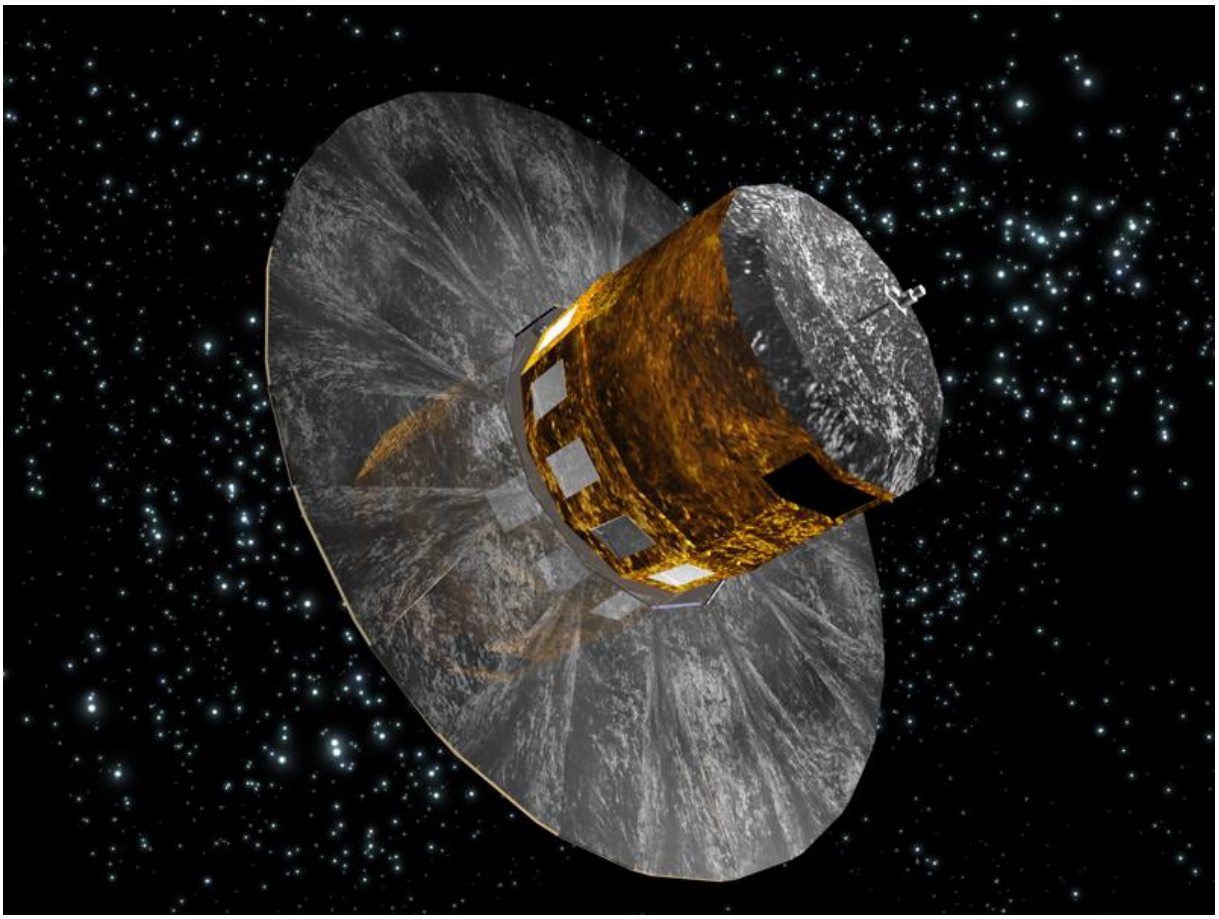
AUSTROSPACE

ANNUAL REPORT 2013



Cover picture: GAIA

Photo Credit ESA

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1 Introduction

The present AUSTROSPACE Annual Report is composed of a brief review of major space events in 2013, contributions from industrial members and research organizations about their space activities, and a current list of members with contact information.

Vienna, September 2014

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President

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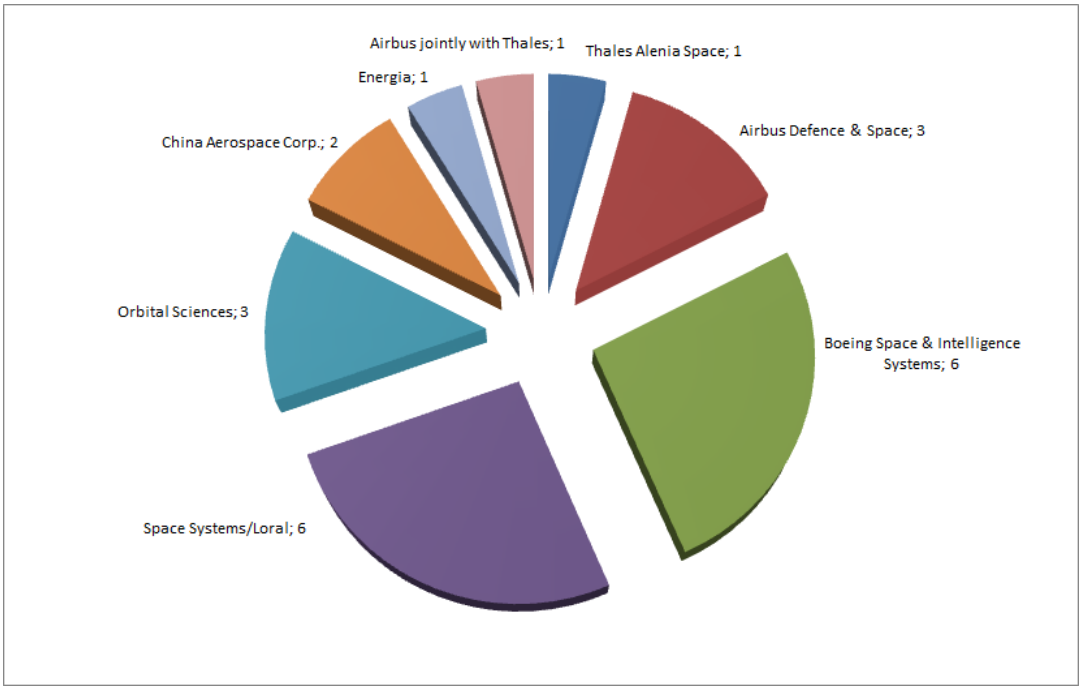
2 Year 2013 Review

In 2013 orders for 23 geostationary commercial telecommunications satellites were placed worldwide (source: Space News, January 13, 2014), with 5 contracts going to the European satellite manufacturers (Airbus Defence & Space: 3, Thales Alenia Space: 1, Airbus jointly with Thales: 1). The total number means a significant increase compared to the 16 satellites in 2012, as more developing countries establish their own domestic satellite systems, and it confirms the level of some 20 orders annually predicted by many analysts for the commercial market in the coming years.



Commercial Geostationary Telecommunications Satellite Orders 2013
(Source: Space News, January 13, 2014)

The German government decided on the procurement of a next generation of military reconnaissance satellites (SARah): two satellites will be built by OHB, while for the third one Astrium Satellites has been selected as a subcontractor to OHB.

The in-orbit validation (IOV) phase of the European satellite navigation system Galileo, based on four IOV satellites, is successfully completed. The deployment of the operational system, however, has experienced significant delay already, with the first four satellites built by OHB scheduled for launch in the second half of 2014. Full service capability is now expected to be available in 2017.

In July Alphasat XL, also called Inmarsat XL, the first satellite using the Alphabus platform in a public-private partnership between the European Space Agency (ESA), Airbus, Thales Alenia Space and Inmarsat, lifted off on an Ariane 5. Alphasat XL will provide mobile communications services to Africa and Europe and test experimental technologies for ESA.

Alphasat XL (Source: ESA)

On November 22 ESA's trio of Swarm satellites took off from the Plesetsk Cosmodrome aboard a Russian Rockot. The purpose of this mission is to measure the magnetic field of the Earth in unprecedented detail, with three satellites orbiting at different altitudes between 400 and 550 km.

Swarm Constellation over Earth (Source: ESA)

The year ended with the launch of ESA's astronomy spacecraft Gaia from Kourou on board of a Soyuz rocket just before Christmas. Gaia will compile a 3D map of our galaxy from the Sun-Earth Lagrange point L2 located at 1.5 million kilometers from Earth. The mission has a planned duration of five years.

Gaia Satellite Positioning on Launcher Upper Stage (Source: ESA)

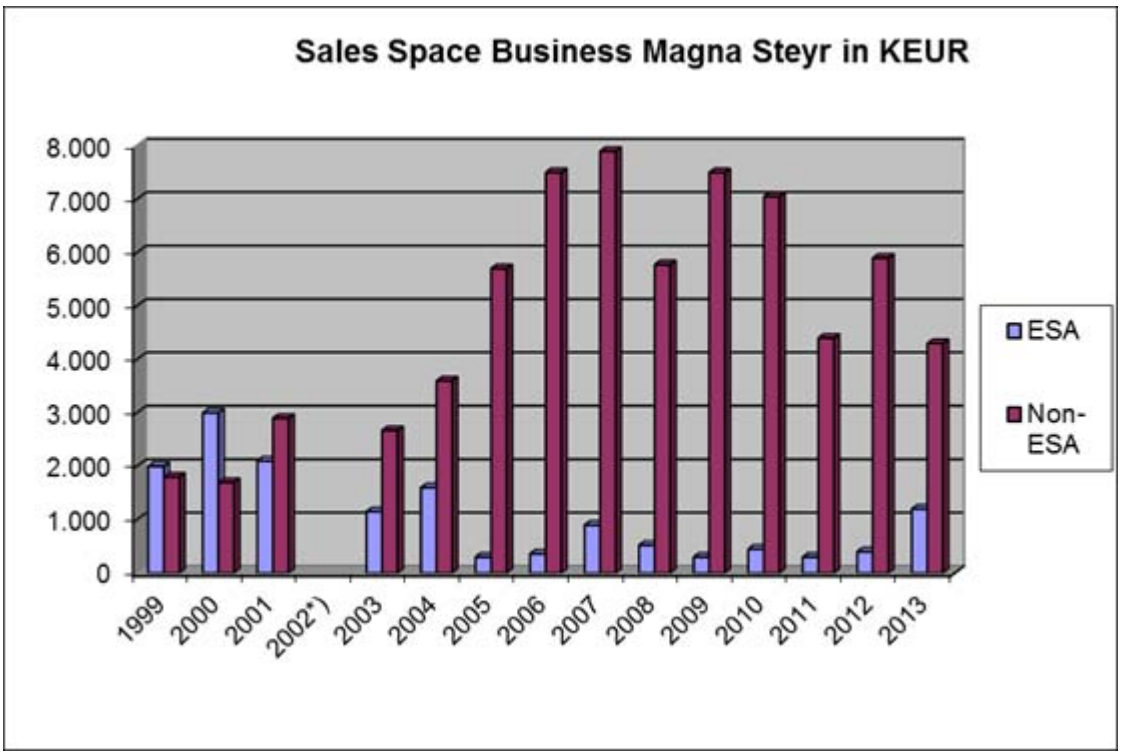
A milestone of Austrian space activities was the successful launch of TUGSAT-1, which received remarkable public attention. The first Austrian nano-satellite, built and tested at the Graz University of Technology, started its mission on board of a Polar Satellite Launch Vehicle (PSLV) of the Indian Space Research Organization (ISRO) in February.

Launch of TUGSAT-1 (Source: TU Graz)

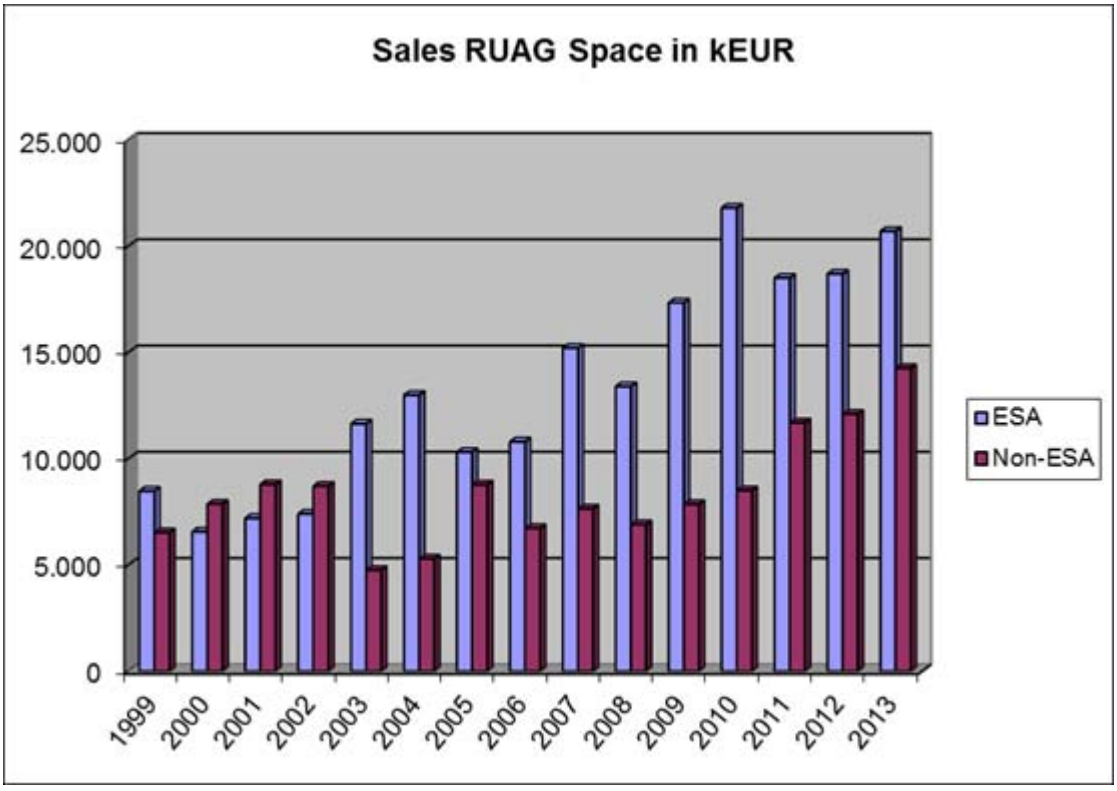
In the frame of the Austrian national space program, the ASAP 10 call for proposals was issued on the occasion of the Space Day 2013 in September.

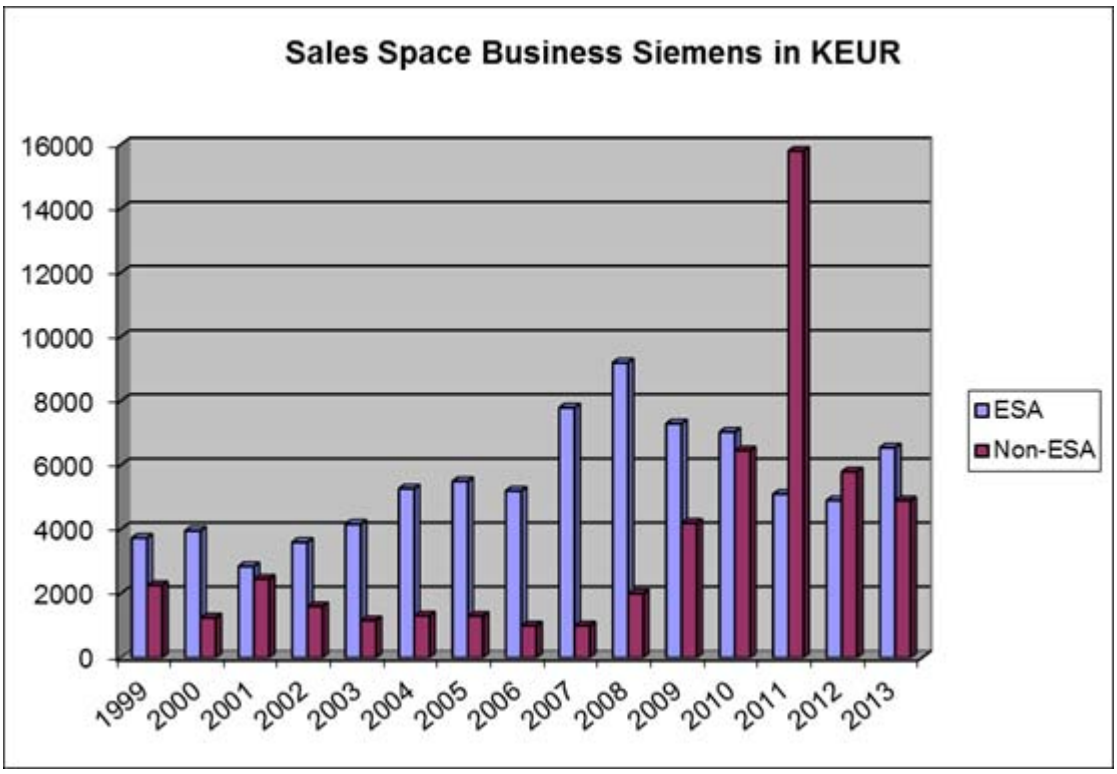
In July AUSTROSPACE, together with the Austrian space Agency ALR, organized a workshop in Warsaw, to explore cooperation opportunities with Polish space industry and institutes.

End of 2013 AUSTROSPACE had 19 members. The evolution of sales of the three biggest AUSTROSPACE companies is illustrated in the following diagrams.



*) no figures available due to organizational changes




Sales Space Business Siemens in KEUR
16000
14000
12000
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2006
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2009
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2012
2013
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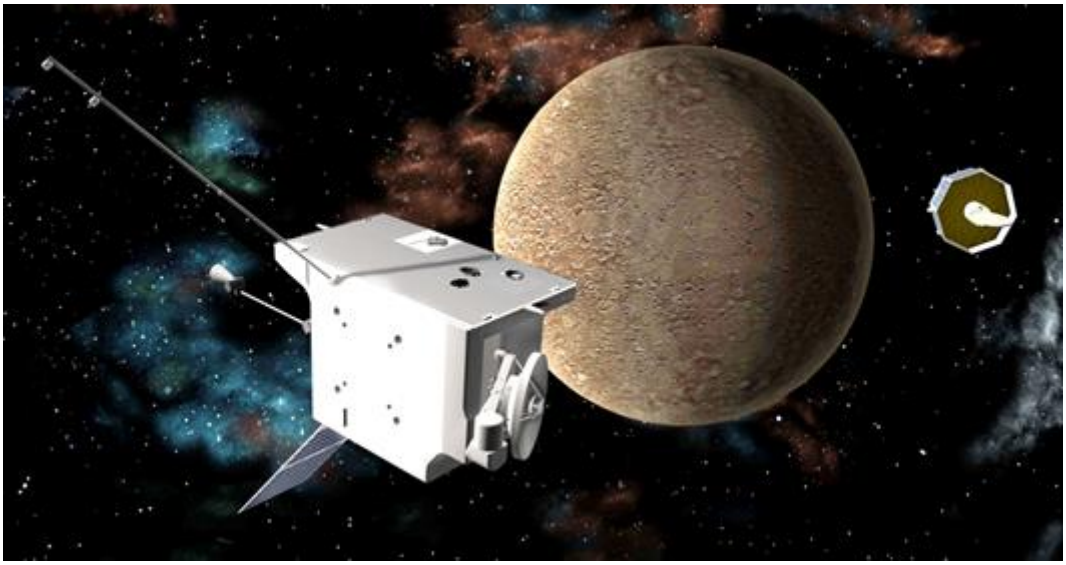
Non-ESA

3 Reports of Industrial and Institutional Members

3.1 Austrian Academy of Sciences

The Space Research Institute (Institut für Weltraumforschung, IWF) of the Austrian Academy of Sciences (Österreichische Akademie der Wissenschaften, ÖAW) in Graz focuses on physics and exploration of the solar system, covering the full chain of research needed in its fields: from developing and building space-qualified instruments to analyzing and interpreting the data returned by these instruments. With over 80 staff members from more than a dozen different nationalities it is the Austrian space research institute par excellence. It cooperates closely with space agencies all over the world and with numerous other national and international research institutions. A particularly intense cooperation exists with the European Space Agency (ESA).

In terms of science, IWF concentrates on space plasma physics, on the upper atmospheres of planets and exoplanets, and on the Earth's, the Moon's, and planetary gravity fields. In the area of instrument development the focus lies on building magnetometers and on-board computers, on antenna calibration, and on satellite laser ranging.



BepiColombo – first dual mission to Mercury (Credits: Astrium).

Presently, the institute is involved in sixteen international space missions:

- *BepiColombo* will be launched in 2016 to investigate planet Mercury, using two orbiters, one specialized in magnetospheric studies and one in remote sensing.
- *Cassini* will continue to explore Saturn's magnetosphere and its moons until 2017.
- ESA's first Small-class mission *CHEOPS (CHaracterizing ExOPlanets Satellite)* will look at exoplanets in detail. Its launch is expected in 2017.
- *Cluster*, ESA's four-spacecraft mission, is still providing unique data leading to a new understanding of space plasmas.
- The Chinese *ElectroMagnetic Satellite (EMS)* will be launched in 2016 to study the Earth's ionosphere.

- *InSight (INterior exploration using Seismic Investigations, Geodesy and Heat Transport)* is a NASA Discovery Program mission that will place a single geophysical lander on Mars to study its deep interior. It is expected for launch in 2016.
- ESA's *JUpiter ICy moons Explorer (JUICE)* will observe the giant gaseous planet Jupiter and three of its largest moons, Ganymede, Callisto, and Europa. It is planned for launch in 2022.
- *Juno* is a NASA mission dedicated to understand Jupiter's origin and evolution.
- *MMS* will use four identically equipped spacecraft to explore the acceleration processes that govern the dynamics of the Earth's magnetosphere. It is scheduled for launch in 2015.
- *Resonance* is a Russian space mission of four identical spacecraft, orbiting partially within the same magnetic flux tube, scheduled for launch in 2015.
- *Rosetta* is on its way to comet 67P/Churyumov-Gerasimenko. It will arrive in summer 2014 and deposit a lander in November.
- *Solar Orbiter* is to study along an innovative trajectory solar and heliospheric phenomena, planned for launch in 2017.
- *STEREO* studies solar (wind) structures with two spacecraft orbiting the Sun approximately at Earth's distance.
- *THEMIS* has been reduced to a near-Earth three-spacecraft mission. The two other spacecraft are now orbiting the moon in the *ARTEMIS* mission.
- The *Van Allen Probes* are two NASA spacecraft which quantify processes in the Earth's radiation belts.
- *Venus Express* explores the space plasma environment around Venus.

Two missions ended in 2013: The French space telescope *COROT* was decommissioned and ESA's Earth observer *GOCE* was deorbited in November.

IWF is naturally engaged in analyzing data from these and other space missions. This analysis is supported by theory, simulation, and laboratory experiments. Furthermore, at Lustbühel Observatory, one of the most accurate laser ranging stations of the world is operated.

Highlights in 2013

- Oscillating magnetic fields in the Earth's magnetotail show their field-aligned current-driven signatures in the ionosphere and aurora.
- The calculated mass-loss of super-Earths shows that they cannot lose their hydrogen envelope and thus are more Neptune-like.
- Key instruments were delivered and mounted on the spacecraft of the upcoming missions *BepiColombo* and *Magnetospheric Multiscale*.

The year 2013 in numbers

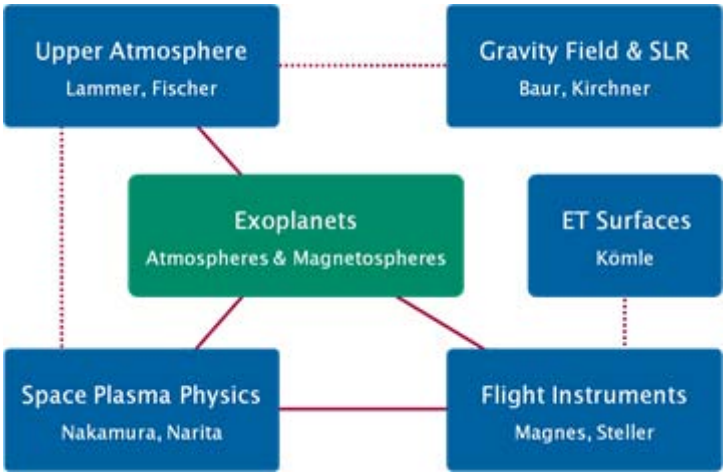
Members of the institute published 105 papers in refereed international journals, of which 34 were first author publications. During the same period, articles with authors from the institute were cited almost 3000 times in the international literature. In addition, 75 talks and 48 posters have been presented at international conferences by members of the IWF. Last but not least, institute members organized 13 sessions at international meetings.

IWF structure and funding

IWF is, as a heritage since foundation, structured into three departments:

- Experimental Space Research
  (Head: Prof. Wolfgang Baumjohann)
- Extraterrestrial Physics
  (Head: Prof. Helmut O. Rucker)
- Satellite Geodesy
  (Head: Prof. Hans Sünkel)

Wolfgang Baumjohann serves as Director. All important decisions are discussed by an institute council consisting of the three research directors and six staff members. Scientifically, there are no walls between the three departments. Staff members from different departments work successfully together in six research fields.



IWF research fields and group leaders.

The bulk of financial support for the research is provided by the ÖAW. Substantial support is also provided by other national institutions, in particular the Austrian Research Promotion Agency (Österreichische Forschungsförderungsgesellschaft, FFG) and the Austrian Science Fund (Fonds zur Förderung der wissenschaftlichen Forschung, FWF). Furthermore, European institutions like ESA and the European Union contribute substantially.

Earth & Moon

In the last decades, space geodesy has become an integral part in Earth and planetary sciences. Dedicated satellite missions provide high-quality data, which are nowadays indispensable for monitoring our home planet and to unlock secrets of the evolution of the Earth and the solar system. IWF analyzes these data with a special focus on the determination of the terrestrial and the lunar gravity field, selected studies of the Earth's atmosphere and crustal dynamics, as well as satellite laser ranging (SLR) to Earth-orbiting spacecraft and debris objects.

Gravity Field

Knowledge about the gravity field is the key to unlock geophysical processes on the surface and in the interior of a body. Furthermore, due to the fact that satellite dynamics are dominated by the gravitational pulls acting on the spacecraft, the gravity field is of fundamental importance for orbit determination and mission design. At IWF, gravity field

research activities include the analysis of data collected by the dedicated Earth-orbiting missions *GOCE* and *GRACE*, the lunar missions *LRO* and *GRAIL,* and SLR to passive satellites.

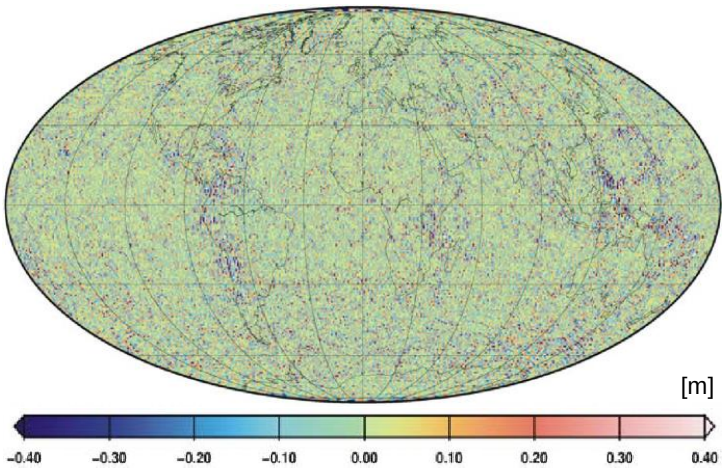
GOCE

The core task of ESA's mission *GOCE (Gravity field and steady-state Ocean Circulation Explorer)* is to provide data for the computation of a model of the Earth's static gravity field with unprecedented accuracy and resolution. The *GOCE* satellite was launched in spring 2009. The nominal mission duration was one year, but owing to less fuel consumption as initially expected, *GOCE* collected science data for about four years. Starting in August 2012 the orbit has been lowered in several steps from 255 km to 225 km. The end of mission was in November 2013, when *GOCE* reentered the Earth's atmosphere.

Data processing: IWF together with the Institute of Theoretical Geodesy and Satellite Geodesy of TU Graz form the *GOCE* team Graz, which processes the official *GOCE* time-wise (*GOCE*-TIM) gravity field solutions. This unit is part of the European *GOCE* Gravity Consortium, which consists of ten European institutions working under ESA contract.

Artist's view of the GOCE satellite. Due to its aerodynamic design, the spacecraft is sometimes dubbed the "Ferrari of space" (Credits: ESA).

GOCE gravity field models: In March 2013, the fourth generation *GOCE* gravity field solutions have been released to the public by ESA. These models span almost three years of data, from November 2009 to July 2012 (opposed to twelve months of data used for the preceding third generation releases). Owing to the longer time span and huge effort put into the reprocessing of the science data, more small-scale features on and near the Earth's surface are now detectable from the space gravimetry measurements. The fifth generaton releases, including the entire set of *GOCE* data, will be compiled in 2014.



Differences between the fourth generation and the third generation GOCE geoid. The pattern reflects the noise reduction in the latest gravity field solution.

Orbit analysis: The *GOCE* mission provides a great opportunity to assess the performance of approaches that have been developed during the last decade to derive gravity field models from kinematic satellite orbits. This is of particular relevance against the background that in the absence of *GOCE* (decommissioned) and *GRACE* (likely to be decommissioned soon) kinematic orbit analysis will be the primary gravity field inference technique. Led by IWF, in a joint effort together with science institutions in Germany, Switzerland, The Netherlands, and Austria the following methods have been evaluated against each other:

- Energy balance approach
- Point-wise acceleration approach
- Averaged acceleration approach
- Short-arc approach
- Celestial mechanics approach

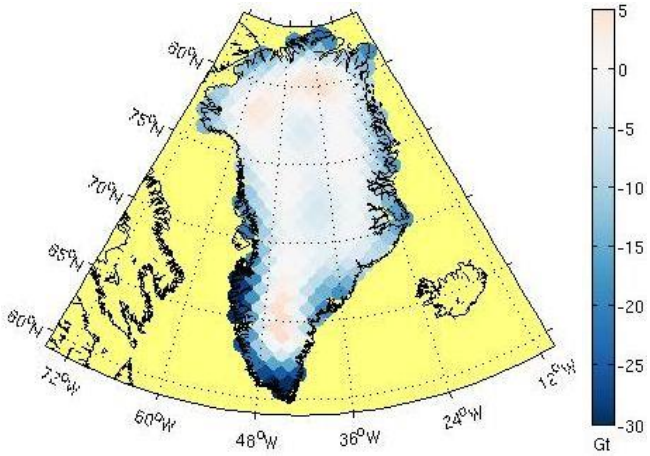
As major conclusion it turned out that apart from energy balance, the gravity field recovery approaches have compatible performance. This overall finding can be drawn if and only if a large degree of consistency in the data processing is provided. The energy balance approach, on the other hand, shows systematic shortcomings.

GRACE

Since 2002, considerable effort is put in the computation of mass changes from time-variable *GRACE (Gravity Recovery And Climate Experiment)* gravity field solutions. The continuing mass loss of the Greenland ice sheets has gained particular interest, particularly against the background of the ongoing debate on global climate change. The remaining liftetime of the *GRACE* mission is hardly predictable, but it is very likely that a gap between *GRACE* and its successor *GRACE* follow-on (supposed to become operational in 2017 at the earliest) occurs.

This gap can be bridged with gravity field information obtained from *GNSS* (Global Navigation Satellite Systems) tracking of low-Earth orbiting satellites. The *Swarm* mission can be considered as the most promising bridging candidate. The spacecraft and orbit design is comparable to that of the *CHAMP (CHAllenging Minisatellite Payload)* mission (operational from 2000 to 2010); as a consequence, time variability as seen by *CHAMP* provides evidence of space gravimetry based mass variation detection in the absence of *GRACE*.

The pattern shown in the following figure suggests mass loss along the entire Greenland coastline and slight mass accumulation in the interior. The basin-wide *CHAMP* change rate is -246 ±10 Gt/yr. This value deviates by only 10% from the *GRACE* result (-223±10 Gt/yr).

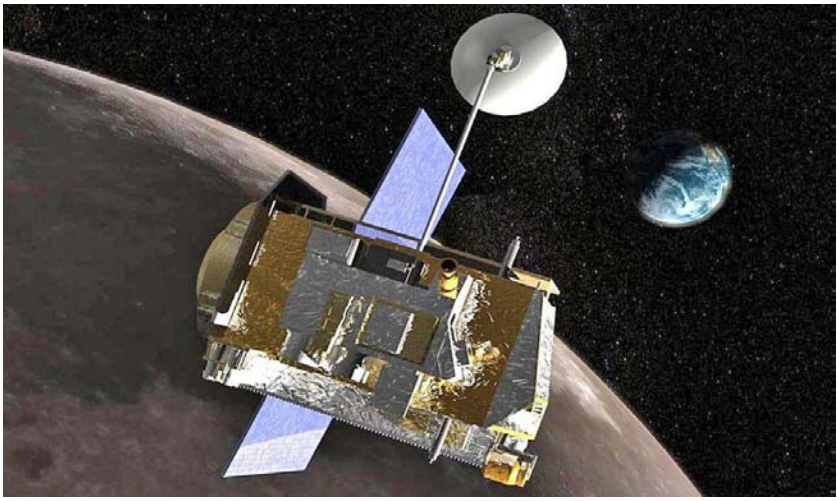


Greenland mass variation pattern from CHAMP time-variable gravity (2003-2009).

LRO

The NASA mission *Lunar Reconnaissance Orbiter (LRO)* was launched in 2009 to prepare for save robotic returns to the Moon. *LRO* is the first spacecraft in interplanetary space routinely tracked with 1-way optical laser ranges in addition to radiometric (Doppler shift) observations. As such, the mission provides a unique chance to investigate the capability of laser ranging for the determination of a satellite's orbit at a distance of roughly 400 000 km from Earth. The analysis of either laser ranges or Doppler data, as well as the combination of both, allows investigating the benefit of having two independent tracking data sets at hand.

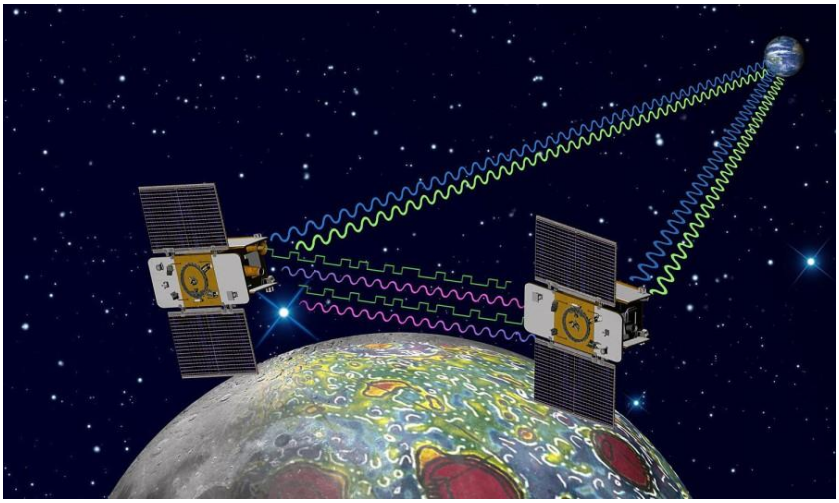
First results indicate that *LRO* orbits estimated from laser ranges alone have a precision in total position of about 100 m. The main reason for this rather large value can be traced back to the sparse laser tracking data, on the one hand, and the involvement of two non-synchronous clocks, on the other hand. When using 2-way Doppler measurements, which are continuously available, the precision increases considerably to about 15 m in total position. In a next step, the two measurement types will be analyzed in a joint parameter estimation procedure. The resulting "best" *LRO* orbit will constitute the basis for the recovery of the long-wavelength lunar gravity field. The lack of tracking data over the farside of the Moon will require regularization to stabilize the normal equation systems.



Artist's rendering of the LRO spacecraft (Credits: NASA).

GRAIL

The *Gravity Recovery And Interior Laboratory (GRAIL)* twin-satellite mission orbited the Moon from March to December 2012. *GRAIL* is the first dedicated gravity mission in planetary science; the mission concept is inherited from the *GRACE* project. Prior to *GRAIL*, lunar gravity field determination was limited due to the lack of measurements on the farside (1:1 Earth-Moon spin-orbit resonance) and due to the accuracy of ground-based Doppler orbit tracking data. Owing to high-precision inter-satellite observations with global coverage, the *GRAIL* mission allows to infer the lunar gravity field with unprecedented accuracy and spatial resolution. Accordingly, *GRAIL* is supposed to considerably improve our knowledge about the interior structure and thermal evolution of the Moon.



GRAIL mission design. The two satellites are following each other in the same orbit. Each spacecraft is tracked from stations on the Earth via radio signals; the relative motion between the spacecraft is observed by an inter-satellite link (Credits: NASA).

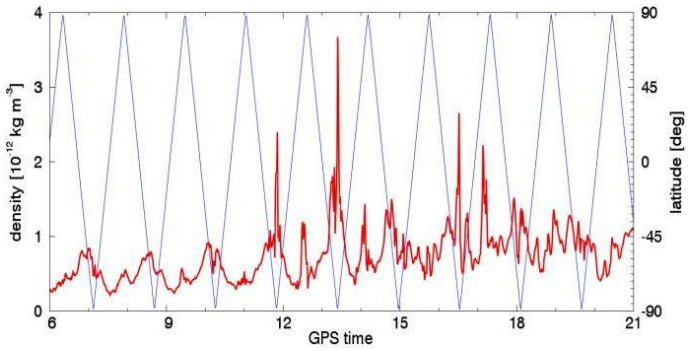
At IWF, *GRAIL* data analysis is performed in cooperation with the Institute of Theoretical Geodesy and Satellite Geodesy at TU Graz, making use of a novel inference technique in planetary sciences. The inter-satellite ranging data is exploited by an integral equation approach using short orbital arcs; it is based on the reformulation of Newton's equation of

motion as a boundary value problem. The integral equation approach is an alternative to more commonly applied gravity field recovery methods based on variational equations.

Atmosphere

Atmospheric density response to flares: Investigations on the impact of flares on the mass density in the Earth's upper thermosphere were performed. The main aim is to use flares and Coronal Mass Ejections (CMEs) as proxies for young Sun atmosphere response studies. A prerequisite for this procedure is the appearance of isolated solar flares. Upper atmosphere density enhancements exclusively caused by an isolated flare are not very numerous – often they are accompanied by CMEs. Additionally, dealing with *GRACE* accelerometer data requires the events to be "visible" for the satellite in terms of spacecraft position.

Another difficulty is that events often appear within short periods. Thus, the assignment of density enhancements to flares may be ambiguous, because knowledge about the time delay between the appearance of the enhanced X-ray flux at the Earth and the density enhancement is still sparse. Against this background, investigations are targeting an improved understanding of the phenomena associated with flares and CMEs. CME-induced events, e.g., appear mainly in the polar regions, whereas flares can enhance density at the whole dayside.



GRACE-A on 17 January 2005. Blue graph: geocentric latitude. Red graph: density enhancements; the four peaks between 11:45 h and 17:30 h are seen in the polar regions, as it is typical for CME events.

Multipath: Apart from the Earth's ionosphere, multipath is still the dominant error source for many *GNSS* applications. Especially multipath effects caused by reflectors in the vicinity of the receiver antenna are to date hard to mitigate or compensate. The core idea of the realized concept is to generate a synthetic aperture from the displacement of the antenna element. Two antennas - one rotating and one vertically moving - were manufactured and tested. These antennas are designed to reduce multipath effects to a harmless level.

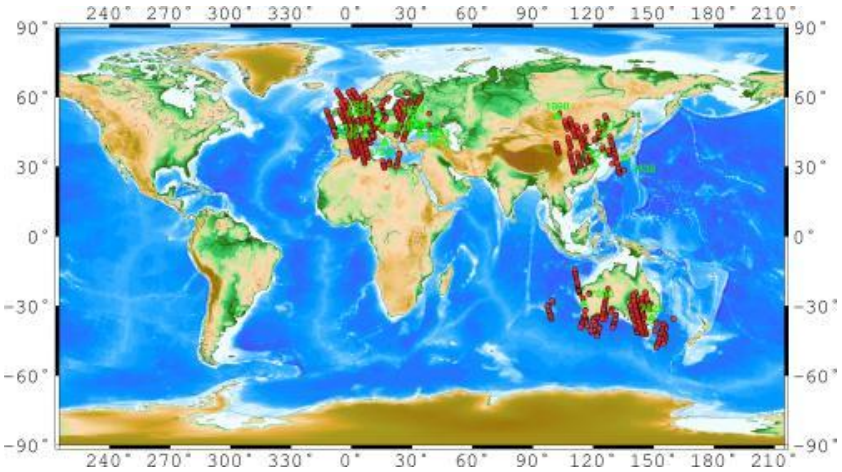
Rotating antenna at the roof of the IWF building. An artificial reflector realized by a copper plate was installed to generate multipath effects in addition to these ones caused by the "natural" environment.

Satellite Laser Ranging

Besides the routine tracking of satellites equipped with retro-reflectors (in the framework of the activities of the International Laser Ranging Service, ILRS), the experimental tracking of space debris targets continued. In addition, in 2013 orbit determination and orbit prediction of debris objects was started. Further SLR activities include bi-/multi-static experiments and satellite spin detection.

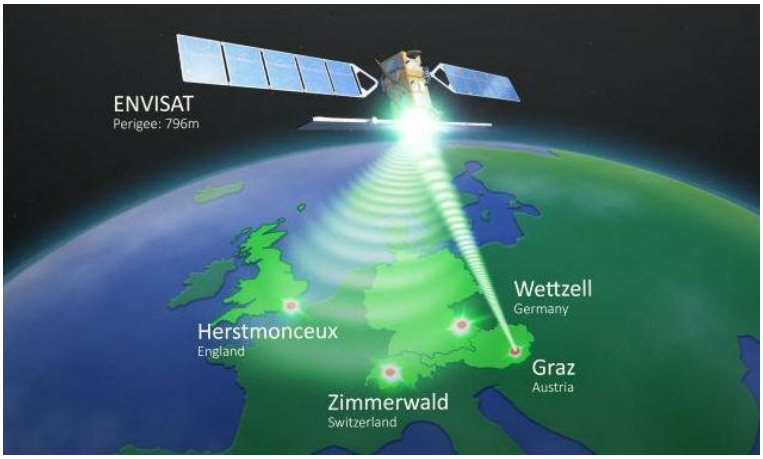
Space debris tracking: A laser from DLR (Deutsches Zentrum für Luft- und Raumfahrt) used during the last year (1 kHz, 20 mJ/shot) was replaced by another laser borrowed from DLR with (almost) 100 Hz repetition rate and 200 mJ/shot. New detection hardware – using a 500 µm diameter Peltier-cooled avalanche diode – was developed and installed. These new detection packages yielded an increase in efficiency and the reduction of dark noise, and they allow for easier tracking of targets with very low-accuracy predictions. The results demonstrate the capability to range to debris targets as small as 0.3 m^2, and to larger targets up to distances of 3100 km. During eleven space debris ranging sessions, about 140 passes of debris targets have been tracked successfully.

Precise orbit determination: The reliable and accurate orbit determination and orbit prediction of debris objects is of crucial importance for any effort towards Space Situational Awareness. However, the sparseness and poor quality of available observations, missing attitude information of the objects with respect to inertial space, and the lack of retro-reflectors make trajectory determination/prediction a highly challenging task. By means of tailored processing in order to cope with these "harsh conditions", very good results for the defunct ENVISAT satellite were achieved. The *ENVISAT* orbit predictions computed at IWF are officially distributed via the ILRS website.



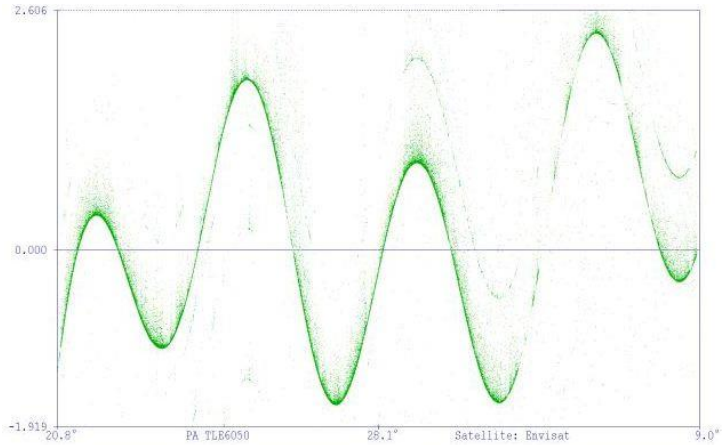
Spatial distribution of SLR observations to the defunct ENVISAT satellite in September 2013 (in red).

Multi-static experiments: In addition to previous bi-static measurements, the first multi-static experiments were successful: the SLR stations in Zimmerwald (Swiss), Wettzell (Germany) and Herstmonceux (UK) were able to detect photons emitted in Graz, diffusely reflected from debris targets. Owing to the unique concentration of SLR stations in Europe, such multi-static observations to space debris targets will allow for more accurate orbit determination compared to stand-alone "traditional" ranging.



Multi-static experiment: the passive SLR stations in Wettzell, Zimmerwald and Herstmonceux were able to receive photons emitted in Graz (Credits: AIUB).

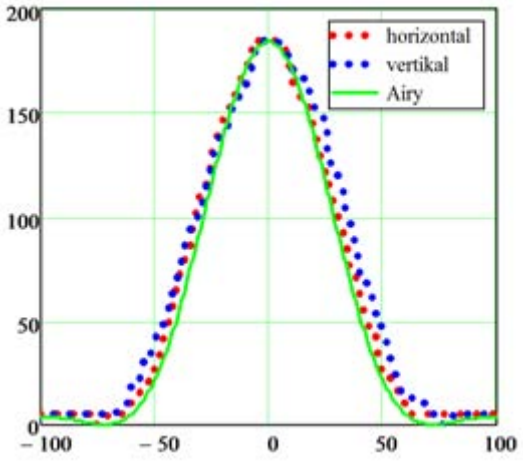
Satellite spin detection: Since April 2012, the *ENVISAT* satellite is defunct, and hence has to be considered as a space debris object. The 8-tons satellite speeds along a crowded sun-synchronous orbit in an altitude of about 800 km. Due to the lack of any control the satellite slowly changed its attitude, and finally started to spin. Since it is difficult to obtain information about this attitude and the spin parameters, IWF started a campaign within the ILRS to range again to *ENVISAT*, using its retro-reflectors whenever they are visible from ground stations. Based on this SLR data it could be shown that the *ENVISAT* satellite (i) has obtained a stable orientation, fixed with respect to its orbit, (ii) spins with an inertial period of 134.74 s (value from 25 September 2013), and (iii) that the spin period increases by 36.7 ms per day. The satellite spins in counter-clockwise direction; the solar array approaches the along track and the radial vectors.



ENVISAT spin as detected by SLR. Shown is the large-scale motion of the retro panel (±2 m).

Quantum cryptography: Within a cooperation between IWF and the Institute for Quantum Optics and Quantum Information (IQOQI) a completely new detection section of the SLR telescope was designed and started to be built. The planned transmission of quantum cryptography keys via satellite needs several additional single-photon detector packages and has to handle new wavelengths (1064 nm, 810 nm, 710 nm). While the old detection package allows for a maximum of two different detectors (with difficult installation and alignment procedures) the new one is designed for up to four detection channels (plus four channels for the quantum experiment), supported by several CCD cameras.

Nano-satellite tracking: An initiative was started to equip nano–satellites in low-Earth orbits with one or several retro-reflectors; this will allow precise orbit determination not only during the operational phase, but also beyond the active mission lifetime - such as in case of technical failures. It could be shown that for orbits around 600 km altitude or lower it is sufficient to use single, off-the-shelf, cheap corner cubes of 10–12 mm diameter, without special shapes or dihedral angles to compensate for velocity aberration.



Off-the-shelf retro-reflector performance. Calculated radar cross section at an orbital altitude of 600 km.

In addition, multiple retro-reflectors on each side of these small (and light) satellites will allow attitude determination with an accuracy of better than 1°. At present, four nano-satellites are foreseen to be equipped with retro-reflectors: OPS-SAT (ESA), TechnoSat (TU Berlin), S-Net

(TU Berlin), and CubETH (ETH Zürich). The launches of these satellites are planned in 2015-2016.

Near-Earth Space

Near-Earth space is an ideal natural laboratory to study space plasmas physics with in-situ measurements of the charged particles together with electric and magnetic fields. IWF both builds instruments for satellite missions that make measurements in this natural laboratory and analyzes the data obtained by them, and participates in future planning.

Missions

The *Cluster* and *THEMIS/ARTEMIS* missions are providing a wealth of exciting data, which lead to many new scientific results. Furthermore, IWF is involved in the upcoming *MMS* mission.

Cluster

The four *Cluster* spacecraft, launched in 2000, study small-scale structures of the magneto-sphere and its environment in three dimensions. The spacecraft are taking data while circling the Earth in polar orbits. The separation distance of the spacecraft has been varied between 200 km and 10 000 km according to the key scientific regions. This ESA mission has been extended to December 2016. IWF is PI of the spacecraft potential control and holds Co-I status on four more instruments.

THEMIS/ARTEMIS

NASA's *THEMIS* mission, launched in 2007, is designed to explore the origin of magnetic storms and auroral phenomena. *THEMIS* flies five identical satellites through different regions of the magnetosphere. As Co-I institution of the magnetometer, IWF is participating in processing and analyzing data. The two outer spacecraft became a new mission, *ARTEMIS*, to study the Moon, the distant magnetotail, and the solar wind from autumn 2010. The other three *THEMIS* spacecraft remained in their orbit to further study the dynamics of the inner magnetosphere.

Van Allen Probes

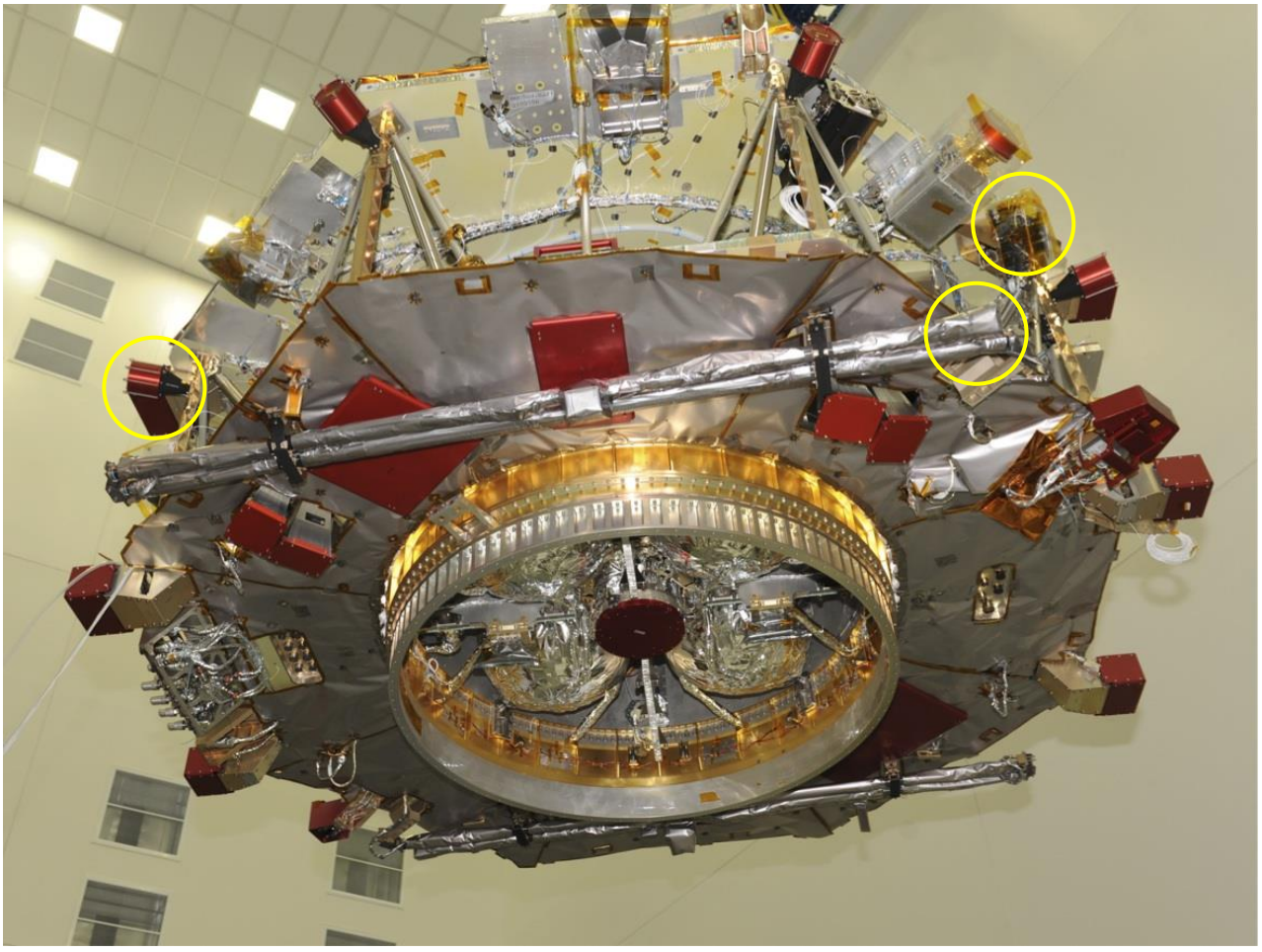
The *Van Allen Probes* (formerly known as the *Radiation Belt Storm Probes)*, successfully launched in 2012, are studying the dynamics of the radiation belts essential for understanding the key component of the space weather system. The instruments on the two *Van Allen Probes* spacecraft provide the measurements needed to characterize and quantify the processes that produce relativistic ions and electrons. As one of the science Co-I institutes, IWF analyzes the data combined with other magnetospheric missions and ground-based data.

MMS

NASA's *MMS* mission *(Magnetospheric Multi-scale)* will explore the dynamics of the Earth's magnetosphere and its underlying energy transfer processes. Four identically equipped spacecraft are to carry out three-dimensional measurements in the Earth's magnetosphere. *MMS* will determine the small-scale basic plasma processes, which transport, accelerate and energize plasmas in thin boundary and current layers. *MMS* is scheduled for launch in 2015. IWF has taken the lead for the spacecraft potential control of the satellites *(ASPOC)* and is participating in the electron beam instrument *(EDI)* and the digital fluxgate magnetometer *(DFG),* which both are part of the *FIELDS* instrument package.

Active Spacecraft Potential Control (ASPOC) instrument: End of February 2013, the last two (out of eight) Flight Models were delivered to the US. All models saw a complete sequence of integration of electronics with ion emitter modules, comprehensive performance testing, vibration, thermal vacuum, EMC, and magnetic tests. Before delivery of the units in pairs to the US, their data packages were compiled and reviewed. Environmental testing was uneventful with the exception of minor issues related to the ion emitters, which required partial re-testing of two Flight Models. Reporting, scheduling, and maintenance of data bases were done as necessary.

After integration of the Flight Models into the Instrument Suites and Observatories at GSFC, a series of observatory level tests including EMC, shock, acoustics, thermal balance and thermal vacuum test has started. On the software side, several improvements to the on-board software concerning the emitter operation have been implemented and tested. After performing the formal acceptance test, the software will be installed on all Flight Models once the environmental testing of the observatories has finished (June 2014). The preparations for system tests and the in-flight commissioning in 2015 were ongoing and the development of the Science Data Processing software has started.



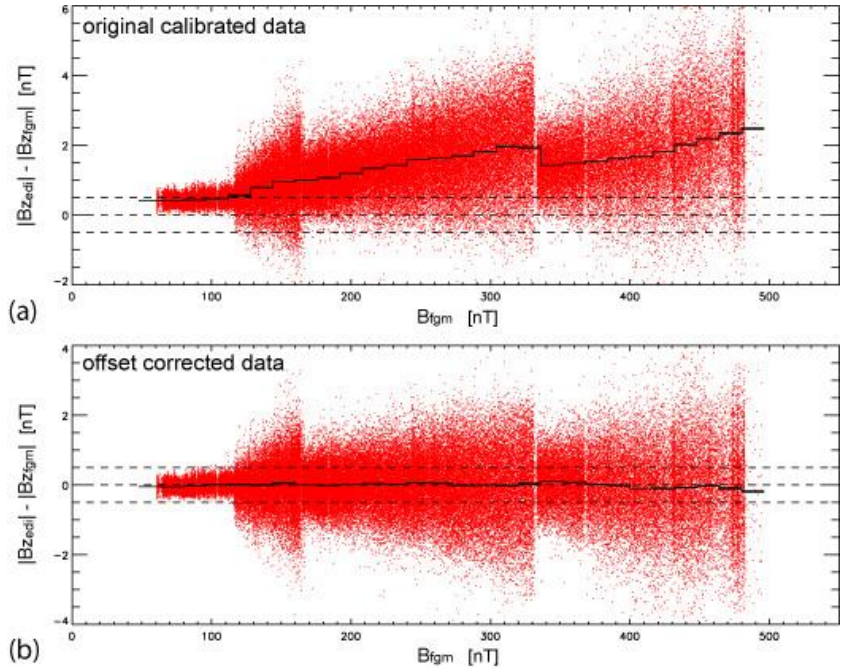
Spacecraft 1 lifted up in the MMS clean room at NASA's Goddard Space Flight Center (GSFC); EDI (left), ASPOC (upper right) and the DFG sensor on the magnetometer boom (lower right) are marked by yellow circles (Credits: SwRI/Ron Black).

Electron Drift Instrument (EDI): IWF contributes to *EDI* with the *Gun Detector Electronics (GDE)* and the electron gun. The *GDE* is developed by Austrian industry in close cooperation with the institute, while the electron gun is entirely developed by IWF.

The *EDI* instrument for *MMS* is based on the *Cluster* development with several improvements. In 2013 IWF manufactured, calibrated and delivered the flight units FM4 to FM7. The contribution of the industry is completed and all nine *GDE* flight models are either available or delivered.

The calibration process is an important step to get an accurate pointing of the electron gun. The requirement is to emit the electron beam with a pointing accuracy of 1° within the 2π sr. On average, the achieved accuracy is much better. The calibration process is done in 2° steps in polar and azimuthal angle. For polar angles above 70° the stepsize for azimuth is 1°. This results in 21600 reference points to generate the correction table. FM8 is presently manufactured and will be delivered together with the last model (FM9) in early 2014.

Digital Flux Gate magnetometer (DFG): *DFG* is based on a triaxial fluxgate developed by the University of California, Los Angeles, and a front-end Application Specific Integrated Circuit (ASIC) for magnetic field sensors. The ASIC has been developed by IWF in cooperation with the Fraunhofer Institute for Integrated Circuits in order to reduce the size, mass and power consumption of the near sensor electronics. In 2013, the spare model of DFG was assembled and calibrated at IWF. Parallel to the final hardware assembly activities, IWF supported the spacecraft integration of the flight magnetometers with all related functional tests.



Difference between spin axis component EDI and FGM fields for (a) the original calibrated data and (b) offset calibrated data.

Cross Calibration: New methods of determining spin axis offset of the flux magnetometers *(FGM)* using absolute magnetic field values deduced from the time of flight data from the *EDI* measurements have been investigated to be included as part of the in-flight magnetometer calibration for *MMS*. Using *Cluster* data, it is demonstrated that the method works when the effects of the different measurement conditions, such as direction of the magnetic field relative to the spin plane and field magnitude, as well as the time-of-flight offset of the *EDI* measurements are properly taken into account.

EMS

The *Electro-Magnetic Satellite (EMS)* mission is scheduled for launch end of 2016 and will be the first Chinese platform for the investigation of natural electromagnetic phenomena with major emphasis on earthquake monitoring from a polar Low Earth Orbit (LEO).

The *EMS* magnetometer is developed in cooperation between the Center for Space Sciences and Applied Research (CSSAR) of the Chinese Academy of Sciences, IWF and the Institute of Experimental Physics of the Graz University of Technology (TUG). CSSAR is responsible for the dual sensor fluxgate magnetometer, the instrument processor and the power supply unit, while IWF and TUG participate with the newly developed absolute scalar magnetometer called *CDSM*. In 2013, the *CDSM* Engineering Model was manufactured and tested. It is scheduled for delivery to China end of February 2014.

Space Weather Magnetometer

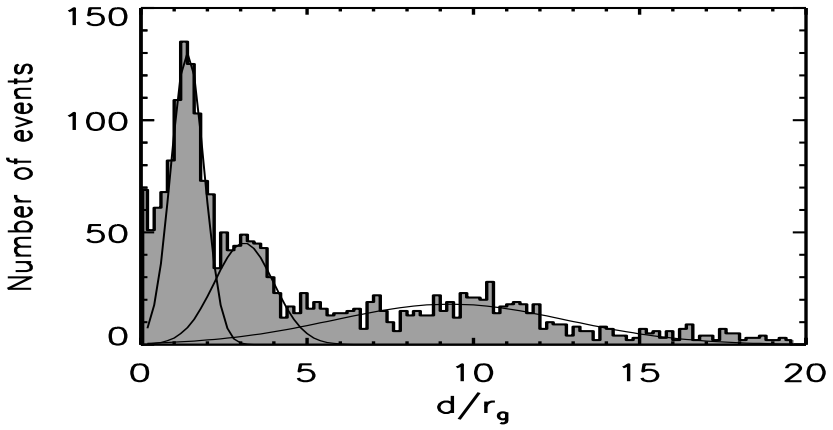
The *Magnetometer Front-end ASIC (MFA)* developed by IWF, together with *Anisotropic Magneto-Resistive (AMR)* sensors, is in use for the development of a service oriented magnetometer package for space weather measurements. It is a flexible design with up to six magnetic field sensors. The *MFA-AMR* combination is used for detecting and characterizing magnetic disturbers of the spacecraft body so that the data measured by the fluxgate sensor at the tip of an up to 2 m long boom (also part of the package) can be corrected for the spacecraft magnetic fields. It is planned to fly such magnetometers on missions, which are not necessarily dedicated to scientific objectives but which go to orbits where space weather forecast measurements are useful. In 2013, an ESA-funded first prototype of the *MFA-AMR* magnetometer was developed.

Physics

Various data from ongoing missions are analyzed and theoretical models are developed to describe the physical processes responsible for the formation of structures and phenomena in the Sun-Earth system at different scales. Most of the data analysis is performed using data provided by the ongoing *Cluster* and *THEMIS* missions, as well as other magnetospheric missions and ground-based observations. The studies deal with interactions between solar wind and magnetosphere, internal disturbances in the magnetosphere such as plasma flows and waves, and plasma instabilities including magnetic reconnection.

Current sheet thickness in the Earth's magnetotail: A new mathematical tool has been developed to unambiguously and directly estimate the current sheet thickness in the Earth's magnetotail. The technique is a combination of eigenvalue analysis and minimum variance estimation adapted to a Harris current sheet geometry, and needs simultaneous four-point magnetic field data as provided by the *Cluster* spacecraft. Two current sheet parameters, thickness and distance to the spacecraft, can be determined any time.

The method was applied to an interval of *Cluster* magnetotail crossings in 2006 under quiet magnetospheric conditions, and the current sheet thickness was estimated to be on the scale of the local proton gyroradius (of the order of several thousand km). The figure below displays the histogram of the current sheet thickness in units of the local proton gyroradius. The thickness is distributed from the proton gyroradius (or smaller) up to 20 gyroradii. The histogram fits reasonably a combination of Gaussian distributions, centered at about 1.4, 3.1, and 9.3 gyroradii. Large variation in the thickness distribution agrees with the earlier estimates using different methods, and supports the notion of multi-scale or embedded current sheet structures. The analysis technique can be used to track the dynamical evolution of the current sheet structure in the magnetotail.

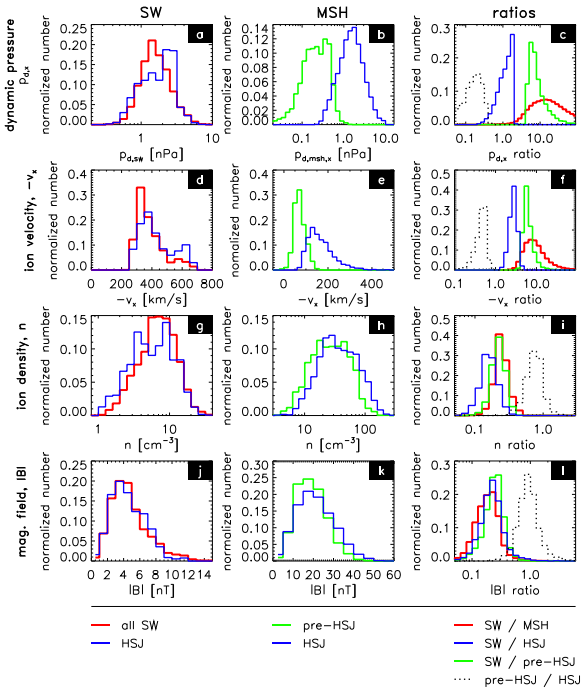


Histogram of determined current sheet thickness d normalized to gyroradius of thermal protons. Dashed lines show fittings with multiple Gaussian distributions.

Magnetic field topology of the plasma sheet boundary layer (PSBL): The PSBL is situated between the magnetotail lobe and the central plasma sheet, a region that is thought to be primarily responsible for mass and energy transport between the magnetosphere and the high-latitude ionosphere during disturbed geomagnetic conditions. The 3D magnetic field topology of the PSBL is shown for the first time, using the reconstruction method, which is an analysis method that applies single spacecraft data to MHD force balance equations in order to recover the surrounding spatial structures of plasma and fields measured by the *Cluster* spacecraft during the substorm recovery phase.

Anti-sunward high-speed jets in the subsolar magnetosheath: Using four years data of NASA's five-spacecraft *THEMIS* mission, the properties and favorable solar wind conditions for the occurrence of high-speed jets in Earth's subsolar magnetosheath were studied. High speed jets occur downstream of the quasi-parallel bow shock, i.e., when the interplanetary magnetic field is essentially directed along the Earth-Sun-line. Jet occurrence is only very weakly dependent on other upstream conditions or solar wind variability.

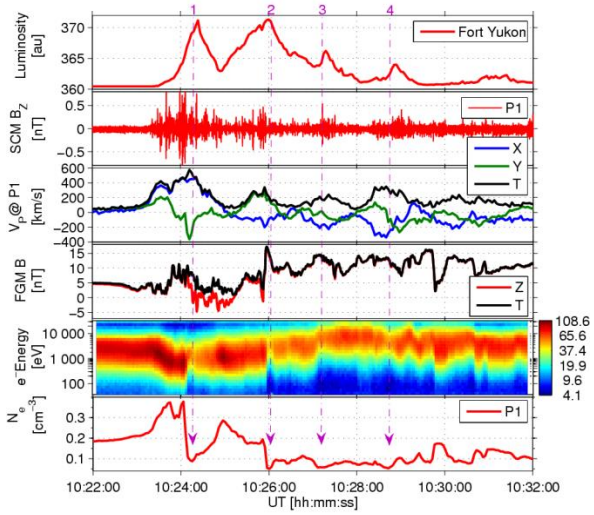
Relative to the ambient magnetosheath, high-speed jets exhibit much higher plasma speed, somewhat higher density and magnetic field intensity, but lower and more isotropic temperatures. The jets are almost always super-Alfvénic, often even super-magnetosonic, and typically feature twice as high total pressure toward the magnetopause as the surrounding plasma does. Consequently, high-speed jets are likely to have a significant impact on the magnetosphere and ionosphere if they hit the magnetopause.



Distributions of solar wind (SW) and magnetosheath (MSH) ion dynamic pressure, velocity, density, and magnetic field observations in general, as well as before and during high-speed jets (HSJ).

Azimuthal size of flux ropes near lunar orbit: Magnetic flux ropes are formed during magnetic reconnection in the Earth's magnetotail and serve as transporter of magnetic flux, energy and accelerated plasma during the course of substorms. Previous observations of flux ropes in the mid- and distant tail were restricted to single spacecraft observations. Hence, an accurate determination of spatial scales of these 3D structures is difficult. With *ARTEMIS*, two probes cross the magnetotail near lunar orbit for ~4 days every lunar month and allow two-point flux rope observations. The observations show that the typical dawn-dusk flux rope extent is ~6 RE and hence smaller than previously thought. For high geomagnetic activity levels flux ropes with azimuthal size >9 RE are common. Flux rope crossings at different distances to their axis also reveal their internal structure.

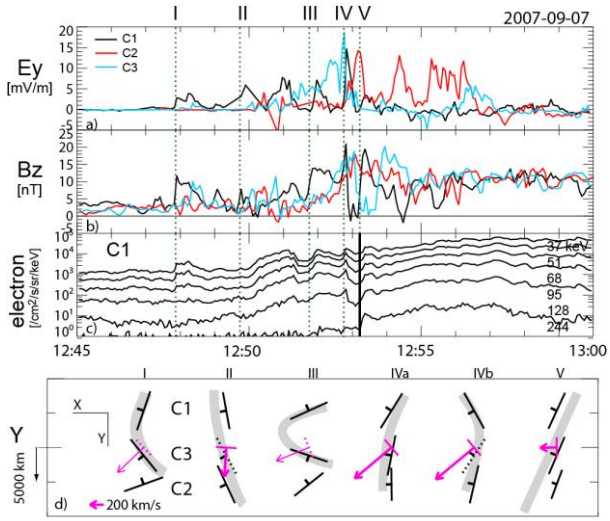
Transient electron precipitation during oscillatory BBF braking: Using *THEMIS* data acquired on 17 March 2008 between 10:22 and 10:32 UT, the mechanism of transient electron injection into the loss cone during oscillatory bursty bulk flow (BBF) braking is studied. During braking, transient regions of piled-up magnetic fluxes are formed. Perpendicular electron anisotropy observed in these regions may be a free-energy source for coexisting whistler waves. Parallel electrons with energies of 1-5 keV disappear inside these regions and transient auroral forms are observed simultaneously by the all-sky imager at Fort Yukon. Quasi-linear diffusion coefficients during electron resonant interaction with whistler waves are estimated. It is found that electron injection into the loss cone is caused by whistler waves scattering.



THEMIS data on 17 March 2008 between 10:22:00 and 10:32:00 UT: (a) total luminosity observed by the all-sky imager at Fort Yukon, (b) Z-component of the magnetic field oscillations from search-coil magnetometer (SCM), (c) X-, Y-, and total component of the ion velocity from ESA, (d) Z-, and total component of the magnetic field from fluxgate magnetometer (FGM), (e) electron energy spectrogram, and (f) electron density from ESA at P1.

Dipolarization front and flow bouncing: One of the unsolved problems in the Earth's magnetotail physics is the dissipation process of the Earthward transported energy via fast plasma flows. Interaction between the fast Earthward plasma flows accompanied by sharp magnetic field front structure, called the dipolarization front, and the ambient plasma in the near-Earth nightside magnetosphere is studied based on *Cluster* multi-point observations. A series of dipolarization fronts were detected starting with a localized (<2 RE) dipolarization front and ending with a large scale (>10 RE) and stronger dipolarization front immediately followed by flow bouncing, i.e. reversal of the flow direction.

The stronger electric field and substantial changes in particle energy suggest that the major energy conversion takes place in the near-Earth flow bouncing region rather than during the Earthward propagation of the dipolarization front. Although the overall enhanced energetic electron flux seems to be dependent on the spatial scale of the front and the strength of the dawn-to dusk electric field, it is shown that a major energization event can take place locally or temporal in the near-Earth region.



Cluster (C1, C2, C3) observations of dipolarization fronts (I-V). (a) EY (dawn-to-dusk electric field), (b) BZ (magnetic field component showing dipolarization), and (c) differential flux of high-energy electrons from C1 and (d) the orientation of the dipolarization fronts in the X-Y (equatorial) plane. The arrows show the propagation of the dipolarization front determined from multipoint observations.

Solar System

IWF is engaged in many space missions, experiments and corresponding data analysis addressing solar system phenomena. The physics of the Sun and the solar wind, its interaction with solar system bodies and various kinds of planetary atmospheres and surfaces are under investigation.

Sun & Solar Wind

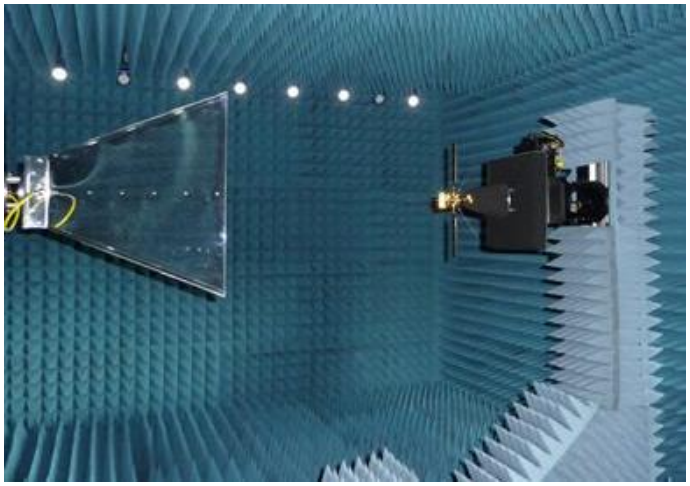
The Sun's electromagnetic radiation, magnetic activity, and the solar wind are strong drivers for various processes in the solar system.

Solar Orbiter

Solar Orbiter is a future ESA space mission to investigate the Sun, scheduled for launch in 2017. Flying a novel trajectory, with partial Sun-spacecraft corotation, the mission plans to investigate in-situ plasma properties of the near solar heliosphere and to observe the Sun's magnetized atmosphere and polar regions. IWF builds the digital processing unit (DPU) for the *Radio and Plasma Waves (RPW)* instrument onboard *Solar Orbiter* and has calibrated the *RPW* antennas, using numerical analysis and anechoic chamber measurements. Furthermore, the institute contributes to the magnetometer.

Radio and Plasma Waves (RPW): *RPW* will measure the magnetic and electric fields at high time resolution and will determine the characteristics of the magnetic and electrostatic waves in the solar wind from almost DC to 20 MHz. Besides the 5-m long antennas and the AC magnetic field sensors, the instrument consists of four analyzers, the thermal noise and high frequency receiver, the time domain sampler, the low frequency receiver, and the bias unit for the antennas. The control of all analyzers and the communication with the spacecraft will be performed by the DPU.

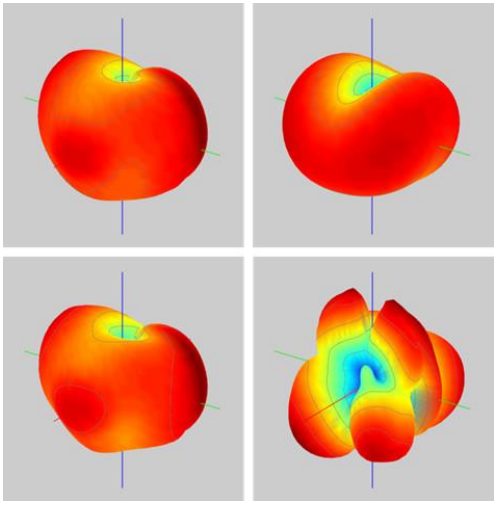
The institute is responsible for the design of the DPU hardware and the boot software. In the first quarter of 2013 the prototype board has been delivered to LESIA to be used as reference model for the flight software development. The two engineering models, a fully flight representative model, but on lower components quality level, has been delivered in the third quarter. Presently, minor re-design and -layout is under preparation, implementing the "lessons learned" from the engineering model. A first release of the boot software has been delivered too. The next development step, the qualification model with the final boot software, will keep the team busy until mid 2014.



A scale model of the Solar Orbiter spacecraft placed in an anechoic chamber for antenna calibration measurements.

The E-field sensors (boom antennas) of the *RPW* instrument aboard the *Solar Orbiter* spacecraft are subject to severe influences of the conducting spacecraft body. Different methods were employed to find the true antenna properties. In an effort to complement numerical simulations, a 1:50 scale model of the spacecraft has been built and tested in an anechoic chamber.

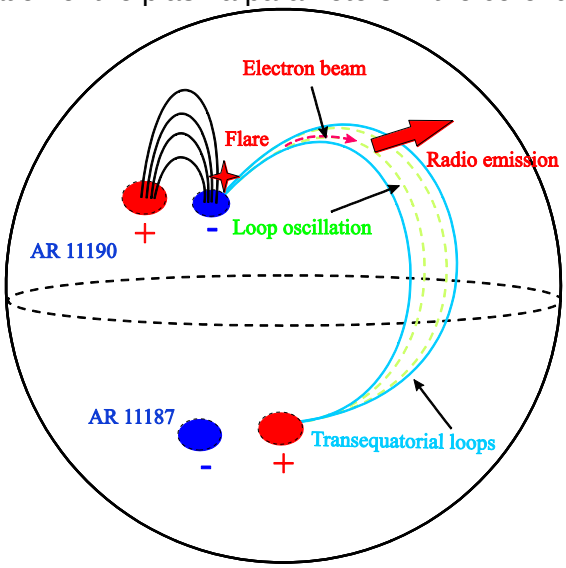
Direct comparisons between numerical simulation and measurement have been made, providing an important benchmark for the numerical results. The top two radiation patterns in the following figure show a reasonable agreement between the anechoic chamber measurements (left) and FEKO numerical simulations (right). In the anechoic chamber, the co- and crosspolar patterns have also been measured, which provide useful input to goniopolarimetry techniques like polarization analysis, direction finding and ray tracing.



Directivity patterns for Solar Orbiter scale model at 600 MHz (scales down to 600/50=12 MHz). Top: anechoic chamber measurement (left) compared to FEKO simulation (right). Bottom: copolar (left) and crosspolar (right) anechoic chamber measurements.

Physics

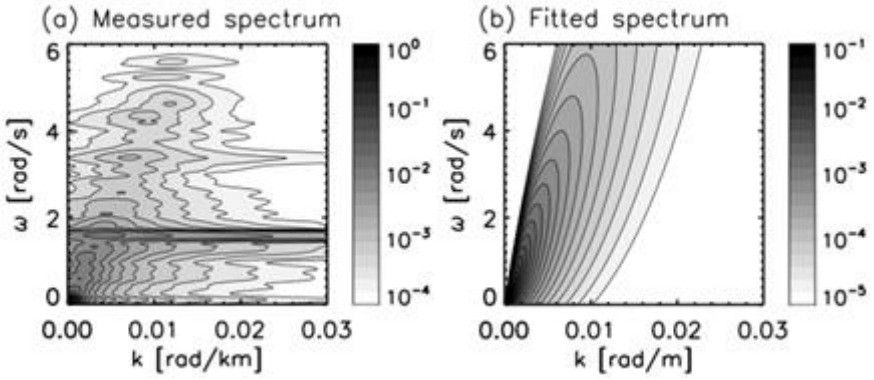
Radio seismology of the outer solar corona: Energetic electron beams generated during solar flares excite Langmuir oscillations in coronal loops, which emit radio emission at corresponding frequencies as type IV bursts. Global oscillations of coronal loops excited by the same flare modify the electron beam density, which may influence the amplitude of Langmuir oscillations and consequently the intensity of radio emission. Therefore, long period modulations of radio emission intensity could be caused by coronal loop oscillations. Comparison of observed periodicities with the theoretical spectrum of coronal loop oscillations allows estimation of the plasma parameters in the coronal loops.



Schematic picture of radio emission from a transequatorial coronal loop after C2.3 solar flare on 14 April 2011.

The large Ukrainian radio telescope URAN-2 observed type IV radio burst in the frequency range of 8-32 MHz during the time interval of 09:50-12:30 UT on 14 April 2011. The burst was connected to a C2.3 flare, which occurred in the active region AR 11190 during 09:38-09:49 UT. Wavelet analysis at four different frequencies (29 MHz, 25 MHz, 22 MHz, and 14 MHz) shows the quasi-periodic variation of emission intensity with periods of 34 min and 23 min. The periodicity can be explained by the first and second harmonics of transequatorial coronal loop oscillations. The apex of transequatorial loops may reach up to 1.2 R_S, where R_S is the solar radius, therefore the estimation of plasma parameters at these heights is possible. The seismologically estimated Alfvén speed at 1 R_S is ~1000 km s^{-1}. Consequently, the magnetic field strength at this height is estimated as ~0.9 G. Extrapolation of magnetic field strength to the inner corona gives ~10 G at the height of 0.1 R_S. Radio observations can be successfully used for the sounding of the outer solar corona, where EUV observations of coronal loops fail because of rapid decrease in line intensity.

Doppler effect in solar wind turbulence: A theoretical model of the energy spectrum for solar wind turbulence has been constructed by incorporating the effects of Doppler shift and broadening. In this model the solar wind magnetic field data measured by the four *Cluster* spacecraft were analyzed. This is the very first study of detailed spatio-temporal dynamics in solar wind turbulence using *Cluster* data and the high-resolution spectral analysis “Multi-point Signal Resonator”.



Panel (a): Energy spectrum derived from magnetic field data of Cluster, using the high-resolution wave number analysis technique. Panel (b): Reconstruction of the turbulence spectrum using the Doppler-shift-and-broadening model.

The measured Doppler shift was consistent with that expected from the ion bulk speed, while the measured Doppler broadening was not small as expected from the amplitude of the fluctuations in the ion bulk speed but much larger. The discrepancy in the Doppler broadening indicates that solar wind turbulence does not represent only anti-sunward propagating waves, but also counter-propagating waves toward the Sun. The large Doppler broadening also implies that Taylor's frozen-in flow hypothesis, time series are purely convected spatial structures, is invalid for solar wind turbulence.

Mercury

Mercury is now in the center of attention because of the current NASA *Messenger* mission and the upcoming ESA/JAXA *BepiColombo* mission. The planet has a weak intrinsic magnetic field and a mini-magnetosphere, which strongly interacts with the solar wind.

BepiColombo

Two spacecraft, to be launched in 2016, will simultaneously explore Mercury and its environment: the Japanese *Magnetospheric (MMO)* and ESA's *Planetary Orbiter (MPO)*. IWF plays a major role in developing the magnetometers for this mission: it is leading the magnetometer investigation aboard the *MMO (MERMAG-M)* and is responsible for the overall technical management of the *MPO* magnetometer *(MERMAG-P)*. For *MPO*, IWF also leads the development of *PICAM,* an ion mass spectrometer with imaging capability, which is part of the *SERENA* instrument suite, to explore the composition, structure, and dynamics of the exo/ionosphere.

In the first half of 2013, the instrument level testing of the *MERMAG-P* Flight Model was finished. In July 2013 it was delivered to Turin for integration on the *MPO* spacecraft. The *MERMAG-M* Flight Model (FM) electronics and sensor, which were delivered to Japan in 2012, were mounted on the *MMO* spacecraft early in 2013. In the following months, the *MMO* spacecraft had to pass a number of environmental tests like vibration and electro-magnetic compatibility under the supervision of Japanese space companies.

A MERMAG-P Flight Model with electronics box (center), two fluxgate sensors (front right and left) and two thermal protection covers for the fluxgate sensors with highly reflective mirrors (background right and left).

For *PICAM*, 2013 was mainly devoted to environmental, functional and performance test campaigns for the qualification model. Environmental testing started with the successful vibration and shock test in January, followed by the thermal vacuum (TV) test and the verification of the physical properties during summer. A non-conformance in the course of the TV test triggered an extensive review of the sensor design resulting in an improvement of various mechanical parts. The time in-between the environmental verification campaigns was used for intensive functional and performance test runs, which verified the sensor's behavior. The Qualification Model was finally delivered in October as a temporary FM replacement for system integration tests.

PICAM Qualification Model in its final configuration, mounted on the transport plate.

In parallel, the FM campaign made good progress. Electronics including its box and the sensor mechanics became available by November. Exhaustive thermal balance tests in particular of the ion optics were carried out afterwards. The development of the detector

electronics by the French partner LPP was again hampered by problems with the front-end ASIC. However, a final decision on the ASIC issue cleared the way for the detector assembly and testing as well as for the integration of the *PICAM* FM in 2014.

Venus & Mars

Two terrestrial planets are located just inside, Venus at 0.7 AU (AU = Astronomical Unit, distance Earth-Sun), and just outside, Mars at 1.5 AU, of the Earth's orbit around the Sun. Venus has a radius only slightly smaller than Earth and is differentiated; it does, however, not exhibit an internal magnetic field. Mars has a radius about half as big as that of the Earth, is also differentiated, but only exhibits remnant surface magnetization of a now defunct internal dynamo. Venus is characterized by a very dense atmosphere, whereas Mars has a very tenuous one. Both planets generate a so-called induced magnetosphere by their interaction with the solar wind.

Venus Express

ESA's first mission to Venus was launched in 2005. IWF takes the lead on one of the seven payload instruments, the magnetometer *VEX-MAG*, which measures the magnetic field vector with a cadence of 128 Hz. It maps the magnetic properties in the magnetosheath, the magnetic barrier, the ionosphere, and the magnetotail.

During 2013, the *Venus Express* spacecraft continued operating normally. The magnetometer remained ON during the whole year and collected magnetic field data both near Venus and in interplanetary space. Routine data processing and cleaning of the magnetic field measurements was undertaken for 1 Hz data. The software for data cleaning and process is robust and error-free. All data were cleaned and issued to the science community. Cleaning on 32 Hz data has been continued for part of the data. Archiving of all available data has been carried out and all data have been delivered to ESA's Planetary Data System.

InSight

NASA's *InSight* Mission to Mars (with an anticipated launch date 2016) is progressing according to plan. IWF is contributing to a self-penetrating probe, nicknamed "the mole", whose aim is to measure the planetary heat flux and the soil properties down to a depth of 5 m below the Martian surface. IWF is responsible for the investigation of the soil-mechanical aspects of the mole penetration.

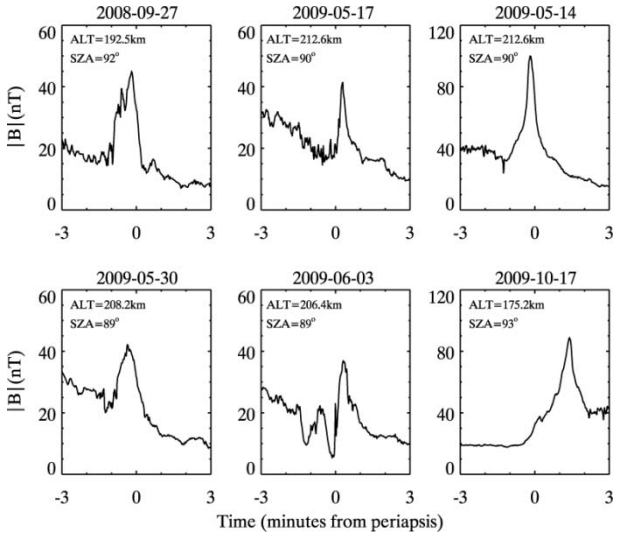
Physics

The solar wind interacts directly with the atmosphere of Venus in contrast to the situation at the Earth whose magnetic field protects the upper atmosphere. Still Venus' atmosphere is partially shielded by an induced magnetic field and it needs to be understood how effective that shield is. It is expected that the effectiveness varies with solar activity but current understanding of the solar wind interaction with Venus is derived from measurements at solar maximum only. *Venus Express*, with improved instrumentation, a different orbital trajectory, and observations at solar minimum, enables understanding the evolution of the Venus atmosphere caused by the solar wind interaction.

Venusian flux ropes: Early *Pioneer* Venus observations during the solar maximum revealed that Venus' ionosphere exhibits two magnetic states depending on the solar wind dynamic pressure conditions: a magnetized ionosphere with a large-scale horizontal magnetic field; or an unmagnetized ionosphere with numerous small-scale thin structures, so-called flux ropes.

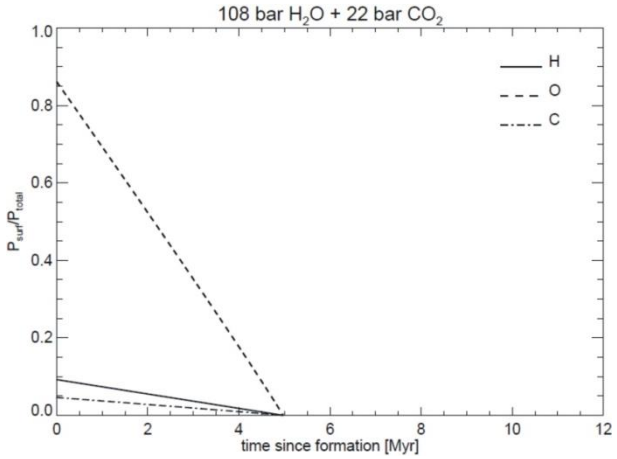
Observations from *Venus Express* during solar minimum indicate yet another magnetic state of Venus' ionosphere, giant flux ropes in the magnetized ionosphere.

These giant flux ropes all have strong core fields and diameters of hundreds of kilometers, which is about the vertical dimension of the ionosphere. They are found to be quasi-stationary. The rope's axis is mainly quasi perpendicular to the solar wind flow direction and the core field orientation is highly correlated with the IMF BY direction. It is suggested that giant flux ropes are formed due to the solar wind interaction with Venus, most probably in the magnetotail, and later transported and deposited in the ionosphere at the terminator.



Examples of giant flux ropes observed in the magnetized ionosphere at Venus. The ALT and SZA are the altitude and solar zenith angle at periapsis.

Escape of the Martian protoatmosphere: Latest research in planet formation indicates that Mars formed within a few million years and remained a planetary embryo that never grew to a more massive planet. Using estimates for the initial water content of the planet's building blocks, the nebula-captured hydrogen envelope and catastrophically outgassed water dominated steam atmosphere during the solidification of Mars' magma ocean has been modeled. Then a hydrodynamic upper atmosphere model was applied to study the soft X-ray and extreme ultraviolet (XUV) driven thermal escape during the early active epoch of the young Sun. The solar XUV flux was 100 times higher than today. Combined with the low gravity of the planet, this results in Mars having lost its nebular captured hydrogen envelope after the nebula gas evaporated, during a short 0.1-7.5 Myr period. After the solidification of early Mars' magma ocean, catastrophically outgassed volatiles in a range of 50–250 bar H_2O and 10–55 bar CO_2 atmosphere could have been lost during 0.4–12 Myr.



Example of the temporal evolution of the partial surface pressures normalized to the total initial surface pressure P_{total} of an outgassed steam atmosphere with 108 bar H_2O and 22 bar CO_2 surface pressure during about 5 Myr after its formation.

If the impact related energy flux of large planetesimals and small planetary embryos to the planet's surface lasted long enough the steam atmosphere could have been prevented from condensing. It can be expected that after the loss of the protoatmosphere during the most active XUV period of the young Sun, a secondary atmosphere may have evolved by a combination of volcanic outgassing and impacts 4:0±0:2 Gyr ago, when the solar XUV flux decreased to values less than 10 times of today's Sun.

Jupiter & Saturn

Jupiter and Saturn are the two largest planets in the solar system. Because of their atmospheric composition they are called "gas giants". Both planets rotate rapidly (approximately 10 hours) and are strongly magnetized, with the Jovian field a multipole field tilted at 10° and the Kronian field almost dipolar and perfectly aligned with the rotational axis. The magnetospheres are dominated by internal plasma sources, generated by the large number of moons, particularly Io at Jupiter and Enceladus at Saturn. The gas giants are also strong sources of radio emissions.

Cassini

The *Cassini* spacecraft is still orbiting Saturn, the second largest planet in our solar system. The 2013 spacecraft orbits were inclined by ~50°-60° with respect to Saturn's equatorial plane. In this year *Cassini* performed eight Titan flybys and its last close flyby of the Saturnian moon Rhea.

JUICE

ESA's first Large-class mission *JUpiter ICy moons Explorer (JUICE)* is planned for launch in 2022 and arrival at Jupiter in 2030. It will spend at least three years making detailed observations of the giant gaseous planet Jupiter and three of its largest moons, Ganymede, Callisto and Europa. Its instruments were selected in February 2013. IWF was successful in obtaining CoI-ship for three different selected instrument packages. For the *Jupiter Magnetic Field Package (J-MAG)* IWF participates in the development of the baseline fluxgate magnetometers. The development of an additional scalar sensor, by IWF in collaboration with TU Graz, is defined as optional. A decision on the scalar sensor is expected for April 2014 as an outcome of the Instrument Preliminary Requirements Review of *J-MAG*. The *Particle Environment Package (PEP)* is a plasma package with sensors to characterize the

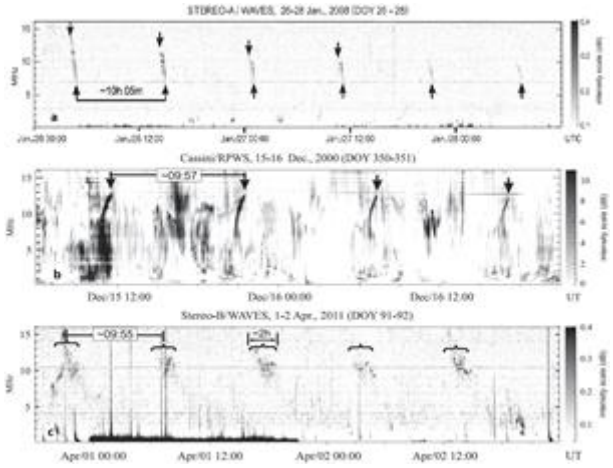
plasma environment in the Jovian system and the composition of the exospheres of Callisto, Ganymede, and Europa. IWF participates in the *PEP* consortium on Co-I basis in the scientific studies related to the plasma interaction and exosphere formation of the Jovian satellites. Last but not least, IWF is responsible for the antenna calibration of the *Radio and Plasma Wave Investigation (RPWI)* instrument. Here, first numerical simulations of the antenna characteristics of the three *RPWI* monopoles have been performed. The antenna triad was placed on the central spacecraft body and on the magnetometer boom to find the configuration with the best performance.

Juno

Juno is a NASA mission to the gas giant Jupiter that was launched in 2011 and will enter into a Jovian orbit in 2016. On 9 October 2013 the spacecraft obtained a gravity-assist sling-shot from an Earth flyby putting it on its way to Jupiter almost perfectly. *Juno* will be in a polar orbit, which is the first of its kind and is solely powered by solar panels, another first. Its scientific objectives are a.o. determining the water content in Jupiter's atmosphere, map the magnetic and gravity fields, and explore the magnetic pole regions, specifically the aurorae. IWF was involved in the antenna calibration of the *WAVES* instrument, which will investigate the auroral acceleration region and measure radio and plasma waves.

Physics

Periodic bursts of Jovian non-Io decametric radio emission (DAM): Three groups of periodic radio bursts in Jovian non-Io controlled DAM have been analyzed. The radio emission was recorded by *Cassini*, *Wind* and *STEREO* in the decametric frequency range. The main group is observed as a series of arc-like radio bursts with negative frequency drift (vertex-late bursts, panel a) which reoccur with ~1.5% longer period than the Jovian magnetosphere rotation rate. The occurrence of these bursts is correlated with pulses of the solar wind ram pressure at Jupiter. In the second group the arc-like periodic radio bursts exhibit positive time-frequency drift (vertex-early bursts, panel b). In contrast to the main group the vertex-early bursts reoccurred with the period close to the Jupiter rotation and were typically observed during 7-10 Jupiter rotations. The last observed group is of the rarely recorded non-arc periodic radio features in the form of a broad beamed radio emission, lacking clear discrete features (panel c).

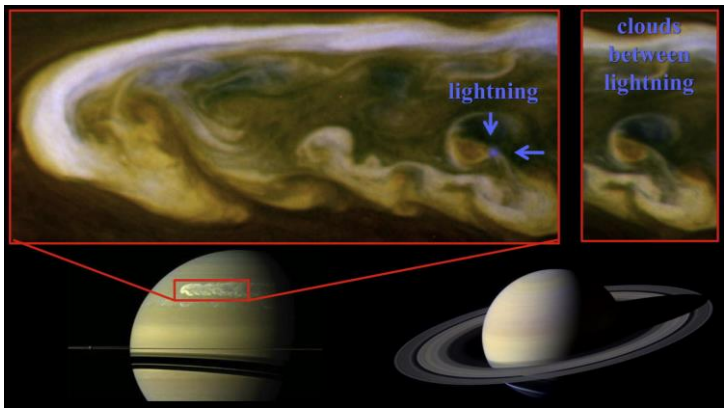


Examples of vertex-late (panel a), vertex-early (panel b) and non-arc (panel c) periodic radio bursts of Jovian non-Io DAM.

Comparative magnetotail flapping: Magnetotail flapping (the up-and-down wavy motion) is commonly observed in the Earth's magnetosphere. Now a comparison of flapping at the

Earth and the two giant planets Jupiter and Saturn has been performed. Due to single spacecraft missions at the giant planets this can only be done through investigation of the current sheet normal of the magnetotail. A case can be made that magnetotail flapping also occurs at Jupiter and Saturn. Calculations of the wave period using generic magnetotail models show that the observed periods are much shorter than their theoretical estimates. However, this discrepancy can be caused by unknown input parameters for the tail models (e.g., current sheet thickness) and by possible Doppler shifting of the waves in the spacecraft frame through the fast rotation of the giant planets.

Lightning in Saturn's atmosphere: Saturn's GWS (Great White Spot) of 2010/2011 was further investigated using data from the *Cassini* camera in combination with its *Radio and Plasma Wave Science (RPWS)* instrument. The GWS was a giant thunderstorm that raged in Saturn's northern hemisphere for about nine months and emitted radio waves caused by lightning discharges. The figure below displays *Cassini* images of the GWS which show the westernmost head region and the storm's long tail. *RPWS* data indicated that the storm's head was the main center of lightning activity, but the region of active thunderstorm cells also extended eastward into the tail. This was confirmed by the first optical observation of flashes on Saturn's dayside located eastward of the head.



The upper part of this figure shows two Cassini images taken on 6 March 2011. The left panel shows a blue spot attributed to a lightning flash, which is absent in the right panel image taken half an hour later. The lower part of this figure displays two Saturn images to show the large extent of the Great White Spot.

The head region periodically spawned anticyclonic vortices, and the optical flashes appeared in the cyclonic gaps between them where the atmosphere looked clear down to the level of deep clouds. The largest anticyclonic vortex in the tail drifted with a rate that was 2°/day slower than the head. Hence, after about half a year one caught up with the other, and it came to a head-vortex collision in mid-June 2011. This led to a significant decrease of lightning and convective activity, which became intermittent and finally ended in late August 2011.

Comets

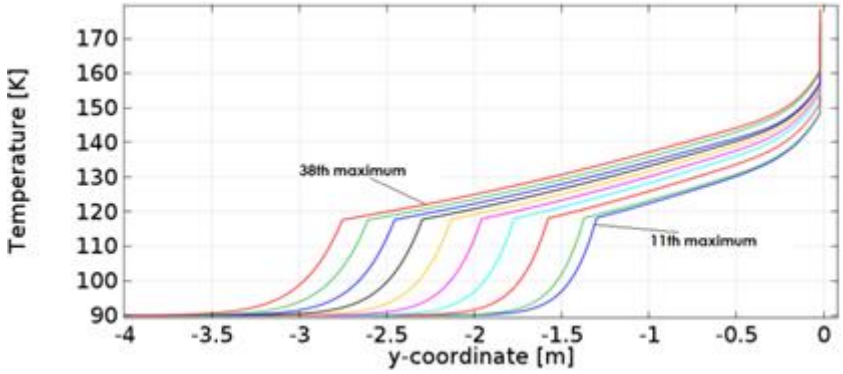
In recent years, successful space missions like *Giotto*, *VEGA*, *Stardust*, *Deep Impact*, and others have dramatically increased our knowledge on comets and their nuclei from flybys only. The next major milestone will be the arrival of *Rosetta* at comet 67P/Churyumov-Gerasimenko (short Chury) in 2014 and the landing of *Philae* on the comet's surface.

Rosetta

ESA's *Rosetta* probe is continuing its already nine year long journey to comet Chury. Solar panels are the only energy source for the spacecraft, which do not supply enough energy around *Rosetta's* aphelion. Therefore, the craft has been placed into sleeping mode. After a successful wake-up call in January 2014, the commissioning phase for the instruments will start. *Rosetta* will arrive at the comet in summer 2014 and after an extensive surface mapping the *Philae* lander will be dropped onto the comet's nucleus. IWF participates in five instruments aboard both orbiter and lander and concentrates now on preparatory work for data evaluation and interpretation.

Physics

Cometary outgassing: In view of the expected landing of *Philae* in November 2014 a theoretical model has been developed, describing the emission of gases from cometary crevasses. It includes both the possible transformation of amorphous ice into crystalline ice and the sublimation from the icy surface. Two qualitatively different cases have been studied: (i) free sublimation from the ice-filled crack and (ii) sublimation and diffusion through a thin dust mantle evolving over time.
The following figure shows the evolution of the temperature over time for an ice-filled crack covered by a thin dust mantle. For the *MUPUS* experiment aboard *Philae* calibration measurements have been performed using an engineering model of the *MUPUS* penetrator in the cryo-vacuum chamber.



Temperature development at different depth levels in a cometary crevasse filled by water ice and covered by a thin dust mantle. The distance from the Sun is 2.7 AU, which corresponds to the solar distance of comet Chury at the expected landing time of Philae.

Exoplanets

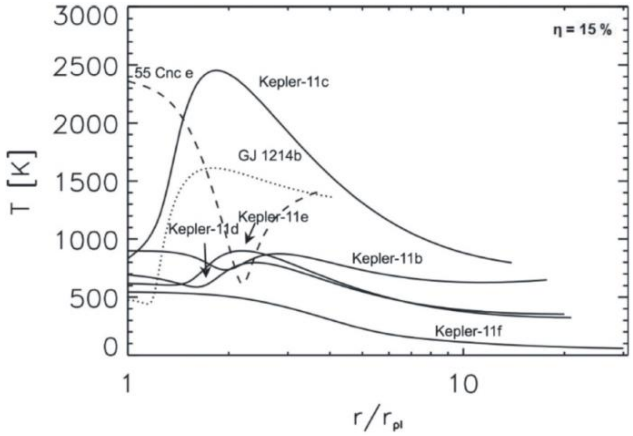
The field of exoplanet (i.e. planets around stars other than our Sun) research has developed strongly, in the past decade. Since the discovery of 51 Peg b, the first Jupiter-type gas giant outside our solar system, more than 1000 exoplanets, about 800 planetary systems with more than 170 multiple planet systems have been detected. Better observational methods have led to the finding of so-called super-Earths, some of them even inside the habitable zones of their host stars. However, the majority of super-Earths have low average densities, which indicate that they are surrounded by dense hydrogen envelopes or volatiles. By minimizing the uncertainties of the radii with the upcoming missions *CHEOPS* and *PLATO* densities and hence the structure of these planets will be better determined.

CHEOPS

ESA's first Small-class mission *CHEOPS (CHaracterizing ExOPlanets Satellite)* will be the first space mission dedicated to characterize exoplanets in detail. It will focus on exoplanets with typical sizes ranging from Neptune down to Earth diameters orbiting bright stars, trying also to specify the components of their atmospheres. *CHEOPS* will be implemented under the leadership of the University of Bern, Switzerland, with Belgium, Italy, Sweden, UK, and Austria delivering substantial contributions. Austria will contribute the back-end-electronics, which contains the Digital Processing Unit (DPU) built by IWF Graz and the power supply for the entire electrical sub-system built by RUAG Space Austria in Vienna. The redundant DPU will handle the complete data traffic, control the camera and compress the data stream. In addition, it will conduct the thermal control for the optical elements except the image sensor itself. It has a planned mission lifetime of 3.5 years, during which it will observe approx. 500 bright stars and characterize their planets.

Physics

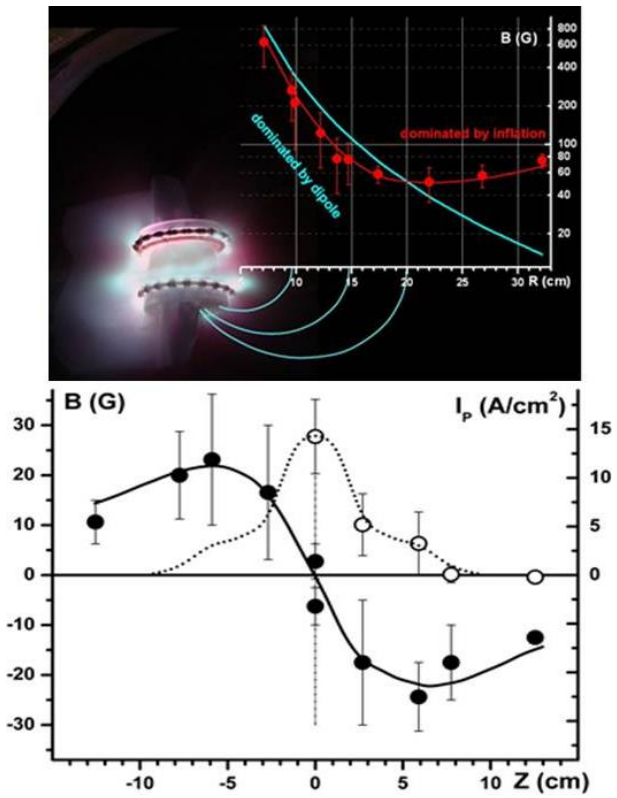
Exoplanet atmosphere-magnetosphere studies: The discovery of transiting super-Earths with inflated radii and known masses, such as Kepler-11b-f, GJ 1214b and 55 Cnc e, indicates that these exoplanets did not lose their nebula-captured hydrogen-rich, degassed or impact-delivered protoatmospheres by atmospheric escape processes. The hydrodynamic blow-off escape criteria of seven hydrogen-dominated super-Earths were studied by applying a time-dependent numerical algorithm which solves the 1D fluid equations for mass, momentum and energy conservation. Results as those shown in the figure below indicate that the upper atmospheres of super-Earths can expand to large distances, so that, except for Kepler-11c, all of them experience atmospheric mass-loss due to Roche lobe overflow.



Modeled temperature profiles of the super-Earths 55 Cnc e, GJ 1214b, Kepler-11b-f from the lower thermosphere up to the Roche lobe distance r_{L1} for a heating efficiency with η=15%.

The atmospheric mass loss of the studied super-Earths is one to two orders of magnitude lower compared to that of "hot Jupiters" such as HD 209458b, which are exposed to higher XUV fluxes at closer orbital distances. The loss rates of these exoplanets are too weak so they cannot lose their hydrogen envelopes during their remaining lifetimes. These results are also supported by stellar wind induced ion pick-up studies of hydrogen envelopes of super-Earths. Using a Monte Carlo simulation of stellar wind-plasma interaction, it is found that thermal escape rates of hydrodynamically outward flowing neutral atoms exceed the non-thermal H^+ loss rates up to an order of magnitude. Therefore, it is possible that super-Earths at orbital distances greater than 0.1 AU may not lose their primordial atmosphere.

Furthermore, the XUV-heated outward expanding upper atmospheres may also be influenced by the presence of a magnetic field. The exoplanet host star's high radiation field will ionize a part of the upper atmosphere. The interaction between the nonhydrostatically outflowing atmospheric plasma and an intrinsic planetary magnetic dipole field leads to the formation of an equatorial current-carrying magnetodisk. The presence of a magnetodisk influences the topology of the exoplanet's magnetosphere and changes the standoff distance of the magnetopause. The basic features of the formation of an exoplanet's magnetodisk have been studied in the laboratory. A localized central source produces plasma that expands outward from the surface of the dipole and inflates the magnetic field. The observed structure of magnetic fields, electric currents, and plasma density indicates the formation of a relatively thin current disk extending beyond the Alfvénic point. At the edge of the current disk, the induced magnetic field is several times larger than the field of the initial dipole.



Experimental setup (upper panel) and profiles of the radial component δB_R (full circles, left axis) and current in plasma (open circles, right axis) across the equatorial plane at a distance of R≈20 cm (lower panel).

Public Outreach

IWF is actively engaged in science education and public outreach. Throughout the year, many different groups and school classes (from WIKU Graz, VS BIPS Krones, NMS 1 Deutschlandsberg, Akademisches Gymnasium, NMS Krottendorf) visited the institute.

In January, ARGE KIWI (working group "Children and Science") invited more than 100 children from VS Berlinerring, VS Gösting, VS Viktor Kaplan, NMS Andritz, and NMS St. Johann to visit both IWF and the laser station at Lustbühel Observatory in the frame of the project "Wissen schaf[f]t Durchblick".

On 24 May, an "Einstein-Junior" families' day was organized at IWF. About 100 people, among them 30 children, learned about our solar system in different talks, guided tours

through the labs, and an extraordinary rap performed by Petra Huber from the Kinderbüro of the City of Graz and her team of five very enthusiastic young ladies and gentlemen. As celebratory end of this day, the Planetary Garden, initiated by IWF employee Christoph Kürbisch, was opened.

In June, the ÖAW Work Council organized an excursion for all employees to Graz, which included a visit to IWF.

In September IWF hosted the UN/Austria Symposium on “Space Weather Data, Instruments and Models: Looking Beyond the International Space Weather Initiative (ISWI)”.

From 15-24 November the ScienceCenter Netzwerk organized the Austrian “Themenwoche Weltraum”, in which IWF also participated. Again approximately 100 space enthusiasts were guided through the institute and the SLR station.

LR Kristina Edlinger-Ploder, initiator Christoph Kürbisch, and IWF Director Wolfgang Baumjohann (from right to left) had the honorable task to cut the ribbon between Mercury, Venus, Earth, and Mars.

From 9-13 December, “Post Alpach” was held at Schloss St. Martin. Günter Kargl and Martin Volwerk served as tutors and organized a visit to the institute for the 16 students.

On 16 December, Bernhard Stehrer from HLFS Urspung, Salzburg, travelled to Graz together with a small group of committed young people who wanted to learn more about the institute and space research in general. They were guided through the labs and interviewed the IWF Director about intelligent life in the universe.

Wolfgang Baumjohann surrounded by students from HLFS Urspung (Photo: HLFS Ursprung).

In the framework of the "FEMtech" program of FFG, four young ladies from KFU and TU Graz worked at IWF for two and four months, respectively. During summer time, five high-school students from BG/BRG Weiz (verification and evaluation of the accuracy and functionality of miniaturized magnetic field and acceleration sensors), HTL Weiz (data analysis of the El Niño phenomenon in the 19th century), HTL-BULME Graz-Gösting (reference box for personnel ground tester and break-out box for a dedicated interface standard), Akademisches Gymnasium (low frequency wave propagation problems), and BORG Deutschlandsberg (simulation of the influence of sensor materials on the magnetic field measurements of *CDSM)* performed an internship at IWF under the "Talente-Praktika" program of FFG. Additionally, a 16 year old girl from the European School of Brussels spent two weeks at IWF to get some work experience.

Throughout the year, several URANIA series of lectures on the topics "From the outer solar system to exoplanets" and "The world of astronomy – The history of matter" were held by members of the institute.

Last but not least, in June the "Topic of the Month" of the Austrian Academy of Sciences was "Aurora, Solar Wind, and Magnetic Field Turbulences", with contributions by Bruno Besser, Rumi Nakamura, and Evgeny Panov.

Publications

For a list of refereed articles and presentations at conferences please refer to iwf.oeaw.ac.at/en/publications.

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3.2 AAC - Aerospace & Advanced Composites GmbH

The ***Aerospace & Advanced Composites GmbH (AAC) was founded in 2010*** as a spin-off from the Austrian Institute of Technology (AIT). AAC is a private company (SME) that provides research, development and engineering capabilities in materials technology and testing for industrial applications with a focus in aeronautics and space.

AAC integrates the staff and the facilities of AIT's former Aerospace Department and continues its aerospace research started in 1998 with the ESA-certified **Space Materials Testhouse** under ESTEC frame contract. AAC is coordinator of European and national research cooperation projects in aeronautics and space.

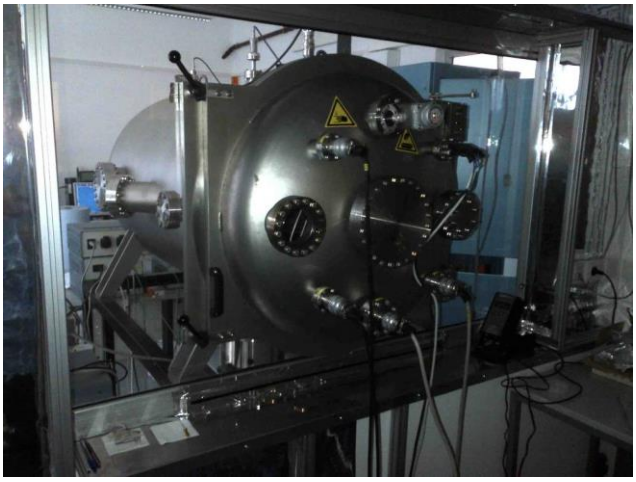
With its 24 employees, comprise an interdisciplinary AAC background in physics, chemistry, materials science, polymer engineering and mechanical and electrical engineering. More than one hundred research projects have been successfully concluded in the past 25 years. Based on the successful development in aerospace, AAC has extended its business to other industrial applications and will focus on three major areas:

- Polymer Composites
- Inorganic Composites
- Materials & Component Testhouse

In 2012 AAC moved to it's new premises in Wiener Neustadt, which is based on strategic decision: in this area several new research entities and one Applied University are located which provide for AAC a more prosperous growth. The infrastructure covers one building with labs and offices and a hall for heavy test equipment and polymer composite prototyping manufacturing.

AAC new facilities at TFZ in Wiener Neustadt (Left: hall and labs with offices)

One more advantage is that the thermal vacuum chamber ("TVC") is now attached to a clean room class 10000. Its door opens to the clean room, the external equipment and the backside of the chamber are placed in the neighboring lab. In addition, a second larger thermal vacuum chamber ("LVC") was installed in 2013. Together with a QCM-system monitored bake-outs can be done. Both chambers enable testing and bake-out of flight hardware, like on structural parts for Bepi-Colombo.

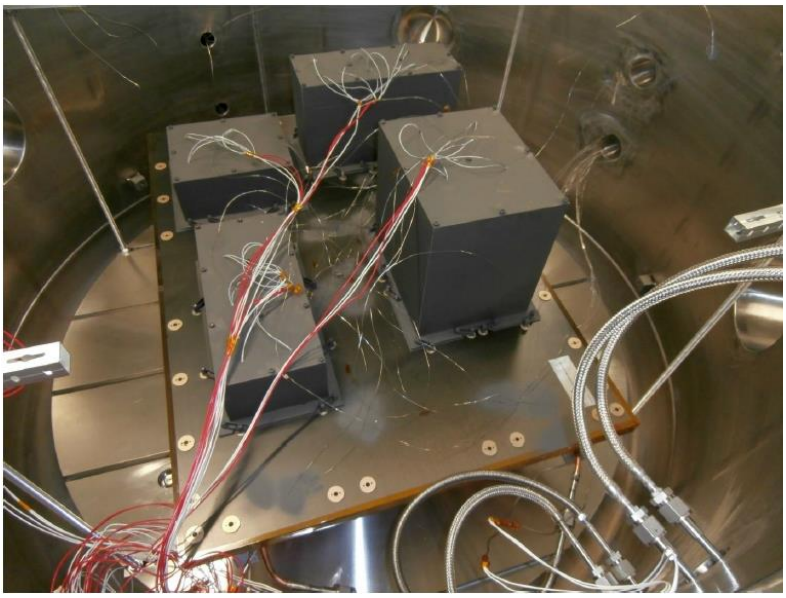


Left: Thermal vacuum chamber (TVC, diameter 0,7m) attached to a clean room class10000.
Right: New Large thermal vacuum chamber (LVC; diameter 1,3m) installed in 2013.

AAC has intensified it's activities in development of new composite materials and coatings for ***dry lubrication*** of mechanisms. Following recent problems with existing self lubricating PTFE based materials used in cages in ball bearing, an action plan was established by ESA ("***duroid replacement***"). Within that AAC is running the major project to develop a new self lubricating material based on PTFE in cooperation with Ensinger Sintimid GmbH. New compositions have been manufactured and tested on material level. Two compositions best of them were selected for testing as cages on ball bearings. Cages were manufactured and testing on bearing level started end 2013. Within a EU-project on development of new ***dry lubricating coatings for harmonic drives*** together with German and Spanish partners, first coatings showing promising results were successfully deposited on gears. Testing has started end 2013. AAC has also gained two more projects on application of dry lubricated gears called "HDGSA" and "Mechanisms operating at low temperatures".

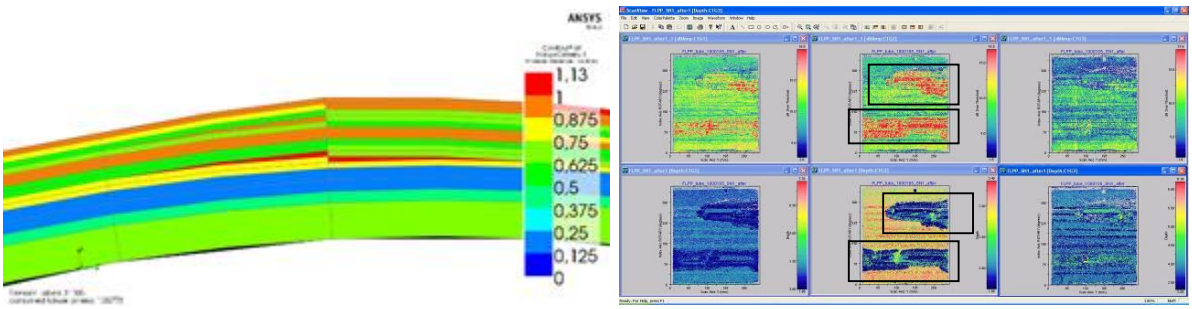
In frame of the ***Space Materials Testhouse*** for ESTEC several studies were handled in 2013. Herein, investigations on material level were performed. One study targeted the extension of the cold welding expertise from general testing of coatings / materials to avoid cold welding towards a test procedure that simulates "life" of hold down contacts, showing that solid lubricants in combination with proper surface treatments can be reliable solutions. A major effort was put into stress corrosion cracking issues on hard chromium steels, which are not SCC-resistant acc. to ECSS-standards. It was shown that AISI440C fails already at much reduced stress levels. For Cronidur testing is ongoing, as first tests showed success at medium stress levels, but at higher stress levels more investigations on the failure modes are necessary. Additive layer manufacturing is becoming of interest as it enables §§D-printing" of metallic structures. However, the microstructure of ALM-parts are not similar to common machined parts. Hence, first ALM-made alloys were successfully tested for SCC-resistance (e.g. Ti6Al4V).

Within "***HICO***", an ESA-project on development of „ High Conductivity CFRP Sandwich Technologies for Platforms", coordinated by HPS (DE), AAC performed an extended testing campaign on material level covering mechanical and thermal properties. Based on these properties, a bread board model (size 1,0x0,7m) was designed representing a main panel for future telecom satellites. Typical electronic boxes made form aluminium were attached introducing appropriate thermal power to the panel. This BB was investigated for it's thermal behaviour. Secondly, a thermal cycling was performed to proof the integrity of the Panel/Box-Interfaces after this exposure.



HICO Demonstrator Panel im Thermalvakuum-Test inside LVC

Currently cryogenic propellant feed lines for the Ariane launchers are made of stainless steel tubes. In order to save mass new lightweight materials such as polymer composites are considered for the replacement of the conventional steel solution. Within the ESA Future Launcher Preparatory Program (FLPP) and the national funded ***ASAP project "Fügetechnologien"*** prototypes of such composite replacements have been developed, analysed and tested by Magna Space and AAC. The used concept is composed of a thin metal liner overwrapped by glass fibre and carbon fibre layers. The thin metal liner is included to avoid oxygen incompatibility effects and to reduce the risk of potential gas permeation either induced by manufacturing or by thermal loads resulting from the cryogenic fluids. An interlayer of glass fibre reinforced polymer is required to reduce the thermo-mechanical stress level as well as avoiding galvanic corrosion at the metal – CFRP interface. Based on theoretically and experimentally determined data for the different materials, FE simulations were performed to predict the thermo-mechanical behaviour of a typical cryogenic composite feed line design under cryogenic cooling conditions. The FE predictions showed first failures of the cryogenic composite feed line structure in the outer CFRP layers, which has been confirmed by the results of the non-destructive inspections of all tested feed line articles.



Distribution of the Inverse Stress Ratio´s close to the edge at -150°C (red color indicates onset of damage) – left side, US inspection of tube 1 after thermal cycling (black rectangles show large delaminations between the CFRP layers) right side

Space Sales: **7.5 MEUR**
ESA Share: **0.9 MEUR**

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3.3 Seibersdorf Laboratories

Space Activities at Seibersdorf Laboratories

Seibersdorf Laboratories focus their space activities to space radiation and its effects to electronic components, materials and humans. The activities cover the following three topics:

- Space Weather and services for aviation dosimetry,
- Radiation hardness assurance of EEE components, and
- Developments of radiation sensors and detectors.

In the following, we present the three project studies carried out during 2013:

- **AVIDOS** – European Space Weather Service for Aviation Dosimetry
- **e^{2}RAD** – Energetic Electron Radiation Assessment Study for JUICE
- **EuCPAD** – European Crew Personal Active Dosimeter

European Space Weather Service

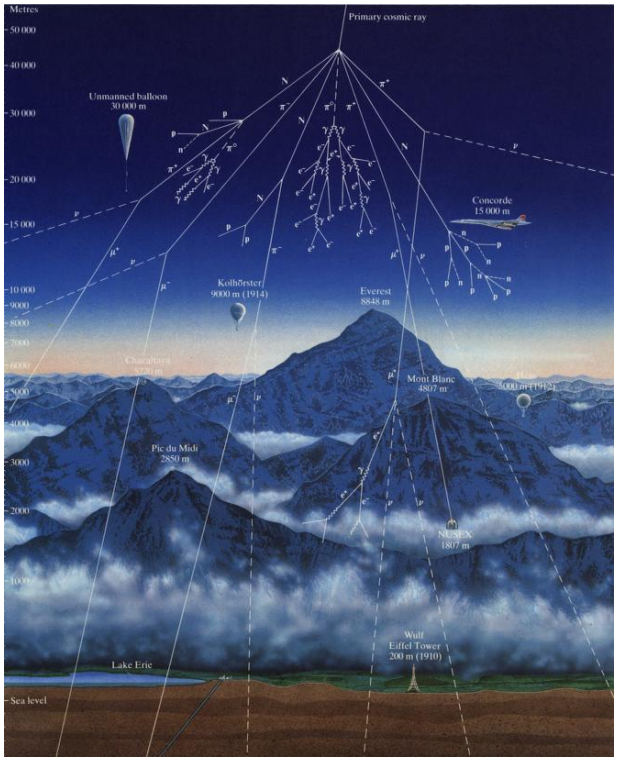

Figure: A constant shower of cosmic rays, energetic photons, protons, and atomic nuclei, enters the Earth's atmosphere from outer space.

Seibersdorf Laboratories carried out the project AVIDOS/SN-I Provisioning between 2011 and 2013. The objective of this project study is to demonstrate Space Weather Services in the frame work of ESA's Space Situational Awareness (SSA) Preparatory Programme (SN-I). Since 2013 AVIDOS is a web service of the Seibersdorf Laboratories federated with ESA's Space Weather portal, accessible under: swe.ssa.esa.int/web/guest/avidos-federated.

AVIDOS is an informational and educational online software for the assessment of galactic cosmic radiation exposure at flight altitudes. It estimates route doses for flights between any two locations. It also provides a comparison of assessed exposure with natural background radiation on Earth.

Galactic cosmic radiation consists of high-energy particles originating mainly outside the solar system. They produce secondary particles in the Earth's atmosphere and some even reach the Earth's surface. Recent investigations show that they originate from supernovae of massive stars. Cosmic radiation is part of natural background radiation on Earth. Persons present at higher altitude, such as aircraft crew, obtain more cosmic radiation exposure than those at sea level. Monte Carlo simulations of cosmic radiation transport in the atmosphere provide the bases for AVIDOS. Numerous on-board aircraft measurements validated AVIDOS extensively. AVIDOS calculates the effective dose, *E*, between 8 km and 15 km of altitude, for any geographic location and for whole cycle of solar activity. Effective dose, *E*, is the limiting radiation protection quantity assessing the cancer risk to an organism due to ionizing radiation. The annual limit for the public is one millisievert (mSv) and 20 millisievert (mSv) for occupational radiation workers.

The current version 1.5 of AVIDOS does not take into account extraordinary solar conditions such as solar flares or solar mass ejections. However, we plan to include them during the next project phase AVIDOS 2.0 (2014/15).

Figure: AVIDOS User Interface at ESA's Space Weather portal.

Acknowledgements

This project was supported by the European Space Agency (ESA Contract: No. 44000105734/12/D/MRP), the Austrian Federal Ministry of Transport and Innovation, and the Austrian Agency for Aviation and Space (ALR) as part of the Austrian Promotion Agency, FFG

E2RAD

ENERGETIC ELECTRON RADIATION ASSESSMENT FOR JUICE

Figure: ESA's Jupiter Icy Moon Explorer Mission JUICE

Since early 2013 Seibersdorf Laboratories is caring out ESA's project study e^{2}RAD (Energetic Electron Radiation Assessment Study) in collaboration with Kallisto Consultancy (UK). The objectives of this study are to investigate radiation effects behind different shielding materials and geometries when exposed to energetic electrons as expected during ESA's Jupiter Icy Moon Explorer Mission JUICE. Our aim is to identify graded shielding configurations for which the dose to an electronic component is lowest at a fixed area density of 2.7 g/cm². The shielding is composed of a high-Z and a low-Z material layer. The investigated electron fields cover mono-energetic electrons with energies ranging from 5 MeV to 50 MeV, and Ganymede's JUICE mission-phase electron spectrum.

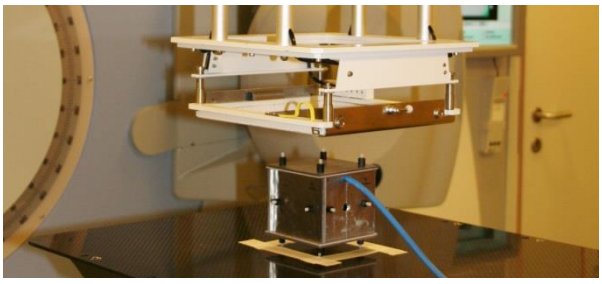

Figure: Exposure of a 10x10x10cm³ box-shielding set-up at an Elekta Synergy LINAC (Medical University Vienna/AKH) between 5 MeV and 20 MeV.

We performed a set of experiments at the linear electron accelerator of the Medical University Vienna/AKH for justifying our numerical approach using the Monte Carlo code FLUKA. We use two different box-shielding geometries (10x10x10 cm³,20x20x30 cm³) and one plane shielding geometry (10x10 cm²) composed of aluminum, titanium, lead, and tantalum. We modelled the experiments in detail regarding geometry and radiation environmental conditions. Subsequently we performed extensive numerical studies using different incident electron energies and different compositions of the graded shielding materials.

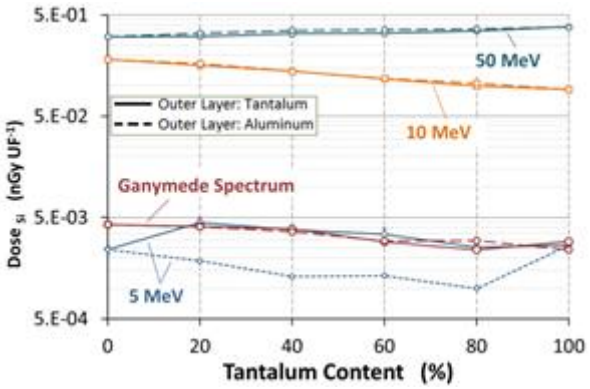

Figure: Numerical dose results in silicon inside a box-shielding (20x20x30 cm³) with 2.7 g/cm^2 area density for 5 MeV, 10 MeV, 50 MeV mono-energetic electrons and Ganymede mission spectrum.

Finally, we investigate the most efficient shielding design. For electron energies, lower than 18 MeV, we observed that increasing the high-Z content the dose decreases, while this is not true for energies higher than 18 MeV. The following figure shows a further observation: the radiation exposure obtained for the Ganymede mission is comparable to those obtained for 5 MeV mono-energetic electrons for Tantalum shielding as the outside high-Z layer.

Acknowledgements

We carry out the project under ESA's coordination (ESA contract No. 4000108163/ 13/NL/SC/fk). We acknowledge the support of the Medical University Vienna for providing us with electron beam time and for support by ARDENT (Marie Curie Initial Training Network, Grant Agreement 289198).

EuCPAD

EUROPEAN CREW PERSONAL ACTIVE DOSIMETER

The EuCPAD (European Crew Personal Active Dosimeter) project runs within the framework of the GSTP-4 program. The project focuses on a development of an appropriate, personnel, radiation detector system for the radiation dose assessment of astronauts at the International Space Station (ISS) that meets European Space Agency's (ESA) requirements.

German Aerospace Center (DLR) coordinates the project and collaborate with Seibersdorf Laboratories (SL, Austria), Physikalisch Technische Bundesanstalt, Braunschweig (PTB, Germany), Mirion Technologies - RADOS (Finland), Tyndall National Institute (Ireland).

In 2013 Seibersdorf Laboratories carried out investigations regarding the outgassing behavior of the micro-dosimeter detector material. We improved the pre-design of the detector concept and delivered a re-design. We investigated the long-term performance of the vacuum system and provided a set-up procedure during gas refilling.

We continued the numerical investigations and compared with experimental radiation calibration campaigns. Together with the whole project team, we prepared a patent. We plan to produce the flight model in the next project phase (2014/2015).

Figure: Vacuum system of the Space TEPC micro-dosimeter instrument

This space TEPC microdosimeter instrument is also suitable for radiation protection purposes in complex, terrestrial radiation environment such as on-board aircraft, around accelerators or medical irradiation facilities.

Acknowledgements

The project is part of ESA's GSTP program, supported by the Austrian Ministry of Traffic, Innovation and Technology, coordinated by the Austrian Space Agency and Research Promotion Agency (FFG/ASA).

ESA Share of Sales: 0.35 MEUR

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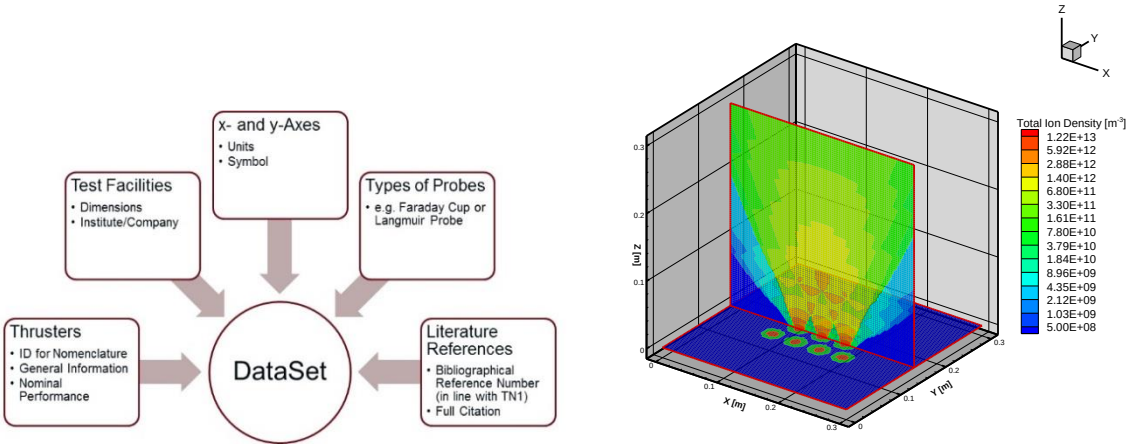
3.4 Fachhochschule Wiener Neustadt – University of Applied Sciences Wiener Neustadt

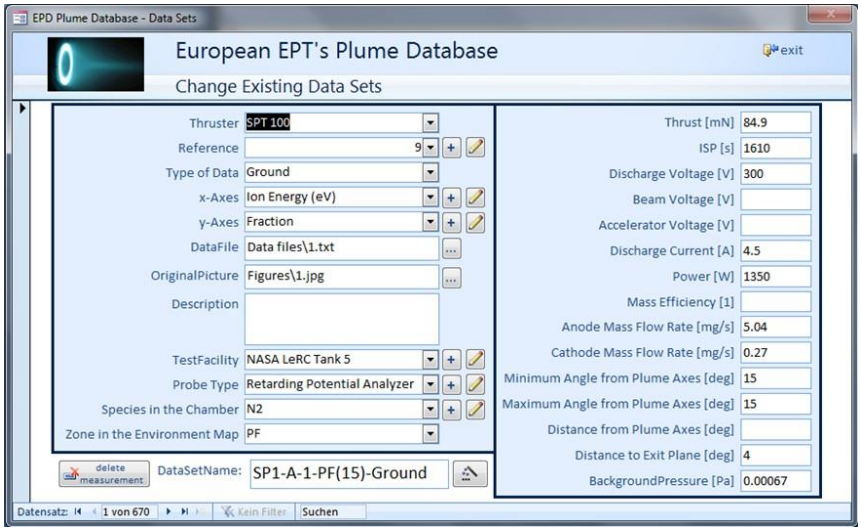
The University of Applied Sciences Wiener Neustadt together with its research company FOTEC was involved in a series of R&D project for ESA and other costumers. Details about some examples are described below.

Assessment of interactions between plasma plumes generated by propulsion systems and spacecraft structures:

With the trend to new spacecrafts equipped with electric propulsion only (instead of chemical propulsion systems) the question with regard to nature of interaction between the plasma plume and the spacecraft becomes more and more important. Under contract from ESA, and together with an international consortium, FHWN/FOTEC was tasked to investigate this issu and to establish a data base correlating all known information about the various types of electric propulsion systems with their plumes.



Simplified depiction of the type of inputs for the Electric Propulsion data base (left) and example of the simulated propulsion plume of a FEEP system



Example of the User Interface with the Electric Propulsion data baseThe NASA flight mission

Magnetospheric Multiscale Mission (MMS):

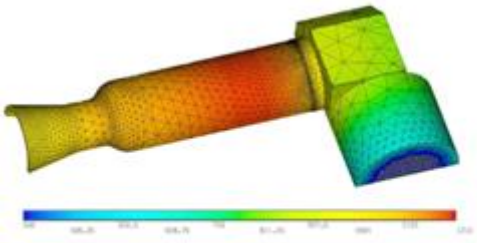
Magnetospheric Multiscale Mission (MMS) funded by ESA's PRODEX program together with the Austrian Academy of Sciences was finalized on schedule. In total nine flight units, each equipped with four Liquid Metal Ion Sources (LMIS) were successfully qualified and delivered to IWF and subsequently to NASA for integration on the spacecraft. Sufficient time for spacecraft qualification and the launch in 2015.

One of the Flight Units (FM). Each FM is equipped with four ion sources

The four MMS spacecrafts ready for environmental testing (source: http://mms.gsfc.nasa.gov/)

Development of chemical propulsion systems with high performing, low-toxicity propellants:

Proceeding with the development of a 1 N bipropellant propulsion system, FHWN/FOTEC has launched a new test and re-design iteration. Improved thermal design and implementation of advanced catalysts for increased decomposition efficiencies, has pushed the system to a new level of performance. Utilization of high temperature materials such as Platinum-Rhodium has allowed to exploit the energetic potential of the low toxicity propellant combination to its fullest. Initial discussion about industrialization of the system has been initiated. Due to the danger that the European commission puts a ban on hydrazine and other important propellants for space applications, this development gains more and more momentum and attention.



Simulation of the thermal properties of the Platinum-Rhodium combustion chamber

In cooperation with the Eurpean Space Agency, a new facility to assess the material compatibility with new propellants has been established. The facility is operating alrady and presently various space rated materials (metallic and non-metallic) are investigated with regard to their compatibility with highly concentrated hydrogen peroxide (H_2O_2).

Sales: **790 kEUR (Aerospace related only)**
ESA Share: **22 kEUR**

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3.5 EOX IT Services GmbH

EOX IT Services GmbH (EOX) is specialized in information technology infrastructures for hosting of, and providing access to, large volumes of geospatial data. Such data include GIS vector layers, Earth Observation (satellite borne, airborne) datasets, and in-situ geophysical measurements (point, profile, volume) acquired at sensor or remotely.

Currently most of EOX' business is generated in developments of complex infrastructure systems which are capable of handling Petabyte/Terabyte of data volumes stemming from new and planned satellite missions. EOX contribution to such developments is manifold: project acquisition, set-up and management; requirements identification, assertion with customers and management; engineering through the software development lifecycle along well-defined review milestones up to formal transfer to operations at customer facilities; maintenance and warranty of the software components delivered by EOX; user documentation and support (administrator and end-user).

EOX acts as a major software developer for the Payload Data Handling Ground Segment (PDGS) of non-commercial European Earth Observation satellite missions as they are being set-up and prepared by the European Commission (EC) and the European Space Agency (ESA). The family of the new Sentinel satellite missions and the legacy or historic missions operated by ESA as well as some 40 different "Contributing Missions" from other operators are all supposed to be managed in a coherent and coordinated environment in order to provide access to the user community.

Projects running in 2013:

Next Generation User Services for Earth Observation

A main development of operational software is contributed by EOX for the user information service part of the PDGS. The software is called “Browse Server” and forms part of the data discovery (metadata) subsystem of the next generation EO User Services (ngEO) package. The design target of the EOX provided component is to hold 20 Mio images with a resolution optimised to be viewed in a preview and portrayal map interface displayed in a Web browser. An essential requirement relates to the user experience and performance of simultaneous fast retrieval of large numbers of images and their display without causing display waiting times. Once a mosaic of images is shown on the interactive map, the user is supported in the download request of the full resolution (multispectral, multi-temporal, multi-sensor) satellite image products.

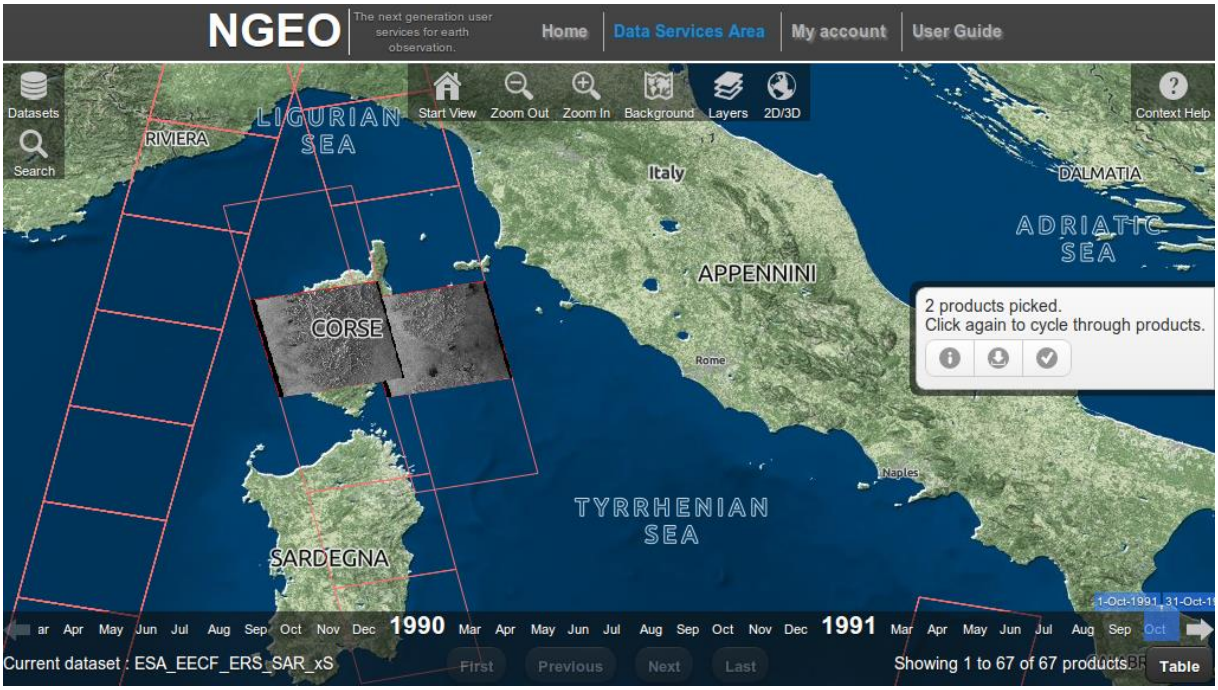

Fig. 1: ESA portal for Earth Observation data discovery and download

Visualisation and Manipulation of Multi-dimensional Data

Almost all of the above described activities and services are provided by EOX to its customer in “Visualisation and Manipulation of Multidimensional Data”, a project which was awarded by the European Space Agency (ESA) to EOX after a competitive Invitation to Tender process. The customer has been requesting that a system is delivered which allows providing “virtual

workspace" functions to users (scientists, operators) who demand tools for advanced data selection from large online archives, for visualization on 2D, 2.5D and 3D cartographic displays, for interaction with the data for the purpose of visual analytics and for the generation of graphical output (plots, diagrams), and for the transfer of data subsets into user exploitation networks and decision support systems.

A key technical requirement for V-MANIP is that the system shall be entirely Web based. This means that a loosely coupled architecture had to be implemented in which subsystems a linked with each other by Web protocols and that graphical user interfaces had to be provided which can be fully controlled from a Web browser, i.e. no need for any other software installation on the user computer, all user client functionality runs in the Web browser.

EOX is full member of the Open Geospatial Consortium (OGC) which is an international body establishing industry standardization for reference architectures, data models and network services for the managing of geospatial data in an interoperable way. The V-MANIP system is a qualified implementation of a number of such standards.

The V-MANIP system provides a multi-functional façade layer in front of the data archive (assumed to have high bandwidths connection to the archive system). This layer holds a database of metadata which is populated during archive registration and when new data are arriving in the archive.

The façade supports flexible integration of processors for on-demand processing on the server side based on the OGC Web Processing Service (WPS) protocol enabling synchronous and asynchronous workflows. Visualization output can be requested from the system by using the OGC Web Map Service (WMS), the Web Map Tiling Service (WMTS), as well as the Web 3D Service (W3DS) protocols.

W3DS is a portrayal service for three-dimensional geodata such as landscape models, city models, textured building models, vegetation objects, and street furniture.

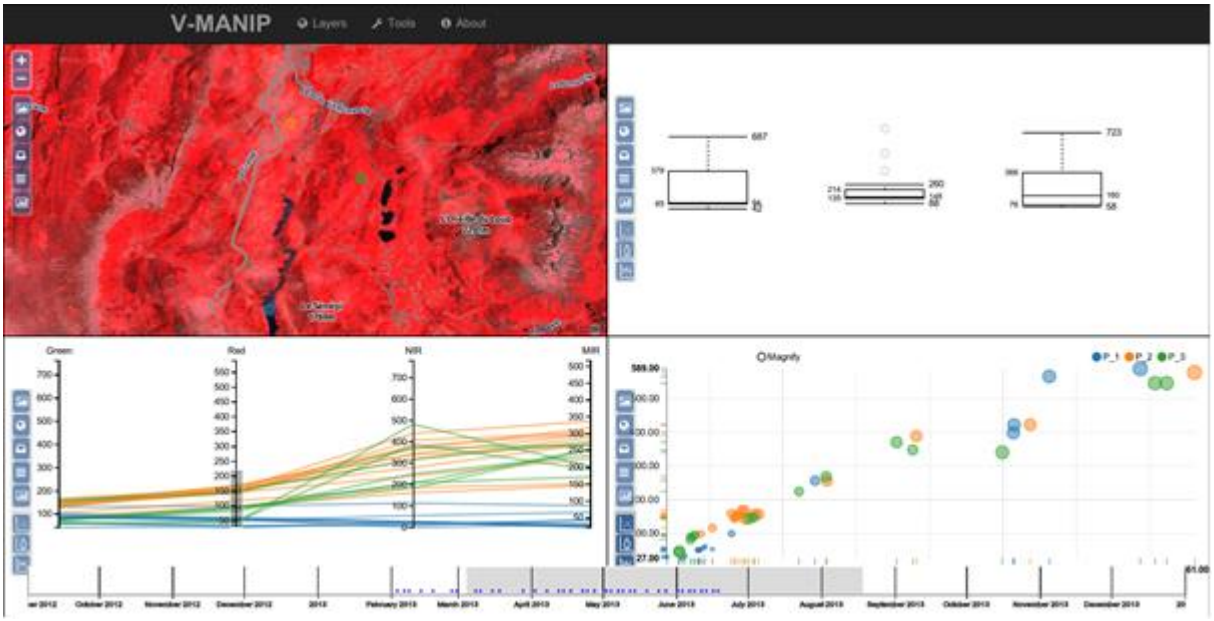

Fig. 2: Web-based visual analytics of satellite data time-series

As part of the ESA contract the V-MANIP System was demonstrated in applications for meteorological and hydrological users. The data sources were mainly high-resolution multi-spectral satellite data, some datasets contained volumetric data, some had particular geometric properties (“curtains” representing vertical cuts through the atmosphere), and most dataset were available as time-series for multi-temporal analysis. A virtual globe widget is integrated in V-MANIP permitting interactively-controlled fly-over 2.5D terrain and 3D man-made objects in the Web browser. Under the label EOX::Maps (maps.eox.at) the company provides global Digital Elevation Model geometries and worldwide topographic maps (generated from multiple data sources including Open Street Maps) and also an independent host service for these mapping products.

At the time of writing the V-MANIP System is at the stage of being transferred into the customers’ operational environment, the software undergoing formal acceptance test procedures following the ECSS (European Cooperation for Space Standardization) methodology which is applicable for most ESA engineering projects.

European Scalable Earth Science Service Environment

EOX plays a prominent role in the EarthServer project which aims at open access and ad-hoc analytics on Earth Science (ES) data, based on the OGC geo service standards Web Coverage Service (WCS) and Web Coverage Processing Service (WCPS). The WCS model defines "coverages" as unifying paradigm for multi-dimensional raster data, point clouds,

meshes, etc., thereby addressing most of Earth Science data. WCPS as aka "XQuery for raster data" allows declarative, SQL-style queries on coverages.

The project will develop a pilot implementing these standards, integrated with NetCDF and GeoSciML, two core formats used in the ESs, and open-source GIS tools. Integration of WCPS with XQuery will allow mixed data/metadata queries. The unified service will support navigation, extraction, aggregation, and ad-hoc analysis on massive n-D ES data through queries of open-ended complexity, achieving flexibility on coverage data as it is known from SQL. Clients will range from mobile devices over Web tools to high-end immersive virtual reality.

Fig. 3: Cryosphere Lighthouse Application in EarthServer

In the **RTD** part, EarthServer will establish open-source client and server technology which is scalable to Petabyte/Exabyte volumes, based on distributed processing, supercomputing, and cloud virtualization.

In the **Service** part, this new service has been installed on super-scale archives of data centers serving atmospheric, oceanography, geology, and general earth observation communities. Queries can span archive sites and cross-domain data sets. Volumes of 20+ TB will be demoed. EOX holds the leading position in this Service Activity part

As EOX specific contribution the “Cryosphere Science Support” Lighthouse Application (Fig. 2) has been set up and is undergoing further evolution.

In the **Networking** part, user training, community involvement and outreach, education of society (students, pupils, etc.) and public authorities, and standardization will be performed (e.g., OGC and INSPIRE).

Reference: http://earthserver.eu/

GMES Snow & Land Ice Service

Already in 2011 he EC signed the Grant Agreement for the implementation of CryoLand, the GMES Downstream Service for Snow and Land Ice. In 2013 EOX, CryoLand ICT infrastructure architect, has been finalizing the implementation of a Web-Services based interoperability environment

connecting data access, processing, archiving, work-flow and security functions at distributed facilities of partner institutions.

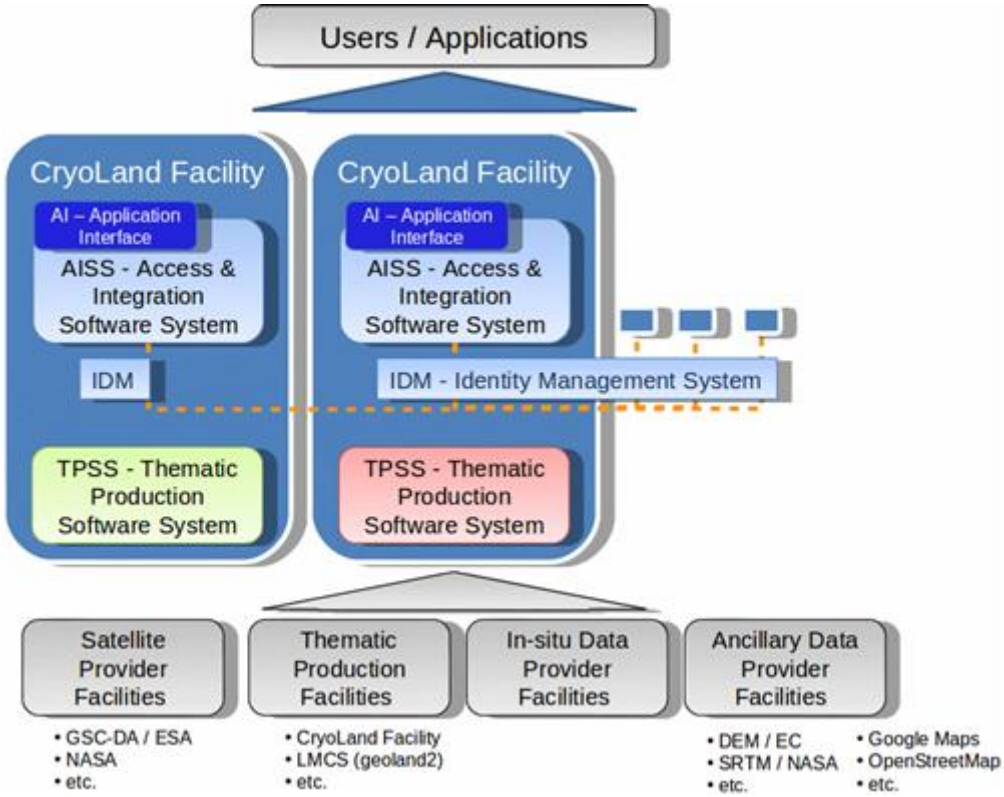

Fig. 4: CryoLand Information System Architecture

CryoLand aims at developing, implementing and validating a standardized and sustainable service on snow and land ice monitoring in a value added chain with the GES Land Monitoring Core Services. Since recent the service provides geospatial products on the seasonal snow cover (snow extent, snow mass, melt state), glaciers (area, snow / ice extent, ice velocities, glacier dammed lakes), and lake / river ice (extent, temporal variations, snow burden) derived from Earth observation satellite data in response to user needs. Pre-operational processing lines and service infrastructure for various product types have been developed on top of existing Web service environments (decentralized business process architectures) supporting the publication, provision and chaining of geospatial data services. User information services offering interactive mapsand product download functions via Web browsers have been designed and are accessible via a corporate “CryoLand Interactive Map Tool” (Fig. 5). Full end to end system tests and verification in pre-operational environment are being performed in cooperation with users in near real time. Finally the transition of the services developed within the project to an operational self-supportive snow and ice monitoring service is planned.

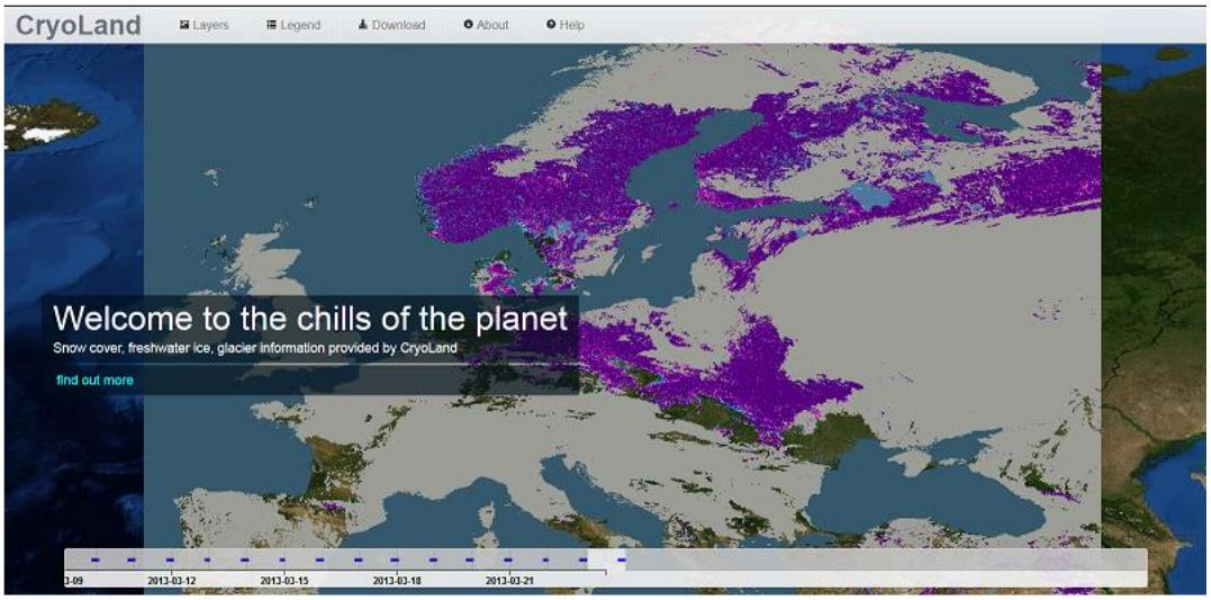

Fig. 5: CryoLand Interactive Map Tool

Reference: http://cryoland.eu

DREAM

The project initiative to deploy the described browse and download tools dedicated to the particular needs of the European Maritime Safety Agency (EMSA) in Lisbon, and the European Satellite Centre (EUSC/SatSen) in Torrejon is “Decision Support and Real Time Data Management (DREAM)”. In this project EOX has configured the tools environment for optimum use by the data preparation administrators at these two EC Agencies. Maximum comfort and efficiency is required for the operator to identify available data products at the large number of satellite operator services, to check their quality and adequateness and to trigger massive data download tasks for ingestion into the respective agency systems. Also the monitoring of the download processes, completeness checks and local storage management are supported functionality of the EOX development.

As an option, the operator could request the generation of cloud-free composite image products which are generated from time series of imagery replacing cloudy (invalid) with cloud-free (valid) pixels. EOX has provided in DREAM the processor for generation of such synthetic products which is optimized for Sentinel-2, 13 band, timeseries and is used for the production of cloud free mosaics of global coverage (similar to NASA’s Blu Marble layer).

EOX has furthermore provided and set-up the working environment of the Image Analyst in EUSC/SatCen. This required in a first place to develop interactive Web based map display widgets and the hosting of a complete global cartography server. The global map is a deployment of EOX::Map (maps.eox.at) and provides cartographic information at all zoom level down to sub-meter resolution (e.g. road network layer). Additionally, an intuitive Region of Interest / Time-period of Interest selection mechanism (a specially developed “time-slider

widget") is provided by EOX which is considered a most efficient data selection tool for a product database containing millions of entries at all locations of the world. An innovative paradigm has been implemented by EOX for this purpose.

In the DREAM project EOX plays also the role of system integrator. There is a subsystem developed by Airbus Space & Defence which provides an orthorectification quality check service, there is a raster database analysis tool to be interfaced via the Web Coverage Processing Service (WCPS).

The software development, verification, validation, and transfer into operations is governed by the ECSS model.

EOX: Maps - Products based on Open Data and Provider Services

The below maps are made of Open Data which are combined, cartographically designed and hosted by EOX. These global map coverages can be accessed via the standardized web services WMTS and WMS.

Background map:

Fig. 6: Terrain background map

This overlay contains labels for topographic features, cities, streets, etc. and is optimized for bright backgrounds like the terrain map above.

Fig. 7: Overlay map

For their customers (e.g. ESA) EOX also provides hosting services for global Open Data maps retrieved from external sources which EOX combines and renders according to customer needs.

Fig. 8: Bright overlay combined with dark background marbles maps

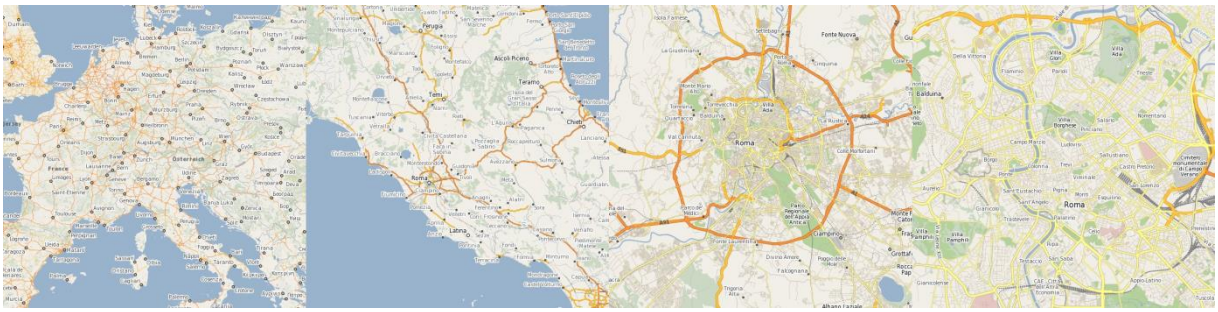

Fig. 8: OpenStreetMap background maps

All maps are provided as WMTS and WMS layers in simple longlat projection also known as WGS84 or EPSG:4326. They will soon also be available in a pseudo-mercator projection also known as Google projection, EPSG:3857, or EPSG:900913 like the OpenStreetMap background map (ID osm_3857).

Interactive demo: http://esa.map.eox.at

EOxServer Open Source Software

EOX is the home of the Open Source Software project “EOxServer”. This software is implementing the Earth Observation Application Profile of the Web Coverage Service 2.0 (EO-WCS).

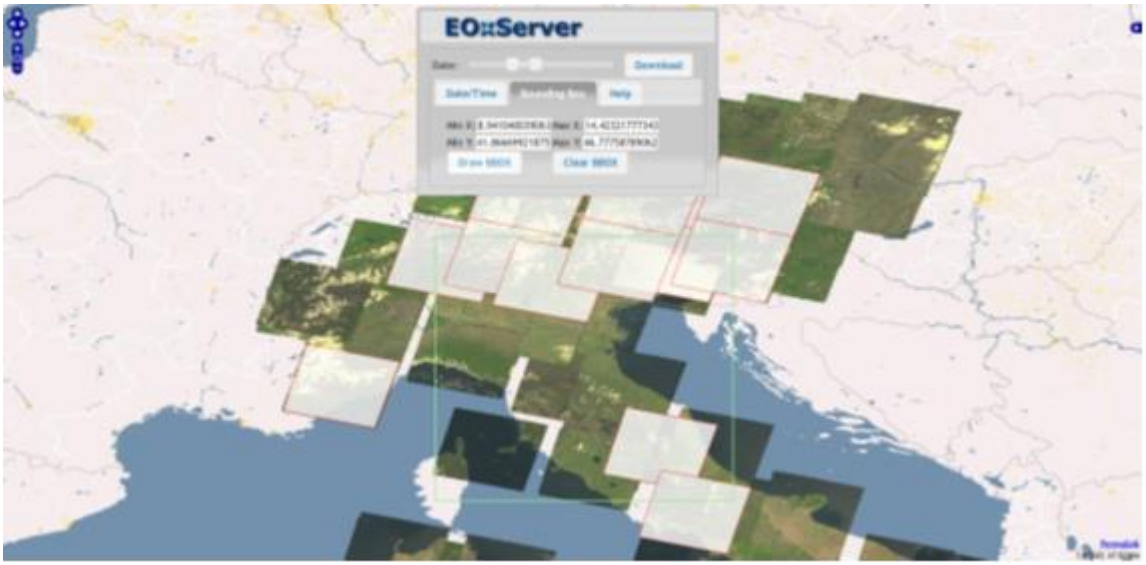

Fig. 9: Illustration of EOxServer’s EO-WMS and EO-WCS functionality

It enables data archive operators to set up a product access Web interface which is compliant with the latest standards of the Open Geospatial Consortium OGC. It augments the widely used Open Source software family MapServer (of which the underlying WCS2.0 functionality is also contributed by EOX), GDAL, SpatiaLite, PostGIS, PROJ.4, Python, and Django.

Reference and software download: http://www.eoxserver.org/

Sales: 432 kEUR

ESA Share: 121 kEUR

ESA Share including Subcontracts: 149 kEUR

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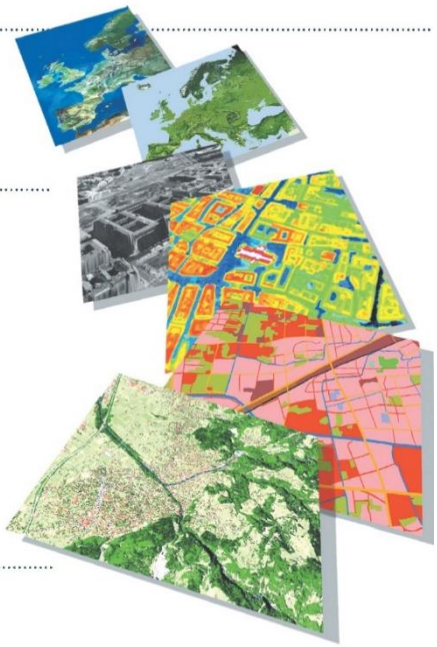
eox.at

3.6 GeoVille Information Systems GmbH

WHAT WE DO

We in GeoVille do the spatial job through the satellite's eye and deliver quality controlled geo-information for geographic accounting. Simple monitoring and customized geoinformation solutions for comprehensive applications.

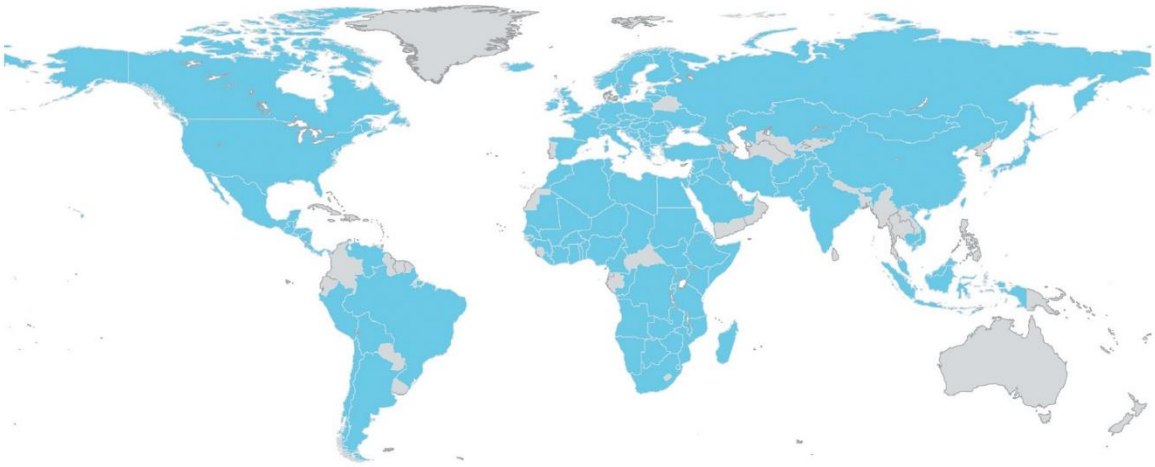


Geo-Information Solutions

Sectors of Impact:
Agriculture
Energy & Extractives
Environment & Natural Resources
Forestry
Infrastructure, ICT & Transport
Natural Hazards
Urban, Rural & Social Development
Water

WORLDWIDE SPOTLIGHT

Within the last 16 years, we successfully implemented **more than 370 projects in over 120 countries.**

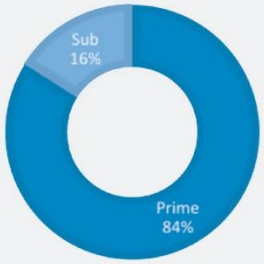


Country with project references

RESEARCH & DEVELOPMENT

GeoVille spends 30 to 35% of its turnover on research and development to be at the forefront of innovation. Consequently, we support our staff to engage in trainings for obtaining the latest technological capabilities.

CONTRACT TYPES



Prime vs sub-contract in %, 2013

GeoVille has rapidly transformed from a small business depending on subcontracts to one that manages complex prime contracts worldwide.

QUALITY & ENVIRONMENT

GeoVille has well established quality and environmental management systems, whose compliance with ISO standards (ISO 9001 & ISO 14000) has been certified by the International Certification Network (IQNet).

OUR CUSTOMERS

International & Transboundary	**International Development Banks**	**National & regional authorities**	**Private sector**
European Environment Agency, European Space Agency, European Union, International Fund for Agricultural Development, United Nations Programmes	Asian Development Bank, European Investment Bank, EuropeAid, World Bank	Various ministries and agencies for environment, agriculture, forestry, research and transportation worldwide, Water and energy commissions	Financial Sector, Consulting, Construction, Oil & Gas, Telecommunication

Sales: 4.01 MEUR

ESA Share: 0.6 MEUR

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3.7 Joanneum Research

JOANNEUM RESEARCH is dedicated to Space research and technology since 1978. The Institute for Information and Communication Technologies (DIGITAL) is focusing on the following competence areas

- Satellite communications and navigation
- Microwave propagation and radar technology
- Development of space-qualified hard- and software
- Verification and optimisation of systems and services in field trials
- Remote sensing
- Processing of data from active and passive space- and airborne sensors
- Space robotics

JOANNEUM RESEARCH is a highly recognised partner in large number of projects by the European Space Agency ESA, the European Union, international and national space industry and research establishments as well as foreign national space agencies such as NASA, ASI and DLR. Prototypes are developed into commercial products in collaboration with national and international industry. Successful examples are an airborne remote sensing and communications platform for disaster management, a video precipitation measurement system (2D video distrometer), a satellite channel emulator, a satellite signal monitor and the contribution to the ExoMars 2018 panoramic camera system. Developed systems are validated and optimised in field trials.

Communications & Navigation Technologies

Alphasat Ground Propagation Terminal

In order to study propagation effects for future satellite communication frequencies ESAs TDP 5 „Aldo Paraboni“ payload onboard of Alphasat satellite includes two beacon transmitters at Ka-band (19.701 GHz) as well at Q-band (39.402 GHz). In the last few years at JOANNEUM RESEARCH in Graz a Ground Propagation Terminal was designed and developed to measure the co- and the cross polar signals of both frequencies with one antenna and thus with the very same slant path geometry. This combination is especially requested to extend existing Ka band propagation models to higher frequencies.

On October 10, 2013 the Alphasat beacon signals have been switched on for the first time. Later in November the in-orbit tests of the payload have been successfully carried out.

Figure 1: Alphasat Ground Propagation Terminal on the Hilmwarte Tower in Graz

For these tests the Ground Propagation Terminal was placed on the Hilmwarte tower co-located to the Alphasat Communication Terminal. The measurement site in Graz hosts a variety of ancillary equipment to measure and document the weather- and the atmospheric situation. Besides a weather station with rain gauge, anemometer, temperature-, pressure- and humidity sensors, a 2D-Video-Distrometer to measure precipitation fine structure and drop-size distributions as well as a 16-channel microwave radiometer/profiler to measure cloud attenuation.

As agreed with ESA the Ground Propagation Terminal will stay in Graz for the next few years to measure propagation time series. From the measured time series and the available meteorological information a variety of parameters will be extracted such as attenuation, fade slope, fade and inter-fade duration due to precipitation, scintillation parameters due to tropospheric turbulence, and depolarization due to non-spherical precipitation particles. The measured propagation parameters from Graz and those measured at other European sites will be used to test existing and to develop new statistical prediction methods and channel models for Ka and Q/V bands satellite communication

The terminal was developed within an ESA/ESTEC contract and has following features

- a transportable and modular system
- remote data access and remote control
- customization- (e.g. Q band only)
- and re-configuration possibilities (to measure beacons signals other than those of Alphasat TDP 5)

Whenever possible off-the shelf standard components were used to guarantee easy maintenance and replacement.

Currently an identical second unit of the terminal is produced for the “Centre national d’études spatiales” (CNES) in Toulouse, France,

Figure 2: Indoor-unit of the Alphasat Ground Propagation Terminal

and further potential customers have already expressed their interest in the system.

Aeronautical Satellite Communications Channel Characteristics (AeroChannel)

The European Space Agency's (ESA) Advanced Research in Telecommunication Systems (ARTES) 5.1 program is dedicated to the long term technological development of the satcom industry. An international project team consisting of JOANNEUM RESEARCH as prime contractor, the Deutsches Zentrum fuer Luft- und Raumfahrt e.V., Germany (DLR), the University of Vigo, Spain (UVigo) and the satcom operator INMARSAT, United Kingdom, was selected to perform measurements and simulations for the AeroChannel project under ESA/ESTEC contract no. 4000106833/12/NL/CLP.

The aim of the AeroChannel project is to enable the development, deployment and optimization of satellite based broad-band communication- and data-services for use in the civilian air-traffic and to improve the commercial feasibility and quality of such services by advancing the understanding and the degree of sophistication for the aeronautical channel model. The main constituent elements in this communication channel are, as indicated in Figure 3:

- the direct (line-of-sight) signal
- effects of the aeronautical platform (including, but not limited to, deformations of antenna patterns, multipath at components of the aircraft, movement of the platform itself, effects due to rotation of turbines, propellers or rotors)
- and ground-based multi-path contributions

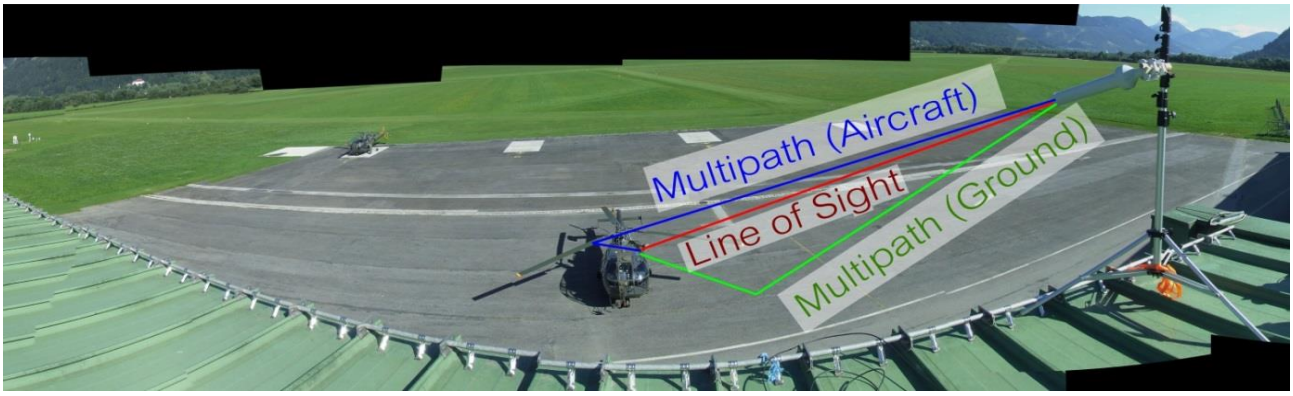

Figure 3: panoramic view of of first exemplary AeroChannel test measurements: test transmit antenna on roof is visible at right side, helicopter on ground in front of. Schematic presentation of the different contributions to the aeronautical channel model, comprised of direct line-of-sight signal path (red), contributions from the aircraft / platform (blue) and ground-based reflections / multi-path (green).

Our ambitious goal is to develop a software tool which allows simulating complete flight-scenarios for (almost) arbitrary combinations of aircraft-, flight-path and aircraft orientation, antenna-configuration, terrain-type, and satellite positions especially with respect to the signal reception.

In concert with the development of the software simulator, dedicated measurements and experiments will be conducted to determine characteristic parameters, thus allowing the verification of each development step by comparing the obtained results from simulation with data gathered in controlled experiments. These measurements include both ground-based as well as airborne activities and target frequencies in the L-band (which are used very intensively for satellite based services) and Ka-band. The latter frequency domain is currently in the focus for upcoming broad-band services and satellite deployments. In addition to this

frequency diversity, all measurements concerned with characterizing the ground-based multi-path propagation will be conducted under summery as well as wintery conditions.

Having the explicit goal of targeting a wide range of different aircraft designs, the practical experiments will be conducted with a total of four distinct airborne vehicles, including both small and large fixed wing aircrafts as well as small and larger helicopters. The project team will cooperate with the Austrian Airforce which will operate all involved aircraft types.

Phase 1, consisting mainly of activities concerning planning and experimental design, has been concluded in 2013, including successful field tests and exemplary measurements to establish the experimental setup and to verify the soundness of the experimental approach.

Figure 4: Alouette III helicopter equipped with antennae for ground based antenna and plattform pattern measurement (right) and during take-off (left).

Currently, the project is progressing towards the finalization of the equipment development and testing. Subsequent measurement campaigns will use actual satellite signals and will be carried out under both summery and wintery conditions. These measurements are scheduled for the time-frame May 2014 – January 2015. The project team expects to finish all activities, including modelling and simulator development, by the end of June 2015.

Alphasat IOT Campaign for TDP#5

The new Alphasat was successful launched in July 2013 with an Ariane 5 rocket into geostationary orbit at 25° east. The satellite has a main Inmarsat payload but host several “Technological Demonstration Payloads” (TDP) too.

Joanneum Research has designed and now operates one of the three ground stations for the TDP#5. The focus in these activities is to gain knowledge in the operation of the 38/48GHz band. This band is very important for the satellite industry because the current Ku and Ka band capacity will soon reach its limits and then the Q/V band has to be well understood to be used for commercial operation. In the framework of this demonstrator a new 3m Q/V band antenna was designed and installed on the top of the Hilmwarte tower in Graz. The satellite payload for the TDP#5 experiment had to be tested after launch to verify all specifications of the space borne hardware. This procedure is called “In Orbit Tests”, (IOT). The ground station in Graz was selected because of two reasons. First the station can fulfil the advanced specifications for the IOT and second it was ready in time for the IOT period.

The experts from Joanneum Research were able to verify successfully the specifications of the TDP#5 payload and proved the involved experts from ESA and the Italian partners the high performance of the ground station in Graz.

The experiments on TDP#5 have started at middle of December 2013 and will last at least 3 years. Joanneum Research together with the two Italian ground station is now worldwide the centre of the research for the Q/V band.

Figure 5: Left: Artist impression of the Alphasat with the big reflector of the main payload from Inmarsat. Right: TDP#5 payload on Alphasat with the three spot beam antennas. Two are focused on Italy sites and one towards Graz. Both © ESA

Remote Sensing

SASISA – Small-Aircraft Service for Instant Situational Awareness

SASISA is an ARTES 20 Demonstration Project for establishing a reliable, affordable and commercially viable airborne sensing service for first responders and other civil security-sector users to supply them with a new dimension of situational awareness information in the most critical initial phase of disaster response operations. In current practice, airborne sensing is a non-real-time activity, with results often only available days later. The SASISA service is designed to fill the gap in near real time imaging and mapping in support of operational decisions to be taken by user commanders during disaster and emergency response operations.

The SASISA Demonstration consortium is led by Knowledge & Analysis (United Kingdom) as ESA's prime contractor. The other consortium partners are the aircraft and airborne sensing operator DEA (United Kingdom), the satellite communications system provider Viasat Antenna Systems (Switzerland), the ground system provider HITEC Luxembourg (Luxembourg), the aviation information system provider Atmosphere (Germany) and the digital communications and remote-sensing research centre Joanneum Research DIGITAL (Austria). The aircraft manufacturer Diamond Aircraft Industries supports the project through its subsidiary Diamond Airborne Sensing (Austria). Satellite EO imagery shall be made available for value-added post-processing and mapping using SASISA imagery, drawing on the existing capacity and access of e-Geos, an Italian company to still join the consortium. Last but not least the project benefits from active support by participating users from Austria and Luxembourg.

The modular system architecture is shown in Figure 6. The components of the envisaged service system include commercial off-the-shelf sensors and SATCOM systems as well as small aircraft. Thus, the proposed service incorporates space technologies (communication & navigation) in combination with terrestrial technologies. It assembles airborne as well as spaceborne components and assets as follows:

- Austrian-built DA-42M small multi-purpose aircraft with external pods (owned by DEA)
- Cameras with integrated precise position and timing measurement units:
    - EO/IR video turret on nose pod (COTS)
    - RGB + TIR downlooking still camera underfloor pod (JR)
- Near real-time data availability using a high-performance data downlink technology
    - Line-of-sight downlink (JR) based on Software Defined Radio (SDR) technology
    - Ku-band SATCOM pod (Viasat) for beyond line-of-sight transmission
- Onboard processing/orthorectification software (JR)
- Onboard mission control tablet (Atmosphere)
- Browser-based visualisation to users (HITEC)
- Operational ground liaison with users (K&A/DEA)

This system design allows effective emergency response as it gives users access to near-real-time, georeferenced airborne image data and value-added information in order to efficiently support emergency management. The modular system architecture is optimised for filling the needs of users in a wide range of disaster events. Relevant usage scenarios highlighted by users include:

- Limiting the damage during river floods, including monitoring the condition of embankments and flood defences;

- Responding to large fires, especially forest fires and other wildfires;
- Responding to landscape-changing disasters (e.g. earthquake, flash flood, avalanche, mudslide, dam failure, storm tide, tsunami wave, volcanic eruption).

By using a broadband satellite link in flight, georeferenced imagery can be sent to the ground over any distance, and without the need for preparing and installing network or transmission infrastructure. The service can be operated even when line-of-sight radio communication is not possible, e.g. when terrestrial networks are disrupted and the affected area on the ground inaccessible.

Following this system design, the demonstration system shall be implemented and demonstrated in 2014. Therefore, dedicated demo campaigns are planned to take place in Austria, Italy and Luxembourg. In a long-term, Europe-wide coverage is envisaged through implementation of multiple base stations in order to deliver current situational awareness products to users all across the continent right on the first day of a disaster event. Exemplary products with respect to flood mapping and detection of fire locations or hot spots, respectively, are shown in Figure 7.

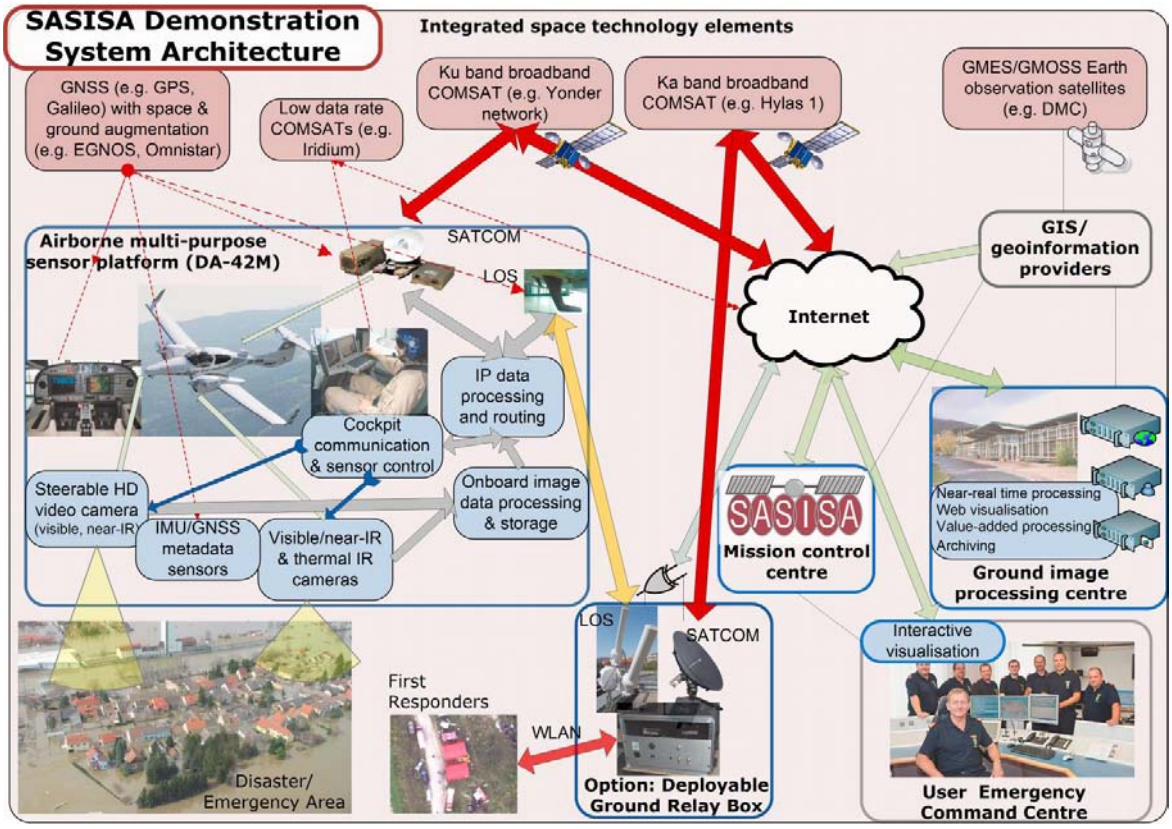

Figure 6: Overall SASISA system architecture

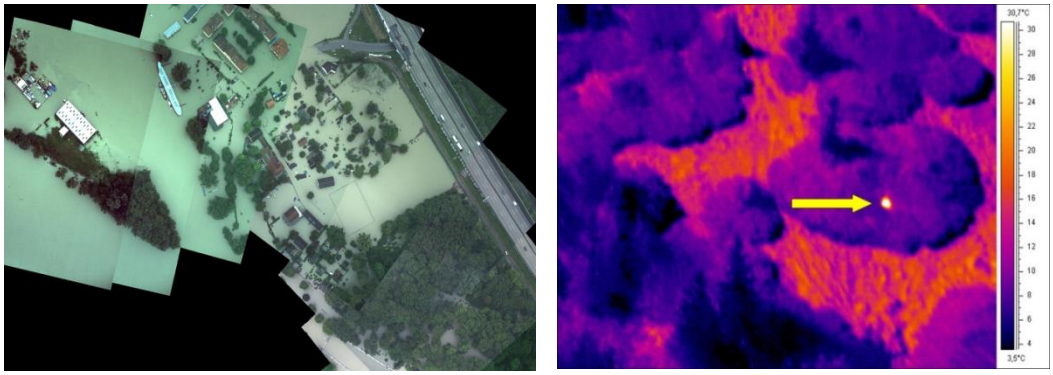

Figure 7: Example of a flood mapping campaign (left) and of a thermal image with hot spot marking (right)

GSE – Forest Monitoring

The GSE-Forest Monitoring project addresses the policy related demands for securing the ecological functions in the forestry sector. It is part of the Global Monitoring for Environment and Security (GMES) Services Element (GSE) and is funded by the European Space Agency (ESA). The developed forest monitoring services are based on high resolution satellite image time series.

JOANNEUM RESEARCH as a main partner in the international consortium which is led by GAF AG is responsible for service evolution, which aims to improve and further automatise forest monitoring services by research and development. In 2013, the main emphasis of JOANNEUM RESEARCH was on the development of methods for full utilisation of the information content provided by dense time series imagery, specifically to:

- automate radiometric pre-processing of dense time series
- develop forest monitoring methods based on the full temporal trajectory of the measured reflectance
- demonstrate the method applications for monitoring degradation in tropical forests

The methods were applied for monitoring forest degradation within the Republic of Congo and in Gabon in the frame of REDD (Reducing Emissions from Deforestation and Degradation). Below figure shows exemplarily the spatio-temporal pattern of forest disturbances in the region of Pokola in the Republic of Congo.

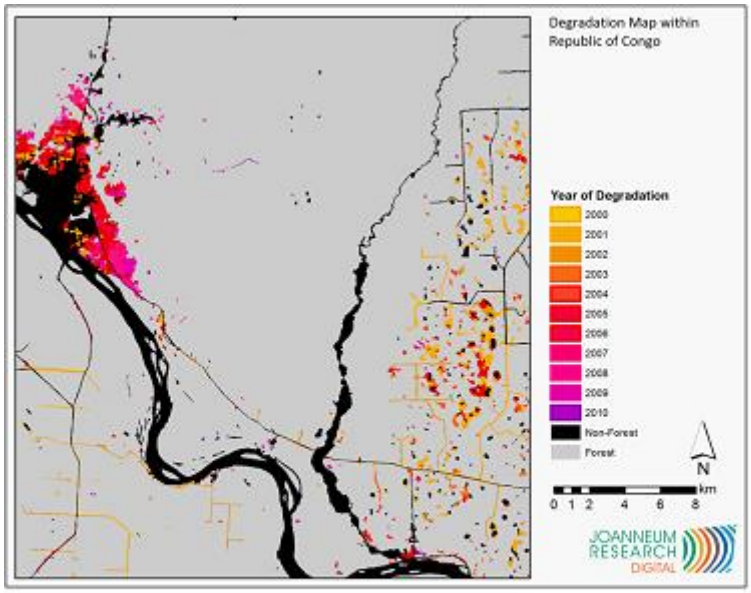

Figure 1: Spatio-temporal pattern of forest degradation derived from satellite time series imagery.

Whereas current operational forest monitoring applications are often based on the comparison of selected satellite scenes, the developed methods utilise the full temporal trajectory of dense time series data such as provided by future SENTINEL-2 satellites. The developments are therefore especially relevant for operational applications based on data from the ESA SENTINEL-2 satellites, which will provide a significantly improved temporal resolution compared to current satellite data and will allow automated forest monitoring from the regional to the global level.

Space Robotics

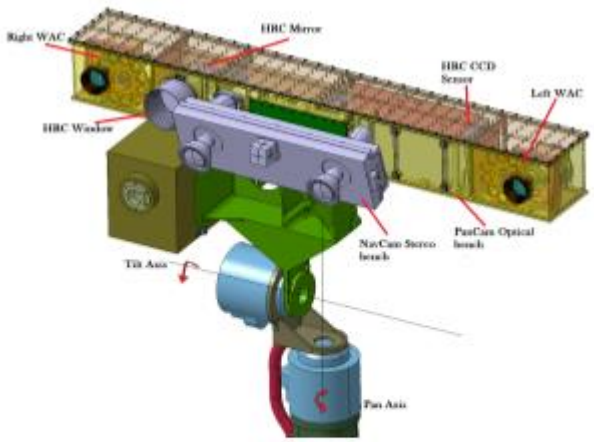

Figure 1: : ExoMars PanCam instrument (left and right Wide Angle Camera– WAC as well as High Resolution Camera– HRC) mounted on the Optical Bench, seen as brown structure in the rear. The grey structure is the navigation camera (NavCam), the front grey box is the Russian ISEM instrument (Credits: ESA / Astrium UK / Thales Alenia Space Italy).

ExoMars PanCam 3D Vision

The joint ESA/Roscosmos ExoMars Rover Mission is scheduled for launch 2018 and landing on the Red Planet in 2019 to search for signs of past and present life on Mars. One important scientific sensor is a panoramic imaging system (PanCam), mounted on the Rover Mast. It consists of a wide angle multispectral stereo pair and a high resolution monoscopic camera. Main objectives during its six months operational phase are the provision of context information to detect, locate and measure potential scientifically interesting targets, localize the landing site, geologically characterize the local environment, and observe experiments.

Three dimensional (3D) PanCam vision processing is an essential component of mission planning and scientific data analysis. Standard ground vision processing products will be digital terrain maps, panoramas, and virtual views of the environment. Such processing is currently developed by the PanCam 3D Vision Team under Joanneum Research coordination (PRODEX Contract), with background coming from the Mars Netlander Panoramic Camera (DLR) and the Beagle 2 camera system (MSSL, JR, and Aberystwyth University). Camera calibration, quality estimation of the expected results and the interfaces to other mission elements and instruments such as operations planning, rover navigation system and global Mars mapping or the data from the ExoMars WISDOM ground penetrating radar are a specific concern of the current work. In terms of visualization, Joanneum Research is supported by the Austrian research entity VRVis.

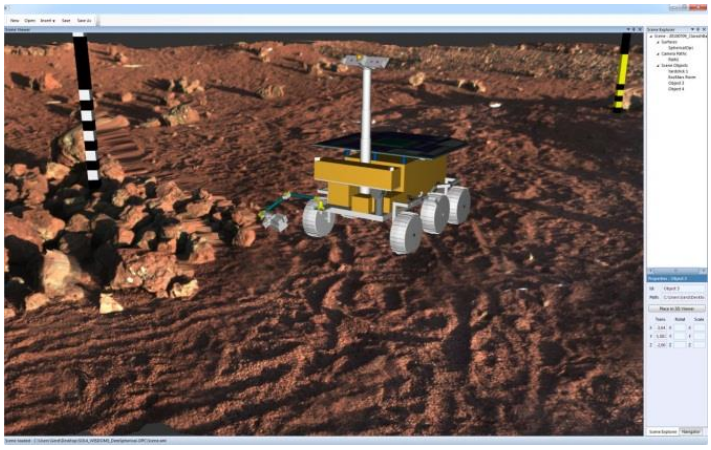

Figure 8: Virtual rendering of PanCam 3D vision processing result (data captured during a field trial at the CNES rover test environment SEROM in Toulouse) with an early ExoMars rover model as well as a scale bar inserted.

After landing in 2019 the resulting software processing tools, their processing products and a real-time 3D data viewer will be used by geologists, exobiologists and mission engineers to decide upon experiments, select scientifically interesting sites for the rover, and determine risks, resource costs and a priori success probability of vehicle operations: PanCam 3D vision is a key element of ExoMars mission success.

FP7-PRoViDE: Planetary Robotics Vision Ground Processing

The international community of planetary science and exploration has launched, landed and operated dozens of human and robotic missions to the planets and the Moon. They have collected various surface imagery that has only been partially exploited for further scientific application purposes. Few attempts have been made so far to bring the data into a unified geospatial context, to exploit spatial relationships between such images and with orbiter data.

The FP7-SPACE project PRoViDE (2013-2015; www.provide-space.eu), coordinated by Joanneum Research, assembles a major portion of the imaging data gathered so far from vehicles and probes on planetary surfaces into a unique database. It processes a complete set of 3D vision products, bringing them into a common planetary geospatial context and providing seamless and immersive real-time access to them through a multi-resolution visualisation engine with various levels of detail for a dynamically rendered 3D scene representation. Project partners include University College London, University of Nottingham, Czech Technical University, Technical University Berlin, MIIGaiK from Moscow, VRVis Vienna, Aberystwyth University and Imperial College London.

Among other main objectives, ProViDE intends to:

- generate a **vision data catalogue** by identifying candidate planetary imagery to be used for 3D vision processing, covering all relevant robotic sites of recent and ongoing missions such as Viking, Pathfinder, MER, MSL, Phoenix, Huygens, and Lunar ground-level panoramas & stereoscopic & multi-view images from Apollo, Russian Lunokhod and selected Luna missions.
- provide the **highest resolution & accuracy remote sensing vision data processing results** for the mentioned mission sites to embed the robotic imagery and its products into

spatial planetary context including updating local-to-global transformations to enable all rover imagery to be co-registered to orbital imagery.

- **collect 3D Vision processing results into a 3D spatial data base**, connected to relevant high-quality remote sensing products.
- **seamlessly integrate orbit and ground vision data** of recent, ongoing and planned missions including the simulation of ground-level imagery from orbital data for future landing sites.
- demonstrate the potential of existing and forthcoming planetary surface vision data by **highly realistic real-time visualisation**.

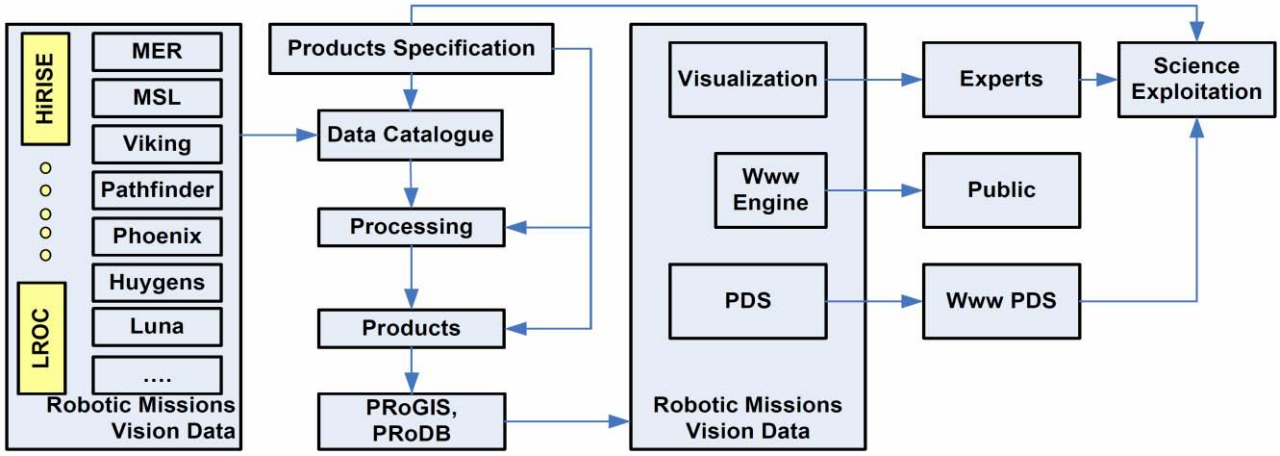

Figure 9: PRoViDE overall layout

The first year (2013) of the ProViDE project period collected scientific requirements to data and visualization products, prepared the image data catalogue and generated the necessary orbiter data products to act as unique spatial frame for the surface robotic vision data products. The main task by Joanneum Research, beside project coordination, is the implementation of 3D vision processing functions.

Sample Acquisition Field Experiment with a Rover (SAFER)

The SAFER (Sample Acquisition Field Experiment with a Rover) project was performed under contract with the European Space Agency by a consortium led by RAL Space (UK), and composed of LATMOS (FR), Space-X (CH), Joanneum Research (AT), Aberystwyth University(UK), UCL (UK), Leicester University (UK), Astrium (UK) and SciSys (UK). Most of the SAFER team members are key scientists and engineers involved in the ESA's ExoMars rover mission, for both platform and instruments.

SAFER's objectives were challenging: Bring together three ExoMars instruments prototypes: PANCAM, CLUPI, and WISDOM, on a rover platform able of autonomous operations, and test in a representative Mars environment the strategies necessary to successful science targets identification, approach, and investigation, including drilling albeit manually.

The SAFER field campaign was completed after 10 months of preparation over 2013, and lasted for about a week in October 2013. During the campaign, Joanneum Research supported the ExoMars PanCam team as well as the SAFER operations team with remote 3D vision processing and visualization.

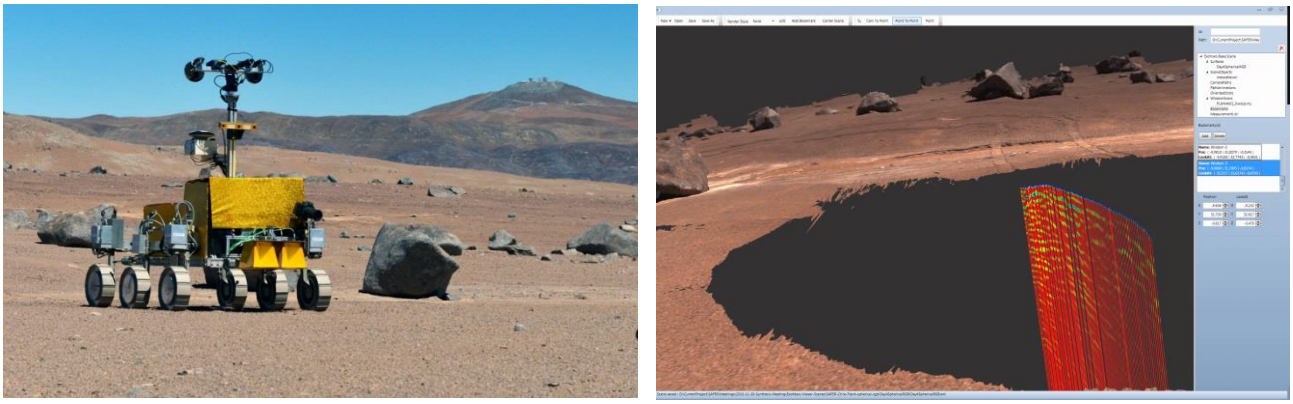

Figure 10: Left: SAFER Rover equipped with ExoMars analogue instruments during the Chile October 2013 campaign (Credits: RAL space / Scisys). Right: 3D vision processing product by Joanneum Research, using PanCam and WISDOM data, displayed by 3D interactive viewer (Credits: LATMOS, VRVis).

Multi-purpose Vision-based Navigation System Engineering Model (VisNav)

Vision-based navigation is one of the major components of growing autonomy in planetary exploration missions. The VisNav ESA study under prime contractor Thales Alenia Space Italy is developing commonly usable software and hardware components – including simulation chain and test environments – for vision-based navigation in the context of landing as well as rover surface operations. Joanneum Research covers the surface mission components in this scenario, by implementing 3D mapping and navigation modules such as visual odometry (Figure 11) in space-relevant hardware and software environment, targeting a lunar rover application.

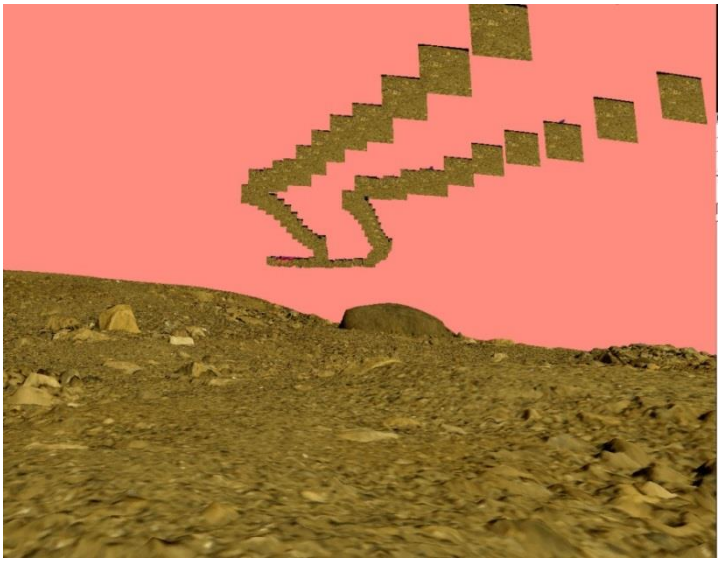

Figure 11 Top: Testing Visual Odometry (an important element of vision-based rover navigation) on synthetic data to evaluate its accuracy: The 3D landscape and the cameras' image positions are displayed.

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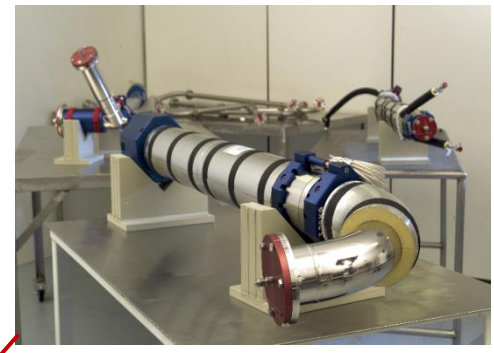
Sales Space (period July 1, 2012 – June 30, 2013): 3.78 MEUR

ESA Share: 1.15 MEUR

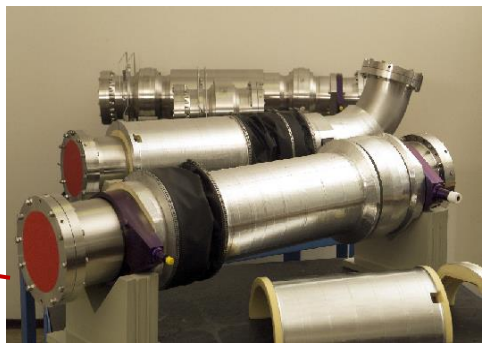
3.8 MAGNA Steyr Aerospace

Cryogenic liquid oxygen and hydrogen lines

MS Aerospace manufactures the cryogenic liquid oxygen and hydrogen lines of the Main Stage and the Upper Stage for the European launcher ARIANE 5:



Manufacturing of Equipped lines for A5-ESC-A (since 2000)



Manufacturing of Equipped lines for A5-EPC (since 1990)

MS Aerospace is also involved in the manufacturing development of the enhanced reignitable upper stage (ARIANE 5-ME) and was also involved in the ARIANE 5-ME preparatory phase. MS Aerospace is also a partner in the Future Launcher Preparatory Programme (FLPP) in focus of cryogenic lines for the ARIANE successor ARIANE 6.

Slush Hydrogen

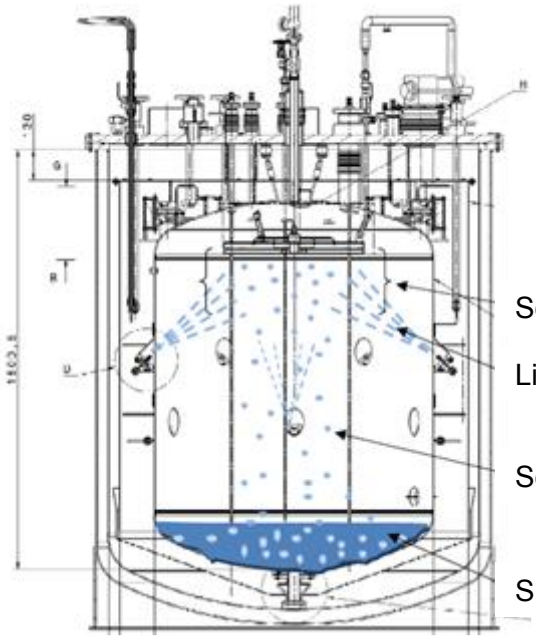
In year 2000 MAGNA Steyr has developed and patented an advanced method for the production of Slush Hydrogen. Slush is a mixture of solid and liquid percentage of a cryogenic agent with the gain of increased density (18% relative to liquid Hydrogen) and an increased heat capacity. This features bring a saving of gross take-off weight for a launchers and a saving of transport cost for shipment.

The Slush production with MAGNA slush gun method was verified first time in laboratory size in year 2005.

Slush production plant (laboratory)

Hydrogen injector

In year 2013 the production of Slush hydrogen with a production rate of 250liter Slush/hour and a quality of 50% (percentage of solids in mixture) was performed successfully with an appropriate designed pilot plant. The Slush gun production method is also applicable for liquid natural gas (LNG).



schematic slush production diagram

Pilot slush production plant (250liter/hour)

Sales: **5.5 MEUR**

ESA Share: **1.2 MEUR**

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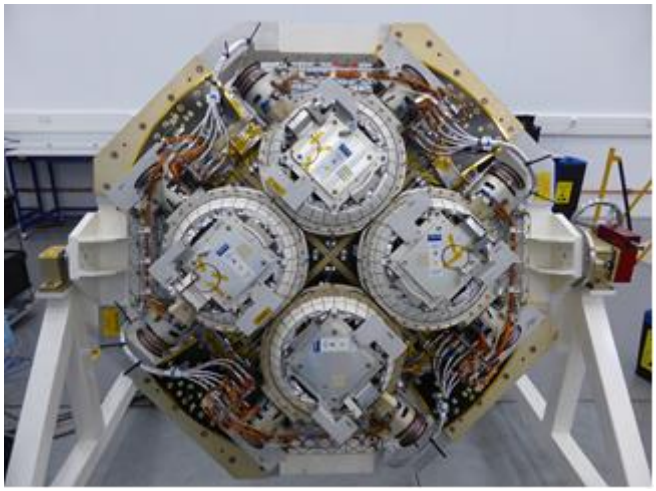
3.9 RUAG Space

One of the major activities of RSA in 2013 concerned the Thruster Pointing Assembly for the solar-electric propulsion subsystem of BepiColombo, ESA's next Cornerstone Mission to Mercury. The responsibility of RSA comprises the Thruster Pointing Mechanisms and the associated drive electronics. This highly advanced activity represents one of the largest contracts ever awarded to RSA. It relies on the extensive experience and heritage of the company in the area of pointing mechanisms for electric propulsion. Assembly and acceptance testing of the four mechanism flight models as well as of the associated drive electronics, to be integrated in the Mercury Transfer Module, has been completed.



BepiColombo Thruster Pointing Assembly Flight Configuration (Source: Airbus)

Further RSA projects of significant size in BepiColombo concern the Solar Array Drive Electronics (SADE) and the spacecraft Multi-Layer Insulation (MLI). Manufacturing and acceptance testing of the SADE Proto-Flight Model (PFM) was completed end of the year.

BepiColombo Solar Array Drive Electronics PFM

The MLI development and production poses real challenges, in view of the spacecraft's exposure to very high temperatures in the inner solar system.

BepiColombo MLI Integration

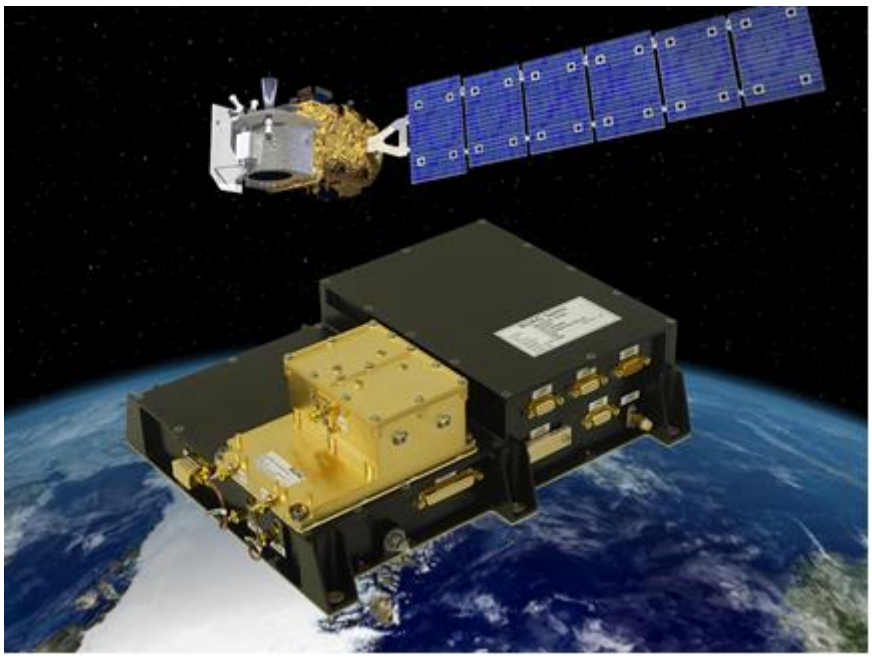
In ExoMars the development of the Orbiter Computer has been completed jointly with RUAG Space AB in Sweden. Other activities concern the Orbiter Module Thermal Hardware and electronics modules for the Rover Computer.

A strategically important contract concerns the SOLAR Orbiter Thermal Hardware Subsystem. For the first time, RSA is responsible for a complete subsystem, including selection and management of a major subcontractor.

Artist's Impression of SOLAR Orbiter (Source: ESA)

Products of high strategic importance for RSA are GPS Precise Orbit Determination (POD) Receivers, with an excellent market position of the company in Europe. GPS POD uses high-quality carrier and code measurements of a dual-frequency receiver on-board of a satellite, to achieve measurement of its position with an accuracy of a few centimeters in on-ground processing. The RSA GPS POD Receiver is based on highly integrated radio frequency (RF) and digital circuits as key innovations, thus offering low mass and power consumption among its attractive performance characteristics. All Sentinel satellites of the joint ESA/EU Copernicus program as well as ESA's EarthCare satellite will fly the RSA receiver. This clearly demonstrates RSA's strong position with this product on the European market.

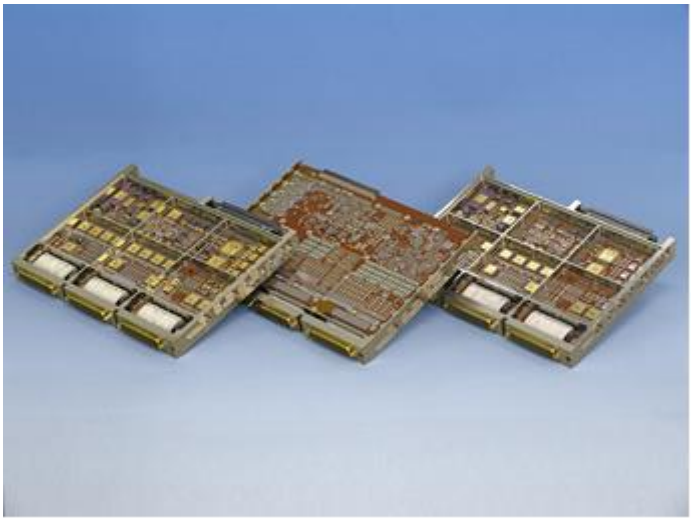
A real break-through for the company in its expansion of business in the US space market is a contract concerning the supply of GPS POD Receivers for the NASA mission ICESat-2 to Orbital Sciences Corporation. This represents the first RSA delivery of electronics to the US, the by far biggest space market today and home country of GPS. This success is directly based on the development for the Sentinel satellites. Manufacturing and test of the flight units is nearing its completion.



GPS POD Receiver for ICESat-2 Mission (Source: RUAG Space/GSFC)

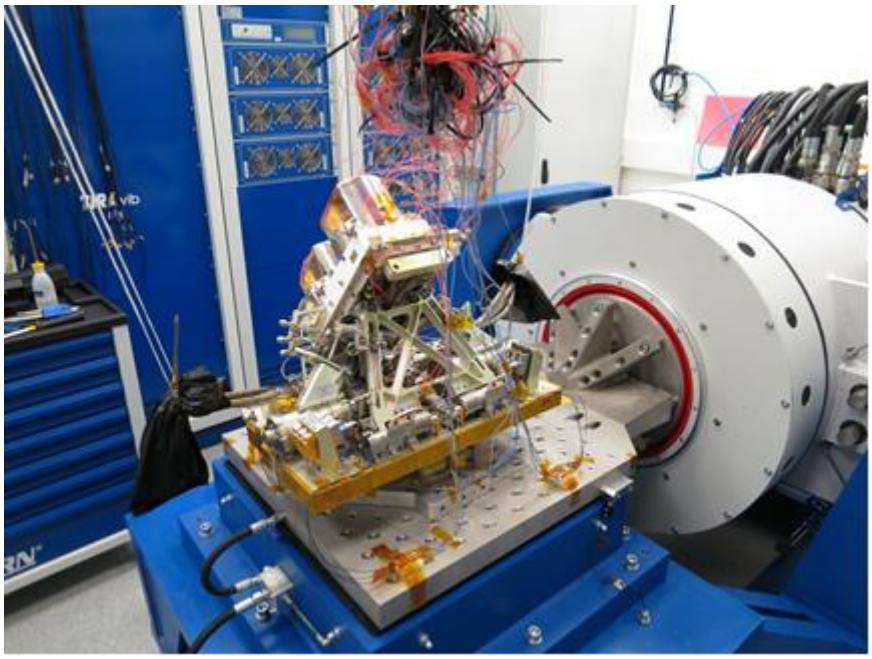
In the frame of the Meteosat Third Generation (MTG) development program, carried out by ESA on behalf of EUMETSAT, the development of electronics modules for the central computer of all six satellites and the Refocusing Mechanism for the meteorological instruments has reached the first milestones. Further RSA contracts in this highly important program, received during 2013, concern the Solar Array Drive Electronics (SADE), the Antenna Deployment and Pointing Mechanism Electronics (ADPME), the Solar Baffle Cover, the Lightning Imager Cover as well as a motorized cover for the Sentinel-4 instrument.

In the full deployment phase of the European satellite navigation system Galileo RSA is supplier of interface modules for the Central Data Unit (CDU) and satellite thermal insulation. Three highly complex electronics modules are integrated in the CDU of each of the Galileo satellites. Delivery of the modules for all 22 satellites of the first two batches has been completed in 2013.



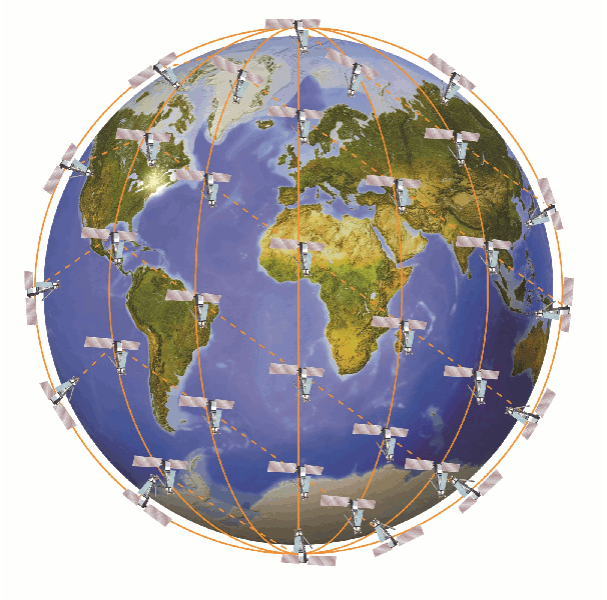
Electronics Modules for Computer of Galileo Satellites

In contracts won in the commercial space market assembly, integration & test (AIV) activities for the first two flight models of a pointing mechanism for the electric propulsion system used on the Eurostar-3000 platform of Airbus Defence and Space has been completed.



First Flight Model of Eurostar-3000 Electric Propulsion Pointing Mechanism in Vibration Test

A milestone in the thermal hardware business of RSA is the contract from Thales Alenia Space France for the supply of thermal insulation for all 81 satellites of the Iridium NEXT mobile communication constellation. The contract calls for the delivery of more than 10.000 insulation blankets to sites in France and the US and represents a real technical and logistic challenge for the company.



Iridium NEXT Constellation

Sales in the area of terrestrial cryogenic insulation, a spin-off of the company's space business, increased by 4% in 2013, and contributed 14% to the total company sales.

Highlights of the year 2013 for RSA were two launches of ESA satellites with major contributions of the company.

The successful launch of the Swarm mission on November 22 meant the in-orbit premiere of the RSA GPS Precise Orbit Determination (POD) Receivers, which are used for attitude control of the three satellites.

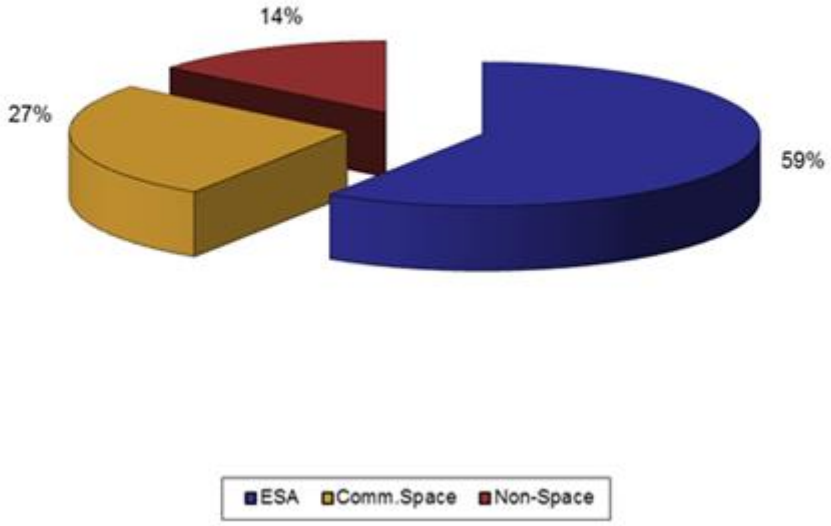
Launch of Swarm Satellite Trio

Just before Christmas, on December 19, the Gaia astronomy spacecraft started its journey to the Lagrange point L2. The sensitive telescopes and their digital cameras are protected from sunlight by means of a giant sunshield. The thermal insulation blankets forming the deployable shield with a diameter of 10 meters were designed and manufactured by RSA.

Deployable Sun Shield for Gaia (Source: ESA)

In December RSA received the Astrium (now Airbus Defence and Space) Master Supplier Award in recognition of the undertaken for the supply of Sentinel 2 & EarthCare GPS Receivers in 2012.

Astrium Master Supplier Award for RSA



Total RSA sales increased by 14% compared to 2012. The non-ESA share reached 41%.

Sales: 35 MEUR

ESA Share: 20.6 MEUR

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3.10 Siemens AG Österreich

Siemens is a modern enterprise, a leader in research and development with a portfolio that provides answers to the biggest challenges of our time.

Siemens is committed to living up to its high values and to being one of the world's best in terms of transparency and compliance.

In the financial year from October 2012 to September 2013, Siemens Aktiengesellschaft Österreich achieved a sales volume of € 2''7 billion, with 8,300 employees. As one of the leading companies in the electric and electronics business, Siemens has a high R&D share of € 167 million.

In December 2009 the Siemens Board has decided to carve-out parts of Siemens IT Solutions and Services (SIS) from Siemens AG, effective October 1, 2010, to become a separate legal entity. As of October 1, 2010, a new unit has been established, "Communications, Media and Technology (CMT)", continuing the former SIS business that remained with Siemens AG. As of February 2013, CMT was itself carved-out of Siemens AG Österreich, becoming a separate legal entity named Siemens Convergence Creators (Siemens CVC). Siemens CVC is a 100% subsidiary of Siemens AG, effective February 1, 2013.

Siemens Convergence Creators, represented in Austria through the Siemens Convergence Creators Holding GmbH and the Siemens Convergence Creators GmbH, acts as an independent company that combines the entire SW solution and service competence for the Communication Media & Technology industries.

Siemens CVC is headquartered in Vienna and provides its customers with turnkey solutions and services in the fields of communication networks, service and customer management, public safety and security, multimedia infotainment, as well as aerospace technology. In fiscal 2013, Siemens CVC had about 1.500 employees at 19 locations in nine countries: Austria, China, Croatia, Czech Republic, Germany, Hungary, India, Romania and Slovakia.

The company supplies more than 70 countries with communication and media products and solutions. Among the most important customers are the top players in their respective industrial sectors, i.e. telecommunications, media (TV, publishing houses), transport (cruise ships, railways, aircraft manufacturers, airlines and airports), space, public safety (action forces) and energy (wind power, oil and gas).

Siemens CVC has six Business Units. One of them, Siemens Space, develops customer-specific solutions for ESA space and ground segments as well as for commercial aerospace manufacturers and operations companies.

Siemens Space offers solutions in the area of EGSE (Electrical Ground Support Equipment), Ground Segment Systems, Carrier Monitoring Systems and Satellite Communication.

With over 25 years of experience, Siemens Space has successfully executed more than 200 projects for ESA, DLR, commercial satellite operators and satellite manufactures.

The year 2013 was driven by final project work for GALILEO FOC (Full Operational Capability) as well as close-out work for the EDRS payload test system and Exomars RF test systems.

Copernicus (formerly GMES), EDRS, SolarOrbiter and Meteosat Third Generation work was continued and ExoMars RF Suitcase, Grace Follow-On (non-ESA mission), further SmallGeo, Sentinel 4, and further Sentinel 5p work was started. We were able to expand our market share in the Instrument Test Equipment market.

The ProUST family of products is a success story and in 2013 we continued with the development programme – further spacecraft interface functionality has been added.

The economic downturn and the late ESA Ministerial did not pass unnoticed. 2013 showed to be a difficult year in terms of Order Intake, which will manifest itself in 2014 in lower revenue.

Trends in the institutional market – Geo Return, less ESA missions and EU funding becomes more and more present - were again confirmed (e.g. Galileo, Copernicus), which bring along tougher competition, specifically over price.

The financial crisis did not considerably hurt the commercial telecom market. This market has been showing some weakening tendency though (after major investment programmes of the big operators peaked in 2011/12). Nevertheless, our Carrier Monitoring business increased in terms of revenue.

In 2013, the share of ESA sales accounted for € 6’55 million.

All in all, the financial year 2013 registered sales revenues of € 11’4 million (+7%), based on commercial market, ESA (incl. Galileo), FFG and DLR activities. Order intake decreased to € 11’8 million (-17%). Focus in 2014 will mainly be laid on business development for ExoMars, Euclid, Sentinel 4, EDRS, SARah and on further extension of the commercial market share, with a particular focus on the payload test market and all satellite operators.

Besides this, the focus in 2013 was on the following topics:

Electrical Ground-Support and Special Check-Out Equipment (EGSE & SCOE)

In the year 2013 Siemens Convergence Creators delivered its first test equipment of the type Instrument Special Check-Out Equipment (Instrument SCOE). The first project of this kind was for the Sentinel 5 Precursor Mission's Tropomi Instrument shortly followed by the Simulation Front-End Equipment for the Solar Orbiter Mission. From the new innovations integrated into this type of equipment also our Radio Frequency Suitcase project GMES XBS (GMES, the European Global Monitoring for Environment and Security Programme, now called Copernicus, X-Band radio frequency Suitcase) could significantly benefit.

Apart from this new business the traditional Radio Frequency and Power Subsystem satellite test business was followed. The technological basis for the continuous evolution of our systems is our consequent innovation strategy for our ProUST product family (Protection and Unification in Satellite Testing funded in part by the Agency's GSTP programme.

Radio Frequency and Telemetry/Telecommand Test Systems

Main focus of our RF business in 2013 was on the European Data Relay Satellite RF Test System (EDRS RFTS) for TESAT Spacecom in Germany and the two projects in the frame of Exomars, the Orbiter Mission EDM (Entry, Descent and Landing Demonstrator Module) UHF TTC-SCOE for Thales Alenia Space, Italy, and the Exomars Orbiter Module X-band RF SCOE for Thales Alenia Space, France. Nearly all systems have been delivered between July and Nov 2013, the second UHF SCOE will be delivered in early 2014.

The GMES (now Copernicus) X-band RF Suitcase (XBS) was delivered after a very intense factory test campaign in May 2013 see photo below. As parts of the Engineering Model of the Satellite are directly included in the RF-Suitcase set-up, particular emphasis has been put by our customer ESA on the verification of each individual assembly, integration and testing step. The Suitcase has been delivered to ESTEC in NL in May 2013.

The GMES XBS was our first project taking advantage of the spacecraft interface development on the ProUST product family from the GSTP Generic Spacecraft Interfaces project, which has been finished in summer 2013.

Copernicus X-band RF Suitcase and EDRS RFTS

Several new projects have been started:
For the Exomars programme, in Sept. 2013, we started the Exomars X-band RF-Suitcase project for the Exomars Orbiter Module Bus. Critical Design review is planned for spring 2014. The Suitcase will be first delivered to Thales Alenia Space France and will later interface the ESOC ground station during the RF test campaign planned one year before launch.

For the Small GEO Satellite platform of OHB in Bremen (SGEO Extension programme Artes 11.3) two more Test Systems are built. These two systems are the Telemetry& Telecommand Transmit and Receive Subsystem Special Check-Out Equipment RF-Front-Ends for S-band and Ka-Band applications, which will be first used for the EDRS-C satellite. The project had its Kick-Off in Oct. and shall reach its Design Review in Jan. 2014. Delivery shall be in early summer 2014.

For ESA's Sentinel 5 Precursor mission (S5P) within the European Copernicus Programme, Siemens CVC will deliver the RF S-band SCOE to Astrium UK as a recurrent system to the A250 S-band SCOE previously delivered to Astrium France. The S5P mission is devoted to measure the troposphere down to the earth's surface in order to quantify emissions and transport of anthropogenic and natural trace gases and aerosols which impact air quality and climate.

Power SCOE and Instrument EGSE Test Systems

Within the European Copernicus Programme, Siemens CVC finished the Test System for the Proto-Flight Model (PFM) of the Tropomi Instrument and delivered it to Dutch Space in Nov. 2013. TROPOMI (the tropospheric monitoring instrument) will fly on ESA's Sentinel 5 Precursor (S5P) mission as part of the European Copernicus programme. TROPOMI consists of Ultraviolet/Visible/Near Infra-Red spectrometers (UVN), a Short Wavelength Infra Red Spectrometer (SWIR), Instrument electronics and a Radiant Cooler (RC) to ensure the low temperature operation of the detectors.

For the US/German Grace Follow-On Mission with its planned launch in 2017, time was an important asset: after a Kick-Off in late June the design review was already held in July and the first of our two Power SCOEs has been delivered to Astrium Germany well in Dec 2013, the second one will be prepared for delivery in April 2014 together with the first set of an S-band RF SCOE for the same mission. With the use of twin satellites small changes in the earth gravitational field can be measured with exceptional accuracy. Those measurements will be used to generate an updated model of the Earth's gravitational field every 30 days. Every day each satellite will create up to 200 profiles of temperature distribution and water vapour content in the atmosphere and ionosphere.

Solar Orbiter is a challenging Science Mission, which will take the next step in observation of the sun from space. Siemens CVC developed the test system for its On-board-computer. A high-end EGSE with 700 interfaces to control could be fit into a single 19" rack due to the high-density ProUST product family and an innovative, industry-first rack-level wiring concept using XXL-PCBs. The second demanding requirement was to achieve real-time I/O-access times below 4 microseconds which were accomplished and surpassed by tuning the PCI-Express bus structure. With additional versatile SW-layers Siemens CVC claims a leadership position in the simulation front-end business. Siemens CVC has built three systems of Simulator Front-End Equipment. Two have already been delivered to our customer Astrium UK in March 2013 and Nov. 2013.

Solar Orbiter Sim FE (left) and the Solar Orbiter Power SCOE (right) in the Astrium UK clean-room

The Solar Orbiter Power SCOE is a primary element of the Spacecraft electrical ground support equipment (EGSE) required to test the Solar Orbiter Spacecraft. The Power SCOE will be primarily used for the integration and testing of the on-board power subsystem. Additionally, it will be used for the general support of the satellite power bus during on-board subsystem activities and system tests. It will also be used during the launch campaign to support the satellite when situated on top of the launcher. The Critical Design Review for the Solar Orbiter Power SCOE has been achieved in March 2013 and the first Solar Array Simulator has been successfully acceptance tested by the end of 2013.

Beginning in 2016, the satellites of the Meteosat system will be replaced by six satellites of a new, a third generation (MTG). The end costumer is the European Agency for the exploitation of satellite-based weather data, EUMETSAT. MTG consists of six satellites. Four Imager satellites will provide imagery with a much higher resolution by their new optical sensors than is possible today, making weather forecast much more precise. Two Sounder satellites will provide information on the distribution and flow of vapour and temperature in the middle part of the atmosphere. By deriving information from cloud formations in the lower atmospheric levels, a distinct improvement of local weather forecasting is enabled.

Siemens CVC in partnership with TERMA B.V. has started with the Central Check-Out system for the MTG mission and already delivered the first two of a total of five planned sets to OHB in Bremen, who are responsible for the six satellite platforms as well as for the two sounder satellites.

Two more projects for MTG have also been started at Siemens CVC:

MTG DHS SCOE for the Data Handling Subsystem tests and MTG PDD Payload Data Distribution Test System with several deliveries starting in 2014.

The DHS SCOE will be used to test the onboard data handling system during Assembly, Integration and Test and to support the flight software development activity by providing an interface to load the flight software and monitor its execution. The DHS SCOE front-end equipment provides the data interfaces to the flight computer including the spacecraft data handling buses and the internal control bus of the flight computer. It also provides interfaces to diagnostic the ports on the flight processor.

The purpose of the MTG Platform PDD SCOE is to facilitate the integration and test of the PDD subsystem during platform and satellite Assembly, Integration and Test. This requires the provision of numerous electrical RF and dedicated data interface like SpaceWire link to the PDD system, plus tools and services to stimulate those interfaces and analyse the resulting data.

Both projects have already reached their Critical Design Reviews before the end of 2013.

With the European Copernicus Programme, another two new projects have been started in 2013 for the Sentinel 4 mission. The Sentinel-4 mission is dedicated to monitoring the composition of the atmosphere for Copernicus Atmosphere Services. Sentinel-4 will be carried on the meteorological satellites operated by Eumetsat (see MTG above). Both new projects deal with the testing of the Sentinel-4 UVN Instrument, the Ultraviolet Visible Near-infrared spectrometer.

S4-UDEE is the UVN Data Evaluation EGSE (Electrical Ground Support Equipment) and had its Requirements Consolidation Review in Sept. 2013 followed by the Preliminary Design Review in Oct. 2013. Customer is Astrium GmbH Germany (Airbus Defence and Space). Two systems will be delivered in 2014 and 2015, respectively.
S4-PISA finally had its Kick-Off in Dec. 2013 and will deliver two sets of the Platform Interface Simulator Assembly (PISA) for the Sentinel-4 UVN Instrument again to Astrium GmbH Germany (Airbus Defence and Space) in the timeframe 2014 to 2015.

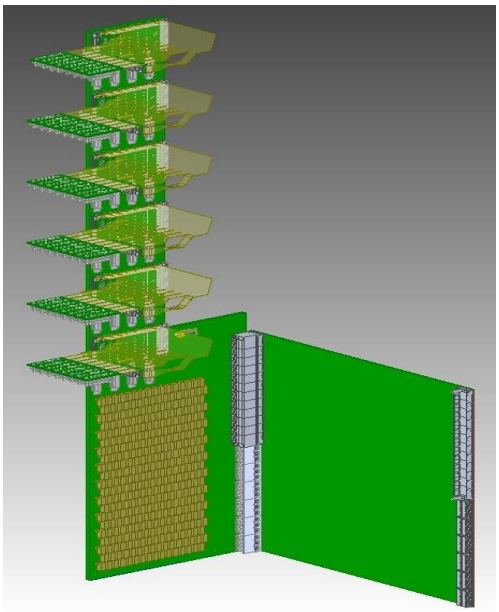
Innovation: GSTP Generic Spacecraft Interfaces

The GSTP Study for Generic Spacecraft Interfaces has been finished in June 2013. The main focus of this project was put on the development of several space related data and signal interfaces on the Siemens ProUST (Protection Unit for Satellite Testing) platform. The ProUST-FE (ProUST-Front End) is a product targeted at cost-efficient Instrument SCOEs with a minimum of mission-specific adaptations.

The ProUST and ProUST-FE approach was made possible by exploiting multiple technological advances:

- State-of-the-art platform FPGAs for complex custom digital logic, including a powerful microprocessor for embedded software
- Sigma-Delta Modulators with iCoupler technology for analog measurement
- Leading-edge Power-MOSFETs allowing fast reaction and dense packing.
- The technology mix comprises the best available Safety Relays.
- Incorporation of High speed interfaces (PCIe, Aurora) for fast data access
- Inclusion of different data interfaces IDL, SpaceWire, MIL-BUS, etc.

All devices are connected by sophisticated PCB technology capable to combine high currents with high-density signal-ICs.



High density ProUST Simulator Front End Test System with innovative rack interconnections

A goal was to achieve the generic, platform-oriented approach also beyond the CBI-boards at the rack level. Attention was given to the rack mechanics.

It can be stated that the effort was successful, because equal parts were used for Galileo FOC SGS, BepiColombo MTM-SAS/SAB, Sentinel 2, Earthcare, GMES X-Band Suitcase, SimFE and Sentinel 5p TROPOMI - quite different missions.

A further extension of ProUS-FE's capabilities is planned. The standard MIL-bus and Spacewire functions will be extended for Error Injection capabilities as well as multi MIL-bus remote terminals. A further increase of PYRO interfaces is also planned on the same ProUST-FE platform, thus further advancing the density of future Instrument Test Systems.

Further enhancements will include:

- Reconfigurable analogue interfaces
- High speed data acquisition

- Crossbar and TM/TC SCOE
- Second level protection enhanced flexibility
- ProUST-Next-Generation Real-Time Framework

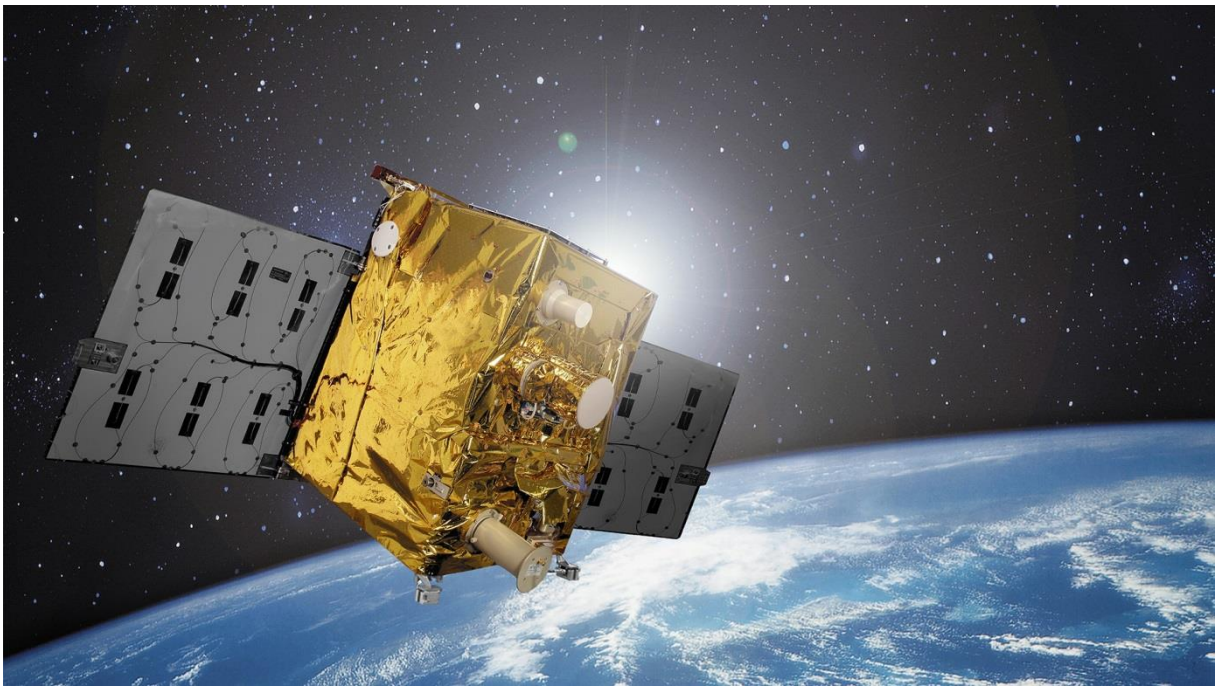
Ground Segment Systems and Mission Control Software

In the year 2013, the main focus of Siemens activities in the Ground Segment Systems and Mission Control Software domain was in the following areas:

- Mission Control System maintenance and evolution
- Near-Real-time Processing of Telemetry and Telecommand (TM/TC) archives and databases
- Evolution of generic Mission Control and EGSE SW architectures and building blocks
- Galileo work for the full constellation system (FOC)

2013 marked the close-out of the current maintenance and evolution contract for the DLR Mission Control System (SCOS-2000) in GSOC (Oberpfaffenhofen, Germany). During the year, DLR issued the RFQ for the next phase, starting in 2014. We are happy that our customer appreciates the work we do and considered our offer the best also for the next period.

Apart from regular corrections, the contract also foresees adaptations for e.g. new DLR missions.

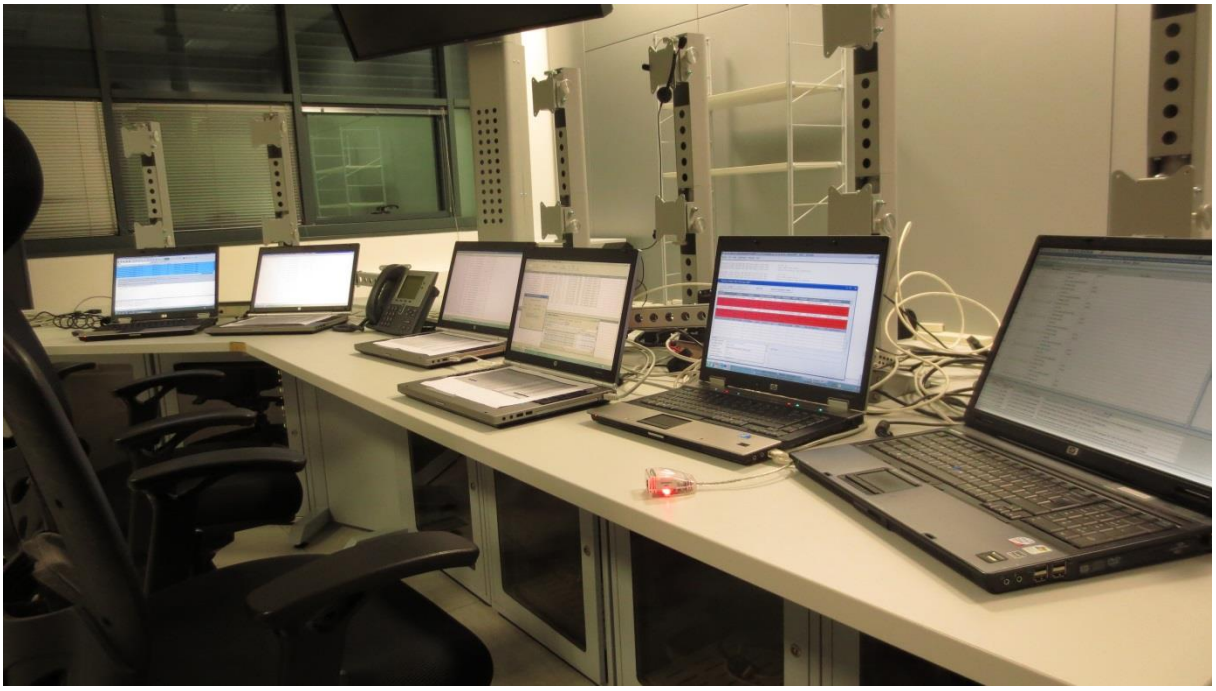


TET-1 in orbit (artist impression) (Source: DLR)

TanDEM-X Control Centre at DLR during launch

Galileo GCS GCC in Oberpfaffenhofen (Source: DLR GfR)

Siemens, as subcontractor of TAS-I (I), continued the story of the Independent Protocol Analyzer (IPA) for the Galileo System Integration and Validation (SI&V). After the success of the IOV version and the order for additional devices in 2012, TAS-I placed a contract for an upgrade of the IPA to Galileo FOC, including the delivery of further IPA units and also software extensions. The new SW and the IPA units were successfully delivered in June 2013.



IPA Notebooks during integration of the Galileo GCC-I in Fucino (Source: Thales Alenia Space Italy)

The ARES (operational data offline Analysis, correlation and REporting System) project (GSTP) for ESOC which had initially been started in 2011, was enhanced by a CCN (ESA infrastructure procurement) to make the software ready for future operational use in the GAIA mission.

As a next step in the same “product line”, the GSTP project REALS, started in 2011, and was more or less finished in 2013. REALS combines the previous functional content of ARES with near-real-time aspects and the use of ubiquitous client devices such as smart phones.

Both projects, ARES and REALS, have become showcases for the introduction of agile development processes (Scrum) in the development of Mission Control Systems, and have as such been presented by ESA and also by Siemens at various conference events not only for their domain-specific added value, but also for the development process approach and its advantages.

Siemens is part of the European initiative to design a new EGSE SW and Mission Control SW core and building blocks, both being represented in the ESA Common Core activities and in the industry-driven project AITS. These activities show the close synergy between

EGSE SW and Mission Control SW, and in 2013, the ground segment community had moved a step closer to this goal.

Earth Observation (EO) incl. COPERNICUS (formerly Global Monitoring for Environment and Security, GMES)

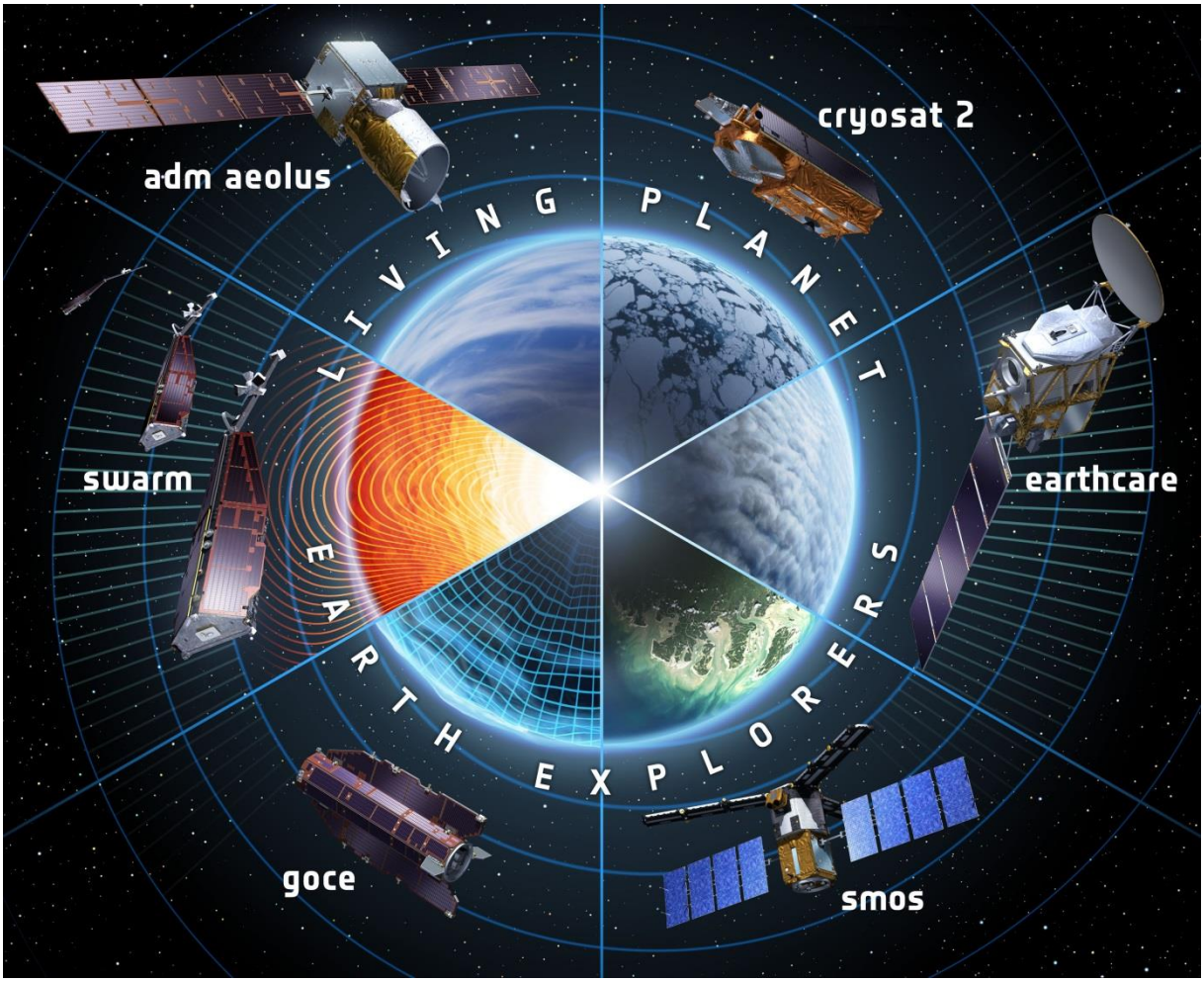
The Siemens Austria activities in Earth Observation in 2013 were mainly focused on the following two areas:

- Integration and Validation of Payload Data Ground Segment systems
- Evolutions of the Payload Data Ground Segment infrastructure

Work on the 3-year OIVV (Operational Integration, Validation and Verification) Frame Contract at ESRIN was finished in July. As part of a consortium with CGI (formerly Logica UK) and Telespazio, Siemens performed the validation of all User Service (US) applications in the EO Payload Data Ground Segment, and in addition validated those Mission Planning (MP) and Multi-Mission Facility Infrastructure (MMFI) applications which had been developed by Telespazio.

Regular corrections were validated in a “testing-as-a-service” approach (based on Service Level Agreements (SLAs) with Key Performance Indicators (KPIs) to assess and continuously improve the service quality).

Major evolutions in architecture or for specific missions (e.g. SWARM, ADM AEOLUS) were validated in a project-like way in addition to the regular service.



ESA Living Planet – Earth Explorer Missions (source: ESA)

In an extension of the USMP Blade 2 project for the virtualization of the ESRIN User Services and Mission Planning (USMP) applications environment, carried out by Siemens and its subcontractor Intecs SpA (Italy), Siemens provided security consulting and configuration support (e.g. hardening) to ESRIN.

In the Operations and Maintenance (O&M) Frame Contract which had started in mid-2010, led by Serco Italy, Siemens continued until mid of the year to provide maintenance for the single-sign-on solution UM-SSO.

The PDGS Evolution Frame Contract led by CMG (formerly Logica UK) as a frame for further evolution work of the existing payload data ground segment applications, did not generate any Siemens projects worth mentioning.

Space Situational Awareness (SSA)

The European Space Situational Awareness (SSA) programme is the key to the monitoring and protection of space and ground assets and services. From solar activity over

approaching asteroids to orbiting debris, all of these can disrupt services and/or damage or even destroy assets.

As a consequence, the European SSA programme is based on three SSA aspects: SWE (Space Weather) for the monitoring of solar activity, NEO for Near Earth Object tracking and SST for the tracking of satellites, debris and any other orbiting objects.

In 2013, Siemens was mainly involved in planning an independent software integration and validation of the precursor phase data centres, as brought together in the SSA DC-II project. Furthermore, Siemens participation is foreseen in the SSA DC-IV project in which the baseline data centre gets transferred to the new SSA middleware architecture (COSIF).

European SSA System (source: ESA)

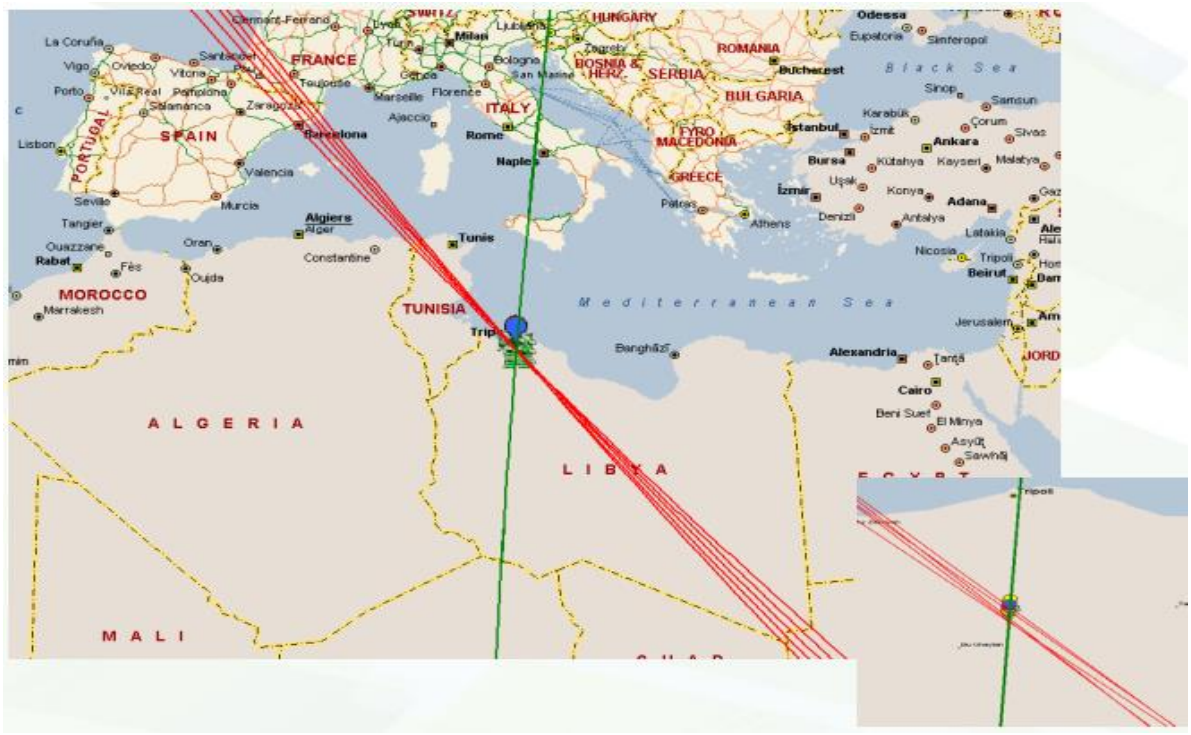
Starting in 2014, a next wave of ITTs is foreseen, already belonging to SSA Period 2, i.e. enhancing and improving the system after the experiences of the precursor phase.

Of course, the reduction of support by a number of countries at the 2012 ministerial conference and the ongoing discussions about the competencies of ESA vs. EU vs. military will have an impact on the next phase of the programme. Nevertheless, the story continues – possibly with new partner constellations, but certainly with an Austrian contribution.

Carrier monitoring systems and Satellite Communication

The advent and rise of data-hungry media like HDTV, mobile services and satellite radio have made satellite links indispensable for global communication. Subsequently, revenues of the satellite industry are expected to rise significantly over the coming years.

However, the amount of interference and anomalies that negatively affect data transmissions will increase even more as a direct side effect of the growing number of satellites crowding the Earth's orbit. Another cause of increasing interference is acts of terrorism or political unrest (e.g. intentional interference of broadcast television in the North African and Mid East region, including Egypt, Syria, Libya, Iran and others).



Interferer localized in Libya

This is a very serious issue – satellite operators may not be able to deliver the required level of service quality, leading to contract penalties and increased churn rates.

Satellite operators are increasingly interested in interference mitigation solutions.

Today only 20% - 30% of all interference issues can be resolved. 95% of the interferences are unintentional, mainly due to inaccurate antenna pointing or HW problems. More than 50% are short recurrent interferences.

That's why Siemens has focused in 2013 on the implementation of satellite interference mitigation technologies.

In order to mitigate satellite interference, a number of organizations were established like the sIRG (Satellite Interference Reduction Group) in which Siemens has become a full member.

The SIECAMS system is highly welcome there as only very few systems are actually available on the market.

THU
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IRG Praises Technology to Prevent Interference

Posted by Helen Weedon on Jun 12, 2014 in LatestNews | 0 comments

In the wake of recent jamming incidents reported by ARABSAT and Eutelsat, the Satellite Interference Reduction Group (IRG) has praised the continued success of Geolocation technology, which is becoming more and more efficient, for discovering the source of the interference.

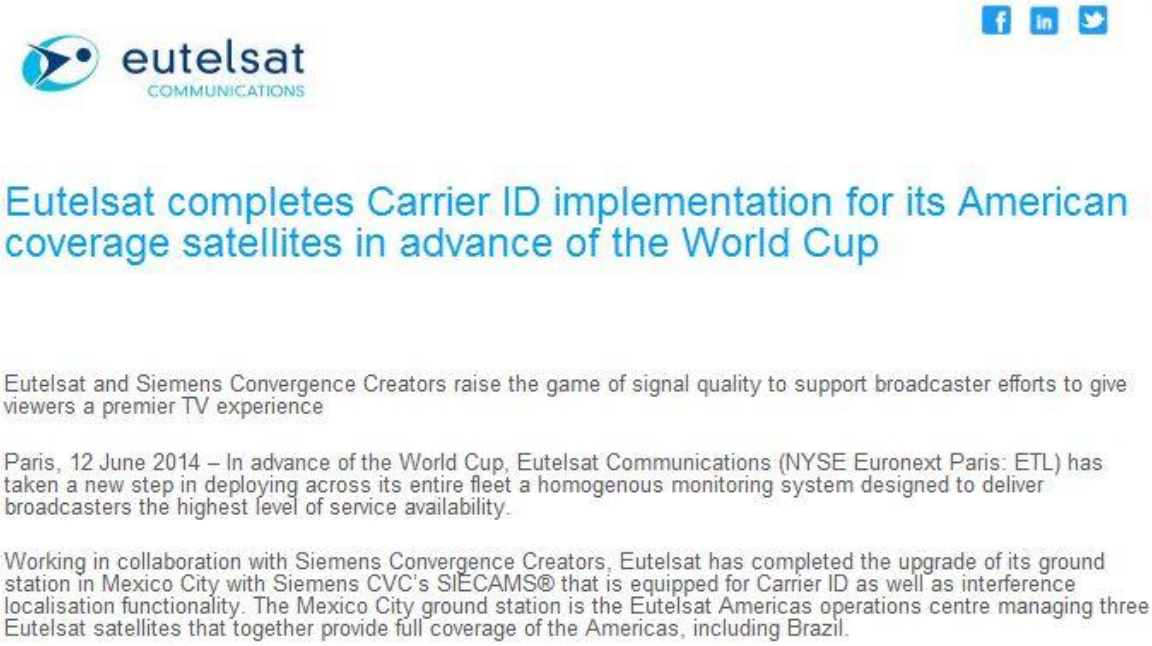
"Along with the rest of the industry, we condemn these actions against legitimate customer services," commented Martin Coleman, Executive Director, the Satellite Interference Reduction Group, "However, we are pleased that the continued technological advancements in Geolocation systems meant that the source was quickly identified, enabling the operators to report the incident efficiently."

sIRG posting

SIECAMS is currently the only system providing an integrated carrier monitoring and geolocation approach. This increases significantly the usability for the operators as the complex setup of a separate geolocation system becomes obsolete. It was one of the reasons why Eutelsat has chosen the SIECAMS ILS (Interference Localisation) system to be deployed on most of their remote stations and operated by "normal" operators instead of geolocation experts.

Another initiative to combat interference problems was started by the sIRG. It deals with the implementation of a Carrier-Id in the DVB tables which contain information about the owner of the signal. As one of the first carrier monitoring system suppliers, Siemens has released the first Carrier ID Detection System by completing the upgrade installation of the latest SIECAMS version. An intermediate solution, the NIT-CID was successfully introduced by Eutelsat during the Olympic Games 2012 in London.

In the meantime Carrier-Id became an ETSI standard. This DVB-CID solution was recently introduced in Siecams in order to be prepared for the World Soccer games in Brazil 2014.
Siecams became the first system which supports both Carrier-Id types, the NIT-CID and the DVB-CID.



eutelsat COMMUNICATIONS

Eutelsat completes Carrier ID implementation for its American coverage satellites in advance of the World Cup

Eutelsat and Siemens Convergence Creators raise the game of signal quality to support broadcaster efforts to give viewers a premier TV experience

Paris, 12 June 2014 – In advance of the World Cup, Eutelsat Communications (NYSE Euronext Paris: ETL) has taken a new step in deploying across its entire fleet a homogenous monitoring system designed to deliver broadcasters the highest level of service availability.

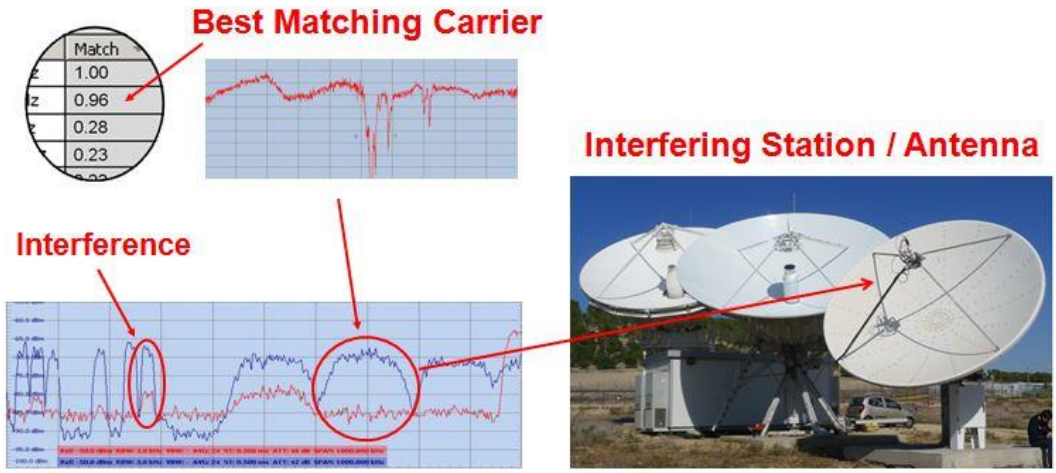
Working in collaboration with Siemens Convergence Creators, Eutelsat has completed the upgrade of its ground station in Mexico City with Siemens CVC's SIECAMS® that is equipped for Carrier ID as well as interference localisation functionality. The Mexico City ground station is the Eutelsat Americas operations centre managing three Eutelsat satellites that together provide full coverage of the Americas, including Brazil.

Joined Eutelsat – Siemens CVC press release

The main drawback of current geolocation systems is the necessity of having two adjacent satellites available. Even though more than 200 geo-stationary satellites (and only this type of satellite is currently used by geolocation systems) are in operation, some of them are still "alone". Alone in this context means, that the next adjacent satellite is more than 8-10 degrees separated. In this case, successful geolocation is impossible.

Based on customer feedback we have started an internal investigation about the possibility to provide accurate geolocation with just one satellite. As a result we have identified 3 possible concepts for a one-satellite geolocation system. The most promising one – "correlation against known transmitters – will be actually implemented in the frame of an ESA ARTES34 project and is expected to be ready for sell end of 2014.

With this technology, we can localize the transmit station of an interference signal in a best case scenario down to the uplink antenna.



One satellite geolocation result

Sales: 11.4 MEUR

ESA Share: 6.55 MEUR

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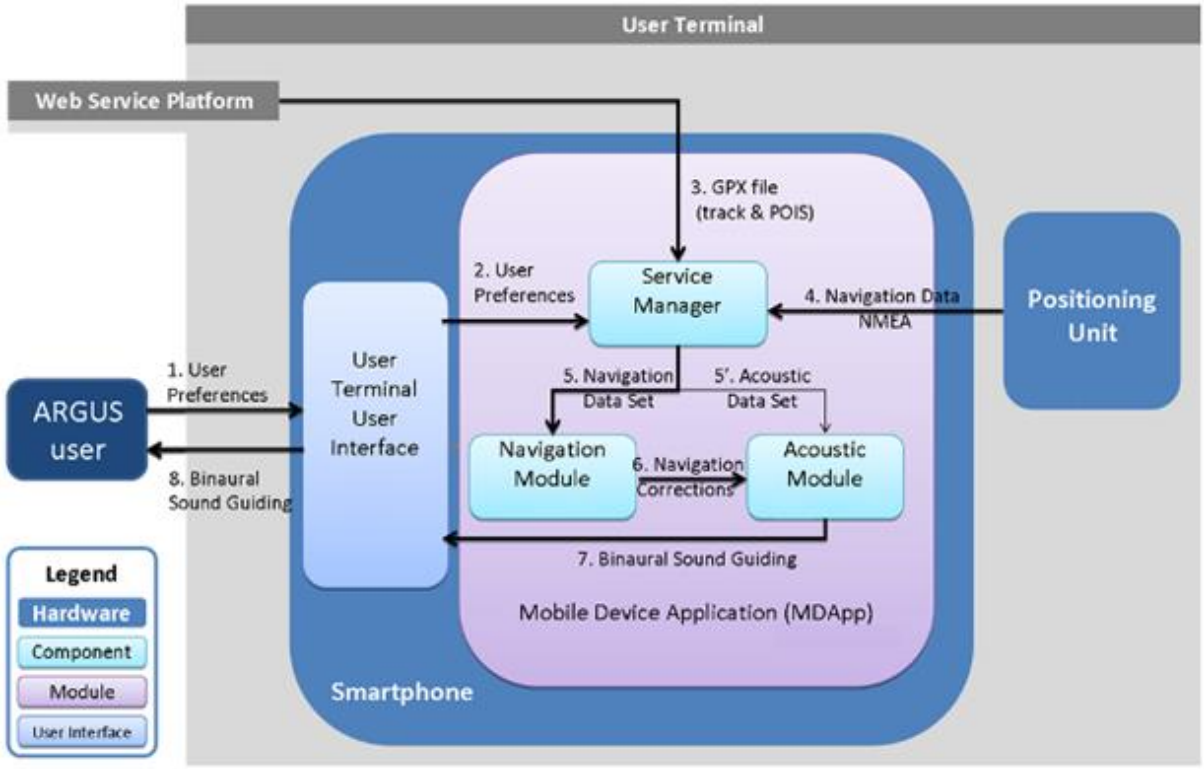
3.11 TeleConsult Austria GmbH

TeleConsult Austria (TCA) – www.tca.at – was founded in 1999. The major activities of TeleConsult Austria GmbH cover the field of precise positioning and reliable navigation, particularly the areas of development and combination of navigation, telecommunication, and information technologies, and services for applications in the context of transport and mobility.
Topics of work include general management support and technical consultancy, system design and analysis, mobile computing, software development, proposal and project preparation and management, business development as well as marketing and development strategies for new products and services.

The following paragraphs report about highlights (projects and product developments of TCA) in the year 2013.

ARGUS (Assisting Personal Guidance System for People with Visual Impairment)

People with visual impairments have striking needs for trustful navigation systems enabling efficient mobility services, mainly considering safety and autonomy. In this context, satellite-positioning and navigation technologies are being implemented leading to innovative personal navigation devices. Existing products and solutions based on GNSS (Global Navigation Satellite Systems) do not meet all needs of this collective and fail since they lack accuracy and integrity; they do not provide a suitable and efficient human machine interface (HMI) adjusted to this user group, or rely on costly infrastructure.
The ARGUS project focuses on a satellite based navigation (GNSS/EDAS – EGNOS Data Access System) terminal for people with visual impairments, guiding them along pre-defined tracks using a specifically designed HMI based on binaural sound guidance.
The project is being partially funded by the FP7 program under the call FP7-ICT-2011-7.



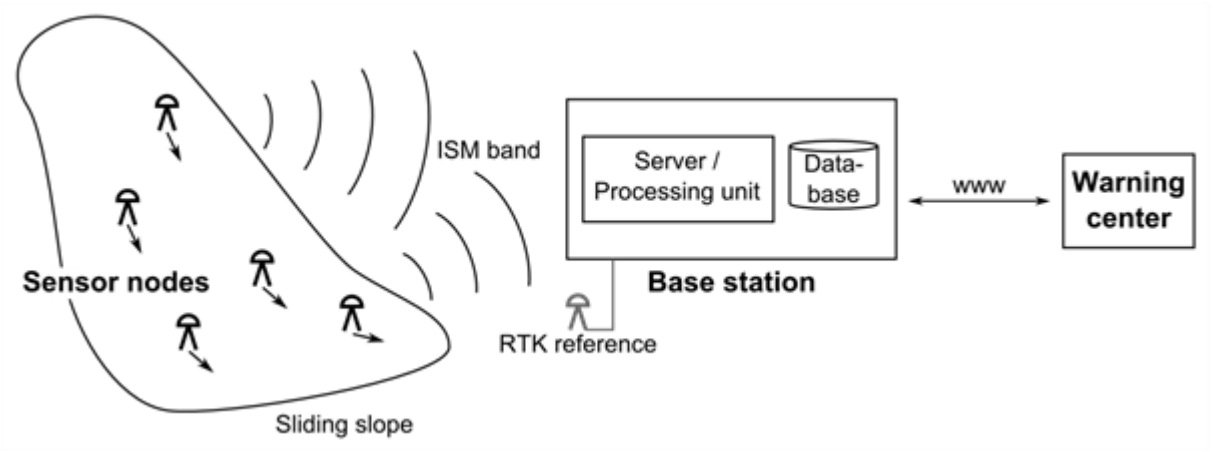
ARGUS system architecture

A separate localization and navigation module has been developed since current smartphones do not support the position accuracy and integrity required in ARGUS. Therefore, ARGUS uses a positioning unit with a GNSS (GPS/EGNOS/GLONASS/Galileo) high sensitivity receiver and an inertial measurement unit (IMU). This unit identifies the position and orientation of the user as well as the quality and integrity parameters of the position. The integration with the IMU ensures that GNSS signal outages can be bridged for some time. Through the design of a custom-tailored Kalman Filter for the ARGUS application, navigation and sensor data can be merged. The positioning unit is also equipped with wireless interfaces for communication with the smartphone.

GeoWSN (Landslide Monitoring and Alerting System)

The surface of the earth constantly remains in movement, especially in mountainous regions. To prevent the population and the infrastructure from further harm, the need for a sophisticated landslide forecasting, monitoring and alerting system is evident. Traditionally, monitoring is performed by geodesists using time-domain reflectometry utilizing ground-based sensors. Since a few years, the Global Positioning System (GPS) dual-frequency Real Time Kinematic (RTK) approach is widely used for monitoring landslides. Even though RTK is known as the state-of-the-art approach for monitoring at high accuracy levels in real-time or near real-time it is considered to be cost-intensive. This is due to the need for at least two GPS receivers operating simultaneously and an additional communication infrastructure. As a counterpart to RTK, Precise Point Positioning (PPP) has gained importance over the last years. In the PPP approach a single (mostly dual-frequency) receiver is utilized, additionally using correction data e.g., precise orbits and clocks. Recent developments in the field of dual-frequency PPP show performances capable of detecting landslides in real-time. One of

the big disadvantages of these approaches is the comparatively high price of such systems, mainly caused by the dual-frequency equipment.

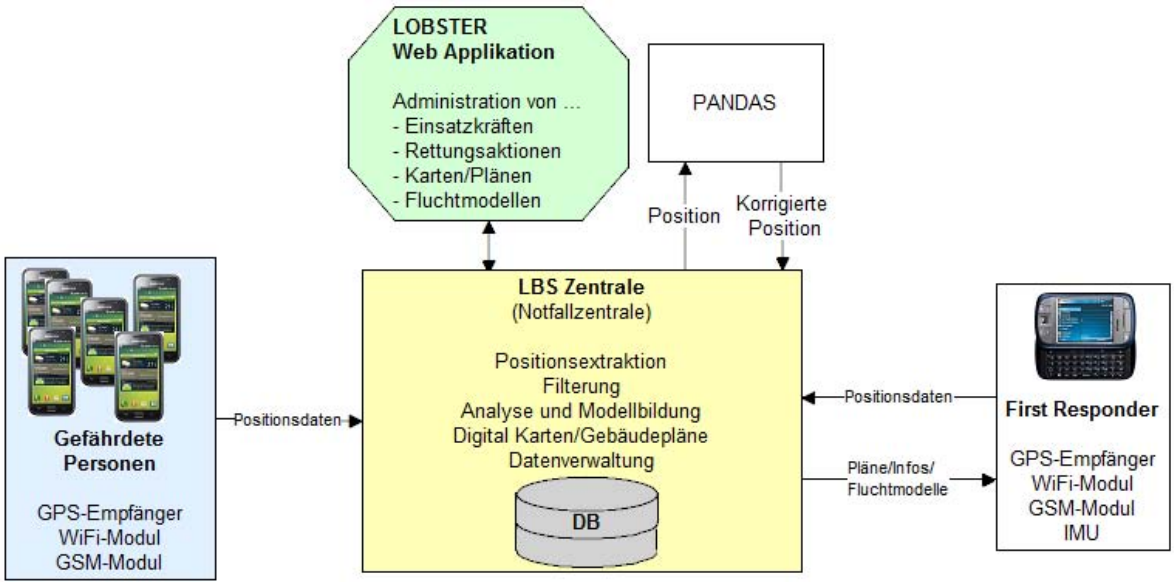


GeoWSN overall system architecture

Keeping an eye on cost-efficiency, it is tempting to consider the development of a landslide monitoring system based on PPP and utilizing low-cost single-frequency receivers. Investigations on this topic are done in the course of the project GeoWSN. Within this project, a landslide monitoring system using low-cost GPS receivers was developed.
The presented work was performed within the GeoWSN project (”Frühwarnsystem zur Beurteilung der Gefährdung kritischer Infrastruktur durch Hangrutschungen”). GeoWSN is carried out under the responsibility of the Austrian Research Promotion Agency and is funded through the Federal Ministry for Transport, Innovation and Technology in the course of their KIRAS programme.

LOBSTER (Location based service for analyzing escaping crowds of people in crisis situations to support first responders)

Within the project LOBSTER a system for analyzing escaping groups of people in crisis situations in public buildings/constructions (e.g. hospitals, shopping centres, airports, etc.) was developed. For the localisation and the analysis of the activities of the escaping groups of people, the positioning technologies GNSS, WLAN, and MEMS of common smart phones are used. The determined positions are transmitted to a LBS centre in case of distress. In the centre, these data are used in combination with building layouts and mathematical filter technologies (particle filter and Kalman Filter) to analyse and predict the escape behaviour. These analyses are carried out totally anonymous and thus, no private data or the positions of single persons are used that would violate data privacy directives.
The analysis supports the first responders in establishing a significantly improved coordination and resource scheduling of the rescue teams. The rescue teams themselves are equipped with a localisation system (GNSS, WLAN, MEMS, plant layouts, etc.) and also send their positions to the LBS centre. In combination with the position data of the fugitives it is now possible to detect the escape ways and thus to coordinate the rescue teams in a best possible manner by specific instructions.



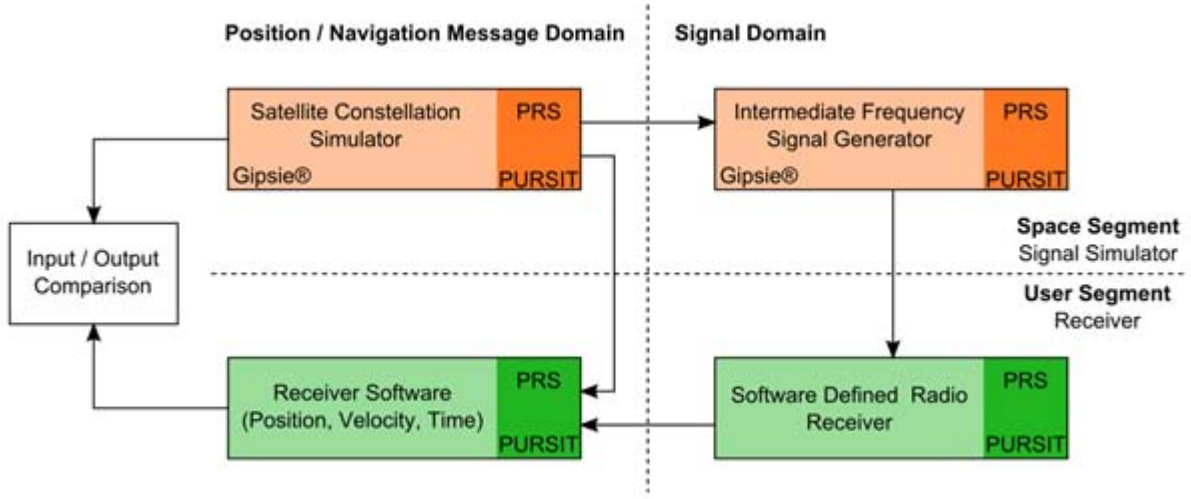
LOBSTER overall system architecture

The main advantage of the present system is that techniques are used for the analysis of escaping groups of people, which are already supported by standard commercial telecommunications equipment. The rescue teams however are equipped with an autonomous system, which provides positioning independently from the infrastructure.
For this purpose, it will be analysed during the project to what extent an improvement of the indoor positioning accuracy can be achieved by the use of UWB (Ultra-Wideband) techniques and thus, the localisation of security-related equipment and assets can be provided. An innovative approach is used which depends on the analysis of signal reflections and building layouts. This approach provides high robustness (especially in cases of blocked line-of-sight between the transmitting stations) and reduces the necessary infrastructure to a minimum. The system concept shall demonstrate its performance and potential in a test scenario to be developed.
Different aspects of human factors are already considered during the specification of the user requirements and the requirements for the first responders in order to implicate system visualisation, information organisation, and operation sequences into the interface design. Further, a psychological analysis of human factors in terms of escaping crowds of people is carried out to identify patterns of movement and escaping reactions in crisis situations.
For every single escape sequence, the performance as well as the mental, physical, and temporal stress of every first responder and of the rescue team are evaluated and validated by using the NASA-Task Load Index. LOBSTER was carried out under the responsibility of the Austrian Research Promotion Agency and is funded through the Federal Ministry for Transport, Innovation and Technology in the course of their KIRAS programme.

PURSIT (Galileo Public Regulated Service Signal Simulation and Position, Velocity, and Time Calculation)

In the project “Galileo Public Regulated Service Signal Simulation and Position, Velocity, and Time Calculation (PURSIT)” funded by the Austrian Research Promotion Agency / BMVIT with funds of the Austrian Space Application Programme, a simulation environment for the Galileo Public Regulated Service (PRS) signals is investigated and developed. The Galileo PRS is dedicated to specific users requiring a high continuity of service, with controlled

access. Therefore two navigation signals with encrypted ranging codes and data will be transmitted on two distinct frequencies within the Galileo system.
During the PURSIT project, the “GNSS multisystem performance simulation environment” (GIPSIE®), developed by TCA, is extended to PRS-like signals. To avoid confidentiality constraints, PRS dummy messages and open access encryption standards are implemented, however by accounting for the processes of security key distribution and deployment as currently under discussion in Galileo. Furthermore, a software defined radio receiver to acquire and track the simulated signals is developed. To calculate a position, velocity, and time (PVT) solution the existing PVT module of TCA is enhanced to process the PRS-like signals. The next figure shows an overview of the simulation environment.



PURSIT simulation environment

The GIPSIE® is divided in two main parts, the satellite constellation simulator to compute the receiver and satellite position, and the intermediate frequency signal generator which processes the data further to output digital intermediate frequency samples. These samples are then fed to the software defined radio receiver to compute pseudoranges which in turn are used by the PVT module to compute a position solution. The performance of the PRS-like signal is investigated under different conditions, including jamming and spoofing events.
In parallel to the technological development, the market for the PRS signal-simulator and receiver is analysed and an appropriate business model defined.

SafeRail (Improving Safety at Railway Level Crossings)

SafeRail is a study project aiming at improving safety at Railway Level Crossings (RLC) by the use of space assets. SafeRail questions the entire life cycle of a RLC. Planning, design, authorization, construction, maintenance and operations of RLC involve many disparate organizations and companies. Every project partner provides significant expertise to the specific areas of automotive, railway, terrestrial communication and space assets as satellite navigation and satellite communication.

Benchmarks for the study are the number of accidents and fatalities occurring at RLC as published by the European Railway Agency (ERA). This study will propose technical means to reduce these figures in any thinkable way. The proposed technical solutions shall integrate into a larger, well established concept of road safety, called the "5 E’s", namely Engineering, Education, Enforcement, Encouragement, and Evaluation.

SafeRail application scenario (© Berner & Mattner)

Target users and stakeholders have specific needs, which include:

- Road users approaching a RLC shall accordingly be informed about the specific situation
- Car drivers, cyclist or pedestrian expect to cross safely with lowest possible delay
- Railway infrastructure manager need to inspect and maintain RLCs regularly
- Safety councils stipulate to design infrastructure (services) to be able to cope with human errors
- Rail infrastructure manager need to know about evolutions of road traffic density at RLCs

The expected benefit – depending on the subsystem focused on – will be:

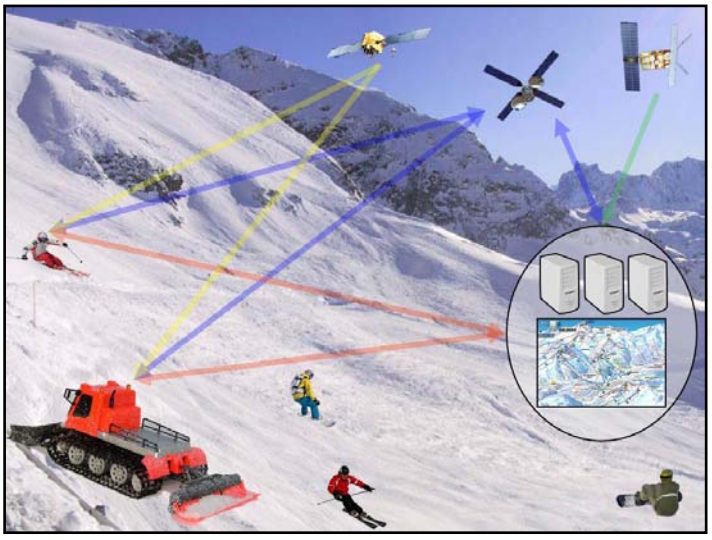
- Improving safety by upgrading of passive RLC into active RLC at affordable costs
- Improving safety by increase in Road User Awareness (in-car and on-road)
- Improving safety through support of maintenance activities

SafeRail liaises with representative organizations for the road users and railway companies and establish user requirements. Depending on the user priorities, an integrated solution will be proposed, defining the necessary service provisions and data interfaces. SafeRail is financed by ESA within IAP (Integrated Applications Programme).

SafeSki (Safety and Information Services for Ski Resorts)

SafeSki is a study project aiming at the development of a target group- and demand-oriented concept for innovative security and information services for ski resorts. The aim of the study is to create a development concept for user-friendly information services which support the operators of ski resorts in the management while increasing security and convenience for skiers, snowboarders, etc.. In the context of this study the requirements on security and information services will be discussed and defined in close cooperation with different users and stakeholders. The technical feasibility and economic analyzes together with potential service providers and users will be examined. SafeSki expects to identify corresponding services, which will improve safety and convenience taking advantage of existing space and

terrestrial technologies. Promising services will be further implemented via a potential follow-on demonstration project.



SafeSki application scenario

The objective of the feasibility study is to investigate and assess the technical feasibility and commercial viability of sustainable services to support the management of ski resorts (e.g., development, operation, maintenance), to support the safety and enjoyment of their visitors, to reduce the operational cost, and to prepare the follow-on steps for the implementation of such services. In order to fully understand the needs of the stakeholders, SafeSki will liaise with representative organizations and user groups and establish user requirements. Depending on the user requirements, relevant services and the associated integrated system will be proposed, defining the necessary service provisions and data interfaces. Thus, the proposed services will satisfy the needs and constraints of the relevant stakeholders and users, and will lead to viable and sustainable services. The aspired solutions combine existing terrestrial solutions with innovative space technologies such as navigation, earth observation, and telecommunications. In this study several relevant business models will be examined as well. The project will prepare a roadmap for the implementation of the system as a demonstration project. SafeSki is financed by ESA within IAP (Integrated Applications Programme).

TROPSY (Assessment Techniques of Tropospheric Effects for Local Augmentation Systems)

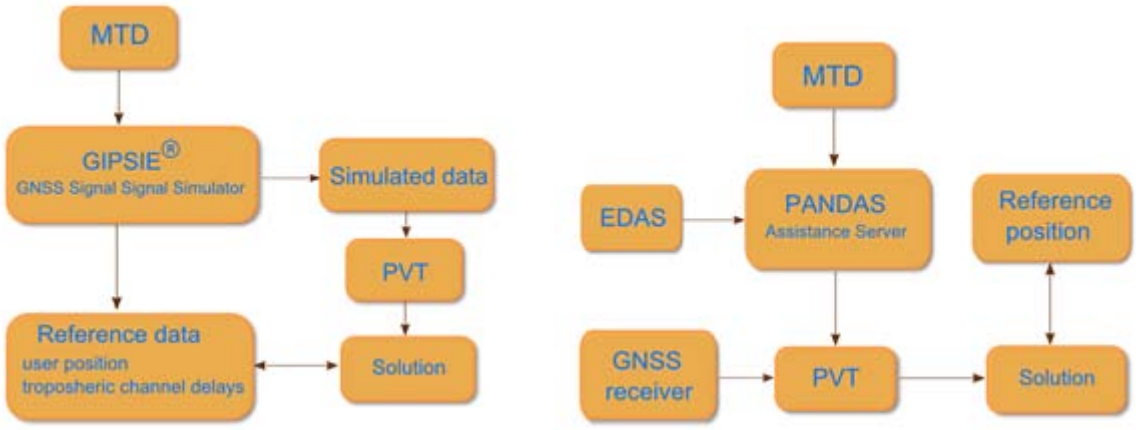
The project aims at an improvement of accuracy of tropospheric correction algorithms for design, verification and operations of GNSS systems. In particular:

- Develop algorithms and input data which reduce the global tropospheric residual error for nominal conditions (1 sigma around mean value) when only data stored in the receiver are used ("blind" mode).
- Assess and model the error distribution of the tropospheric correction algorithms (in all modes of operation) in both nominal and extreme conditions (error values ranging from 1 sigma to 4 sigma around the mean value) to allow the definition of tropospheric error over bounding for integrity purposes in augmentation systems.
- Identify data, algorithms, requirements and performances for the operations of a Local Area Augmentation Systems (LAAS) providing tropospheric correction

parameters to GNSS receivers in "augmented" mode (when correction algorithm receives real time parameters applicable for the LAAS coverage area).

- Develop tropospheric space/time channel models to be used for GNSS constellation simulators.

Global Navigation Satellite Systems (GNSS) are based on the broadcasting of electromagnetic ranging signals. The radio wave propagation effects that can affect GNSS are due to multipath signal propagation, site shielding effects and propagation through the atmosphere of the earth (mostly ionosphere and troposphere). Among those effects, the excess path length due to the troposphere (tropospheric delay) has usually lower impact than the other propagation effects on the navigation solution. However, while other error sources may be mitigated by system design (e.g. use of multi-frequency receivers, modulation schemes and antenna design for multipath mitigation, etc.), the reduction of the tropospheric delay error relies almost exclusively on the use of a correction algorithm (troposphere signal delay model) driven by meteorological data or the use of differential techniques.
The previous ESA Galileo User Receiver model (ESA GALTROPO) has been created 10 years ago as an evolution of the RTCA-MOPS standard. Accounting for increasing demands for accuracy and integrity of GNSS systems it is necessary to revise and improve existing tropospheric error models.



TROPSY testing environments using simulated data (left) and real data (right)

In the frame of the TROPSY project a new tropospheric signal delay model will be obtained using the recent meteorological data. The derived model will be tested under different weather conditions, user positions (including locations with height more than 2 km above mean sea level) and on low satellite elevation angles (starting with 2 degrees). On successful tests, the obtained model and correspondent data sets will be submitted to a Regulatory Body for Radio systems (e.g., ITU-R) and for Aviation (e.g., EUROCAE, ICAO) for new or updated recommendations. TROPSY is financed by ESA within TRP (Technology Research Programme).

Space Sales: 720 kEUR

ESA Share: 290 kEUR

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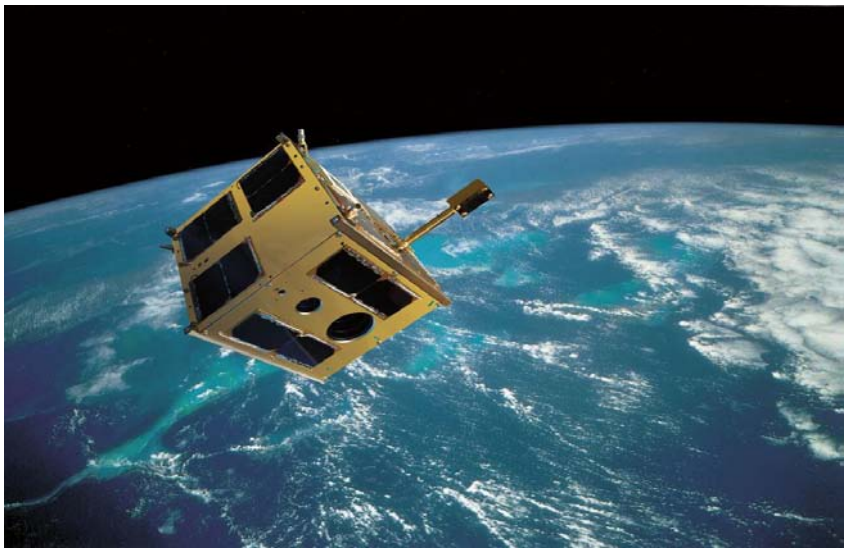
3.12 Graz University of Technology (TU Graz)

Graz University of Technology has been active in Space research and technology for more than 40 years. The first Austrian space object, an ionospheric research probe was launched on board of a Scandinavian sounding rocket in 1969 and in 2013 the first Austrian satellite TUGSAT-1 was successfully brought into orbit. In the ESA framework TU Graz is prominently involved in missions such as the highly successful Earth gravity mission GOCE. The Institute of Communication Networks and Satellite Communications, the Institute of Satellite Navigation, the Institute of Theoretical and Satellite Geodesy and the Institute of Remote Sensing and Photogrammetry are engaged in ESA, NASA and national Space programs in the areas of satellite communications & navigation, satellite geodesy, remote sensing and the development and qualification of Space hard- and software. With the Observatory Lustbühel a unique infrastructure comprising an internationally recognized Laser tracking station, several satellite communications ground stations and a time & frequency laboratory exists. The Institute of Navigation (INAS) at Graz University of Technology focuses its teaching and research on the complete aspect of navigation, which means that the thematic work goes beyond the determination of positions and trajectories, and also covers the sub-aspects of route planning and guidance.

Institute of Communication Networks and Satellite Communications

BRITE-Austria/TUGSAT-1

Austria's first satellite BRITE-Austria/TUGSAT-1 was successfully launched on 25 February 2013 by the Indian PSLV-C20 launcher. Its mission is the measurement of the brightness variation of massive luminous stars.



Already three hours after launch contact with TUGSAT-1 could be established during the first pass over the Graz ground station. Telemetry showed excellent health status. After check-out

of the on-board computer and the telemetry system, all other subsystems were thoroughly tested. Following the verification of the attitude sensors and the actuators, the spacecraft was de-tumbled using the magnetorquers. The satellite was then brought into coarse pointing mode. On 23 March the first image of the star Delta Corvus was taken, showing that the point spread function and sensitivity meets the specification. Achieving fine-pointing was considerable effort due to the facts that the ADCS system in this configuration had never flown before and only limited tests could be performed on ground. The star tracker needed careful parametrisation. During summer 2013 the ADCS system was optimised and the instrument tested in detail. The performance of the attitude control system could be improved by optimising the parameters of the star tracker and mission planning (e.g. determining the required warm-up time of the star tracker prior to transition from coarse to fine pointing). The pointing accuracy is below 1 arcsecond resulting in an average error of 1.5 pixels on the CCD (the specification stated 2 arcseconds and 2-3 pixel error). This high pointing accuracy allowed to reduce the raster size around the target stars from 32 x32 pixels to 24x24 pixels leading to a reduced science data volume per target star. Hence more stars can be observed simultaneously.

Procedures for best data quality eliminating hot pixel effects on the CCD caused by radiation were elaborated by the science team.

From November onwards regular science data collection commenced. The first star field was Orion which could be observed until mid March 2014. The BRITE Executive Science Team (BEST) which consists of the PIs of each satellite and astronomers from Austria, Poland and Canada decides on the target fields. The second target field which is currently observed is Centaurus. Up to 30 stars per field have been observed which is an increase of science data by a factor of 15 with respect to the original specification.

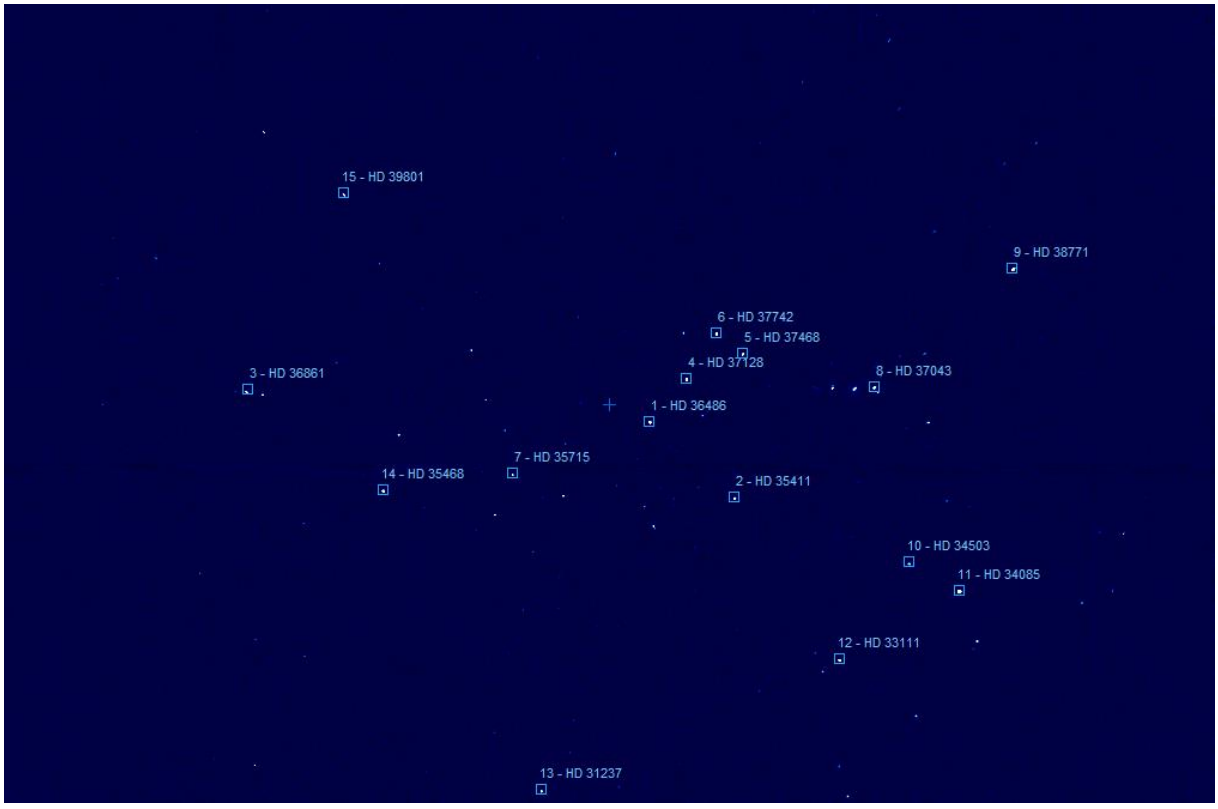
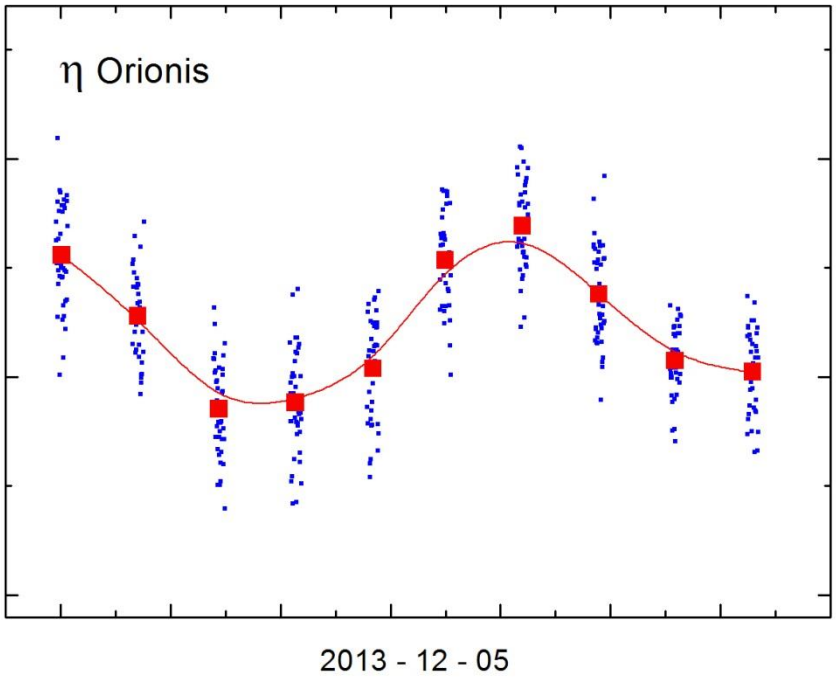


Image of the star field Orion observed by BRITE-Austria/TUGSAT-1. The squares around the target stars constitute the rasters which are read out from the CCD sensor to determine the brightness variations by photometric means

The spacecraft is operated from the mission control centre and S-band/UHF tracking ground station at TU Graz

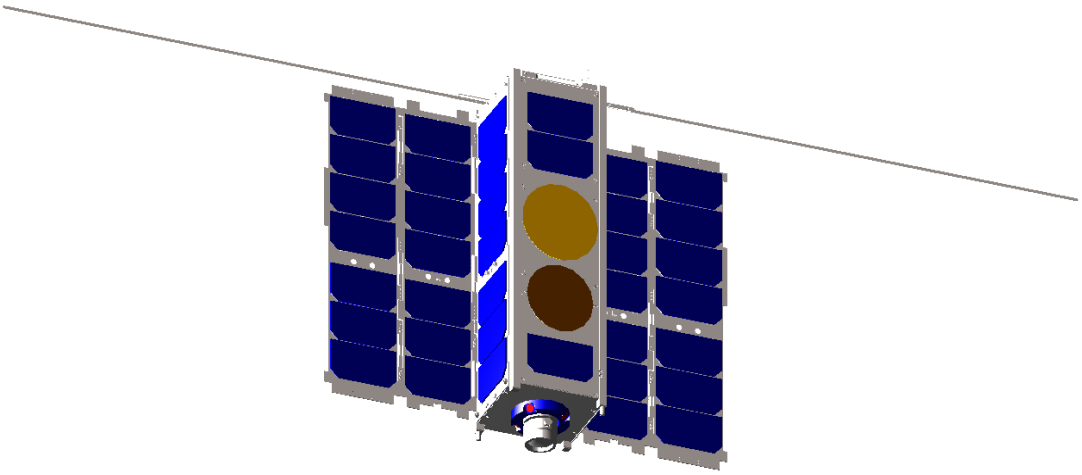


Data analysis performed by the payload scientist at the Insitute of Astrophysics, Vienna, is continuously carried out. A light curve (figure above) for the star Eta Orionis shows pulsations of the star. In summary, it can be stated that the BRITE mission outperforms the original specification. In June/July 2014 the BRITE constellation will be completed with the launch of two Canadian BRITEs and the second Polish BRITE spacecraft. This constitutes the world's first nanosatellite constellation dedicated to an asteroseismological mission. With the end of the operations of the Canadian MOST satellite in September 2014, BRITE will provide the only operational Space telescopes for measuring bright stars.

OPS-SAT Nanosatellite Mission

While the common perception of Space missions is that the most up-to-date technology is used there, in reality the utilised hardware and software is quite old. The processors used for Space are several generations behind terrestrial versions. To give another example, the CCSDS and PUS (Packet Utilisation Standard) telemetry standards were specified three decades ago. The reason is risk aversion which is advantageous for reliability and safety, but not for innovation. On the other hand lots of innovative solutions and patents have been generated, e.g. by ESA, industry and academia, but they suffer that they have never got a chance to gain Space heritage. In order to break the cycle “has never flown- will never fly”, the European Space Operations Centre ESOC launched an initiative for the definition of a Cubesat mission to demonstrate new operational concepts and to verify new technology in orbit . A concurrent design facility (CDF) study was carried out by ESA showing the feasibility of the concept. In 2013 an open call for ideas was launched with more than 100 experiments being suggested, followed by an experimenters’ day with an attendance of more than 150 participants. In July 2013 a Phase A/B1 study contract was awarded by ESA to a consortium led by the Institute of Communication Networks and Satellite Communications of TU Graz with MAGNA STEYR Engineering and the Zentrum für Telematik in Germany as subcontractors. This study was successfully completed. Phase C/D will start in Fall 2014.

OPS-SAT will carry a powerful processor payload with sufficient on-board memory in order to carry out advanced software and hardware experiments . In order to support this, the 3U Cubesat having a size of 10x10x30 cm and a mass of about 6 kg will have to generate about 30 W of electrical power. This can be achieved by two deployable solar array panels.



OPS-SAT with Deployed Solar Arrays

Key requirements of OPS-SAT are that at least one configuration must be representative of a standard ESA mission and that the spacecraft has to be inherently safe. To achieve this, in the OPS-SAT design all potential single points of failures have been removed. The spacecraft will utilize a CCSDS-compatible telemetry system operating in S-band. This is relatively new for Cubesats which normally rely on amateur radio technology and UHF/VHF telemetry.

SARONTAR III

Based on two predecessor projects funded by the Styrian “Zukunftsfonds”, an ESA contract was given to a consortium led by Teleconsult in the framework of the Integrated Applications Program IAP. The aim of the project is to demonstrate an integrated solution for a system to assist the Alpine Police in case of accidents in mountainous regions. Smartphones with connections to both 3G and satellite networks allow to automatically report the position of the rescue teams to an emergency centre and provide means to exchange standardized messages between the centre and the rescue teams as well as situation maps. Graz University of Technology with the Institute of Communication Networks and Satellite Communications and the Institute of Photogrammetry and Remote Sensing (Prof. Mathias Schardt) are responsible for the communications and GIS aspects, respectively.

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Institute of Navigation

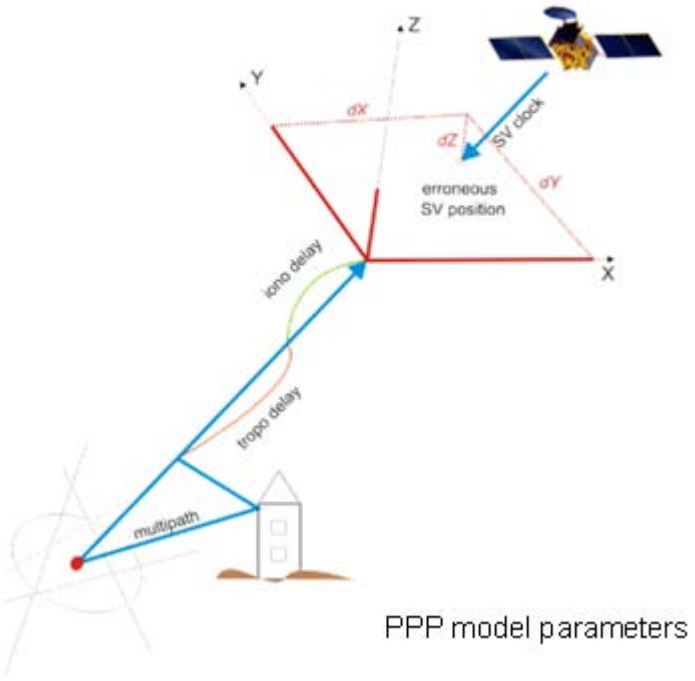
In general, the Institute of Navigation (INAS) at Graz University of Technology focuses its teaching and research on the complete aspect of navigation, which means that the thematic work goes beyond the determination of positions and trajectories, and also covers the sub-aspects of route planning and guidance.

As far as Global Navigation Satellite Systems (GNSS) are concerned, INAS was involved in research and development from the very beginning. Regarding trajectory determination, the current topics mainly cover multi-sensor systems, i.e., the sensor fusion of GNSS, INS (Inertial Navigation System), etc., and filtering (Kalman filter, Particle filter). INAS owns a highly accurate Inertial Measurement Unit (IMU) which can be used as a sensor in multi-sensor environments and helps to verify cheaper and smaller sensors (MEMS, etc.). Another research area is the determination of the earth’s gravitational field with the necessity of the provision of geoid heights with high accuracy for local to regional applications.

Similar to previous years, in 2013, three main topics were covered within space-related R&D-projects at INAS: Precise Point Positioning (PPP) by means of GNSS, integration of GNSS and INS with respect to vehicle navigation (driver assistance), and GNSS-based landslide monitoring. In the sequel, representative projects are shortly described.

Precise Point Positioning (PPP):

In 2013, the main research project in the field of PPP was **PPPserve** (Network-based GNSS Phase Biases to enhance PPP Applications – A new Service Level of GNSS Reference Station Providers). This R&D project (FFG/ASAP) lasted till November 2013. Besides INAS, the project consortium consisted of Vienna University of Technology (Department of Geodesy and Geoinformation) as the project lead and Wien-Energie Stromnetz GmbH. PPPserve aims at the development and realization of adequate algorithms to enhance fast GNSS-based point positioning at cm level. Regularly established RTK-techniques (Real-Time Kinematic) are based on processing observation differences while the required observation corrections are forwarded to the user community in the standardized RTCM format. In contrast, the PPP model is based on code/phase single point positioning, which requires a limited amount of correction data just transferring model parameters instead of observation corrections. New receiver hard- and software will be capable to process the new RTCM Standard (RTCM 3.1 Amendment 5, State Space Representation = SSR) which supports PPP. Therefore, GNSS-service providers have to adapt to this situation by offering new service levels. In a further step, PPPserve aimed at the provision of so-called satellite phase-biases which are the missing link at user side to allow for PPP-based phase ambiguity resolution to solve the problem of long convergence times typical for PPP to make the technique more suitable for modern real-time applications.



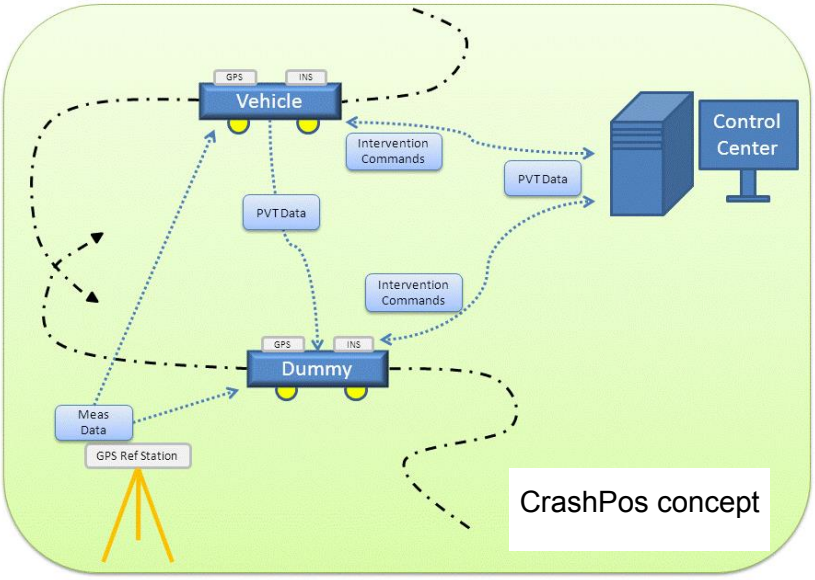
PPP model parameters

Against the background of PPP, a second FFG/ASAP project has just started in October 2013. **POScity (**New Positioning Approach for visually impaired People in urban Areas) aims at the development of new algorithms for the positioning component of a pedestrian navigation system for visually impaired or blind people. The consortium (INAS, Vienna University of Technology / Department of Geodesy and Geoinformation, Strauß & Hollinger: GeoIT OG, Alice Geiger) plans to investigate new approaches based on PPP and a Particle filter including a navigable map. The navigable maps used in this project will contain special information relevant to visually impaired pedestrians.

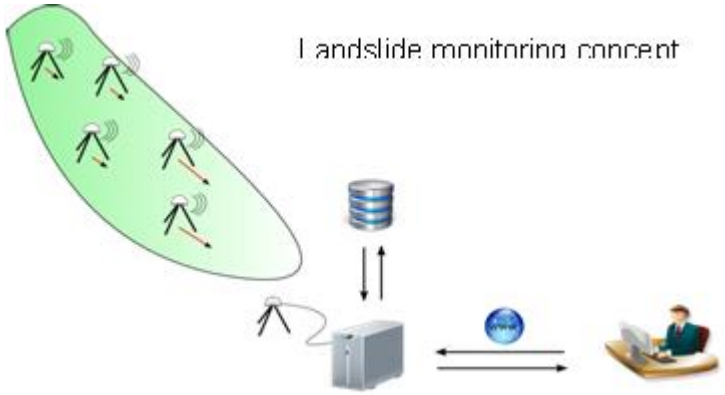
Integrated navigation and vehicle navigation:

One main research topic at INAS is the integration of GNSS with IMU measurements. The complementary characteristics of these two measurement systems lead to an increased accuracy and robustness, while GNSS outages and errors can be mitigated. For these investigations and software implementations, INAS investigates both low-cost and high-cost sensors. For the comparison of the derived position, velocity, and attitude, INAS uses a calibrated, vehicle-mounted platform.

Within the FFG/ASAP project **CrashPos** (Single-frequency RTK for an Advanced Driver Assistance System test-bed), the position integration for a novel test platform for development and testing of advanced driver assistant systems (ADAS) is investigated. The moving test platform is designed very flat to be overrunnable by a test car which allows the testing of ADAS for preventing accidents. To localize and guide such a platform, low-cost GNSS equipment, low-cost IMUs and specific integration algorithms are investigated. The consortium consisted of INAS, Dr. Steffan Datentechnik (DSD), and the University of Klagenfurt (Institute of Smart System-Technologies). The project ended in December 2013.



different dimensions. As Austria is located within the inner alpine regions, its infrastructure and its population is exposed to a certain danger. Within the project **GeoWSN** (FFG/KIRAS), the possibilities for a wireless sensor network with GPS carrier phase positioning based on low-cost GNSS components was to be investigated. Furthermore, an energy-autarkic and maintenance-free power supply using energy-efficient principles was explored. The project lasted till December 2013 and was performed in cooperation with the Institute of Technical Informatics (TU Graz), TeleConsult Austria, Geolith and Landeswarnzentrale Steiermark.



In addition, a further project, funded by ESA-IAP, investigated a landslide monitoring service integrating a low-cost wireless GNSS-node network with terrestrial radar interferometry and satellite-based InSAR (Interferometric Synthetic Aperture Radar). The scope of **MATIST**

(Monitoring Alpine Transportation Infrastructure using Space Techniques) was to provide services to the alpine transportation infrastructure and was based on the integration of two complementary techniques. Radar Interferometry was covered by GAMMA (Switzerland) and the GNSS node network was implemented by INAS. The project also phased out by the end of 2013.

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Institute of Theoretical Geodesy and Satellite Geodesy

GOCE (Gravity Field and Steady-State Ocean Circulation Explorer) was a satellite mission of the "Living Planet" programme of the European Space Agency (ESA), which was launched on 17-03-2009. The mission ended on 11-11-2013, after four successful years of operations, with the re-entry of the satellite into the Earth's atmosphere. The objective of the mission was the determination of **a high resolution model of the Earth's gravity field with high spatial resolution and accuracy.** The knowledge about the Earth's gravity field essentially supports research activities in **oceanography, geophysics, geodesy, and sea-level research.** Thus, the GOCE mission provides substantial inputs for studies about climate change and our system Earth.

Artists view of the GOCE satellite in orbit. (c) ESA

Key payload of the GOCE satellite was the worldwide unique gravity **gradiometer**. In conjunction with a precise orbit determination with an accuracy of a few centimeters and an active drag-free and attitude control system it is possible to derive a global model of the Earth's gravity field with unprecedented accuracy and spatial resolution.

The scientific data analysis is carried out under ESA contract by a consortium of 10 European university and research institutes in the frame of the project **"GOCE High-Level Processing Facility (HPF)".** Within GOCE HPF, the GOCE team Graz, a co-operation of the **Institute of Theoretical Geodesy and Satellite Geodesy (TU Graz)** and the **Space Research Institute (Austrian Academy of Sciences)** is responsible for the computation of GOCE gravity field models parameterized as spherical harmonic series expansions from GOCE orbit and gradiometry data.

Four releases of GOCE Earth gravity models have been processed in Graz and are officially provided to public as „Time-wise" solutions. In 2013 the computation of the fifth and final solution has been started. First results have been presented at the European Geophysical Union General Assembly in Vienna in April 2014. The final release contains reprocessed data spanning the whole lifetime of the satellite. This includes observations up to several hours before the satellite's disintegration in the atmosphere. The gravity field solution is solved up to spherical harmonic degree and order 280, which corresponds to a spatial resolution of about 70 km.

In the frame of the international GOCO consortium, the ITSG contributes to the computation of combined gravity field models. The combination is based on data from several satellite missions, like for example GOCE, GRACE, and CHAMP. In addition these datasets are supplemented by SLR and ground data. The combination is performed consistently by the weighted addition of full normal equations and by an adequate stochastic modeling of the individual observations. Up to now three models have been released, which already gained a high reputation among international scientists.

Furthermore, in 2013 the project TVGOGO (Time variable gravity observed by GPS derived orbit positions) started at the Institute. The project is funded by the Austrian Research Promotion Agency (FFG) in the frame of the Austrian Space Application Programme Phase

9. The aim of this project is to retrieve gravity variations solely from satellite positions. The necessary orbit positions, determined by GPS observations, are computed in house with a newly developed software. Knowledge of variations in the Earth's gravity field are of crucial importance to further enhance our understanding of the changing environment in the context of global climate change.

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TU Graz SpaceSales (total): 633 kEUR

TU Graz ESA Share (total): 222 kEUR

3.13 TTech Computertechnik AG

European technology champion TTTech Computertechnik AG joined Austrospace in 2013. TTTech is the leading supplier of dependable networking solutions based on time-triggered technology and modular safety platforms. The company's solutions improve the safety and reliability of networked electronic systems in the transportation and industrial segments according to IEC 61508, ISO 26262, EN 13849, DO-254 or DO-178C requirements. Key customers include Audi, Lockheed-Martin, Honeywell and UTAS (former Hamilton-Sundstrand).

TTTech was established in 1998 as a spin-off of the Vienna University of Technology (TU Wien). Time-triggered technology has been developed over more than 30 years by the TU Wien and TTTech in cooperation with industrial partners and leading research institutions. The TTTech Group currently employs more than 320 employees worldwide. Around two thirds of them are working in engineering & development departments, providing broad experience in hardware development, software development and chip IP design. A significant number of the employees have gained comprehensive project management skills over the years, including complex long-term projects with program partners spread worldwide. The majority of TTTech's workforce is based in Vienna, Austria. Most of the employees hold Bachelor degrees or higher. Due to long-lasting cooperation with Vienna University of Technology – the place of birth of time-triggered data-communication architectures – availability of highly-skilled engineers with expertise in robust real-time networks is ensured also in the long run.

TTTech provides development tools for time triggered communication solutions for the protocols Time-Triggered Protocol (TTP), FlexRay and TTEthernet. In addition TTTech offers verification tools and middleware for the above named protocols as well as communication controller chip designs (VHDL models and designs for FPGA, ASIC/ Chip implementation).

TTTech has successfully deployed TTP products in the aerospace industry and has gained wide experience in certification including DAL level A. The projects range from data communication in the cabin pressure control system of the Airbus A380 up to data communication for power generation and distribution systems in the Boeing 787 as well for flight controls in regional aircraft. TTTech's technologies are applied by Honeywell for production programs in the space industry including NASA's MPCV utilizing TTEthernet.

European Space Activities 2013

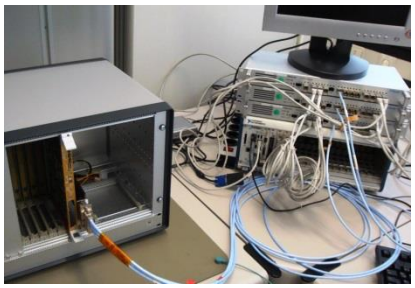
As a first step toward a European, space qualified high speed data bus Airbus Defence & Space Bremen performed a study with the main scope to characterize and trade-off different network technologies. TTEthernet was identified as most promising technology which meets the space requirements of reliability, availability, maintainability and safety (RAMS).

Accordingly a TTEthernet simulator/demonstrator was designed and built together with TTTech that allows the verification of the basic timing functions of TTEthernet using a COTS based space computer built by Airbus DS.

TTEthernet Demonstrator at Airbus Defence & Space

Within Avionique-XE TTTech supported RUAG Space Sweden, Airbus Defence & Space Les Mureaux and ÅAC Microtec with chip IP and TTEthernet development equipment and tools as TTEthernet is widely seen as best candidate for the Ariane 6 data backbone.

Finally, since ESA had agreed with NASA to build the European Service Module (ESM) for NASA's MPCV, development activities around the ESM accounted for a large increase in TTTech's work with ESM prime contractor Airbus Defence & Space Bremen. A test campaign using an existing TTEthernet demonstrator was performed to verify compatibility of Airbus' own developments with the TTEthernet technology. A commercial TTTech cPCI card was integrated into the flight computer. In a second step, the same was done with the SNIC interface controller, plugged onto a radiation tolerant single-board computer (SPAICE RTSBC). The SNIC (provided by Honeywell) is the dedicated interface controller for all MPCV avionics which are connected to its on-board network.



TTEthernet demonstrator with SNIC

Key co-operations and shareholders:

- Audi – more than 25% shareholder, key partner in the automotive field
- NXP – TTEthernet chip IP licensee for the automotive market
- CISCO – partnership signed for real-time applications in the "internet of things" utilizing core elements of the TTEthernet technology
- NASA – space act agreement

Space Sales: 422 kEUR
ESA Share: 299 kEUR

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