NORWEGIAN NATIONAL REPORT – ARCTIC ACCESS TO SPACE

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ABSTRACT

Norway has long traditions as a space nation, much due to our northern latitude. Our space science activities are concentrated in relatively few areas. This concentration is necessary due to limited resources, both in funding and personnel. The main scientific activities are within Solar-terrestrial physics and cosmology.

The first field has been a priority since before the space age and is still the major priority. The usage of the ground infrastructure in Northern Norway and on Svalbard is essential in studying the middle and upper atmosphere and the interaction with the Sun. This includes the utilization of sounding rockets, both small and large, and ground based installations like radars, lidars and other optical instrumentation. The planned use of Svalbard as a launch site for large stratospheric balloons may allow the cosmology community access to our northern infrastructure. The solar physics community is also heavily involved in the HINODE and IRIS missions and Norway is supporting downlink of data via the Svalbard Station for these missions.

The sounding rocket program is in close collaboration with many countries like Germany, USA, France, Canada and Japan. Two scientific sounding rocket programs are currently being pursued: The ICI series (from Svalbard) and MaxiDusty (from Andoya). A series of scientific publications have recently appeared from the ECOMA campaign a few years ago.

A significant improvement of today’s polar and ionospheric research infrastructure in Northern Norway and Svalbard has recently been put on the ESFRI roadmap for European research infrastructure through the SIOS and EISCAT 3D initiatives. The Norwegian government has recently decided to upgrade the VLBI facilities at Svalbard.

1. HISTORIC PERSPECTIVES

The early aurora and solar research led to the establishment of the rocket range on the island of Andoya in North Norway, where the first Norwegian research rocket was launched in 1962. Researchers from numerous countries now utilize this rocket range in their studies of the northern lights and the Earth’s atmosphere and the facility is NASA’s most important launch facility for sounding rockets outside USA. More than 1000 rockets have been launched since 1962, the biggest being NASA’s 15 meter long Black Brant XII, with an apogee of up to 1500 km.

The solar observatory at Harestua north of Oslo was opened in 1957 and included several optical and radio telescopes. One telescope was dedicated to tracking satellites passing across the sky. These observations were made on a request from the US Air Force and this was Norway’s first connection to satellites.

Norwegian scientists participated in the solar telescope HRTS (High Resolution Telescope and Spectrograph) that flew on the space shuttle Challenger in 1985 and several times on sounding rockets. More recently they played a central role in the successful SOHO mission - a large satellite based solar observatory including 12 different telescopes and instruments launched in 1995, which is still operating. SOHO is a collaboration between ESA and NASA in which Norwegian industry provided equipment and services to the tune of 80 million Norwegian kroner.

Scientists at the Norwegian Defence Research Establishment (FFI) participated on Spacelab 1 flying onboard the space shuttle Challenger in 1983. They built the electron accelerator, which produced artificial aurora in space. Later Norwegian institutes participated in the European Space Agency’s Cluster mission, a «space fleet» of four identical satellites flying in formation through the Earth’s magnetosphere. The University of Oslo (UiO), The University of Bergen (UiB) and NDRE all delivered electronics and parts to three different instruments on Cluster.

NASA’s Polar satellite, launched in 1996, studied the aurora from space. UiB delivered important electronics to the PIXIE instrument taking images of the X-rays from the aurora. Scientists at UiB were also involved in data analysis and recently their results made the front page of the journal Nature.

2. OVERALL SPACE SCIENCE PRIORITIES

Due to its size and the resulting limited resources, Norway needs to concentrate efforts to compete with other space nations. Space related science in Norway can be divided into three major fields: research OF space, research FROM space and research IN space.

- “OF space”
  - Solar-Terrestrial physics (about 80%)
  - Cosmology
- “FROM space”

o Ocean monitoring
o Polar and climate research
o Science leading to needed applications

• “IN space”
o Plant physiology
o Human psychology
o Technology demonstrators

In this article the main focus is science OF space and the other fields will just be mentioned briefly. Science OF space includes space physics with the emphasis on the magnetospheric-ionspheric physics and processes in the neutral middle atmosphere at high latitudes. Solar physics and cosmology and life sciences with a focus on plant physiology are also included.

Norway is participating in ESA's Space Situational Awareness program. The Norwegian Mapping Authority is contributing to monitoring space weather effects on the ionosphere and degradation of positioning systems. Tromsø Geophysical Observatory is monitoring deviations in the Earth’s magnetic field. Kongsberg Spacetecc is involved in the Phase A Study for Space Weather part of the SSA program. They have a contract related to the architectural design of the Space Weather system, with responsibilities related to ground based sensors, services and the overall system architectural design.

3. SOUNDING ROCKET PROGRAM

3.1 Andoya Rocket Range

Andøya Space Center (ASC) provides sounding rocket and balloon operations from Norway. ASC was established in the 1960s as Andøya Rocket Range and more than a thousand sounding rockets have been launched from Andøya since the first lift-off in 1962. Due to the increased and diversified activities, as well as the need for a modernisation of the company profile, the name was changed to Andøya Space Center in 2014. Both subsidiaries, Andøya Test Center (ATC) and NAROM were included in the modernisation of the profile program as well. The sophisticated infrastructure includes a cluster of ground-based state-of-the-art instruments. The Norwegian Institute for Air Research (NILU), the Institute of Atmospheric Physics (IAP Kühlingsborn), ASC, the Norwegian Defence Research Establishment (FFI), University of Oslo, and eight other science groups from outside Norway run their instruments at ALOMAR (Arctic Lidar Observatory for Middle Atmosphere Research) and contribute to the running costs of the observatory. The instruments include four lidars, four atmospheric radars, and a number of passive instruments, such as an imaging riometer, all-sky camera, several spectrometers, microwave radiometers, and others. ASC has operated the observatory since 1994, celebrating its 20-years anniversary with a scientific symposium at ASC in 2014.

ASC offers the scientists the opportunity for in-depth studies of the Arctic atmosphere and ionosphere by both short- and long-term monitoring techniques which can be combined with in-situ measurements from rocket and/or balloons. The new Science Centre, located beside the ASC telemetry section, has replaced the former USOC and provides real-time monitoring of scientific parameters and other phenomena during operational campaigns.

ASC has recently ordered a new, mobile 23ft telemetry antenna to further enhance its telemetry services for NASA, DLR, JAXA and other customers. This procurement adds to the already fully updated ASC telemetry equipment featuring state of the art Cortex receivers, capable of 30Mb/s. Used together with the ATC telemetry, also of the same standard, ASC now is capable of serving the most demanding telemetry needs with a very high quality.

The high latitude location of ASC (69°N), north of the Arctic Circle, is favourable because it is close to the southern boundary of the Polar Vortex and lies within the nightside auroral oval. The infrastructure gives the scientists the opportunity to exploit these advantages; the physics, chemistry and dynamics in all atmospheric layers can be investigated, thus both climate change and space weather parameters can be monitored.

In the context of Space Weather Services, there are several relevant ground-based instruments located at Andøya. In particular, the ALOMAR Imaging Riometer for Ionospheric Studies (AIRIS) is important because it can monitor the ionosphere and its response to particle precipitation. An All-sky camera will monitor the aurora and the cluster of radars have the capability to monitor the mesosphere and lower ionosphere and

Figure 1. Andøya Rocket Range (ARS).

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provide information on electron density, meteors, turbulence, wind field and tides.

The ALOMAR observatory provides measurements of the troposphere to the lower thermosphere and includes profiles of temperature, total density, wind speed and direction, certain trace constituents such as Na and O₃, atmospheric gravity waves and their momentum flux. Several of the scientific parameters that are monitored play an important role regarding the space weather. ASC also has the knowledge and expertise to build sounding rocket payloads, which can be used to study parameters relevant to the understanding of space weather phenomena.

Sounding rockets could either be launched from Ny Ålesund (78.92°N, 11.93°E) on Svalbard (SVALRAK) or at Andøya (69.28°N, 16.01°E). At Andøya two launchers are capable of launching large rockets such as Black Brant XII up to more than 1600 km in altitude. At Ny Ålesund the launcher can launch rockets to altitudes above 1100 km while from Longyearbyen (78.25°N, 15.47°E) long duration balloons are launched up to altitudes between 30 and 40 km.

So far in 2015 (and end of 2014) four sounding rockets have been launched from ASC. NASA C-REX (Dec 2014), UiO ICI-4, DLR/IAP WADIS-2 and DOST/DLR HIFire 7. The NASA CAPER rocket was scheduled for launch in Dec. 2014, but due to problematic weather and science conditions, this mission had to be moved to Dec. 2015. This will make 2015 a year with three NASA launches form ASC NASA CARE-2 (Bernhardt), NASA RENU-2 (Lessard) and NASA CAPER (LaBelle). In addition to this, the first launch of the NAMMO 28 kN hybrid rocket motor – NUCLEUS, is scheduled for September.

The NUCLEUS, which will serve as the basic building block for the North Star series of rocket motors, has been undergoing full scale static testing at NAMMO’s new hybrid test center at Raufoss since mid-2014. The NUCLEUS will serve as the second stage on two stage rockets from ASC, and will be complemented by the a bigger version – the AURORA booster, which will consist of a cluster of 4 NUCLEUS motors. The AURORA is expected to be ready for test in 2016, providing ASC and associated scientists with a hybrid, controllable and environmentally friendly alternative to the Brazilian S-30 booster and US Improved Orion.

3.2 ICI Rocket Programme

The ICI-series of rockets is a space weather mission. There is an increasing demand for scintillation forecasts in the polar caps. For Norway this is due to an increasing amount of activities in the high north relying on communication and high precision GNSS signals (offshore and opening of the northern sea route). With the ICI-series of rockets, the University of Oslo aims to study instability processes in connection with auroras, high speed plasma flow channels and polar cap patches, and in particular to quantify growth rates and to characterize electron plasma structures associated with these instabilities. The ICI-rocket program delivers building blocks for space weather scintillation models.

The ICI rocket program takes advantage of the total Hotel payload services developed Andøya Rocket Range where the scientists only take care of preparing their own instruments and tell when science conditions are met for launch. This is cost effective approach that increases the change to revive a sustainable Norwegian sounding rocket program. The ICI payload is optimised to perform high resolution measurements of the electron plasma structures, down to meter scale, and it is equipped with an electron particle spectrometer that can resolve the thickness of magnetic field-aligned electron beams down to –meter resolution, i.e. down to an electron gyro radius which is thinnest thinkable structure which has not been measured before!

Figure 2. Artist concept of future ICI-4 (T. Abrahamsen, ASC)

ICI-2 was successfully launched from Ny-Ålesund in 5 December, 2008. It intersected 3 regions of HF radar backscatter targets. With UiO’s new concept Langmuir probe system it measured absolute electron density at 5.7 kHz resolution, and for the first time it resolved decametre HF backscatter irregularities.

ICI-3 was launched from Ny-Ålesund in December 2011. The ICI-3 payload consisted of several instruments with contributions from University of Oslo (UiO), Japan Aerospace Exploration Agency/Institute of Space and Astronautical Science (ISAS/JAXA) and Laboratoire de Physique des Plasmas (LPP). University of Alberta, Canada contributes to the payload.
instrumentation of ICI-4 that will be launched in December 2013. As illustrated in Figure 3 the ICI-5 rocket planned for December 2016 will include three or more sub payloads.

3.3 MUDD/MAXIDUSTY Rocket Programme.

The aim of the MAXIDUSTY (MXD) programme at the University of Tromsø, in cooperation with the University of Oslo, is to enhance our understanding of key physical and chemical processes in the Earth’s mesosphere and of its coupling to other atmospheric regions. The project represents a continuation of the Norwegian rocket programme on the mesosphere, including the rocket projects TURBO, TURBO/DUSTY, MINIDUSTY, MIDAS, ROMA, and ECOMA. The MXD project has a particularly strong emphasis on the investigation of dust and aerosol particles, their structure and composition, compared to earlier mesosphere projects. The investigations will involve the launch of rocket payloads from Andoya Rocket Range, Norway. The first launch in this programme (MXD-I) will be in July 2016, after some delays due to motor problems. This launch will contain 11 different experiments with 6 aimed at measuring dust composition, number density, sizes and charges. There are two new instruments, the MUDD (Multiple Dust Detector, built by University of Tromsø - UiT) to measure the fragments produced by impacting icy particles near the mesopause and a mass spectrometer ICON (UiT) which will focus the ice particles into a collection/evaporation chamber which will be opened to a mass spectrometer just below a NLC or PMSE cloud. ICON will then look for elements besides water vapour, for example meteoric metals. A single MUDD was launched in 2011 from Kiruna, on the Swedish rocket PHOCUS. MXD-1 is planned to contain several daughter payloads to be released below the NLC/PMSE clouds, in addition to several plasma detectors and a photometer.

Instruments for a second MXD-2 is being constructed. It will contain most of the instruments that MXD-1 carries and in addition there will be a new instrument MESS (Meteoric Smoke Sampler - UiT). It works on the much the same principle as ICON, where icy particles are channelled by a funnel into a collection chamber which will be opened below and closed above the NLC/PMSE layers. The NLC icy particles are expected to contain a large amount of meteoric smoke particles (MSP) embedded in them, and we expect that when the ice evaporates the MSP will remain. MESS will be recovered and the collection chamber inspected for MSP. The results will be compared with a dummy collection chamber which will also be launched but remain closed during the flight.

4. AURORA RESEARCH

The old Aurora Station in Adventdalen at Svalbard was built in 1978 but was in recent years outdated and hampered by increasing light pollution from Longyearbyen. The new Kjell Henriksen Observatory was opened in 2008 and is the largest of its kind with a gross total area of approximately 700 square meters, which includes a service section of approximately 200 square meters floor space.

Figure 4. Kjell Henriksen Observatory at Svalbard was opened in 2008 (KHO)

The instrument section contains 30 instrument rooms with domes. During the auroral winter season from November to the end of February, 25 optical instruments operate 24 hours a day. The 10 non-optical instruments run all-year-round 24 hours a day. 21 different institutions from 9 nations were present at
KHO in 2014. KHO also serves as the main laboratory for hands on training and teaching of students in the Space Physics group at UNIS.

The main task of KHO is in general to study processes associated with the Magnetospheric cusp and its connection to the Sun-Earth environment. The dayside aurora gives an open window to processes on the Sun and how they interact with our upper atmosphere. Studies of phenomena such as airglow and aurora are therefore essential for understanding how energy is transported into the Magnetospheric Clefts down the whole vertical column of the atmosphere, and how it on a larger scale contributes to the climate. KHO was a central part of the Cusp Region Experiment (C-REX), a NASA sounding rocket mission that released a large constellation of artificial clouds into the ionosphere over the Greenland Sea. The rocket was launched from Andoya Space Center on 24th of November 2014.

Each instrument at KHO has its own scientific task and objective listed at the observatory’s own home page: http://kho.unis.no.

5. BIRKELAND CENTRE FOR SPACE SCIENCE

The Birkeland Centre for Space Science (BCSS) is a centre of excellence that was established in 2013 to tackle a broad range of scientific topics. It is located at the University of Bergen in collaboration with NTNU and UNIS. It will strengthen the international position of the Norwegian space physics community by making significant progress on compelling science questions. The primary objective for the centre is to understand How is the Earth coupled to Space? This includes understanding when and why the aurora in the two hemispheres are asymmetric, better understanding of the ionosphere, the effects of particle precipitation on the atmospheric system, and the role of energetic particles from thunderstorms in geospace.

![Fig. 5. ASIM will detect terrestrial gamma ray burst from the International Space Station (DTU Denmark).](image)

BCSS will maximize the utilization of existing Norwegian infrastructure at Svalbard, Northern Norway as well as our large investments in Cluster and ASIM. It will also strengthen and expand UiB’s capability to develop and build state-of-the-art instrumentation for space. Furthermore it will contribute to educate and position the next generation of Norwegian space physics scientists through an ambitious educational and public outreach components.

6. TROMSØ GEOPHYSICAL OBSERVATORY

Tromsø Geophysical Observatory (TGO), is a small unit under the Faculty of Science and Technology at UiT – the Arctic University of Norway. The unit exist to continue and ensure the quality of the long time series of geophysical measurements performed in Northern Norway since the establishment of the Haldåe observatory (1916) and the Auroral Observatory (1928).

TGO operates a network of 15 magnetometers in mainland Norway and Norwegian areas in the Arctic. Three of them - Bear Island, Tromsø and Dombås - are geomagnetic observatories, the remaining are stable variometers with less accurate absolute calibration aimed to serve ionospheric physics and monitoring magnetic field variations for space weather purposes. Data from he stations are included in the IMAGE and SuperMAG databases.

Near real time data can be found at [http://flux.phys.uit.no/geomag.html](http://flux.phys.uit.no/geomag.html) where they are displayed along with corresponding data from Finland, Denmark, Greenland, Alaska, Canada and Russia.

Additionally, TGO is operating an ionosonde near Tromso; this instrument represents one of the world’s longest time-series of ionospheric electron density soundings dating back to 1934. TGO also operates three meteor radars (jointly with Japanese institutions) at Tromsø, Alta and Longyearbyen, an MF radar (with Japan and Canada) at Tromso, the SOUSY MST radar and an imaging riometer (with Denmark) in Longyearbyen. Recent new operations include single-beam riometers in Ny-Ålesund and Skibotn. TGO is also contributing to the operation of a sensitive, multispectral all-sky imager owned by UiO at Skibotn.

7. SPACEWEATHER SERVICES

7.1 Ionosphere monitoring service “seSolstorn”

The Norwegian Mapping Authority (NMA) has developed a publicly accessible service that displays an overview of the state of the ionosphere, as viewed from a GNSS perspective, in real-time. The service is primarily intended for users of the positioning service
CPOS, but is open to everyone. The main parameters are the total ionospheric electron content (TEC) and the Rate-Of-TEC Index (ROTI), which is a measure of ionospheric turbulence level. These parameters are related to errors in GNSS positioning. The service can be accessed at http://sesolstorm.kartverket.no/.

7.2 Ionosphere monitoring service at ESAs space weather portal

As part of ESAs Space Situational Awareness program, the NMA has developed a service of the same kind as that described in the previous paragraph, but with additional products available. The additional data products are scintillation maps, and data files for all types of data displayed. The service is currently accessible at http://swe.ssa.esa.int/web/guest/rim-federated. It requires the user to log in to the ESA space weather portal system. The only requirement for getting an account is that a valid email address is needed.

7.3 A service Supporting Resource Exploitation System

As part of the ESA SSA program preparatory phase project Provision of Space Weather Additional Services (SN-VI) led by Rhea Group, TGO and the NMA have developed a Service Supporting Resource Exploitation System Operators (RESSOS).

The RESSOS service provides near real-time information about geomagnetic disturbances which primarily affect directional drilling and aeromagnetic surveys, and ionospheric disturbances which primarily affect GNSS-based services. The RESOSS service provides these two independent service components as parts of a single service. RESOSS will be aimed at a broader user base, and introduces existing end users of the detailed service components to additional, available and related service components, which should be of interest and benefit to them.

7.4 The Norwegian Center for Space Weather

TGO has for many years supported the oil industry with real-time magnetometer data during directional drilling operations on the Norwegian continental shelf. The experience from this type of space weather related activity has gained TGO the role of Expert Service Center coordinator for geomagnetic conditions within the ESA Space Situational Awareness (SSA) program. TGO currently participates in many activities within this program. In light of the above and the increasing awareness of space weather in non-scientific areas as well as the increasing commercial activity in the auroral zone/Barents Sea, the Norwegian Center for Space Weather (NOSWE) was established as a unit under TGO during summer of 2014. The Norwegian Space Center is supporting the development of the center, which will be built around a physical forecasting room from where space weather will be monitored and forecasts issued. The main purpose of NOSWE is to act as a tool to enhancing Norwegian abilities to participate in the ESA SSA program, to be a national source for information and knowledge about space weather hazards and to provide means towards mitigation of these. An important aim of NOSWE is to establish contact with national directorates, industries and other activities that are vulnerable to or dependent on space weather, ranging from search and rescue and offshore drilling operations to the tourist industry and the amateur radio community. Already, collaboration with Norwegian power grid company, Statnett, is underway to increase preparedness for major space weather events.

8. GEODETIC RESEARCH

The Space Geodetic Research Facility of the Norwegian Mapping Authority in Ny Ålesund, Svalbard, is part of an international network of stations, which is crucial for society’s satellite-based infrastructure and provides the basis for accurate climate monitoring in the far north. The observatory is the northernmost facility of its kind, and maps movements in the Earth’s surface, planetary rotation, and the Earth’s position in space. The Norwegian government appropriated funds for a new geodetic observatory with new technology in its revised national planning budget for 2012. Construction of the new geodetic observatory is under way after the first pile was driven in the autumn of 2014. The new observatory is due to be completed in 2018.

Figure 6. The VLBI antenna in Ny Ålesund, Svalbard
(Photo: Bjørn-Owe Holmberg)

The upgraded observatory will combine several geodetic measuring techniques - very long baseline interferometry (VLBI), satellite laser ranging (SLR), global navigation satellite systems (GNSS) – including
GPS – and Doppler orbitography and radio positioning integrated by satellite (Doris), based on the standard set by the global geodetic network. Norway’s Uninett group has laid fibreoptic cables on the seabed between Longyearbyen and Ny–Ålesund. This link is important for the research community at the latter site. The cables were in operation for the first time on 9 May 2015. With this fibreoptic link, the Norwegian Mapping Authority will be able to transmit real-time data from its new observatory to such recipients as NASA in the USA and the international geodetic research network.

9. SOLAR RESEARCH

The solar research environment blossomed early in Norway and today Norway has one of the strongest solar research groups in the world. Today observations of the sun are carried out from large international observatories as well as from satellites. Norway is currently involved in the SOHO mission and the Japanese solar satellite Hinode. Data from the satellite are downloaded at the Svalbard archipelago and a European data centre at the University of Oslo is processing the raw material making it accessible for the entire European science community.

In addition Norwegian scientist are involved in NASA’s Solar Dynamics Observatory (SDO) launched in 2010. SDO is a super-telescope taking images with four times higher resolution than HD-TV quality every 10 seconds, transmitting 1500 Gb of data every single day. The NASA solar mission IRIS (Interface Region Imaging Spectrograph) was launched in June 2013 with a significant Norwegian contribution in modeling of the solar atmosphere as well as providing downlink of data via the Svalbard Satellite Station.

What has become increasingly clear is that a proper utilization of high quality satellite data requires extensive numerical modelling. This is needed in order to make the connection between observed quantities such as spectral lines and the physical conditions in the radiating atmosphere. The solar physics group in Norway has built up a considerable expertise in this area and is now, as one of the first groups in the world, producing three-dimensional models of the solar atmosphere, from the convection zone to the corona. These models include enough of the relevant physics so that synthetic observations from them can be compared directly with observations.

10. COSMOLOGY AND ASTRONOMY

A small cosmology group has existed at the University of Oslo since the 1960’s, but in the last decade it has grown to become an internationally leading research group. Presently the most important research subject is the Cosmic Microwave Background, the group emphasizes the closest interaction between analysis of data from experiments and fundamental theory to further the understanding of the Universe.

The last decade has seen an enormous growth in cosmology, making it a leading branch of both astronomy and physics. While cosmology until one or two decades ago was a data-starved science, the opposite is the case today. The wealth of new data coming out of new large space- and ground-based experiments has made cosmology a data-rich science where one poses detailed questions and where simplified models are no longer sufficient. Already with NASA’s Wilkinson Microwave Anisotropy Probe (WMAP), large classes of cosmological models are today ruled out, and a concordance model has been established.

The cosmology group concentrates its activities on The cosmology group concentrates its activities on studies of the cosmic microwave background through ESA’s Planck mission and until recently the ground based QUIET experiment, and theoretical cosmology, concentrating on inflationary physics and on models that can explain the mysterious observed acceleration of the expansion of the Universe. The group’s studies of large-scale anisotropies in the cosmic microwave background have caught world-wide attention. About 20 people at the University of Oslo have been involved in analyzing the first results from Planck. The initial cosmological results from Planck were released in May 2013, and the UiO group had contributed strongly to separation of components, estimation of power spectrum, measurements of gaussianity of the fluctuations and of large-scale anisotropies.
11. SPACE EXPLORATION

Svalbard offers a unique variety of geological sites in an Arctic desert environment perfectly suited for planetary exploration. Mars analogue activities have been ongoing since 1997 when rocks in the Bockfjord Volcanic Complex (BVC) were discovered to be identical to the Martian meteorite ALH84001. The Arctic Mars Analog Svalbard Expedition project (AMASE) was initiated by Norway in 2003 and is funded by ESA and NASA to develop and test instruments onboard “Search for Life” missions to Mars including Mars Science Laboratory, ExoMars and Mars Sample Return. AMASE also provides training for mission scientists and engineers as well as field-testing of astronaut suits and robotic platforms and plays an important role in fostering collaboration between ESA and NASA teams.

Fig. 8. NASA’s Mars rover and space suits being tested at Svalbard (AMASE)

The Norwegian Defence Research Establishment (FFI) developed and tested a prototype of the WISDOM georadar for the ESA ExoMars mission. WISDOM will chart ice, water and rocks to a depth of three meters on Mars and is being field tested on AMASE. FFI is now developing the ground penetrating radar RIMFAX for NASA’s Mars 2020 rover mission. FFI was also responsible for the CAPS instrument designed to study plasma processes onboard the Cassini mission. The University of Bergen delivered components to the SIR-2 infrared spectrometer on the Indian Chandrayaan-1 lunar mission.

12. INTERNATIONAL SPACE STATION

The International Space Station (ISS) also contains a mini-greenhouse (EMCS - European Modular Cultivation System) with a number of plant cultivation chambers developed by Prototech in Bergen in collaboration with the Plant Biocentre at the Norwegian University of Technology and Sciences (NTNU) in Trondheim. They cost 500,000 NOK apiece and can safely be said to be Norway’s most expensive flowerpots. All experiments in this mini-greenhouse are controlled and operated from the Norwegian User Support and Operation Centre at the Plant Biocentre. Everything - water, nutrients, light, temperature - are controlled by commands from this center. The first Norwegian experiment on the ISS called MULTIGEN-1 was performed in 2007 and the scientists are very satisfied with the results. One of the major results obtained solved a problem that has been a challenge since Charles Darwin asked the question about gravity and plant movements as they grow; Are circulations in plants dependent on gravity or will internal control mechanisms in plants also participate? The results from the ISS show clearly that both factors are required.

Figure 9. The Norwegian User and Operation Centre for plant research on the International Space Station.

The Oslo branch of the research and technology group SINTEF has developed the Multi-Component Trace Gas Monitor (ANITA) to monitor air quality on the International Space Station (ISS). The instrument was launched in 2007 on the space shuttle to detect whether the air might contain gases potentially hazardous to the astronauts. The instrument can trace gasses no other previous systems on ISS could detect. Only ANITA detected a leak in the cooling system in 2007. The possibility of an operational instrument for the Space Station and in preparation of possible future missions, ANITA 2, is under discussion.

The University of Bergen is one of the key participants in the ASIM instrument currently being built for the International Space Station for observation of transient effects such as sprites, elves and blue jets. ASIM (Atmosphere- Space Interaction Monitor) is scheduled for launch in 2016/2017.

NORAIS-2, the second generation AIS receiver for the International Space Station, was successfully integrated on ISS in February 2015. The NORAIS-1 receiver has been successfully brought back to Norway for technical inspection and will be a valuable space-historic artefact.
13. ACCESS TO SATELLITE DATA

Norway has since the early 1980 been active in development of satellite based services for Marine situational awareness including oil spill - ship and ice detection. The services are primarily based on data from polar orbiting radar satellites. This near real time operational services is used world-wide among others by the European Maritime Safety Agency. The services are being developed through various national initiatives and offered commercially by Kongsberg Satellite Services (KSAT). KSAT also owns and operates the world’s largest station for satellites in polar orbits (KSAT SvalSat) located at Svalbard Norway. Combined with the other KSAT ground stations daily contacts are made to about 100 satellites using more than 70 antennas. Important Norwegian antenna installations are also located in Tromsø and at the Troll Station (TrollSat) in Antarctica. All the major space agencies are using Norwegian ground stations, including ESA, NASA and JAXA science missions and ensures easy access to high quality science data for Norwegian scientists.

Norway is therefore a big operational user of remote sensing data from satellites, and Norwegian scientists are involved in many of ESA’s Explorer satellites for earth observation research. We will not go into the details in this article.

13.1. Ship Detection from Space

In July 2010 Norway’s first satellite for ship traffic monitoring was launched. AISSat-1 has been a big success, and a copy AISSat-2 is being launched in 2013. A Norwegian built AIS receiver has also been placed on the ISS and is being used for anti-piracy operations in the Indian Ocean. Combined with the oil spill detection from radar satellites, the space based AIS system is a unique system to detect and identify illegal release of oil or illegal fishing and even support monitoring of pirates.

Figure 10. AISSat-1 has for the first time monitored all ship traffic in the Arctic and it is obvious that most traffic is within Norwegian territories.

Norway is now building a small satellite called NORSAT-1 to be launched in 2016. The payload will consist of a new generation Solar Total Irradiance monitor delivered by PMOC/WRC in Switzerland and will provide important data for the Sun-climate connection. A Mini-Langmuir probe from the University of Oslo will provide space weather measurements while a new AIS receiver will be tested out.

Figure 11. NORSAT-1 will be launched in 2015 and will provide Sun-Earth connection observations as well monitoring ship traffic.

14. EDUCATION AND PUBLIC OUTREACH

NAROM (Norwegian Centre for Space-related Education), partly funded by the Norwegian Government, offers educational programmes for teachers and students at many different levels to promote appreciation for the benefits of space activities, to facilitate recruitment in the space industry, and to stimulate an interest in science in general.

NAROM is co-located with Andaya Rocket Range (ARR). The close proximity to the facilities and personnel at ARR provides important advantages with respect to educational activities, and NAROM uses the unique technical facilities at ARR to provide an exciting educational experience. The European Space Educational Resource Office ESERO in Norway is established at ARR by NAROM. The office provides five different courses for teachers in upper secondary schools.

14.1 Student Satellite Program

NSC is actively sponsoring a student satellite programme in Norway, which is implemented together with NAROM and ARR. The aim is to plan, build, launch and operate three student satellites within three Norwegian Universities. One satellite has already been launched, but attempts to obtain contact with it have not been successful. Two others are currently being built, planned for possible launch in 2016.
14.2 CaNoRock— a Canadian Norwegian Student Exchange & Rocket Programme

The Canada-Norway Student Sounding Rocket (CaNoRock) exchange program is a partnership between the Universities of Alberta, Calgary and Saskatchewan, the University of Oslo, University of Tromsø, Andøya Rocket Range and NAROM (Norwegian Center for Space Related Education) in Norway. The University of Bergen and University Centre in Svalbard (UNIS) in Norway are currently working to be included in the program. To further enhance the educational benefits and cooperation between students in the two countries a student satellite program – CaNoSat will be developed to run in parallel and coordinated with the sounding rocket activities. Funding for the necessary student activities like travel and subsistence will be covered by CaNoRock STEP, funded by Norwegian Centre for International Cooperation in Education (SIU) for 2012-2016.

14.3 European Space Camp

Each year a group of students (17-19 years old) meet at Andøya Rocket Range to learn more about the Sun, the atmosphere, and the aurora. After a week they are among the few that can call themselves real rocket scientists.

The goal of Space Camp is to let the students take part in real science. They get to work with the same tools as real rocket scientists. Tutors from Norway, the European Space Agency (ESA), and NASA guide the students while they construct their own instruments to take measurements in the atmosphere. The highlight is launching their instruments on a self-built rocket.

![Figure12: European Space Camp at Andøya](image)

14.4 Public Outreach

The Norwegian Space Centre is focusing on outreach and media activities to increase the interest in science and technology among young people and the general audience.

On the web site svomsenter.no and the more static version spacecentre.no is the main access to the target groups. NSC publishes stories on astronomy, industrial policy, ESA activities and space activities in general, all with a Norwegian hook or commented by the staff at the space centre.

This pays off in media and NSC staff is a much sought after source for journalists writing stories on space. Last year the NSC was cited 700 times in papers, magazines, websites, TV and radio.

In 2014 NSC launched a section for kids up till 12 years old, called Space for Kids. The site is commonly in use by young students and schools as a source for space related projects.

November 12 the Norwegian Space Centre hosted a public Rosetta event when Philae landed on the comet 67P. The media coverage was good with live reporting on the main broadcasters and live web events. This year the big public outreach happening will be Space Expo, an EU based exhibition showing how satellites impact our daily lives. The exhibition will take place in Oslo from August 28 till September 6.

Presentations for schools, students and the general public are a priority as well. The staff of 39 employees makes more than 200 presentations a year.