, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). In the meantime, two other main activities have been established within EUMETSAT in addition to the geostationary programmes: (1) low Earth orbit programmes (e.g. European Polar System EPS), and (2) the decentralized processing facilities, the Satellite Application Facilities (SAF's). The Federal Office of Meteorology and Climatology MeteoSwiss is the responsible federal office for the Swiss representation in EUMETSAT. The EUMETSAT governing bodies include the EUMETSAT Council, the Policy Advisory Committee (PAC), the Administrative and Finance Group (AFG) and the Scientific and Technical Group (STG) with its two subgroups STG Science Working Group (STG-SWG) and STG Operations Working Group (STG-OPS).

European Union

Through its Framework Research Programmes (FRP), the European Union (EU) is fostering EO related research and application development. There are two major elements focussed on Earth Observation in the current FP7: projects in support of the Global Earth Observation System of Systems (GEOSS), and support to GMES. The latter consists of service development and a substantial contribution to the GMES Space Component programme of ESA. Since Switzerland is associated to FP7, Swiss actors have full access to all activities.

Committee on Earth Observation Satellites

The Committee on Earth Observation Satellites (CEOS) performs international coordination between the space agencies. The three primary objectives of CEOS are (a) to optimize benefits of spaceborne Earth Observations through cooperation of its participants in mission planning and in development of compatible data products, formats, services, applications, and policies, (b) to serve as a focal point for international coordination of space-related Earth Observation activities, and (c) to exchange policy and technical information to encourage complementarities and compatibilities of observation and data exchange systems. Switzerland is represented in CEOS through ESA and EUMETSAT.

Global Climate Observing System

The implementation of the Global Climate Observing System (GCOS) was initiated in 1992, in connection with the UN Framework Convention on Climate Change (UNFCCC), Article 5 'Research and Systematic Observation', and the subsequent Kyoto Protocol. In 2006, a 'satellite supplement' to the GCOS Implementation Plan was compiled by GCOS in consultation with CEOS, describing in detail the role of satellite data within GCOS, for a better understanding and prediction of the climate system and global/regional climate change. The Swiss GCOS Office at the Federal Office of Meteorology and Climatology MeteoSwiss responsible for the coordination of the GCOS activities in Switzerland.

European cooperation in the field of scientific and technical research (COST)

COST was founded in 1971 by the Ministerial Conference for science and technology, and represents the oldest European structure of cooperation in the field of research. As one of the founding members, Switzerland has fully participated in COST activities ever since their beginning. COST enables national institutes and research institutions, as well as companies from the private sector to participate in a large-scale of activities in research and technology, in particular in the areas of fundamental and pre-competitive research. Many COST actions have been dedicated to the advancement of remote-sensing. COST offers Swiss researchers the possibility propose new actions in a bottom-up principle, and to participate as equal partners in the accepted concerted actions. The objective is to coordinate and to intensify the network of international partners in research.

In Switzerland, the authority responsible for the financial, scientific and the administrative issues of COST actions is the State Secretariat for Education and Research SER.

Coordination Group for Meteorological Satellites and the Space Programme of the World Meteorological Observation
In the field of operational meteorology, there are two further international coordination bodies, the Coordination Group for Meteorological Satellites (CGMS) and the Space Program of the World Meteorological Organisation (WMO SAT), to guarantee a complete global coverage by meteorological satellites.

The Network of European Meteorological Services
EUMETNET is an Economic Interest Group of most European Weather Services; among its activities, it also includes a European-wide coordination of operational remote sensing networks (e.g. the European Weather Radar Network OPERA).

Others
The increasing use of Earth Observation for various application areas is also reflected in the setup of Earth Observation groups or divisions in other international organisations. Examples are the European Centre for Medium-Range Weather Forecasts (ECMWF), the United Nations Educational, Scientific and Cultural Organisation (UNESCO), and the United Nations Environment Programme (UNEP). The extension of data assimilation at ECMWF to include Earth Observation data has significantly improved the forecast skill scores of the global medium-range numerical weather prediction (NWP) models in recent years, resulting in better boundary conditions for regional NWP models and consequently improved weather forecasts and warnings in the European Member States.

Global Monitoring for Environment and Security
An important step towards a better use of Earth Observation data for European policy areas is the joint initiative of the European Commission and ESA, the Global Monitoring for Environment and Security (GMES), which started in 1998. GMES is a European initiative for the implementation of information services dealing with environment and security. It will be based on observation data received from Earth Observation satellites and 'in-situ' data, which is in this context understood as all necessary data and observations not received from Earth Observation satellites. GMES will provide a set of services for European citizens and administrations helping to improve their quality of life regarding environment and security.

Group on Earth Observation
Internationally, GMES will be one important contribution to the Global Earth Observation System of Systems (GEOSS), being implemented by the Group on Earth Observation (GEO) with its administrative office in Geneva. The goal of GEO is an optimal integration of the existing observation systems and models, thereby connecting the benefits in the following nine areas: 'Disasters', 'Health', 'Energy', 'Climate', 'Water', 'Weather', 'Ecosystems', 'Agriculture' and 'Biodiversity'.

Collaboration with national entities
The various Swiss institutions active in Earth Observation have different international links, through their participation in the EU Framework Programmes and through their collaboration with national and multi-national agencies: e.g. DLR ('Deutsches Zentrum für Luft- und Raumfahrt), ESA, EUMETSAT, NASA (National Aeronautics and Space Administration – USA), JAXA (Japan Aerospace Exploration Agency) and with international universities (see chapter 2.4).

2.4 Earth Observation Research and Development

Basic Earth Observation research and development (R&D) in Switzerland has evolved since the 1960's from pioneering work performed by a few research groups to instrument development, methodology and radiative transfer, i.e. long before interests in the applications of EO data were expressed [Büro für Weltraumangelegenheiten, 2000]. Methods were discovered by chance and by innovative investigations, and new groups joined the efforts when more and more EO potential became apparent. The research has continued until today, mostly in international collaboration and

- with the involvement of space agencies and international organisations: e.g. ESA, NASA, EUMETSAT
- research programmes: e.g. COST Actions (European Cooperation in the field of Scientific and Technical research), EU programmes.

The harvest has led to leading roles and key expertise in remote sensing methods (e.g. imaging spectrometry, synthetic-aperture radar, microwave radiometry, rain radar, methods using Global Positioning System (GPS) signals). Furthermore, Swiss researchers at universities, research institutes and at dedicated companies have contributed to the development of value-adding tools to better understand and exploit EO data in view of a wide range of applications (geodesy, security, weather forecasting, nowcasting, climate monitoring, pollution control, hazard assessments, atmospheric, cryospheric and soil research, bio-geochemistry, oceanography and archaeology). Although the growing population tends to increase the number of problems on our planet, EO has provided significant information for their solution.

EO measurements can be acquired by surface-based, airborne and spaceborne systems, depending on the needs for spatial and temporal coverage and resolution. Satellite data can have a very long time span, such as Landsat optical data collected continuously since 1972, Meteosat images since 1977 and Synthetic Aperture Radar (SAR) images acquired without interruption by the European Space Agency since 1991. However, they suffer from limited spatial resolution, though very recent systems have the capability of acquiring data at sub-metric spatial resolution. In addition, satellite measurements offer a global and repetitive coverage, providing homogeneous datasets, and more and more in near-real time. On the other hand, surface-based systems are useful for monitoring key quantities and can give very accurate information, but with a limited spatial coverage.

2.4.1 Current State of Research and Development

Because of the advantages of EO data, they are used nowadays in many scientific fields such as previously described.

Several parameters for **land applications** such as surface soil moisture, vegetation height and cover types can be measured from space. Recent developments also enable the detection of tiny displacements (millimetres per year) from satellites orbiting at 800 km of altitude using radar interferometer techniques which is paving the way to brand new applications for earthquakes, landslides and glacier monitoring. Forest biomass may also be measured and forest fires may be detected from spaceborne instruments.

For the **cryosphere**, snow coverage, type and water equivalent can be inferred from satellite measurements. Furthermore, frozen and unfrozen ground can be distinguished, allowing monitoring the extent of permafrost. Similarly sea ice extent and type can be measured. Altimeters are capable to measure changes of the ice volume of Greenland and Antarctica, the major contributing factors to sea-level change. New sensors are being built to measure sea-ice thickness. Monitoring of glacier extent, mass balance and movements with remote sensing techniques is essential for better understanding the impacts of climate change.

For the **atmosphere**, cloud properties and extent can be derived from satellite data as well as atmospheric temperature and humidity profiles. Ground-based remote sensing also provides useful data (e.g. operational weather radar networks for precipitation). Today they comprise the most important input to weather prediction models. Similarly rain intensity and rain extent can be measured from space. Wind direction and intensity aloft will soon be acquired by satellite flying Lidar instruments. Ozone, carbon dioxide, trace gases, aerosols and several atmospheric pollutants can be traced and quantified by satellites. Operational meteorology is one of the largest user of EO data for nowcasting,

weather prediction as well as monitoring of the climate system. Without realising, we consume information based on satellite data, when watching the weather forecast at the daily TV news.

For **solid Earth**, subsidence and volcano activities can be measured by satellites. The geoid and the fine structure of the marine gravity field can also be tracked from space. A satellite mission is presently being built to monitor the Earth gravity and magnetic fields.

For **oceanography**, sea surface temperature, ocean chlorophyll concentration, surface wind speed and direction can be routinely measured. Moreover, missions are being presently built to measure ocean salinity. Icebergs, ship wakes, and man-made oil pollution can be easily spotted using spaceborne radars.

It should be noted that many of the applications listed above, though demonstrated by scientific satellite missions, cannot be considered as operational due to the lack of commitment for the long-term availability of the data.

More important than the 'simple' retrieval of bio- or geophysical parameters, scientists are increasingly using EO data to monitor processes such as the carbon and the water cycles as well as biodiversity, allowing a much wider and thorough understanding of the interactions of the Earth with its environment. Of particular importance are the latest coupled radiative transfer and Earth system models of the ocean, atmosphere and land based on EO data that have recently attracted a lot of attention by the scientific community in order to better understand problems related to global change.

Earth Observation data are also of key importance for large political initiatives such as GMES and GEOSS as described in Chapter 2.3 in order to monitor global change, the environment degradation and to support sustainable development.

The main achievements in recent years can be divided into two main areas: the enhanced observation capabilities and the progress made in data analysis and exploitation.

Observation capabilities have been significantly increased by the deployment of new instruments on a growing number of spaceborne, airborne and ground-based platforms. Europe, with its research satellites (such as ERS and ENVISAT) and its operational missions (in particular EUMETSAT's geostationary and polar-orbiting meteorological satellites), but also with an increasing number of national missions, has become a worldwide recognized player in spaceborne remote sensing. In addition, the United States, Japan, India and China are continuously modernizing their fleet of EO satellites. More than a dozen other countries have also launched their own observation missions. Among the newly developed airborne sensors, we should note the digital aerial cameras that have become almost a standard for aerial image acquisition in Europe, and LIDAR (light detection and ranging) sensors for the production of digital terrain and surface models. Ground-based radar meteorology for precipitation measurements has continued to increase weather nowcasting and forecasting capabilities, as well as contributing to flood and pollution control.

The progress made in data analysis by refining existing methods and developing new ones has led to a better exploitation of available observations. Data assimilation opened the way for optimized state analysis and, subsequently, more reliable predictions of the state of the Earth. A part of this trend is also due to the European Centre for Medium-Range Weather Forecasts, which has led the meteorological community in the technique of re-analysis, developed to study time series of historical data using all available observations. The most recent project, ERA-40, has allowed the production of a 45-year (1957-2002) time series, using all available satellite and in-situ observations of the atmosphere. Earth system models in different domains of Earth sciences have been developed and improved through complex, systematic comparison and verification of their model predictions with observations. Interactions between key elements of the Earth system are better understood today thanks to the coupling of Earth system models with radiative transfer models.

2.4.2 Research and Development Entities Active in Earth Observation in Switzerland

Several R&D establishments deal with EO in Switzerland. The following tables have been compiled based on a questionnaire widely distributed in early 2007:

R&D establishment (alphabetical order)	Institute	EO Expertise
Empa	Laboratory of Air Pollution and Environment Technology	Atmospheric pollution
EPFL	Laboratoire de Télédétection Environnementale	Remote sensing of precipitation
	Space Centre EPFL	Retrieval of bio- and geo-physical parameters, small satellites
	Laboratory of Environmental Fluid Mechanics and Hydrology	Hydrologic and atmospheric boundary layer
	Signal Processing Institute	Image processing
ETHZ	Institute of Geodesy and Photogrammetry	Sensor calibration, modelling, orientation, digital surface model generation, geocoding, feature and object 2D and 3D extraction, satellite geodesy and navigation, troposphere modelling
	Institute of Terrestrial Ecosystems	Soil moisture
	Institute for Atmospheric and Climate Science	Atmosphere, hydrology
FHNW	Institute of Geomatics Engineering	EO with unmanned aerial systems (UAS), virtual globes and visualisation of EO data
ISSI	International Space Institute, Bern	Network partner in remote sensing for space sciences
University of Basel	wMCR Institute for Meteorology, Climatology and Remote Sensing	Urban micro-climatology
University of Bern	Institute of Geography	Aerosol and snow mapping, vegetation dynamic, time series analysis of NOAA-AVHRR, satellite data archive 25+ years
	Institute of Applied Physics	Remote sensing of the middle atmosphere (water vapour and ozone). Remote sensing of the troposphere (atmospheric water and temperature). Remote sensing methodology. Exploration of terahertz frequencies
	Physical institute	Remote sensing instruments for space science
	Institute of Archaeology	Geophysics and soil research for archaeology exploration
	Astronomical Institute	GPS and geodesy

R&D establishment (alphabetical order)	**Institute**	**EO Expertise**
University of Zürich	Institute of Geography - Remote Sensing Laboratories	SAR processing, imaging spectrometry and spectroscopy, land cover land use, geocoding and radiometric processing, retrieval of bio- and geo-physical parameters, LIDAR processing
	Institute of Geography – Physical Geography	Glacier inventory
World Radiation Centre, Davos	Observatory for Physics and Meteorology	Solar radiation
WSL Swiss Federal Institute for Forest Snow and Landscape Research	Land Resource Assessment	Land cover / land use mapping, forestry, national forest inventory
	Land Use Dynamics	Mapping large area, climate change, modelling vegetation dynamics
	Warning and Prevention / Snow and Permafrost	Snow mapping, avalanche dynamics

The competences in R&D can be mainly classified in the following domains:

Earth system element	**R&D establishments**
Atmosphere	Empa, EPFL, ETHZ, ISSI, MeteoSwiss, University of Bern, WRC
Cryosphere	SLF, ETHZ, MeteoSwiss, University of Bern, University of Zürich
Land	EPFL, ETHZ, MeteoSwiss, WSL, FHNW, University of Bern, University of Zürich
Solid Earth	ETHZ, University of Bern

2.5 The Swiss Federal Offices

A number of federal offices and research institutions of the federal ETH domain are active in the field of Earth Observation as data providers or as data users.

Federal Office	Major EO related activities	
Federal Office of Topography (swisstopo)	'Maintenance and updating of the 3D topographic landscape model (incl. DTM) and the national map series. Various services in the technical domain of photogrammetry and (rapid) mapping. Operates together with the Swiss armed forces platforms for aerial imagery and other airborne sensors. Hosts the national archives for aerial and satellite imagery as well as maps and various geodata	Operates the NPOC
Federal Office of Meteorology and Climatology (MeteoSwiss)	Meteorology, climate monitoring, atmospheric composition (aerosol, ozone), snow mapping, land cover, vegetation	
Federal Statistical Office (FSO)	Land use statistics	
Department of Defence (excl. swisstopo)	(rapid) mapping, intelligence	
Federal Office for the Environment (FOEN)	Land slides, natural hazards, land use, air quality	
Swiss Agency for Development and Cooperation (SDC)	Rapid mapping, humanitarian aid	
Federal Office for Agriculture (FOAG)	Land cover / land use	
Agroscope Reckenholz-Tänikon Research Station (ART)	Land cover / land use	

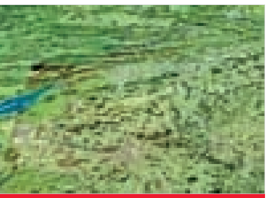
Most of the offices listed above use aerial photographs for their applications. Satellite imagery have been used for generating pilot products but also for operational applications, usually in cooperation with research institutes and value adding companies.

2.6 The Swiss Space Industry Active in Earth Observation

2.6.1 The Hardware Industry

The Swiss space industries active in the development of hardware have been involved since the very beginning of such activities in Europe and have built up tremendous expertise over the years. Among the key Swiss players, one should note Oerlikon Space (former Contraves Space) in Zürich, RUAG Aerospace in Emmen, Wallisellen, and Nyon, APCO Technologies in Vevey, Hexagon Leica Geosystems in Heerbrugg and Syderal in Gals for their participation in the development of several EO satellites such as ERS, METEOSAT, ENVISAT and METOP. These industries do not concentrate only on EO but also offer hardware and equipment for the full range of space activities (e.g. launcher, space exploration, navigation). Since 2000, the Swiss based hardware manufacturer Leica produces one of the few worldwide successful digital aerial camera systems, the Leica ADS80 (the former ADS40).

Working as a space company is a difficult endeavour due to the institutional nature of the European market, the lack of the development of recurrent pieces of hardware, and the dominance of large system integrators. Swiss industries are, however, recognised for the very high quality of the hardware they deliver, either at equipment or sub-system level.



2.6.2 The Value-adding Industry

The Earth Observation value-adding industry – in Switzerland represented by the Swiss EO Service Providers (SED) – is a diverse sector which develops products and services that address a wide range of thematic domains. EO based mapping is a key element of R&D and services provided by the SED members. Applications covered include risk management, vegetation monitoring and natural resources inventory, flood protection, hydrology, telecommunication, planning, and rapid mapping. To support these thematic fields, SED produces a wide range of products (i.e., software tools, hardware components, and data) and services ranging from research cooperation to integrated services including important non-EO based components. Due to the diverse characteristics of the various applications, no single member of the SED is able to cover all of them alone. The typical value-adding company is a small, specialized organisation that focuses on a few thematic fields and geographic areas. The EO industry is characterized by groups of experts offering niche services.

At present the Swiss EO value-adding companies, namely sarmap s.a. (Purasca), Gamma Remote Sensing (Bern), Ernst Basler+Partner (Zürich), and MFB GeoConsulting (Messen) are relatively small and slowly growing. In their field of competence they are well integrated and recognized in the corresponding international community, with a large fraction of the revenues coming from abroad. At the international level this industrial sector is an emerging one and expected to become very important, in particular considering the numerous new EO systems that are foreseen to be launched worldwide, and considering national and private initiatives in the coming years. Furthermore, the EO value-adding industry is faced with considerable untapped opportunities within national, European, and world markets. A significant growth of the demand for geospatial information products in general is good news for the EO value-adding industry.

The growth rate of the Swiss value-adding companies depends on one hand on the presently heterogeneous and fragmented EO community. On the other hand, mainly external factors limit a faster growth: For operational applications, EO data must be available and accessible on a reliable, continuous and long-term (decades) basis at competitive prices. Further hindrances are the limited market size in a small country as well as the lack of public awareness of the possibilities and chances of the EO technology and related tools for the benefits of societies.

A Swiss EO program accounting for this situation would significantly support and strengthen the activities of the Swiss EO value-adding companies and sustainably help growing the EO market in Switzerland.

2.7 Education in Earth Observation in Switzerland

Education in Earth Observation in Switzerland starts during the first two years of secondary school at the earliest, but to date at selected schools only. At the university level Earth Observation is taught at several Swiss universities. Earth Observation education is strongly coupled with the teaching of the principles of Remote Sensing in the context of Geography and/or Geosciences programs.

2.7.1 Earth Observation Teaching at Secondary Schools

For a long time, the Swiss Commission for Remote Sensing has aimed to strengthen the teaching of Earth Observation in Switzerland, supporting initiatives and theses that provide educational materials and research opportunities on Earth Observation themes and remote sensing methodologies. The focus has been put on strengthening the awareness of Earth Observation and its applicability to environmental issues.

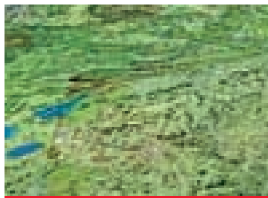
A survey of teachers as well as investigations in journals, textbooks, atlases and on the internet, show that a number of teachers use airborne and satellite images for illustration purposes. However, they do not often actually work with them. The main reasons cited were – apart from the time-consuming preparation and the absence of graphic material and exercises – the teachers' own lack of skills in remote sensing.
In curricula of secondary schools, remote sensing is mostly included indirectly. Only about one third of the tested curricula mention the process of working with airborne and satellite images. However, the development of methodical skills is a goal within most curricula. Remote sensing is suit-

ed to this purpose in a classroom setting, as many topics in education can be linked to remote sensing applications.

2.7.2 Earth Observation Teaching at University Level

Earth Observation through remote sensing is taught at most Swiss universities (Basel, Bern, Fribourg, Geneva and Zürich), the two Federal Institutes of Technology (ETHZ and EPFL) and the two universities of applied sciences of Western (HEIG-VD Yverdon) and Northwestern Switzerland (FHNW Muttenz). The following figure shows the quantities as surveyed in March 2007. Since the Bologna system change is in transition the figures may change slightly in the coming years.
As demonstrated in Fig. 1, remote sensing teaching is well distributed over Switzerland with core teaching intensities at Zürich, Bern, Lausanne and Basel. While basic introductory courses are given at each location, the individual institutes concentrate on specific fields, such as SAR processing, hyperspectral remote sensing and land use change monitoring at RSL, urban climate investigations in Basel, atmospheric remote sensing and snow studies in Bern etc. Thus the teaching landscape is diversified giving each institution the freedom of cooperation in national and international teaching and research networks.

Besides the education on how to use EO data, students are also trained on the hardware aspects related to the design and building of EO instruments and EO satellites. This expertise is highly encouraged by the Swiss space industry. Worth noting is the Minor of space technologies recently put together at EPFL with the precise goal of promoting space careers.
Education and research with major in photogrammetry is performed at the Federal Institute of Technology in Zürich (ETHZ) and at the two universities of applied sciences in Muttenz (FHNW) and Yverdon (HEIG-VD).



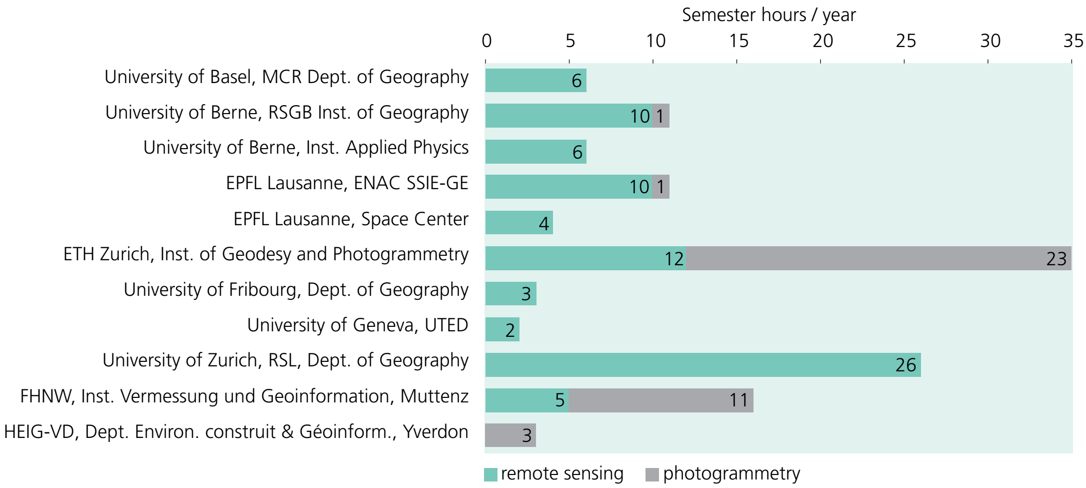


Fig. 1: Total semester hours per year of remote sensing and photogrammetry teaching. Figures include hours for exercises.

3 Benefits of Earth Observation for Switzerland

3.1 Research and Development

The American Under Secretary of Commerce for Oceans and Atmosphere Conrad Lautenbacher uttered the following sentences in the frame of the 2004 Earth Observation summit:

> '... people are building components of Earth Observing systems today. All of the developed nations are using this kind of data to improve their economies and their social structures. This information now will become available to the world, the world will contribute to it, and we believe will be an enormous benefit, both economically and socially to everyone that's involved with it, all nations ...'

Among the many benefits obtained by Earth Observation data, we should note that satellite measurements offer a global and repetitive coverage, provide homogeneous datasets, and are more and more provided in a near-real time environment. Thanks to inversion methods, it is now possible to retrieve important properties such as temperature and humidity profiles in the atmosphere, wind speed and direction over the oceans which are routinely used by the meteorological offices for weather prediction. The reliability and the accuracy of the weather forecasts have hence greatly increased because of the use of EO data.

In Switzerland, Earth Observation data are being used in many fields, such as landslide detection, glacier monitoring, weather prediction, air pollution monitoring, or topographic applications. Most of these domains are still at research level but their potential for operational applications is presently being demonstrated. 'For instance, snow cover maps based on Meteosat data are used in near-realtime in numerical weather prediction models for an improved snow analysis. The future use will, of course, depend on the availability of the data acquired from space, hence on the commitment at international level to the continuity to build and operate complex and expensive systems for global observations.

3.2 Federal Offices

Airborne EO data, in particular aerial photographs, have been produced and used by Federal Offices since a long time and for many important monitoring programs, such as production and regular updating of the national topographic map series, the Swiss land use statistics, the national forest inventory etc. It is considered essential and constitutes an indispensable prerequisite to maintain and – if needed – to expand the existing national capacities regarding airborne EO, in order to react flexibly and in an autonomous/independent way, should new political requirements and priority fields emerge.

For the time being, there are only a few Federal Offices using satellite borne EO data on an operational basis. For example, in the field of meteorology and climatology, satellite data from the operational meteorological satellites (both geostationary and polar-orbiting) are continuously used for nowcasting, weather forecasts and climate monitoring since more than 20 years and profound expertise has thereby been acquired over these years in their application to user needs. In addition, thanks to the obvious potential of EO applications even for a small, well developed country such as Switzerland, several offices have started to use EO applications for pilot projects to evaluate the potential of such applications. The close links between research institutes, value adding companies and Federal Offices as end users facilitate their uptake of new methods involving a wider variety of less traditional EO data.

A recent inquiry among Federal Offices concerning their potential interest in GMES services has revealed that 5 out of 7 Ministries will be able to improve current products and services, and may also obtain savings.

3.3 Industry

3.3.1 Hardware Industry

For the hardware industry, EO should not be looked at as a single activity but rather being linked to the global know-how of the Swiss industries in the space sector. It is clear that this business is creating employment in our country but also ensures that our industry stays at the cutting-edge of what is technically feasible for such a demanding activity as the development of space hardware.

Some Earth Observation programmes are among the very few space programmes that develop not only one single satellite of a specific type, but several recurring units. This is the case in the joint ESA-EUMETSAT programmes, and will also be the case for the 'Sentinels', the GMES specific observation satellites. It is therefore of crucial importance for space hardware industries to be in a strong position in Earth Observation programmes.

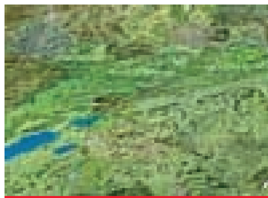
3.3.2 Value-adding Industry

Since geographical information pervades all social levels and economic sectors, it is a key resource for all decision makers at public or private level. Therefore, it has – in a broader sense – a strategic importance not only for security but also for any government to be an acceptable and accepted player at the table of international negotiations. To ensure access to the right data acquisition systems is one thing. To guarantee capabilities to exploit those data in a secure, economically efficient, and operationally optimized way is another. This is where the EO value-adding industry is both crucial and remains indispensable.

It must be stressed that the strategic importance of the value-adding sector is not only present in the many new socio-economic benefits generated by the applications themselves, but also in the creation of many new jobs to process and exploit the produced information. However, there have not been any strategic directions for the development of this industry. The results are the aforementioned fragmentation of the EO industry and the still existing barriers that hinder the industry to enter this market thoroughly.

3.4 Education in Remote Sensing and EO

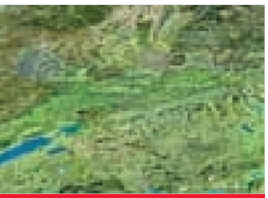
Since EO teaching can be found at almost all universities in Switzerland, the involved institutes serve as focal points of know-how and disseminators of remote sensing methodologies with fruitful connections into other disciplines. Furthermore dense networks between university institutes, cantonal and federal offices and organisations exist. Remote sensing in Switzerland profits from an extremely dense and well structured organisation through all involved bodies. This includes also private industry, especially with the group of Swiss Earth Observation Service Providers.



With the introduction of the Bologna structure the transparency and mobility in Europe, but also within Switzerland offers to each interested student excellent possibilities in Bachelor-, Master- and PhD programmes.

Training students in the EO domain is also very attractive for the Swiss industries since they benefit of a large pool of young graduates with a high-level of theoretical and practical education. The fact that students are also trained in the design of EO instruments and EO satellites should be stressed. This makes it possible to close the loop between setting the requirements for a space mission, designing and building the mission, analysing and using the data acquired, and improving future missions based on the results obtained.

4 Vision



The rapidly changing environment, the limited natural resources, and the fast growing worldwide population are only three of the major challenges for mankind. Earth Observation has become a tool of strategic importance to face such challenges, for the world at large but also for small countries like Switzerland.

Our vision is composed of two elements. The first element highlights the importance of Earth Observation for Switzerland:

Earth Observation at the service of Switzerland

Earth Observation as a provider of information and knowledge for sustainable and prosperous development in Switzerland.

Since Earth Observation has become such an important tool, in particular in the fields of environment and security, it is important that Swiss actors will continue to play an increasingly strong role in Earth Observation:

Switzerland – a strong player in Earth Observation

Switzerland as an attractive and competitive place for Earth Observation in research, technology, application and service development.

4.1 Earth Observation at the Service of Switzerland

Switzerland can benefit from Earth Observation if the applications developed are those that best serve the public interests. Good data availability and user-friendly dissemination channels are prerequisites for a broad usage of EO data. The exploitation of historical archives will lead to additional applications and further enlarge the user community.

Applications

- The applied research in EO is primarily to be focused on the needs of Swiss institutional users and international humanitarian organisations in Switzerland.

- Nowcasting and short-term forecasting tools will be enhanced by high-resolution information from various sources to assist in the control of power stations, air, rail and road traffic, river and lake-level forecasts, warnings against possible disease migration, UV radiation, avalanches, landslides, forest fires and much more.

- Challenges posed by global change and limited resources of food, water and energy, but also by technological developments, trade and political issues will be studied by socio-economic model extensions.

- Precipitation over land will be observed by radar networks and by microwave transmission links.

Data availability and dissemination

- Calibrated and geo-located EO data (microwave, infrared, optical) of low-to-medium spatial resolution will be available and will be processed to adapted and operational user products by national, European and global services.

- Web-based geo-visualisation technologies – from freely available to highly-specialised and custom-built ones – in combination with open access data policies, will be used to enhance the dissemination and exploitation of EO data by specialists and the general public alike.

- Swiss users will have unrestricted access to data acquired by remote sensing instruments and in-situ sensors that are operated at the national, European or global level.

Exploitation of historical archives

- Scientific, commercial and institutional users will benefit from a thorough exploitation of historical EO data archives.

4.2 Switzerland – a Strong Player in Earth Observation

Since Earth Observation is a tool of strategic importance, but not all aspects can be covered by a small country such as Switzerland, some key capabilities must be acquired and maintained by Swiss actors. Training, education and research, combined with a good national organisation of EO actors and their international networking will assure a strong Swiss position in the future as well.

Swiss niche expertises

- Switzerland makes its own key competences in EO and remote sensing techniques for the most important domains of welfare and national security available, and it fosters and broadens them systematically.

- Switzerland is an international competitor in selected technological niches for the construction of ground based, airborne and spaceborne remote sensing systems.

- Switzerland contributes test sites in remote sensing due to its outstanding geodata sets with national coverage, its densely meshed ground-based observation networks and its topographic and natural variety.

Training, education and research

- Earth Observation is a required subject at secondary school level and contributes to all geoscience- and environment-related master's program at the university level, as well as teacher training.

- Swiss research groups are, and will continue to be, world players in fundamental Earth Observation research.

- The Swiss R&D community is active in key domains related to the sustainable development of the society (e.g. climate change, disaster monitoring).

Organisation and recognition of the EO community

- Attractive basic conditions and a considerable domestic demand create the conditions for the growth of existing value-adding industry and the formation of new spin-offs.

- All Swiss actors from research and development, hardware and value-adding industry, federal offices and education entities are well linked, within Switzerland and internationally.

- Thanks to clear demonstration of the scientific, political, social and economical benefits, there is broad acceptance of and support for the use of the Earth Observation data by policymakers and the general public.

International cooperation

- Switzerland is an important and acknowledged player when it comes to European and global EO initiatives relevant to our interests.

- The Swiss EO research and development groups, industry and the value-adding industry in particular are active and leading members of international scientific networks and consortia.

5 Recommendations

Switzerland has always been an active and proficient member of the different international organisations in Earth Observation (for instance ESA, EUMETSAT, etc.) and has contributed substantially to the collaboration among Member States. It is important to maintain this active involvement in the future by strongly supporting major steps towards better integrated Earth Observation systems and by facing the world's major challenges. These challenges include global change, natural disasters, water shortage and health threats. However, it will also be necessary to satisfy the Swiss users' needs by defending and improving the position of Swiss actors in science and industry. To achieve these goals, and to make the vision stated in the previous chapter reality, we have formulated the following five recommendations, and urge the responsible decision-makers to implement them without any delay.

Each major recommendation is explained and further structured into detailed recommendations. The addressees for each of these detailed recommendations are added in [brackets], with the understanding that this listing is not conclusive.

Recommendation no. 1
Identify relevant niche EO sectors and develop corresponding Swiss key expertise

Earth Observation has continuously grown into a business which needs international scientific networking, considerable funding, international agreements and markets to be handled in its entirety. Thus, Switzerland cannot do EO autonomously. However, Switzerland can qualify as a crucial international partner in EO, focussing on high-quality niches. We therefore recommend the following:

- to identify niches of key importance, based on the available expertise in Switzerland (SAR processing, hyperspectral analysis, atmospheric constituents analysis, radar meteorology, digital aerial cameras, etc.) and in domains of institutional user needs (e.g., alpine environment, glaciers, forestry, air pollution, humanitarian help, security) [scientific community, SKF, SED, IDA-Fern, GMES-IKAR, SGPBF].

- to focus research and application development on a limited but clear set of objectives tackling Switzerland's major interests for which EO plays a significant role [scientific community, SKF, SED, NPOC, SSO, SGPBF].

- to influence the programme contents of funding entities at national (SNF) and international level (ESA, EU, GEO) according to the defined niches and the key competences of Swiss actors [delegations to ESA, GAC, FP7, Foundation Council of SNSF, EUMETSAT].

- to submit competitive proposals addressing forward-looking scientific and industrial EO subjects [research institutes, SED].

- to keep track at all times of worldwide scientific and technological progress in order to be up to date concerning current EO developments [research institutes, SKF, SGPBF, NPOC]

Recommendation no. 2
Foster training and education, and increase the awareness to EO data and its applications

Swiss participation in dealing with urgent challenges of the changing Earth requires more concerted efforts in teaching Earth Observation. Should Swiss scientists be allowed to utilize today's EO systems, and be allowed to contribute to the development of tomorrow's, a special national effort in strengthening teaching and education at all levels, with a special focus on the university level is of utmost importance. From an economic point of view, scientific and technical skills have been the best selling Swiss product for decades. We therefore recommend the following:

- to increase the integration of Earth Observation in any geo-science and environment-related education at the secondary level, university level and teacher training and to permanently embed remote sensing into curricula [education directorates, principals, universities of applied sciences in teacher training, universities].

- to involve private companies and operational remote sensing data users in education and

joint applied research in order to assure the reference to reality [universities, SED, SSIG, SwissMem, SGPBF].

- to put strong emphasis on the development of key technologies for airborne and spaceborne EO instruments and platforms [SSO, SSIG, SwissMem].

Efforts are needed to increase the awareness of EO data and bridging the gaps between the different scientific communities using them. As a logical conclusion, scientists will be more aware of the benefits that EO data offer to their research, and at the same time EO experts will be attracted by the current needs of other communities. We therefore recommend the following:

- to strengthen the cooperation between remote sensing scientists, engineers, and Earth system scientists, such as climatologists, biologists, etc. in order to bridge the existing gaps between the different scientific communities [scientific community, SKF, NPOC, SGPBF].

- to attract new user groups through application development and to engage the public's interest [SKF, SED, NPOC, SGPBF].

- to inform decision makers about the benefits of EO for environmental mapping, monitoring and forecasting, security, intelligence, exploration, etc. [SED, scientific community, SKF, IDA-Fern, GMES-IKAR, CFAS].

Recommendation no. 3
Ensure observations according to users' needs, and make data easily available

Monitoring the environment is the basis for future social, economical and political decisions. Some spaceborne and airborne systems (such as Landsat, Meteosat, Envisat, air photo cameras, etc.) already provide relevant data. We therefore recommend the following:

- to encourage the long-term data continuity at appropriate spatial, spectral, and temporal resolutions [delegations to ESA, EUMETSAT, GAC, FP7, GEO, swisstopo].

- to make new technologies and data (multi-frequency, polarimetric SAR and hyperspectral data at high spatial and temporal resolution) available for Swiss users [NPOC, delegations to ESA, EUMETSAT, GAC, FP7, GEO].

- to participate in the programmes that will provide the required assured supply of data [SSO, MeteoSwiss, FOEN, swisstopo].

- to maintain and continue existing EO programmes [swisstopo, FSO, WSL, FOEN].

- to support the acquisition and maintenance of high-quality ground based datasets for calibration and validation [universities, industry, federal offices].

- to develop archiving services for digital and analogue data in parallel, either internationally or nationally [federal entities, e.g. swisstopo].

- to enhance the national competence for near-automatic analysis of the data sets [universities, industry].

- to assure that spatial and temporal resolution and delivery times are compatible with users' needs [delegations to ESA, EUMETSAT, GAC, FP7, GEO].

For applications to become operational, the price of EO data has to follow the approach of meteorological data more closely, which have traditionally been available at reasonable prices. We therefore recommend the following:

- to encourage efforts for disseminating EO data at low, even zero cost on an open-access basis [delegation to ESA, GAC, EUMETSAT].

Recommendation no. 4
Create and implement a national EO programme

The objective of a national EO programme is to strengthen the ability of Swiss actors from academia and industry on the European and global level in the competitive phase of research and development. The lack of a coherent Swiss EO pro-

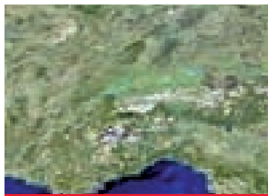
gramme has made it increasingly difficult to win contracts against competitors from other European countries who benefit from such programmes.
A national EO programme helps to identify areas where advancements are of high priority, to focus on problem-oriented research and helps to pool the resources of the government, industry and the scientific community. We therefore recommend the following:

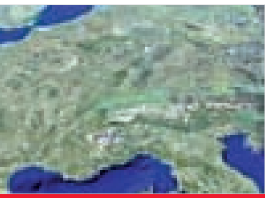
- to coordinate the Swiss EO research community and to bundle its knowledge, capacity, and its activities into a national EO programme [scientific community, SSO, IKAR, CFAS, SKF].
- to implement the Swiss EO programme as a complement to existing funding sources [SSO, IKAR, CFAS].
- to support hardware technology developments, methodological advancements as well as data exploitation activities by the Swiss EO programme [scientific community, SSO, IKAR, CFAS, SSIG, SED].

Recommendation no. 5
Intensify international cooperation

Switzerland can pursue only little of the potential avenues of EO on its own. To optimise benefits for Switzerland, we must contribute our share to international endeavours and, hence, gain access to relevant programmes and bring in our potential and needs in a sustainable manner. Agreements with carefully chosen and balanced partners (international and national organisations, industry, user groups, scientists) improve the return on Swiss investments. Key changes in the regulatory framework at the European level and commitments to international treaties such as the Climate Convention and its Kyoto Protocol, provide a policy framework and will drive EO-based services tailored to Switzerland. We therefore recommend the following:

- to relate and coordinate Swiss EO policy with the Swiss and European space policies and relevant national policies of selected European states [SSO, IKAR, CFAS].
- to continue actively participating in relevant international programmes, and to shape these programmes as far as possible according to Swiss interests (e.g., ESA EO programmes, EUMETSAT programmes, EU/FP7, etc.) [delegations to ESA, EUMETSAT, GAC, FP7, GEO].
- to enable bi- and multilateral collaborations in selected domains of Swiss interests [scientific community, SSO, IKAR, CFAS, SED; SwissMem].





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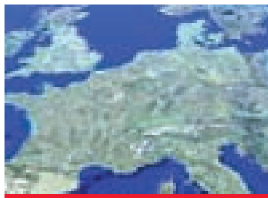
9 Verne, Jules, 1865: De la Terre à la Lune

10 Verne, Jules, 1869: Autour de la Lune



II. LIST OF ACRONYMS AND ABBREVIATIONS

AFG	Administrative and Finance Group
ALOS	Advanced Land Observing Satellite (Japan)
APEX	Airborne Prism Experiment (airborne imaging spectrometer; Switzerland and Belgium, on behalf of ESA)
ART	Agroscope Reckenholz-Tänikon research station
AQUA	Global climate EOS satellite with an emphasis on water, in A-train constellation (USA)
ASL	above sea level
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer on TERRA
A-Train	Afternoon satellite constellation of AQUA, CLOUDSAT, CALYPSO, AURA, PARASOL (USA)
AVHRR	Advanced Very High Resolution Radiometer (USA)
AVNIR-2	Advanced Visible and Near Infrared Radiometer type 2 on ALOS
AURA	Atmospheric chemistry satellite in A-train constellation (USA)
BIRD	Bispectral Infra-Red Detection Satellite (Germany)
CALYPSO	Spaceborne Lidar satellite in A-train constellation (USA)
CEOS	Committee on Earth Observation Satellites
CERES	Clouds And The Earth's Radiant Energy System on TERRA
CGMS	Coordination Group for Meteorological Satellites
CFAS	Commission fédérale pour les affaires spatiales (see EKWF)
CLOUDSAT	Cloud profiling radar satellite in A-train constellation (USA)
COP	Conference of the Parties
COSMO-SKYMED	Constellation of Small Satellites for Mediterranean basin Observation (Italy)
COST	European Cooperation in the field of Scientific and Technical research
DDPS	Federal Department of Defence, Civil Protection and Sport
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DOSTAG	Data Operations Scientific and Technical Advisory Group of PB-EO
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
EEA	European Environment Agency
EKWF	Eidgenössische Kommission für Weltraumfragen (Federal Space Affairs Advisory Commission)
Empa	Swiss Federal Laboratories for Materials Testing and Research
ENVISAT	European Environmental Satellite (ESA)
EO	Earth Observation
EOS	Earth Observing System of NASA (several EO satellite systems)
EPFL	Ecole Polytechnique Fédérale de Lausanne (Federal Institute of Technology Lausanne)
EPS	European Polar System
ERA	ECMWF Re-Analysis
ERS	European Remote Sensing Satellite (ESA)
ESA	European Space Agency
ETHZ	Eidgenössische Technische Hochschule Zürich (Federal Institute of Technology Zürich)
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUMETNET	Economic Interest Group of most European Weather Services
FHNW	Fachhochschule Nordwestschweiz (University of Applied Sciences Northwestern Switzerland, Muttenz)
FOAG	Federal Office for Agriculture
FOEN	Federal Office for the Environment
FP7	Seventh Framework Programme of EU
FRP	Framework Research Programme
FSO	Federal Statistical Office

GAC	GMES Advisory Council
GCOS	Global Climate Observing System
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of Systems
GMES	Global Monitoring for Environment and Security
GPM	Global Precipitation Measurement
GPS	Global Positioning System
HEIG-VD	Haute école d'ingénierie et de gestion du canton de Vaud (university of applied sciences Western Switzerland, Yverdon)
IAP	Institute for Applied Physics, University of Bern
IDA-FERN	Interdepartementale Arbeitsgruppe Fernerkundung (Interdepartmental Working Group Remote Sensing)
IKAR	Interdepartementaler Koordinationsausschuss für Raumfahrtfragen (Interdepartmental Coordination Committee for Space Issues)
ISPRS	International Society for Photogrammetry and Remote Sensing
ISSI	International Space Science Institute, Bern
JAXA	Japan Aerospace Exploration Agency
LIDAR	Light Detection and Ranging
MCR	Meteorology, Climatology and Remote Sensing
METEOSAT	Meteorological Satellite of EUMETSAT
MeteoSwiss	Federal Office of Meteorology and Climatology
METOP	Meteorological Operational satellite (EUMETSAT)
MISR	Multiangle Imaging Spectro-Radiometer on TERRA
MODIS	Moderate Resolution Imaging Spectroradiometer on TERRA and AQUA
NASA	National Aeronautics and Space Administration (USA)
NOAA	National Oceanic and Atmospheric Administration (USA)
NPOC	National Point of Contact for Satellite Images
NWP	Numerical Weather Prediction
ODIN	Odin satellite of the Swedish Space Cooperation
OPERA	European Weather Radar Network
PAC	Policy Advisory Committee
PALSAR	Phased Array type L-band Synthetic Aperture Radar on ALOS
PARASOL	Aerosol detecting satellite in A-train constellation (USA)
PB-EO	Programme Board Earth Observation of ESA
PRISM	Panchromatic Remote-sensing Instrument for Stereo Mapping on ALOS
R&D	Research and Development
RGB	Red Green Blue
RS	Remote Sensing
RSRG	Remote Sensing Research Group Bern, University of Bern
RSL	Remote Sensing Laboratories, University of Zürich
SAF	Satellite Application Facility
SAR	Synthetic Aperture Radar
SCNAT	Swiss Academy of Sciences
SCRS	Swiss Commission for Remote Sensing
SCSR	Swiss Commission on Space Research (Schweizerische Kommission für Weltraumforschung)
SDC	Swiss Agency for Development and Cooperation
SED	Gesellschaft der Schweizer Erdbeobachtungs-Dienstleister (Swiss Earth Observation Service Providers Society)
SER	(Swiss) State Secretariat for Education and Research
SGPBF	Schweizerische Gesellschaft für Photogrammetrie, Bildanalyse und Fernerkundung (Swiss Society for Photogrammetry, Image Analysis and Remote Sensing)
SKF	Schweizerische Kommission für Fernerkundung (see SCRS)
SLF	Eidgenössisches Institut für Schnee- und Lawinenforschung, Davos (Swiss Federal Institute for Snow and Avalanche Research)

SNSF	Swiss National Science Foundation
SPOT	Satellite Pour l'Observation de la Terre (France)
SSIG	Swiss Space Industry Group
SSO	Swiss Space Office (Space Affairs Division of the SER)
STG	Scientific and Technical Group
STG-OPS	STG Operations Working Group
STG-SWG	STG Science Working Group
SwissMem	Swiss Mechanical and Electrical Engineering Industries
swisstopo	Swiss Federal Office of Topography, Wabern
TC	Technical Commission
TERRA	Global climate EOS satellite with an emphasis on Earth, (USA)
TERRASAR-X	German X-band satellite
TRMM	Tropical Rainfall Measuring Mission (NASA, USA)
UAS	Unmanned Aerial System
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	UN Framework Convention on Climate Change
UZH	University of Zurich
WMO	World Meteorological Organisation
WMO SAT	Space Program of the WMO
WRC	World Radiation Center, Davos
WSL	Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft (Swiss Federal Institute for Forest Snow and Landscape Research, Birmensdorf)