Space Applications for the Polar Regions – An Overview

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Abstract

It is beyond dispute now that global warming is especially tangible in the poles. It leads to new challenges and opportunities in the Arctic. In the Antarctic, even if economic activities are banned, the threat to the ecosystem exists, and security and safety of research has to be ensured, as well as the ones of the tourists that are more and more tempted to visit this continent.

Both the Arctic and the Antarctic feature large, remote areas with limited accessibility, low population densities, and harsh living conditions. As needs for more observations, reliable communications and navigation means increase, space systems now provide an increasing part of the solution.

Space systems have the potential to support more and more enhanced monitoring of the Polar regions, telecommunications, navigation or security and the Agency's programmes provide already a significant contribution to e.g. ice monitoring.

The European Space Agency is currently analysing the issues at stake and possible extensions to its current programmes, such as Navigation, Earth observation and Telecommunication programmes, including the necessary technology developments and international cooperation where feasible. The status of the analysis and proposed activities will be presented.

I. Introduction

Both the Arctic and the Antarctic feature large, remote areas with limited accessibility, low population densities, and harsh living conditions. As needs for more observations, reliable communications and navigation means increase, space systems will provide an increasing part of the solution.

With satellites on orbits compatible with a view on the Arctic and Antarctic regions (polar or highly elliptical orbits), space systems have the potential to support more and more enhanced monitoring of the Polar regions, telecommunications, navigation or security and the Agency's programmes such as ENVISAT in

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the near past, now Cryosat or SMOS, and soon the Sentinels, provide already a significant contribution to e.g. ice monitoring.
At the service of its Member States, the European Space Agency (ESA) has put in place a "Space for Earth" initiative at corporate level aiming at identifying and supporting in a coordinated way "earthly problems and concerns where space systems can be an efficient tool. Themes concerned today include energy, oceans and the poles, and new themes are under consideration. For each theme, a review of the existing ESA programmes supporting it, directly or indirectly, is performed, and complemented by the analysis of the concern and needs of the actors of the sector. This allows then to improve the communication (in particular via dedicated web pages under construction at <www.esa.int/Our_Activities/Preparing_for_the_Future/Space_for_Earth>) on the support provided and existing programmes and to define potential future programmes and activities that will answer some of those concerns and needs. This can concern all ESA programmes, such as Navigation, Earth observation, Telecommunication or Human Spaceflight programmes, including the necessary technology developments and international cooperation where feasible.
This paper will present the status of the analysis and proposed activities concerning the Poles.

II Context

It is beyond dispute now that global warming is especially tangible in the poles. Mean temperatures at the North pole increase faster than elsewhere and many effects can already be observed, such as the reduction of thickness and extent of summer sea ice in the Arctic, with records measures from satellite nearly every summer, or the melting of the permafrost. These changes lead to new challenges and opportunities, which range in the North from the confirmed opening of new maritime routes, the threat to fragile ecosystems and the traditional life of the native inhabitants, to greater use of natural resources. In the Antarctic, even if economic activities are banned, the threat to the ecosystem exists, and security and safety of research has to be ensured, as well as the ones of the tourists that are more and more tempted to visit, mainly by boat, this continent.
With an increasing attention from the European Union to the Arctic (see Communication JOIN(2012)19 final), with a conference held under the Danish presidency of the EU in 2012 (follow-on of a conference held in 2009 under the Swedish Presidency of the EU), and the performance at ESA of a study on the "Contribution of Space Technologies to Arctic Policy Priorities", with the planned development of the cooperation activities with the European Polar Board in the Antarctic, the European Space Agency is currently analysing how it can answer to help solving the issues at stake via applications of its existing programmes or possible extensions or new programmes.

III Political Context

Some recent elements confirm the growing importance in particular of the Arctic region for an increasing number of countries and organisations:

- The access in May 2013 as observers to the Arctic Council of China, India, Italy, Japan, the Republic of Korea and Singapore
- The repeated request by the EU to the Arctic Council to be granted the status of observer – this made progress at the last meeting of the Arctic Council and is now conditioned by some political answers to concerns expressed by Council Members
- The publication in 2012 by the EC of a communication on the Arctic (JOIN(2012)19 final) with 2 associated documents, one of which on space and the Arctic prepared with the support of ESA – the two EU flagship programmes, Galileo et Copernicus, being major assets for the implementation of its policy
- The organisation end of August 2013 of an "Arctic Business Round Table" preparatory workshop with political and industry decision-makers assessing whether and how such a round table would serve business needs and contribute to achieve political objectives of a sustainable development of the Arctic Region and People
- The Arctic Council Agreement on "Search and Rescue in the Arctic" in May 2011.
- The Arctic Council "Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic" in May 2013
- Numerous visits of ministers of non-Arctic Asiatic states to Arctic States to discuss Arctic issues and business opportunities
- Recognition that important oil and gas reserves exist in the Arctic region, with drilling costs more and more affordable with the increase of the price of fuel

The growing importance in national policies of the Arctic has also been confirmed by a study commissioned by ESA in 2012 on the "Contribution of Space Technologies to Arctic Policy Priorities".

IV Technical Evolution

The implementation in particular of the Search & Rescue agreement of the Arctic Council will require means that are perhaps not available in the signatory countries, in particular for what concerns assistance to navigation, all-weather observation or communication.

The Galileo et Copernicus programmes in particular, as well as other ESA programmes, will provide important means to cover those needs. However, and as also confirmed by the ESA study on the "contribution of space technologies", high bandwidth communication means might not be covered by the existing or

planned commercial systems. This would also be a concern for the increase of the normal activities in the region, as well as for ensuring security & safety for the activities in the Antarctic.

V The Arctic

The 2009 Stockholm Arctic Conference

Development of European agreed space programmes will allow to meet some of the objectives identified in the Arctic conference held in 2009 under the auspices of the Swedish Presidency in Stockholm[1]:

- Measurements of sea-ice extent, useful for supporting human activities and monitoring climate change, would be assured through the Sentinel satellites of the Copernicus Space Component.
- Ice thickness measurements of multi-year sea-ice, important for climate change research, are made possible by the experimental satellite, CryoSat-2, launched in 2010. The altimeter on Copernicus Sentinel-3 would provide long-term monitoring of ice-thickness except for the highest latitudes.
- Earth Observation based services providing information for navigation on sea-ice, wave height and wind are being provided by European and Canadian national and private entities. A number of new services are also being tested under research programmes. However these are currently only covering discrete national areas of interest.
- Low and medium data rate communications should be assured through commercially-operated systems.
- Because of the low traffic density in the Arctic, effective monitoring of vessel traffic should be assured by present or planned commercially operated satellites carrying AIS receivers. Norway has since launched its first AIS satellite to be followed by two nore, and an AIS receiver has been installed on the International Space Station. However the fact that those present or planned tools is sufficient still needs to be checked.
- Earth Observation satellites provide essential information on climate variables such as sea ice thickness, extent and ice drift. However, sustained observations are required in order to make more effective numerical weather forecasts for safety at sea, and as a basis for robust forecasts of the impacts of climate change and increasing human activity in the Arctic region.

The 2012 'Space for the Arctic' Copenhagen Conference

The objectives of the Space for the Arctic'12 Conference, held during the Danish presidency of the Council of the EU were then to take stock of these reflections, in dialogue with third countries, to identify possible gaps and to explore future opportunities.

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1 Staff from the European Space Agency and the European Commission assessed jointly the recommendations of the Stockholm conference in the 2012 communication from the European Commission (JOIN(2012)19 final).

The Conference was addressed by Morten Østergaard, Danish Minister of Science and Innovation, and it gathered some 100 participants, among which the Danish and Swedish ambassadors to the Arctic Council, representatives from the European Commission, the European Environment agencies and experts from the Arctic region. In his address, the Minister highlighted the importance and uniqueness of space-based monitoring for the Arctic. He noted that Earth observation data products are playing an important role in climate change sciences, and derived services are contributing to a safer and more sustainable exploitation of the region.
The conference also evidenced a certain number of gaps to support the policies and commitments of Canada, European states and the EU in the Arctic and issued recommendations. The most salient ones are:

- The need to secure the Copernicus programme (then called GMES) to ensure continuity of observations, both for climate science and operational use of satellite data in the context of safe navigation, environmental monitoring and border control.
- The lack of high bandwidth communications required by sustained exploitation of the Arctic resources, maritime transport and emergency operations.
- High reliability navigation through the European Geostationary Navigation Overlay Service (EGNOS) will not be possible in the Arctic. Means such as the Galileo Arctic test bed[2] should be investigated.
- A scaling up will be required to meet the increasing demand for services supporting trans-Arctic vessel traffic and resource exploitation.

International collaboration and partnership will be fundamental to reach the objectives above.

ESA Study on 'Contribution of Space Technologies to Arctic Policy Priorities'

ESA also commissioned a study on the 'Contribution of Space Technologies to Arctic Policy Priorities' within the framework of its General Studies Programme. It aimed at supporting the development of a coherent Agency position towards Arctic issues, increasing the synergies among ESA programmes and preparing grounds for ESA programmatic proposal(s) relevant to the Arctic. The study matched an inventory of national and international policies with capabilities of existing or planned space systems. The study revealed a strong policy convergence on maritime transportation, sustainable development, environmental protection, search and rescue altogether with a potential strong contribution of space systems. Galileo and GMES programmes would be very relevant, with a potential gap in broadband communications and pan Arctic

2 The objective of the Arctic Testbed (started in May 2012 and lasting 2 years) is to develop, deploy and operate a testbed to support the demonstration of Satellite-Based Augmentation Services (SBAS) in the Arctic on the basis of EGNOS subsystems and other existing infrastructure deployed and operated in this region. The testbed will also support the definition phase of EGNOS Version 3 for what concerns extension of the coverage to the High North.

integrated services. The study has been completed in June 2012 and the results presented to ESA Member States.

Upcoming Studies

In order to identify applications that can already be developed from existing satellites, a study on "Improved Situational Awareness in the Arctic" has been launched in the frame of the ESA Integrated Applications Programme and the proposals received evaluated during the summer. It is aimed at investigating the role that existing space assets can play in the provision of the demanded services, including their technical feasibility and economic viability. Out of the many players with interest in the region, the Invitation To Tender focused on three main sectors: Oil & Gas, Shipping and Tourism. The selected studies will start soon.

Recognising the importance of telecommunications for the activity and security of the region, and taking into account the fact that high bandwidth communication might be missing, ESA is investigating the possibility to support a detailed analysis of those needs for the actors in the region, the potential answers that would be available on the market or being planned, and whether it could support the development of missing needs.

VI The Antarctic

Existing Cooperation

The Antarctic Treaty is a unique governance scheme that emphasises 'peace and science'; with some analogy with Space and its Outer Space Treaty. ESA interest in the Antarctic is focused on science and exploration and cooperation exist with the Franco-Italian Concordia base since more than 10 years.

The Director General of ESA and the Director of the French Polar Institute decided in 2011 to investigate whether cooperation between ESA and European Antarctic stations could be increased. A strategic workshop was thus jointly organised by ESA and the European Polar Board (EPB) in April 2012 to review the current state of the art and identify synergistic trends as well as a concrete way ahead. Several ESA Member States were represented by their polar institutes (Belgium, France, Germany, Italy, Portugal, Sweden, United Kingdom).

There are currently many individual activities that link Antarctic programmes to space activities, namely at the Franco/Italian Concordia station. however they are generally lacking an overall coordination and integration at the European and international level. There is a shared understanding that Concordia is a successful cooperation example that should be extended to other bases and/or extend cooperation in Concordia for other countries. By doing so a European approach could be put in place.

Potential for Further Synergies

The potential for synergies is quite large with interest and benefits on both sides:

- Activities include personnel recruitment, selection, training, performance and pre/post mission monitoring methods; physical countermeasures protocols (fitness exercising, nutrition guidelines), remote or on site medical assistance and psychological support (incl. training of medical doctors); technology validation such as water recycling, thermal control, energy production and storage, air and microbial contamination monitoring, green houses, etc. There is an interest to extend activities to sea-level stations and use winter stays at Concordia as full space mission simulation.
- There is a constant and even increasing need for long duration calibration and validation in stable sites for access to quality data and to define standards and for electromagnetic interaction and propagation for EO instruments and ionosphere monitoring, using for example inflatable structures for antennas. Access to ground stations is essential for in situ measurements, satellite data reception, retransmission via telecom satellites; monitoring astronomical geodetic reference frames for orbit characterisation and planetary travel.
- Improved satellite-based weather/ice forecasting is needed for increased efficiency and safety. Many data are already provided, via Polar View (ESA support is recognised here) but continuation should be ensured (with Sentinels). New data should be guaranteed such as sea-ice forecasts tailored to users.
- Space weather forecast, using direct measurements from Antarctica, can be improved if near-real time communications is available.
- Constant data for geophysical and climate research are needed for atmosphere thermodynamics combining space and ground observations, for ice sheet surface conditions and mass balance or outlet glacier flow and subglacial geology.
- Telecommunications and support services to navigation are needed to support logistics, safety and science (space data outbound). There is a need for large antennas and especially near real-time broadband information. Navigation and SAR needs higher precision in all weather conditions for aircraft and vessel tracking, sea ice monitoring, and link to COSPAS-SARSAT beacons.

Fields of Interest

Fields of interest for evaluation and selection of potential research proposals to be conducted at European Antarctic Stations or research vessels include:

- analogue studies between space and Antarctic environments (personnel recruitment, selection, training, performance and pre/post mission monitoring methods);
- physical countermeasures protocols (fitness exercising, nutrition guidelines);
- psychological and physiological adaptive processes to isolation, confinement and high altitude;
- remote or on site medical assistance and psychological support (incl. training of medical doctors);
- life support;
- habitability;

- radiation;
- weather/ice forecasting, space weather forecasting, climate research; and
- general survivability in hostile environments.

In addition, if there are identified needs for telecommunications, logistics, safety or security matters that could be covered/partly covered via satellite means, ESA could investigate whether its programmes (existing or planned) could be used or adapted.

Extension of Cooperation

Cooperation mechanisms for Antarctic activities do already exist at multinational level, but they are often limited in nature and scope. Although each national programme has its specific emphasis, common goals do exist such as to increase cooperative activities (e.g. the European Project for Ice Coring in Antarctica - EPICA) or emphasizing the human dimension of activities, due to the especially harsh and hostile environment. Recent financial pressures are an incentive for smarter cooperative work. For example in the field of exploration more stations can be made available, such as the Neumayer station III, but sharing resources would be needed.

EPB encompasses 22 countries, including Russia and Greenland. It uses a stepwise progression towards cooperation by interconnecting scientific priorities and strategies, including influence on EU programmes such as Horizon 2020. Managing big infrastructure projects is a common concern between EPB, national organisations and ESA.

It is currently being investigated to put in place the cooperation between ESA, EPB and Member States in form of a platform for information exchange, followed by specific projects implementation. An ESA/EPB arrangement is being discussed, that will define the working relations between the two organisations, and identify concrete immediate actions and long term opportunities.

VII Conclusions

The conference held in Copenhagen on the Arctic in 2012 confirmed the trend already seen in Stockholm in 2009. Recommendations for further work were issued, in particular about continuity of data (ever more after the end of the ENVISAT mission).

In the Antarctic, an agreement is being finalised with the European Polar Board to widen the cooperation between the space and the Antarctic research sectors and to set up an effective information exchange and cooperation platform.

Of particular relevance, both for the Arctic and for the Antarctic, high bandwidth communications is of specific importance to ensure safety and security of those in the area and good scientific return. Specific work is planned to analyse further the needs and define the potential system that would be needed.