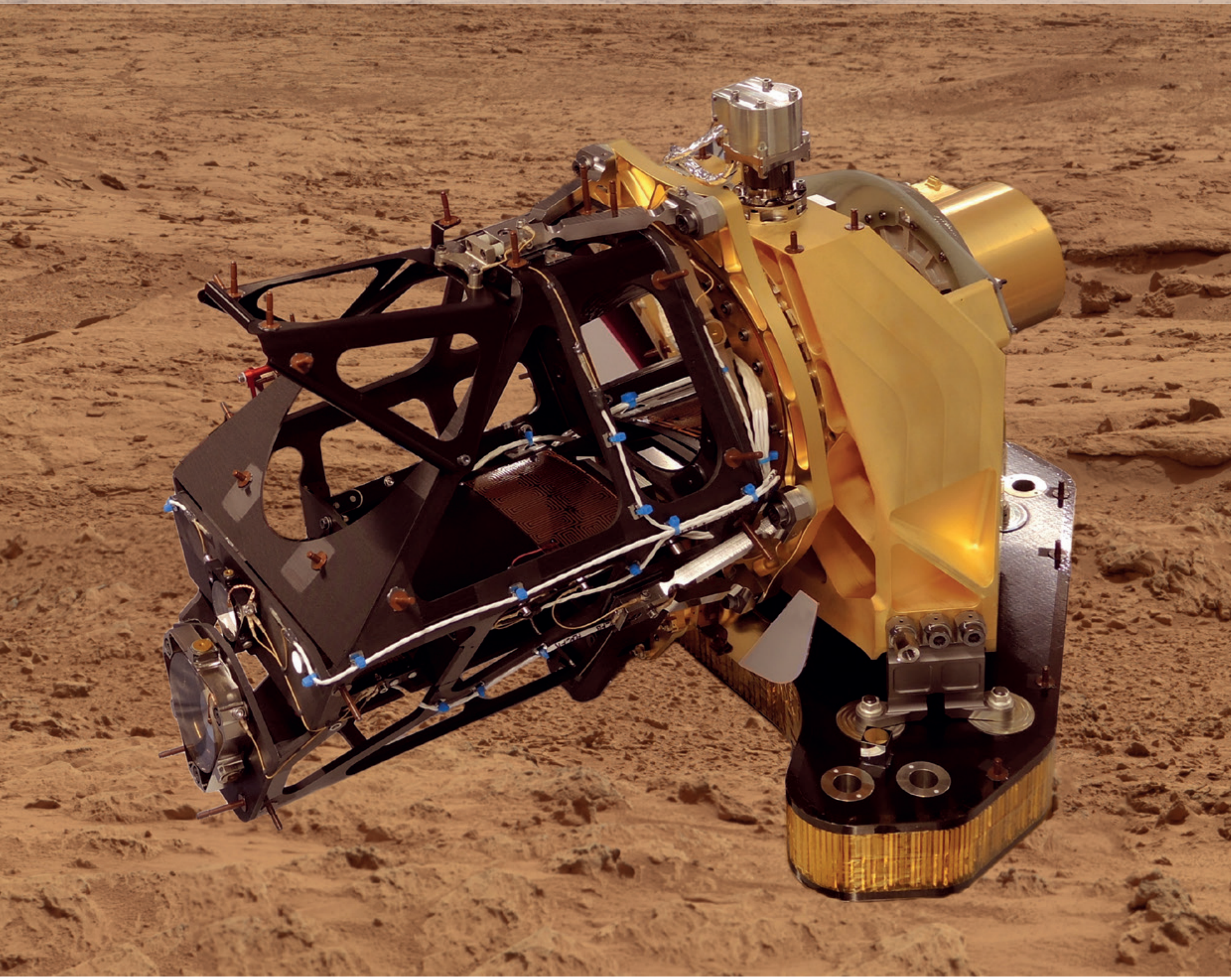
Space Research

2014-2016
in Switzerland



sc | nat

Swiss Academy of Sciences
Akademie der Naturwissenschaften
Accademia di scienze naturali
Académie des sciences naturelles

Space Research 2014 – 2016 in Switzerland

Report to the 41st COSPAR meeting, Istanbul, Turkey, 30 July – 7 August 2016

Editors: Werner Schmutz and Stephan Nyeki
Layout: Stephan Nyeki

Publication by the Swiss Committee on Space Research
(Committee of the Swiss Academy of Sciences)

Edition: 1000, printed 2016
PMOD/WRC, Davos, Switzerland

Cover Page: Swiss CaSSIS (Colour and Stereo Surface Imaging System) experiment onboard the ExoMars Trace Gas Orbiter. Copyright AIUB.

Background picture: Curiosity's view from "Rocknest" looking eastward toward "Point Lake" (center) on the way to "Glenelg Intrigue" (November 26, 2012). White-balanced raw color image. Copyright NASA/JPL-Caltech/Malin Space Science Systems.

Contents

1 Foreword

On the occasion of the 41st COSPAR meeting in Istanbul 2016, the Swiss national Committee on Space Research is reporting to the international community. The Committee on Space Research (COSPAR) is an interdisciplinary scientific organization, which is focused on the exchange of information on progress of all kinds of research related to space. It was established in 1958 by the International Council for Science (ICSU) as a thematic organization to promote scientific research in space on an international level. COSPAR's main activity is the organization of biennial Scientific Assemblies.

The majority of Swiss space research activities are related to missions of the European Space Agency (ESA) and therefore, ESA's science program is of central importance to the Swiss science community.

The ESA mission attracting most attention among the general public in the current reporting period was Rosetta, a space mission designed to visit the comet 67P/Churyumov-Gerasimenko. Two years ago, when the last Swiss COSPAR report appeared, the latest news about the mission was that the Rosetta spacecraft had been successfully woken from hibernation in January 2014. Looking back, we now recognise the incredible success of ESA's space mission, which culminated in the landing of the Philae probe on the comet's surface.

From the Swiss point of view, we are proud that there is a Swiss experiment that contributed to the key science goals of the ROSETTA mission: the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA). Its measurements allowed the hypothesis to be tested that comets brought water to Earth. ROSINA's measurements observed that water on comet 67P /Churyumov-Gerasimenko contains about three times more deuterium than water on Earth. If 67P/Churyumov-Gerasimenko is considered to be a typical comet similar to those existing in the early solar system, then it is unlikely that comets are the source of terrestrial water. This successfully achieves a major goal of the mission, and the hypothesis that asteroids ferried water to Earth, is now being more earnestly considered.

A huge compliment goes to the ESA teams who designed a spacecraft and instruments back in 1995, built the mission and launched it in 2004. Finally, the space experiment performed to the highest expectations from 2014 to 2016. Most of us have probably long ago disposed of our electronic devices from the turn of the century – but Rosetta's instruments have been in best health and delivered what they were designed for.

We have witnessed the launch of the ExoMars mission which, among other experiments, carries the Swiss CaSSIS experiment: the Colour and Stereo Surface Imaging System for the ExoMars Trace Gas Orbiter (see title page). We hope to witness similar science highlights as those achieved by ROSINA.

Looking further into the future, the Swiss space community is eagerly awaiting the operation of the first Swiss research satellite: CHEOPS, CHaracterizing ExOPlanet, which was selected by ESA's science program as its first small mission. CHEOPS was adapted for construction in early 2014, designed in the last two years, and successfully passed the critical design review, giving green light for construction of the flight hardware. The launch is currently scheduled for the end of 2017. This mission is of special interest and importance to the Swiss community as it is the first Swiss science satellite.

As the highlights above illustrate, the Swiss space community is very healthy and active. For your information and to trigger your interest, the brochure at hand is a compilation of Swiss national projects related to space research.

Werner Schmutz
President of CSR

Weblinks

COSPAR:
http://cosparhq.cnes.fr

Swiss Committee on Space Research:
www.spaceresearch.scnatweb.ch

Swiss Commission on Remote Sensing:
http://www.naturwissenschaften.ch/organisations/skf

Swiss Academy of Sciences:
www.scnat.ch

2 Institutes and Observatories

INTERNATIONAL SPACE SCIENCE INSTITUTE

2.1 ISSI – International Space Science Institute

Directors

R. Rodrigo (Executive Director)
A. Cazenave
R. von Steiger
J. Zarnecki
J. Geiss (Honorary Director)

Staff

11 Scientific
7 Administrative

Board of Trustees

Georges Meylan (Chairman),
École Polytechnique Fédérale de Lausanne, Switzerland

Science Committee

Tilman Spohn (Chairman),
German Aerospace Center (DLR), Berlin, Germany

Contact Information

International Space Science Institute (ISSI)
Hallerstrasse 6
CH-3012 Bern
Switzerland

Tel.: +41 31 631 48 96
Fax: +41 31 631 48 97

http://www.issibern.ch
e-mail: firstname.name@issibern.ch

Fields of Research

The programme of ISSI covers a widespread spectrum of disciplines from the physics of the solar system and planetary sciences to astrophysics and cosmology, and from Earth sciences to astrobiology.

Introduction

The International Space Science Institute (ISSI) is an Institute of Advanced Studies at which scientists from all over the world are invited to work together to analyze, compare and interpret their data. Space scientists, theorists, modelers, ground-based observers and laboratory researchers meet at ISSI to formulate interdisciplinary interpretations of experimental data and observations. Therefore, the scientists are encouraged to pool their data and results. The conclusions of these activities - published in several journals or books - are expected to help identify the scientific requirements of future space science projects. ISSI's study projects on specific scientific themes are selected in consultation with the Science Committee members and other advisers.

ISSI's operation mode is fivefold: International Teams, multi- and interdisciplinary Workshops, Working Groups, Visiting Scientists and Forums are the working tools of ISSI.

The European Space Agency (ESA), the Swiss Confederation, and the Swiss National Science Foundation (SNF) provide the financial resources for the ISSI's operation. The University of Bern contributes through a grant to the Director and in-kind facilities. Since 2010, the Russian Academy of Sciences is supporting ISSI with an annual financial contribution.

Realizations in 2014 and 2015

In total, 149 International Team meetings, 9 Workshops, 8 Working Group meetings, and one Forum took place in the years 2014 and 2015. ISSI welcomes about 900 visitors annually.

Furthermore, ISSI offers a unique environment for facilitating and fostering interdisciplinary Earth Science research. Consequently ESA's Earth Observation Programme Directorate entered a contractual relationship with ISSI in 2008 to facilitate synergistic analysis of projects of the International Polar Year, International Living Planet Teams, Workshops and Forum. The contract with the ESA Earth Science Directorate with ISSI has been extended until 2016.

ISSI established jointly with the National Space Science Centre of the Chinese Academy of Sciences (NSSC/CAS) a branch called ISSI-BJ (International Space Science Institute – Beijing) in 2013. ISSI-BJ shares the same Science Committee with ISSI and uses the same study tools. Since 2014, ISSI has released together with ISSI-BJ an annual joint Call for Proposals for International Teams in Space and Earth Sciences.

Since 2015, ISSI has held a Forum every year followed by a Workshop and publication of a book in collaboration with the ESA High-level Science Policy Advisory Committee (HISPAC).

ISSI is also a part of the Europlanet 2020 Research Infrastructure (RI) project. Europlanet 2020 RI addresses key scientific and technological challenges facing modern planetary science by providing open access to state-of-the-art research data, models and facilities across the European Research Area.

ISSI is a participant in the Europlanet Activity called "Innovation through science networking" and is working together with eight other Europlanet institutes to organize three Workshops and two strategic Forums over the duration of the contract which will address some of the major scientific and technical challenges of present-day planetary sciences. Europlanet 2020 RI will run until 2019.

All scientific activities result in some form of publication, e.g. in ISSI's hardcover book series Space Sciences Series of ISSI (SSSI), ISSI Scientific Report Series (SR), both published by Springer (reprinted from Space Science Reviews), or individual papers in peer-reviewed international scientific journals. As at the end of 2015, 50 volumes of SSSI, and 13 volumes of SR have been published. Information about the complete collection can be found on ISSI's website http://www.issibern.ch, in the section "Publications".

Publications

The following new volumes appeared in 2014 and 2015:

SSSI Volume 46: *The Earth's Hydrological Cycle,* L. Bengtsson, R.-M. Bonnet, M. Calisto, G. Destouni, R. Gurney, J. Johannessen, Y. Kerr, W. A. Lahoz, M. Rast (eds.), ISSI Workshop, February 2012, published in July 2014, ISBN 978-94-017-8788-8.

SSSI Volume 47: *Microphysics of Cosmic Plasmas,* A. Balogh, A. Bykov, P. Cargill, R. Dendy, T. Dudok de Wit, J. Raymond (eds.), ISSI Workshop, Apr. 2012, publ. February 2014, ISBN 978-1-4899-7412-9.

SSSI Volume 49: *The Physics of Accretion on to Black Holes*, M. Falanga, T. Belloni, P. Casella, M. Gilfanov, P. Jonker, A. King (eds.), ISSI-Workshop held in October 2012, published in November 2014, ISBN 978-1-4939-2226-0.

SSSI Volume 50: *Giant Planet Magnetodiscs and Aurorae,* K. Szegö, N. Achilleos, C. Arridge, S. Badman, P. Delamere, D. Grodent, M. Galland Kivelson, P. Louarn (eds.), ISSI- and Europlanet Workshop held in November 2012, published in September 2015, ISBN 978-1-4939-3394-5.

SSSI Volume 53: *The Solar Activity Cycle: Physical Causes and Consequences,* A. Balogh, H. Hudson, K. Petrovay, R. von Steiger (eds.), ISSI-Workshop held in November 2013, published in April 2015, ISBN 978-1-4939-2583-4.

Forthcoming Publications

SSSI Volume 51: *Multi-Scale Structure Formation and Dynamics in Cosmic Plasmas,* A. Balogh et al. (eds.), ISSI-Workshop held in April 2013, to be published in 2016.

SSSI Volume 52: *Plasma Sources of Solar System Magnetosphere,* A. F. Nagy et al. (eds.), ISSI Workshop held in September 2013, to be published in 2016.

SSSI Volume 54: *The Strongest Magnetic Fields in the Universe,* V. S. Beskin et al. (eds.), ISSI Workshop held in February 2014, to be published in 2016.

SSSI Volume 55: *The Disk in Relation to the Formation of Planets And Their Protoatmospheres,* M. Blanc et al. (eds.), ISSI Beijing Workshop held in August 2014, to be published in 2016.

Furthermore, results and published papers of international Teams in scientific journals or books can be found in ISSI's Annual Reports 19 (2013–2014) and 20 (2014–2015), which are available online (http://www.issibern.ch/publications/ar.html).

Outlook

Twenty-nine new International Teams, approved in 2015 by the Science Committee, are starting their activities in the twenty-first business year (2015/16). In addition, five Workshops will take place in the 21st business year:

- Jets and Winds in Pulsar Wind Nebulae and Gamma-ray Bursts.
- High Performance Clocks, with special emphasis on Geodesy and Geophysics and applications to other bodies of the Solar System (ISSI Workshop in collaboration with HISPAC).
- Shallow Clouds, Water Vapor, Circulation and Climate Sensitivity.
- The Scientific Foundation of Space Weather.

2.2 ISDC – INTEGRAL Science Data Centre

Institute

Dept. Astronomy,
Univ. Geneva (UNIGE)

In Cooperation with

European Space Agency
German Aerospace Center
Polish Academy of Sciences
Istituto Nazionale di Astro., Italy
APC, France
CNRS, France
DTU Space, Denmark
Centro de Astrobiología, Spain

Principal Investigator

T. J.-L. Courvoisier (UNIGE)

Method

Measurement

Developments

Data from the INTEGRAL gamma-ray space observatory are processed, archived, and distributed to scientists worldwide together with the software to analyze them. Quick-look and automated analyses ensure the data quality and the discovery of relevant astronomical events.

Contact Information

INTEGRAL Science Data Centre,
Astronomical Obs., Univ. Geneva,
CH-1290 Versoix, Switzerland

Tel.: +41 22 379 21 00
Fax: +41 22 379 21 33

http://www.isdc.unige.ch/integral
e-mail: isdc@unige.ch

Purpose of Research

The INTEGRAL Science Data Centre (ISDC) was established in 1996 as a consortium of 11 European institutes plus NASA. It has a central role in the ground-segment activities for ESA's INTernational Gamma-Ray Laboratory (INTEGRAL). INTEGRAL operates a hard-X-ray imager with a wide field-of-view, a gamma-ray polarimeter, a radiation monitor, and X-ray and optical monitors, which have significantly advanced our knowledge of high-energy astrophysical phenomena. INTEGRAL's ground segment activities are divided into Mission Operation Center, Science Operation Center (both operated by European Space Agency), and the ISDC, which is a PI partner of the mission and provides essential services for the astronomical community to exploit the mission data.

ISDC processes the telemetry from the spacecraft to elaborate a set of widely usable products and it performs a quick-look analysis to assess the data quality and discover transient astronomical events. These products are distributed to guest observers and archived at ISDC, which is the only source of publicly accessible and distributed INTEGRAL data. ISDC also has the task of integrating and distributing software with handbooks for the offline analysis of INTEGRAL data together and to support users. Only as a result of the ISDC contribution are data available to the community.

The presence of the ISDC has guaranteed Swiss scientists a central role in the exploitation of INTEGRAL data. To date, ISDC members have participated in almost 20% of papers based on INTEGRAL data.

Status

INTEGRAL was launched in October 2002 and its data are an important tool of the worldwide high-energy astrophysics community. They have generated about 100 PhD theses (with 15 ongoing), more than 2200 publications (900 in referred journals, increasing steadily), and several astronomical telegrams per month. Moreover, every second day, a gamma-ray burst is detected by INTEGRAL and an automatic alert is sent to robotic telescopes within seconds of the detection so that the GRBs can be localised.

INTEGRAL carries the most sensitive all-sky monitor for gamma-ray bursts without localisation capability and is an essential tool to discover a gamma-ray counterpart of a gravitational wave event (Savchenko et al., 2016). ESA has conducted reviews in the past years, and concluded that fuel consumption, solar panel and battery ageing and orbital evolution will allow the mission to be prolonged for many more years. In 2016, an operational review will ascertain the reliability of INTEGRAL for the next extension (2017–2018). Further extensions will be discussed based on the scientific relevance of the mission and budget constraints.

ISDC is an essential pillar of the mission and is currently funded by the Swiss Space Office, the University of Geneva, and ESA, with contributions from the German DLR through the Inst. Astronomy and Astrophysics Tübingen, and the Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences. It scientific and technical personnel works in synergy with other space missions in the Department of Astronomy.

To ensure data quality and to exploit the potential of the INTEGRAL observatory, the ISDC staff continuously performs scientific validation to report relevant "hot" discoveries in collaboration with guest observers. Remarkably, INTEGRAL managed to capture the first pulsar swinging from accretion and rotation powered emission, which has been searched for since the first evolutionary theories appeared in 1982 (Papitto et al., 2013). It followed the extraordinary outburst of the black-hole binary V404 Cyg in 2015 and 2016 for which ISDC has provided ready-to-use data. ISDC is leading a Memorandum of Understanding between INTEGRAL and the LIGO-Virgo consortium to follow-up on-line triggers of potential gravitational wave events, which are confidentially distributed.

Follow-up studies performed at ISDC are mainly in the field of high-energy astrophysics, which was and remains its core science. Although a significant fraction of the research topics are linked to areas in which INTEGRAL makes a significant contribution, a variety of other observation facilities, such as XMM-Newton, Swift, Chandra, Planck, and Fermi, have so far been exploited. The science topics span from nearby X-ray binaries up to cosmological scales, with the study of active galactic nuclei and clusters of galaxies.

Based on an approach merging high-energy astrophysics with particle physics, astroparticle physics is rapidly developing around ISDC. Its central topics are the nature of dark matter and dark energy, the origin of cosmic rays and astrophysical particle accelerators. Research in this field needs data from space and ground-based gamma-ray telescopes which operate at higher energies.

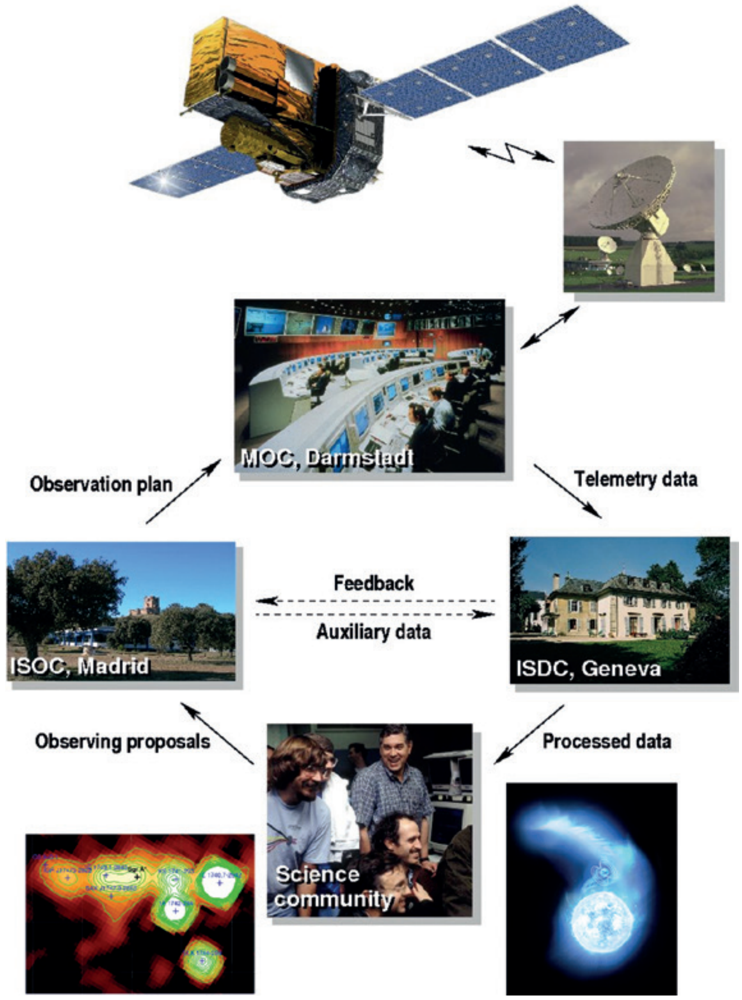
Publications

1. Courvoisier, T. J.-L., et al., (2003), The INTEGRAL Science Data Centre (ISDC), A&A, 411, L53–L57.

2. Papitto, A., C. Ferrigno, E. Bozzo et al., (2013), Swings between rotation and accretion power in a binary millisecond pulsar, Nature, 501, 7468, 517–520.

3. Savchenko, V., C. Ferrigno et al., (2016), INTEGRAL upper limits on gamma-ray emission associated with the gravitational wave event GW150914, Astrophys. J. Lett., 820, L36, 5 pp.

Schematic view of the INTEGRAL ground segment activities.



2.3 CODE – Center for Orbit Determination in Europe

Institute

Astronomical Institute,
Univ. Bern (AIUB), Bern

In Cooperation with

Bundesamt für Landestopographie (swisstopo), Wabern, Switzerland

Bundesamt f. Kart. u. Geodäsie (BKG), Frankfurt a. M., Germany

IAPG, Technische Universität München, Germany

PrincipalSwiss Investigator

R. Dach (AIUB)

Co-Investigators

A. Jäggi (AIUB)
E. Brockmann (swisstopo)
D. Thaller (BKG)
U. Hugentobler (IAPG)

Method

Measurement

Developments

GNSS data analysis and software development

Purpose of Research

Using measurements from Global Navigation Satellite Systems (GNSS) is (among many other applications) well established for the realization of the global reference frame, the investigation of the system Earth, or the precise geolocation of Low Earth Orbiting (LEO) satellites in space. To support the scientific use and the development of GNSS data analysis, the International GNSS Service (IGS) was established by the International Association of Geodesy (IAG) in 1994.

CODE is one of the leading global analysis centers of the IGS. It is a joint venture of the Astronomical Institute of the University of Bern (AIUB), Bern, Switzerland, the Bundesamt für Landestopographie (swisstopo), Wabern, Switzerland, the Bundesamt für Kartographie und Geodäsie (BKG), Frankfurt a.M., Germany, and the Institute of Astronomical and Physical Geodesy (IAPG) of the Technische Universität München, Munich, Germany. Since the early pilot phase of the IGS (21 June 1992) CODE has been running continuously. The operational processing is located at AIUB using the Bernese GNSS Software package that is developed and maintained at AIUB for many years.

Nowadays, data from about 250 globally distributed IGS tracking stations are processed every day in a rigorous combined multi-GNSS (currently the American Global Positioning System (GPS) and the Russian counterpart GLONASS) processing system of all IGS product lines (with different latencies). CODE started with the inclusion of GLONASS in its regular processing scheme back in May 2003. For five years it has been the only analysis center following this approach. In the meanwhile, other IGS analysis centers have started to follow this strategy as well.

In a seperate processing line, a fully integrated five-system solution has developed, including the established GNSS, GPS and GLONASS but also the currently developed systems, namely the European Galileo, the Chinease BeiDou, and the Japanease QZSS. The resulting solution is generated in the frame of the IGS multi-GNSS extension (IGS MGEX).

Status

The main products are precise GPS and GLONASS orbits, satellite and receiver clock corrections, station coordinates, Earth orientation parameters, troposphere zenith path delays, and maps of the total ionospheric electron content. The coordinates of the global IGS tracking network are computed on a daily basis for studying vertical and horizontal site displacements and plate motions, and to provide information for the realization of the International Terrestrial Reference Frame (ITRF). The daily positions of the Earth's rotation axis with respect to the Earth's crust, as well as the exact length-of-day, is determined each day and provided to the International Earth Rotation and Reference Systems Service (IERS).

Apart from regularly generated products, CODE significantly contributes to the development and improvement of modeling standards. Members of the CODE group contribute or chair different IGS working groups, e.g., the working group on Bias and Calibration. With the ongoing modernization programs of the established GNSS and the upcoming GNSS, e.g., the European Galileo, such work is highly relevant because of the increasing manifold of signals that need to be consistently processed in a fully combined multi-GNSS analysis scheme. Other contributions from CODE are the derivation of calibration values for the GNSS satellite antenna phase center model, GLONASS ambiguity resolution, and the refinement of the CODE orbit model.

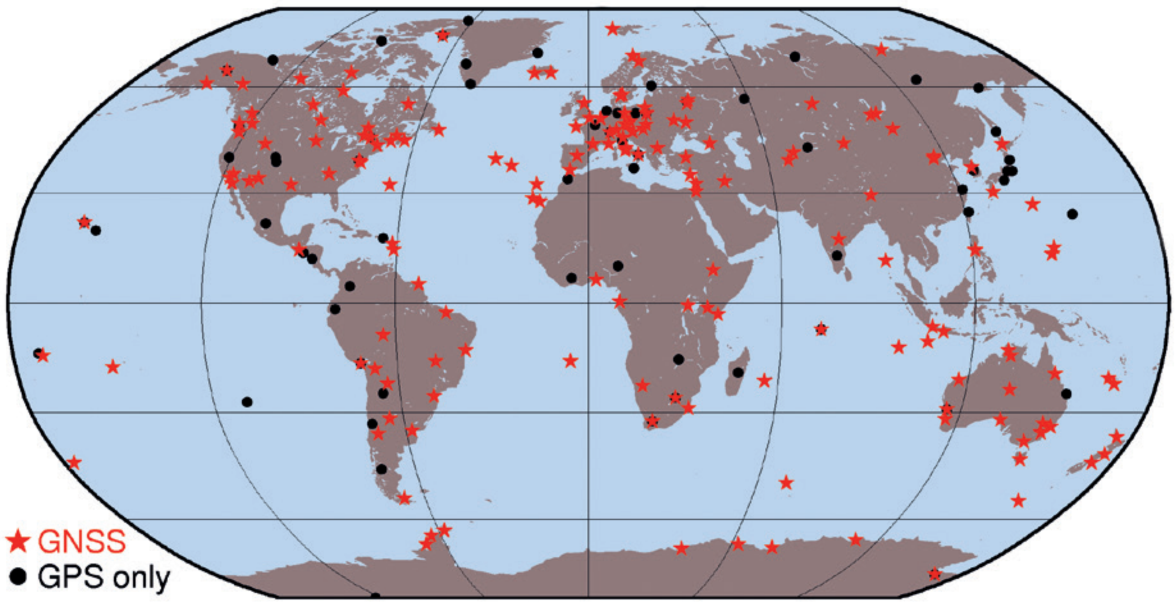
Publications

A list of recent publications is available at:

http:// www.bernese.unibe.ch

Abbreviations

CODE	Center for Orbit Determination in Europe
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GLONASS	Globalnaja Nawigazionnaja Sputnikowaja Sistema
IGS	International GNSS Service
ITRF	International Terrestrial Reference Frame
LEO	Low Earth Orbit
QZSS	Quasi-Zenith Satellite System



Network of stations processed by CODE for its final processing scheme (status: March 2016).

eSpace
EPFL SPACE ENGINEERING CENTER

2.4 eSpace – EPFL Space Engineering Center

Mission

The EPFL Space Engineering Center (eSpace) shall contribute to space knowledge and exploration by providing world-class education, leading space technology developments, coordinating multi-disciplinary learning projects and taking EPFL's laboratory research to space.

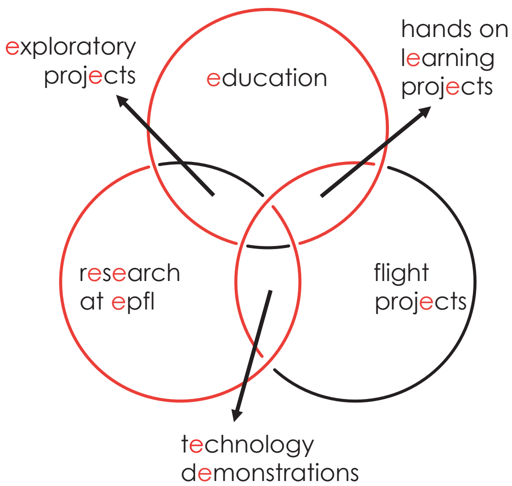
Vision

To establish EPFL as a world renowned Center of Excellence in Space Engineering, and creating intelligent space systems in service to humankind.

Description

The Space Engineering Center (eSpace) is an interdisciplinary entity with the mission of promoting space related research and development at EPFL. eSpace was created in 2014 following a restructuring of the "Swiss Space Centre". eSpace is active in three key areas: education, development projects and fundamental research. The center coordinates the minor in Space Technologies, which allows master-level students to acquire extensive formal teaching in the field. These theoretical classes are complemented by hands-on multidisciplinary projects, which often lead to the construction of real hardware (e.g. SwissCube, with ~200 students involved). Several projects are currently ongoing at eSpace, including CubETH (a second "CubeSat" and natural successor to SwissCube) and CleanSpace One, which will demonstrate de-orbiting technologies necessary for space debris removal.

The center possesses expertise particularly in the field of system engineering, including Muriel Richard-Noca and Anton Ivanov as part of its senior staff, two experienced scientists who worked at NASA-JPL prior to joining EPFL. eSpace also relies on close collaborations with research laboratories and institutes at EPFL. In many cases, the research and development activities performed are carried out directly within these entities, with support or coordination from eSpace. In this way, the center can lean on an extensive knowledge base and state-of-the-art research in a number of areas, ranging from robotics to computer vision, and help take these technologies to space.



Institute

EPFL Space Engineering Center (eSpace)

Director

H. Shea (EPFL)

Deputy Director

S. Dandavino (EPFL)

Staff

5 Scientific, 4 Admin.

Contact Information

EPFL Space Engineering Center
EPFL–ENT–ESC, Station 13
CH-1015 Lausanne
Tel: +41 (0) 21 693 6948
Fax: +41 (0) 21 693 6940
email: espace@epfl.ch
URL: http://eSpace.epfl.ch

2.5 SSA – International Space Situational Awareness

Purpose of Research

The central aim of Space Situational Awareness (SSA) is to acquire information about natural and artificial objects in Earth orbits. The growing number of so-called space debris (artificial non-functional objects) results in an increasing threat to operational satellites and manned spaceflight.

Research in this domain aims at a better understanding of the near-Earth environment through extending the catalogs of "known" space objects toward smaller sizes, by acquiring statistical orbit information on small-size objects in support of statistical environment models, by characterizing objects to assess their nature and to identify the sources of space debris.

The research is providing the scientific rationale to devise efficient space debris mitigation and remediation measures enabling sustainable outer space activities.

Status

This is an ongoing international collaboration between the Astronomical Institute of the University of Bern (AIUB), the Keldish Institute of Applied Mathematics (KIAM), Moscow, ESA, and DLR. Optical surveys performed by AIUB using its ZIMLAT and ZimSMART telescopes in Zimmerwald and the ESA telescope in Tenerife on behalf of ESA, as well as the surveys performed by KIAM, using the ISON telescopes, provide the data to maintain orbit catalogs of high-altitude space debris. These catalogs enable follow-up observations to further investigate the physical properties of the debris and to eventually discriminate sources of small-size debris.

Results from this research are used as key input data for the European ESA meteoroid and space debris reference model MASTER. The AIUB telescopes constitute primary optical sensors in the ESA Space Situational Awareness preparatory program.

Publications

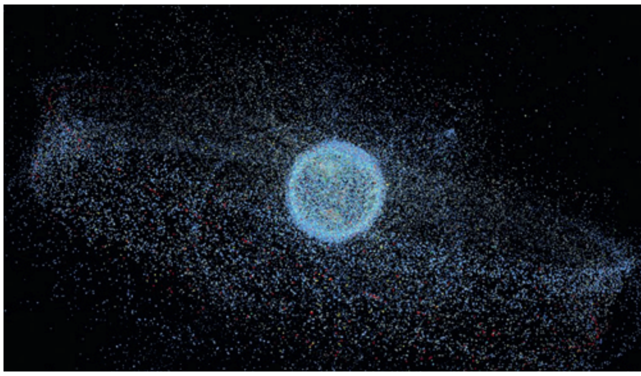
1. Siminski, J. A., O. Montenbruck, H. Fiedler, T. Schildknecht, (2014), Short-arc tracklet association for geostationary objects, Adv. Space Res., 53, 1184 – 1194.

2. Linder, E., J. Silha, T. Schildknecht, M. Hager, (2015), Extraction of spin periods of space debris from optical light curves, Proc. 66th Int. Astron. Cong., Jerusalem, Israel.

3. Zittersteijn, M., A. Vananti, T. Schildknecht, J. C. Dolado-Perez, V. Martinot, (2015), Associating optical measurements and estimating orbits of geocentric objects through population-based meta-heuristic methods., Proc. 66th Int. Astron. Cong., Jerusalem, Israel.

Abbreviations

SSA	Space Situational Awareness
ZIMLAT	Zimmerwald Laser and Astrometry Telescope
ZimSMART	Zimmerwald SMall Aperture Robotic Telescope



Graphical representation of the space debris population of objects >1 cm as seen from three Earth radii (ILR TUB).

Institute

Astronomical Institute
Univ. Bern (AIUB), Bern

In Cooperation with

European Space Agency (ESA)

Keldish Institute of Applied Mathematics (KIAM), Moscow

International Scientific Optical Observation Network (ISON)

Deutsches Zentrum für Luft- und Raumfahrt (DLR)/German Space Operation Centre (GSOC)

Principal Investigators

T. Schildknecht (AIUB)

Co-Investigators

V. Agapov (KIAM)
H. Fiedler (DLR)

Method

Measurement, Compilation

Observatories

Zimmerwald, Switzerland
Siding Spring, Australia
ESA, Tenerife
ISON telescopes

swiss
space center

2.6 SSC – Swiss Space Center

Director

V. Gass (EPFL)

Staff

3 Professors
15 Scientific & Technical
3 Administrative

Board of Directors

D. Neuenschwander (SERI/SSO)
P. Gillet (EPFL)
D. Günther (ETHZ)

Steering Committee

N. de Rooij (EPFL), Chairman
M. Rothacher (ETHZ)
U. Frei (SSO)
S. Krucker (Acad. rep.)
A. M. Madrigal (RTO rep.)
U. Meier (Industry rep.)
C. Schori (Industry rep.)

Contact Information

Swiss Space Center
EPFL, PPH338, Station 13
CH-1015 Lausanne,
Switzerland
Tel.: +41 21 693 69 48
http://space.epfl.ch

ETH Zurich, c/o Inst. Geodesy and Photogrammetry, HIL C61.3,
Stefano-Franscini Platz 5,
CH-8093 Zurich,
Switzerland
Tel.: +41 44 633 30 56
www.space.ethz.ch

Mission

The Swiss Space Center (SSC) provides a service supporting institutions, academia and industry to access space missions and related applications, and promote interaction between these stakeholders.

Roles

- To network Swiss research institutions and industries on national and international levels in order to establish focused areas of excellence internationally recognized for both space R&D and applications.
- To facilitate access to and implementation of space projects for Swiss research institutions and industries.
- To provide education and training.
- To promote public awareness of space.

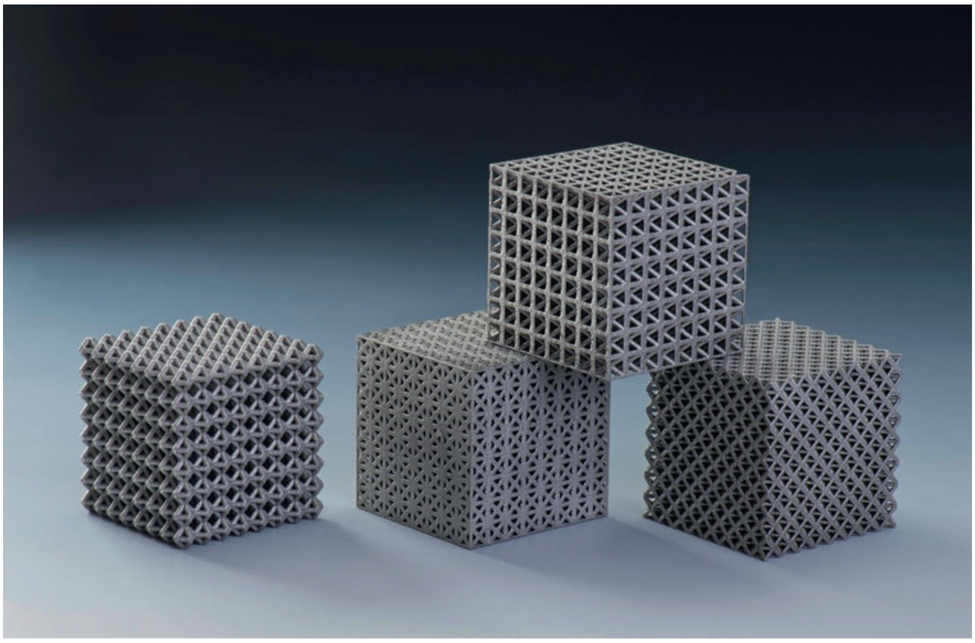
Members

At the end of 2015, the Swiss Space Center counted 32 members from each region of Switzerland, who represent all types of companies (large size, medium and start-up), academies (Swiss Federal Institutes, Universities, Universities of applied sciences), Research and Technology Organizations and institutions.

Activities 2015

Pursuing its mission to bring Swiss space actors together, the Swiss Space Center established three working groups in 2014, addressing the following domains: education, miniaturization & mini- or micro-systems, high precision mechanisms & structures. A new working group on Earth observation & Remote sensing was proposed by the members and accepted by the steering committee in June 2015. These networking platforms give the members the

The Swiss Space Center.



An ESA-NPI co-funded PhD thesis carried out at the Swiss Space Center is focused on additive manufacturing. Periodic cellular structures in aluminum alloy (AlSi12) done by selective laser melting could be a great advantage in solving the eternal mass saving problem for space applications. These kinds of structure could reduce the weight of spacecraft by allowing the integration into structural panels of other functions such as heat exchange, energy absorption, micro-meteoroid and orbitals debris (MMOD) shielding or even radiation protection.

opportunity to present their activities and express their opinions.

A workshop was hosted in June 2015 by the Time and Frequency Laboratory of the University of Neuchatel which was inspired by the working group on Miniaturization and Mini- or Micro-Systems (M3S). In this first Swiss workshop on "LASER for Space Applications", experts from over ten Swiss organizations (academia, Research and Technology Organizations (RTO) and industry) came together to present and discuss the development and use of lasers for space applications.

Lasers are key components for many scientific instruments and technologies, such as next-generation atomic clocks, spectrometers and laser telecommunication systems. Novel developments in laser technology will push the boundaries of science and technology. This workshop was extended to UK representatives in October 2015 with the support of the British Embassy in Switzerland. Four different themes were addressed: LASER fundamentals, future LASER developments, applications for High-Power LASERs and space applications.

In support of the Swiss Space Office (SERI/SSO) for the implementation of Swiss space policy, the SSC has launched two "Call for Ideas" in 2015. The first one targeted short studies addressing new innovations for space. The second one aimed "to select the best concepts for a future small mission". These initiatives were a great success with more than 30 proposals submitted in total.

In parallel, two selections of the new National Trainee Program (NTP) were carried out by the SSC. This program, funded by SERI/SSO, allows six Swiss citizens (young graduates) to work in one of the ESA centers across Europe for a maximum of two years. The SSC is also involved in the ESA Networking Partnering Initiative (NPI) with two co-funded PhD theses where the candidate will spend three months per year directly at ESA. Work from one of these theses is illustrated in the figure above.

In addition, the continuation of education classes, space careers events, participation in public presentations and the international space summer camp are other activities the Swiss Space Center conducts throughout the year with its partners in different Swiss locations.

Above: The 1-meter Zimmerwald Laser and Astrometry Telescope (ZIMLAT)

Right page: Laser beam transmitted from the 1-meter Zimmerwald Laser and Astrometry Telescope (ZIMLAT) to measure high accuracy distances of artificial satellites..

Institute

Astronomical Institute,
Univ. Bern (AIUB)

In Cooperation with

Bundesamt für Landestopographie (swisstopo), Wabern, Switzerland

Principal Investigator

T. Schildknecht (AIUB)

Co-Investigators

P. Lauber
M. Ploner
A. Jäggi (AIUB)

Method

Measurement

2.7 Satellite Laser Ranging at the Swiss Optical Ground Station and Geodynamics Obs. Zimmerwald

Purpose of Research

The Zimmerwald Geodynamics Observatory is a station of the global tracking network of the International Laser Ranging Service (ILRS). SLR observations to satellites equipped with laser retro-reflectors are acquired with the monostatic 1-m multi-purpose Zimmerwald Laser and Astrometric Telescope (ZIMLAT).

Target scheduling, acquisition and tracking, and signal optimization can be performed fully autonomously whenever weather conditions permit. The collected data are delivered in near real-time to the global ILRS data centers, while official products are generated by the ILRS analysis centers using data from the geodetic satellites LAGEOS and Etalon.

SLR significantly contributes to the realization of the International Terrestrial Reference Frame (ITRF), especially with respect to the determination of the origin and scale of the ITRF.

Status

The design of the 100 Hz Nd:YAG laser system used at the Swiss Optical Ground Station and Geodynamics Observatory Zimmerwald enables a high flexibility in the selection of the actual firing rate and epochs, which also allows for synchronous operation in one-way laser ranging experiments to spaceborne optical transponders such as the Lunar Reconnaissance Orbiter (LRO).

The highly autonomous management of the SLR operations by the in-house developed control software is mainly responsible for Zimmerwald Observatory evolving into one of the most productive SLR stations worldwide in the last decade.

This achievement is remarkable when considering the facts that weather conditions in Switzerland only allow operations about two thirds of the time, and that observation time is shared during nights between SLR operations and the search for space debris with CCD cameras attached to the multi-purpose telescope.

Publications

1. Ploner, M., P. Lauber, M. Prohaska, P. Ruzek, T. Schildknecht, A. Jäggi, (2015), History of the laser observations at Zimmerwald, Proc.19th Int. Workshop on Laser Ranging, Annapolis, Maryland, USA.

2. Schildknecht, T., A. Jäggi, M. Ploner, E. Brockmann, (2015), The Swiss Optical Ground Station and Geodynamics Observatory Zimmerwald, Swiss National Report on the Geodetic Activities in the years 2011 – 2015.

Abbreviations

ILRS	International Laser Ranging Service
ITRF	International Terrestrial Reference Frame
LRO	Lunar Reconnaissance Orbiter
SLR	Satellite Laser Ranging
ZIMLAT	Zimmerwald Laser and Astrometry Telescope

3 Space Access Technology

3.1 ALTAIR – Air Launch Space Transportation Using an Automated Aircraft and an Innovative Rocket

Purpose of Research

ALTAIR's strategic objective is to demonstrate the economic and technical viability of a novel European launch service for the rapidly growing small satellites market. The system is specially designed to launch satellites in the 50 – 150 kg range into Low-Earth Orbits, in a reliable and cost-competitive manner.

The ALTAIR system comprises of an expendable launch vehicle built around hybrid propulsion and lightweight composite structures, which is air-launched from an unmanned carrier aircraft at high altitudes. Following separation, the carrier aircraft returns to the launch site, while the rocket propels the payload into orbit, making the entire launch system partly reusable and more versatile than existing rideshare and piggyback launch solutions.

ALTAIR will hence provide a dedicated launch service for small satellites, enabling on-demand and affordable space access to a large spectrum of users, from communication and Earth observation satellite operators to academic and research centers, for whom launch solutions were previously not easily accessible.

The key feature of the expendable rocket will be an advanced lightweight composite structure, designed around environmentally green hybrid propulsion stages. A versatile upper stage and innovative avionics contribute to mission flexibility and cost reduction, paired with novel ground system architectures. All systems are optimized by exploiting multi-disciplinary techniques, and the resulting design will be supported by flight experiments to advance the maturity of key technologies.

Within the ALTAIR project, the ETH Zurich will lead the development of the launcher structure. By exploiting advanced composite materials, implementing novel and structurally optimized designs, as well as tailoring the composite manufacturing processes, the structural performance of the vehicle will be increased, thereby enabling the launch of heavier payloads.

These state-of-the-art design techniques will eventually advance the technology of lightweight systems and promote the use of composite materials in launch vehicles, expanding the current bounds of structural efficiency.

Status

The project, funded through the EU "Horizon 2020" program, started in December 2015. The consolidation of target mission and costs through market analyses has been completed, and the output in terms of high level requirements is being used to perform subsequent specific studies at systems level.

Time-Line	From	To
Planning	Dec. 2015	Jun. 2017
Construction	Jul. 2017	Mar. 2018
Measurement Phase	Apr. 2018	Dec. 2018
Data Evaluation	Apr. 2018	Dec. 2018

ALTAIR

Institute

Insitute of Design, Materials and Fabrication, ETH Zurich (ETHZ)

In Cooperation with

ONERA, France
Bertin Technologies, France
Piaggio Aerospace, Italy
GTD Sistemas de Inform., Spain
Nammo Raufoss, Norway
SpaceTec Partners, Belgium
CNES, France

Principal Investigator

Nicolas Berend

Swiss Principal Investigator

P. Ermanni (ETHZ)

Co-Investigators

G. Molinari
C. Karl

Method

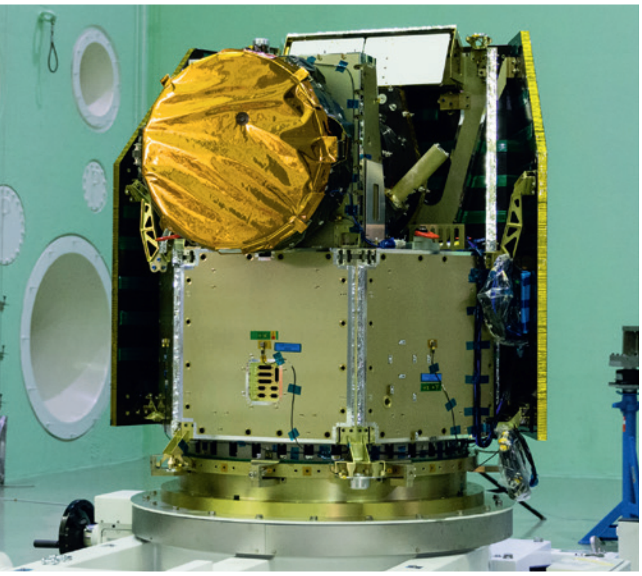
Measurements and Simulation

Developments

Development and construction of a 50 – 150 kg-class satellite launcher based on a hybrid aircraft-rocket design for low-cost, low-Earth-orbit space access.

4 Swiss Space Missions

4.1 CHEOPS – Characterising ExOPlanet Satellite



CHEOPS SQM satellite model at ESA ESTEC for accoustic testing.

Institute

Center for Space and Habitability & Institute of Physics,
Univ. Bern (UNIBE)

In Cooperation with

Institut für Weltraumforschung Graz
Centre Spatial de Liege
ETH Zurich
EPFL Space Engineering Center
Observatoire Geneve
Lab. d'Astrophysique de Marseille
DLR Inst. for Planetary Research
DLR Inst. for Optical Sensor Systems
Konkoly Observatory
INAF Osserv. Astrofisico di Catania

INAF Osserv. Astro. di Padova
Centro de Astrofisica da Universidade do Porto
Deimos Engenharia
Onsala Space Observatory
Stockholm University
Univ. Warwick

Purpose of Research

CHEOPS is the first mission dedicated to search for transits of exoplanets by means of ultrahigh precision photometry on bright stars already known to host planets.

It will provide the unique capability of determining accurate radii for a subset of those planets for which the mass has already been estimated from ground-based spectroscopic surveys, providing on-the-fly characterisation for exoplanets located almost everywhere in the sky.

It will also provide precise radii for new planets discovered by the next generation of ground- or space-based transits surveys (Neptune-size and smaller).

By unveiling transiting exoplanets with high potential for in-depth characterization, CHEOPS will also provide prime targets for future instruments suited to the spectroscopic characterisation of exoplanetary atmospheres.

In particular, CHEOPS will:

- Determine the mass-radius relation in a planetary mass range for which only a handful of data exist and to a precision not previously achieved.
- Identify planets with significant atmospheres in a range of masses, distances from the host star, and stellar parameters.
- Place constraints on possible planet migration paths followed during the formation and evolution of planets.
- Bring new constraints on the atmospheric properties of known hot Jupiters via phase curves.
- Provide unique targets for detailed atmospheric characterisation by future ground- (e.g. the European Extremely Large Telescope, E-ELT) and space-based (e.g. the James Webb Space Telescope, JWST) facilities with spectroscopic capabilities.

In addition, 20% of the CHEOPS observing time will be made available to the community through a selection process carried out by ESA, in which a wide range of science topics may be addressed.

Status

The Structural Thermal Model (STM) campaign has been successfully completed on instrument and spacecraft.

The instrument Engineering Model (EM) has been delivered to the spacecraft, and spacecraft level testing of the EM will commence shortly.

The instrument has gone through Critical Design Review (CDR), while system CDR is on-going.

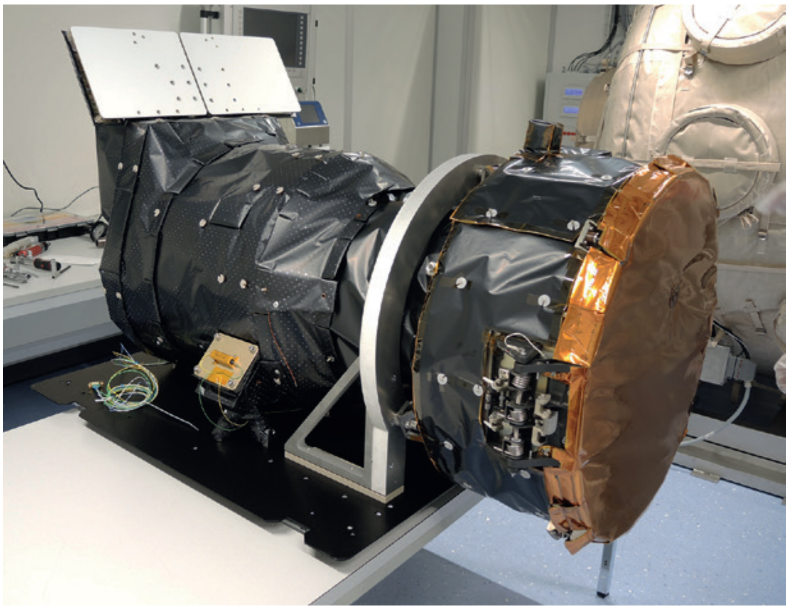
Publications

1. Broeg, et al., (2013), CHEOPS: A transit photometry mission for ESA's small mission programme, EPJ conf., 47, p. 3005.
2. Fortier, A., T. Beck, W. Benz, C. Broeg, V. Cessa, D. Ehrenreich, N. Thomas, (2014), CHEOPS: A space telescope for ultra-high precision photometry of exoplanet transits, Proc. SPIE 9143, 91432J.

Abbreviations

CHEOPS	CHaracterising ExOPlanet Satellite
CDR	Critical Design Review
E-ELT	European Extremely Large Telescope
JWST	James Webb Space Telescope
SQM	Spacecraft Qualification Model
STM	Structural Thermal Model

Time-Line	From	To
Planning	Mar. 2013	Feb. 2014
Construction	Mar. 2014	End 2017
Measurement Phase	2018	Mid 2021
Data Evaluation	2018	Onwards



CHEOPS Structural and Thermal Model (STM) in the CHEOPS Lab at the University of Bern being prepared for the environmental tests.

Principal Investigator

W. Benz (UNIBE)

Co-Investigators

T. Barczy, W. Baumjohann, T. Beck, C. Broeg, M. Davies, M. Deleuil, D. Ehrenreich, A. Fortier, M. Gillon, A. Gutierrez, L. Kiss, A. L.-d-Etangs, G. Olofsson, G. Piotto, D. Pollacco, D. Queloz, R. Ragazzoni, E. Renotte, N. Santos, T. Spohn, M. Steller, S. Udry and the CHEOPS Team

Method

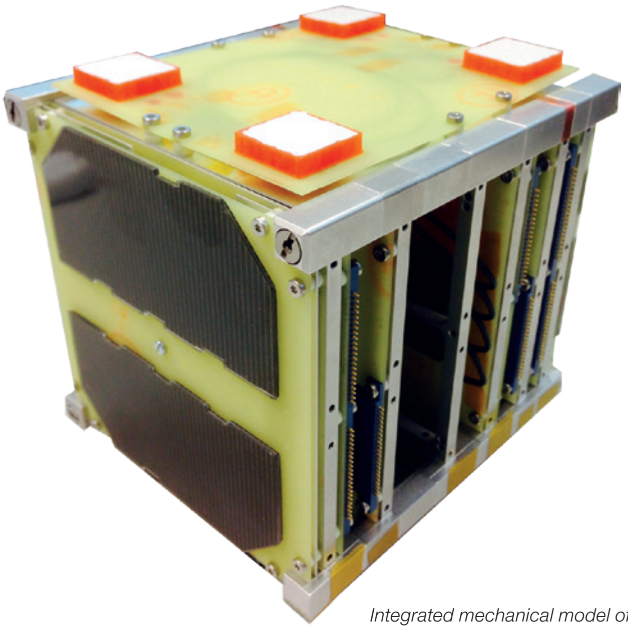
Measurement

Development and Construction of Instruments

Switzerland is responsible for the development, assembly, and verification of a 32 cm diameter telescope as well as the development and operation of the mission's ground segment.

Industrial Hardware Contract to

Almatech
Connova AG
Pfeiffer Vacuum AG
P&P
RUAG Space



Integrated mechanical model of CubETH ©Space Engineering Center

Institute

Geodesy and Geodynamics Lab., ETH Zurich (ETHZ)

EPFL Space Engineering Center, (eSpace), EPFL

In Cooperation with

Hochschule Lucerne

Hochschule Rapperswil

Haute école spécialisée de Suisse occidentale – HES-SO, Sion

u-blox AG

RUAG Space, Switzerland

ELSE SA

CSEM

Saphyrion

Principal Investigator

M. Rothacher (ETHZ)

4.2 CubETH

Purpose of Research

CubETH is a project to evaluate low-cost Global Navigation Satellite Systems (GNSS) sensors on a nanosatellite by following the CubeSat standard. GNSS sensors will be used for precise orbit determination and validation of attitude determination of the cube. The project will verify in-space use of commercial off-the-shelf (COTS) GNSS detectors and novel algorithms for onboard data processing.

A programme goal of the project is to encourage cooperation between ETHZ and EPFL schools, involving engineers and students from federal schools as well from the HES/FH domain. The project will serve to educate new generations of highly qualified engineers.

The Geodesy and Geodynamics Lab. at the ETHZ is responsible for the scientific instrument (payload). GNSS sensors are provided by the Swiss company u-blox AG. The Space Engineering Center is working on the satellite bus (1U-Cubesat). Both main responsible entities (ETHZ and EPFL) work closely together with the different "Fachhochschulen" and industry partners of Switzerland.

Final integration and testing will be performed at the Space Engineering Center. Science operations will be driven by ETHZ in close collaboration with ground stations for mission operations located at the Hochschule Lucerne and Hochschule Rapperswil.

Collaboration with industry is very important for this project. The following companies are playing a vital role in various aspects:

1) u-blox AG is supplying GNSS chips and knowledge on chip algorithms.

2) RUAG Space is helping with testing procedures and the analysis of test data.

3) Saphyrion is helping with expertise in electrical systems and beacon design.

4) ELSE SA is supporting the design and fabrication of the bus.

By 2016, over a hundred students and staff were involved in the project across five different schools, ranging from bachelor students to senior scientists and professors.

Status

PDR was passed in early 2015. By mid-2015, a structural model of the satellite was constructed and vibration-tested. The electrical model (also known as FlatSat) is now under develoment. It represents all electrical and data interfaces (payload, control and data management, electrical power and communication). Programmatic considerations now target a launch in 2018.

Publications

1. Ivanov, A. B., M. Rothacher, L. Masson, S. Rossi, F. Belloni, N. Mullin, R. Wiesendanger, C. Hollenstein, B. Mannel, D. Willi, M. Fisler, P. Fleischman, H. Mathis, M. Klaper, M. Joss, and E. Styger, (2015), CubETH: Nanosatellite mission for orbit and attitude determination using low-cost GNSS receivers, 66th International Astronautical Congress.

Abbreviations

1U-CubeSat	Standard unit volume for pico-satellites 10 x 10 x 10 cm
COTS	Commercial off-the-shelf
FlatSat	Open version of the satellite
GNSS	Global Navigation Satellite System
PDR	Preliminary Design Review

Time-Line	From	To
Planning	Jan. 2013	Dec. 2014
Construction	Jan. 2014	Dec. 2017
Measurement Phase	2018	2019 TBC
Data Evaluation	2018 TBC	2019 TBC

Project Manager

A. Ivanov

Method

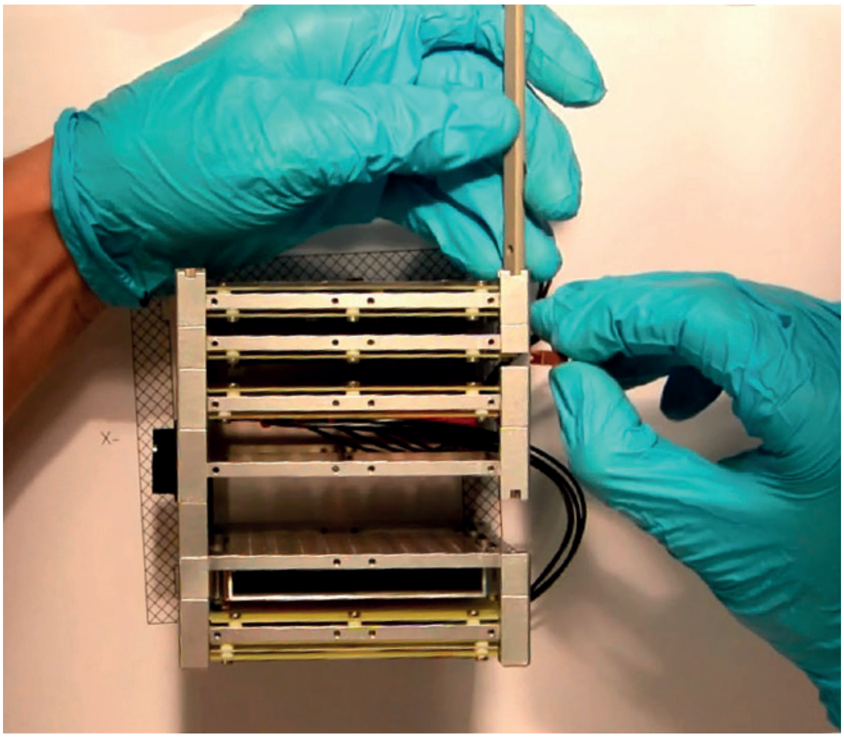
Measurement

Research Based on Existing Instruments

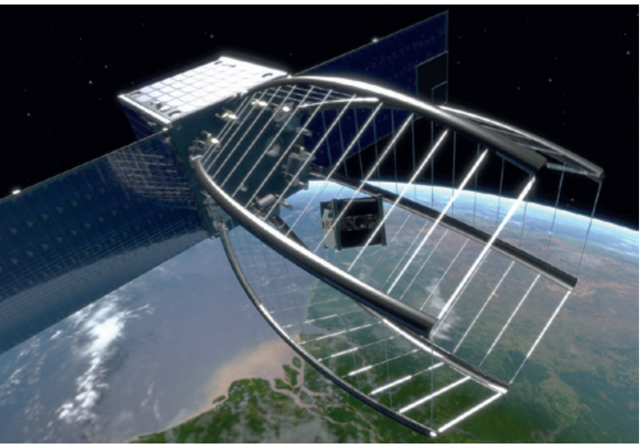
GNSS Sensors developed and tested by u-blox AG.

Industrial Hardware Contract to

EPFL Space Engineering Center (eSpace)



CubETH mechanical model by student Sébastien Von Rohr. Structure concept by ELSE SA.



Artist's impression of SwissCube capture by CleanSpace One ©Jamani Caillet, EPFL.

Institute

EPFL Space Engineering Center (eSpace), EPFL

In Cooperation with

Haute école spécialisée de Suisse occidentale – HES-SO (HEPIA, Valais, HE-ARC)

Fachhochschule NTB

ELSE SA

Principal Investigator

M. Richard-Noca (EPFL)

Swiss Principal Investigator

EPFL

Co-Investigators

HES-SO, ELSE, NTB

Method

Measurement

4.3 CleanSpace One

Purpose of Research

China's demonstration of its capability to destroy an aging satellite in 2007, and the collision between the American operational satellite Iridium and the Russian Cosmos in 2009 brought a new emphasis to the orbital debris problem. Although most of the work had been concentrated on avoidance prediction and debris monitoring, all major space agencies are now claiming the need for active removal of debris (ADR). About 23,500 debris items above 10 cm have been catalogued. Roughly 2000 of these are remains of launch vehicles, 3000 belong to defunct satellites and the rest are either mission-generated or fragmentation debris.

The motivation behind the CleanSpace One project is to increase international awareness and start mitigating the impact on the space environment by acting responsibly and removing our "debris" from orbit. The objectives of the project are thus:

1) To increase awareness and responsibility with regard to orbital debris and educate aerospace students.

2) To demonstrate technologies related to ADR which are scalable to the removal of micro-satellites.

3) To de-orbit a target, SwissCube or any Swiss similar satellite that complies with the launch constraints.

This project will contribute to the Space Sustainability and Awareness with ADR actions. Current activities include development of the capture system, Guidance-Navigation and Control, and systems related to the rendezvous sensors and image processing.

Status

The project is now looking for funding and technical partners.

Publications

1. Chamot, B., (2013), Technology Combination Analysis Tool (TCAT) for active debris removal, 6th European Conference on Space Debris, ESA/ESOC, Darmstadt, Germany.

2. Richard, M. et al., (2013), Uncooperative rendezvous and docking for MicroSats – The case for CleanSpace One, 6th International Conference on Recent Advances in Space Technologies (RAST), Istanbul, Turkey.

3. Richard, M., et al, (2013), Uncooperative rendezvous and docking for MicroSats, The case for CleanSpace One, 6th International Conference on Recent Advances in Space Technologies, RAST 2013, Istanbul, Turkey.

Abbreviations

ADR	Active Debris Removal

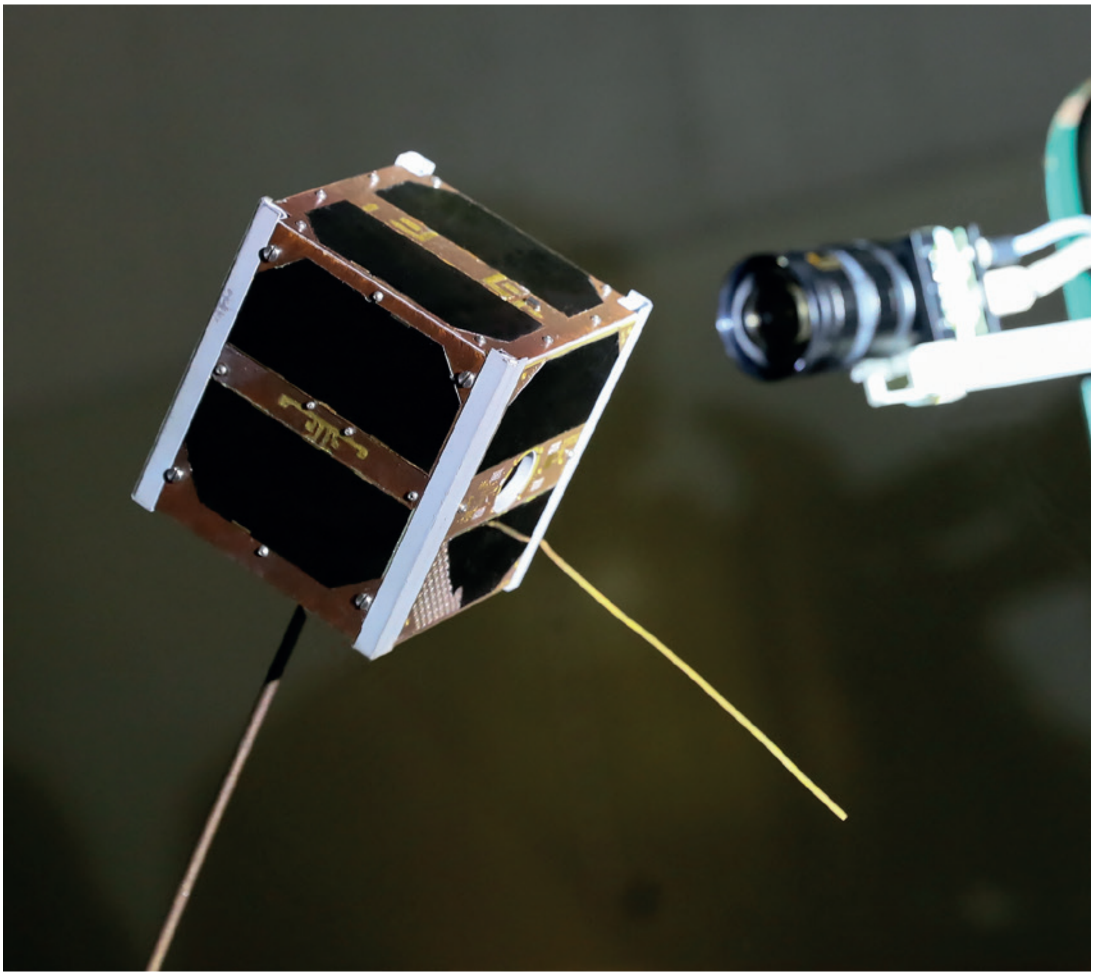
Time-Line	From	To
Planning	Oct. 2016	July 2018
Construction	Aug. 2018	July 2020
Measurement Phase	Mar. 2020	Nov. 2020
Data Evaluation	Mar. 2020	Dec. 2021

Development and Construction of Instruments

Mission design, systems and subsystems design and validation, launch and flight operations

Industrial Hardware Contract to

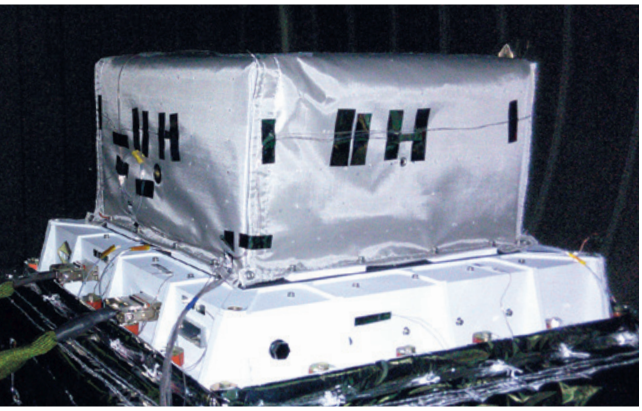
EPFL Space Engineering Center (eSpace)



Testing the image processing algorithms developed by PhD student Christophe Paccolat in the HEPIA facilities. ©Alain Herzog, EPFL.

5 Astrophysics

5.1 POLAR



POLAR Flight Spare during thermal balance tests in 2015, Shanghai.

Institute

ISDC, DPNC (UNIGE)

PSI

In Cooperation with

IHEP, Beijing, China
NCBJ, Warsaw, Poland

Principal Investigator

S. Nan Zhang (IHEP)

Swiss Principal Investigator

M. Pohl (ISDC)

Co-Investigator

N. Produit (ISDC)

Method

Measurement

Research Based on Existing Instruments

POLAR was designed, constructed and qualified by a Swiss collaboration. The flight model and flight spare passed the Chinese acception program.

Purpose of Research

POLAR is a compact gamma-ray polarimeter that will be launched at the end of 2016 on the Chinese space station Tiangong 2.

It is dedicated to the measurement of the polarization of Gamma-Ray Bursts (GRB) in hard X-ray energies. GRB belong to the most important subjects of contemporary astrophysics, and are linked with explosive births of black holes. GRB are of cosmological origin. The polarization of GRB is one of the most important parameters to understand the GRB phenomenon. This parameter hasnot yet been measured with good statistics and controlled systematics.

POLAR is a wide field-of-view Compton polarimeter using light scintillation material. It covers an energy range from a few tens up to several hundred keV. The polarization detection capability is 10 GRB per year with a polarization precision on the polarization degree better than 10%.

POLAR is meant to be taking data for three years onboard of the Tiangong 2 Chinese space station. Using this dataset, POLAR should be able to discriminate between currently proposed models of primary emission of GRBs.

Status

In 2015, the Flight Spare instrument finished all qualification tests both in Europe and China. The Flight Model instrument passed the acception test in Europe. It was then calibrated using the Grenoble ESRF accelerator facility. The Flight Model (FM) was subsequently sent to China to pass the integration tests on Tiangong 2. The FM officially passed all integration tests in early 2016.

Building of a European data center is continuing in 2016. The flight analysis software and Monte Carlo developments are proceeding before the launch that should take place in September 2016.

Publications

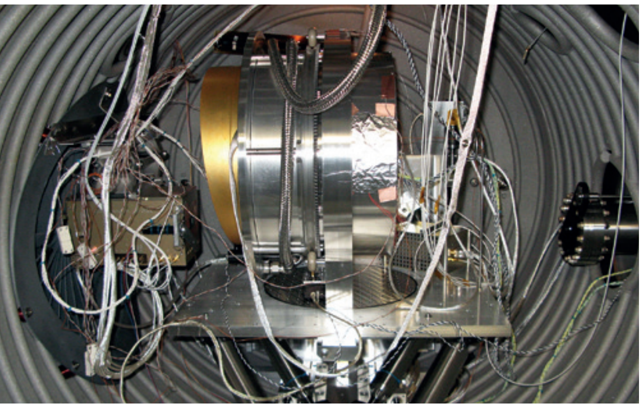
1. Produit, N. et al., (2005), Nucl. Instrum. Meth., A 550, 616.
2. Suarez, E., (2010), Doctorate thesis, University Geneva library.
3. Orsi, S. et al., (2011), Nucl. Instrum. Meth. A, 648.

Abbreviations

DPNC	Département de Physique Nucléaire et Corpusculaire, Univ. Geneva
ESRF	European Synchotron Radiation Facility, Grenoble
GRB	Gamma-Ray Bursts
IHEP	High Energy Physics Institute, Beijing
ISDC	Data Centre for Astrophysics, Univ. Geneva
NCBJ	Nuclear Research Institute of Poland
POLAR	POLAR is a compact gamma-ray polarimeter
PSI	Paul Scherrer Institute, Villigen

Time-Line	From	To
Planning	2009	2011
Construction	2012	2014
Measurement Phase	2016	2019
Data Evaluation	2016	2021

Final integration of the POLAR Flight Model (FM) and Flight Model Spare (FMS), before shipping to China.



IBEX-Lo flight instrument in the MEFISTO calibration facility, Univ. Bern.

5.2 IBEX – Interstellar Boundary Explorer

Institute

Space Research and Planetology, Physics Inst., Univ. Bern (UNIBE)

In Cooperation with

SwRI, Austin, USA
Lockheed Martin Advanced Tech. Lab. Palo Alto, USA
Space Research Centre PAS, Warsaw, Poland
Univ. New Hampshire, Durham, USA

Principal Investigator

D. McComas (SwRI)

Swiss Principal Investigator

P. Wurz (UNIBE)

Co-Investigator

A. Galli

Method

Measurement

Development and Construction of Instruments

IBEX-Lo Instrument on IBEX

Industrial Hardware Contract to

Sulzer Innotec

Purpose of Research

The IBEX mission (NASA SMEX class) is designed to record energetic neutral atoms arriving from the interface of our heliosphere with the neighbouring interstellar medium in an energy range from 10 eV to 6 keV. This energy range is covered by two sensors, IBEX-Lo measuring from 10 eV to 2 keV, and IBEX-Hi measuring from 500 eV to 6 keV. For each energy channel a full-sky map is compiled every half year, which allows the plasma physical processes at the interface between the heliosphere and the interstellar medium to be studied.

Status

IBEX was successfully launched in October 2008 and brought into a highly elliptical orbit around the Earth. In June 2011, the orbit was changed so that it was in resonance with the Moon, which tremendously extends the orbital life-time of the spacecraft and thus allows the mission life to cover more than a solar cycle of 11 years with minimal fuel consumption. IBEX continues to take nominal measurements of ENAs originating from the interface region between our heliosphere and the surrounding interstellar matter.

Publications

1. Rodríguez Moreno, D. F., P. Wurz, L. Saul, M. Bzowski, M. A. Kubiak, J. M. Sokół, P. Frisch, S. A. Fuselier, D. J. McComas, E. Möbius, and N. Schwadron, (2013), Evidence of direct detection of interstellar deuterium in the local interstellar medium by IBEX, Astron. Astrophys. 557, A125, 1–13. DOI: 10.1051/0004-6361/201321420.

2. Galli, A., P. Wurz, S. A. Fuselier, D. J. McComas, M. Bzowski, J. M. Sokół, M. A. Kubiak, and E. Möbius, (2014), Imaging the heliosphere using neutral atoms from solar wind energy down to 15 eV, Astrophys. J., 796, 9, (18pp), doi:10.1088/0004-637X/796/1/9.

3. McComas, D. J., M. Bzowski, S. A. Fuselier, P. C. Frisch, A. Galli, V. V. Izmodenov, O. A. Katushkina, M. A. Kubiak, M. A. Lee, T. W. Leonard, E. Möbius, N. A. Schwadron, J. M. Sokół, P. Swaczyna, B. E. Wood, and P. Wurz, (2015), Local interstellar medium: Six years of direct sampling by the Interstellar Boundary Explorer, Astrophys. J. Suppl. 220(2), article id. 22, 11 pp, DOI: 10.1088/0067-0049/220/2/22.

Abbreviations

ENA	Energetic Neutral Atom
IBEX	Interstellar Boundary Explorer
SMEX	Small Explorer

Time-Line	From	To
Measurement Phase	on-going	
Data Evaluation	on-going	

5.3 HEAVENS – High-Energy Data Analysis Service

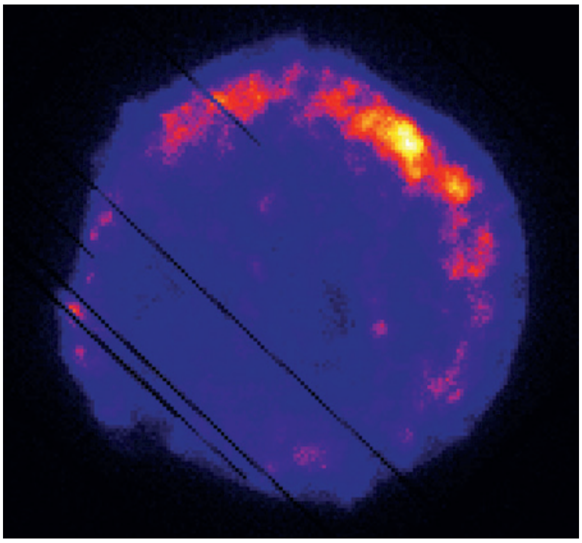
Purpose of Research

High-energy astrophysics space missions have pioneered and demonstrated the power of legacy data sets to generate new discoveries, especially when analysed in ways the original researchers could not have anticipated. HEAVENS provides analysis services for a number of recent and important high-energy missions. These services allow any user to perform on-the-fly data analysis to straightforwardly produce scientific results for any sky position, time and energy intervals without requiring mission specific software or detailed instrumental knowledge. The ultimate goal is to ensure that the data of the present instruments can be effectively used by everyone and everywhere for decades to come. By providing a straightforward interface to complex data and data analysis, HEAVENS makes the data and the process of generating science products available to the public and higher education. HEAVENS promotes the visibility of high-energy and multi-wavelengths astrophysics to the society at large and encourages the public to actively explore the data. This is a fundamental step to transmit the values of science and to evolve towards the knowledge society.

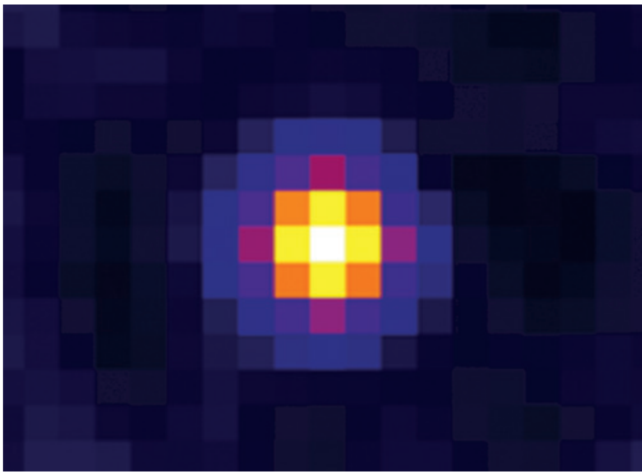
HEAVENS generates custom-made high-level science data products that are unique and not available elsewhere, such as data from all INTEGRAL instruments, RXTE, Swift BAT etc.

Status

HEAVENS includes data from several major ESA and NASA missions. It is regularly enhanced with new instruments and capabilities, typically following important data analysis advances/campaigns performed at the ISDC for scientific research. In 2015, HEAVENS served 800 requests from 100 different external users on average, every month. Data generated by the HEAVENS service are also used for scientific research at the University of Geneva.



X-ray image of the Tycho SuperNova Remnant.



Hard X-ray image collected by stacking 1.1 billion seconds of exposure time with Swift/BAT on a sample of active galactic nuclei. This is the deepest hard X-ray image ever obtained.

Institute

ISDC Data Centre for Astrophysics, Astronomical Observatory of the Univ. Geneva

In Cooperation with

CAMK, Poland
GSFC, USA
FAU, Germany
Univ. Leicester, England
CEA, France

Principal Investigator

R. Walter (ISDC)

Method

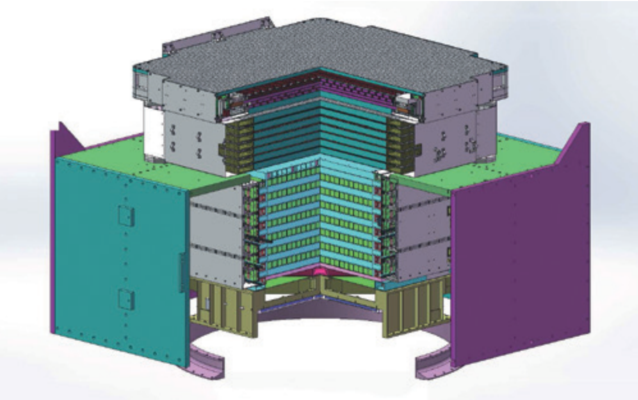
Measurement

Development of Software for

The generation, provision and utilisation of customized high level data analysis products.

Publications

http://www.isdc.unige.ch/heavens/



A sketch of the DAMPE payload showing its sub-detector systems.

Institute

DPNC, Univ. Geneva

In Cooperation with

INFN, Perugia, Italy
INFN, Bari, Italy
INFN, Lecce, Italy
IHEP, Beijing, China
PMO, Nanjing, China

Principal Investigator

J. Chang (PMO, China)

Swiss Principal Investigator

X. Wu (DPNC)

Method

Measurement

Development and Construction of Instruments

DPNC leads an international collaboration that has developed and constructed the Silicon-Tungsten Tracker for DAMPE

Industrial Hardware Contract to

Composite Design SA, Crissier
Hybrid SA, Chez-le-Bart
Meca-Test SA, Geneva

5.4 DAMPE – DArk Matter Particle Explorer

Purpose of Research

The DAMPE (DArk Matter Particle Explorer) satellite is one of the five selected space missions in the Strategic Priority Research Program in Space Science of the Chinese Academy of Science, and was the first to be launched (17th December 2015). The main scientific objectives of DAMPE are:

- To measure electrons and photons with much higher energy resolution and energy reach than achievable with existing space experiments in order to identify possible Dark Matter signatures.
- To advance the understanding of the origin and propagation mechanism of high energy cosmic rays by measuring their spectra and compositions.
- To extend the direct observation of high energy gamma sources.

DAMPE consists of a plastic scintillator strip detector (two layers) that serves as an anti-coincidence detector, followed by a silicon-tungsten tracker-converter (STK), which is made of six tracking double layers. Each consists of two layers of single-sided silicon strip detectors measuring the two orthogonal views perpendicular to the pointing direction of the apparatus. Three layers of tungsten plates with a 1 mm thickness are inserted in front of tracking layer 2, 3 and 4 for photon conversion. The STK is followed by an imaging calorimeter of about 31 radiation lengths thickness, made up of 14 layers of BGO bars in a hodoscopic arrangement. Finally, a layer of neutron detectors is situated at the bottom of the calorimeter.

DAMPE will have unprecedented sensitivity and energy reach for electrons, photons and cosmic rays (proton and heavy ions). For electrons and photons, the detection range is 5 GeV – 10 TeV, with an energy resolution of about 1 % at 800 GeV. For cosmic rays, the detection range is 100 GeV – 100 TeV, with an energy resolution better than 40 % at 800 GeV. The geometrical factor is about 0.3 m^2 sr for electrons and photons, and about 0.2 m^2 sr for cosmic rays.

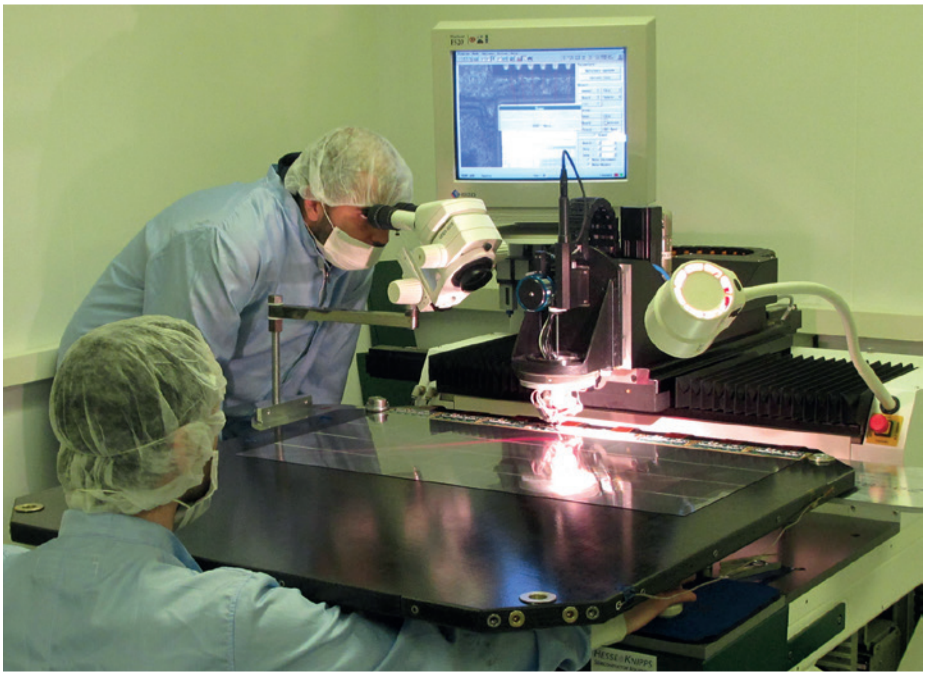
The STK, which greatly improves the tracking and photon detection capability of DAMPE, was proposed by the Geneva-DPNC group. An international collaboration led by DPNC, including INFN Perugia, Bari, Lecce and IHEP, Beijing, is responsible for the development, construction, qualification, on-ground calibration, and in-orbit calibration and monitoring of the STK.

Status

The development and the construction of the STK was completed after 3 years of intensive effort. Final assembly occurred at the DPNC after which it was delivered to China in April 2015 and integrated into the satellite in May 2015. The DAMPE satellite was successfully launched from the Jiuquan Satellite Launch Center in northwest China on 17 December 2015.

Three days after the launch, on 20 December, the STK was powered on, and four days later, the high voltage of the calorimeter was also turned on. All onboard instruments function very well, and the 3 months in-orbit commissioning period has been completed. Initial assessments showed that all performance specifications have been satisfied. The mission has now entered the observation period, initially planned for 3-years. Detailed calibration of the payload and data processing and data analysis is in progress.

The STK is performing above expectation. In-orbit mechanical and thermal conditions are very stable. More than 99.5% of the 73728 read-out channels are functioning well. Monitoring and calibration of the STK is being done in Europe. First in-orbit calibration and alignment have been completed. High energy photons have been reconstructed and known sources such as the Vela Pulsar have been observed.



The production of a Silicon Tungsten Tracker plane at the DPNC, Univ. Geneva.

Abbreviations

BGO	Bismuth Germanium Oxide
DAMPE	DArk Matter Particle Explorer
DPNC	Département de Physique Nucléaire et Corpusculaire, Univ. Geneva
IHEP	Inst. of High Energy Physics, Chinese Academy of Sciences, Beijing, China
INFN	Istituto Nazionale di Fisica Nucleare, Italy
PMO	Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing, China
STK	Silicon-Tungsten Tracker

Time-Line	From	To
Planning	2012	2013
Construction	2013	2015
Measurement Phase	2016	2018
Data Evaluation	2016	2020

5.5 Gaia Variability Processing and Analysis

Institute

Department of Astronomy,
Univ. Geneva (UNIGE)

In Cooperation with

17 institutes in Europe, USA, Israel
(more than 70 people)

Principal Investigator

ESA

Swiss Principal Investigator

L. Eyer (UNIGE)

Co-Investigators

N. Mowlavi
B. Holl
J. Charnas
L. Guy
I. Lecoeur-Taibi
D. Ordonez
L. Rimoldini
M. Süveges
K. Nienartowicz
G. Jevardat de Fombelle
& the Software company, SixSQ

Method

Measurement

Development of Software for

The Gaia mission

Purpose of Research

The exploration and detailed understanding of our Galaxy require all-sky measurements with a multitude of instruments. The Gaia ESA satellite was successfully launched in December 2013 to tackle many outstanding questions relating to (among other subjects) the dynamics and origin of our Galaxy, the evolution and variability of its stellar components, as well as the more home-based solar system bodies. It does so by repeatedly measuring more than a billion objects in our Galaxy for a period of at least five years. Its instruments consist of a broad-band (white-light) CCD array, a blue and red low-dispersion spectrograph, and a narrow-band spectrograph that can measure radial velocities from the Calcium-triplet absorption bands.

Gaia's unique capability to measure distances of sources on the other side of our Galaxy allows us to extract astrophysical information that up until now would need to be inferred through indirect means, such as for example the absolute brightness of a star. All these results will be compiled in huge online catalogs, and are expected to be a goldmine for astrophysicists for the coming decades as no such mission will fly soon hereafter. Hence, great care needs to be taken to process the raw observations into astrophysical meaningfully statistics. To do so, the Gaia European community has organized itself into 9 Coordination Units (CUs), dividing the task into different thematics. Following a formal ESA selection process in 2007, two entities managed by the Geneva University were formed to support the variability processing and analysis of Gaia:

- Coordination Unit 7 (CU7), which is an international consortium.
- The Geneva Data Processing Centre (DPCG), which is responsible for operating the software developed by CU7.

This activity directly builds upon the expertise gathered through the important participation of the University of Geneva in two other ESA missions: Hipparcos and INTEGRAL. The CU7/ DPCG group is in charge of the analysis of the variability of celestial objects, in particular, characterization and classification of these objects into different variability types.

The CU7 Geneva team also contributes to the work of other Coordination Units: in the CU6 analysis of radial velocity variability and in the CU2 models of variable objects implemented in the Universe Model used for simulations. The main goal is to produce parts of the intermediate and final Gaia catalogs which will be released by ESA (final release planned in 2021).

The Geneva team is also pursuing an active research program on stellar variability which will benefit from and contribute to the Gaia development and create a synergy between software development and science. The group consists of 17 people, contributing at different levels (scientists, software engineers, post-docs, PhD students, system administrators).

The ESA Gaia project-related activities in Geneva are supported by UNIGE: Funding is provided by the Swiss Prodex Programme and the Swiss Federal Activités Nationales Complémentaires (ANC). The preparation of the scientific exploitation of Gaia data has been supported by FNRS, ESF (European Sci. Foundation) and RTN-FP6/ ITN-FP7 EU grants.

Status

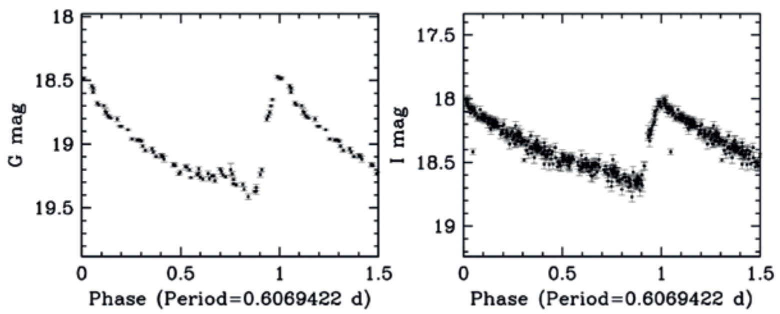
The Gaia spacecraft has been gathering operational data since Summer 2014, and since then the processing chain has been put in motion. Due to our work from the operation rehearsals, we are able to contribute to the very first intermediate Gaia data release planned for the end of Summer 2016, releasing stellar variability data much earlier than originally planned. The figure shows an example of a typical RR Lyrae star observed by Gaia compared with the ground-based OGLE survey. It shows the already excellent photometric precision of the first reduction of initial Gaia data, which will only improve as calibrations improve. These initial results make us confident that great science can be done with the Gaia data, and that the integration of the software pipelines of all Coordination Units is working under real-data conditions.

Publications

1. Holl, B. et al., (2014), Automated eclipsing binary detection: Applying the Gaia CU7 pipeline to Hipparcos, EAS, 67, 299.

2. Anderson, R. I. et al., (2015), Investigating Cepheid ℓ Carinae's cycle-to-cycle variations via contemporaneous velocimetry and interferometry, MNRAS, 455, 4231.

3. Eyer, L. et al., (2015), The Gaia mission, binary stars and exoplanets, ASPC, 496, 121.



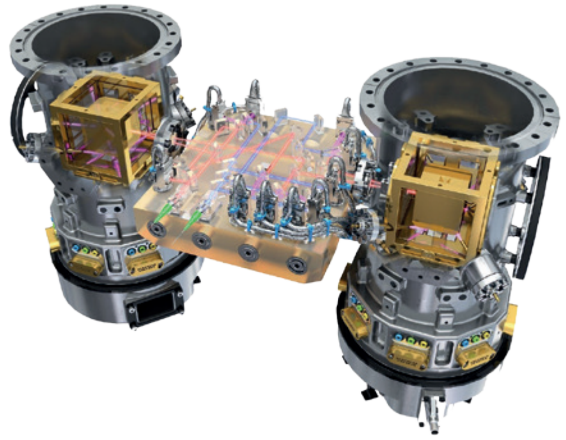
Folded light curve of a (periodically pulsating) RR Lyrae star. Gaia data are on the left, and data from the ground based OGLE survey are on the right.

Abbreviations

CU	Coordination Unit	DPCG	Data Processing Center of Geneva
Gaia	ESA Satellite	OGLE	Optical Grav. Lensing Exp.

Time-Line	From	To
Planning	2006	2021
Construction	Cyclic development	2021
Measurement Phase	2013	2019
Data Evaluation	Cyclic	2021/2022

5.6 LISA Pathfinder/LISA Technology Package



Inertial Sensor Assembly with both test masses, enclosed by the electrode housings. The optical bench is situated between both test masses.

Institute

Inst. Geophysics, ETH Zurich (ETHZ)

Physics Institute, Univ. Zurich (UNIZH)

In Cooperation with

Univ. Trento, Italy

Principal Investigators

S. Vitale (Univ. Trento)
K. Danzmann, (Albert Einstein Inst.)

Swiss Principal Investigator

D. Giardini (ETHZ)

Co-Investigators

P. Jetzer (UNIZH)
L. Ferraioli (ETHZ)
D. Mance (ETHZ)
P. Zweifel (ETHZ)

Method

Measurement

Purpose of Research

The LISA Technology Package (LTP) is the payload onboard the LISA Pathfinder Mission (LPF). LPF is a technology mission in view of ESA's planned L3 mission eLISA (evolved Laser Interferometer Space Antenna).

LPF/LTP will demonstrate the feasibility of the eLISA required performance including laser interferometry and new methods of spacecraft control. It's key objective is to test the ideas behind gravitational wave detectors that free-falling particles follow geodesics in space-time. LPF/LTP places two test or proof masses (solid cubes of gold-platinum alloy, edge length ~4.6 cm, mass 2 kg) in a nearly perfect gravitational free-fall, and controls and measures their motion with unprecedented accuracy and resolution. This is achieved through state-of-the-art space technology comprising inertial sensors, a laser metrology system, a drag-free control system and an ultra-precise micro-propulsion system.

The Swiss contribution to LTP consists of the development of an Inertial Sensor Front-End Electronics (ISFEE), which senses and controls the position and attitude of the test mass with respect to its frame and the spacecraft respectively, using ultra-stable capacitive sensing and electrostatic actuation techniques. The measurement and actuation requires nanometer resolution and stability in the low-frequency band from 1 Hz down to 0.1 mHz. The ISFEE is built fully redundant due to its criticality for the mission success.

The eLISA mission will be dedicated to measure gravitational waves - for the first time in space - and thus to enable direct observation of a broad variety of systems and events throughout the Universe, including the coalescences of supermassive black holes brought together by galaxy mergers, the inspiral of stellar-mass black holes and compact stars into central galactic black holes (so-called EMRI) and to gain unique information about the behaviour, structure and early history of the Universe. eLISA will complement/enhance Earth-based interferometers such as LIGO and VIRGO and will open the gravitational wave window in space and measure gravitational radiation over a broad band of frequencies, from about 0.1 mHz to 1 Hz, a band where the Universe is richly populated by strong sources of gravitational waves.

The LISA Pathfinder science operation is dedicated to the collection and analysis of LISA Pathfinder data in order to understand all spurious effects that can affect purely gravitational motion of both test masses in space. The knowledge of all non-gravitational forces acting on them will be essential to calibrate and optimize the future fullscale gravitational observatory eLISA.

Status

The involvement of the Institute of Geophysics, ETH Zurich, and the Institute of Physics, University of Zurich, goes back to the year 2003. A technical team from the Institute of Geophysics ETHZ established the required specifications and the concept of the ISFEE in collaboration with the international partners, in particular with the University of Trento (LPF Principal Investigator) and Airbus Defence and Space, Friedrichshafen (Prime). It prepared the necessary specification documents for the industrial work. The industrial contract with RUAG Space and thus the development of ISFEE started in April 2005. Furthermore, the ETHZ group supervised the development process at RUAG together with the ESA Prodex office. The ISFEE flight hardware was delivered by RUAG to Airbus Friedrichshafen in December 2010.

The LISA Pathfinder mission was eventually launched on 3 December 2015 by a VEGA launcher from Europe's space port in Kourou, French Guiana. After several progressively expanded Earth orbits using its own propulsion module, the satellite was finally placed at Lagrange point L1, 1.5 Mio km from the Earth.

The LPF satellite is controlled by the European Space Operations Centre (ESOC) in Darmstadt, Germany. The Science and Technology Operations Centre is located at the European Space Astronomy Centre (ESAC) at Villaneuva de la Cañada in Spain and was re-located to ESOC during LISA Pathfinder operations.

The satellite and payload commissioning began in December 2015 and was successfully completed at the end of February 2016. The science operation started on 1 March 2016 and will last about 6 months. The Institute of Geophysics ETHZ is directly involved in the experiments as part of the LISA Pathfinder data analysis team as well as in the monitoring of the ISFEE hardware during the mission.

Time-Line	From	To
Planning	2003	2005
Construction	2005	2010
Measurement Phase	2016	2016
Data Evaluation	2016	

Publications

1. Gan, L., D. Mance, P. Zweifel, (2011), Actuation to sensing cross-talk investigation in the inertial sensor front-end electronics of the laser interferometer space antenna pathfinder satellite, Sens. Actuators A Physical, 167, 2, 574–580.

2. Armano, M. et al., (2015), A noise simulator for eLISA: Migrating LISA Pathfinder knowledge to the eLISA mission, J. Phys. Conf. Ser., 610, 1, 012036, 6 pp, DOI: 10.1088/1742-6596/610/1/012036.

3. Gibert, F. et al., (2015), In-flight thermal experiments for LISA Pathfinder: Simulating temperature noise at the Inertial Sensors, J. Phys. Conf. Ser. 610, 012023, 6 pp, DOI: 10.1088/1742-6596/610/1/012023.

Abbreviations

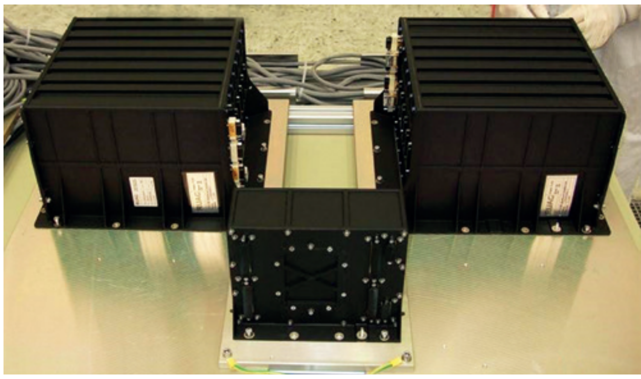
eLISA	evolved Laser Interfero-meter Space Antenna
EMRI	Extreme Mass Ratio Inspiral
HES-SO	(Haute École Spécialisée de Suisse Occidentale)
ISFEE	Inertial Sensor Front-End Electronics
LPF	LISA Pathfinder
LTP	LISA Technology Package (LPF Payload)

Development and Construction of Instruments

Inertial Sensor Front-End Electronics (ISFEE) for LISA Technology Package on LISA Pathfinder mission.

Industrial Hardware Contract to

RUAG Space, Zurich
HES-SO, Sion



The ISFEE, consisting of two fully redundant Sensing and Actuation Units (SAU) and the switching unit (SSU), was designed and built by RUAG Space AG in Zurich and HES-SO in Sion (Sensing and actuation boards). The Power Control Unit was developed by ASP GmbH in Salem-Neufrach. The picture shows the flight hardware without cabling, the SAUs in the back and the SSU in front. The SSU connects the highly sensitive sensing and actuation channels from the nominal or redundant SAU to the Inertial Sensor head.


The SPICA satellite (Planck configuration, 2.5m@8K telescope).

Institute

Dept. Astronomy,
Univ. Geneva (UNIGE)

In Cooperation with

SRON, Netherlands
ISAS, japan
and the SPICA Consortium

Principal Investigator

P. Roelfsema (SRON)

Swiss Principal Investigator

M. Audard (UNIGE)

Co-Investigators

M. R. Meyer (ETHZ)
D. Schaerer (UNIGE)
S. Paltani (UNIGE)

Method

Measurement

Development of Software for

Instrument Control Center for the SAFARI instrument onboard the SPICA mission.

5.7 SPICA Infrared Observatory

Purpose of Research

The SPICA mission is a collaborative project between Europe and Japan. It will be proposed in the upcoming M5 ESA call. SPICA will carry SAFARI, an infrared grating (R ~ 300, up to 3000 for bright sources) spectrometer operating from 34 to 210 μm, proposed by a European Consortium led by SRON (Netherlands) with Swiss participation, and SMI, proposed by Japan, that will provide imaging spectroscopy with R ~ 50 and full-band slit-fed spectroscopy at R ~ 1,000 from 17 to 36 μm, and R ~ 28,000 from 12 to 18 μm.

The SPICA mission recently underwent a significant redesign, for example, in its telescope configuration and its instrument's capabilities and configuration. The SPICA telescope will be cooled down to about 8K, effectively suppressing most of the satellite's infrared thermal background, which will allow us to reach down to very low fluxes.

The main science topics addressed by SPICA are: 1) Understanding the physical processes that regulate galaxy evolution, 2) tracing the gas, dust and ice evolution in planetary systems, and 3) the dynamic ISM: The fuel and exhaust of galaxies.

Apart from its science interests in SPICA, the University of Geneva aims to lead the development and operations of the SAFARI Instrument Control Center, in collaboration with members of the SAFARI Consortium. The ICC will be responsible for the calibration, software development, and routine operations tasks of the instrument. It will work in cooperation with the ESA and JAXA ground segments.

Status

Although SPICA has passed several reviews in Japan, SPICA has not yet undergone the JAXA phase-up review that would formally transform its status into an approved project. In mid-2013, it became apparent that, due to the financial situation in Japan, the SPICA mission could not be launched without a stronger financial involvement by international partners.

JAXA/ISAS and ESA/SRON agreed upon a stronger involvement of the European contribution to SPICA, including the SAFARI instrument and the European ground segment. In Autumn 2014, ESA further conducted a CDF study to determine the scope of a cold infrared mission within the ESA M scheme in collaboration with JAXA.

Consequently, the SPICA consortium will propose the SPICA mission in the upcoming M5 call. If nominated, the final mission selection will take place in 2018–2019, with a foreseen launch in the late 2020s.

During the reporting period, the main effort of the SPICA Consortium was on the redesign of the SPICA mission in the new ESA/JAXA framework, and on preparing the upcoming M5 call. Switzerland actively participates in the writing of the science part of the proposal.

Publications

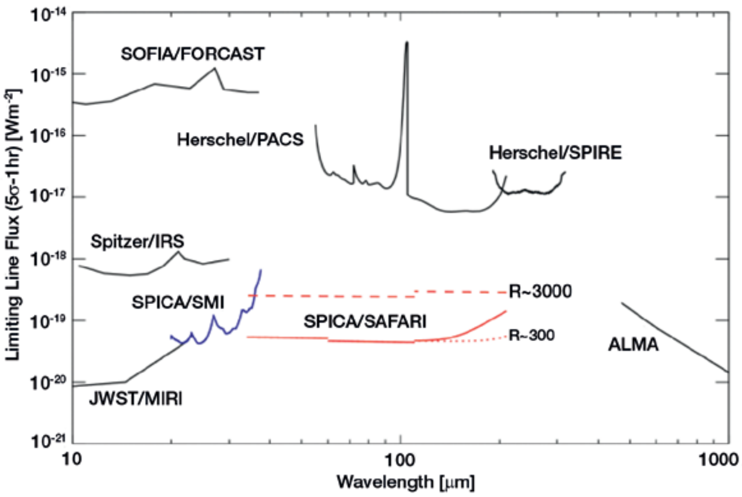
1. Goicochea, J. R. et al., (2013), The far-IR view of star and planet forming regions, Proc. of the SPICA's New Window on the 'Cool Universe' conference, arXiv: 1310.1683.

2. Nakagawa, T. et al., (2014), The next-generation infrared astronomy mission SPICA under the new framework, Proc. SPIE, 9143, art. id 91431I, 9pp.

3. Roelfsema, P. et al., (2014), SAFARI new and improved: extending the capabilities of SPICA's imaging spectrometer, Proc. SPIE, 9143, art. id 91431K, 11pp.

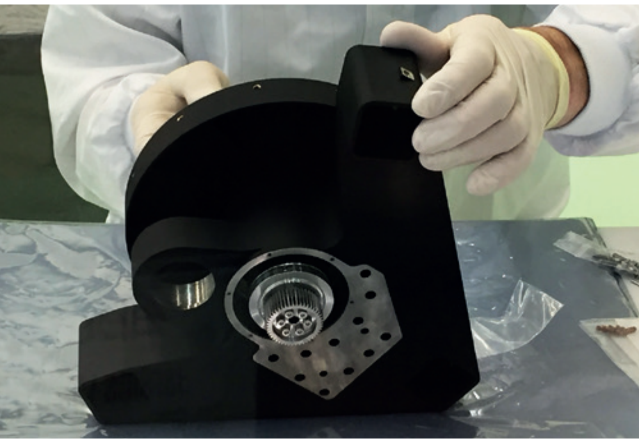
Abbreviations

ICC	Instrument Control Center
ISAS	Institute of Space and Astronautical Science
JAXA	Japanese Space Agency
SAFARI	SpicA FAR-infrared Instrument
SMI	SPICA Mid-Infrared Instrument
SPICA	Space Infrared Telescope for Cosmology and Astrophysics
SRON	Netherlands Institute for Space Research



SPICA SMI and SAFARI expected line sensitivities compared to other infrared and mm instruments. Status: end of 2015.

Time-Line	From	To
Planning	2017	2020
Construction	2020	2030
Measurement Phase	2030	2035
Data Evaluation	2030	2040



RSU Structural and Thermal Model being assembled at APCO Technologies. Copyright APCO/UNIGE.

5.8 Swiss Contribution to Euclid

Purpose of Research

Euclid is a mission of the European Space Agency designed to understand the origin and evolution of the Universe by investigating the nature of its most mysterious components: dark energy and dark matter, and by testing the nature of gravity. Euclid will achieve its scientific goal by combining a number of cosmological probes, among which the primary ones are weak gravitational lensing and baryonic acoustic oscillations.

The Euclid payload consists of a 1.2 m Korsch telescope designed to provide a large field of view. The Euclid survey will cover 15,000 deg^2 of the extragalactic sky with its two instruments: the VISual imager (VIS) and the Near-Infrared Spectrometer Photometer instrument (NISP), which includes a slitless spectrometer and a three-band photometer. Euclid is the second Medium Class mission of the ESA Cosmic Vision 2015–2025 programme, with a foreseen launch date in 2020.

Switzerland is playing an important role in Euclid, with participation at all levels, from the science definition, to the building of space hardware, the development of analysis algorithms, the participation in the data processing and the science exploitation.

Several Swiss institutes are strongly involved in Euclid: the EPFL, the FHNW, UNIGE and UNIZH. On the science level, the EPFL (strong lensing), UNIGE (theory) and UNIZH (cosmological simulations) are co-coordinating the respective Science Working Groups. On the software and algorithms level, the EPFL is active in the development of algorithms for the measurement of the galaxy shear (weak lensing), as well as the detection of strong gravitational lenses. FHNW contributes to the so-called system team, which provides the overall infrastructure binding the different components of the Euclid data centers.

UNIGE is in charge of the coordination of the development of algorithms and software for the determination of photometric redshifts. UNIGE also hosts the Swiss Euclid Science Data Center and is in charge of the determination of the photometric redshifts and the detection of strong lenses. The Euclid data processing is a large distributed effort, which will have to operate a multi-petabyte archive and a commensurate processing power. UNIGE also develops the Read-out Shutter Unit (RSU), a cryogenics shutter for the VIS instrument.

All participating institutes will partake in the science of Euclid, whether for the main science goals or for the very rich secondary science that will result from the huge Euclid survey.

Institute

École Polytechnique Fédérale de Lausanne (EPFL)

Fachhochschule Nordwestschweiz (FHNW)

Univ. Geneva (UNIGE)

Univ. Zurich (UNIZH)

In Cooperation with

ESA
about 100 European institutes
NASA
more than 1000 astronomers and engineers worldwide

Principal Investigator

Y. Mellier
(Inst. d'Astrophysique de Paris)

Status

On the hardware side, Euclid passed the Preliminary Design (Phase B) in Spring 2014. Phase C (Critical Design) will be concluded in Spring 2016. The launch is currently scheduled for the fourth quarter of 2020. The RSU Electrical Model was delivered at the end of 2015 and the Structural and Thermal Model is currently being built by APCO Technologies.

On the ground-segment side, Euclid passed the System Requirement Review in Summer 2015. The ground-segment development is structured with IT Challenges and Scientific Challenges. The Swiss Science Data Center has participated in several IT Challenges, and is now preparing IT Challenge 6. The Scientific Challenges are incremental and include more and more functions. The Scientific Challenge 5 will include the production of photometric redshifts. Several algorithms are currently being assessed as part of two "Data Challenges" organized under the lead of UNIGE.

Publications

1. Laureijs, R. et al., (2011), Euclid Definition Study Report, Euclid Red Book, ESA/SRE(2011)12, eprint arXiv: 1110.3193.

2. Cropper, M. et al., (2014), VIS: the visible imager for Euclid, Proc. SPIE, 9143, Article ID. 91430J.

Co-Investigators

Swiss consortium members with lead responsibilities only:

F. Courbin (EPFL)
P. Dubath (UNIGE)
J.-P. Kneib (EPFL)
M. Kunz (UNIGE)
G. Meylan (EPFL)
S. Paltani (UNIGE)
R. Teyssier (UNIZH

Method

Measurement

Developments

Development and construction of the Read-Out Shutter Unit (RSU) of the VIS instrument.

Development of algorithms for photometric redshifts, weak and strong lensing.

Development of the Swiss Euclid Science Data Center.

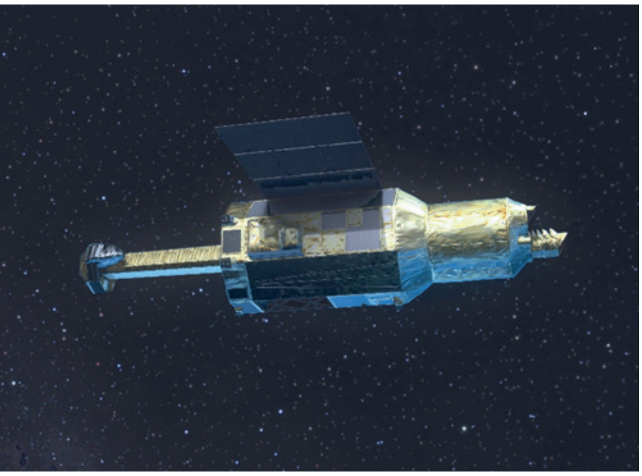
Industrial Hardware Contract to

APCO Technologies
(VIS RSU Phase C/D)

Abbreviations

Euclid	ESA mission
NISP	Near-Infrared Spectrometer Photometer instrument
RSU	Read-out Shutter Unit
VIS	VISible imager

Time-Line	From	To
Planning		2012
Construction	2012	2017(HW)/2019(SW)
Measurement Phase	2020	2027
Data Evaluation	2020	2030



Artist's impression of ASTRO-H ©JAXA.

Institute

Dept. Astronomy
Univ. Geneva (UNIGE)

In Cooperation with

Japan Aerospace Exploration Agency (JAXA)
Netherlands Institute for Space Research (SRON)
European Space Agency (ESA)

Principal Investigator

T. Takahashi (JAXA)

Swiss Principal Investigator

S. Paltani (UNIGE)

Method

Measurement

Developments

Development and construction of the Filter Wheel Mechanism and Filter Wheel Electronics. Development of user-support activities.

Industrial Hardware Contract to

Ruag Space AG (FWM)
Micro-Cameras & Space Explor. (FWE)

5.9 Swiss Contribution to ASTRO-H/Hitomi

Purpose of Research

ASTRO-H is a mission of the Japan Aerospace Exploration Agency (JAXA) that was successfully launched on 17 February 2016, and later renamed Hitomi. It is part of a very successful Japanese scientific program dedicated to high-energy astrophysics, the latest mission being Suzaku (launched in 2005), which is still in operation. Hitomi was an essential mission for high-energy astrophysics, between the current generation with XMM-Newton, INTEGRAL, Chandra and Suzaku, and the future Large Mission of ESA's Cosmic Vision program, dedicated to the study of the hot and energetic Universe. UNIGE participated in the Hitomi mission together with the Dutch space agency (SRON), by developing a filter wheel for the Soft X-ray Spectrometer (SXS). The SXS is a cryogenics silicon detector working at 50 mK, aiming to provide excellent energy resolution (better than 5 eV) in the 0.3–10 keV energy range, while preserving some imaging capabilities and high throughput. The filter wheel is used to select different optical elements, either to reduce the X-ray count rate or optical load on the detector, as well as to protect the detector from micro-meteorites. It also supports and commands active calibration sources, which are provided by SRON, and assembled on top of the filter wheel.

The filter wheel consists of two separate units: the Filter Wheel Electronics (FWE) and the Filter Wheel Mechanism (FWM). The control and power electronics module FWE was designed by Micro-Cameras & Space Exploration and assembled and qualified by UNIGE. The FWM was built and qualified by Ruag Space. The Flight Models were successfully delivered to SRON and then to JAXA in Autumn 2013. Both subsystems operated nominally after launch.

UNIGE also started the development of the European Science Support Center (ESSC), which was part of the European user support activities for Hitomi. The ESSC aimed to provide direct support to European astronomers interested in submitting Hitomi proposals and in reducing and analyzing Hitomi data. In collaboration with ESA, it ran a user helpdesk interface. The ESSC staff also contributed to the in-flight calibration of the Hitomi instruments.

Status

Unfortunately, Hitomi experienced a failure on 26 March 2016, resulting in a complete loss of the mission, and in the termination of all Hitomi-related activities.

Publications

1. Takahashi, T. et al., (2014), The ASTRO-H X-ray observatory, Proc. SPIE, 9144, 25.

Abbreviations

ESSC	European Sci. Support Center
FWE	Filter Wheel Electronics
FWM	Filter Wheel Mechanism
SXS	Soft X-ray Spectrometer

Time-Line	From	To
Planning		2010
Construction	2010	2014
Measurement Phase	2016	2016
Data Evaluation	2016	2016

5.10 ATHENA – Advanced Telescope for High Energy Astrophysics

Purpose of Research

ESA has recently selected 'The Hot and Energetic Universe' as the science theme of the second Large Mission of the Cosmic Vision programme. ATHENA is an evolution of former proposals: XEUS, International X-ray Observatory and ATHENA L1, which is now in an excellent position to become Europe's next major X-ray astronomy mission, after ESA's cornerstone mission XMM-Newton. ATHENA will provide tremendous improvements over the current generation for high spatial and spectral resolution spectro-imaging. ATHENA will carry a large-field-of-view fast imager, the Wide FIeld Imager (WFI), and a cryogenic imaging calorimeter, the X-ray Integral Field Unit (X-IFU). The X-IFU will allow imaging at electron-volt resolution, i.e. an improvement by a factor about 50 over current imaging instruments. It has to operate at cryogenic (50 mK) temperatures. This will be achieved by a complex, multi-stage mechanical cooling chain. Switzerland is actively participating in the development of the X-IFU for ATHENA. It is responsible for the development of the Filter Wheel subsystem. The filter wheel will allow the insertion of different optical and X-ray attenuating blocking filters to reduce optical light from bright objects (O and B stars) and to reduce the X-ray count rate for very bright objects in order to prevent degradation in detector performance. The filter wheel will also drive active X-ray sources, which can generate mono-energetic photons in order to perform gain calibrations of the detector. The filter wheel heavily relies on heritage from the Swiss contribution to ASTRO-H. UNIGE envisages a significant participation in the ATHENA ground-segment, both in the development phase and during scientific operations. The model under discussion involves two separate Instrument Science Centers (ISC) attached to each of both instruments. UNIGE is well-positioned to play a significant role in the X-IFU ISC, and is in discussion with the WFI proto-consortium.

Status

The ATHENA proto-consortium is currently working toward the preparation of the Instrument Announcement of Opportunity, in Summer 2016. Adoption is foreseen in February 2020.

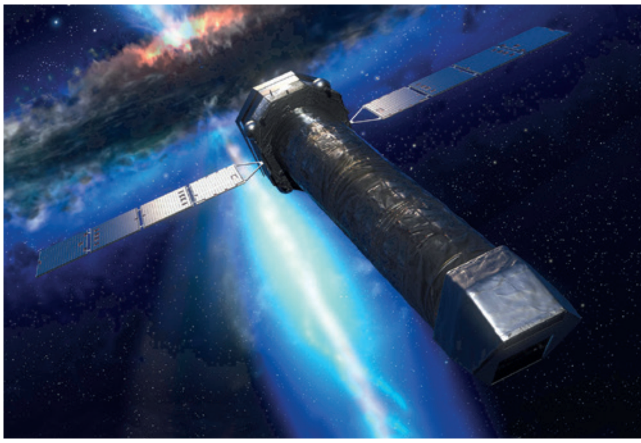
Publications

1. Nandra, K. et al., (2013), The Hot and Energetic Universe: A White Paper presenting the science theme motivating the Athena+ mission, arXiv: 1306.2307.
2. Meidlinger, N. et al., (2014), The wide field instrument imager for Athena, Proc. SPIE, 144, 91442J.
3. Ravera, L. et al., (2014), The X-ray Integral Field Unit (X-IFU) for Athena, Proc. SPIE, 9144, 91442L.

Abbreviations

ISC	Instrument Science Center
WFI	WIde Field Imager
X-IFU	X-ray Integral Field Unit

Time-Line	From	To
Planning	2015	2020
Construction	2020	2026
Measurement Phase	2028	2038
Data Evaluation	2028	2048



Artist's impression of ATHENA ©ESA.

Institute

Dept. Astronomy
Univ. Geneva (UNIGE)

In Cooperation with

Max-Planck-Institut für Extraterrestrische Physik (MPE) Garching, Germany

Institut de Recherche en Astrophysique et Planétologie (IRAP), Toulouse, France

European Space Agency (ESA)

Principal Investigator

K. Nandra (MPE)

D. Barret (IRAP)

Swiss Principal Investigator

S. Paltani (UNIGE)

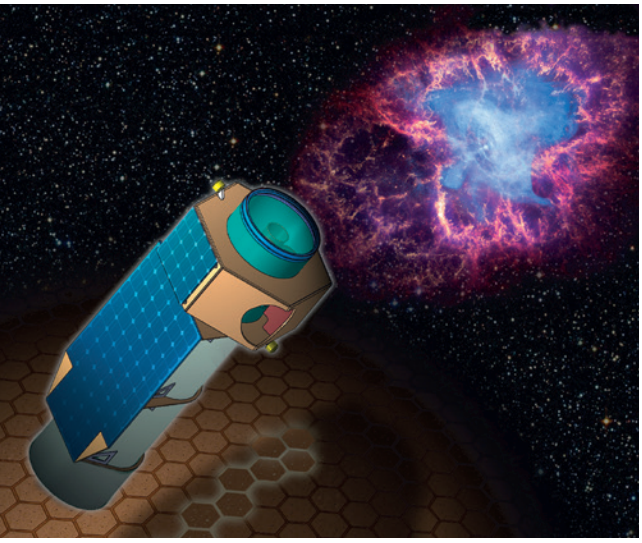
Method

Measurement

Developments

Development and construction of the Filter Wheel subsystem of the X-IFU instr.

Development of data center activities.



Artist's impression of XIPE ©INAF-IAPS.

5.11 XIPE – The X-Ray Imaging Polarimetry Explorer

Institute

ISDC,
Univ. Geneva (UNIGE)

In Cooperation with

INAF-IAPS, Italy

Principal Investigator

P. Soffitta

Swiss Principal Investigator

T. J.-L. Courvoisier (UNIGE)

Co-Investigators

E. Bozzo
S. Paltani (UNIGE)

Method

Measurement

Development and Construction of Instruments

XIPE Space Mission

Purpose of Research

XIPE, the X-ray Imaging Polarimetry Explorer, is a newly proposed space mission concept competing with two other candidates for a launch opportunity in 2026 within the context of the ESA M4 call. The mission has been selected in 2015 for an assessment phase study that will last until July 2017, when a down-selection among the three M4 candidates is expected and only one will proceed to the implementation phase.

XIPE will be entirely dedicated to measurements of X-ray polarization from celestial Galactic and extra-Galactic X-ray sources. Polarimetric X-ray measurements are long known to be the key to probe in-situ the details, and geometry of many poorly understood emission mechanisms, but have so far remained an undeveloped tool due to the lack of technology required to build a sufficiently sensitive instrument. XIPE will finally cover this gap and provide the possibility to perform spatially-resolved polarimetric measurements of a large sample of Galactic and extragalactic X- ray sources.

XIPE is equipped with three focusing Wolter I X-ray telescopes and the latest generation of the Gas Pixel Detectors (GPDs) developed by INFN-Pisa in collaboration with INAF-IAPS. These innovative detectors permit not only the spectral, spatial and timing information of the X-ray intensity from celestial sources to be recorded, but also permit recording of the two additional Stokes parameters, Q and U, thus measuring the polarization of the X-ray emission as a function of position, photon energy and time.

The combination of the selected optics and detectors achieve an effective area of 1100 cm^2 at 2 keV (the total operating energy range is 2–8 keV), translating into a minimum detectable polarization lower than 10% in 100 ks of observations for a source with the intensity of 1 mCrab.

It has been argued from theoretical considerations that X-ray radiation from many astrophysical sources must be significantly polarized because it often originates in highly aspherical emission and scattering geometries or from regions with structured magnetic fields. The wider set of observables provided by XIPE, compared to any previously flown X-ray instruments, will thus help in breaking degeneracies in the X-ray modeling of a wide range of astrophysical objects.

The induced observable polarization can solve long-standing problems in both astrophysics and fundamental physics: What is the structure of magnetic fields close to the site of particle acceleration in pulsar wind nebulae, supernovae or extragalactic jets? Where do the seed photons for the Comptonized emission in extragalactic jets come from? What is the nature of the reprocessed emission we observe from the molecular clouds in the Galactic Center? What is the accretion geometry in accreting X-ray pulsars? Can the theoretically predicted QED vacuum birefringence in the atmospheres of magnetars be confirmed? What is the angular momentum of accreting black holes in X-ray binaries? Is the theory of Loop Quantum Gravity correct? Can we detect axion-like particles that would constitute dark matter?

The Swiss XIPE team, based at the ISDC (Department of Astronomy, University of Geneva), is currently in charge of the overall project management and definition of the mission science ground segment (in collaboration with ESA). A number of scientists from different Swiss institutions are directly involved in the XIPE science working groups.

Status

During the on-going assessment phase, XIPE succesfully completed the Concurrent Design Facility (CDF) study performed by ESA. The mission technology has been declared solid and very mature, thus providing XIPE a likely chance to be able to launch even ahead of the current foreseen time slot for the M4 missions.

The first scientific international conference dedicated to the XIPE mission will take place in May 2016 in Valencia (Spain), and it is expected to lead to a major consolidation of all core and observatory XIPE science goals. The assessment phase of XIPE and the other M4 mission candidates will end in July 2017, when a single mission will then be selected for the implementation phase and launch in the 2026 time-frame.

Publications

1. Costa, E. et al., (2001), Nature, 411, 662.

2. Soffitta, P. et al., (2012), Proc. SPIE, 8443, 84431F.

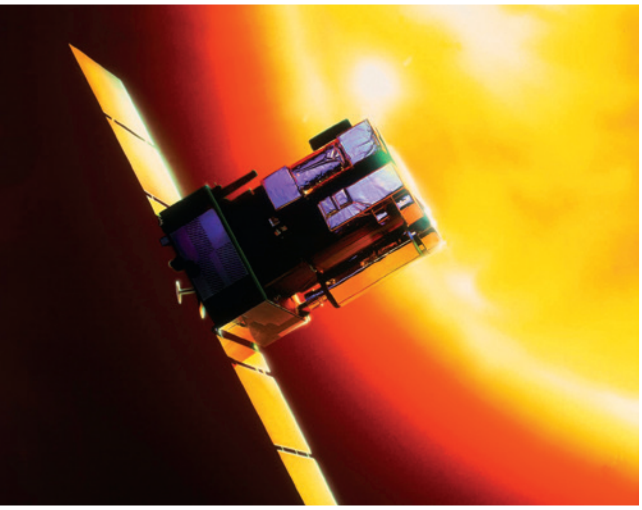
3. Soffitta, P. et al., (2013), NIMPA, 700, 99.

Abbreviations

CDF	Concurrent Design Facility
GPD	Gas Pixel Detector
XIPE	X-ray Imaging Polarimetry Explorer

Time-Line	From	To
Planning	Sep. 2015	Jul. 2017
Construction	Oct. 2017	Jun. 2026
Measurement Phase	Jan. 2027	Jan. 2030
Data Evaluation	open	open

6 Solar Physics



VIRGO on the SoHO spacecraft. Copyright: ESA.

6.1 The VIRGO Investigation on SoHO, an ESA/NASA Cooperative Mission

Purpose of Research

The Variability of Solar Irradiance and Gravity Oscillations (VIRGO) experiment provides continuous high precision measurements of the total and spectral solar irradiance (TSI and SSI). Two different types of absolute cavity radiometers measure TSI: A PMO6V every min. and a DIARAD every 3 mins. The SSI is sampled every minute in three narrow wavelength bands centred at 402, 500, and 862 nm. Data are used for research in several areas:

- Evaluation of the direct and indirect solar influence on terrestrial climate.
- Helioseismology: investigation of solar acoustic modes and their variation with solar activity, and the search for solar gravity modes, which is still an open issue.
- Investigation of short and long-term variations of solar irradiance.
- Solar radiometry for TSI and SSI, and its long-term behaviour in space.

Status

The Solar and Heliospheric Observatory (SoHO) was launched in December 1995, and the VIRGO experiment started observations in early 1996. VIRGO is still operational and keeps extending the longest available space-based TSI time-series. The 20th anniversary of SoHO was recently celebrated, and it continues to be operational.

Publications

1. Fröhlich, C., (2013), Total solar irradiance: What have we learned from the last three cycles and the recent minimum, Space Science Reviews, 176, 237 – 252.
2. Wehrli, C., et al., (2013), Correlation of spectral solar irradiance with solar activity as measured by VIRGO, A&A, 556, L3.
3. Fröhlich, C., (2016), Determination of time-dependent uncertainty of the TSI records from 1978 to present, J. Sp. Weath. Sp. Clim., 6, A18.

A recent meeting of several members of the original VIRGO team took place, celebrating the 20th anniversary of SoHO. Left to right: Christoph Wehrli, Antonio Jiménez, Torben Leifsen, Bo Andersen, Claus Fröhlich, Hansjörg Roth, Vicente Domingo, Berhard Fleck, Thierry Appourchaux (photographer), Steven Dewitte, and André Chevallier (not in picture). © Argilas 2016.

Institute

Physikalisch-Meteorologisches Observatorium Davos und Weltstrahlungszentrum (PMOD/WRC), Davos, Switzerland:
PI: C. Fröhlich, CoI: W. Finsterle, W. Schmutz, C. Wehrli

Instituto de Astrofísica de Canarias (IAC), Tenerife, Spain:
Virgo Data Center
CoI: A. Jimenes

Institut Royal Météorologique de Belgique (IRMB), Bruxelles, Belgium:
CoI: S. Dewitte

Institut d'Astrophysique Spatiale (IAS), Orsay, France:
CoI: T. Appourchaux

Research Based on Existing Instruments

Instruments of the VIRGO experiment on SoHO.

Abbreviations

SoHO: Solar and Heliospheric Observatory
SSI: Spectral Solar Irradiance
TSI: Total Solar Irradiance
VIRGO: Variability of Solar Irradiance and Gravity Oscillations

6.2 Probing Solar X-Ray Nanoflares with NuSTAR

Purpose of Research

The Nuclear Spectroscopic Telescope Array (NuSTAR) is a NASA Small Explorer satellite using true focusing optics and pixellated X-ray detectors to achieve unprecedented sensitivity in the medium-to-hard X-ray band (2 – 80 keV). While NuSTAR is an astrophysics mission, it can point at the Sun.

NuSTAR is 200 times more sensitive than the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI), the current state-of-the-art satellite for solar hard X-ray studies. With the extraordinary increase in sensitivity provided by NuSTAR, we will be able to test the so-called 'nanoflare heating' theory predicting that many tiny explosions seen in X-rays provide enough energy to keep the solar atmosphere at its extraordinarily hot temperature (million degree range).

Status

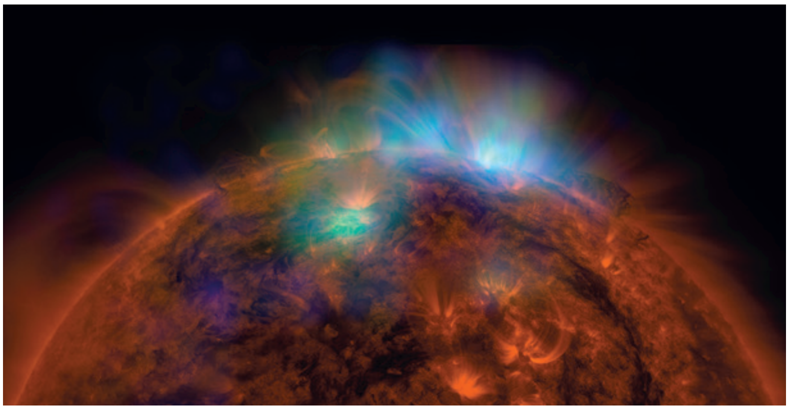
NuSTAR was successfully launched in June 2012. First solar observations were performed in September 2014, with 7 different observation runs for a total of about 1 day of exposure time. Future solar observations are beinging considered as a Target of Opportunity. Best observation conditions for our main science goal (nanoflare heating) will occur around solar minimum (~2017 – 2021) at times of lowest solar activity to minimize contamination from unfocused X-rays ('ghost-rays') from outside of NuSTAR's field-of-view.

Publications

1. Fiona, A. et al., (2013), ApJ., 770, 103.
2. Hannah, I. G. et al., (2016), ApJ. Letters, 820, 1, article id. L14, 7.

Abbreviations

NuSTAR	Nuclear Spectroscopic Telescope Array
RHESSI	Reuven Ramaty High Energy Solar Spectroscopic Imager



First NuSTAR image of the Sun (NASA press release). The NuSTAR image illustrates bluish colors superposed on an extreme UV image (around 171 Å) taken by SDO/AIA shown in red. While the EUV image represents 'cold' coronal plasma around 1 MK, the NuSTAR image outlines the location of the hottest plasma (typically 4 – 5 MK during non-flaring times).

Institute

i4Ds

Fachhochschule Nordwestschweiz (FHNW)

In Cooperation with

Caltech, USA
UC Santa Cruz, USA
Univ. Glasgow, UK
Univ. Minnesota, USA

Principal Investigator

F. Harrison (Caltech)

Swiss Principal Investigator

S. Krucker (FHNW)

Co-Investigator

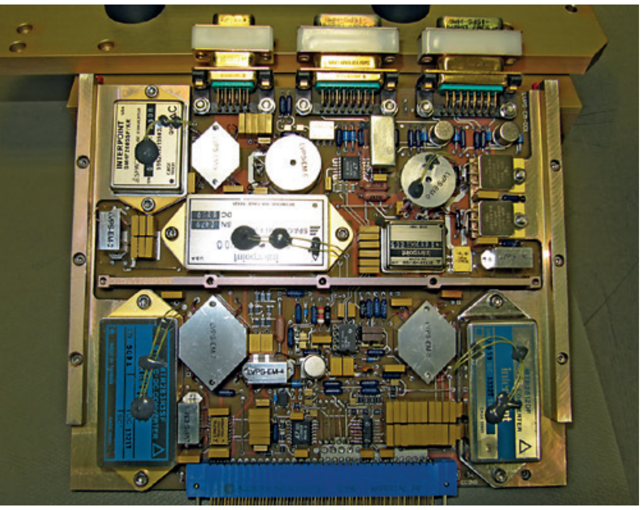
M. Kuhar (FHNW)

Method

Measurement

Research Based on Existing Instruments

NuSTAR is currently the leading X-ray observatory launched in June 2012. NuSTAR's unprecedented sensitivity opens up entirely new views on astrophysical X-ray objects including our Sun.



The SPICE Low Voltage Power Supply (LVPS).

6.3 SPICE – Spectral Imaging of the Coronal Environment Instrument on Solar Orbiter

Institute

Physikalisch-Meteorologisches Observatorium Davos und Weltstrahlungszentrum, PMOD/WRC, Davos

In Cooperation with

RAL, UK
GSFC, USA
IAS, France
ITA, Norway
MPS, Germany
SwRI, USA
ESA, Europe
NASA, USA

Principal Investigators

A. Fludra (RAL)
D. Hassler (IAS)

Swiss Principal Investigator

W. Schmutz (PMOD/WRC)

Co-Investigators

F. Auchere, T. Appourchaux, E. Buchlin, S. Parenti, J.-C. Vial (IAS, France)

Purpose of Research

The Spectral Imaging of the Coronal Environment Instrument (SPICE) on the Solar Orbiter mission is a high resolution imaging spectrometer operating at extreme ultraviolet (EUV) wavelengths, 70.4 – 79.0 nm and 97.3 – 104.9 nm. It is a facility instrument on the ESA Solar Orbiter mission.

SPICE will significantly contribute to the key science question of Solar Orbiter: How does the Sun create and control the heliosphere?

For this purpose, SPICE is designed to study the structure, dynamics and composition of the corona, in particular investigating the source regions of outflows and ejection processes which link the solar surface and corona to the heliosphere, by observing key emission lines on the solar disc on timescales from seconds to several minutes.

The EUV wavelength region observed by SPICE is dominated by emission lines from a wide range of ions formed in the solar atmosphere at temperatures from 10000 to 10 Million Kelvin. SPICE will measure plasma densities and temperatures, flow velocities, the presence of plasma turbulence and the composition of the source region plasma. It will be observing, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun's magnetized atmosphere.

A key aspect of the SPICE observing capability is to quantify the spatial and temporal signatures of the coronal temperature and density to explain the inter-relationship between the chromosphere, the low corona, coronal structures, coronal mass ejections, and the solar wind.

Status

The SPICE engineering model was delivered to Airbus Defence and Space (ADS) in November 2015. The Flight Model (FM) of the Low Voltage Power Supply (LVPS), built at PMOD/WRC, was delivered to the Southwest Research Institue (SwRI). The delivery of the SPICE FM is planned for November 2016. The launch of Solar Orbiter is scheduled for October 2018.

The Assembly Validation Model (AVM) of the SPICE Slit Change Mechanism (SCM) was fully assembled by Almatech in 2015. In early 2016, the QM of the SCM was assembled and QM tests are ongoing.

The QM and FM SPICE Contamination Door (SCD) was successfully assembled by APCO, and the lifetime test is ongoing. All other tests have been successfully finished.

Publications

1. Fludra, A. et al., (2013), SPICE EUV spectrometer for the Solar Orbiter mission, Proc. SPIE, 8862, 88620F, doi 10.1117/12.2027581.

2. Guerreiro, N., M. Haberreiter, V: Hansteen, W. Schmutz, (2015), Small-scale heating events in the solar atmosphere. I. Identification, selection, and implications for coronal heating, Astrophys. J., 813, 1, article id. 61, 11 pp.

3. Rogers, K. et al., (2015), Optical alignment of the SPICE EUV imaging spectrometer, Proc. SPIE, 9626, id. 962621, doi 10.1117/12.2191050.

Abbreviations

ADS	Airbus Defence and Space
AVM	Assembly Validation Model
EUV	Extreme Ultraviolet
FM	Flight Model
LVPS	Low Voltage Power Supply
PMOD	Physikalisch Meteorologisches Observatorium Davos
QM	Qualification Model
RAL	Rutherford Appleton Laboratory
SCD	SPICE Contamination Door
SCM	SPICE Change Mechanism
SPICE	Spectral Imaging of the Coronal Environment Instrument
SwRI	Southwest Research Institute

FM of the LVPS for the SPICE instrument, built at PMOD/WRC by Daniel Pfiffner (left) and Pierre-Luc Lévesque (right), was delivered to RAL for inspection and afterwards to SwRI for integration into the SPICE FM electronics box.

Time-Line	From	To
Planning	2008	2010
Construction	2010	2017
Measurement Phase	2029	2029
Data Evaluation	2020	2030 and beyond

M. Carlsson, S. V. Haugan
(ITA, Norway)

U. Schühle, S. Solanki,
W. Curdt, E. Marsch,
H. Peter, L. Teriaca,
D. Innes
(MPS, Germany)

R. Wimmer-Schweingruber
(Univ. Kiel, Germany)

M. Haberreiter
(PMOD/WRC, Switzerland)

M. Cladwell, R. Harrison,
N. Waltham, (RAL, UK)

W. Thompson, J. Davila
(GSFC, USA)

C. de Forest
(SWRI, USA)

Method

Measurement

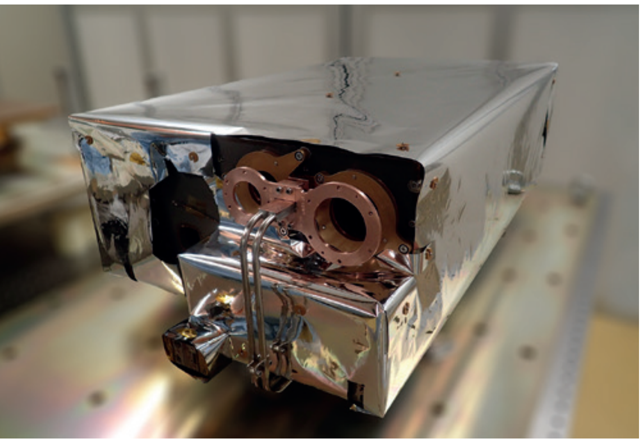
Development and Construction of Instruments

SPICE is a payload on the ESA/NASA M-class mission Solar Orbiter. The hardware, electronics and software have been developed and manufactured by institutes and industry partners located in the USA and Europe. PMOD/WRC is responsible for the development and manufacturing of the SPICE contamination door (SCD), the slit change mechanism (SCM) and the low voltage power supply (LVPS) for SPICE.

Industrial Hardware Contract to

APCO Technologies and

Almatech, Switzerland



EUI Qualification Model.

Institute

Physikalisch-Meteorologisches Observatorium Davos und Weltstrahlungszentrum, PMOD/WRC, Davos

In Cooperation with

Centre Spatiale de Liège (CSL), Belgium

Royal Observatory of Belgium (ROB), Belgium

Institut d'Astrophysique Spatiale (IAS), France

Institut d'Optique (IO), France

UCL Mullard Space Science Laboratory (MSSL), UK

Max Planck Institute for Solar System Research (MPS), Germany

ESA

NASA

Principal Investigator

P. Rochus (CSL)

Swiss Principal Investigator

W. Schmutz (PMOD/WRC)

6.4 EUI – Extreme Ultraviolet Imager on Solar Orbiter

Purpose of Research

EUI is designed to investigate structures in the solar atmosphere from the chromosphere to the corona, therefore providing a very important link between the solar surface and the outer most layers of the solar atmosphere that ultimately influences the characteristics of the interplanetary medium.

EUI has a suite composed of a Full Sun Imager (FSI) and two High Resolution Imagers (HRI). HRI and FSI have spatial resolutions of 1 and 9 arc seconds, respectively. The HRI cadence depends on the target and can reach sub-second values to observe the fast dynamics of small-scale features. The FSI cadence will be ~10 minutes in each passband, but can also achieve low cadences of ~10 s.

The FSI works alternately in two passbands, 174 Å and 304 Å, while the two HRI passbands observe in the hydrogen Lyman alpha (1216 Å) and the extreme UV (174 Å). During the mission phase the spacecraft will have the closest perihelion at 0.28 UA, while the Aphelion will range from 0.78 to 1.13 AU.

Furthermore, about 3 years after the launch, the spacecraft will initiate an out-of-ecliptic phase where the inclination will increase in relation to the solar equatorial plane by up to 33°.

EUI will significantly contribute to the following Solar Orbiter scientific themes:

- What are the origins of the solar wind streams and the heliospheric magnetic field?
- What are the sources, acceleration mechanism, and transport processes of solar energetic particles?
- How do coronal mass ejections evolve in the inner heliosphere?
- Explore, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun's magnetized atmosphere.

Status

The qualification model has been manufactured and qualification tests are running. Vibration tests were successful, and shock tests are now ongoing. The FM is currently being manufactured while the launch of Solar Orbiter has been re-scheduled for October 2018.

Abbreviations

AU	Astronomical Unit
EUI	Extreme Ultraviolet Imager
FSI	Full Sun Imager
HRI	High Resolution Imagers

Publications

1. Halain, J.-P. et al., (2014), The extreme UV imager of solar orbiter: From detailed design to flight model, Proc. SPIE, 9144, id. 914408 19 pp.

2. Rossi, L. et al., (2014), Solar simulation test up to 13 solar constants for the thermal balance of the Solar Orbiter EUI instrument, Proc. SPIE, 9144, id. 91443H 18 pp.

3. Guerreiro, N., M. Haberreiter, V. Hansteen, and W. Schmutz, (2015), Small-scale heating events in the solar atmosphere - I: Identification, Selection and implications for coronal heating, Ap. J., 813, 61.

4. Halain, J.-P. et al., (2015), The extreme UV imager telescope onboard the Solar Orbiter mission: Overview of phase C and D, Proc. SPIE, 9604, id. 96040G 11 pp.

5. Halain, J.-P., (2015), The extreme ultraviolet imager of solar orbiter: Optical design and alignment scheme, Proc. SPIE, 9604, id. 96040H 11 pp.

EUI Qualification Model integration of sub-systems.

Time-Line	From	To
Planning	2008	2010
Construction	2011	2017
Measurement Phase	2020	2029
Data Evaluation	2020	2030 and beyond

Co-Investigators

D. Berghmans, A. Zhukov, S. Parenti, L. Rodriguez (ROB)

T. Appourchaux, F. Auchère, J.-C. Vial, K. Bocchialini, E. Quémerais, E. Buchlin (IAS)

F. Delmotte (IO)

L. Harra, S. Matthews, D. Williams, L. Green, L. van Dreiel-Gesztelyi (MSSL)

U. Schühle, J. Büchner, W. Curdt, E. Marsch, L. Teriaca, S. Solanki (MPS)

W. Finsterle, M. Haberreiter, N. Guerreiro (PMOD/WRC)

Method

Measurement

Development and Construction of Instruments

EUI is a payload on the ESA/NASA M-class Solar Orbiter mission. The hardware, electronics and software is being manufactured by different European institutes and industry partners. The instrument consortium lead is held by CSI, Belgium. PMOD/WRC together with Swiss industry is responsible for the EUI optical bench structure. This is built with an aluminium honeycomb, carbon fiber face sheets and sandwich panels.

Industrial Hardware Contract to

APCO Technologies

Internal view of CLARA Flight Model.

6.5 CLARA – Compact Lightweight Absolute Radiometer on NORSAT-1

Institute

PMOD/WRC, Davos
Switzerland

In Cooperation with

Norsk Romsenter, Oslo, Norway
LASP, Boulder CO, USA

Swiss Principal Investigator

W. Schmutz (PMOD/WRC)

Co-Investigators

B. Anderson (NSC, Norway)
T. Leifsen (UiO, Norway)
G. Kopp (LASP, USA)
A. Fehlmann (IAF, USA)
W. Finsterle (PMOD/WRC)
B. Walter (PMOD/WRC)

Method

Measurement

Development and Construction of Instruments

dlab GmbH
RUAG Space

Purpose of Research

Space Climate

The Compact Lightweight Absolute Radiometer (CLARA) on NORSAT-1 is an absolute radiometer for measuring Total Solar Irradiance (TSI), which is the mean energy input to Earth (per m^2 Earth cross-section). Any long-term variation of TSI will directly translate into a change of the terrestrial climate. Measurements of TSI from space have been conducted since 1979 and during these 36 years TSI has been 1361 $W.m^{-2}$ on average and varied in phase with the solar cycle by about ±0.6 $W.m^{-2}$ (±0.04%). So far, no long-term trend of TSI has been established outside the uncertainties of a composite from records of eight different experiments.

The uncertainty of a trend in the TSI composite is difficult to assess but, is of the order of 0.5 $W.m^{-2}$. It is unknown and controversially discussed in the science community whether the solar irradiance has a long-term trend and whether climate variations within the past 10,000 years are related to changes in solar irradiance (see Schmutz, 2016). This is why the World Meteorological Organization lists TSI as an essential climate variable (see GCOS Essential Climate Variables).

In view of the unknown role of suspected (and predicted) TSI variability on the terrestrial climate, it is mandatory that monitoring of TSI continues on an accuracy level that is capable of capturing any variations that could have a significant impact on the terrestrial climate. The main science goal of CLARA is to measure TSI with an uncertainty better than 0.4 $W.m^{-2}$ on an absolute irradiance level and a relative stability of 5 $mW.m^{-2}.yr^{-1}$ (0.0004% of the TSI per year). PREMOS on PICARD, which was a previous PMOD/WRC experiment running from 2010 to 2014, had a similar absolute uncertainty in its TSI measurements. CLARA's performance will be sufficient to measure any climate-significant variation even in the eventuality that the TSI monitoring record were to be interrupted before the launch of NORSAT-1.

Radiometry

The CLARA experiment sets new standards for TSI radiometers in terms of a reduction in weight and size, without compromising accuracy and stability (Finsterle et al., 2014). The radiometer is fully characterized on the component level as well as calibrated end-to-end at the TSI Radiometer Facility (Walter et al., 2016). The measuring cadence is 30 s, which will be the highest cadance of an absolute radiometer in space. This will allow the study of solar irradiance variations at its high frequency end to be extended.

Instrument development

The PMOD/WRC has built one engineering and two flight units of the CLARA instrument. The institute made the mechanical and thermal design and manufactured most of the hardware. The electronics was developed and manufactured completely in-house. Swiss industry was responsible for software development, parts of the hardware manufacturing tasks, for mechanical and thermal simulations, and for environmental testing. CLARA was assembled at PMOD/WRC and calibrated at Lab. for Atmospheric and Space Physics (LASP) in Boulder Colorado, USA.

The NORSAT-1 Mission

The Norwegian Space Center selected the NORSAT-1 mission as an affordable approach to science in space, as part of the National Space Program. The satellite will investigate solar radiation, space weather, and detect ship traffic with an AIS transponder. The science payload will cover two aspects of scientific research focusing on the sun, including measuring TSI with a radiometer, and measuring electron plasma around the Earth with Langmuir probes, which have been developed by the University of Oslo. The CLARA radiometer instrument was developed by PMOD/WRC. The satellite platform has dimensions of 20x20x40 cm and was built by the University of Toronto Institute for Aerospace Studies Space Flight Lab, Canada.

Status

The CLARA flight model was finished in Summer 2015 and calibrated in Autumn 2015 at the TRF in Boulder Colorado, USA. It was delivered thereafter to Toronto for integration on NORSAT-1. The satellite was shipped in March 2016 to ESA's space center near Kourou in French Guiana for a scheduled launch in April 2016. However, Arianespace cancelled NORSAT-1's integration onto the launcher at short-notice. The cancellation was due to an incompatibility between the satellite and launcher supporting-structure provided by Arianespace. It was concluded that it was unsafe to proceed with the launch. The next launch opportunity for NORSAT-1 still needs to be identified.

Publications

1. Finsterle, W. et al., (2014), The new TSI radiometer CLARA, SPIE 9264, eid. 92641S-5, doi: 10.1117/12.2069614.

2. Schmutz, W., (2016), Chapter 3.2 in: Our Space Environment: Opportunities, Stakes, and Dangers, Eds. C. Nicollier, V. Gass, EPFL Press, ISBN 978-2-940222-88-9.

3. Walter, B. et al., (2016), The CLARA/NORSAT-1 solar absolute radiometer: Instrument design, characterization and calibration, Metrologia, in preparation.

Abbreviations

CLARA	Compact Lighweight Absolute Radiometer
NORSAT-1	Norwegian Satellite
NSC	Norwegian Space Centre
TRF	Total solar irradiance Radiometer Facility
TSI	Total Solar Irradiance

Time-Line	From	To
Planning	2013	
Construction	2014	Sep. 2015
Measurement Phase	launch 2016/2017	open-ended

PMOD/WRC engineers with the finished CLARA Flight Model (end of 2015). CLARA has the dimensions 11.4×14.1×15.5 cm and a mass of 2.63 kg.

6.6 STIX – Spectrometer/Telescope for Imaging X-Rays on Solar Orbiter

Institute

i4Ds
FHNW

In Cooperation with

SRC, Poland
CEA, Sacaly, France
Leibniz-Institut für Astrophysik, Potsdam, (AIP), Germany
Czech Space Office, Czech Rep.
Univ. Graz, Austria
Trinity College Dublin, Ireland
LESIA, France
Univ. Genova, Italy

Principal Investigator

S. Krucker (FHNW)

Co-Investigators

J. Sylwester (SRC), O. Limousin (CEA)
G. Mann (AIP), N. Vilmer (LESIA)
A. Vernonig (U. Graz), F. Farnik (CSO)
P. Gallagher (TCD), M. Piana (Genova)

Method

Measurement

Development and Construction of Instruments

STIX is a Swiss-lead instrument onboard ESA's Solar Orbiter mission (launch Oct. 2018). STIX is a hard X-ray imaging spectrometer based on a Fourier-imaging technique similar to that used successfully by the Hard X-ray Telescope (HXT) on the Japanese Yohkoh mission, and related to that used for the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) NASA SMEX mission.

Industrial Hardware Contract to

Almatech
Art of Technology
Syderal

Purpose of Research

Solar Orbiter is a joint ESA-NASA collaboration that will address the central question of heliophysics: How does the Sun create and control the heliosphere? To achieve this goal, Solar Orbiter carries a set of 10 instruments to perform joint observations. Through hard X-ray imaging and spectroscopy, the STIX instrument provides information of heated (>10 MK) plasma and accelerated electrons that are produced as magnetic energy is released during solar flares.

By using this set of diagnostics, STIX plays a crucial role in enabling Solar Orbiter to achieve two of its major science goals of:

1) Understanding the acceleration of electrons at the Sun and their transport into interplanetary space, and

2) Determining the magnetic connection of the Solar Orbiter back to the Sun. In this way, STIX provides a crucial link between the remote and in-situ instruments of Solar Orbiter.

Status

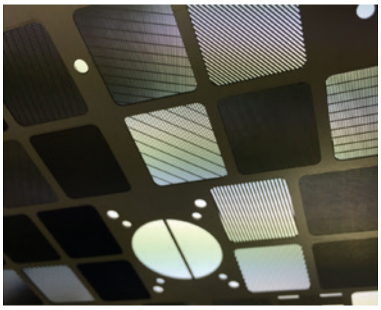
In October 2012, Solar Orbiter was selected as the first medium-class mission of ESA's Cosmic Vision 2015-2025. STIX was previously selected as one of the 10 instruments onboard Solar Orbiter. STIX successfully passed the Critical Design Review (CDR) in 2015 and instrument delivery is foreseen for October 2016.

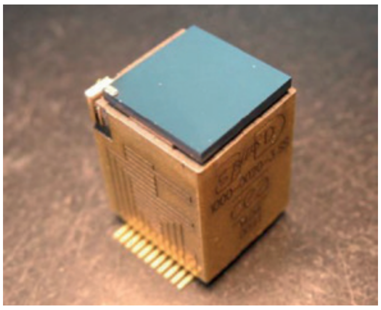
Publications

1. Benz, A. O., S. Krucker, G. J. Hurford, N. G. Arnold, P. Orleanski, H.-P. Gröbelbauer, S. Klober, L. Iseli, H. J. Wiehl, A. Csillaghy, and 50 co-authors, (2012), Space telescopes and instrumentation 2012: Ultraviolet to gamma ray, Proc. SPIE, 8443, article id. 84433L, 15 pp.

Abbreviations

CDR	Critical Design Review
STIX	Spectrometer/Telescope for Imaging X-Rays





The Flight Model of the STIX tungsten grids (left) and the STIX detector system called Caliste-SO (right).

Time-Line	From	To
Planning	2010	2014
Construction	2014	2016
Measurement Phase	2019	2026
Data Evaluation	2018	2026

6.7 DARA – Digital Absolute Radiometer on PROBA-3

Purpose of Research

The sun is the primary energy source for Earth's climate system. Continuous and precise TSI measurements are indispensable to evaluate the influence of short and long-term solar radiative emission variations on the Earth's energy budget.

The DARA absolute radiometer will be one of PMOD/WRC's future contributions to the seamless series of spaceborne TSI measurements since 1978. The existence of a potentially long-term trend in the suns activity, and whether or not such a trend could be climate effective, is still a matter of debate. Independent DARA measurements will also be important to prove if the new TSI value of 1361 W.m^{-2} can be verified. The main goal of DARA is to continue the TSI data record with unprecedented accuracy and precision.

DARA is a three-channel active cavity Electrical Substitution Radiometer (ESR) comprising the latest radiometer developments by PMOD/WRC to achieve long-term stability and high accuracy. The calibration of DARA against a NIST calibrated cryogenic radiometer will guarantee full SI-traceability of irradiance measurements. DARA is a payload experiment on ESA's PROBA-3 satellite with a nominal mission duration of two years. PROBA-3 will be the world's first precision formation flying mission. A pair of satellites will fly together maintaining a fixed configuration as a "large rigid structure" in space, representing a coronagraph configuration.

Status

The new DARA radiometer design was established and a prototype was built and already tested within ESA's Prodex Programm in 2010. Based on this, the similar but smaller instrument CLARA, built for the Norwegian micro-satellite NORSAT-1, was delivered in October 2015 to be integrated with the satellite. A continuation of the DARA development re-started in 2015. The DARA design was adapted and based on the CLARA design experience in order to cover internal and external requirements. The harsh environmental influences on PROBA-3, with high radiation doses accumulating during mission lifetime, requires special care in the selection of components. EM manufacturing and testing will occur in 2016. A critical review of the EM will release design changes followed by the flight-unit manufacturing phase.

Publications

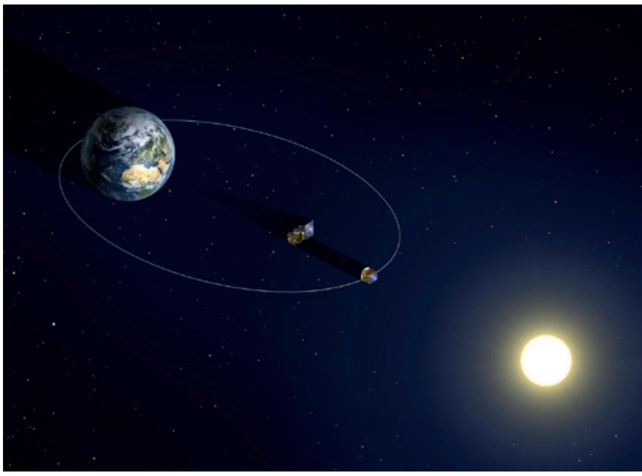
1. Schmutz, W., et al., (2009), Metrol. 46, S202 – S206, doi: 10.1088/00261394/46/4/S13.

2. Fehlmann, A., et al., (2011), Metrol. 49, S34 – S38, doi: 10.1088/0026-1394/49/2/S34.

Abbreviations

CLARA	Compact Lightweight Absolute Radiometer
EM/FM	Engineering/Flight Model
ESR	Elec. Substitution Radiometer
PROBA-3	Project for On-Board Autonomy
TSI	Total Solar Irradiance

Time-Line	From	To
Planning	end of 2013	early 2015
Construction	end of 2015 (EM)	May 2017 (FM)
Measurement Phase	2018	open
Data Evaluation	2018	open



Artist's impression of PROBA-3 in orbit.

Institute

PMOD/WRC, Davos
Switzerland

In Cooperation with

ESA

Principal Investigator

W. Schmutz (PMOD/WRC)

Co-Investigators

W. Finsterle (PMOD/WRC)
B. Walter (PMOD/WRC)
A. Zhukov (ROB)

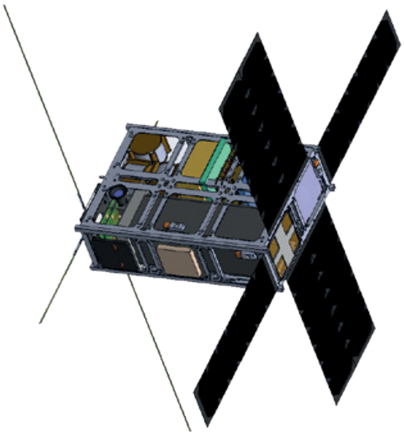
Method

Measurement

Development and Construction of Instruments

The DARA experiment is PMOD/WRC's contribution to the ESA mission PROBA-3. It is a three channel absolute radiometer to measure TSI. DARA has been developed and built in-house at PMOD/WRC.

6.8 MiSolFA – The Micro Solar-Flare Apparatus



Preliminary satellite concept for MiSolFA.

Purpose of Research

Operating at the same time as the STIX instrument on the ESA Solar Orbiter mission during the next solar maximum (2020), MiSolFa and STIX will have the unique opportunity to observe the same flare from two different directions:

1) Solar Orbiter will be very close to the Sun with significant orbital inclination.

2) MiSolFA will be in a near-Earth orbit.

MiSolFA will adopt the same photon detectors as STIX, precisely quantifying the anisotropy of solar hard X-ray emissions for the first time to investigate particle acceleration in solar flares.

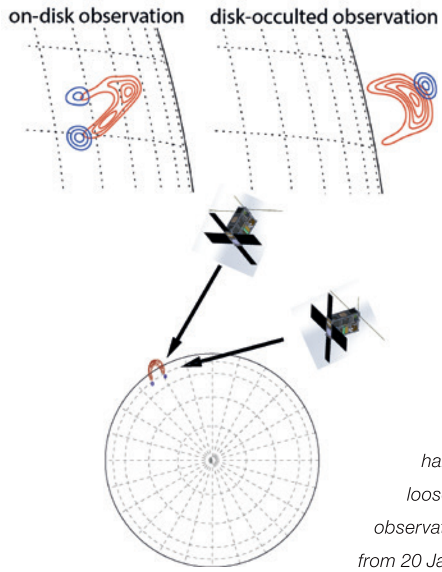
Status

The mission definition will be complete in 2016, in collaboration with the Italian Space Agency (ASI) and the IMT company in Rome. The goal is to be ready for flight in 2020.

ASI will take care of the launch and will contribute to the operation by providing a ground station and telecommunication.

Abbreviations

ASI	Italian Space Agency
MiSolFA	The Micro Solar-Flare Apparatus
STIX	Spectrometer/Telescope for Imaging X-rays



Sketch of the flare hard X-ray stereoscopy, loosely based on RHESSI observations of the solar flare from 20 Jan. 2005 (only in 2-D).

Time-Line	From	To
Planning	2015	2017
Construction	2017	2020
Measurement Phase	2020	2021
Data Evaluation	2020	2022

Institute

i4Ds

Fachhochschule Nordwestschweiz (FHNW)

Principal Investigator

D. Casadei (FHNW)

Co-Investigator

S. Krucker (FHNW)

Method

Measurement

Development and Construction of Instruments

The Micro Solar-Flare Apparatus (MiSolFA) is a compact X-ray imaging spectrometer that fits into a micro-satelite (30 cm x 20 cm x 10 cm, a so-called 6 unit cubsat).

Industrial Hardware Contract to

Still in R&D phase.

6.9 FLARECAST – Flare Likelihood and Region Eruption Forecasting

Purpose of Research

FLARECAST will develop an advanced solar flare prediction system based on automatically extracted physical properties of solar active regions, coupled with state-of-the-art flare prediction methods and validated using optimal validation practices.

FLARECAST will form the basis of the first quantitative, physically motivated and autonomous active-region monitoring and flare-forecasting system, designed for unrestricted use by space-weather researchers and forecasters in Europe as well as around the globe.

Status

FLARECAST has evolved from establishment to maturity phase. Active region flare-associated properties have been catalogued. Explorative research on devising new predictors, studying the evolution of existing ones toward flaring and linking flares to coronal mass ejections has begun.

The infrastructure for accessing and processing SoHO/HMI data using machine- and deep-learning techniques is up and running, while dissemination efforts toward the scientific community, governmental and industrial end-users and the general public are intensifying.

Abbreviations

FLARECAST	Flare Likelihood and Region Eruption Forecasting
HMI	Helioseismic and Magnetic Imager
SoHO	Solar and Heliospheric Observatory

Institute

i4Ds
FHNW

In Cooperation with

Academy of Athens (AA), Greece
Trinity College Dublin (TCD), Ireland
Univ. Degli Studi Di Genova, (UNIGEN), Italy
CNR, Italy
CNRS, France
Univ. Paris-Sud, (PSUD), France
Met. Office, UK

Principal Investigator

M. K. Georgoulis
(RCAAM, Academy of Athens)

Swiss Principal Investigator

A. Csillaghy

Co-Investigators

M. Soldati (FHNW)
H. Sathiapal (FHNW)

Method

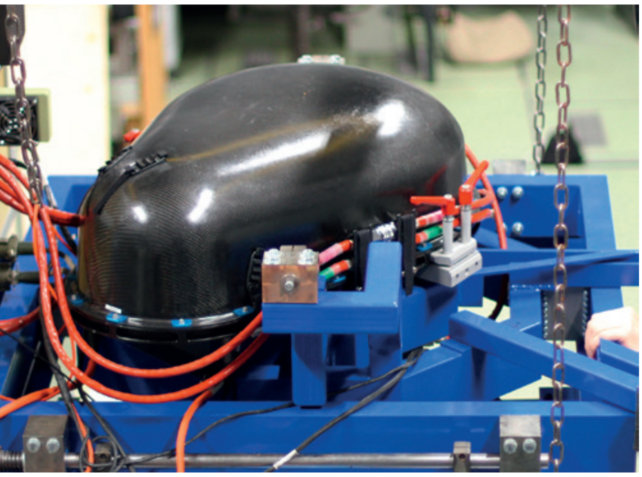
Measurement and Simulation

Research Based on Existing Instruments

A European research project aiming to develop a fully automated solar-flare forecasting system with an unmatched accuracy compared to existing facilities.

7 Earth Observation, Remote Sensing

7.1 APEX – Airborne Prism Experiment



APEX in the calibration laboratory.

Institute

Remote Sensing Labs (RSL)
Dept. Geog., Univ. Zurich

In Cooperation with

ESA/PRODEX

ESA/EOEP

VITO, Belgium

Principal Investigator

M. E. Schaepman (RSL)

Co-Investigators

K. Meuleman (VITO)
A. Hueni (RSL)

Method

Measurement

Research Based on Existing Instruments

Exploitation of the APEX instrument during extensive measurement campaigns in the calibration home base and in the field.

Purpose of Research

ESA's Airborne Imaging Spectrometer APEX (Airborne Prism Experiment) was developed under the PRODEX (PROgramme de Développement d'EXpériences scientifiques) program by a Swiss-Belgian consortium and entered its operational phase at the end of 2010 (Schaepman et al., 2015). It collects spectral data in the VNIR–SWIR range from 385 nm to 2500 nm. APEX is designed to collect imaging spectroscopy data at a regional scale, serving as data source to answer questions within Earth System Sciences, and to simulate, calibrate and validate optical airborne and satellite-based sensors.

Status

RSL is responsible for the scientific management of the project, for added value within the calibration chain of the APEX instrument, the product generation, and for extending and maintaining the Processing and Archiving Facility. The latter is a universal, database driven system supporting the processing and distribution of all APEX raw data acquisitions. Sophisticated information technology tools are used for a versatile processing system, which is designed to be persistent throughout the operational phase of the instrument.

The processing and archiving facility is being continuously updated to allow the reprocessing of data acquired since 2009 using the latest processing algorithms. In parallel, RSL manages the flights for Swiss partners within Switzerland and occasional special campaigns with partner institutes abroad. General operations are carried out by the partner organisation VITO.

Publications

1. Hueni, A. et al., (2013), The APEX (Airborne Prism Experiment - Imaging Spectrometer) calibration information system, IEEE Trans. Geo. Rem. Sens. 51 (11), 5169–5180.

2. Hueni, A. et al., (2014), Impacts of dichroic prism coatings on radiometry of the airborne imaging spectrometer apex, Appl. Opt., 53, 5344–5352.

3. Schaepman, M. et al., (2015), Advanced radiometry measurements and Earth science applications with the airborne prism experiment (APEX). Rem. Sens. Environ., 158, 207–219.

Abbreviations

APEX	Airborne Prism Experiment
ENMAP	ENv. Map. & Analysis Prog
EOEP	Earth Obs. Envelope Prog
PRODEX	PROg. de Dev. d'EXperiences Scient.
RSL	Remote Sensing Lab.
SWIR	Short Wave InfraRed
VITO	Vlaamse Inst. Tech. Onder.

Time-Line	From	To
Planning	1997	2000
Construction	2002	2010
Measurement Phase	2011	ongoing
Data Evaluation	2011	ongoing

7.2 APEX Instrument and Uncertainty Model

Purpose of Research

ESA's Airborne Imaging Spectrometer APEX (Airborne Prism Experiment) was developed under the PRODEX (PROgramme de Développement d'EXpériences scientifiques) program by a Swiss-Belgian consortium and entered its operational phase at the end of 2010 (Schaepman et al., 2015).

Work on the sensor model has been carried out extensively within the framework of the European Metrology Research Program as part of the Metrology for Earth Observation and Climate (MetEOC and MetEOC2). The focus has been to improve laboratory calibration procedures in order to reduce uncertainties, to establish a laboratory uncertainty budget and to upgrade the sensor model to compensate for sensor specific biases.

Status

The updated sensor model relies largely on data collected during dedicated characterisation experiments in the APEX calibration home base, but includes airborne data as well where the simulation of environmental conditions in the given laboratory setup was not feasible. The additions to the model deal with artefacts caused by environmental changes and electronic features, namely: 1) the impact of ambient air pressure changes on the radiometry in combination with dichroic coatings, 2) the influence of external air temperatures and consequently instrument baffle temperatures on the radiometry, and 3) electronic anomalies causing radiometric errors in the four shortwave infrared detector readout blocks. Work on the sensor model and the uncertainty budget for the in-flight case is currently ongoing.

Publications

1. Hueni, A., J. Biesemans, K. Meuleman, F. Dell'Endice, D. Schläpfer, S. Adriaensen, S. Kempenaers, D. Odermatt, M. Kneubuehler, J. Nieke, and K. Itten, (2009), Structure, Components and Interfaces of the Airborne Prism Experiment (APEX) Processing and Archiving Facility, IEEE Trans. Geo. Rem. Sens., 47, 29–43.

2. Hueni, A., K. Lenhard, A. Baumgartner, and M. Schaepman, (2013), The APEX (Airborne Prism Experiment – Imaging Spectrometer) Calibration Information System, IEEE Trans. Geo. Rem. Sens., 51, 5169–5180.

3. Hueni, A., S. Sterckx, and M. Jehle, (2013), Operational Calibration of APEX, in Proc. IGARSS 2013, Melbourne (AUS), July 21–26, (2013), Melbourne.

4. Hueni, A., M. Jehle, A. Damm, A. Burkart, and M. Schaepman, (2013), Spectroscopy information systems for Earth system science, in ESA PV2013 Workshop, Frascati.

5. Hueni, A., D. Schlaepfer, M. Jehle and M. E. Schaepman, (2014), Impacts of dichroic prism coatings on radiometry of the Airborne Imaging Spectrometer APEX, Appl. Opt. 53(24), 5344–5352.

Abbreviations

APEX	Airborne Prism Experiment
PRODEX	PROg. de Dev. d'EXperiences Scient.

Institute

Remote Sensing Labs (RSL)
Dept. Geog., Univ. Zurich

In Cooperation with

NPL, UK

Principal Investigator

N. Fox

Swiss Principal Investigator

A. Hueni (RSL)

Co-Investigators

M. E. Schaepman (RSL)
M. Kneubühler (RSL)

Method

Measurement

Research Based on Existing Instruments

Improvement of the APEX sensor model and establishment of an uncertainty budget.

7.3 SPECCHIO – Spectral Information System

Institute

Remote Sensing Labs (RSL)
Dept. Geog., Univ. Zurich

In Cooperation with

ANDS
(Australian National Data Service)

EuroSpec COST Action ES0903

OPTIMSE ES1309 COST Action

Specnet Spectral Network

Principal Investigator

A. Hueni (RSL)

Co-Investigators

L. Chisholm (UoW, Australia)
M. E. Schaepman (RSL)
M. Kneubühler (RSL)

Method

Measurement

Development of Software

Development of a Spectral Information System for the storage of spectral field and laboratory data and associated metadata.

Purpose of Research

Scientific efforts to observe the state of natural systems over time, allowing the prediction of future states, have led to a burgeoning interest for the organised storage of spectral field data and associated metadata .This is seen as being key to the successful and efficient modeling of such systems.

A centralised system for such data, established for the remote sensing community, aims to standardise storage parameters and metadata, thus fostering best practice protocols and collaborative research. The development of a spectral information system will not only ensure the long-term storage of data but support scientists in data analysis activities, essentially leading to improved repeatability of results, superior reprocessing capabilities, and promotion of best practice.

Status

SPECCHIO is being actively and continuously developed. Major contributions have been made to the system in the past year via funding provided by the Australian National Data Service and the EuroSpec COST Action ES0903. SPECCHIO also serves as the "Spectral Information System" component which is being fostered and developed within Working Group 1 of the OPTIMSE ES1309 COST Action.

SPECCHIO is being routinely used at about 40 research institutions worldwide as well as in teaching activities at the Remote Sensing Laboratories, University of Zurich.

SPECCHIO is currently the most advanced spectral information system within the domain of Earth observing remote sensing.

SPECCHIO is also open source and was made available in 2015 as a virtual machine image, which allows anyone to run the full system on their personal laptop, thus supporting its full functionality under field conditions.

For further information please refer to www.specchio.ch and http://optimise.dcs.aber.ac.uk/working-groups/wg1-spectral-information-system/.

Publications

1. Hueni, A., J. Nieke, J. Schopfer, M. Kneubühler, and K. Itten, (2009), The spectral database SPECCHIO for improved long term usability and data sharing, Computers & Geosciences, 35, 557–565.
2. Hueni, A., T. Malthus, M. Kneubuehler, and M. Schaepman, (2011), Data exchange between distributed spectral databases, Computers & Geosciences, 37, 861–873.
3. Hueni, A., L. Chisholm, L. Suarez, C. Ong, and M. Wyatt, (2012), Spectral information system development for Australia, in Geospatial Science Research Symposium Melbourne, Australia.
4. Hueni, A., M. Jehle, A. Damm, A. Burkart, and M. Schaepman, (2013), Spectroscopy information systems for Earth System science, in ESA PV2013 Workshop, Frascati, Italy.

7.4 HYLIGHT – Integrated Use of Airborne Hyperspectral Imaging Data and Airborne Laser Scanning Data

Example of PAI output for the Laegern test site.

Purpose of Research

The Joint Research Activity (JRA) HYLIGHT is developing methodologies and tools for the integrated use of airborne hyperspectral imaging (HSI) data and airborne laser scanning (ALS) data in order to produce improved HSI and ALS vegetation information.

The developed methodologies, prototypes and tools will be tested by the involved data processing facilities to improve the quality of both HSI and ALS data products for the scientific users. RSL contributes by providing advanced, ray-tracing based vegetation layers from ALS data to be used in radiative transfer modelling.

HYLIGHT tools and datasets are freely available via the EUFAR toolbox and the EUFAR handbook. Additionally, RSL provides access to HSI and ALS data gathered over the calibration supersite Lägeren, established in the ESA STSE project '3D Vegetation Laboratory'. EUFAR (www.eufar.net) was an Integrating Activity funded by the EC 7th Framework Programme.

The activity was extended as EUFAR2 to run from 2014–2018 (24 partners). It aims to provide and improve the access to airborne facilities (i.e. aircraft, airborne instruments, data processing centers) for researchers in environmental and geo-sciences through Networking Activities (NA), Trans-national Access (TA) Activities and Joint Research Activities (JRA). The long term objectives of EUFAR are to lay the groundwork of a European distributed infrastructure for airborne research in environmental and geosciences for each European scientist to obtain access on "equal terms" to the airborne facility which is most suited to his/her scientific objectives.

Status

EUFAR2-HYLIGHT started in 2014.

Publications

1. Reusen, I. et al., (2009), EUFAR goes hyperspectral in FP-7. In: Workshop on hyperspectral image and signal processing: evolution in remote sensing, Grenoble, France, 1–4.
2. Bachmann, M. et al., (2011), EUFAR FP7 HyQuaPro (JRA-2), Report on Quality Layers for VITO, DLR, INTO and PML, Toulouse, EUFAR.
3. Schneider, F. D. et al., (2014), Simulating imaging spectrometer data: 3d forest modeling based on lidar and in situ data, Rem. Sens. Environ. 152, 235–250.

Abbreviations

HYLIGHT	FP7/EUFAR2 Joint Res.Activity on Integrated use of airborne hyper spectral imaging data and airborne laser scanning data
EUFAR2	FP-7 Integrating Activity 'European Framework for Airborne Research', 2014–2018.

Time-Line	From	To
Measurement Phase	2014	2018
Data Evaluation	2014	2018

Institute

Remote Sensing Labs (RSL)
Dept. Geog., Univ. Zurich

In Cooperation with

VITO, Belgium
ONERA, France
DLR, Germany
INTA, Spain
PML, UK
CVGZ, Czech Republic
TAU, Israel
TU Wien, Austria

Principal Investigator

Ils Reusen (VITO)

Swiss Principal Investigator

F. Morsdorf (RSL)

Co-Investigators

A. Hueni (RSL)
M. Kneubühler (RSL)
D. Kükenbrink (RSL)
M. E. Schaepman (RSL)

Method

Simulation

Research Based on Existing Instruments

Airborne hyperspectral sensors and laser scanners.

7.5 Wet Snow Monitoring with Spaceborne SAR

Institute

Remote Sensing Labs (RSL)
Dept. Geog., Univ. Zurich

In Cooperation with

European Space Agency (ESA)

Canadian Space Agency (CSA)

WSL Institute for Snow and Avalanche Research (SLF)

Swiss Principal Investigator

D. Small (RSL)

Co-Investigators

E. Meier (RSL)
A. Schubert (RSL)

Method

Measurement

Research Based on Existing Instruments

Sentinel-1
ENVISAT ASAR
ALOS PALSAR
TerraSAR-X
RADARSAT-2
COSMO-SKYMED

Purpose of Research

The University of Zurich Remote Sensing Laboratories (UZH-RSL) works with ESA and other partners to develop a novel spaceborne SAR image product whereby many of the effects of topography on radar image brightness are modelled and corrected before estimating the backscatter coefficient at each image coordinate.

The new type of product offers several benefits. Comparisons of backscatter from image acquisitions made from differing orbital tracks become possible. Flattening the terrain-induced effects on radar brightness enables significantly more frequent revisits to a specific point on the Earth, particularly given the availability of a wide swath mode such as C-band ASAR WS, RADARSAT-2 SCN & SCW, L-band ALOS PALSAR WB (wide beam), or the wide ScanSAR modes from the X-band sensors CosmoSkymed, TSX, TDX, and (soon) PAZ.

Use of the new products enables a great improvement in "temporal resolution", a parameter of critical importance in land-cover monitoring to lower the probability of missing events of brief duration. Data-rich time-series can be built up for a chosen area much more quickly from a single sensor given a wider variety of tracks (even combinations of ascending and descending passes), and especially to integrate backscatter measurements from a diversity of sensors.

Each sensor is typically characterised by the single orbital repeat period chosen at launch and the set of beam modes on offer. Building algorithms that are open to multiple sensors therefore implies by necessity openness to differing tracks, modes, and nominal incident angles. Not being open to multiple tracks triggers (in the absence of terrain-flattening) incompatibility with meaningful short-term comparisons or quick revisits when monitoring large regions. Only terrain-flattened backscatter, a product we call terrain-flattened gamma nought, offers the possibility of combining data from multiple SAR sensors acquired over rolling terrain.

The ESA Sentinel-1 radar satellites, the first of which was launched in April 2014, are acquiring regular images of Europe at 20 m resolution. RSL has been generating composite backscatter images of the European Alps as well as other regions to test a new method for snow-melt monitoring.

Given the severe topography in Switzerland, construction of backscatter time-series requires rigorous radiometric calibration that accounts for track-dependent terrain-induced effects. If a standard terrain-flattened backscatter product could be offered by ESA, this would simplify interpretation of SAR imagery not only in Switzerland, but throughout the world.

Status

A terrain-normalisation method for SAR imagery covering steep terrain has been developed and tested using data from major spaceborne SAR sensors. Further tests are under way using data from Sentinel1A, RADARSAT-2, and TerraSAR-X. In the case of wide-swath C-band data covering Switzerland, seasonal trends have been established (see accompanying image).

Springtime melting in the Swiss Alps is clearly visible: terrain-flattened backscatter makes monitoring the snow-melt theoretically possible with multiple observations per week using data from the Sentinel-1 satellites. The companion satellite to Sentinel-1A, Sentinel-1B, is due for launch later in 2016.

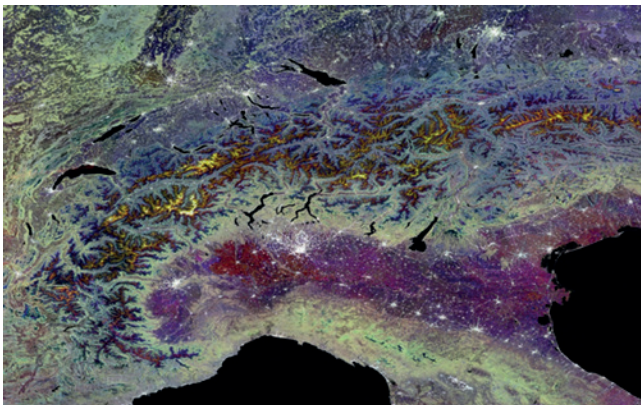
Wet snow measurements have been evaluated qualitatively and are being compared with state-of-the-art operational methodologies. Harmonized data acquisition strategies for the different spaceborne SAR sensors are being coordinated through the WMO Polar Space Task Group (WMO-PSTG). Tools are in development for integration of wide swath C-band Radarsat-2 and Sentinel-1, and X-band CSK, TSX, TDX, and PAZ data.

Publications

1. Small, D., (2011), Flattening gamma: Radiometric terrain correction for SAR imagery, IEEE Trans. Geosci. Rem. Sens., 49, 8, 3081–3093, doi: 10.1109/TGRS.2011.2120616.

2. Small, D., N. Miranda, T. Ewen, and T. Jonas, (2013), Reliably flattened backscatter for wet snow mapping from wide-swath sensors, Proc. ESA Living Planet Symposium, 8pp.

3. Schubert, A., D. Small, N. Miranda, D. Geudtner, and E. Meier, (2015), Sentinel-1A product Geolocation accuracy: Commissioning phase results, Rem. Sens., 7(7), 9431–9449.

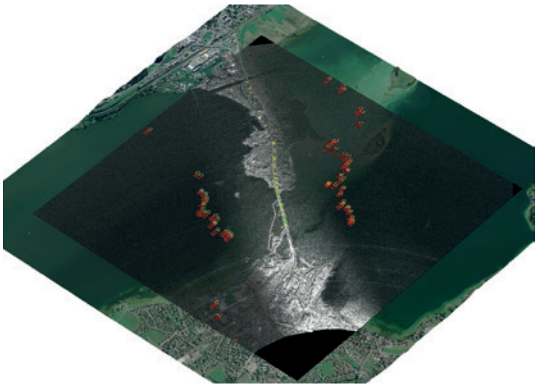


The 2015 springtime melting process is shown in the image. Three 16-day periods were available. All Sentinel-1 IW acquisitions within each window were used to automatically generate a radiometrically and geometrically corrected backscatter mosaic product. The three products were assigned to the red (late March), green (mid April), and blue (early June) channels, respectively. High mountain peaks that only began melting in late May appear yellow, as they generate dark 'wet snow' backscatter only in the last period: bright red/green and dark blue produces the yellow colour seen. The highest peaks (e.g. in the Bernese Oberland and Valais) covered by snow that remained dry in all 3 time-windows returned strong backscatter, appearing white.

Abbreviations

PALSAR	Phased Array L –band Synthetic Aperture Radar
RSL	Remote Sensing Labs
SAR	Synthetic Aperture Radar
SCN	RADARSAT ScanSAR Narrow
SCW	RADARSAT ScanSAR Wide
TSX/TDX/PAZ	TerraSAR–X satellites (X–band)

Time-Line	From	To
Planning	ongoing	
Construction		
Measurement Phase	2002	ongoing
Data Evaluation	2010	ongoing



Moving objects as detected by the tracking algorithm. The circles with the identification number indicate the position in the SAR image space, and the crosses the real position on the road.

Institute

Remote Sensing Labs (RSL)
Dept. Geog., Univ. Zurich

In Cooperation with

armasuisse (CH)

German Aerospace Center (DLR), Germany

Fraunhofer Inst. High Freq. Physics and Radar Techn. (FHR), Germany

Swiss Principal Investigator

E. Meier (RSL)

Co-Investigators

D. Henke (RSL)
E. Casalini (RSL)
M. E. Schaepman (RSL)

Method

Measurement

Research Based on Existing Instruments

Airborne SAR sensors

7.6 Moving Target Tracking in SAR Images

Purpose of Research

Ground Moving Target Indication (GMTI) in synthetic aperture radar (SAR) data addresses the task of extracting information about moving objects. SAR-GMTI allows moving objects to be indicated while simultaneously imaging the area of interest and works independently of weather conditions and daytime.

However, since SAR was originally developed for use in static scenes, the problem of extracting information from moving objects is a challenging task which has evolved over the last decade and demands state-of-the-art processing techniques. Best results are achieved when: (1) combining several extraction schemes, and (2) analyzing the dynamic behavior of the moving objects over time using sub-aperture processing techniques.

In recent years, a temporal tracking framework has been developed at RSL and several different extraction methods have been implemented. For the extraction scheme, (1) single-channel, video-like processing, (2) along-track interferometry, and, (3) more recently, exo-clutter methods relying on a high pulse repetition sensor configuration, are available. The final output of the tracking algorithm provides the trajectories of the moving objects. An example case at a specific time-step is presented in the adjacent figure.

Status

A campaign recording the traffic flow on the Seedamm over Lake Zurich with DLR's F-SAR in 2013 demonstrated the high accuracy of the approach: All vehicles driving on the Seedamm were successfully detected and their velocities were estimated within an error of 0.09 ± 1.13 km.h^{-1}, evaluated using ground-based measurements. As the vehicles are illuminated by the sensor for 30 s on average, velocity profiles can be calculated and analyzed for each moving object. Due to the Doppler effect, all moving objects are smeared and displaced in SAR images.

With accurate estimates of velocity and position, it becomes possible to re-focus the detected vehicles. This allows private cars to be distinguished from trucks. The vehicles' length was estimated with an error of -0.03 m ± 0.48 m.

The SAR-GMTI project is an ongoing research topic. While in recent years the focus has been placed on the GMTI data processing of a pulsed SAR system belonging to DLR, it is planned to design and extend an in-house experimental frequency-modulated continuous wave sensor for SAR-GMTI applications, in close collaboration with armasuisse and Fraunhofer FHR.

Publications

1. Henke, D., et al., (2015), Moving target tracking in single and multi-channel SAR, IEEE Trans. Geosci. Rem. Sens. 53(6), 3146–3159.

2. Henke D., and E. Meier, (2015), Tracking and refocussing of moving targets in multichannel SAR data, IEEE Geosci. Rem. Sens. Symp. (IGARSS), 3735–3738.

Abbreviations

GMTI	Ground Moving Target Indication
SAR	Synthetic Aperture Radar

7.7 Calibration Targets for MetOp-SG Instruments MWS and ICI

Purpose of Research

The second generation of the Meteorological Operational (MetOp-SG) satellite is a series of polar orbiting meteorological satellites carrying scientific instruments to provide atmospheric remote sensing observations for numerical weather prediction. Two of the instruments to be flown on MetOp-SG satellites are the Microwave Sounder (MWS) and Ice Cloud Imager (ICI). MWS is a cross-track scanning radiometer measuring atmospheric temperature and humidity profiles in the microwave regime, while ICI is a conically scanning radiometer providing ice cloud and snowfall imaging in a broad frequency spectrum from millimetre to sub-millimetre waves.

A key component of MWS and ICI are their blackbody calibration targets which are required for the accurate radiometric calibration of the instruments. Ensuring a high temperature uniformity and a low microwave reflectivity at the same time constitutes the major challenges in their development. The IAP is responsible for the design and the experimental verification of the onboard calibration targets. They are optimized using electromagnetic simulations based on the finite element method and asymptotic techniques.

In order to determine the effective brightness temperature of the target, we have developed a numerical procedure to couple electromagnetic results with temperature distributions obtained by thermal simulations. To support the design process, electromagnetic properties of numerous microwave absorber materials have been experimentally assessed and evaluated. First breadboard targets were manufactured by Thomas Keating (UK) and have been tested in a specially developed quasi-optical measurement set-up at the IAP.

In addition, IAP is collaborating with TK Instruments and IABG in the development of the on-ground calibration targets for the ICI instrument. These will be used for the ground calibration and radiometric performance verification of the ICI instrument. These on-ground targets need to operate at cryogenic temperatures with an accurately controlled variable temperature, and they have to meet more challenging performance requirements than the flight targets.

Status

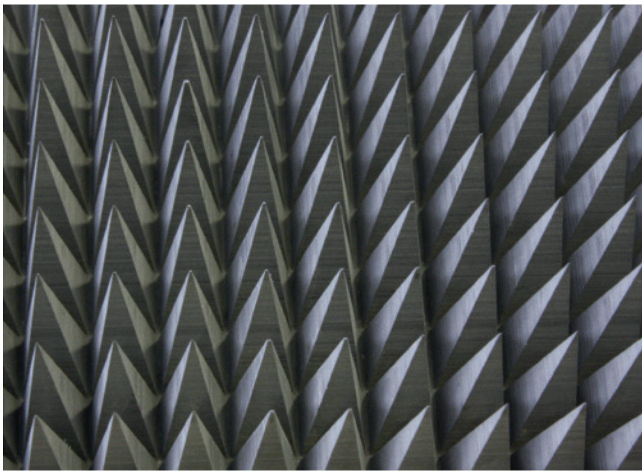
The contracts for the three projects were awarded in 2015. First prototypes of the ICI and MWS onboard targets have been manufactured and tested. The Preliminary Design Review is scheduled for June 2016.

Publications

1. Schröder, A. and A. Murk, (2015), 36th ESA Antenna Workshop on Antennas & RF Systems for Sp. Sci.

2. Murk, A. et al., (2016), 10th Euro. Conf. Antennas & Propagation.

Time-Line	From	To
Planning	2013	2015
Construction	2015	2016
Measurement Phase	2015	2018
Data Evaluation	2016	2019



Detail of a pyramidal calibration target prototype of ICI.

Institute

Institute Applied Physics (IAP), Univ. Bern

In Cooperation with

TK Instruments, UK
Airbus Space and Defence, UK
Airbus Space and Defence, Spain
IABG, Germany
European Space Agency

Swiss Principal Investigator

A. Murk (IAP)

Co-Investigators

A. Schröder
M. Kotirantat

Method

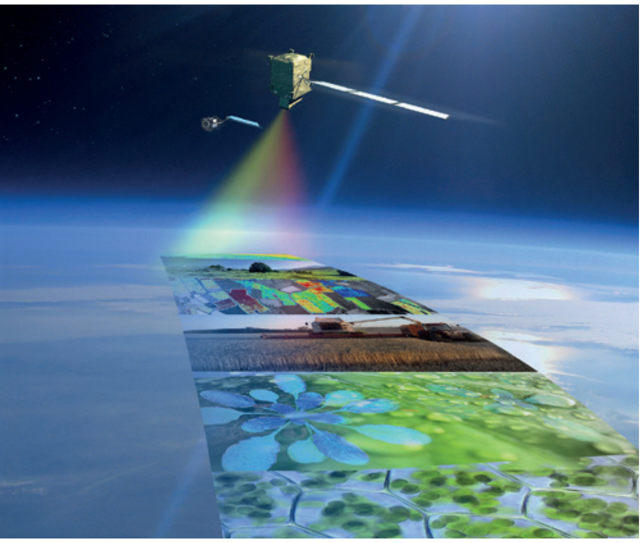
Simulation

Developments

Development and Construction of Instrument

Industrial Hardware Contract to

TK Instruments, UK



Mission concept of ESA's 8th Earth Explorer Mission FLEX (Fluorescence Explorer) © ESA/ATG medialab.

Institute

Remote Sensing Labs (RSL)
Dept. Geog., Univ. Zurich

In Cooperation with

ESA, Netherlands
Univ. Valencia, Spain
Forschungszentrum Jülich, Germany
CNR, Inst. Biometeorology, Italy
Lab. Meteorologie Dyn., France
P&M Technologies, Canada
Univ. Twente, Netherlands
Univ. Milano Bicocca, Italy
Univ. Helsinki, Finland
NASA Goddard, USA

Principal Investigator

J. Moreno

Method

Measurement

Development and Construction of Instruments

Development of the tandem satellite mission FLEX/Sentinel-3, and FLORIS (fluorescence imaging spectrometer).

7.8 FLEX – FLuorescence EXplorer Mission

Purpose of Research

The FLuorescence EXplorer satellite mission will map sun-induced chlorophyll fluorescence (SIF) emitted by vegetation at a global scale. SIF is the most direct measurement of photosynthesis at an ecosystem scale. Key objectives of FLEX are to measure several properties of emitted SIF signals, including:

i) SIF emitted around the two oxygen absorption features O2-A and O2-B,

ii) SIF emissions at the two emission peaks at 685 and 740 nm,

iii) total fluorescence integrated over the full emission spectrum, and

iv) the individual contributions from photosystem I and II.

The FLEX mission will have significant implications for ecosystem research and food security in the context of environmental change. SIF is a complementary measurement of vegetation status and health and offers new pathways to assess, e.g., ecosystem functioning, gas and energy exchanges of terrestrial ecosystems, as well as biodiversity.

Status

In November 2015, FLEX was selected for implementation as an outcome of ESA's user consultation meeting in Krakow, Poland. After several preparatory studies in the frame of Phase 0 of ESA's Earth Explorer 7 and Phase A/B1 of ESA's Earth Explorer 8 activities, FLEX has now entered Phase B2.

At the beginning of 2016, the FLEX Mission Advisory Group (MAG) was established. Together with eight other experts from European countries and Canada, Dr. Alexander Damm (Remote Sensing Laboratories, University of Zurich, Switzerland) has become a member of the MAG. The launch of FLEX is foreseen for 2022.

Publications

1. Kraft, S. et al., (2013), FLORIS: phase A status of the fluorescence imaging spectrometer of the Earth Explorer mission candidate FLEX. Proc. SPIE 8889, Sensors, Systems, and Next-Generation Satellites XVII, 8889, 88890T–88812.

2. ESA, (2015), Report for Mission Selection: FLEX. ESA SP-1330/2 (2 volume series), European Space Agency, Noordwijk, The Netherlands.

3. Rascher, U. et al., (2015), Sun-induced fluorescence – a new probe of photosynthesis: First maps from the imaging spectrometer HyPlant Global Change Biology, 21, 4673–4684.

Abbreviations

FLEX	FLuorescence EXplorer Mission
MAG	Mission Advisory Group
SIF	Sun-Induced chlorophyll Fluorescence

7.9 SEON – Swiss Earth Observatory Network

Purpose of Research

The Swiss Earth Observatory Network (SEON), funded by the Swiss University Conference and ETH-board, is a competence centre to monitor status and functioning of Swiss ecosystems in a changing environment. An increasing demand for natural resources impacts important biotic and physical processes within the Earth system and causes complex interactions within terrestrial ecosystems. SEON pursues a holistic Earth system science approach to assess environmental change impacts on ecosystem functioning and considers complex feedback mechanisms between the Earth's spheres, including the human impact.

Complex interactions between the Earth's spheres and underlying physical processes will be assessed using coupled models and observations in a holistic fashion. Backbones of SEON are state-of-the-art observatories, in-situ measurements, and models. The project consortium focuses on several research topics:

- Spatio-temporal quantification of ecosystem processes (i.e., NPP).
- Energy and gas exchange of terrestrial ecosystems.
- Resource utilization and efficiency of major crop species.
- Exchange processes of aquatic ecosystems and mapping of IOP/AOP.
- Air quality and atmospheric transport processes of NO_2.
- Dynamics of the cryosphere and monitoring of snow/ice parameters.
- Modelling trends of agricultural management and impact on soil functions.

SEON actively supports young academics and contributes to regular curricula to educate next-generation professionals in Earth system science.

Status

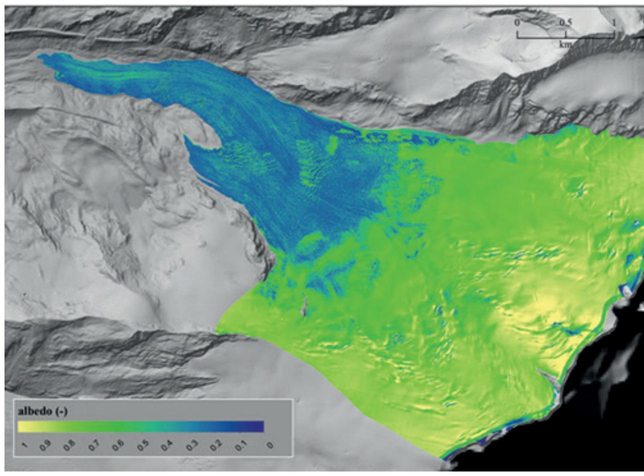
The SEON project started in January 2013. Selected Swiss ecosystems are monitored using the APEX imaging spectrometer and in-situ instrumentation. Since 2015, activities have also focussed on the integration of observations in process models and the assessment of policy relevant scales.

Publications

1. Damm, A. et al., (2015), Far-red sun-induced chlorophyll fluorescence shows ecosystem-specific relationships to gross primary production: An assessment based on observational and modeling approaches, Rem. Sens. Environ. 166, 91 – 105, DOI: 10.1016/j.rse.2015.06.004.

2. Naegeli, K. et al., (2015), Imaging spectroscopy to assess the composition of ice surface materials and their impact on glacier mass balance, Rem. Sens. Environ., 168, 388-402, DOI: 10.1016/j.rse.2015.07.006.

3. Schaepman, M. E. et al., (2015), Advanced radiometry measurements and Earth science applications with the Airborne Prism Experiment (APEX), Rem. Sens. Environ. 158, 207 – 219, DOI: 10.1016/j.rse.2014.11.014.



Spectral surface albedo of Findelen Glacier from APEX-HCRF data.

Institute

Remote Sensing Labs (RSL)
Dept. Geog., Univ. Zurich

In Cooperation with

Dept. Geowiss. – Alpine Cryos. Geomorph., Univ. Fribourg
Aquatic Physics, Eawag
Lab. Air Poll. Environ. Techn., EMPA
Inst. Agricultural Sci. – Grassland Science, ETH Zurich
Inst. Agricultural Sci. – Crop Science, ETH Zurich

Principal Investigator

M. E. Schaepman (RSL)

Co-Investigators

D. Brunner, N. Buchmann
A. Damm, M. Hoelzle
A. Walter, J. Wüest

Method

Measurement

Research Based on Existing Instruments

SEON is based on state-of-the-art airborne instrs. (APEX), optical satellite data, in-situ meas., process models.

European Gravity Service for Improved Emergency Management

7.10 EGSIEM – European Gravity Service for Improved Emergency Management

Institute

Astronomical Institute,
Univ. Bern (AIUB)

In Cooperation with

EGSIEM Consortium

Swiss Principal Investigator

A. Jäggi (AIUB)

Co-Investigators

U. Meyer
Y. Jean

Method

Measurement

Purpose of Research

Earth observation satellites yield a wealth of data for scientific, operational and commercial exploitation. However, the redistribution of environmental mass is not yet part of the standard Earth observation data products to date. These observations, derived from the Gravity Recovery and Climate Experiment (GRACE) mission and in the near future by GRACE-FO (follow-on), deliver fundamental insights into the global water cycle. Changes in continental water storage control the regional water budget and can, in extreme cases, result in floods and droughts that often claim a high toll on infrastructure, economy and human lives.

The aim of the European Gravity Service for Improved Emergency Management (EGSIEM) is to demonstrate that mass redistribution products open the door for innovative approaches to flood and drought monitoring and forecast.

The timeliness and reliability of information is the primary concern for any early-warning system. EGSIEM aims to increase the temporal resolution from one month, typical for GRACE products, to one day and to provide gravity field information within 5 days (near real–time).

Early warning indications derived from these products are expected to improve the timely awareness of potentially evolving hydrological extremes and to help in the scheduling of high-resolution follow-up observations.

EGSIEM will provide adequate data products and indicators for tentative integration into the work of the Center for Satellite Based Crisis Information (ZKI, operated by the German Aerospace Center) and its future use within international initiatives such as the Copernicus Emergency Management Service and the International Charter 'Space and Major Disasters'.

The performance of the EGSIEM products will be assessed with complementary data and post-processed mass products derived from the combined knowledge of the entire European GRACE community unified in the EGSIEM project. The EGSIEM effort culminates in three dedicated services:

1) A scientific combination service,

2) A near real–time service, and

3) A hydrological/early warning service.

Status

Starting in January 2015, EGSIEM has initated a unification of knowledge within the entire European GRACE community, in order to pave the way for a long-awaited standardisation of gravity-derived products. By combining the results obtained from different analysis centers belonging to the EGSIEM consortium, each of which use independent analysis methods but employ consistent processing standards, it is expected that the quality, robustness and reliability of these data can be significantly increased.

In addition, EGSIEM has started working to increase the temporal resolution from one month to one day.

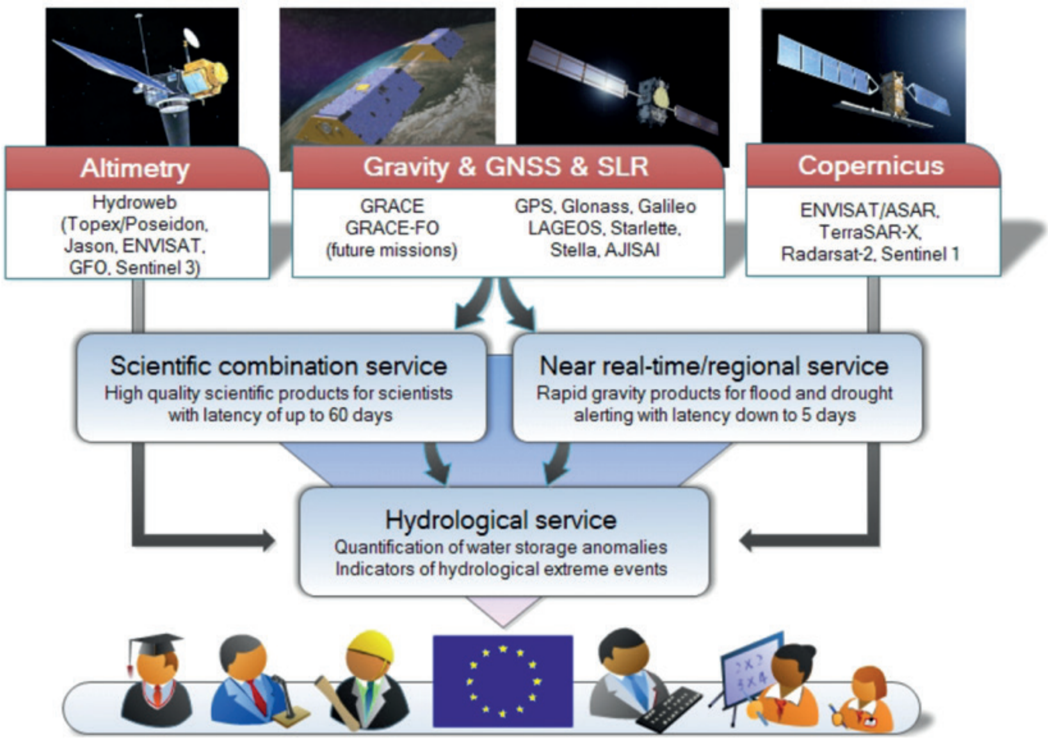
This is an essential step to provide gravity field information within five days (essentially near real-time) that will translate into tremendous added value for warning and forecasting the onset of natural hazards based on gravity-based indicators.

Publications

1. Jäggi, A., et al., (2015), European Gravity Service for Improved Emergency Management – Project Overview and First Results. AGU Fall Meeting 2015, San Francisco.

Abbreviations

EGSIEM	European Gravity Service for Improved Emergency Management
GNSS	Global Navigation Satellite Systems
GRACE	Gravity Recovery And Climate Experiment
SLR	Satellite Laser Ranging



General concept of EGSIEM: Satellite data from Altimetry, Gravity, GNSS, SLR and Copernicus missions will be used to create three services, all tailored to the needs of governments, scientists, decision makers, stakeholders and engineers. Special visualisation tools will be used to inform, update, and to also attract the wider public.

7.11 Relative Normalization of Multi-Sensor Remote Sensing Images with Machine Learning

Institute

MultiModal Remote Sensing (MMRS), Dept. Geography
Univ. Zurich-Irchel

In Cooperation with

Univ. València, Spain

Swiss Principal Investigator

D. Tuia (MMRS)

Co-Investigators

G. Camps-Valls (Univ. València)

M. Volpi (MMRS)

D. Marcos (MMRS)

Method

Simulation

Development of Software for

Open source software.

Purpose of Research

The MultiModal Remote Sensing (MMRS) Unit of the University of Zurich works together with the University of València to develop statistical methodologies making classification algorithms better: with this project, we aim to make classification models more robust to changes in illumination and atmospheric conditions, as well as making classifiers directly applicable when using different sensors.

This line of research offers several benefits. A classification model is always a tributary of a series of ground samples that are used to recognize the objects represented. But such examples provide spectral information that is dependent on the specific acquisition conditions (e.g. illumination, angle, atmospheric conditions), the seasonal effects (pheonological cycles) and the sensor specifications (e.g. number of bands, spectral bandpasses). Such dependencies make it difficult, if not impossible, to re-use ground samples on new image acquisition, reducing strongly the generalization of image classification algorithms. As a consequence, one should provide ground samples for each image or resort to unsupervised methodologies, which are known to be less accurate in remote sensing image classification. With such constraints, advanced classification algorithms have difficulties in entering the applications world.

This project develops methodologies derived from statistical learning, which aims at making the images more similar with respect to the types of land use they are observing. In other words, they modify (match, register) the spectral space in a way that a given type of crop, or a given ground material, shares a similar spectral response throughout all the acquisitions considered. The task is very challenging, especially in the case where the pixels are observed by different sensors (e.g. WorldView2 vs RGB aerial data). The outcome of the method is a relative normalization scheme that provides the image data in a projected space that is the same for all acquisitions and in which a single classification algorithm, valid to process all images, can be deployed.

The methodologies allow the following:

- Increase the value of field campaigns, since the data acquired can be reused to process images other than those acquired during the campaign.

- Increase the value of remote sensing data acquired, since it allows the generation of quality products for a higher number of image acquisitions (as of today most remote sensing images remain unused, and the lack of field campaign data is one of the reasons, among others).

- Offer a multimodal (multi-temporal, multi-resolution and multi-sensor) solution to timely applications such as post-catastrophe intervention, where analysts are often forced to perform manual damage detection, since they lack the image from the right sensor at the right time.

- Obtain more accurate classification models, since the proposed methodology allows the use of more ground data simultaneously and works irrespectively from the classifier employed after the relative data normalization.

Status

Linear and nonlinear normalization methods have been developed in MMRS, and have been applied to the tasks of multi-temporal very-high resolution classification, automatic shadow compensation on hyper-spectral images and multi-sensor classification (QuickBird to WorldView 2 and RGB to FCIR aerial data).

In all cases, the method was successful in the relative data normalization and allowed the use of the ground reference to process the newly acquired images.

Publications

1. Tuia, D., M. Volpi, M. Trolliet, and G. Camps-Valls, (2014), Semisupervised manifold alignment of multimodal remote sensing images, IEEE Trans. Geosci. Remote Sens., 52(12), 7708–7720.

2. Marcos Gonzalez, D., R. Hamid, and D. Tuia, (2016), Geospatial correspondence for heterogeneous domain adaptation, In Computer Vision and Pattern Recognition (CVPR), Las Vegas, NV.

3. Tuia, D. and G. Camps-Valls, (2016), Kernel manifold alignment for domain adaptation, PLoS One, 11(2):e0148655.

Abbreviations

FCIR	False Color Infra Red
MMRS	MultiModal Remote Sensing
RGB	Red green blue
UZH	University of Zurich

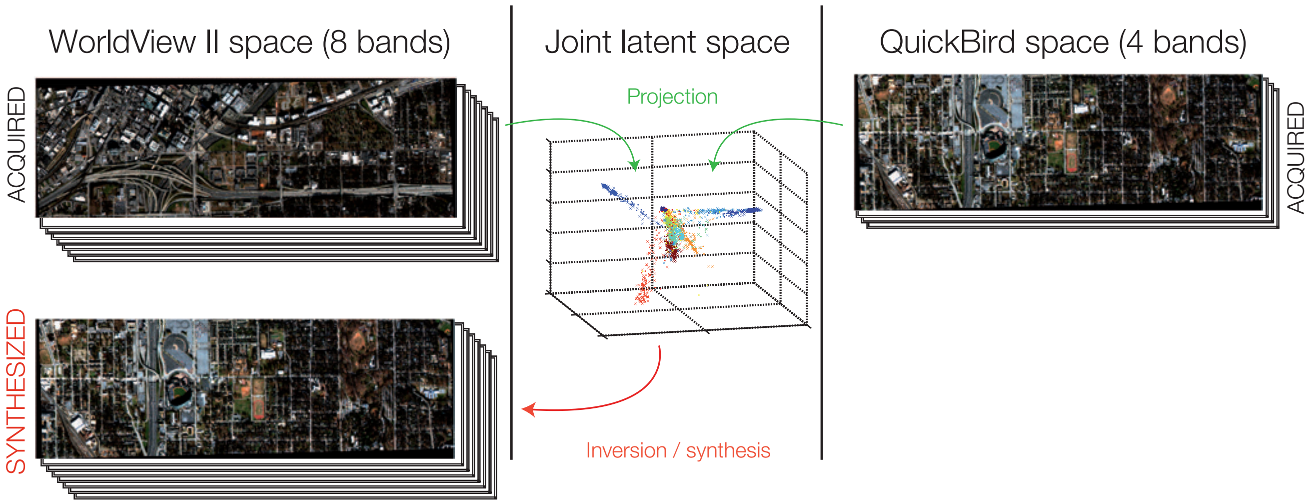


Illustration of the relative normalization strategy pursued in this project. In this example, a QuickBird image of Houston is aligned with a WorldView 2 image of another area of the city. The images are acquired at different time instants, by different sensors and represent non-overlapping areas.

8 Comets, Planets

Landing of the Philae probe on 67P/Churyumov-Gerasimenko.

Institute

Institute of Physics,
Univ. Bern (UNIBE)

In Cooperation with

ESA
MPS
TUB
BIRA
CESR
IPSL
LMM
UMich
SwRI

Principal Investigator

K. Altwegg (UNIBE)

Co-Investigators

H. Balsiger
A. Jäckel
E. Kopp
M. Rubin
P. Wurz

Method

Measurement

Industrial Hardware Contract to

Contraves (Ruag) Space
APCO
Montena etc.

8.1 ROSINA – Rosetta Orbiter Spectrometer for Ion and Neutral Analysis

Purpose of Research

In Summer 2014, the European Space Agency's Rosetta spacecraft arrived at comet 67P/Churyumov-Gerasimenko. Since then the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) has been continuously monitoring the gases emanating from the nucleus. ROSINA consists of two mass spectrometers and a pressure sensor that together have a high mass range, mass resolution, sensitivity, and time resolution (Balsiger et al., 2007).

ROSINA measures the elemental, molecular, and isotopic composition of the volatiles in the coma of the comet. These are crucial measurements used to improve our understanding of comets, and the conditions at the time when they, and our Solar System formed. This is particularly the case for comets which have remained far from the Sun for most of the time and therefore retained most of their volatiles as opposed to meteorites.

Status

Already early in the mission, the ROSINA team was able to derive the deuterium to hydrogen ratio in the cometary water. It is approximately 3 times the ratio of the water in the Earth's oceans, indicating that comets such as 67P/Churyumov-Gerasimenko are most likely not the major source of the water on Earth (Altwegg et al., 2015). ROSINA has furthermore detected, for the first time in comets, molecular oxygen (Bieler et al., 2015a), molecular nitrogen (Rubin et al., 2015), and the noble gas argon (Balsiger et al., 2015) directly in the coma of a comet. These investigations are important to constrain models of how our Solar System formed, including the origin of volatiles in the atmosphere of the Earth (Marty et al., 2016).

ROSINA data also show that the coma of the comet is remarkably diverse even far from the Sun, and contains almost all volatiles detected in comets so far (Le Roy et al., 2015). The composition of the gases varies strongly with the illumination conditions on the nucleus and therefore the comet's atmosphere exhibits strong seasonal variations, depending on whether the spacecraft crosses over the summer or the winter hemisphere (Bieler et al., 2015b; Hässig et al., 2015).

Future Observations

ROSINA investigations will carry on up until the end of the mission in September 2016 when the Rosetta orbiter will smoothly land on the surface of the nucleus almost two years after the lander Philae in November 2014.

Abbreviations

ROSINA — Rosetta Orbiter Sensor for Ion and Neutral Analysis

Time-Line	From	To
Planning	1995	1996
Construction	1996	2002
Measurement Phase	launch 2004, asteroid flyby's 2008 & 2010	
Comet phase	2014	2016
Data Evaluation	2014	ongoing

Publications

1. Balsiger, H. et al., (2007), ROSINA–Rosetta Orbiter Spectrometer for Ion and Neutral Analysis, Space Sci. Revs., 128, 745–801.

2. Altwegg, K. et al., (2015), 67P/Churyumov-Gerasimenko, a Jupiter family comet with a high D/H ratio, Science, 347, 1261952.

3. Balsiger, H. et al., (2015), Detection of argon in the coma of comet 67P/Churyumov-Gerasimenko, Sci. Adv., 1, e1500377.

4. Bieler, A. et al., (2015a), Abundant molecular oxygen in the coma of comet 67P/Churyumov-Gerasimenko, Nature, 526, 678–681.

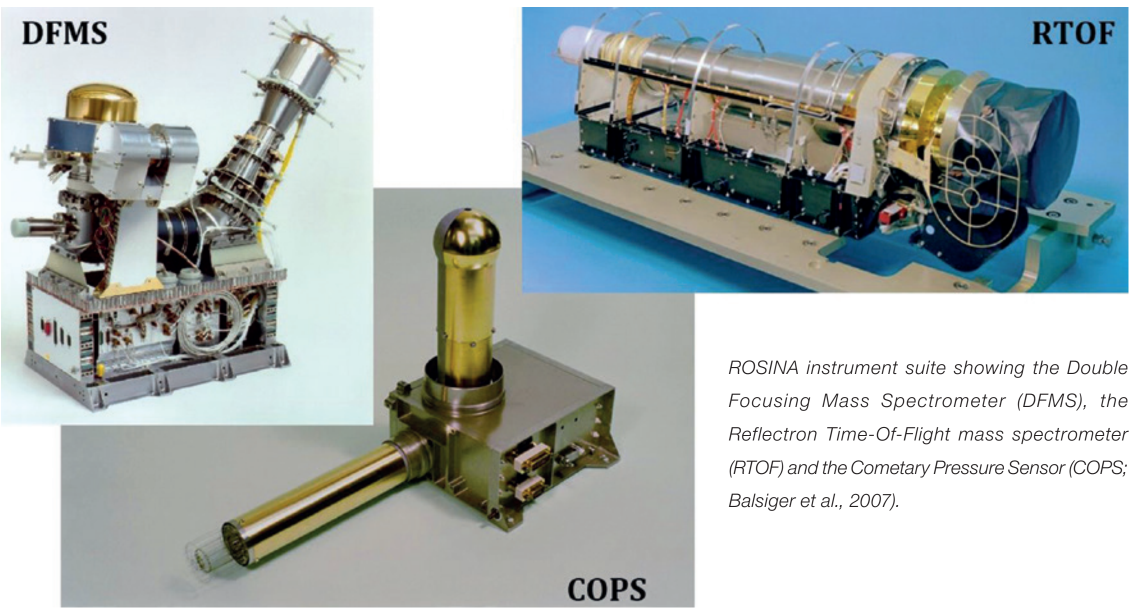
5. Bieler, A. et al, (2015b), 3D kinetic and hydrodynamic modeling of the neutral coma of 67P/Churyumov-Gerasimenko, A & A.

6. Hässig, M. et al., (2015), Time variability and heterogeneity in the coma of 67P/Churyumov-Gerasimenko, Science, 347, aaa0276.

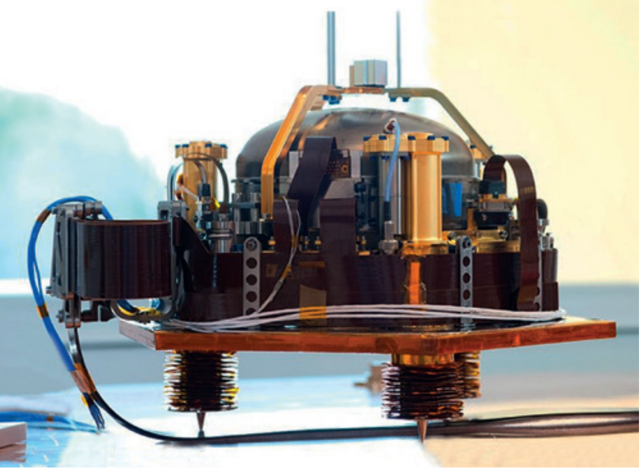
7. Le Roy, L. et al., (2015), Inventory of the volatiles on comet 67P/Churyumov-Gerasimenko from Rosetta/ROSINA. A & A., 583, A1 (12).

8. Rubin, M. et al., (2015), Molecular nitrogen in comet 67P/Churyumov-Gerasimenko indicates a low formation temperature, Science, 348, 232–235.

9. Marty, B. et al., (2016), Origins of volatile elements (H, C, N, noble gases) on Earth and Mars in light of recent results from the ROSETTA cometary mission, Earth Planet. Sci. Lett., 441, 91–102.



ROSINA instrument suite showing the Double Focusing Mass Spectrometer (DFMS), the Reflectron Time-Of-Flight mass spectrometer (RTOF) and the Cometary Pressure Sensor (COPS; Balsiger et al., 2007).



SEIS sensor assembly during integration at CNES.

Institute

Inst. Geophysics,
ETH Zurich (ETHZ)

In Cooperation with

Inst. Physique du Globe,
Paris, France

Imperial College,
London, England

MPS, Göttingen,
Germany

Jet Propulsion Lab.,
Pasadena, USA

Principal Investigator

P. Lognonné
(Inst. Physique du Globe, Paris)

Swiss Principal Investigator

D. Giardini (ETHZ)

8.2 Seismometer Instrument for NASA InSight Mission

Purpose of Research

The SEIS instrument (Seismic Experiment for Interior Structure) onboard the NASA Mars mission InSight (Interior exploration using Seismology, Geodesy, and Heat Transfer) will advance the planetary seismometry beyond the Viking experiments with a much higher sensitivity over a broader frequency band. SEIS will measure seismic waves traveling through the interior structure and composition of the planet Mars. The science objectives are defined as follows:

1. Understand the formation and evolution of the terrestrial planets through investigation of the interior structure and processes of Mars.

• Determine the size, composition, physical state (liquid/solid) of the core.

• Determine the thickness and structure of the crust.

• Determine the composition and structure of the mantle.

2. Determine the present level of tectonic activity and impact rate at Mars.

• Measure the magnitude, rate and geographical distribution of internal seismic activity.

• Measure the rate of meteorite impacts on the surface.

The InSight Lander will carry three instruments to the surface of Mars to take the first-ever in-depth look at the planet's 'vital stats': its pulse, or internal activity, as measured by the SEIS instrument; its temperature as measured by the HP3 instrument; and its reflexes as measured by the RISE instrument. Together, the data will provide essential clues about the evolution of not just Mars, but also all the terrestrial planets. The mission is under the lead of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, USA, and the SEIS instrument is under the lead of CNES (Centre National d'Etudes Spatiales) in Toulouse, France.

The SEIS instrument consists of two 3-axial sensor assemblies mounted on a leveling mechanism: a 3-axis very broad-band (VBB) oblique seismometer, and an independent 3-axis short period (SP) seismometer. In addition, it comprises a wind-shield and acquisition and control electronics. The Inst. Geophysics, ETH Zurich is in charge of:

• The electronics box, which consists of all electronics including the modules of the partners.

• The provision of the acquisition and control electronics, which continuously acquires the seismic sensor ouputs and a set of house-keeping signals, which controls the leveling-mechanism of the instrumentas well as the sensor configuration and re-centering.

• The power-conditioning electronics for the whole instrument.

The SEIS acquisition and control electronics are redundantly built as SEIS is the InSight core instrument, providing most of the scientific return, and is therefore mission critical. It is built by Syderal SA, and has been delivered to CNES in Toulouse for SEIS instrument integration. The Swiss Seismological Service at ETH Zurich will take the lead role in building a catalogue of seismic events recorded by SEIS (the "Mars Quake Service") during the mission. This service will comprise automatic and reviewed event detection and characterization of local and teleseismic events, as well as meteor impacts. The goal of this service is to provide a comprehensive high-quality event catalogue for Mars that is critical to the SEIS project, in particular as input to the development of Martian deep structure models. Furthermore, the Institute of Geophysics has an active research team engaged in modelling planetary structure.

Status

The InSight mission was selected by NASA in 2012 in the frame of the NASA Discovery Program. The original launch date was 4 March 2016 but unfortunately could not be kept because of a persisting technical problem with the vacuum enclosure of the VBB seismic sensor, which could not be fixed after several attempts. InSight is now targeting a new launch window from May 2018 onwards, with a Mars landing scheduled for 26 November 2018. Under a challenging schedule, the Swiss contribution (the electronics box flight hardware) was delivered in March 2015 to CNES for further instrument integration. Apart from the flight electronics, a qualification model (QM), an electrical model (ELM) and a hardware simulator (Simu-SEIS) were delivered to CNES and JPL/Lockheed Martin. The ELM is used in the Spacecraft Test Lab for flight software (FSW) validation. The QM was integrated on the lander in order to support the Assembly, Test and Launch Operations (ATLO) process. Simu-SEIS is used to validate FSW with respect to certain instrument processes (re-centering of the sensors, leveling of the sensors). In view of the new 2018 launch window, replanning and risk assessment activities are ongoing, and in addition some improvements are being considered. JPL will redesign, build and conduct qualifications of the new SEIS vacuum enclosure, the component that failed in December. CNES will lead instrument level integration and test activities. The ETHZ instrument team will support the integration activities with its expertise on the electronics functionalities and performance.

Publications

1. Dandonneau, P-A. et al., (2013), The SEIS InSight VBB Experiment, 44th Lunar and Planetary Sci. Conf.

2. Böse, M., et al., (2016), A probabilistic framework for single-station location of seismicity on Earth and Mars (to be submitted GJI).

3. Khan, A., et al., (2016), Single-station and single-event marsquake location and inversion for structure using synthetic Martian waveforms (submitted to PEPI).

Abbreviations

ATLO	Assembly, Test and Launch Operations
ELM	Electrical Model
FSW	Flight Software
QM	Qualification Model
SEIS	Seismic Exp. Interior Struct.

Time-Line	From	To
Planning	2010	2012
Construction	Sep. 2012	Mar. 2015
Measurement Phase	Nov. 2018	Oct. 2020
Data Evaluation	Nov. 2018	> 2020

Co-Investigators

J. Clinton
D. Mance
P. Zweifel

Method

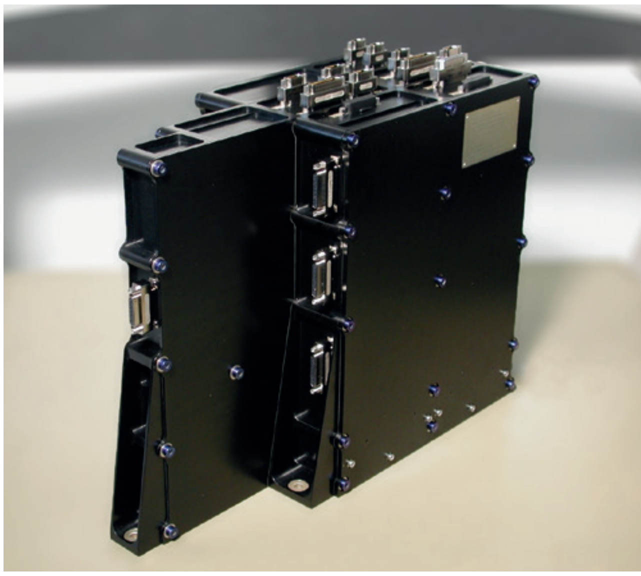
Measurement

Development and Construction of Instruments

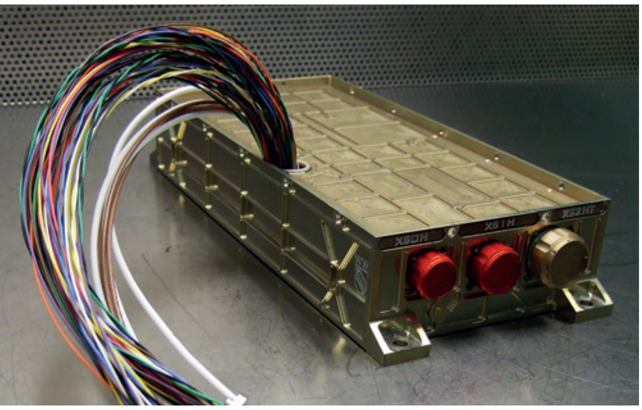
Electronics box, including instrument power conditiong and acquisition and control electronics for the SEIS instrument onboard of NASA's InSight mission.

Industrial Hardware Contract to

Syderal SA, Gals



The Electronics Box was designed and built by Syderal SA in Gals. The picture shows the qualification model without cabling. The connections on top and on the side are towards the various sub-systems and sensors and to the lander units (power and communication). The shape of the Ebox is predetermined by the available triangular footprint in the lander's heated compartment.



LASMA Engineering Model.

8.3 Investigation of the Chemical Composition of Lunar Soils (Luna-Glob and Luna-Resurs Missions)

Institute

Space Research and Planetology, Physics Inst., Univ. Bern (UNIBE)

In Cooperation with

Inst. Sp. Res., IKI, Moscow, Russia, (G. Managadze, A. Chumikov)

Principal Investigators

G. Managadze
P. Wurz (Co-PI, UNIBE)

Swiss Principal Investigator

P. Wurz (UNIBE)

Co-Investigator

M. Tulej

Method

Measurement

Development and Construction of Instruments

Laser ablation mass spectrometer, LASMA, for direct measurements of elemental composition of solid materials.

Industrial Hardware Contract to

WaveLab Engineering AG
Montena Technology SA
nanoTRONIC GmbH

Purpose of Research

The Russian Space Agency will launch two landers to land on the lunar South and North Poles, Luna-Glob and Luna-Resurs.

LASMA, a laser ablation mass spectrometer, which is part of the scientific payload of both landers, will perform direct elemental analysis of soil samples collected in the vicinity of the spacecraft landing site and from the sub-surface (Luna-Resurs only). Elemental and isotopic analysis will be performed on 12 soil samples.

Status

Spacecraft and scientific instruments are currently under development. Launch of Luna-Glob is forseen for mid–2019, and Luna-Resurs will launch in 2022. Instrument development is ongoing.

The LASMA instrument is a further development of the LASMA instrument that was part of the Phobos–Grunt mission.

Publications

1. Rohner, U., J. Whitby, P. Wurz, and S. Barabash, (2004), A highly miniaturised laser ablation time-of-flight mass spectrometer for planetary rover, Rev. Sci. Instr., 75(5), 1314–1322.

2. Wurz, P., D. Abplanalp, M. Tulej, M. Iakovleva, V. A. Fernandes, A. Chumikov, and G. Managadze, (2012), Mass spectrometric analysis in planetary science: Investigation of the surface and the atmosphere, Sol. Sys. Res., 46, 408–422.

3. Tulej, M., A. Riedo, M. B. Neuland, S. Meyer, D. Lasi, D. Piazza, N. Thomas, and P. Wurz, (2014), A miniature instrument suite for in situ investigation of the composition and morphology of extraterrestrial materials, Geostand. Geoanalyt. Res., 38, 441–466.

Abbreviations

LASMA	Laser Ablation Mass Spectrometer

Time-Line	From	To
Planning	Sep. 2010	Feb. 2011
Construction	Mar. 2011	Sep. 2015
Measurement Phase	2019	2022
Data Evaluation	2019	2024

8.4 Investigation of the Volatiles Contained in Lunar Soils (Luna-Resurs Mission)

Purpose of Research

The Russian Space Agency will launch a lunar lander to land on the lunar South Pole, Luna-Resurs. The gas-chromatography mass spectrometer complex, GC-MS, which is part of the scientific payload of this lander, will perform detailed investigations of the volatile content of soil samples collected in the vicinity of the spacecraft landing site and from the sub-surface by means of a drill.

The GC-MS consists of a thermal differential analyser, a gas chromatograph and a Neutral Gas Mass Spectrometer (NGMS), which is provided by the University of Bern.

Status

Spacecraft and scientific instruments are currently under development. Launch of Luna-Resurs is forseen for 2022. Instrument development is ongoing. The NGMS is based on an ealier design used for stratospheric research.

Publications

1. Abplanalp, D., P. Wurz, L. Huber, I. Leya, E. Kopp, U. Rohner, M. Wieser, L. Kalla, and S. Barabash, (2009), A neutral gas mass spectrometer to measure the chemical composition of the stratosphere, Adv. Space Res., 44, 870–878.

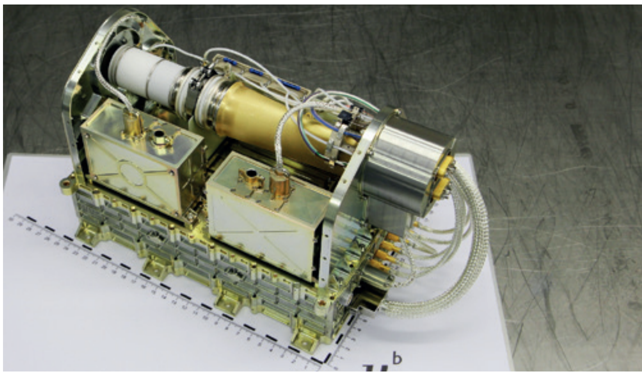
2. Wurz, P., D. Abplanalp, M. Tulej, and H. Lammer, (2012), A neutral gas mass spectrometer for the investigation of lunar volatiles, Planet. Sp. Science, 74, 264–269.

3. Hofer, L., P. Wurz, A. Buch, M. Cabane, P. Coll, D. Coscia, M. Gerasimov, D. Lasi, A. Sapgir, C. Szopa, and M. Tulej, (2015), Prototype of the gas chromatograph – mass spectrometer to investigate volatile species in the lunar soil for the Luna-Resurs mission, Plant. Sp. Sci., 111, 126–133.

Abbreviations

NGMS	Neutral Gas Mass Spectrometer

Time-Line	From	To
Planning	Sep. 2010	Jun. 2011
Construction	Jul. 2011	Jun. 2017
Measurement Phase	2022	2022
Data Evaluation	2022	2024



NGMS Engineering Model for Luna-Resurs.

Institute

Space Research and Planetology
Inst. Physics, Univ. Bern (UNIBE)

In Cooperation with

Inst. Sp. Res., IKI, Moscow, Russia,
(M. Gerasimov, A. Sapgir, D. Rodinov)
Univ. Pierre, Marie Curie, Paris, France
(M. Cabane, D. Coscia)

Principal Investigators

M. Gerasimov, P. Wurz (UNIBE)

Swiss Principal Investigator

P. Wurz (UNIBE)

Co-Investigators

M. Tulej, L. Hofer

Method

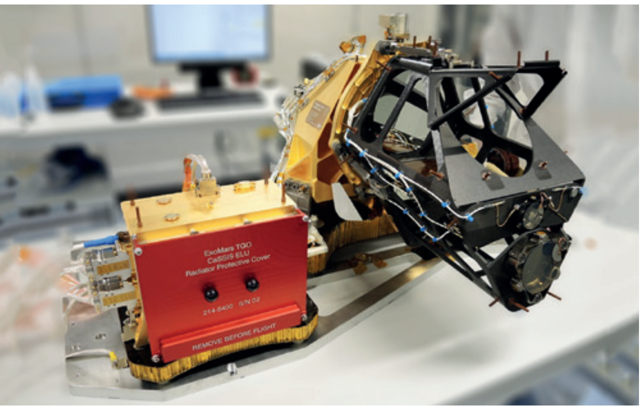
Measurement

Development and Construction of Instruments

NGMS to measure the chemical composition of volatiles.

Industrial Hardware Contract to

EMPA
WaveLab Engineering AG
nanoTRONIC GmbH
Montena Technology SA



CaSSIS Flight Model

Institute

Space Research and Planetology, Inst. Physics, Univ. Bern (UNIBE)

In Cooperation with

Astr, Obs., Padova, Italy
Sp. Res. Center, Warsaw, Poland

Swiss Principal Investigator

N. Thomas (UNIBE)

Co-Investigators

26 scientists from Europe and the US

Method

Measurement

Development and Construction of Instruments

Construction of the high resolution imager for the ExoMars Trace Gas Orbiter launched on 14 March 2016.

Industrial Hardware Contract to

RUAG Space, Zurich

8.5 CaSSIS – The Colour and Stereo Surface Imaging System on the ExoMars Trace Gas Orbiter

Purpose of Research

CaSSIS has three main science objectives.

1. Image and analyse surface features possibly related to trace gas sources and sinks in order to better understand the broad range of processes that might be related to trace gases.

The science team will compile and prioritize a list of observation targets needed to test specific hypotheses concerning active surface processes on Mars. This objective will be addressed early on in the mission, prior to new trace-gas discoveries from the ExoMars Trace Gas Orbiter (EMTGO). Unusual or changing colours indicate active processes, perhaps linked to methane formation or release.

2. Map regions of trace gas origin as determined by other experiments to test hypotheses.

EMTGO experiments are designed to discover trace gases and study atmospheric dynamics to track the gases back to their source regions (perhaps tens of km). Once these discoveries are made (if that goal is realized), CaSSIS will place top priority on imaging these regions to formulate and test specific hypotheses for the origin and/or release of trace gases.

3. Search for and help certify the safety of new candidate landing sites driven by EMTGO discoveries.

The discovery of methane has helped stimulate exploration plans in Europe and the U.S. A portion of NE Syrtis Major has recently been approved for priority MRO coverage as a candidate landing site for the Mars Science Laboratory; this site is at the margin of the Syrtis Major methane plume . It is likely that the pair of NASA/ESA landers in 2021 will also consider methane areas for landing sites.

At the workshop 'Habitability and Landing Sites' the surfaces associated with methane plumes were identified as high priority exploration targets. However, the best locations will presumably be found by EMTGO, and MRO/HiRISE may or may not be able to certify new landing sites post 2017. Although CaSSIS cannot identify meter-scale hazards, it can provide the 5 m scale slope information needed to complete certification of thousands of locations imaged by HiRISE, but not in stereo.

Status

CaSSIS was delivered in Nov. 2015 and EMTGO launched on 14 March 2016. Currently awaiting switch-on.

Abbreviations

CaSSIS	The Colour and Stereo Surface Imaging System
EMTGO	ExoMars Trace Gas Orbiter
HiRISE	High Resolution Imaging Science Experiment
MRO	Mars Reconnaissance Orbiter

Time-Line	From	To
Planning	Aug. 2010	Oct. 2013
Construction	Oct. 2013	Nov. 2015
Measurement Phase	Apr. 2016	Dec. 2019
Data Evaluation	Jun. 2017	Dec. 2020

8.6 BepiColombo

Composition of Crust, Exosphere, Surface Evolution, Formation and Evolution of Planet Mercury

Purpose of Research

ESA has defined the Cornerstone Mission, named BepiColombo, for the detailed exploration of planet Mercury. Because of observational difficulties ,Mercury is a largely unknown planet and therefore a high scientific return is expected from such an exploratory mission. The launch of BepiColombo is foreseen in April 2018 and the transfer to Mercury will take until 2022. Thus the dataphase will start in December 2024 at the earliest, and will last for one year with a possible extension of another.

The University of Bern is participating in the BepiColombo mission, as part of an international collaboration, by developing two mass spectrometers. The first mass spectrometer is on the BepiColombo/MMO spacecraft to perform Energetic Neutral Atom (ENA) imaging of the space around Mercury. The second instrument will go on the BepiColombo/MPO spacecraft to measure the elemental, chemical, and isotopic composition of Mercury's exosphere with a sensitive neutral gas mass spectrometer. These two instruments will make a substantial contribution to three out of the six main scientific goals set for BepiColombo.

The Univ. Bern is participating in two instruments: 1) SERENA on the BepiColombo/MPO spacecraft, for which Bern provides substantial hardware for the STROFIO mass spectrometer and for the MIPA ion sensor, and 2) The MPPE package on the BepiColombo/MMO spacecraft, for which Bern provides substantial hardware for the ENA instrument.

Status

The BepiColombo spacecraft are currently under development with a launch scheduled for 2018. Scientitifc instruments were delivered for integration on the spacecraft in Autumn 2014.

Publications

1. Wurz P. and H. Lammer, (2003), Monte-Carlo simulation of Mercury's exosphere, Icarus, 164(1), 1–13.

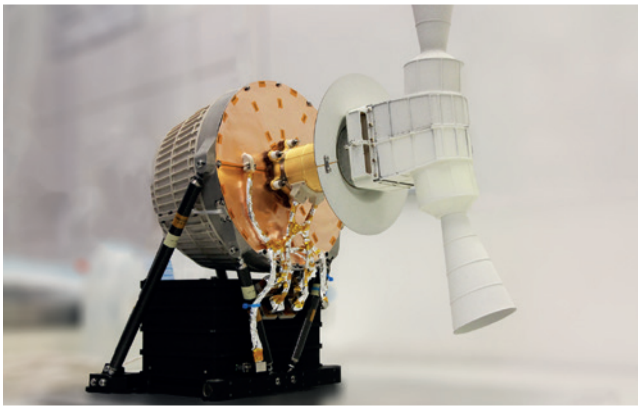
2. Wurz, P. et al., (2010), Self-consistent modelling of Mercury's exosphere by sputtering, micro-meteorite impact and photon-stimulated desorption, Planet. Sp. Sci., 58, 1599–1616.

3. Pfleger, M. et al., (2015), 3D-modeling of Mercury's solar wind sputtered surface-exosphere environment, Planet. Sp. Sci., 115, 90–101.

Abbreviations

ENA	Energetic Neutral Atom	MIPA	Mini. Ion Precip. Analyz.
MMO	Mercury Magnetosph. Orb.	MPO	Mercury Plan. Orbiter
MPPE	Mercury Plasma Particle Exp.		
SERENA	Search Exopheric Refilling and Emitted Natural Abundances		
STROFIO	Start from a Rotating FIeld mass spectrOmeter		

Time-Line	From	To
Measurement Phase	2024	2026
Data Evaluation	2024	2030



The STROFIO instrument (part of SERENA experiment) on BepiColombo.

Institute

Space Research and Planetology
Inst. Physics, Univ. Bern (UNIBE)

In Cooperation with

Inst. Fisica Sp. Interpl., Rome, Italy (S. Orsini, A. Milillo)
Swed. Sp. Res. Inst., Kiruna, Sweden (S. Barabash, M. Wieser)
SwRI, San Antonio, USA, (S. Livi)

Principal Investigators

S. Orsini
S. Barabash

Swiss Principal Investigator

P. Wurz (UNIBE)

Co-Investigator

A. Vorburger

Method

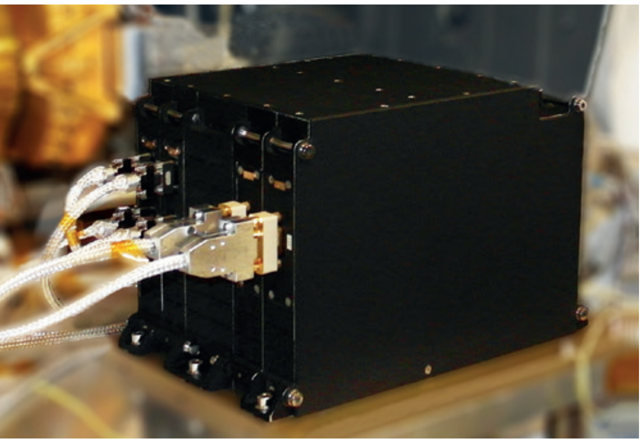
Measurement

Development and Construction of Instruments

SERENA and MPPE instruments

Industrial Hardware Contract to

EMPA, Rekolas, Sulzer Innotec, SWSTech AG



BepiColombo Laser Altimeter (BELA).

Institute

Space Research and Planetology, Inst. Physics, Univ. Bern (UNIBE)

In Cooperation with

DLR Institute for Planetary Research (DLR), Berlin, Germany

MPS, Göttingen, Germany

IAA, Granada, Spain

Principal Investigators

N. Thomas (Co-PI, UNIBE)
T. Spohn (Co-PI)

Swiss Principal Investigator

N. Thomas (UNIBE)

Co-Investigators

30 leading geophysicists from Europe

Method

Measurement

Industrial Hardware Contract to

RUAG Space, Syderal
FISBA Optik,
Cassidian Optronik, Germany,
CRISA, Spain

8.7 BELA – BepiColombo Laser Altimeter

Purpose of Research

BepiColombo laser altimeter (BELA) is a joint Swiss-German project with a smaller involvement from Spain. The scientific objectives of the experiment are to measure the:

- Figure parameters of Mercury to establish accurate reference surfaces.
- Topographic variations relative to the reference figures and a geodetic network based on accurately measured positions of prominent topographic features.
- Tidal deformations of the surface.
- Surface roughness, local slopes and albedo variations, also in permanently shaded craters near the poles.

BELA will form an integral part of a larger geodesy and geophysics package, incorporating radio science and stereo imaging. Although stand-alone instruments in their own right, only the synergy between these will make full use of current technology and their scientific potential.

The synergy will cover the problems of planetary figure and gravity field determination, interior structure exploration, surface morphology and geology, and extend to the measurement of tidal deformations. The reference surfaces and the geodetic network will provide the coordinate system for any detailed exploration of the surface with respect to geological, physical, and chemical scientific questions.

The topography is needed to develop digital terrain models that allow quantitative explorations of the geology, the tectonics, and the age of the planet surface. The topography is further needed for a reduction of the gravity field data because topographical contributions to gravity must first be removed before using gravity anomalies for the investigation of sub-surface structures.

The use of topography together with gravity data will constrain, by an admittance analysis between the two and with the help of a lithosphere flexure model, lithosphere and crust properties. Examples here would include the lithosphere elastic thickness (essential for the reconstruction of the thermal history of Mercury) and the crustal density (essential for the construction of a Hermean internal model).

In addition to the moments of inertia which will be provided by the radio science experiment, the tidal deformations measured by BELA and the radio science instrument will place further constraints on global models of the interior structure.

BELA will contribute by providing the deformation of the surface while the

Time-Line	From	To
Planning	2004	2008
Construction	2008	2016
Measurement Phase	2024	2026
Data Evaluation	2024	2028

radio science package will measure the mass relocations. Under favourable conditions, it will even be possible to constrain the rheology of the interior of the planet by measuring the time lag between the motion of the tidal bulge and the disturbing potential.

The instrument (see Figure) comprises a transmitter producing a 50 mJ laser pulse at 1064 nm. The laser passes through a beam expander to collimate the beam before exiting to the planet through a baffle. The return pulse is captured by a 20 cm beryllium telescope which is protected by a novel reflective baffle.

The light then passes through a transfer optic containing a 1064 nm filter before collection on an avalanche photodiode detector. Conversion to a range is performed using time-of-flight electronics within an electronics box which also houses the instrument computer and power supply.

Status

The EM, STM and EQM programmes have been completed. Construction of the Flight Model is in progress.

Publications

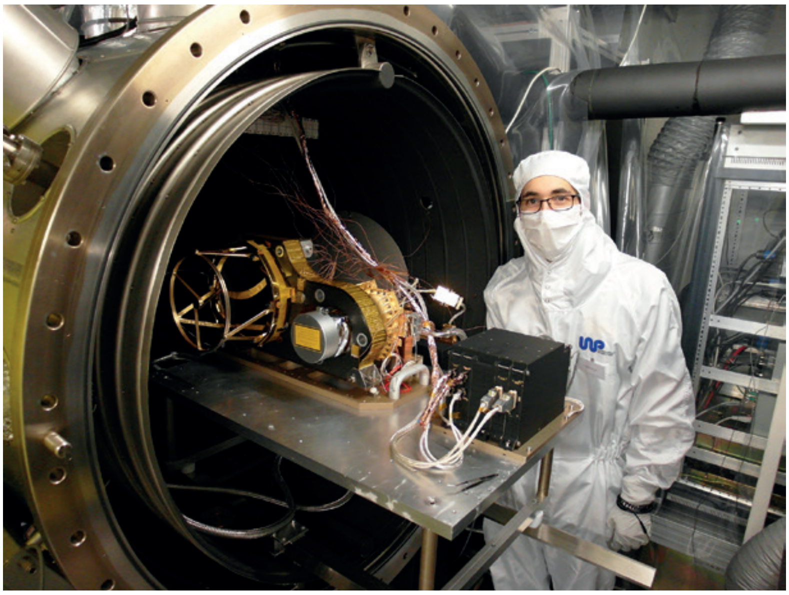
1. Seiferlin, K., et al., (2007), Design and manufacture of a lightweight reflective baffle for the BepiColombo laser altimeter, Opt. Eng., 46(4), 043003-1.

2. Thomas, N., et al., (2007), The BepiColombo Laser Altimeter (BELA): Concept and baseline design, Planet. Sp. Sci., 55, 1398–1413.

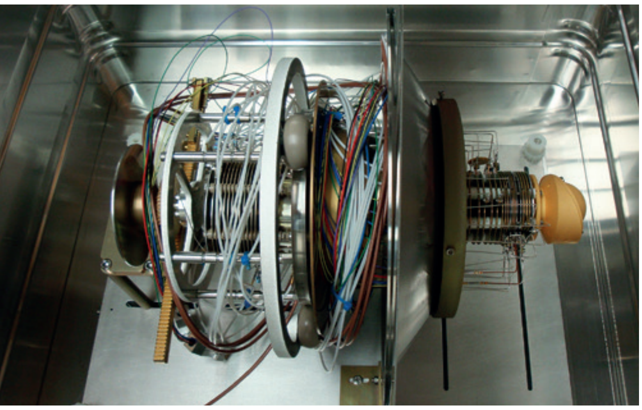
3. Gunderson, K. and N. Thomas, (2010), BELA receiver performance modeling over the BepiColombo mission lifetime, Planet. Sp. Sci., 58, 309–318.

Abbreviations

BELA	BepiColombo Laser Altimeter
EQM	Engineering Qualification Model
STM	Structural Thermal Model



The BELA EQM instrument in the thermal vacuum chamber at the University of Bern. To the top, the beryllium telescope structure can be seen mounted to the optical bench (an aluminium honeycomb). In the foreground, the laser head box is mounted to the same optical bench. The electronics unit specifically for the laser electronics is to the lower right. The necessary baffles for the telescope and the laser are not mounted in this configuration.



NIM prototype stored in transport container.

8.8 PEP – Particle Environment Package on JUICE

Institute

Space Research and Planetology, inst. Physics, Univ. Bern (UNIBE)

In Cooperation with

Swedish Space Research Institute, (SSRI), Kiruna, Sweden
Appl. Phys. Lab., John Hopkins Univ. Laurel, USA
MPS, Göttingen, Germany
FMI, Helsinki, Finland
Univ. Wales, Aberystwyth, Wales, UK

Principal Investigators

S. Barabash (SSRI)
P. Wurz (Co-PI, UNIBE)

Swiss Principal Investigator

P. Wurz (UNIBE)

Co-Investigators

A. Galli N. Thomas
M. Tulek A. Vorburger

Method

Measurement

Development and Construction of Instruments

NIM instr. for PEP experiment.

Purpose of Research

The European Space Agency selected the JUICE mission as an L – class mission to explore Jupiter and its icy moons in great detail, with particular emphasis on the moon Ganymede. The Particle Environment Package (PEP) investigates all particle populations in Jupiter's magnetosphere and at its moons in the energy range from thermal energies to beyond MeV.

The Neutral and Ion Mass spectrometer (NIM) will measure the chemical composition of the neutral atmospheres of the icy moons and their thermal ion population. JUICE is scheduled for launch in May 2022 and will arrive in the Jupiter system in 2030.

Status

The JUICE mission is currently in the implementation phase. The JUICE mission was adopted by ESA in November 2014, and the industrial prime was selected in July 2015. PEP is one of the 10 selected science experiments for the JUICE missions.

The Swedish Institute for Space Physics is the PI institution, while the University of Bern is the Co-PI institution for this experiment. The PEP experiment and the NIM instrument development are ongoing.

Publications

1. Vorburger, J. A., et al., (2015), Monte-Carlo simulation of Callisto's exosphere, Icarus, 262, 14–29.
2. Wurz, P., et al., (2014), Measurement of the atmospheres of Europa, Ganymede, and Callisto, European Planetary Science Congress 2014, EPSC Vol. 9, id. EPSC2014-504.

Abbreviations

JUICE	Jupiter and Icy Moons Explorer
NIM	Neutral and Ion Mass Spectrometer
PEP	Particle Environment Package

Time-Line	From	To
Planning	Oct. 2012	Feb. 2014
Construction	Mar. 2014	Jun. 2021
Measurement Phase	Jan. 2030	Jul. 2033
Data Evaluation	2030	2036

8.9 SWI – Submillimeter Wave Instrument on JUICE

Purpose of Research

The JUpiter ICy moons Explorer (JUICE) is an L-class mission of the ESA Cosmic Vision 2015–2025 program to investigate Jupiter and its Galilean satellites as planetary bodies and potential habitats for life.

The Submillimeter Wave Instrument (SWI) on JUICE will study the chemical composition, wind speeds and temperature variability of Jupiter's atmosphere, as well as the exosphere and surface properties of its icy moons.

SWI consists of two heterodyne receivers tuneable between 530–630 GHz and 1080–1280 GHz. It includes different high resolution and broadband spectrometers, and a steerable off-axis telescope with a 30 cm aperture.

The Institute of Applied Physics is responsible for the optical design of the instrument, for the development of the optical components in the receiver unit, and for the onboard calibration target. In addition IAP is conducting the radiometric performance tests of the SWI Receiver Unit and planar near-field antenna measurements of the telescope.

Status

The SWI instrument is currently in Phase B2 with a Preliminary Design Review (PDR) date in October 2016. The JUICE mission is scheduled for launch in 2022.

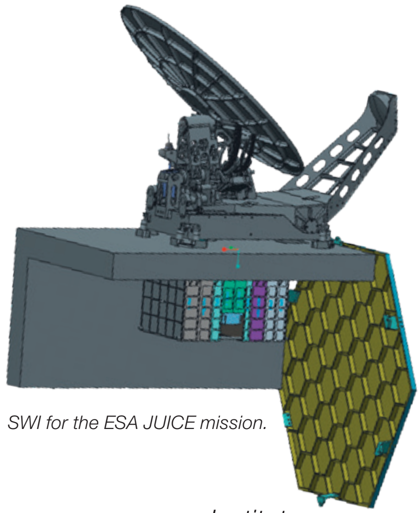
Publications

1. Jacob, K., A. Murk, H. Kim, P. Sobis, A. Emrich, V. Drakinskiy, J. Stake, A. Maestrini, J. Treuttel, F. Tamazouzt, B. Thomas, M. Philipp, P. Hartogh, (2015), Characterization of the 530 GHz to 625 GHz SWI receiver unit for the Jupiter Mission JUICE, in: Proceedings of the 35th ESA Antenna Workshop on Antennas and RF Systems for Space Science.

Abbreviations

PDR	Preliminary Design Review
JUICE	Jupiter Icy Moons Explorer
SWI	Submillimeter Wave Instrument

Time-Line	From	To
Planning	2010	2012
Construction	2013	2017
Measurement Phase	2015	2019
Data Evaluation	2015	2019



SWI for the ESA JUICE mission.

Institute

Inst. Appl. Phys., Univ. Bern (UNIBE)

In Cooperation with

MPS, Göttingen, Germany
Omnisys Instruments, Sweden
LERMA, France
RPG, Germany
NICT, Japan
CBK, Poland

Principal Investigator

P. Hartogh (MPS)

Swiss Principal Investigator

A. Murk (UNIBE)

Co-Investigators

H. Kim, M. Kotiranta

Method

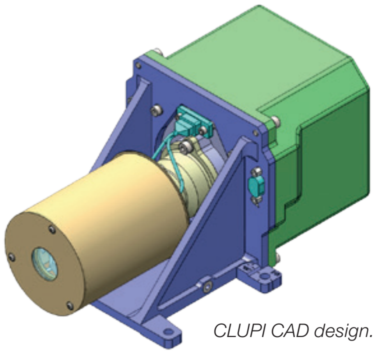
Measurement

Development and Construction of Instruments

Optics and receiver unit for the SWI instrument on JUICE.

Industrial Hardware Contract to

Micos Engineering



CLUPI CAD design.

Institute

Space Exploration Institute (SEI), Neuchâtel

In Cooperation with

F. Westall
(Co-PI; CNRS, Orléans)

B. A. Hofmann
(Co-PI; NHM, Bern)

Principal Investigator

J.-L. Josset (SEI)

Co-Investigators

A. Souchon, M. Josset (Co-I; SEI), T. Bontognali, (ETHZ, GI Zurich)

K. Foelmi, E. Verreccia, S. Erkman (Univ. Lausanne)

L. Diamond
(IGS, Univ. Bern)

and 14 other scientists from Canada, France, Germany, Austria, The Netherlands, Belgium, United Kingdom, Italy, and Russia.

Method

Measurement

8.10 CLUPI – CLose-Up Imager for ExoMars Rover 2020

Purpose of Research

CLUPI, part of the Pasteur Payload onboard the ESA ExoMars Rover 2020, is a powerful high-resolution colour camera. It is designed for close-up observations, to obtain visual information similar to that from a geologists hand lens.

The two main scientific objectives are:

- Geological context for establishing habitability:

  1) Identification of the lithologies,

  2) identification of eventual structures/textures (primary or secondary alteration features) that could provide information to interpret habitability.

- Identification of biosignatures:

  1) Observation of structural features, and

  2) observation of carbon (EXM looking for carbonaceous biosignatures) concentrations.

CLUPI is a miniaturized, low-power, efficient, and highly adaptive imaging system with a mass under 1 kg. It has specific micro-technical innovations regarding its sensor and focus mechanism.

The imager can focus from ~10 cm to infinity (~16 µm per pixel at 20 cm from the target), where colour imaging is achieved using a detector with three layers of pixels (red, green, and blue). CLUPI can also perform auto-exposure, auto-focus, binning, windowing, and z-stacking, to send a flexible amount of data and to increase the scientific return. A calibration target is used to colour calibrate images during science operations.

CLUPI will be housed on the rover drill box, and use mirrors to observe with three different fields-of-view. CLUPI will carry out specific science operations:

- Geological environment survey for the area immediately in front of the rover.

- Close-up observation of outcrops to: 1) obtain geological information on rock texture and structure, possible alterations, etc., 2) allow the geological history of targets to be established, and 3) apprase the potential preservation of biosignatures.

- Drilling area observation.

- Drilling operation observation: 1) to monitor the process, 2) observe the generated mound of fines with potential colour and textural variations, and 3) to obtain information on the mechanical properties of the soil.

- Drill hole observation (with deposited fines).

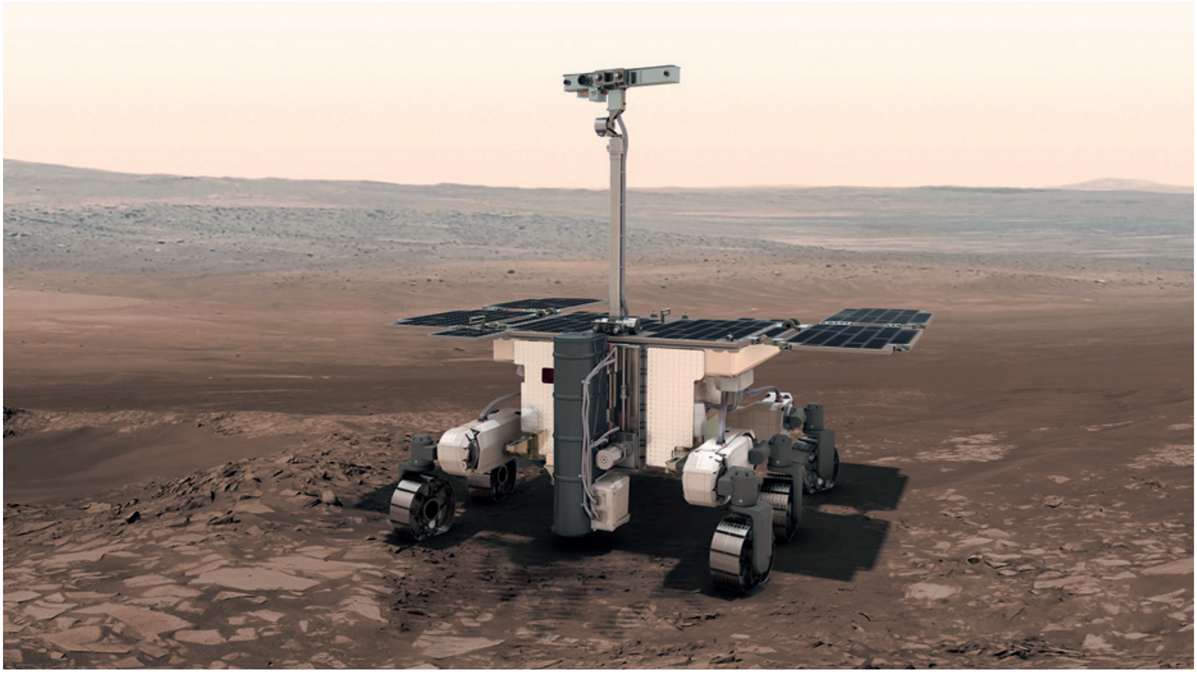
- Drilled core sample observation collected by the drill up to 2 m below the Martian surface.

Status

CLUPI had a successful Preliminary Design Review (PDR) in Dec. 2015. It is currently in phase C/D of its development.

Publications

1. Josset, J.-L. et al., (2016), The Close-Up Imager (CLUPI) on-board the ESA ExoMars Rover: Objectives, description, operations, and science validation activities, Astrobiology, submitted.
2. Payler, S. J. et al., (2016), Planetary science and exploration in the deep subsurface: Results from the MINAR program, Int. J. Astrobiol., accepted.



ExoMars Rover 2020.

Abbreviations

CLUPI	CLose-Up Imager
PDR	Preliminary Design Review

Time-Line	From	To
Planning	2003	2010
Construction	2011	2018
Measurement Phase	2021	2022
Data Evaluation	2021	2024

Development and Construction of Instruments

Imaging instrument for colour close-up observation of Martian rocks, surfaces, and samples.

Industrial Hardware Contract to

Ruag Space
CSEM
Fisba Optik AG
Petitpierre SA
e2V (funded by CNES)

9 Life Science

9.1 Yeast Bioreactor Experiment

Network biology of stress responses and cell flocculation of *Saccharomyces cerevisiae* grown in a continuous bioreactor under microgravity conditions.

Institute

Lucerne Univ. of Applied Sciences and Arts (HSLU), Centre of Competence in Aerospace Biomed. Sci. & Tech. Hergiswil

In Cooperation with

Vrije Universiteit, Brussel,
Lab. Structural Biology, Brussels,
Dept. Bioengineering Sciences,
Brussels, Belgium

Univ. Gent,
Lab. Protein Biochemistry and Biomolecular Engineering,
(L-Probe), Gent, Belgium

KU Leuven & VIB,
Dept. Molecular Microbiology,
Lab. Molecular Cell Biology,
Leuven, Belgium

Principal Investigator

R. Willaert (Vrije Univ.)

Swiss Principal Investigator

M. Egli (HSLU)

Co-Investigators

B. Devreese (Univ. Gent)
P. Van Dijck (KU Leuven & VIB)
D. Kauss (HSLU)

Method

Measurement

Development and Construction of Instruments

Bioreactor for continuous cultivation of yeast.

Purpose of Research

The project is focused on the effect of microgravity on the physiology of *S. cerevisiae*. Studies have shown that microgravity results in a disturbed physiology, derived from experiments in a rotating wall vessel suspension culture (modeled microgravity). The expression of a significant number of genes (1372) was changed when yeast cells were cultured for 5 generations or 25 generations in a simulated microgravity environment. The relevance of gravity on *S. cerevisiae* cell-cell and cell-surface interactions is best shown by the fact that *S. cerevisiae* cells grow in clusters in microgravity conditions compared to cells grown on Earth. In addition, it was found that continuous cultivation of *S. cerevisiae* in microgravity had an influence on the bud scar positioning, a critical factor in cell adhesion and invasion.

In this experiment different *S. cerevisiae* strains will be used to investigate the effect of microgravity on non-interacting and cell-cell interacting (flocculation) yeast growth, and on induced stress responses by applying a heat and osmotic shock in microgravity. An integrative-experimental approach will be used to assess the effect of microgravity. Therefore, various -omics technologies, i.e. fluxomics, transcriptomics, proteomics and genomics and specific cell analysis methods will be used to study the samples. A network biology model for *S. cerevisiae* will be set-up to process the -omics data. This will lead to insight into how gravity influences global regulation of energy metabolism, (stress) signaling transduction pathways, transcriptional regulatory networks, gene regulatory networks, protein-protein interaction networks, and metabolic networks.

Yeast cultivation will be performed in a specifically designed continuous bioreactor. The use of a continuous cultivation mode (chemostat) gives defined and controlled conditions over time (i.e. growth at one specific growth rate) permitting the repetition of an experiment, without having different starting conditions except for the elapsed microgravity time. The hardware will monitor and control growth parameters like temperature, flow rate and monitor pH, oxygen and carbon dioxide levels which are necessary to achieve a steady-state and stable growth.

The samples will be automatically withdrawn, treated (shock), filtrated and fixed. The fixation and treatment of all samples will be performed inside several automatic investigation blocs (IB) which will be part of the BIOREACTOR infrastructure. The experiment hardware will finally have to fit inside an European Modular Cultivation System (EMCS) container.

Status

The project's status is a delta B phase where scientific requirements for the hardware development are established. The hardware is currently under construction by RUAG Space, Nyon.

Time-Line	From	To
Planning	2013	2013
Construction	2014	2018
Measurement Phase	2018	2018
Data Evaluation	2018	2019

9.2 SPHEROIDS

Purpose of Research

The SPHEROIDS project is focused on human endothelial cells. The goal of this study is to investigate three-dimensional cell assembly under the condition of microgravity while emphasizing proliferation, differentiation and induction of apoptosis (programmed cell death).

Extensive studies have been performed on cultured endothelial cells over the last few years using the Random Positioning Machine (RPM). These studies have shown that cultured endothelial cells are highly sensitive to simulated hypogravity, which induced three-dimensional cell aggregation, as well as up-regulation of several growth factors and of extracellular matrix components. It also initiated apoptosis in the EA.hy926 human endothelial cell line.

The flight experiment will enable the science team to distinguish the effects, which are caused by the RPM technique, from those which are due to the influence of real microgravity.

The above figure illustrates the SPHEROIDS hardware which allows the cultivation of mammalian cells for an extended period of time under microgravity conditions. SPHEROIDS has the dimensions 100 x 100 x 100 mm, and consists of the following components (see figure): CC = Cultivation Chamber, MC = Medium Chamber, SC = Supernatant Chamber, FC = Fixative Chamber and V = Valve.

Status

The hardware for the SPHEROIDS experiment has been designed, developed and built by RUAG Space, Nyon.

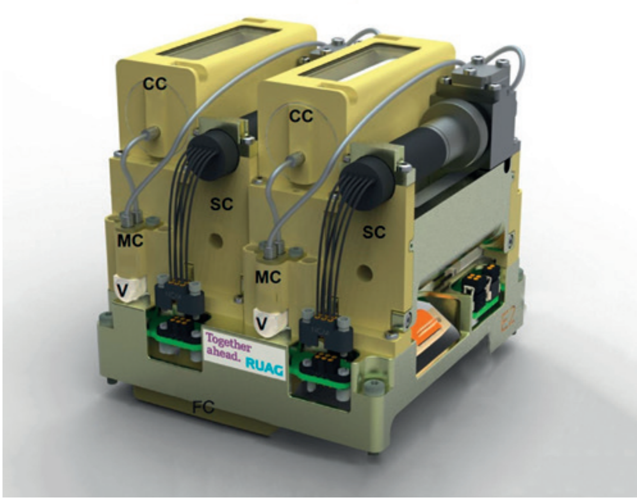
Publications

In preparation.

Abbreviations

RPM	Random Positioning Machine

Time-Line	From	To
Planning	2008	2012
Construction	2012	2016
Measurement Phase	2016	2016
Data Evaluation	2016	2017



SPHEROIDS hardware manufactured by RUAG Space, Nyon.

Institute

Lucerne Univ. of Applied Sciences and Arts (HSLU), Centre of Competence in Aerospace Biom. Sci. & Tech., Hergiswil, Switzerland

In Cooperation with

Univ. Aarhus, Dept. Biomed. & Pharma., Aarhus, Denmark

Principal Investigator

D. Gabriele Grimm

Swiss Principal Investigator

M. Egli (HSLU)

Method

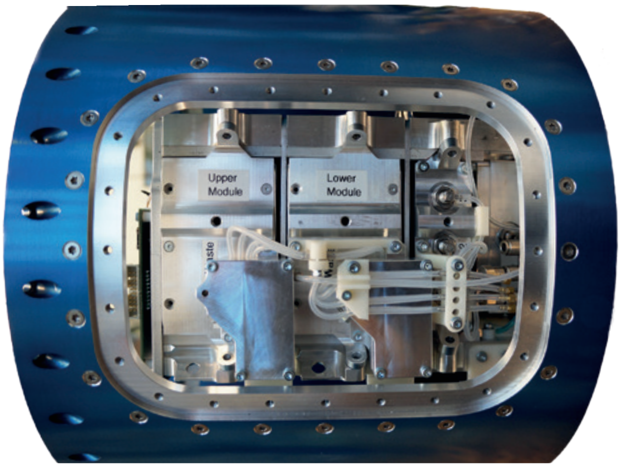
Measurement

Development and Construction of Instruments

Bioreactor for cultivating human cells.

Industrial Hardware Contract to

RUAG Space, Nyon



CEMIOS experiment hardware mounted inside the sounding rocket module. The hardware is designed to capture electrophysiological recordings of living cells under microgravity conditions.

Institute

Lucerne Univ. of Applied Sciences and Arts (HSLU), Centre of Competence in Aerospace Biomed. Sci. & Tech. Hergiswil, Switzerland

In Cooperation with

REXUS/BEXUS Education Program

Principal Investigator

M. Egli (HSLU)

Co-Investigator

S. Wüest

Method

Measurement

Development and Construction of Instruments

The entire hardware flown in this experiment was developed and assembeld in-house.

9.3 CEMIOS – Cellular Effects of Microgravity Induced Oocyte Samples

Purpose of Research

The mechanisms how cells detect external mechanical forces has not been fully clarified yet. For instance, mechano-sensitive ion channels are thought to be of central importance in transducing physical forces into biological responses. In this study, the gating properties of mechano-sensitive channels under various gravity conditions are investigated with our previously introduced "Ooclamp" device.

The device applies an adapted patch clamp technique that has proven to be functional even during parabolic flights and on centrifugation up to 20 g. In the framework of the REXUS program, we have proposed to conduct electrophysiological measurements onboard a sounding rocket that provides a microgravity environment for up to 2 minutes.

The aim of the CEMIOS experiment is to study possible adaptation processes of the mechano-sensitive channels during the flight, based on modified gating properties in microgravity. In addition, the measurements will also demonstrate the feasibility of conducting electrophysiological experiments onboard sounding rockets.

In order to determine the transmembrane conductivity through the target ion channels, an oocyte from the *Xenopus laevis* is captured in a silicone chip. A small aperture electrically isolates a patch of the cell membrane. This membrane patch is adjacent to a fluidic chip, allowing the fast exchange of medium in contact with the patch. By using particular drugs, the ion channels of interest can be pharmaceutically isolated. The conductivity across the patch under the different treatment protocols is then measured using a four electrode voltage clamp.

Status

With the REXUS 20 flight in March 2016, we assessed for the first time whether electrophysiological measurements with *Xenopus laevis* oocytes onboard a sounding rocket are possible. The analysis of the data gathered are still ongoing, but it is expected that a paper will soon be published.

Publications

In preparation.

Abbreviations

CEMIOS	Cellular Effects of Microgravity Induced Oocyte Samples
REXUS/BEXUS	Rocket and Balloon Experiments for University Students

Time-Line	From	To
Planning	Dec. 2014	Jun. 2015
Construction	Feb. 2015	Dec. 2016
Measurement Phase	Mar. 2016	Mar. 2016
Data Evaluation	Mar. 2016	Jun. 2016

10 Swiss Space Industries Group

ESA, the Key Account

The world space industry is a strategically important growth sector of high value-creating potential and great economic importance. If Europe is to compete globally and secure a leading position, the available resources must be efficiently deployed and activities pooled.

These tasks are handled by the European Space Agency (ESA). It coordinates and promotes the development of European space technology and ensures that the investment made goes to the lasting benefit of all Europeans. The EU aims to utilise the benefits of its space policy in its security, environment, transport, economic and social policy.

ESA has an annual budget of about three billion euros. Switzerland contributes around 166 million francs annually. As a result, funds flow into research and enable Swiss scientists to participate in significant ESA missions, while the manufacturers benefit as suppliers to the research sector or directly through contracts awarded by ESA.

Swiss Collaboration

While the Swiss space market cannot match the biggest European countries for size, it can definitely keep up with them in terms of quality and innovation. The Ariane and Vega launchers, Galileo and MetOp, the space astrometry mission Gaia or the Sentinel satellites for Copernicus, Europe's Global Monitoring for Environment and Security system, are just some examples of important space programmes in which Swiss manufacturers have played a major role. There is hardly a current European mission which does not incorporate Swiss technology.

None of this would be possible without Switzerland's early commitment to ESA, right from day one. ESA's ambitious programmes enable Swiss space companies to acquire the expertise that underpins its excellent reputation and promising position in the global growth market for space technology.

Strengthening and further expanding this position has to be the goal in the coming years. This means not only overcoming technological and economic challenges but also dealing with difficult political issues. The leading players – science, politics and industry – have to work seamlessly together.

Engagements within the Space Industry

Swissmem unites the Swiss electrical and mechanical engineering industries and associated technology-oriented sectors. The space industry is an important division among them. International competitiveness is not self-evident despite having ESA membership. The ability to compete internationally is not a matter of course – it must be worked on. Having a location that is able to compete is the basis of success. Swissmem is committed to Swiss companies and the qualities of Switzerland as a centre of industry and research. Continuous basic work has made Swissmem into a centre of strategic commercial and employer skills. This allows the association to represent the concerns of the sector to politicians, national and international organizations, representatives of employees and the public.

Apart from this, Swissmem offers companies numerous practice-oriented services, which help them to maintain their ability to compete and to successfully meet new challenges.

Preparation of the Intermediate eXperimental Vehicle (IXV), APCO Technologies – Mechanical Ground Support Equipment.

Contact

Swiss Space Industries Group (SSIG)

President

P. Guggenbach
RUAG Schweiz AG
RUAG Space

Secretary General

R. Keller (SSIG)

Swissmem
Pfingstweidstr. 10
PO Box, 8037 Zurich
Switzerland

www.swissmem.ch

SSIG Members

3D PRECISION SA, www.3dprecision.ch

Apco Technologies SA
www.apco-technologies.com

Art of Technology AG
www.art-of-technology.ch

Blösch AG, www.bloesch.ch

Boa AG, www.boa.ch

Clemessy (Switzerland) AG
www.clemessy.ch

CSEM, www.csem.ch

EPFL, Swiss Space Center, www.epfl.ch

Fisba Optik AG, www.fisba.ch

Franke Industrie AG, www.industech.ch

Meggitt SA, Sensing Systems
www.meggittsensingsystems.com

MetalUp3 SA, www.metalup3.ch

Orolia Switzerland SA, www.spectratime.com

Precicast SA, www.precicast.com

RUAG Schweiz AG, RUAG Space
www.ruag.com/space

SAPHYRION Sagl, www.saphyrion.ch

Schurter AG, www.schurter.ch

Shirokuma GmbH, www.shirokuma-gmbh.ch

SYDERAL SA, www.syderal.ch

ViaSat Antenna Systems SA, www.viasat.com

WEKA AG, www.weka-ag.ch

The Specialists: SSIG, Swiss Space Industries Group

Within Swissmem, SSIG (Swiss Space Industries Group) is organized as a technology group. SSIG includes companies that are significantly involved in the wide-ranging, competitive Swiss space technology environment. These manufacturers and engineering companies play a prominent role in the broadly faceted, competitive Swiss space industry, and develop solutions for all areas of space business, including: Structures for rockets, satellites, space transporters, and components for propulsion engines and scientific instruments.

Our companies participate in various ESA projects and earn themselves a merited high place in the fiercely competitive European market by delivering quality, expertise, flexibility and on-time reliability. Space research is a driving force of innovation. Space engineering brings together virtually all the strategic technologies. The sector therefore stands out as a future-oriented, innovative and attractive employer.

Jobs and Training

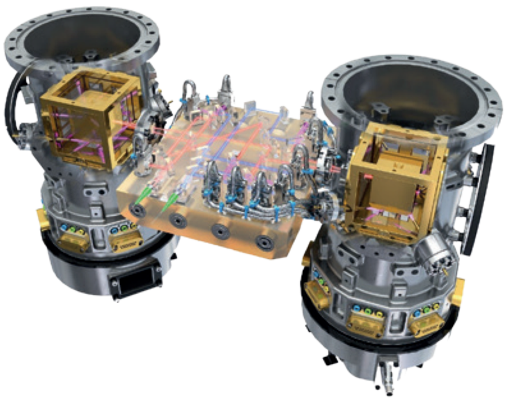
The Swiss Space companies in SSIG currently engage ~900 employees in the Space sector, but thousands of other professionals are also indirectly connected. Many of them are university graduates who find attractive jobs in the diverse areas of the production of space components and systems and contribute specialist expertise to the companies concerned. The employees of those companies concerned, not only come from a broad spectrum of educational and training backgrounds, but also represent a wide range of disciplines and therefore help to create a highly diverse store of expertise. This includes specialist knowledge in the fields of electronics, optics, precision mechanics, aero- and thermodynamics, tribology, information technology, material science and additive manufacturing.

This broadly based expert knowledge enables the companies to provide innovative solutions to the complex challenges arising in the space sector.

Final assembly of payload fairings at RUAG Space in Emmen, Switzerland.

11 Index of Authors

Kathrin Altwegg	WP/PI, Univ. Bern
Marc Audard	Univ. Geneva
Willy Benz	WP/PI, Univ. Bern
Enrico Bozzo	Univ. Geneva
Rolf Dach	AIUB, Univ. Bern
Alexander Damm	RSL, Univ. Zurich
Simon Dandavino	EPFL Space Eng. Center, EPFL
Marcel Egli	HSLU, Hergiswil
Laurent Eyer	Univ. Geneva
Carlo Ferrigno	ISDC, Univ. Geneva
Wolfgang Finsterle	PMOD/WRC
Andrea Fischer	ISSI, Bern
Volker Gass	Swiss Space Center, EPFL
Domenico Giardini	ETH, Zurich
Nuno Guerreiro	PMOD/WRC
Margit Haberreiter	PMOD/WRC
Daniel Henke	RSL, Univ. Zurich
Berry Holl	Univ. Geneva
Andreas Hueni	RSL, Univ. Zurich
Anton Ivanov	EPFL Space Eng. Center, EPFL
Adrian Jäggi	AIUB, Univ. Bern
Raoul Keller	Swissmem, SSIG
Mathias Kneubühler	RSL, Univ. Zurich
Säm Krucker	FHNW
Jean-Luc Josset	Space Exploration Inst., Neuchatel
Erich Meier	RSL, Univ. Zurich
Giulio Molinari	ETH, Zurich
Felix Morsdorf	RSL, Univ. Zurich
Axel Murk	IAP, Univ. Bern
Stéphane Paltani	ISDC, Univ. Geneva
Nicolas Produit	ISDC, Univ. Geneva
Muriel Richard-Noca	EPFL Space Eng. Center, EPFL
Markus Rothacher	ETH, Zurich
Thomas Schildknecht	AIUB, Univ. Bern
Werner Schmutz	PMOD/WRC
David Small	RSL, Univ. Zurich
Nicolas Thomas	WP/PI, Univ. Bern
Devis Tuia	RSL, Univ. Zurich
Benjamin Walter	PMOD/WRC
Roland Walter	ISDC, Univ. Geneva
Xin Wu	DPNC, Univ. Geneva
Peter Wurz	WP/PI, Univ. Bern
Peter Zweifel	ETH, Zurich



Swiss Committee on Space Research
www.spaceresearch.scnatweb.ch

Swiss Commission on Remote Sensing
http://www.naturwissenschaften.ch/organisations/skf

Swiss Academy of Sciences
www.scnat.ch