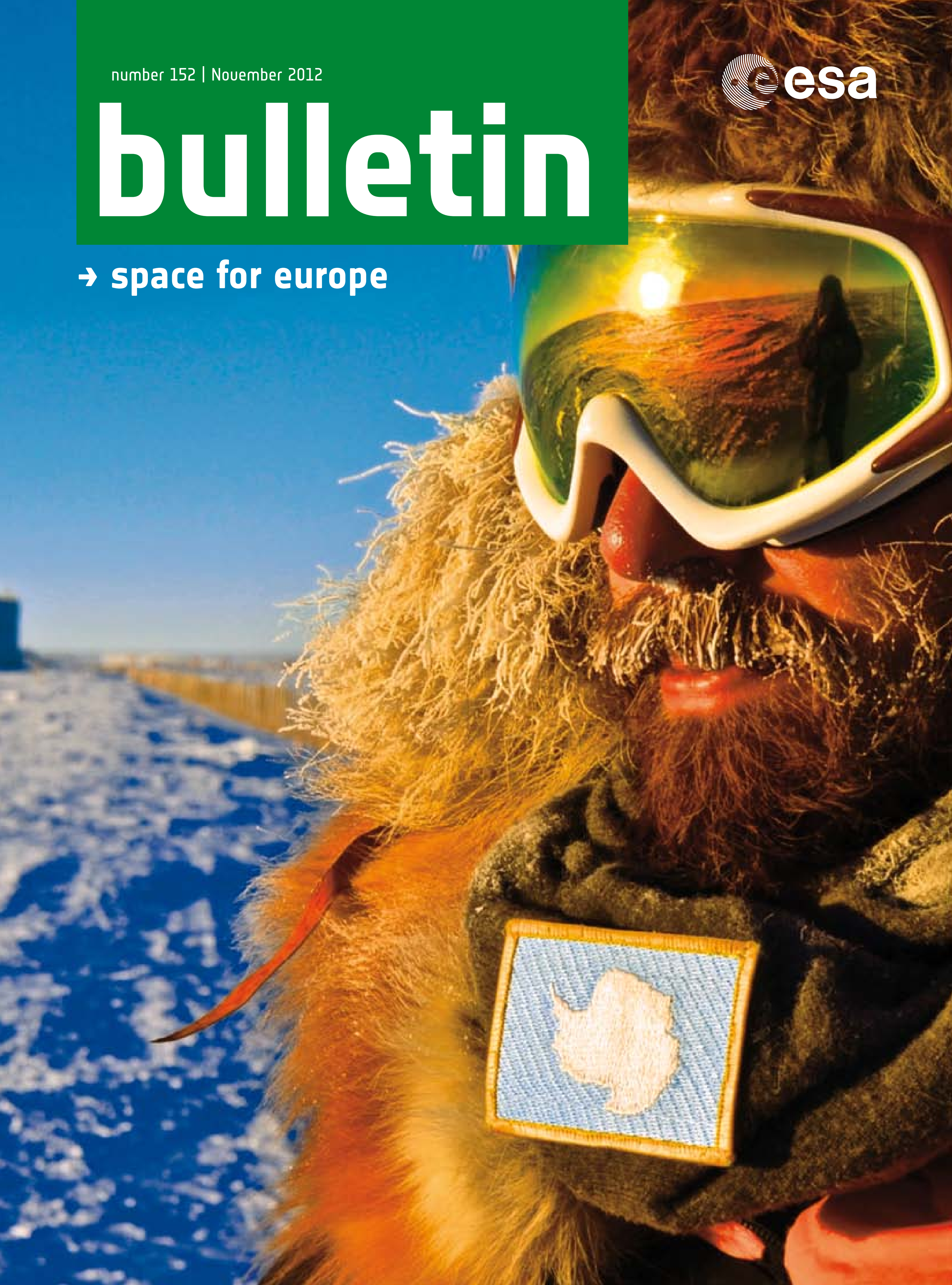
number 152 | November 2012

esa

bulletin

→ space for europe



European Space Agency

The European Space Agency was formed out of, and took over the rights and obligations of, the two earlier European space organisations – the European Space Research Organisation (ESRO) and the European Launcher Development Organisation (ELDO). The Member States are Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland and the United Kingdom. Canada is a Cooperating State.

In the words of its Convention: the purpose of the Agency shall be to provide for and to promote, for exclusively peaceful purposes, cooperation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems:

- by elaborating and implementing a long-term European space policy, by recommending space objectives to the Member States, and by concerting the policies of the Member States with respect to other national and international organisations and institutions;
- by elaborating and implementing activities and programmes in the space field;
- by coordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;
- by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

The Agency is directed by a Council composed of representatives of the Member States. The Director General is the chief executive of the Agency and its legal representative.

The ESA headquarters are in Paris.

The major establishments of ESA are:

ESTEC, Noordwijk, Netherlands.

ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

Chairman of the Council: D. Williams

Director General: J.-J. Dordain

←

On cover:
Dr Alex Kumar is an ESA-sponsored medical doctor studying the long-term effects of isolation on the crew of Concordia Base in Antarctica. This is the closest thing on Earth to interplanetary exploration. Research in this extreme environment is preparing ESA for the real thing: a mission to Mars (ESA/IPEV/PNRA/A. Kumar)

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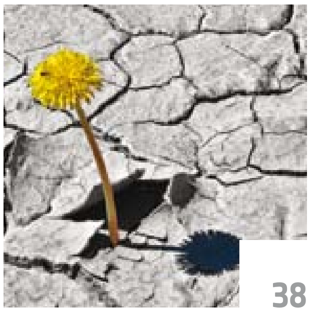

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→ ESTEC: ESA'S TECHNICAL HEART

Bringing space to life for fifty years

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Seen from space: ESTEC, between Katwijk and Noordwijk, the Netherlands

Nestled beside the dunes of Noordwijk, on the Netherlands' North Sea coast, ESTEC – the European Space Research and Technology Centre – is the largest space centre in Europe, the technical heart of ESA.

Today, ESTEC is the incubator of European space efforts, where missions are conceived and guided through development. This is where the technology is born to enable the space missions of the future, and where their hardware can be tested in space-like conditions.

But the creation of ESTEC preceded the ESA we know today. While ESA came into being in 1975, ESTEC was established as part of the European Space Research Organisation (ESRO), Europe's first space organisation. The decision to locate ESTEC in the Netherlands was made half a century ago this year, in April 1962, and planning of the facility itself began in earnest on 1 January 1963.

A 'CERN' for space

The history of ESTEC – and the prehistory of ESA – goes back to 1960 when the United Kingdom and French national space programmes were beginning to take shape. Both countries were aiming at getting their own satellites into orbit, and had already built their own sounding rockets. However, it took the efforts of two scientists at the European nuclear research facility CERN to begin bringing the idea of European space cooperation to life.

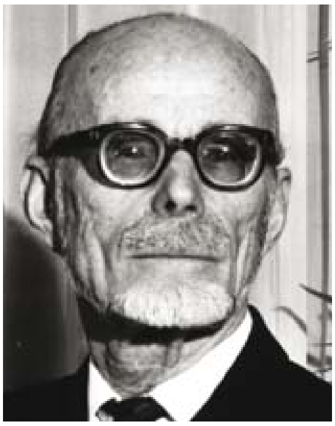
Italian Prof. Edoardo Amaldi and French Prof. Pierre Auger invited eight European scientists to meet at Auger's home on 29 February 1960 to discuss the idea of a European space research organisation. These eight scientists came from the UK, France, Italy, Germany, Belgium, the Netherlands, Sweden and Switzerland. Norway could not attend.

Following a proposal from the UK that the discussions take place more formally, a meeting was held in London on 29 April 1960. Twenty European scientists met with their British colleagues and each country reported on national developments. It was agreed that the idea of using the UK's Blue Streak missile for a European launcher would be put to the UK government.

The French government agreed, thanks to the efforts of Auger, that this was a feasible project, and gave the go-ahead for a small conference in Paris in June 1960 to discuss the idea further. The Paris conference proposed that a commission be set up for European cooperation in satellite and launcher development. Five countries sent governmental representatives instead of scientists, which indicated that European nations were prepared to take the idea seriously.

At a conference in Meyrin, Switzerland, in late 1960, 11 countries agreed to form COPERS, the preliminary Commission on Space Research. COPERS was based in Paris, with Auger as Executive Secretary. With his colleagues, he drew up a draft convention, open for

↑ Prof. Edoardo Amaldi (U. Amaldi)



↑ Prof. Pierre Auger

↑ Dr Alfred W. Lines, first Technical Director of ESRO, 1964 (R. Duham)

↑ Prof. Werner Kleen, Director of ESTEC in 1968 (R. Duham)

> **This is where the technology is born to enable the space missions of the future...**

signature between February 1961 and March 1964, which became the basis of ESRO, the forerunner of ESA.

Eleven European states joined: Belgium, UK, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden and Switzerland. The convention was formally signed on 14 June 1962, with Denmark joining afterwards, and it came into operation formally on 20 March 1964. European cooperation in space had become a reality.

Accommodation wanted

From the beginning it was agreed that the facilities needed for ESRO would be spread around Europe. The main facilities were a 'Payload Engineering Unit', later called the European Space Research and Technology Centre (ESTEC), ESDAC (a data acquisition and tracking centre), ESLAB (a science laboratory for experimental satellite development), ESRIN (a space science institute for theoretical work), ESTRACK (a tracking network) and ESRANGE (a sounding rocket launch facility). Of these, the headquarters, technical centre and tracking centre had the highest priority.

France immediately claimed the honour of accommodating the head office, since the French considered Paris to be the centre of the 'new Europe' (although this claim was contested initially by the Benelux countries and Switzerland). Germany asked for the tracking centre, which was eventually located in Darmstadt. But the most prestigious facility would be the research centre and laboratories, where some 500 people would work.

All European countries wanted to be considered for this, and there were six candidates: Munich in Germany, Zaventem near Brussels in Belgium, Bretigny in France, Delft in the Netherlands, Geneva in Switzerland and Bracknell near London.

Dahl's grand tour

The well-known Norwegian physicist Dr Odd Dahl – an early pioneer of CERN – was hired to arbitrate the competition for the locations of the ESRO sites. The locations were determined by mainly by cost, efficiency and political considerations.

Dahl recommended Delft: the most central, with good communications links, suitable housing and schools nearby and lowest costs, with the Technical University of Delft being the suitable location. Initially the University's own Senate was against the idea because it wanted to construct its own laboratories on the site in question. The decision was swayed by the Chairman of the Executive Board, F.W. den Hollander, the man who had re-established the Dutch national railway after World War Two.

↑ ESTEC's first home, Mijnbouwplein 11 in Delft, and
↓ the rear garden house where plans for the future ESTEC site were drawn up

The COPERS committee charged with deciding the location had actually first settled on the site near Brussels, close to Zaventem airport, but that was before they visited Delft and encountered the irresistible force of Dr Johan Ferrier. Ferrier led the Delft University welcoming committee and would later become the first President of independent Surinam. His tour of this technologically advanced university and the proposed building site next door was so impressive that the committee reversed their initial selection.

On 4 April 1962, it was decided that ESTEC would be based in Delft. In an article published in the ESRO Bulletin of July 1966, Dr Alfred W. Lines, the first Technical Director of ESRO and responsible for ESTEC, described how a small group of staff began planning ESTEC in Delft on 1 January 1963.

The group was led by Englishman Dr Sidney Shapcott, later the Director of Projects at ESTEC. It had three main tasks: to recruit staff, plan temporary and final accommodation, and set up an operational and technical programme. They work from the garden house of a Delft University building, Mijnbouwplein 11.

↑ ESTEC Board room at the temporary Delft offices

↑ Staff accommodation in Delft

There were problems from the start: in the low-lying Netherlands, the land had to be prepared for building, with what the Dutch call making the ground 'ripe for building'.

Experts pointed out that a building on the Delft site would need to stand on stilts extending down through 16 m of waterlogged soil to the firm layer of sand underneath. In the ESRO Council meeting, there were a lot of unexpected objections about this concept of building preparations. A new location for the technical centre had to be found without delay.

ESTEC goes to Noordwijk

But political logic stuck with the decision already made. The Netherlands had been chosen, so ESTEC would go to the Netherlands. There were two more possibilities: one in the Amersfoort area, not too far from Dutch research laboratories in Utrecht, and the other at Noordwijk, close to the university city of Leiden.

Noordwijk was selected in spring 1964 and the first temporary buildings appeared on the site that June. ESTEC still had premises in Delft, but the rapidly growing numbers of staff meant that accommodation had to be provided in Noordwijk, and quickly. In December 1963, ESTEC had 95 staff members but a year later that had increased to 270 and by December 1965, 364 employees were working for ESTEC.

Other difficulties also began to emerge. Local industry objected to ESTEC recruiting technical labour in the area, where it was already in short supply. Secretaries could easily find work in the Hague and it was proving difficult to get them to move to Delft, where living conditions were also less attractive.

In March 1965, the first foundations of a 33 000 m^2 building planned to accommodate 800 people were laid at Noordwijk. Steensen and Varming of Copenhagen had been chosen as consulting engineers for the design and construction of the ESTEC laboratories.

↑ The mechanical workshop, equipment and office for the sounding rockets team in Delft

The ESLAB laboratory was proposed in June 1964 to be set up 'near' ESTEC in Noordwijkerhout, to ensure coordination with the technologists in the preparation of payloads, and conduct research in three main fields: particle physics, ionospheric physics and surface physics.

In February 1965, ESLAB was established in the Netherlands at Hotel Helmhorst in Noordwijk. A few months later, ESLAB moved into prefabricated buildings on the ESTEC site, then under construction.

Disaster strikes

During 1966, ESTEC was declared operational for satellite testing purposes, with its environmental testing chambers commissioned and a suite of cleanrooms completed. But a disastrous fire in October 1966 razed all temporary buildings on the site, destroying the office accommodation of about 150 people. Workers were soon placed in hotels all over Noordwijk – fortunately rooms were easy to find because it was the end of the holiday season.

↑ The first foundation being laid with piles put into the ground in February 1965

← The new site at Noordwijk before construction began

← Hotel Helmhorst in Noordwijk, the temporary home of ESRO's ESLAB laboratory offices, 1965

The Science department relocated temporarily to a motel in Sassenheim, about 10 km away. Other services were spread around all over Noordwijk. The personnel office, for example, was located in a hotel on the promenade in Noordwijk.

After the fire, ESLAB moved to another hotel in Noordwijk, Hotel Zinger, and then to a new building in the nearby village of Noordwijkerhout. Here the offices remained until April 1969, when they moved back to ESTEC (earlier, in September 1968, ESLAB had been officially merged with ESTEC and was renamed the 'Space Science Department').

↓ A fire broke out in the prefabricated building occupied by ESLAB and part of ESTEC on night of 14/15 October 1966, just before completion of the new buildings

→ Milestones in the history of ESTEC

1962

March
Committee led by Dr Odd Dahl proposes Delft, the Netherlands, for ESTEC

1 November
Dr Alfred W. Lines nominated as Technical Director, to head the European space technology centre. Under his authority, Mr E. Kesselring is named Director of ESTEC in 1964

1963

1 January
Under Dr S. Shapcott, (later Director of Projects at ESTEC), planning of ESTEC begins from Delft

1964

20 March
ESRO Convention entered into force

June–July
Dutch Government proposes new sites for ESTEC (Noordwijk or Amersfoort)

October
ESRO Council approves the Noordwijk site

1965

1 March
First foundation pile laid for ESTEC at Noordwijk

1 September
First major vacuum test facility installed at ESTEC

The administration building of ESRO's ESLAB facility at 's Gravendamseweg 18, Noordwijkerhout – about a kilometre from the present ESTEC site in Noordwijk The site of the former ESLAB building remains today, now with a complex of apartment flats rebuilt in 2007

However, it was only in April 1967 that all staff based in Delft, the Noordwijk hotels and ESLAB could be brought together in completed main buildings at the new ESTEC site.

Some ESRO staff were relocated later from ESTEC to ESDAC (the facility for spacecraft operations and data processing in Darmstadt, Germany, which was renamed ESOC, the European Space Operations Centre, in 1967). From then on, ESTEC and ESOC would be responsible for spacecraft development and spacecraft operations respectively.

HRH Princess Beatrix and Prince Claus of the Netherlands officially inaugurated ESTEC on 3 April 1968. She was welcomed by the Director General of ESRO, Prof. Hermann Bondi, and by the Director of ESTEC, Prof. Werner Kleen. Also present was Dr Ferrier, then governor of Surinam, who had played a major role in bringing ESTEC to the Netherlands.

The logo for ESTEC, in use 1975–80

1966

12 January
First Large Space Chamber inaugurated at ESTEC

14 October
Fire destroys temporary buildings at ESTEC

1968

3 April
Inauguration of ESTEC by HRH Princess Beatrix of Netherlands

1 September
ESLAB integrated into ESTEC as Space Science Department

1990

29 June
Space Expo, ESTEC's visitor centre, opened by HM Queen Beatrix and HRH Prince Friso

1999

28 June
Erasmus Centre opened by Monique de Vries, Dutch State Secretary for Transport, Public Works and Water Management

2008

8 April
New laboratories and Concurrent Design Facility opened by HRH Prince Willem Alexander

↑ January 1967, the 'topping-out' ceremony for the new ESTEC building with awards for the suppliers and workers

↑ Signature of the agreement on the 'Establishment and operation of the European Space Technology and Research Centre', at the Hague on 2 February 1967 between ESRO's Pierre Auger (signing) and Dutch Minister of Foreign Affairs Mr J.M.A.H. Luns. Dr Alexander Hocker, chairman of ESRO Council, is on the left

↑ Inauguration day, 3 April 1968, HRH Princess Beatrix of the Netherlands is welcomed by the Director General of ESRO, Prof. Hermann Bondi, and by the Director of ESTEC, Prof. Werner Kleen. At right, Mr Joseph M. Bonnike, Mayor of Noordwijk

↑ Princess Beatrix of Netherlands shares a toast to ESTEC with Prof. Werner Kleen, Mr Marcel Depasse, ESRO Director of Administration, and Prof. Hermann Bondi, Director General of ESRO

After rounds of negotiations, disasters and some very hard work, ESTEC could at last continue the activities that had been started in hired rooms in Delft six years earlier.

The first satellites to pass through ESTEC were launched that same year – ESRO-2A on 29 May, ESRO-1A on 3 October to study solar and cosmic radiation and HEOS-1 on 15 December, entered a high Earth orbit to study the solar wind. ESTEC's work in space had begun.

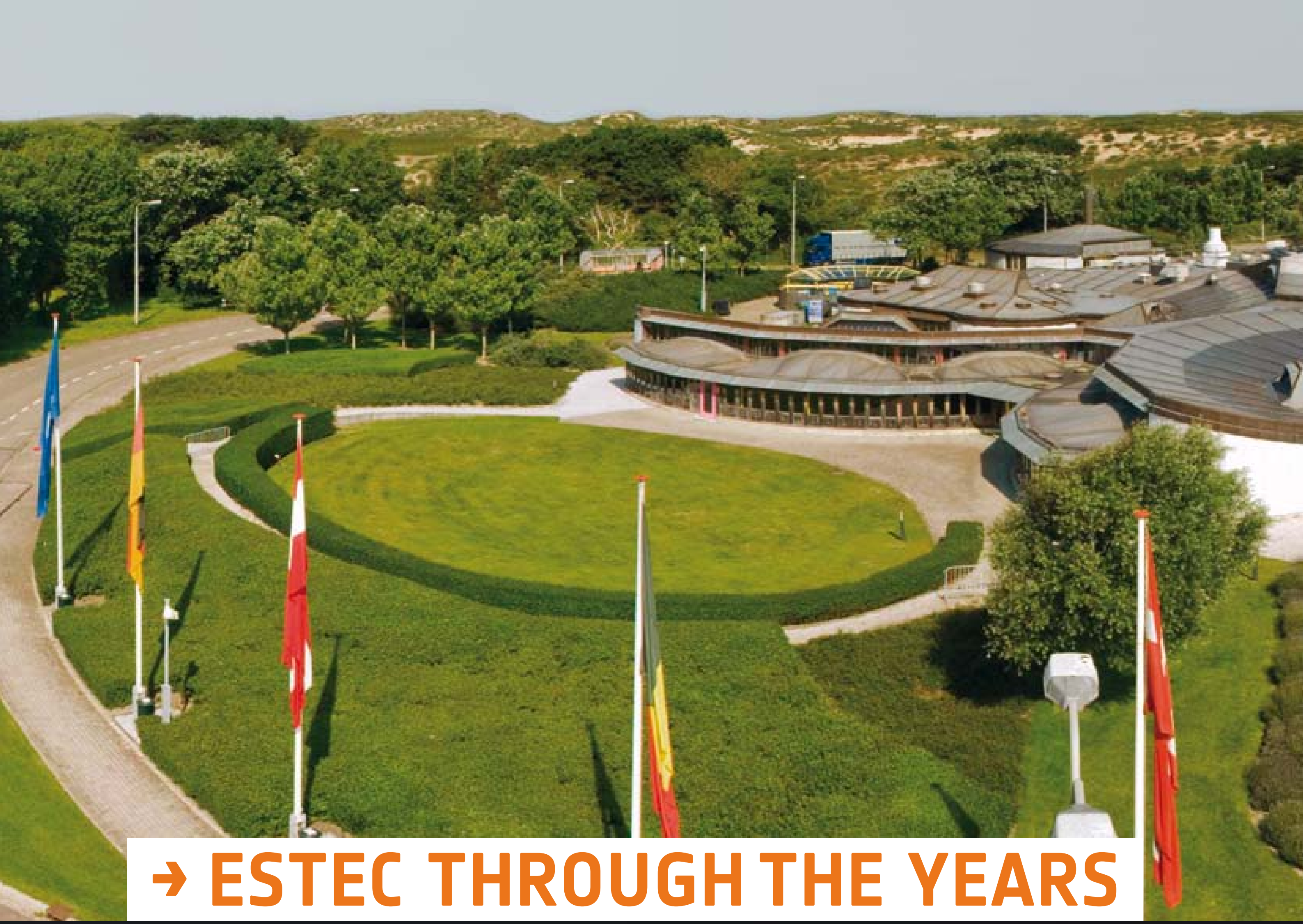
ESTEC today

This coastal site remains ESA's largest centre, with almost 2500 personnel from all over Europe. They are responsible for developing and managing all types of ESA missions: science, exploration, telecommunications, human spaceflight, satellite navigation and Earth observation. ESTEC specialists work to support European space industry and cooperate closely with other organisations, such as universities, research institutes and national agencies from ESA Member States, as well as cooperating with partners from around world.

ESTEC houses a collection of test facilities that are unique in Europe, used to subject satellite components or complete spacecraft to the high accelerations, vibrations and noises experienced when going into space, and the harsh vacuum, extreme temperatures and radiation found in orbit. More than 180 spacecraft have passed through the gates of ESTEC on their way into space. ■

More reading on the history of Europe in space

- ESRO, Information about the European Space Research Technology Centre – ESTEC, 1965
- A.W. Lines, 'The first two years of ESTEC', *ESRO Bulletin*, No. 3, July 1966
- H. Massie, M.O. Robins, *History of British space science*, Cambridge University Press, 1986
- J. Krige, A. Russo, A *history of the European Space Agency 1958–1987, Vol.1: The story of ESRO and ELDO 1958–1973*, ESA SP-1235, 2000
- Brian Harvey, *Europe's space programme: to Ariane and beyond*, Springer-Praxis, 2003
- Matthew Godin, *The Skylark rocket: British space science and the European Space Research Organisation 1957-1972*, Editions Beauchesne, 2007
- Kees de Jager, *Hoe ESTEC naar Nederland kwam*, Zenit, *Nederland kwam*, 2007
- Roy Gibson, *Recollections*, Editions Edite & IFHE, 2011



→ ESTEC THROUGH THE YEARS


1966


1997


1972


2012

MetOp-B's Payload Module being lowered into ESTEC's Large Space Simulator in 2010 for 17 days of thermal vacuum testing

→ ESTEC TODAY

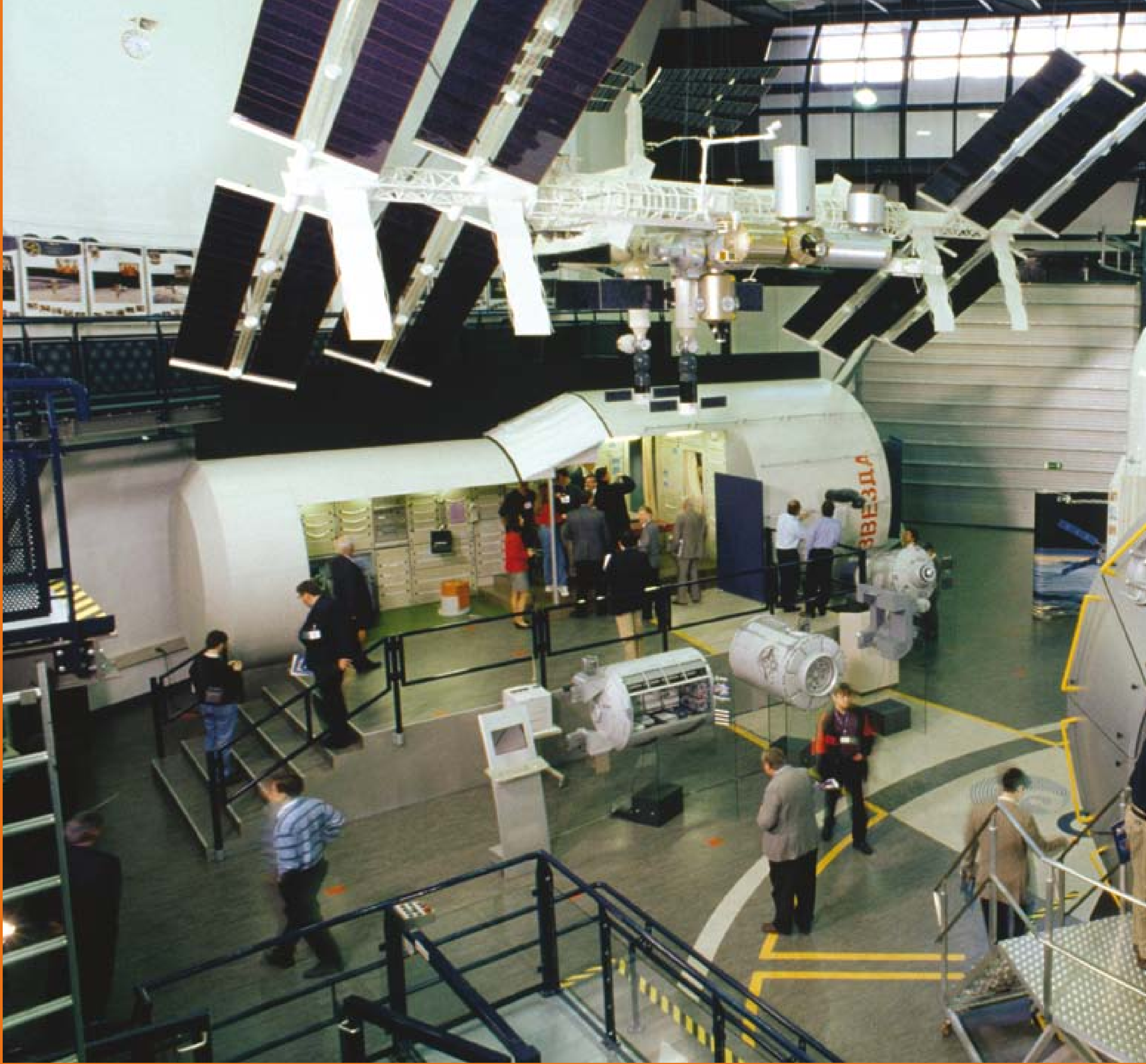
The ESA/JAXA Mercury spacecraft BepiColombo during testing at ESTEC, here in the Large Space Simulator – Europe's single largest vacuum chamber – used to test full-size spacecraft in representative space conditions

↑ ATV *Jules Verne* undergoing preparation for testing in the clean one word room outside the Large European Acoustic Facility (LEAF), the largest test facility of its kind in Europe

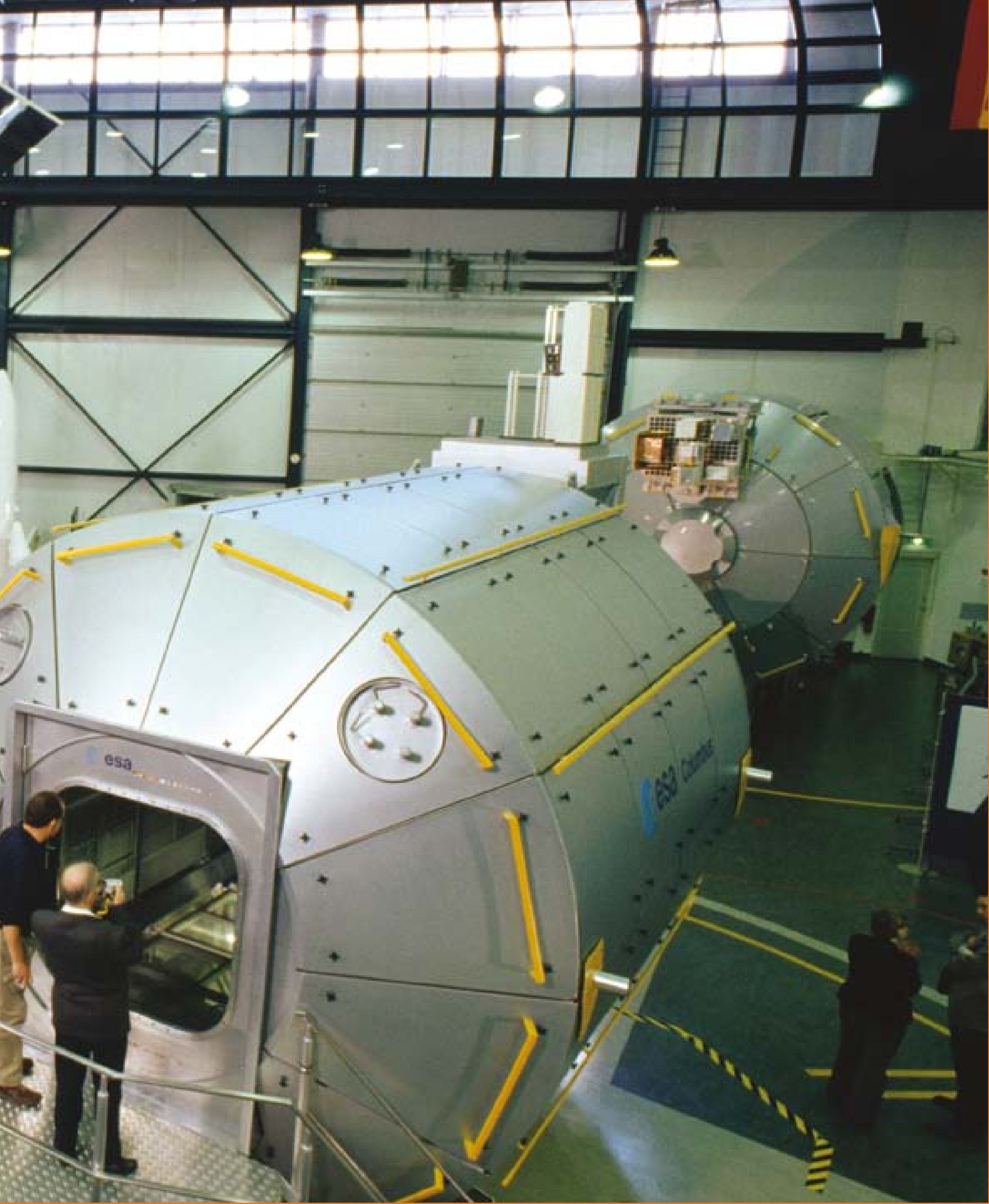
The Small GEO satellite under test in ESTEC's Large European Acoustic Facility in 2012

↑ ATV *Jules Verne* inside ESTEC's Maxwell chamber for electromagnetic compatibility and interference testing in 2004

↑ Demonstrating how ESTEC is also able to serve wider European industry, Airbus completed a complex set of vibration tests on a fuselage section using ESTEC's largest vibration facility, called Hydra, in 2010



New Engineering Laboratories, for materials, mechanical and electrical engineering, propulsion, software and product assurance, were opened in 2008 by Dutch Crown Prince Willem Alexander



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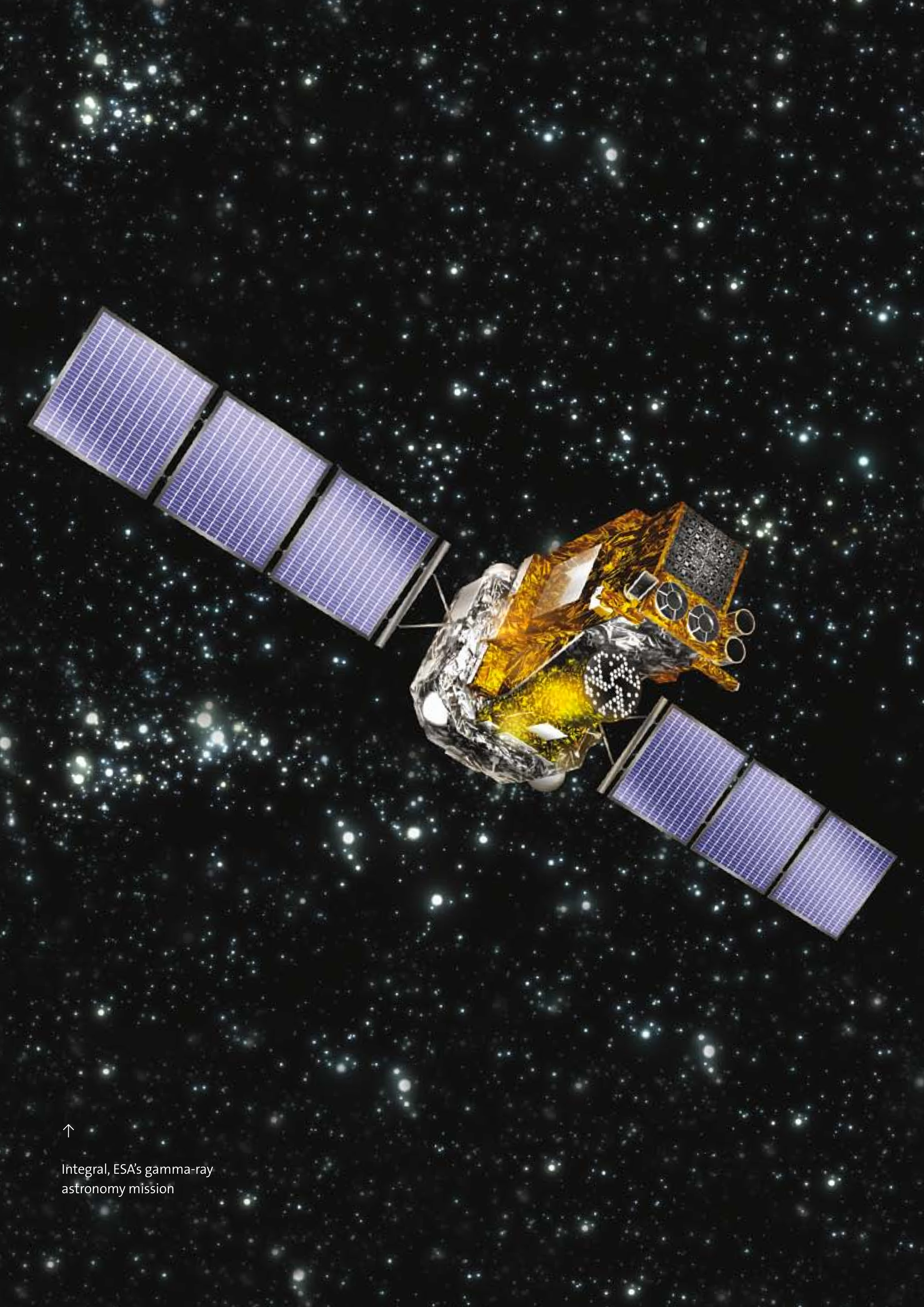
The Erasmus Centre, a showcase for ESA's human spaceflight programmes and missions, with the role of advising institutional and commercial users making use of ESA's space platforms and ground facilities

↑ ESTEC's Concurrent Design Facility where engineers from all disciplines of spacecraft systems and mission design participate in a simultaneous design process

↑ In the Erasmus Centre, ESA astronaut André Kuipers trains on the Microgravity Science Glovebox engineering model (the actual Glovebox facility is on the International Space Station)

↑ The Large Diameter Centrifuge, run by the Life and Physical Sciences Instrumentation and Life Support Laboratory of ESTEC, now made available for scientists interested in artificial gravity effects

↑ Schoolchildren examine a piece of moonrock, returned from the Moon by Apollo 17 and on display at ESTEC's visitor centre Space Expo



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Integral, ESA's gamma-ray astronomy mission

→ INTEGRAL'S TEN YEARS IN SPACE

A view of the high-energy sky

Christoph Winkler
Directorate of Science and Robotic Exploration, ESTEC, Noordwijk, the Netherlands

Peter Kretschmar
Directorate of Science and Robotic Exploration, ESAC, Villafranca de la Cañada, Spain

Richard T. Southworth
Directorate of Human Spaceflight and Operations, ESOC, Darmstadt, Germany

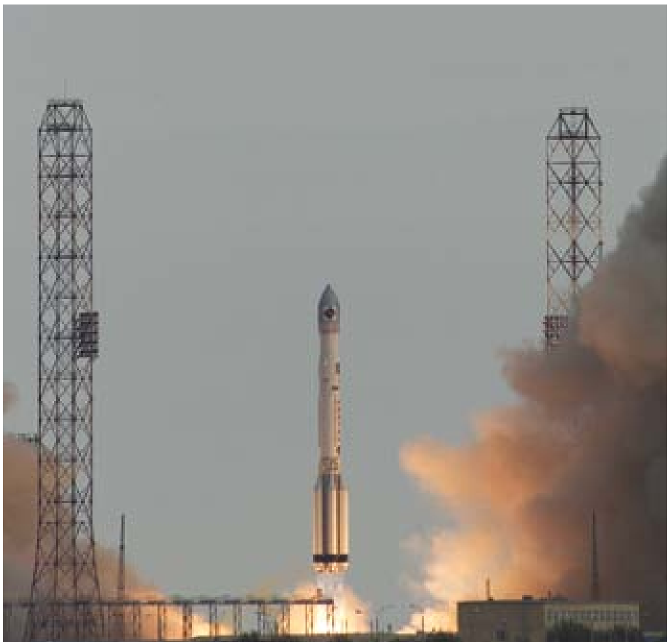
ESA's gamma-ray observatory Integral was launched on 17 October 2002 on a nominal mission of two years. But Integral continued to operate, very successfully, for the next ten years.

Gamma-ray astronomy explores the most energetic phenomena that occur in nature. It embraces a great variety of gamma-ray continuum and gamma-ray line processes: nuclear excitation, radioactivity, positron annihilation and photon–electron (Compton) scattering.

This energy range is shown in a great diversity of astrophysical objects and phenomena: nucleosynthesis, nova and supernova explosions, the interstellar medium, sources of cosmic rays and their interactions, neutron stars, black holes, gamma-ray bursts, active galactic nuclei and the cosmic gamma-ray background.

Not only do gamma rays penetrate absorbing matter, but also the bulk of the power radiated by these objects is often at gamma-ray energies.

↑ ↗ The Integral Structural/Thermal Model during testing at ESTEC in 1998, (centre) in the Large Space Simulator and (right) in the Large European Acoustic Facility test chamber



↑ Launch of Integral on a Proton rocket from the Baikonur Cosmodrome in Kazakhstan on 17 October 2002

Integral's key features are a very large field of view (about 100 square degrees), millisecond timing resolution, a unique energy coverage (3 keV–10 MeV), with excellent sensitivity and polarimetry capabilities. Integral is the only observatory worldwide providing these capabilities to the astronomy community. Its observing programme is established via annual Announcements of Opportunity (AOs), inviting the submission of scientific observing proposals to be peer-reviewed by an international Time Allocation Committee.

Integral observations have resulted in about 2000 publications, including around 700 refereed papers (as of June 2012). At least 88 PhD theses related to Integral science have been completed since launch, and another 23 PhD students are currently working on Integral data.

Spacecraft and payload operations

Integral is a three-axis stabilised observatory-type satellite, with a platform design closely resembling that of its ESA sister mission, XMM-Newton. Integral is a realtime mission with no onboard telemetry storage or automatic telecommand schedule execution. In standard observation modes, attitude control is achieved with a set of three reaction wheels based on the output of the Star Tracker

and Fine Sun Sensor. Power is supplied by solar arrays, with a pair of 24 Ah nickel cadmium batteries to ensure that the satellite remains powered during eclipse periods.

Integral had a planned lifetime of two years and an extended mission life of three years. However, owing to the excellent performance and health of the satellite, and the very good margins on consumables, it has been possible to extend the mission lifetime several times since then.

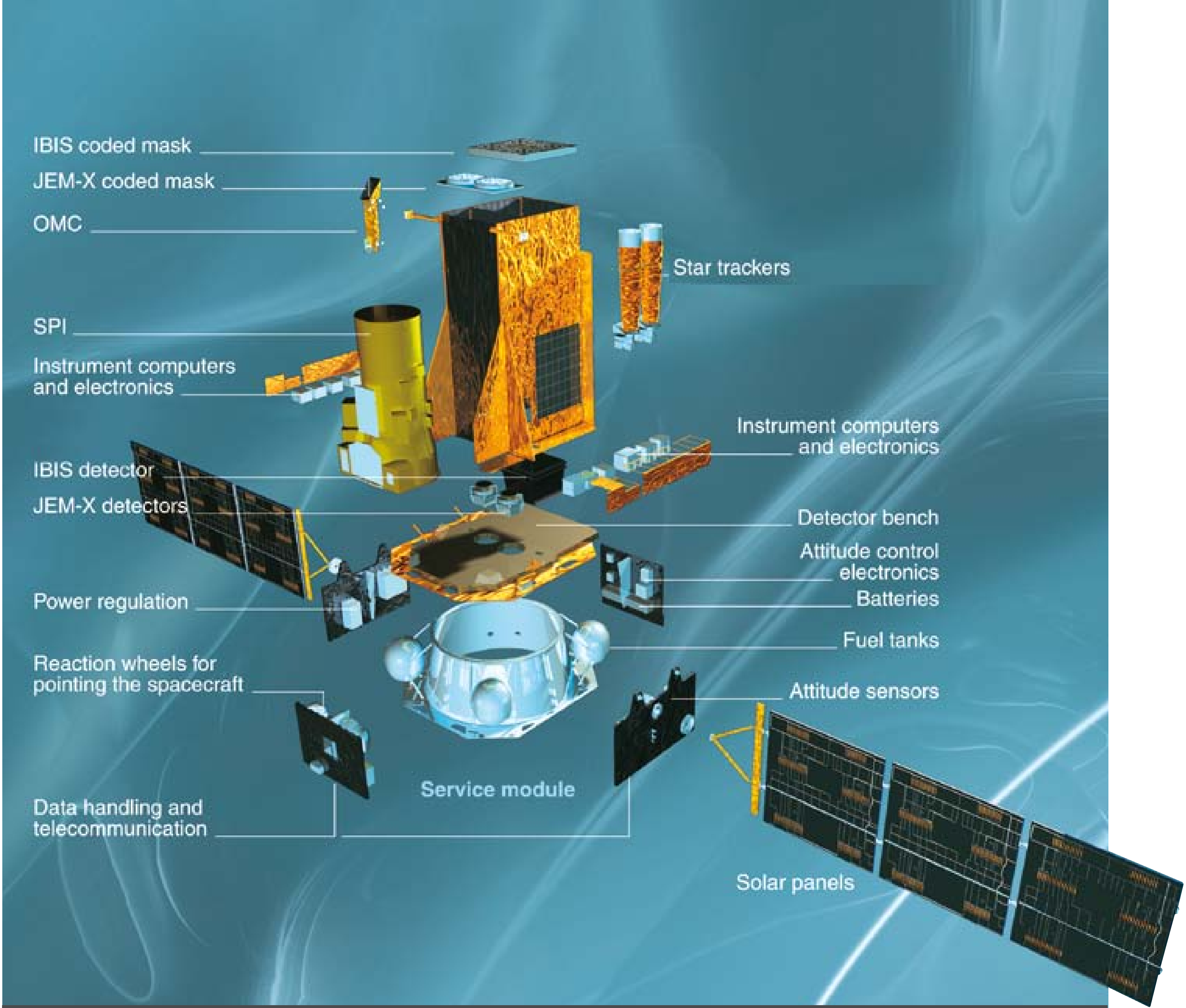
To date, Integral has clocked up ten years of highly successful operations, and a further two years are planned with the potential for many more. Currently, Integral is operating fully on its nominal units, with only some minor degradation observed. The solar array power margin is sufficient for normal operations with no restrictions on scientific attitude selection, while regular battery reconditioning has revealed no measurable loss of battery capacity. There is sufficient fuel for over ten more years of operations at the current rate of usage.

The payload consists of a set of four complementary instruments with detectors operating at various energy levels:

- Spectrometer on Integral (SPI), dedicated to high-resolution spectroscopy in a wide band from 18 keV to 8 MeV;
- Imager on Board Integral Satellite (IBIS), providing fine imaging in the gamma-ray band with two detector layers (ISGRI and PICsIT) covering the energy range 15 keV to 10 MeV;
- Joint European X-Ray Monitor (JEM-X), supplementing SPI and IBIS with imaging and spectroscopy in the 3–35 keV range;
- Optical Monitoring Camera (OMC), adding measurements in the visible band.

All instruments except the OMC use coded-mask technology. The data-handling interface to each instrument is identical, allowing a high level of commonality in the operations across the scientific payload.

Integral has a three-day orbital period of which all but eight hours are above the Van Allen belts, allowing long periods of uninterrupted science observations. The high inclination (currently 64°) and an apogee over the northern hemisphere means that Integral is visible from ESA's Redu ground station in Belgium for all but three hours of the orbit close to perigee. Currently, Integral has an apogee of 159 000 km and a rather low perigee of 3500 km, compared to a maximum of over 13 000 km in 2006. This low perigee has led to increased exposure to proton radiation with some noticeable but non-critical increase in the rate of solar array degradation.



↑ Integral's dimensions are 5 × 2.8 × 3.2 m, the deployed solar panels are 16 m across and the mass was 4 tonnes at launch, including 2 tonnes of payload

Integral has been controlled from the Mission Operations Centre (MOC) at ESOC in Darmstadt, Germany, since launch. MOC cooperates closely with two other establishments for Integral operations. The Integral Science Data Centre (ISDC) at Versoix, near Geneva, Switzerland, receives a constant real-time telemetry flow from MOC, and performs quick-look and standard scientific analysis. The Integral Science Operations Centre (ISOC) at ESAC near Madrid, Spain, has responsibility for the detailed planning of the science missions.

While the prime Integral ground station is at Redu, several other ESA ground stations provide occasional support. For the first eight years of the mission, a significant level of support was also given by the NASA Deep Space Network.

Because Integral is a realtime mission, a very robust and reliable ground segment and operations concept is necessary in order to execute the demanding science observations. A particular feature of Integral operations is the high frequency of manoeuvres implied by the required observing strategies: during intense observing periods, Integral executes a manoeuvre every 30 minutes.

As a consequence, a short interruption in any of the ground segment elements involved with generating and executing the command sequence for the manoeuvre can lead to its loss and failure of the subsequent scientific pointing. The fact that Integral consistently has a 'slew' success rate well above the required 95% is a testament to the high standard of all ground segment elements and operating procedures.

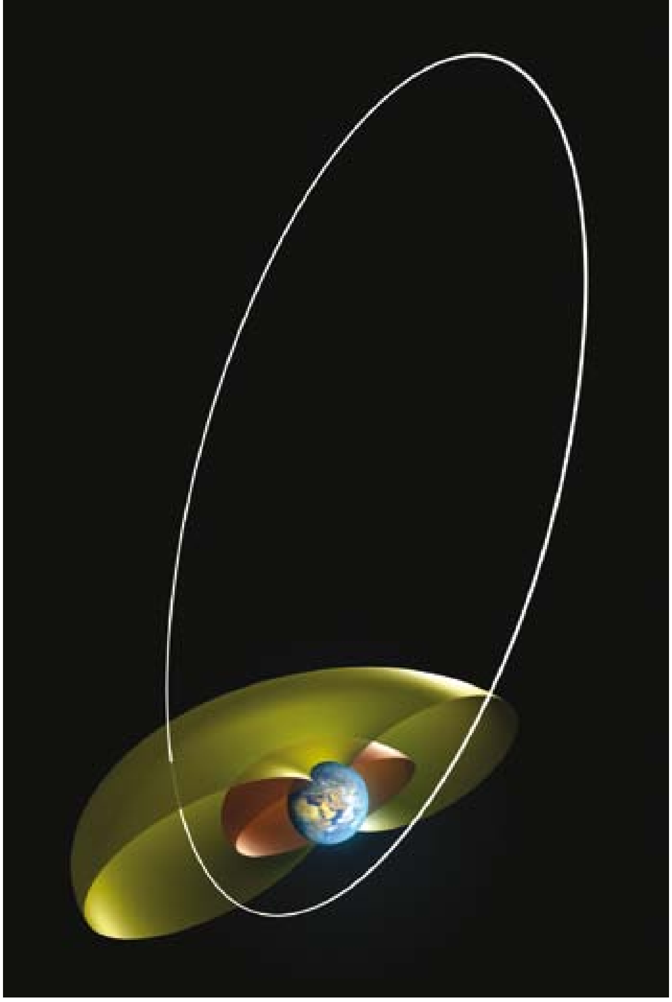
Continuing improvements to Integral operations in terms of reliability and efficiency have made it possible to reduce the manpower needed to run the mission. It also became possible to merge the operations of Integral and XMM-Newton, so that both missions are now operated by a single controller with no loss in scientific performance.

Science operations

Integral is operated as an astrophysical observatory, with access provided for the worldwide scientific community. The observing programme, established through annual AOs, is characterised by both deep (greater than 1 Ms) and often multi-year 'Key Programmes', complemented by flexible 'Target of Opportunity' (ToO) observations. The latter enable Integral to react to transient events of astrophysical significance in the strongly variable gamma-ray sky.

ISOC is the main point of contact for the scientific community. Scientific observing proposals received in response to an AO are evaluated for scientific merit by a Time Allocation Committee, supported by the ISOC for a technical evaluation and the determination of possible source conflicts. A major change was introduced in 2006 with the concept of Data Right Proposals, allowing many more astronomers to share the data obtained by one observation within the very wide field of view of Integral. This maximises the scientific exploitation of originally accepted observations by focusing on some, but not all, targets in the field of view.

Once a programme of accepted observations has been approved, the ISOC works to optimise the scientific output. Firstly, a long-term plan is generated covering the entire year of an AO, distributing the observations based on the visibility of the sources on the sky, the relative scientific ranking of the accepted proposals, possible fixed observing time requirements, and other technical considerations.



↑ Integral's 72-hour highly elliptical orbit, showing both the electron (yellow) and proton (orange) radiation belts around Earth

↓ Integral MOC staff executing an observation of Earth, used to shield the fields of view of the instruments from the diffuse gamma-ray background for payload calibration purposes

Once the plan is accepted, the observations are then planned in more detail, revolution by revolution, optimising the sequence of observations to maximise the scientific observing time (a 'revolution' is a complete three-day orbit of the spacecraft around Earth, and about 66 hours of uninterrupted scientific observing time, above the Van Allen radiation belts, is available per revolution). Besides science observations, a small number of spacecraft and scientific calibration observations with their own specific requirements are also scheduled.

The high-energy sky is very variable, with most sources changing in intensity on all possible timescales, from minutes and hours, to weeks and months. Some may undergo unexpected bursts or flares, meriting a ToO observation. These interrupt the planned sequence of observations and so, in order to implement ToO observations, an ISOC scientist is on call every day of the year.

The process starts with a scientist raising a ToO alert via a web-based interface, which then notifies the ISOC duty scientist automatically. The request is assessed by the

Integral ISOC staff discussing the planning for a series of scientific observations

Project Scientist, assisted by the ISOC mission planner to see if it matches various scientific criteria, whether the source is visible to Integral, to what extent the observations would disrupt the current plan, and which preplanned observations would need to be postponed or even cancelled. If the proposal is approved by the Project Scientist, the ISOC duty scientist works with the MOC to schedule the observations.

The ToO observations may start within a few hours after receipt of the alert, but is more typically started within a few days: this depends both on the requirements of the observations and on the technical feasibility. ToO observations with Integral are usually quite long, from several hours to days or even weeks, so they not only interrupt the short-term planning, but also usually lead to an update of the long-term plan, restructuring the remaining observations to maximise the overall scientific output.

Data from all observations are transmitted in real time from the satellite to the ground stations and then via the MOC to the ISDC in Switzerland. The ISDC is funded by a national Principal Investigator collaboration with a small ESA contribution and is responsible for quick-look analysis, distribution of the data to observers, and for building and maintaining an archive of Integral data. The data are also maintained by the ISOC as part of the archives from ESA missions at ESAC, providing users another way to access to public data.

More Integral science data archives are maintained at IKI/Moscow and NASA/HEASARC. Staff from ISOC and ISDC run the Integral Helpdesk jointly, advising users on everything from proposing a scientific observation to the final data analysis.

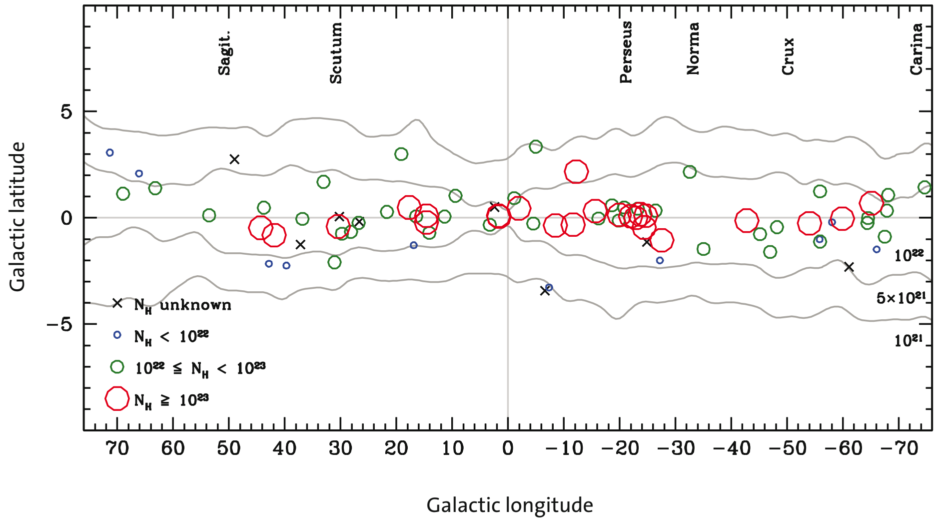
The interests of the scientific community are represented by the Integral Users Group (IUG), which includes independent scientists, external to ESA, and representatives of the instrument teams, mission scientists, and representatives of participating agencies. The IUG advises the Project Scientist on all matters relevant to maximising the scientific return of Integral as a scientific observatory. The IUG also identifies a coherent calibration policy, monitors the activities of ISOC and ISDC, and advises on the maintenance and possible further enhancement of the science ground segment with particular reference to the operational scenario, observatory products, and database structure.

Science highlights

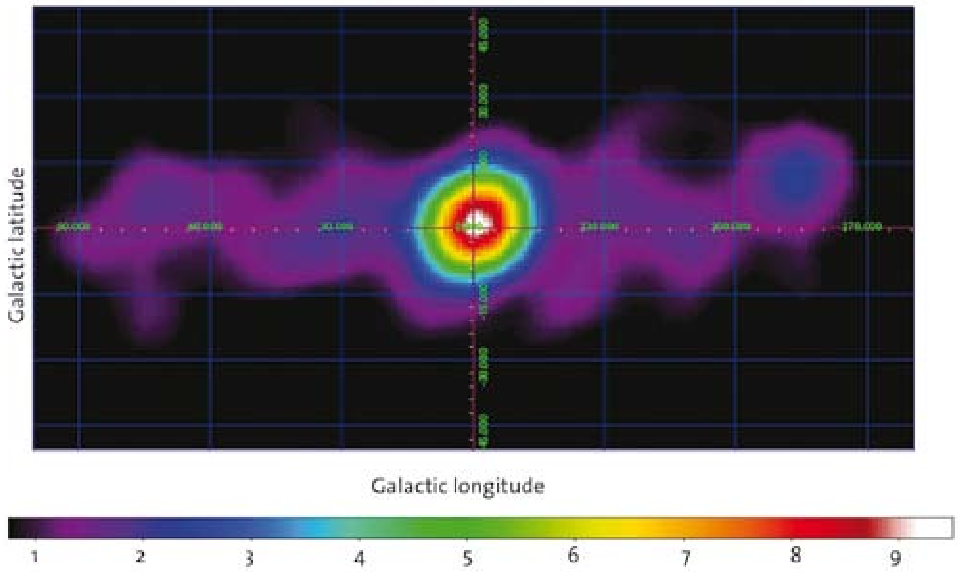
Nucleosynthesis, gamma-ray line emission, supernovae, and galactic structure

The annihilation of electrons with their anti-particles, positrons, in interstellar space results in a strong gamma-ray line emission at 511 keV. The first large-scale sky map at 511 keV gamma rays was produced by Integral. However, the origin of the interstellar positrons producing this line remains a 40-year-old mystery. Plausible producers include supernovae, accreting binaries, pulsars, gamma-ray bursts, the supermassive black hole in the centre of our galaxy and 'dark matter' particles.

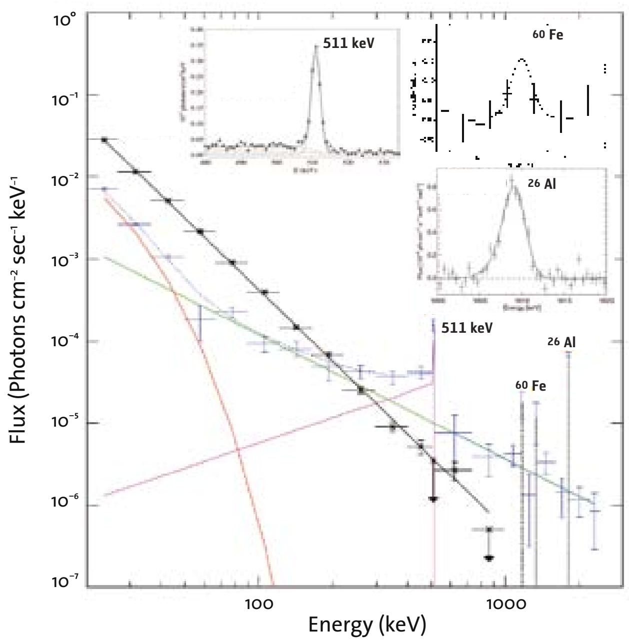
Gamma-ray photons from the radioactive decay of aluminium -26 (line emission at 1.8 MeV) trace galactic nucleosynthesis processes during the past million years. Integral observations of aluminium-26 sources along the plane of the galaxy have shown that the line energy is Doppler-shifted due to the large-scale galactic rotation,



← The spatial distribution of Integral/ISGRI-detected sources in galactic coordinates with symbol size proportional to the published X-ray measured column density. A cluster of heavily-obscured sources can be seen in the direction of the Perseus/Norma Arms with no comparable overdensity towards the Scutum/Sagittarius Arms (Bodaghee *et al*)



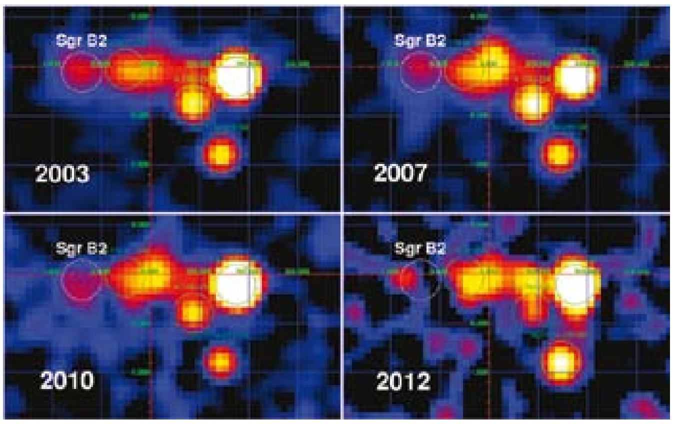
← Spatial distribution of the 511 keV positron annihilation emission in the Galactic Centre. Long Integral exposures show a dominant central bulge and surprisingly weak emission from the disc (L. Bouchet *et al*)



← Integral spectra from the centre of the galaxy: black, total emission of resolved point sources; blue, total diffuse emission; magenta, 511 keV annihilation radiation (positronium continuum and line emission); green, emission from the galactic ridge resulting from interstellar particle interaction; red, accreting magnetic white dwarfs. The vertical dotted lines indicate the narrow lines. Inserts show the fine spectroscopy analysis of selected lines (L. Bouchet)

→

Integral/IBIS 17-60 keV images of the Galactic Centre region obtained between 2003 and 2012. Circles show the positions of some known sources. The white circle shows the position of the molecular cloud Sgr B2. The hard X-ray emission from Sgr B2 = IGR J17475-2822 has clearly declined over the past decade (Terrier *et al*/Krivonos *et al*)



directly proving the galaxy-wide origin of the aluminium-26. These observations also allowed an independent determination of the galactic core-collapse supernova rate of about one per 50 years.

Gamma-ray lines from the radioactive decay of titanium-44 lines at 67.9 keV and 78.4 keV were detected from the young supernova remnant Cas A, as well as from the nearest recent supernova SN 1987A in the Large Magellanic Cloud, clearly showing that these remnants originated from the collapse of a very massive star.

Survey science

Because of its unique capability to monitor the Galactic Centre and bulge area for long uninterrupted periods at a sensitivity level unreachable by other wide-field instruments, Integral is especially powerful at discovering faint and/or short-lived phenomena. Integral has more than doubled the number of known sources in the hard X-ray sky and has also massively increased our knowledge about the nature of individual sources.

For example, Integral has discovered a new class of high-mass X-ray binaries, which are embedded in local environments with very high absorption, meaning that these sources could not be identified earlier with soft X-ray instruments.

Many of these sources have supergiant companion stars, where a significant fraction of the absorption is due to the supergiant's stellar wind. Observations of several of these sources show X-ray pulsations, indicating that the compact object is a neutron star.

Integral's unique survey capability was further illustrated by its extensive studies of the class of 'supergiant fast X-ray transients'. These objects are high-mass X-ray binaries that display short X-ray outbursts, typically lasting only hours and with a low duty cycle. The cause for the short outbursts is likely connected to the mode of stellar wind accretion.

Neutron stars and black holes

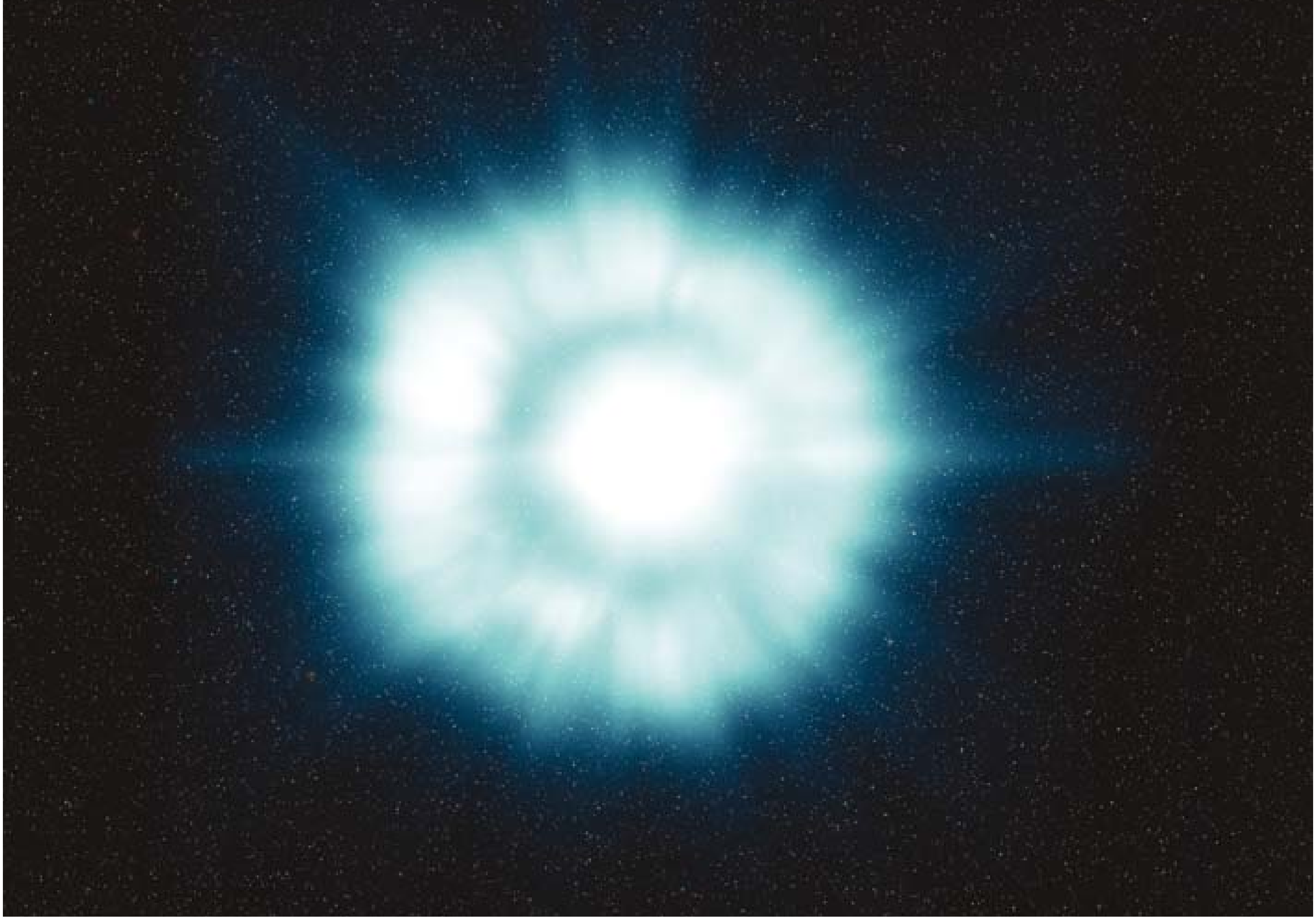
Integral has discovered hard 'tails' extending to 200–300 keV in the spectrum of extremely magnetised neutron stars ('magnetars'), which show a complex dependence on the pulse phase. The observations of these anomalous X-ray pulsars have provided new constraints on the geometry and physics of the strongest magnetic fields in the Universe.

In neutron star systems with weaker magnetic fields, cyclotron lines are the only direct way to determine their magnetic fields. The energy of these lines can be used to measure directly the magnetic field. Integral's monitoring of spectral changes during the outbursts of neutron star binaries with cyclotron lines has led to the discovery that the observed intensity is correlated with the mass accretion rate via the height of the accretion column above the stellar surface.

X-ray polarisation measurements: Crab and Cygnus X-1

Integral detected the degree and phase-dependence of polarisation in the Crab nebula and its associated pulsar

“ **With a sensitivity unreachable by other wide-field instruments, Integral is especially powerful at discovering faint or short-lived phenomena.** ”



↑ Artist impression of a gamma-ray burst. These bursts are mysterious blasts apparently exploding at random in the distant realms of the Universe and probably caused by the collision of neutron stars (the hearts of dead stars) or the explosion of very massive stars

in the hard X-ray to soft gamma-ray regime. The degree of polarisation and the polarisation angle are comparable to optical data for the point source in the Crab nebula, indicating that the hard X-rays and gamma-rays from the Crab must originate in the same region, close to the pulsar. Recently, Integral also detected polarisation in the hard spectral tail of the black hole candidate Cygnus X-1. Consistent with some emission models for black holes, the polarisation is likely to be due to synchrotron radiation, being emitted in the base of the radio jets.

The Galactic Centre and galactic diffuse emission

The centre of our galaxy harbours a supermassive black hole Sgr A* (around four million time our Sun's mass), which is surprisingly faint at high energies compared to galactic stellar-mass black holes (a few solar masses). Integral's discovery of hard X-rays from the giant galactic molecular cloud Sgr B2, located near the Galactic Centre, is best interpreted as scattering of radiation emitted by Sgr A*, meaning that the emission likely traces the activity of Sgr A* some 300 years in the past.

The most compelling evidence of such reflection is the Integral discovery of Sgr B2 fading in hard X-rays during the last decade. The behaviour of Sgr A* resembles that of a low-luminosity active galactic nucleus and it might become brighter again in the future.

In the galactic plane, outside the Galactic Centre, Integral has discovered that accreting white dwarfs are responsible for a significant fraction of the originally apparently 'diffuse' galactic ridge emission at energies less than 50 keV while, at energies above 50 keV, this emission is produced by the interaction of cosmic ray particles with the gas of the interstellar medium. This provides important information for our understanding of the gas and energy content of the galaxy as a whole and of its interstellar medium.

Active galactic nuclei and the cosmic X-ray background

Integral plays a key role in our understanding of active galactic nuclei (AGN), the centres of galaxies thought to host supermassive black holes strongly accreting from their environment, covering the energy range where the non-thermal processes are dominant.

The IBIS all-sky catalogue comprises now more than 300 AGN. So far, Integral has more than doubled the number of AGN detected above 100 keV compared to earlier surveys and the number of sources is increasing with deep exposures outside of the galactic plane. Broadband spectral analysis of many AGN has shown that their high-energy radiation is due to multiple scattering of soft photons by electrons in plasma ('thermal Comptonisation') surrounding the central black hole, which is mildly relativistic and has a low optical depth.

Integral is a key instrument in the study of absorbed AGN and has discovered new highly absorbed sources. Integral has revealed that the percentage of absorbed sources is around 80%, while the fraction of highly absorbed objects is about 20%, compatible with results obtained from optically selected samples.

Wide-band Integral spectra are a unique tool to characterise the primary spectral shape of AGN, which is of paramount importance for synthesis models of the cosmic X-ray background. Integral has provided first direct comparison between the collective hard X-ray spectral energy distribution of local AGN and the cosmic diffuse X-ray background spectrum in the 3keV–300 keV energy range.

Special observations using Earth as a blocking device in the field of view have been performed to determine the integrated hard X-ray background flux with Integral, thereby disentangling the contributions from the cosmic diffuse X-ray background and the total instrumental background.

Gamma-ray bursts

Integral is one of the major facilities for studying gamma-ray bursts (GRBs) above 20 keV. Realtime, arcminute positions of GRBs imaged with IBIS are distributed via the Internet at a rate of about 10 per year. Follow-up observations by other space- and ground-based observatories have revealed more than 50 X-ray, optical and/or radio counterparts to these events, many at very large distances with high redshifts. The omnidirectional SPI veto subsystem detects about one GRB every three days. This subsystem has also played a key role in localising and identifying two events believed to be extragalactic giant magnetar flares from M81 and M31.

With its unique sensitivity, Integral detects a large number of faint GRBs. This capability is essential to investigate the fraction of GRBs with long spectral lags, which appear to be a low-luminosity population distinct from the high-luminosity one. These low-luminosity sources are thought to be relatively local, an important Integral discovery.

The detection of polarisation in GRB 041219A with Integral has opened a new observational window providing information on the physical mechanism by which the central engine of a GRB emits the huge observed energies, a presently unresolved but crucial issue.

In addition, the polarised emission from this GRB, detected by Integral, was analysed to search for any violations of 'Lorentz invariance'. This is a prediction about the fundamental nature of spacetime, the fabric of the Universe, and symmetries relating to rotations and changes of velocity, made by Dutch physicist Hendrik Lorentz during the development of the theory of special relativity about a century ago.

However, if spacetime is quantised, Lorentz invariance might be violated and photons with different energies (wavelengths) could propagate differently in space via the 'vacuum birefringence' effect, leading to polarisation.

Polarised emission of very distant sources can be used to test this effect. Integral showed that the polarised light from GRB 041219A (at a distance of about 300 million light-years) does not show the effects of energy-dependent propagation, and provided a new stringent upper limit on any violation of this important aspect of fundamental physics five orders of magnitude better than before.

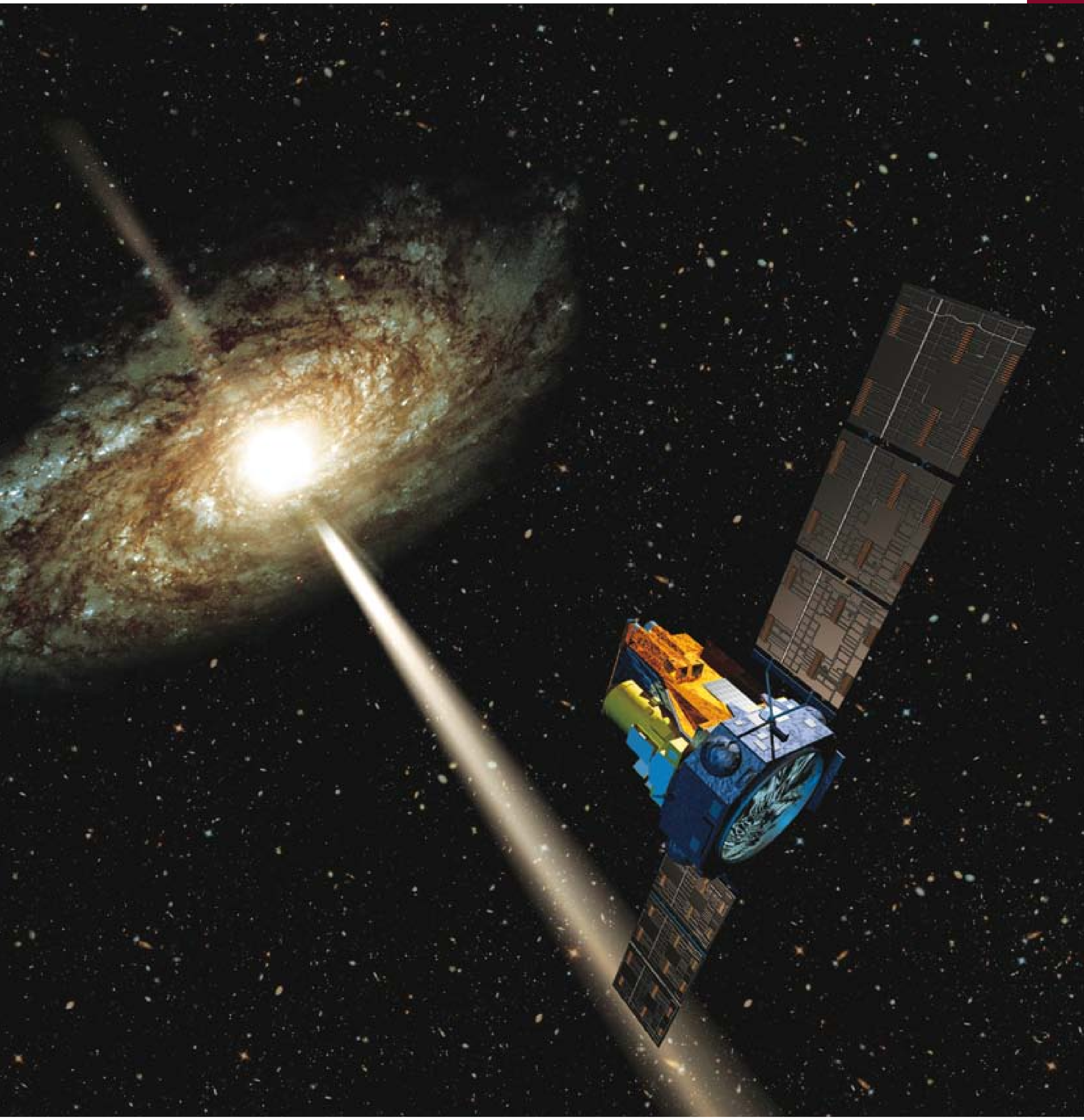
Outlook

On 17 October 2012, Integral celebrated its tenth very successful year in orbit. Science operations of the mission are approved until the end of 2014, and a new request to extend the mission by another two years until the end of 2016, is under review by ESA's Advisory Structure.

Integral will remain the only hard X-ray/soft gamma-ray observatory for the foreseeable future. Science results expected in the coming years span a wide range of high-energy astrophysics, including studies of the distribution of positrons in our galaxy; the study of nucleosynthesis in the galaxy, including the long-overdue next galactic supernova, studies of black holes and neutron stars in high-mass systems, gamma-ray polarisation measurements for X-ray binaries and gamma-ray bursts, and sensitive detection capabilities for obscured active galaxies.

> **"Integral has more than doubled the number of known sources in the hard X-ray sky and also massively increased our knowledge about the nature of individual sources."**

> “Integral will remain the only hard X-ray/soft gamma-ray observatory for the foreseeable future.”



New data products provided by SMOS have been opening the door for novel applications (Image - MetroTiff)

→ SMOS OVER LAND

New applications for ESA's water mission

Matthias Drusch
Directorate of Earth Observation, ESTEC, Noordwijk, The Netherlands

Susanne Mecklenburg
Directorate of Earth Observation, ESRIN, Frascati, Italy

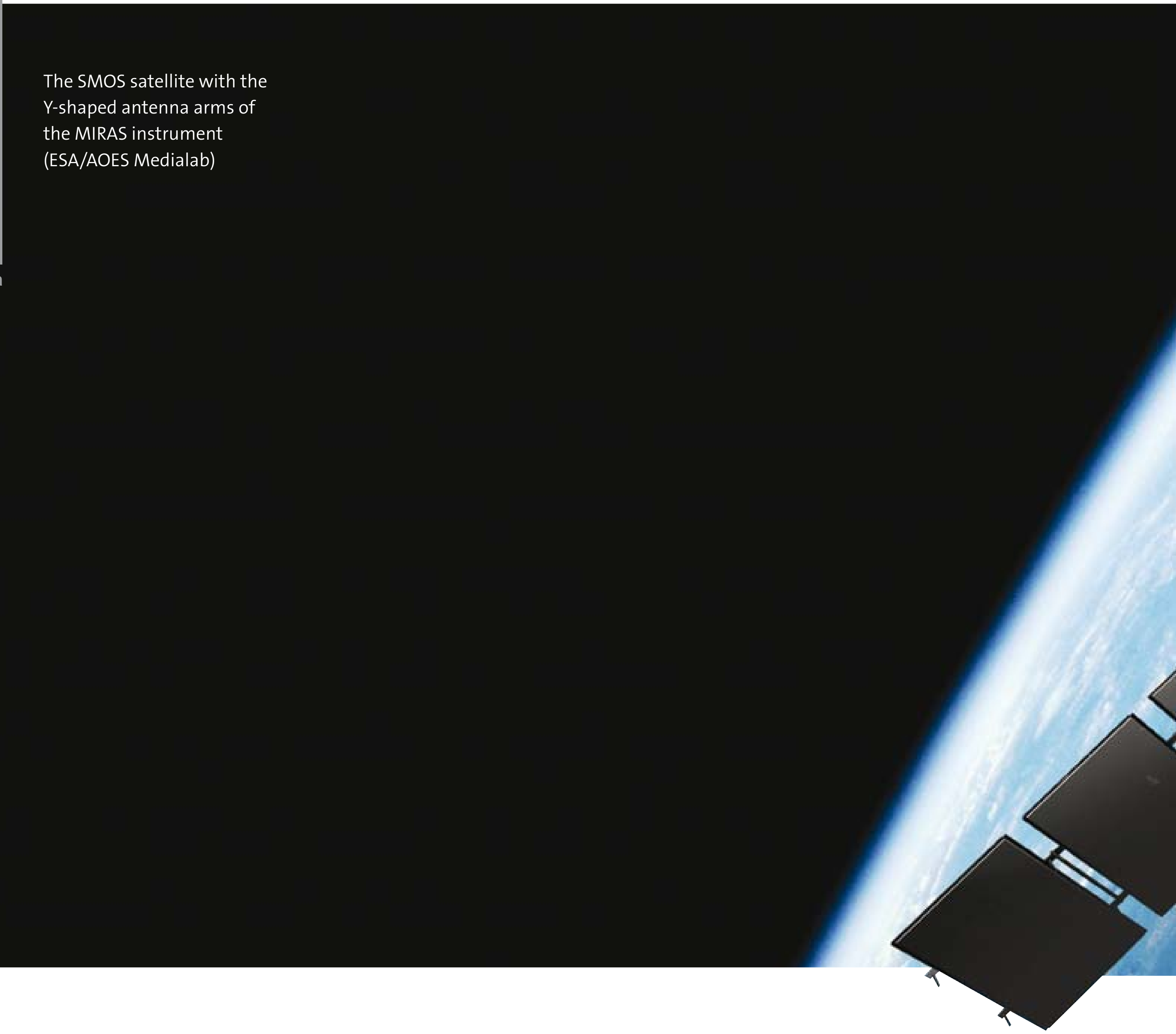
Yann Kerr
CESBIO, Toulouse, France

After three years in space, the number and variety of applications of ESA's water mission SMOS have exceeded expectations. Novel data products have been opening the door for new application areas.

Launched in 2009, SMOS, standing for Soil Moisture and Ocean Salinity, is observing key elements of Earth's water cycle. SMOS is the second Earth Explorer Opportunity mission to be developed as part of ESA's Living Planet Programme. Designed to operate for three years in orbit, SMOS is in very good shape technically at the end of its nominal mission lifetime and is thus able to continue to provide data beyond 2012.

One of its main features is a pioneering instrument called MIRAS, the first synthetic aperture L-band radiometer ever operated from space. This instrument works on the same principle as an array of astronomical radio telescopes – but it points back to Earth, not out into space. It features 69 separate radiometer receivers assembled on three arms in a Y-shaped configuration. As well as demonstrating the use of this new instrument, the data acquired from this mission will contribute to furthering our knowledge of Earth's water cycle.

Soil moisture and sea-surface salinity are two variables in Earth's water cycle that scientists need on a global scale for a variety of applications, such as oceanographic,



The SMOS satellite with the Y-shaped antenna arms of the MIRAS instrument (ESA/AOES Medialab)

meteorological and hydrological forecasting, as well as research into climate change.

Moisture and salinity decrease the 'emissivity' of soil and seawater respectively, and thereby affect microwave radiation emitted from Earth's surface. To observe soil moisture over Earth's landmasses and salinity over the oceans, SMOS effectively measures the microwave radiation emitted from Earth's surface. MIRAS picks up faint microwave emissions to map levels of moisture in the ground and the saltiness of the oceans, and these are provided as 2D images, or 'snapshots', of 'brightness temperature'. SMOS makes these measurements in the L-band (electromagnetic waves with a wavelength of 21 cm)

"The enthusiasm in the corresponding scientific communities with the number and variety of applications has clearly exceeded our expectations."

because it is particularly well suited for observing the ocean and land surfaces.

Measurements made in this band are hardly affected by the atmosphere and clouds, and even vegetation looks transparent over large regions of the world. Because this radiation partly originates from inside the water and the soil, the properties of the top layers can be determined down to a depth of several centimetres.

SMOS is also the first ESA Earth Explorer mission with a dedicated near-real-time processing chain for its brightness temperature observations in its operational ground segment. This means that the observations have to be delivered to the end user within 180 minutes of sensing. This fast data processing is a prerequisite for many users who produce forecasts, such as weather centres and hydrological agencies.

To date, SMOS is performing very well according to its system requirements for the satellite and the ground segment. The derived Level 2 soil moisture datasets meet the mission requirements and have been widely used by the science community.

However, a measure of success for an Earth Explorer satellite mission could also be its potential impact for operational applications and on its added socio-economic value.

SMOS data are currently being used in weather and flood forecasting. Drought monitoring systems based on SMOS

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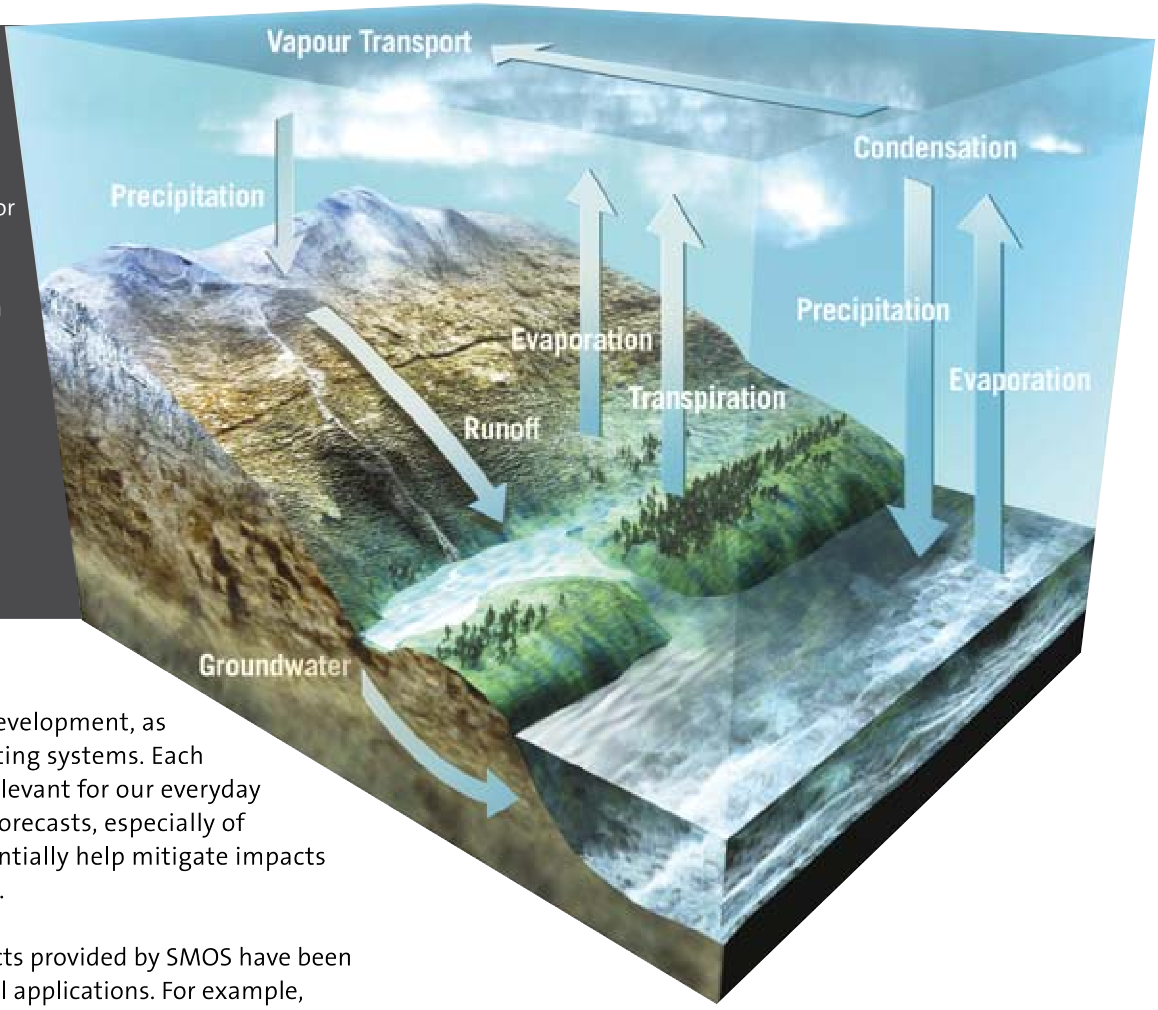
Soil moisture and ocean salinity are the key geophysical parameters for enhanced understanding of the terrestrial water balance, ocean circulation and climate change



observations are under development, as well as crop yield forecasting systems. Each of these areas is highly relevant for our everyday lives. Improved weather forecasts, especially of extreme events, can potentially help mitigate impacts and save billions of euros.

Recently, new data products provided by SMOS have been opening the door for novel applications. For example, it was found that the freeze-thaw cycle of soils can be determined, and this could result in the improved monitoring of the active surface layer in permafrost regions and a more accurate description of the gas exchange between land surfaces and the atmosphere, which is highly relevant for our climate system.

Applications

Soil moisture is a key variable determining the exchange of water and energy between the land surface and the atmosphere. SMOS soil moisture data have their own scientific value, because they provide an independent estimate of the current state of the land surface. Monitoring the spatial and temporal global dynamics of soil moisture is important for a variety of applications, such as water resources management, weather forecasting, agriculture, flood prediction and climate research. An additional socio-economic value of these Earth observation data comes from their use in forecasting systems and the subsequent decision-making process.

To reduce forecasting uncertainty, satellite observations can be used in data assimilation systems to improve the accuracy of the initial conditions. For our daily weather forecasts, out to a few days ahead, soil moisture mainly influences the development of air temperature and humidity in the lower atmosphere. Locally, convection, the formation of clouds and subsequent precipitation events, can be modified or triggered by the amount of water in the soil and its availability for the atmosphere as well.

“Improved weather forecasts, especially of extreme events, can potentially help mitigate impacts and save billions of euros.”

↑ The drought-stricken Debar Lake, 150 km west of Skopje in Macedonia. The western Balkans have been hit by an ongoing heat wave this September that has seen temperatures over 42°C, triggering hundreds of wildfires (Miller and Farmer Assoc.)

Early studies by ECMWF indicated that the use of satellite-derived soil moisture estimates reduces the errors in the temperature and humidity forecasts and influences a variety of weather parameters.

Soil moisture also plays an important role in long-range forecasts, such as in monthly and seasonal weather prediction. For example, it could be shown that the 2003 heatwave in Europe followed a very dry spring. Low soil moisture contents over large parts in Europe influenced the onset and the duration of this very extreme event, which led to the deaths of over 30 000 people and damage costing an estimated €11 billion in the farming, livestock and forestry industries alone. Using SMOS data in seasonal forecasting systems will be addressed in a future scientific study starting in 2013.

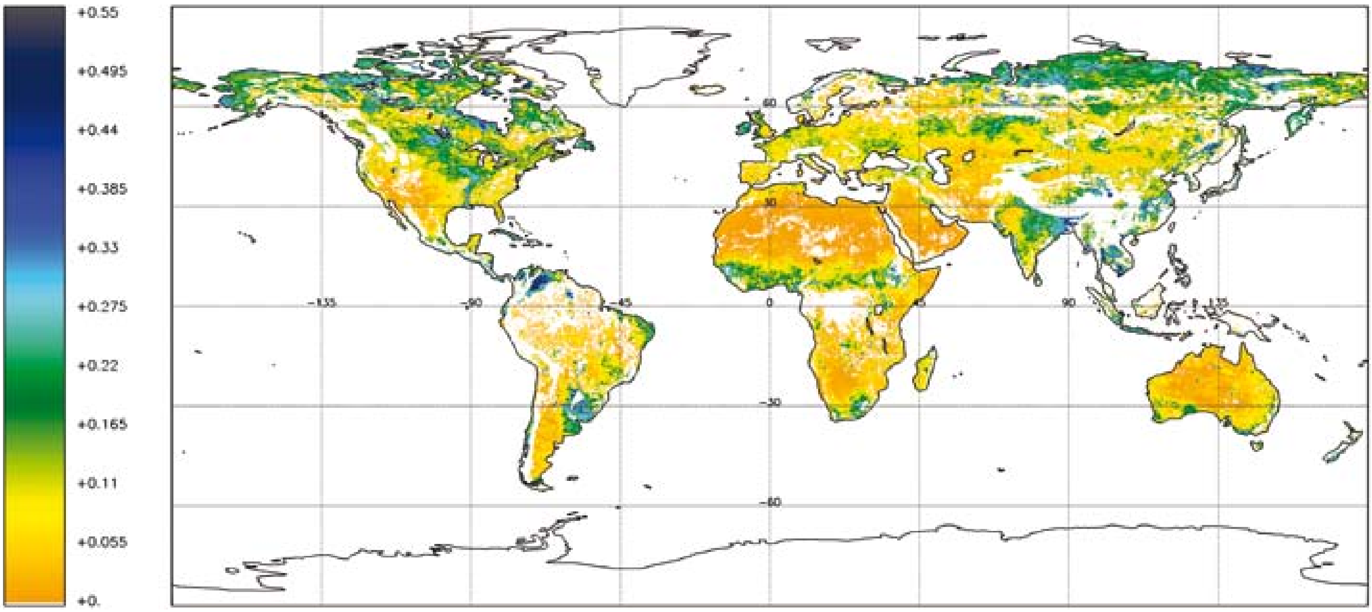
The dynamics of surface soil moisture are an important source of uncertainty in flood forecasting models as well. Floods, as a consequence of too much water runoff, can be generated through saturation excess overland flow and infiltration excess overland flow. In the first case, soil moisture determines how much water can be stored in the soil before runoff and flooding starts. In the second case, soil moisture determines the infiltration capacity and the moment when runoff starts. Knowing the soil moisture distribution before an expected heavy rainfall event will in both cases help to determine whether the water reaching the land surface can infiltrate and be stored in the soil or will cause flooding.

Combining information on storm tracks, the corresponding precipitation forecasts and SMOS soil

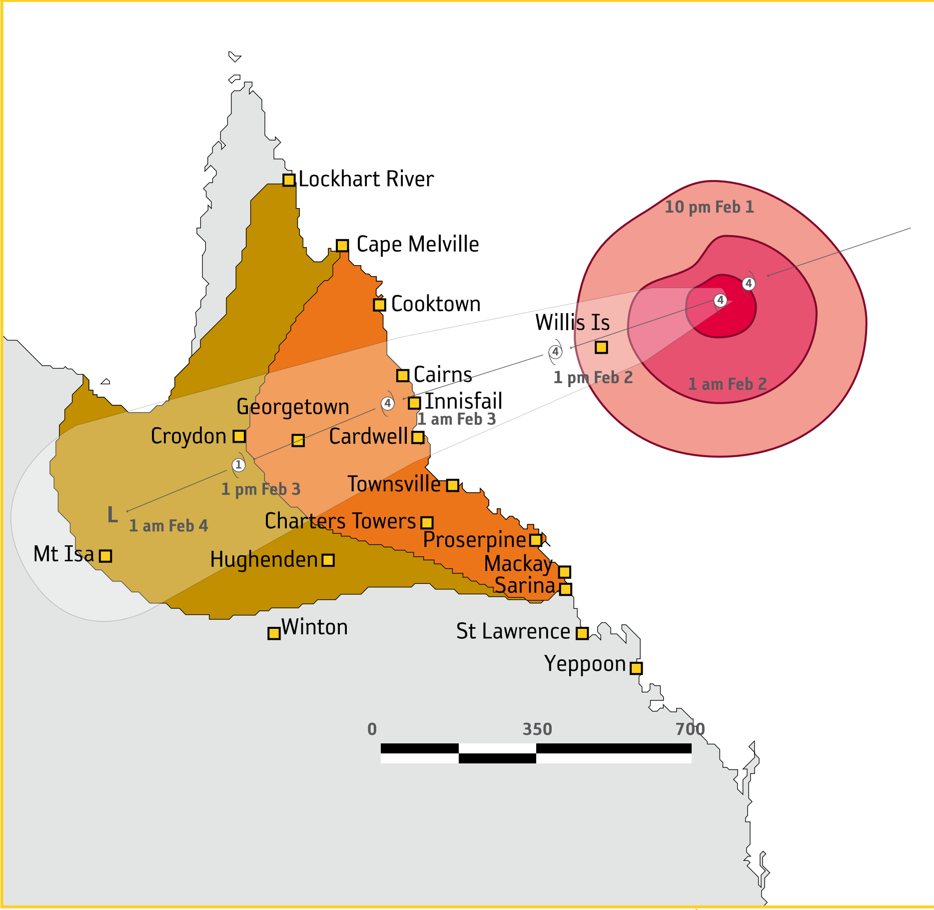
↑ Roofs of houses are visible above flood waters in Brisbane, Australia, during disastrous floods in early 2011 (Reuters/T. Wimborne)

moisture maps can give us flood risk maps, which can be used to mitigate the effects of extreme weather events. The concept was demonstrated using data over Australia's east coast in 2011 and which is being further developed by an international consortium through the 'SMOS + Hydrology' study within ESA's Support to Science Element (STSE) programme.

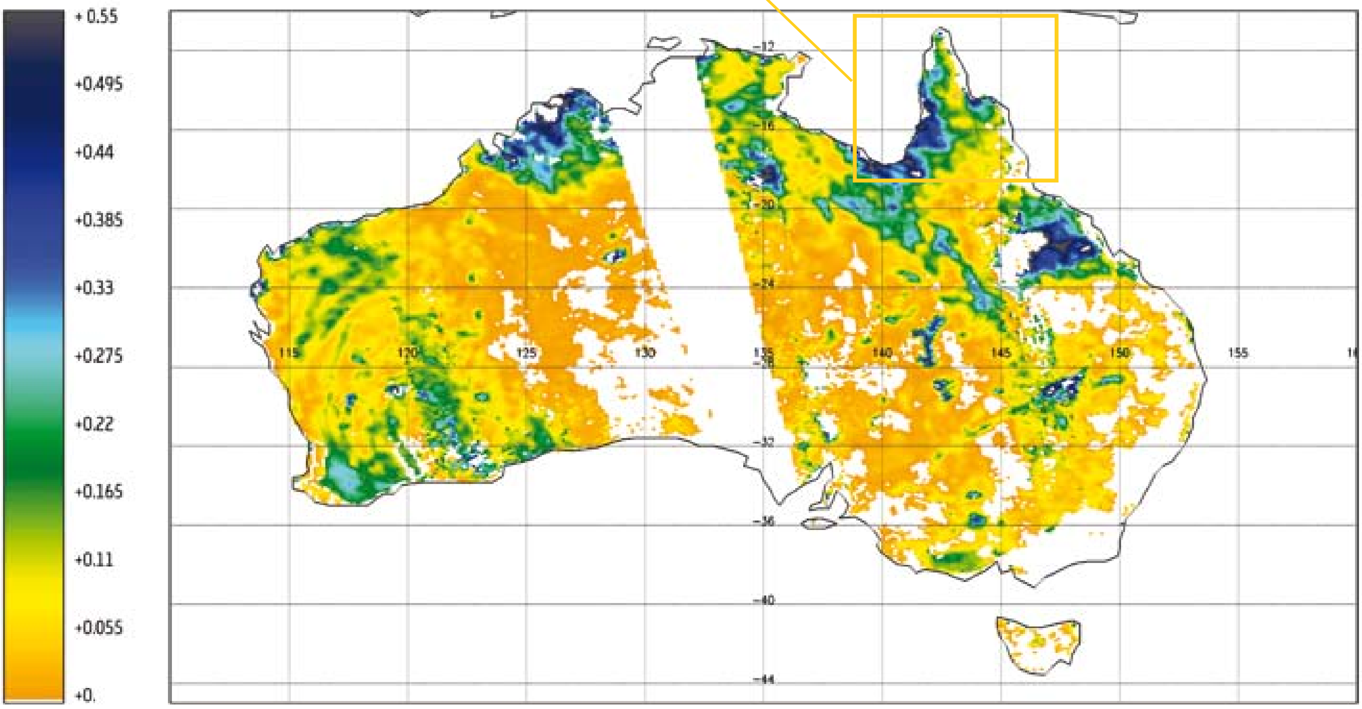
The growth of vegetation is intrinsically dependent on the amount of plant-available soil moisture for photosynthesis



↑ Global surface soil moisture fields for June 2011, with moisture in m³/m³ (CESBIO/Y. Kerr)



← The forecast storm track issued by the Bureau of Meteorology shows that the centre of the storm was expected to hit the coast on 3 February with heavy rainfall. By combining information from the weather forecast and the soil moisture state from SMOS, the risk of severe flooding could be assessed. Here, the risk was assumed to be low because the rain from this storm could be largely absorbed by the relatively dry soil. If the storm had hit the coast further south, where the soil was already saturated, the risk of severe flooding would have been high



↑ SMOS-derived soil moisture conditions in Australia for 29–31 January 2011, just before a tropical storm system hit the northeast coast, with moisture in m³/m³ (CESBIO/Y. Kerr)

→ How do we verify SMOS data?

Brightness temperature data

The key data produced for the user communities are geolocated 'brightness temperatures' for the individual orbits of the satellite. Radiative transfer calculations are needed to extract the information on geophysical parameters, such as surface soil moisture, vegetation opacity or soil frost depth.

Three brightness temperature (Level 1) data streams have been implemented in the ground segment: (1) a near-real time product providing operational power users (such as the European Centre for Medium-range Weather Forecasts, ECMWF) with global observations within three hours of sensing, (2) a near-realtime 'light' product with a reduced spatial coverage over land areas for hydrological applications, and (3) the nominal Level 1C product received by the user within 12 to 48 hours.

Data products have been made available to users operationally since the end of the SMOS commissioning phase in May 2010 and the payload data ground segment is performing to expectations.

Verification and quality control

Verifying these top-of-the-atmosphere brightness temperature observations and assessing the products' accuracy is extremely difficult and is done independently from the in-orbit instrument calibration.

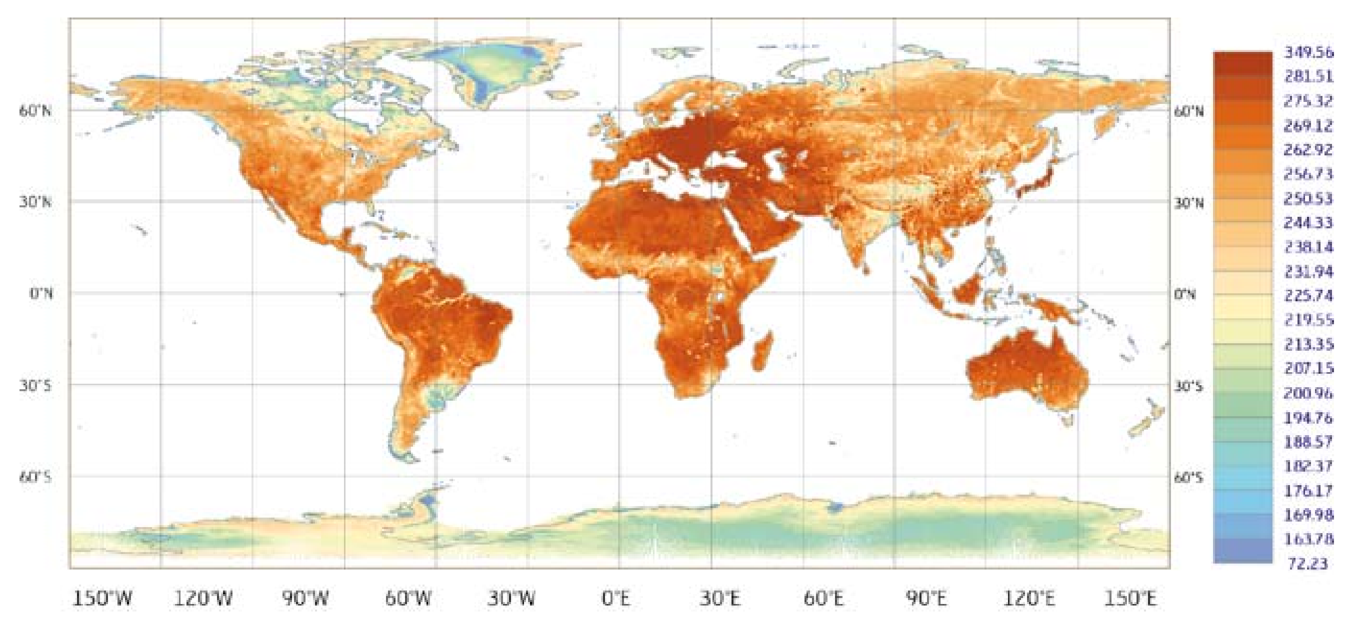
An external homogeneous target is needed, one that is large enough to represent an individual observation of about 2500 km^2, and with dielectric properties that hardly vary with time. This target should also be well positioned with respect to the instrument's observation geometry to ensure systematic and frequent revisits.

One such area that fits these requirements is the East Antarctic Plateau, specifically the area near the Italian/French base of Concordia. This site is particularly well suited for Level 1 product verification because the extinction of radiation of dry snow is low, the upper ice sheet layer is almost transparent for low-frequency microwave observations and the observed signal mainly originates from the thermally stable deep ice layers.

For the evaluation of the satellite data, a radiometer operating at the same frequency was installed on a tower at Concordia and operated from 2008 to 2010. Both instruments, the tower-based radiometer and the SMOS MIRAS, provided data for a direct comparison. Time-series indicate an excellent agreement between the satellite observations and the ground truth.

However, operating a ground-based radiometer over Antarctica is expensive and only feasible for limited periods when there are dedicated campaigns. The ECMWF is performing day-to-day quality control of the brightness temperature observations

↓ Mean SMOS brightness temperatures in Kelvin for September to October 2012 as monitored by ECMWF (www.ecmwf.int/products/forecasts/d/charts)



↑ A view of the tower-based radiometer RadomeX and ice-sheet area at Concordia Station (G. Macelloni/IFAC-CNR)

within their data-monitoring framework. Together with more than 100 million observations per day delivered from satellites, aircrafts, ships, buoys, radiosondes and weather stations, the SMOS observations are compared against modelled brightness temperatures based on the daily weather forecast.

Although this approach does not allow an absolute validation of the SMOS product, trends, jumps and spikes in the satellite observations can be detected against a stable reference, meaning statistics derived from the global forecast fields. In addition, the ECMWF monitoring allows a comparison against similar satellite data, for example from the Special Sensor Microwave/Imager. More than 600 images are produced each day and published for public access through the ECMWF web site for the SMOS quality control only.

and the assimilation of carbon. When soil moisture becomes a limiting factor for these processes, information on this anomaly can provide a leading signal for subsequent problems in vegetative health and a shortfall in plant productivity. Consequently, soil moisture information is commonly used in operational drought forecasting activities. For example, the US Department of Agriculture's Foreign Agricultural Service predicts end-of-season global crop yields for commodity crops. The accuracy of these forecasts is partly limited by the quality of rainfall accumulation data used in the model to predict soil moisture in the plant's root zone. With the data derived from the SMOS mission we should see a significant expansion in our ability to forecast ecosystem productivity and/or agricultural yields by using remotely sensed soil moisture information directly.

Level 2 soil moisture and verification

A radiative transfer model is used to compute multi-angular brightness temperatures based on a set of 'first guess' geophysical parameters including surface soil moisture. These model values are compared against the observations, using the sum of the squared weighted differences in the so-called 'cost function'. Finding the optimal soil moisture value then minimises the differences. The resulting Level 2 product is volumetric soil moisture representing the top centimetres of the soil on a swath-by-swath basis. From these data, higher-level products can be calculated, for example maps showing the daily distribution of soil moisture or monthly averages.

Verifying these soil moisture products is again a challenge. There are many different ways of taking *in situ* measurements. Soil moisture can be determined by first weighing a soil sample, oven drying it at 105°C and then reweighing it. Knowing the density of water and the sample's volume the loss in mass can be easily transformed into volumetric water content. Other methods comprise electrical resistance blocks, neutron moisture meters, and capacitance and time-domain reflectometry. However, taking and collecting these measurements is time-consuming and costly. In addition, these point measurements do not necessarily support the coarse resolution satellite observations due to the heterogeneity of the soil and the vegetation cover.

↑ Taking *in situ* soil moisture measurements during a five-week campaign in southeast Australia to validate SMOS data (Univ. Melbourne)

In order to collect, quality control and harmonise the local and regional soil moisture data sets, the Technical University of Vienna and ESA established the International Soil Moisture Network (ISMN). The Global Energy and Water Cycle Experiment (GEWEX) coordinate this international initiative in cooperation with the Group of Earth Observation (GEO) and the Committee on Earth Observation Satellites (CEOS). As of now, observations from more than 1200 stations can be downloaded and visualised through the ISMN's web interface under a free and open data policy. The ISMN has more than 500 registered users and has become the world's largest database for *in situ* soil moisture observations. Comparisons between the SMOS derived soil moisture estimates and the *in situ* measurements indicate a good overall performance in line with the expectations.

Frontiers

Soil moisture and ocean salinity have been the two key geophysical parameters driving the SMOS mission concept and its design. The corresponding validation activities and some of the applications have been carefully addressed and planned during the mission preparation phases on the ground and in orbit. However, as the observations have become available, new parameters and exciting applications have been analysed and developed by scientists.

Over the oceans, research into sea-ice thickness and extreme wind speeds associated with storms and hurricanes has been performed successfully. Over land, monitoring the freeze-thaw cycle of soil and detecting frost depth seem feasible. Soil freezing, wintertime evolution of soil frost and thawing are important characteristics influencing the hydrological and climate processes of the large land areas of North America and northern Eurasia.

Changes in the seasonal behaviour of frost have a major effect on the surface energy balance, as well as on the intensity of carbon dioxide (CO_2) and methane (CH_4) fluxes. CH_4 releases from wetlands have been found to increase during recent decades, for example in Siberia because of

←

Tundra ponds in Alaska. Because of permafrost (up to 500–600 m thick in places), the land is frozen and holds a lot of water on the surface (Omniterra Images)

←

Networks and stations providing *in situ* measurements for the International Soil Moisture Network database. Data are available at www.ipf.tuwien.ac.at/insitu (Wagner, TU Vienna)

the thickening of the seasonally thawed active layer above the permafrost. On the other hand, it has been shown how to relate this information to changes in CO_2.

In the case of boreal forests, the annual CO_2 balance has been found to be highly dependent on conditions during autumn and early winter.

The first soil frost depth datasets based on SMOS observations were derived by the Finnish Meteorological Institute for two consecutive winter periods starting in 2010. Key elements, such as the southward progression of soil freezing in autumn and early winter, were monitored successfully as well as the late onset of winter in northern Europe in 2011.

These results are potentially interesting for climate applications because they could enhance our understanding of the temporal behaviour of the active layer in permafrost regions and the gas exchange process.

More research involving the climate modelling community will be dedicated to this topic over the next few years when multi-year time-series of SMOS observations will allow the analysis of seasonal and inter-annual variations. ■

→ HOME ALONE

Recreating space on Earth

Julien Harrod and **Carl Walker**
Communication Department, ESTEC, Noordwijk, The Netherlands

Dr Alex Kumar, British medical doctor overwintering at Concordia base in Antarctica, conducting research for ESA for a future mission to Mars (ESA/IPEV/PNRA/A. Kumar)

←

A new form of training for the US Mercury astronauts in 1959, flying 'zero-g' trajectories in a C-131 aircraft. These parabolic flights are still used for spaceflight training purposes (NASA)

No single environment on Earth can recreate all aspects of space travel but, by combining lessons learnt from 'analogue' simulations, we are providing a wealth of knowledge and helping to prepare astronauts for future missions.

In the last decade, studies conducted by ESA, NASA and other space agencies have diversified, each offering their own simulations of spaceflight on Earth. ESA runs and takes part in a number of projects that put equipment, protocols and people through their paces in these 'space analogues'.

By sending future astronauts and scientists on missions underground, to the Antarctic and underwater, or locking them into confinement for over a year, ESA is recreating conditions of space exploration missions.

The long road to Mars

It's amazing to think that we are so close to sending a person to another planet for the first time in the history of civilisation – the world's space agencies are discussing long-term plans for space exploration, including investigations on how to send humankind beyond Earth orbit.

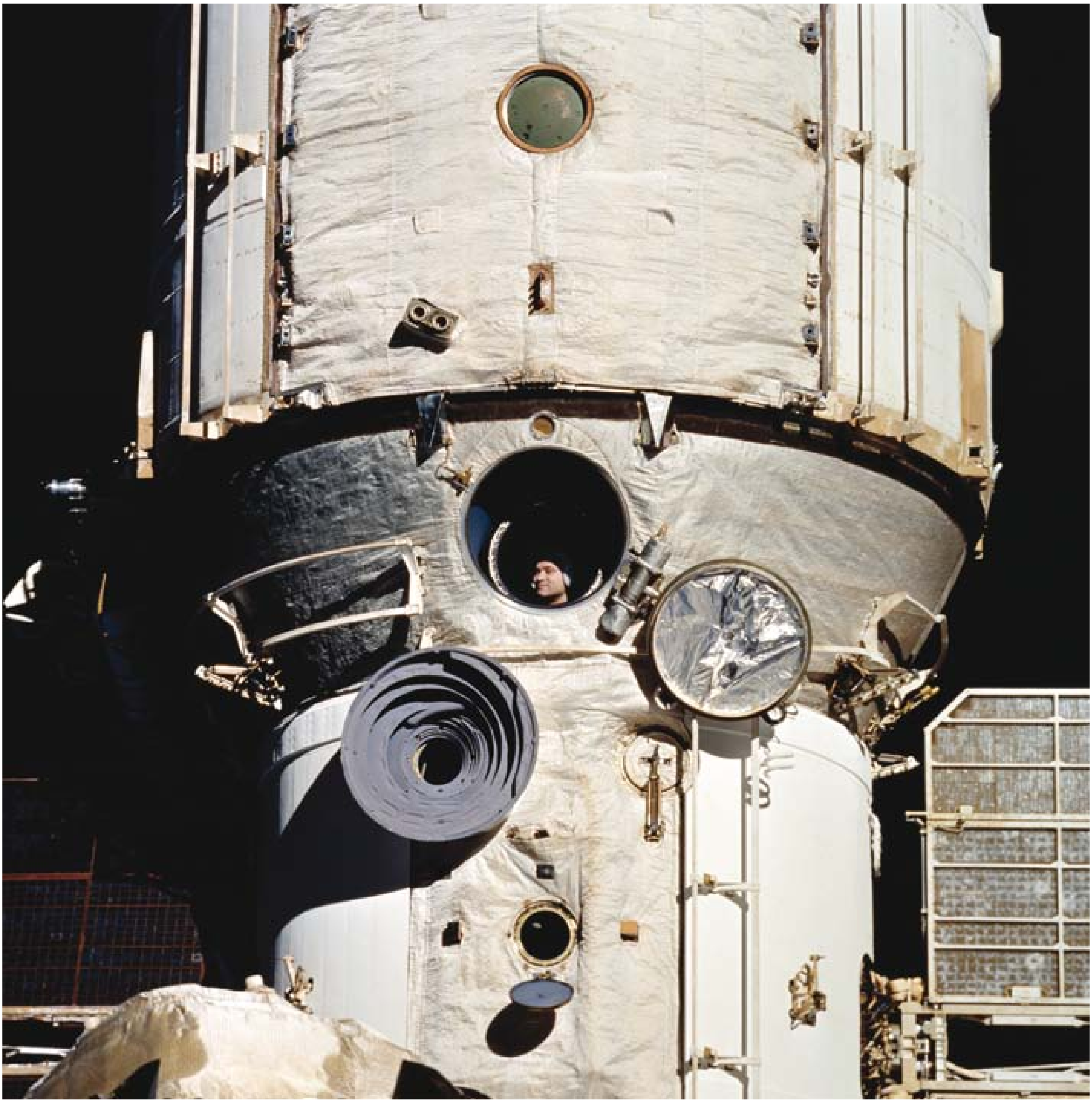
One possible destination, Mars, has beckoned since the first humans gazed at the night sky and observed its distinctive colour and movement. It is our nearest planetary neighbour and has been assumed, even before we reached the Moon, to be our next target.

When people eventually go to Mars, chances are it will take them up to a year to get there, and scientists and engineers know that there are still many problems to overcome. For example, what is the best way to land a heavy spacecraft on another planet with a thin atmosphere? How do we carry enough fuel, food and water for a two-year trip? How do we deal with the ever-present danger of radiation? These are engineering challenges that need to be solved and some day will be.

But there are also 'human' challenges to take into account, and few have inspired as much scientific and popular speculation as that of the effects of weightlessness. Before the first living creatures were sent into space in the 1940s, some scientists believed that humans would not be able to survive in weightlessness. They feared basic functions, such as swallowing or pumping blood, could work only with gravity.

For Yuri Gagarin, the first man in space in 1961, the knowledge that the dog Laika and other test animals had also stayed alive in their spacecraft was not completely reassuring. He is known to have had doubts about his own survival. However, he need not have worried. Since then, astronauts and cosmonauts have been travelling into space on progressively longer missions, and now they fly regularly to the International Space Station for six-month stays.

Although there are still many things to learn about the effects of weightlessness on our bodies, Russian



↑ Cosmonaut Valeri Polyakov looks out of Mir's window during rendezvous operations with the Space Shuttle *Discovery* STS-63 in February 1995 (NASA)

cosmonaut Dr Valeri Polyakov proved that a human could survive the first leg of the trip to Mars. Polyakov is the holder of the record for the longest single spaceflight, staying aboard the Mir space station for more than 14 months (437 days 18 hours) in 1994–95.

What are the psychological impacts of such a long stay in space? Data from Polyakov's flight show that humans are able to maintain a healthy mental and physical state during long spaceflights just as they would on Earth. But it was also revealed that Polyakov experienced changes in mood as well as feelings of increased workload at times, although he did not suffer from any prolonged negative effects after returning to Earth.

However, the first people to travel to Mars will experience something unique. The dangers, isolation and confinement associated with this journey are not everyday occurrences.

←

In 1968, astronauts Joe Kerwin, Joe Engle and Vance Brand spent a week inside an Apollo capsule before the first manned Apollo mission (NASA)

Some of the closest approximations to a Mars mission that people have ever experienced, in terms of the psychological effects, are long deployments on submarines.

A submarine is similar to a spacecraft. Both are pressurised self-contained environments, both are without Earthly comforts like fresh air, fresh food or sunlight. Both environments involve spending months at a time with crewmates in a claustrophobically confined space. Years of naval submarine experience have demonstrated that crews can tolerate conditions of confinement and remain effective for long periods. Even so, conditions on submarines are sufficiently different from those in space to be not directly comparable.

Alongside a small Mars-bound spacecraft, a modern nuclear submarine looks huge and luxurious. With a crew of hundreds, not only are there more people to socialise with, but also there is more space on board for privacy. So how can Earth-based simulations prepare astronauts for the stresses they will face when going to Mars?

Training for space

When training future astronauts and designing long-duration space missions, we are faced with a problem: it is impossible to recreate all aspects of space travel on Earth at one time.

If gravity is omnipresent and the loneliness, remoteness and dangers of spaceflight are not easy to simulate, then how do psychologists, scientists and engineers plan for long space missions beyond Earth orbit?

Hans Bolender, Head of Astronaut Training at ESA's European Astronaut Centre in Cologne, explains, "We can recreate some of the stressors encountered in spaceflight. Often these involve a combination of limited food, loss of sleep, low hygiene and taking decisions under stressful situations."

One of the first experiments involving these stress factors was performed in 1962 by caving expert Michel Siffre. He spent two months underground with no way of being able to tell the passage of time. With no sunlight, near-freezing temperatures and extreme humidity, it is a wonder the explorer survived at all. Siffre contacted a support team by telephone whenever he went to sleep or woke up.

When Siffre eventually came out of his underground habitat, he had grossly misjudged the passage of time. What he had believed to be brief siestas were actually a full night's sleep and his body clock had adapted to staying awake for an average of 24 hours at a time. Siffre's research continued and in 1972 he conducted a repeat experiment for NASA in caves in Texas.

In the 1960s, both the former Soviet Union and the United States locked people into closed-chamber systems to test their spacecraft life-support systems. In order to prepare to fly to the Moon, NASA made two closed-chamber tests to simulate the Apollo and Skylab missions.

In 1970, a 90-day manned test of a regenerative life-support system was completed by McDonnell Douglas Astronautics. Four male volunteers were sealed in a pressurised chamber, 4 m in diameter and 10 m long.

Water and oxygen were totally recycled with no resupply. All expendables, food, chemicals, filters and spare parts were stored at the beginning of the study. These tests were successful and provided important information about crew health in enclosed systems, but they were still only operational tests of life-support systems.

As space missions became longer, during the 1980s and 1990s, space mission planners were becoming concerned about interpersonal issues in astronaut crew composition.

The nature of NASA's crews was undergoing significant change. In the past, its astronauts were primarily young American men with military backgrounds. Missions were short and crews were small. Before a mission, a crew trained together for a year or more, so that any conflicts could be worked out in advance.

The future, however, promised crews that would be far less homogeneous and regimented. There would be international crews, different languages and mixed genders, and larger crews on longer missions. This was the start of Soviet/American cooperation and planning for the International Space Station.

The psychological aspect was still one of the main unknowns, especially on even longer flights, such as a manned mission to Mars. ESA conducted a series of isolation studies in the early 1990s involving culturally mixed crews in hyperbaric chambers. The first study, ISEMSI, put six European men in isolation for four weeks in Norway. The results were positive, with the crew reporting that they emerged from their isolation bonded as a team.

A further isolation study in 1992 included both male and female crewmembers in a hyperbaric chamber in Germany. This time the participants lived together for 60 days. Particular attention was given in both studies to crew interaction, and how they positioned themselves in the habitat. Conclusions drawn from the first study recommended six astronauts as the ideal number for group dynamics on a space station, which corresponds to the permanent crew number on the International Space Station today.

"We can recreate some of the stressors encountered in spaceflight. Often these involve a combination of limited food, loss of sleep and taking decisions under stressful situations."

↓ French underground explorer Michel Siffre in 1962

Partly in preparation for the EuroMir '95 mission, ESA teamed up with the Russian Institute for Biomedical Problems (IBMP) to study three men in isolation for 135 days. In 1999, another study was conducted in preparation for the sending astronauts to the International Space Station. A permanent crew was confined for 240 days, then complemented by two other crews that stayed in the simulated spacecraft for 110 days. Simulated Soyuz and Space Shuttle flights brought supplies and several short-term visitors.

To determine any psychological problems associated with such a mission and develop pre-emptive countermeasures, simulation projects are being run today. do exist. Two in particular are: the Mars Society's Desert Research Stations, and Mars500, run by the IBMP and ESA.

The Mars Society's Desert Research Station project puts volunteer 'astronauts' in a simulated martian environment for two weeks at a time, either in the Arizona desert or in northern Canada – environments that are similar to the terrain found on Mars.

The crew lives and works in a single cylindrical habitat with only the barest essentials for comfort, necessary food portioned out for each astronaut by meal, and minimal water for consumption and hygiene. They only go outside wearing full (simulated) pressure suits to conduct field tests. They communicate with 'mission control' in Colorado with a 20-minute time delay – the delay of radio communications between Mars and Earth. They also live on a schedule of martian days, which are 39 minutes longer than Earth days.

↑ The Mars500 crew at one year into their simulated trip to Mars in 2011 (ESA/IBMP)

The Mars Desert Station has its limitations. Its two-week duration is not long enough to determine any real psychological effects. Mars500 took martian simulation a step further, putting a crew of six 'marsonauts': two Europeans, three Russians and one Chinese through a full mission, not just a two-week taste.

Mars500

After being locked inside a simulated spacecraft in Moscow for 520 days, the Mars500 crew of volunteers emerged 'back on planet Earth' last November. Through the year and a half of isolation, the all-male crew lived in quarters the size of a caravan and, apart from a short 'marswalk' on a mock-up planetary surface, the crew spent two eight-month periods in total confinement.

They could shower only once a week, ate canned food and received emails with a delay that depended on how far away they were supposed to be from Earth. At the maximum simulated distance in their voyage to Mars, an artificial 12-minute time delay was put in place for all communication with ground control.

The crew got updates from their family in recorded messages, recording their own messages in return. Communication with friends and relatives was important for crew morale. At the end of their 520-day isolation, the Mars500 crewmembers were treated to a direct talk with family. Crewmember Diego Urbina remembered how important that call was. "Hearing people talk live means a lot. It is the best gift you can get," he said.

> **Hearing people talk live means a lot. It is the best gift you can get.**

Because no sunlight entered the Mars500 cabin, scientists tested a system of blue lights to regulate the inhabitants' sleeping patterns. Diego Urbina recounted, "Dreams became much more vivid after a couple of months of isolation."

Data collection focused on the biophysical and psychological condition of the crew. Body temperature, hormone levels, concentration and morale were constantly monitored. The crew spent a large amount of their time taking blood and saliva samples and filling in questionnaires. As Diego put it, "Our bodies were the best researched living bodies in the world."

Many studies looked at the morale and stresses of the crew. As anyone who enjoys a good meal knows, food is extremely important for morale. Preparing a balanced meal that provides the right nutrition, and tastes good while making sure it will stay edible for eight months is a difficult task for chefs and dieticians tackling food for long spaceflights.

The isolation study was a complete success in its primary goal: to assess the psychology of group dynamics and individual performance under isolated and confined conditions. Patrik Sundblad, the lead human life scientist at ESA, said, "Yes, the crew can survive the inevitable isolation of a mission to Mars and back. Psychologically, we can do it. They had their ups and downs, but these were to be expected. In fact, we anticipated many more problems, but the crew did surprisingly well."

Cooperation between the crew and ground control teams was essential. "It is not only about the spacecraft and its crew, but also about close cooperation on Earth between all the teams and the international space agencies," said Sundblad.

But can either of these studies really approximate what a crew will likely experience when travelling to Mars? As gruelling as the Mars500 simulation was, there are still several other challenges of space travel — both physical and psychological — that simply cannot be accounted for in any simulated Mars mission on Earth.

Astronauts on a real trip to Mars would be much more cramped and isolated. They would be completely trapped in their pressurised cabins with no escape or way of rescue if things went wrong. Once en route to Mars, there is no turning back. Collision with space debris might also weigh heavily on the minds of these space travellers, but perhaps most significantly, they would have to be psychologically capable of dealing with the fact that they are really and literally millions of kilometres from home, which could create a sense of uneasy detachment.

The biggest limitation is that all martian simulations so far are on Earth. No matter how little communication a crew has with the outside world or how physically isolated they are, the crews do not forget that they are still on Earth. Psychologically, they know that they are being monitored closely and that in an emergency help is minutes away, not years.

↑ A Mars500 crewman walking on a simulated 'martian' surface

↑ The physical exercise area of the Mars500 enclosure

↑ Mars500's Diego Urbina in the recreation/living area module

Alex Kumar, ESA-sponsored medical doctor, enjoys a bracing sub-zero outdoor bath in Concordia base's meltwater tank (ESA/IPEV/PNRA/A. Kumar)

The two towers of Concordia base in Antarctica (ESA/IPEV/PNRA/A. Kumar)

Is there any way to create the mental separation needed to really gather data on the psychological effects of a possible manned mission to Mars?

The science of stress

At the Concordia research station in Antarctica, the crew knows that whatever happens, help will never come during the winter months.

Built on a plateau 3200 m above sea level, Concordia consists of two towers, like a science-fiction Moon base. The site was chosen for its relative good weather and the area is well known because many climate research ice-drilling projects have been conducted there. The base was completed in 2005 and is crewed all year round. Every year geologists, astronomers and climate scientists conduct research they could not carry out anywhere else on Earth.

The base has a number of unique characteristics: it is one of the coldest, darkest, driest and most remote places on Earth. For four months, the Sun does not rise above the horizon and temperatures fall below –70°C. Because of this, planes and helicopters cannot land at the base from April to November, because of the risk of their fuel freezing. With no other living things within a radius of 600 km, Concordia is more remote than the International Space Station.

ESA sponsors a medical research doctor, Dr Alex Kumar, to study how the international crew cope with the stress of

> **Living on Concordia is a psychological marathon. It is unpredictable and cannot be imagined until you face it.**

↑ "Red sky at night, shepherd's delight"; what appears to be evening light from a low Sun at Concordia, but the night lasts for four months (ESA/IPEV/PNRA/A. Kumar)

living and working in such extreme conditions. Alex described his experience, "Living on Concordia is a psychological marathon. It is unpredictable and cannot be imagined until you face it."

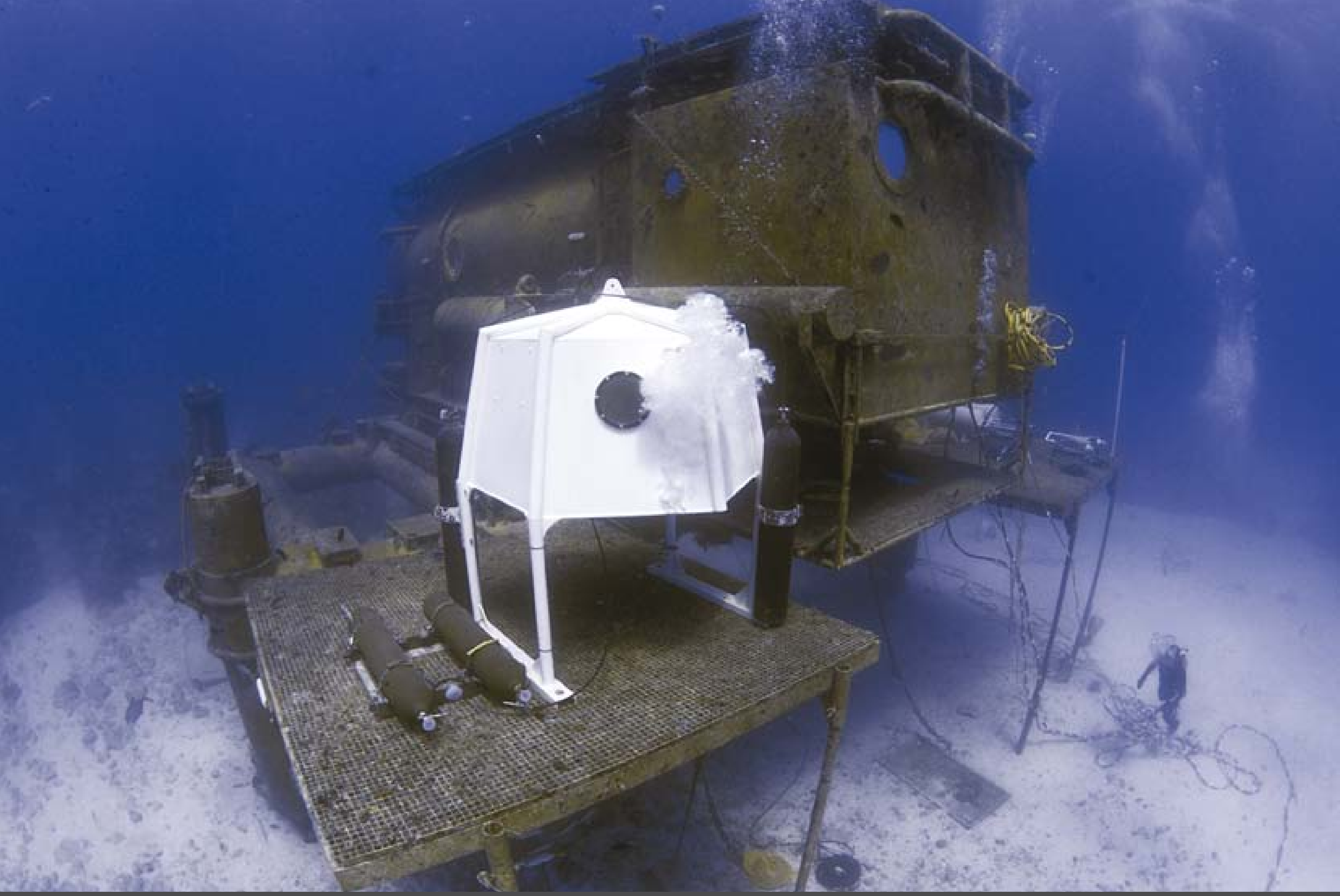
Oliver Angerer, ESA's Concordia coordinator, said, "The environment is a continuous stress and poses challenges to all the participants involved. We are looking at how the crew performs in this harsh environment, in particular regarding sleep."

Concordia is a 24-hour operation, so even at night there is always at least one person on the base doing things, such as making night-time measurements. Sleep is always disrupted by others coming or going. Concordia is a test of character as much as a test of bodily strength and adaptation.

This year, Alex has been recording hormone levels of his crewmates and finding out if exercise can counter the effects of living without Sun for months. This research, coupled with the findings of Mars500, will give mission designers an idea of how astronauts' bodies will respond on long missions and how best to counteract negative side-effects.

↓ Medical research at Concordia will give mission designers an idea of how astronauts' bodies will respond on long space missions (ESA/IPEV/PNRA/A. Kumar)

On the positive side, Concordians can think themselves lucky in one area: with a vast freezer just outside the door, they are less reliant on dried, processed and powdered food.



↑ Home to NEEMO crews, the Aquarius underwater habitat owned by the US National Oceanic and Atmospheric Administration and operated by the US National Undersea Research Center (NOAA)

Heading to inner space

There are also dangers associated with a Mars mission that Earth-based simulations can't replicate. In both Mars500 and the Mars Society simulations, there was no vacuum outside the astronaut habitats. A broken hatch or a rip in a spacesuit did not mean instant death.

But NASA's underwater scenario, NEEMO, introduces another dimension in space simulation. Living together in the cramped conditions of the Aquarius base 20 m down on the seafloor, NEEMO 'aquanauts' spend around six days at a time underwater. Diving can be very dangerous unless you are properly trained, and escape to the surface is not possible without lengthy decompression stops.

Astronauts spend many hours training for spacewalks underwater because floating in a swimming pool is as close as it gets to floating in space, so these missions offer a unique chance to test, experiment and teach astronauts to work together in conditions not unlike space.

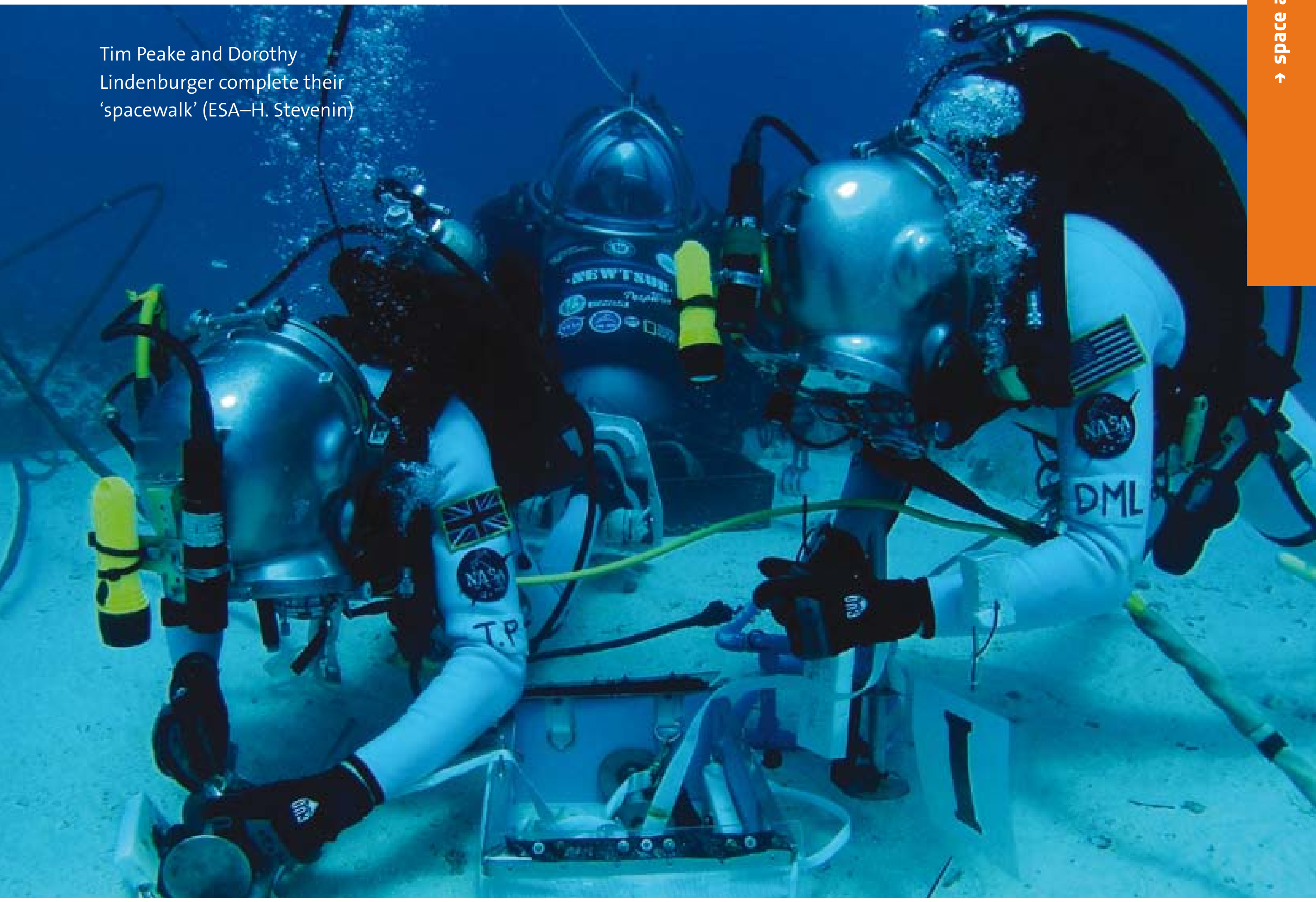
ESA astronaut trainer Loredana Bessone described her first view of the base, "When I dived down to the underwater habitat, it looked exactly how I imagined a lunar base would look like. Aquanauts were 'floating' around in slow motion, performing repairs and installing equipment. I could not take my eyes off the scene."

The 16th NEEMO mission's purpose was to practise techniques for a sample collection mission to an asteroid,

"When I dived down to the underwater habitat, it looked exactly how I imagined a lunar base would look like."

→ The crew of NEEMO 16 a few minutes before their 'splashdown' to the Aquarius underwater habitat off Key Largo, from left: ESA astronaut Tim Peake, NASA astronaut Dorothy Lindenburger, ESA trainer Hervé Stevenin, scientist Steve Squyres and JAXA astronaut Kimiya Yui (NASA/K. Kehe)

↑ NEEMO aquanauts Tim Peake and Steve Squyres check their email at 20 m below the sea surface (NASA)



Tim Peake and Dorothy Lindenburger complete their 'spacewalk' (ESA–H. Stevenin)

involving six crewmembers and over 80 support divers and ground control staff off the coast of Florida. Flying to an asteroid is one thing, but once near the asteroid how will astronauts approach the surface, chip away a piece and return it to their spacecraft safely? Several methods were tested during NEEMO.

This year, an ESA astronaut joined NEEMO for the first time. Tim Peake remembers the mission as an exemplary form of teamwork. "The 80-person team in a short space of time gelled together into a tight-knit and highly efficient unit that speaks volumes about our common goal: pushing the boundaries of mankind's exploration into the Solar System," said Tim.

To make the situation more realistic, a two-minute communication delay was imposed, which is about the same time radio signals would take to travel to a real asteroid near our planet. Conducting a full-scale mission under these conditions had never been done before, so neither mission control nor the aquanauts had any idea what to expect.

"Our common goal: pushing the boundaries of mankind's exploration into the Solar System."

Sa Grutta caves in Sardinia, home to six astronauts for a week (ESA/V. Crobu)

Going underground

ESA has developed a new variant of training for space called CAVES. Loredana Bessone, a specialist in human behavioural training and the CAVES course designer, says that the idea for CAVES came from wanting to increase the resemblance of ESA outdoor behavioural training courses to spaceflight.

"Caves as an environment and caving activities present many similarities to spaceflight, such as isolation, confinement, limited resources and the need for safety protocols. Caves are perfect environments that allowed me to shape the course to fit the requirements," said Loredana.

Now in its second year, CAVES sends six astronauts underground for almost a week in the Sa Grutta caves on the island of Sardinia, Italy. This year astronauts from Japan, Russia, USA, Canada and ESA, all five partners of the International Space Station, participated. Importantly, experienced astronauts were also included in the team who can extrapolate lessons to CAVES from their own spaceflight experience.

> **Caves as an environment and caving activities present many similarities to spaceflight.**

← This year an international crew of six astronauts trained for a caving adventure designed to prepare them for spaceflight. From left: Roscosmos' cosmonaut Nikolai Tikhonov, David Saint-Jacques from the Canadian Space Agency, NASA's Drew Feustel, ESA astronaut Andreas Mogensen, JAXA's Soichi Noguchi and Mike Fincke also from NASA (ESA/V. Crobu)

"Having all partners on board allows the course to put a strong focus on multicultural approaches to leadership, followership, teamwork and decision-making," says Loredana.

Mission operations in the caves are kept as realistic as possible. After a week of training, the astronauts are tasked with making cave survey maps of the areas they explore. They also perform a scientific research programme, including searching for life.

While exploring the caves, they follow standard practices, as they would during a spacewalk on the International Space Station. Moving in a cave is similar to spacewalking, requiring safety tethering, three-dimensional orientation and staying clear of dangerous areas.

CAVES offers the chance for astronauts from all partner agencies of the International Space Station to get to know each other, have confidence in each other and understand their different ways of working. This is not to be underestimated, as Hans Bolender explains, "Astronaut training is very scattered, so astronauts often do not have time to get to know well enough their crewmates with whom they will spend the next six months on the Space Station."

Every possible resource exploited

Numerous sites on Earth are used to test space equipment where the terrain resembles that found on neighbouring planets. In the 1960s, the Apollo astronauts received geology training in the lunar-like landscapes of Iceland, Greenland, Nevada and Arizona. Today, Norway's volcanic archipelago of Svalbard, resembling the surface of Mars,

↓ Collecting samples during the orientation phase of CAVES. Astronauts need to get used to confined spaces, minimal privacy, limited equipment and supplies for hygiene and comfort – just like in space (ESA/V.Crobu)

↓ A 'cavewalk': moving in a cave is similar to a spacewalk (ESA/V. Crobu)

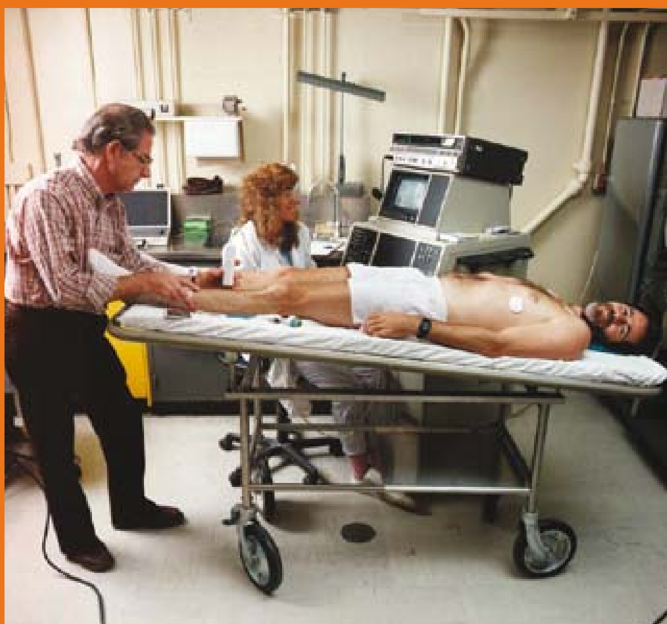
↑ The Eurobot Ground Prototype and 'Aouda.X' spacesuit mockup in the Mars-like terrain of Rio Tinto in Andalucia, Spain, in 2011. The tests were organised by the Austrian Space Forum together with ESA and Prof. Felipe Gomez from the Centro de AstroBiologia, Madrid (ESA/ÖWF/P. Santek)

→ Get some rest

Recreating some of the conditions of spaceflight does not always mean going to extreme environments. For example, it has been found that simply lying in bed for several weeks, in beds tilted at an angle of 6° below horizontal, induces changes to bones, muscles and the cardiovascular system similar to those experienced by astronauts in weightlessness.

Bedrest studies offer scientists a way to assess the role of nutrition and physical exercise to combat our body's adaptation to weightlessness. These studies require highly motivated test subjects. During the observation periods, sometimes lasting up to 90 days, volunteers have to lie down in this unusual position and undertake all daily activities with their heads slightly below the level of their feet.

Bedrest studies on healthy subjects were first recorded in the mid 1800s, and were later used used in the 1960s by both Russian and American space programmes. ESA has performed a number of bed rest studies in collaboration with European partners.



↑ Head-down tilt bed rest is a way for researchers on Earth to simulate the effects of microgravity on the body (NASA)

↑ ESA astronaut Andreas Mogensen testing communication equipment on loan from the Italian alpine and speleological rescue organisation that ensured CAVES course safety (ESA/V. Crobu)

was used to test equipment of NASA's Mars Curiosity rover. The Rio Tinto river in Spain is used to test ESA's Eurobot and prototype spacesuit equipment, among other things.

Testing equipment on Earth is one thing, but sending astronauts to Rio Tinto or Svalbard would not be a suitable stand-in for spaceflight. Working and living in most places on Earth is too comfortable and safe to offer similarities with the stresses of spaceflight. In order to learn more about the psychology of spaceflight, astronauts have to be sent to more extreme environments.

"No single environment on Earth can recreate all aspects of space travel, but the wealth of data from these space analogues helps us anticipate problems and, importantly, at low cost compared to sending the astronauts into space," said Hans Bolender. ■

→ Analogue pioneers

On 14 July 1969, just two days before the Apollo 11 launch, the Grumman/Piccard PX-15 mesoscaphe *Ben Franklin* descended to 300 m off the coast of Florida with a six-man international crew. This vehicle drifted 2300 km north with the current for more than four weeks, surfacing near Maine.

↑ Undersea pioneers Don Walsh and Jacques Piccard (Life)

Among the crew was Jacques Piccard, the Swiss oceanographer and engineer, known for having developed underwater vehicles for studying ocean currents. He and Lt Don Walsh of the US Navy were the first people to explore the deepest part of the world's ocean, and the deepest location on the surface of the Earth's crust, the Challenger Deep, in the Mariana Trench in the Pacific Ocean.

Also in the crew was Chet May from NASA. His specialty was 'man working in space'. Dr Wernher von Braun had learned about the Franklin mission and considered it as an analogue to a long-duration space mission, such as on the forthcoming Skylab. He appointed May as a NASA observer to accompany the submariners and study the effects of prolonged isolation on the crew.

↑ The mesoscaphe *Ben Franklin* (NASA)

→ NEWS IN BRIEF

Neil A. Armstrong
1930–2012


ARMSTRONG

Mission accomplished

ESA's third Automated Transfer Vehicle cargo ferry, ATV *Edoardo Amaldi,* completed its six-month servicing mission to the International Space Station on 3 October by reentering the atmosphere and burning up over an uninhabited area of the Pacific Ocean.

During its mission, ATV *Edoardo Amaldi* delivered nearly seven tonnes of propellant, oxygen, air and water, as well as scientific equipment, spare parts, supplies, clothes and food to the astronauts circling Earth. The dry cargo consisted of more than a hundred bags packed into eight racks – two more racks than on previous ATV missions.

ATV *Edoardo Amaldi* was launched to orbit on 23 March by an Ariane 5 launcher and docked with the ISS five days later. On 22 August, *Edoardo Amaldi*'s eighth boost lasted for 40 minutes (nearly half an orbit) and raised the ISS to a record-breaking orbit of 405 km x 427 km above Earth. During the six months that ATV spent at the ISS, it provided 48 cubic metres of extra space for the astronauts.

Before its departure, the crew loaded its pressurised module with waste material. The European ferry undocked on 28 September, and after a short free flight, it manoeuvred into a safe reentry trajectory. *Edoardo Amaldi* and its waste burnt up harmlessly in the upper atmosphere.

Its successor, ATV *Albert Einstein*, is already set to deliver the next round of supplies to the ISS and is scheduled for launch in April 2013. ATV *Georges Lemaître* is being assembled and is scheduled for launch in April 2014.

↑ ATV *Edoardo Amaldi* as seen from the ISS after undocking (ESA/NASA)

Poland accedes to ESA Convention

Poland took a step further in its relations with ESA by exchanging Accession Agreements on the ESA Convention on 13 September, to become the 20th ESA Member State.

The ceremony took place at the Copernicus Science Centre in Warsaw, with the participation of Jean-Jacques Dordain, ESA Director General, Waldemar Pawlak, Polish Minister of Economy, and Grażyna Henclewska, Under Secretary of State in the Polish Ministry of Economy. Other government officials and dignitaries attended the ceremony, including representatives from the Polish Parliamentary Group in charge of space affairs.

Poland's cooperation with ESA is long-standing. In 1994, Poland was one of the first Eastern European countries to sign a Cooperation Agreement in the field of the peaceful use of outer space with ESA. A second step, the signature of European Cooperating State Agreement in 2007, paved the way for Polish participation in several ESA research projects.

← Exchange of accession agreements in Warsaw on 13 September (Ministry of Economy, Poland)

Poland has a long aerospace tradition and has contributed to many scientific and technological projects. Poland has participated actively in several ESA science missions, such as Integral, Rosetta, BepiColombo and Solar Orbiter, and in Earth observation activities with Envisat and GMES.

Poland is also working on ESA microgravity and exploration programmes, on EGNOS for navigation and on the Space Situational Awareness Programme (focusing on space weather), as well as in technology activities and educational projects. PW-Sat, the first Polish student satellite, was launched on the maiden Vega rocket flight in February 2012.

The Government of Poland plans to conclude the ratification process at the earliest opportunity and once the ratification instrument is deposited with the Government of France, Poland will become officially the 20th ESA Member State and will participate in the ESA Ministerial Council in November 2012 as a full Member State.

Luca flying into the blue

ESA astronaut Luca Parmitano is set to fly to the International Space Station in 2013, and his flight came a step a closer with the unveiling of his mission name and logo on 7 September.

Luca will spend six months on the International Space Station on Expedition 36/37 under an agreement with Italy's ASI space agency and NASA. A competition was opened for Italian residents to suggest a mission name and logo.

Luca took time out from his busy training schedule in the run-up to his mission to present the winning entries. Norberto Cioffi, 32, from from Milan, sent in the winning name 'Volare', meaning 'to fly' in Italian. The winning logo was designed by 28-year-old Ilaria Sardella from from Taranto.

↑ Luca Parmitano

← Volare mission logo

Greenland's vice president visits ESA

In his first official visit to ESA's ESRIN on 29 August, Greenland's Vice Premier and Minister for Housing, Infrastructure and Transport, Jens Frederiksen, discussed the monitoring of the Arctic, one of the regions most affected by climate change.

Mr Frederiksen, accompanied by the Minister Counselor and Head of the Greenland Representation to the EU, Mrs Lida Skifte Lennert, attended a series of presentations that mostly discussed the monitoring of the Arctic, one of the regions most affected by climate change.

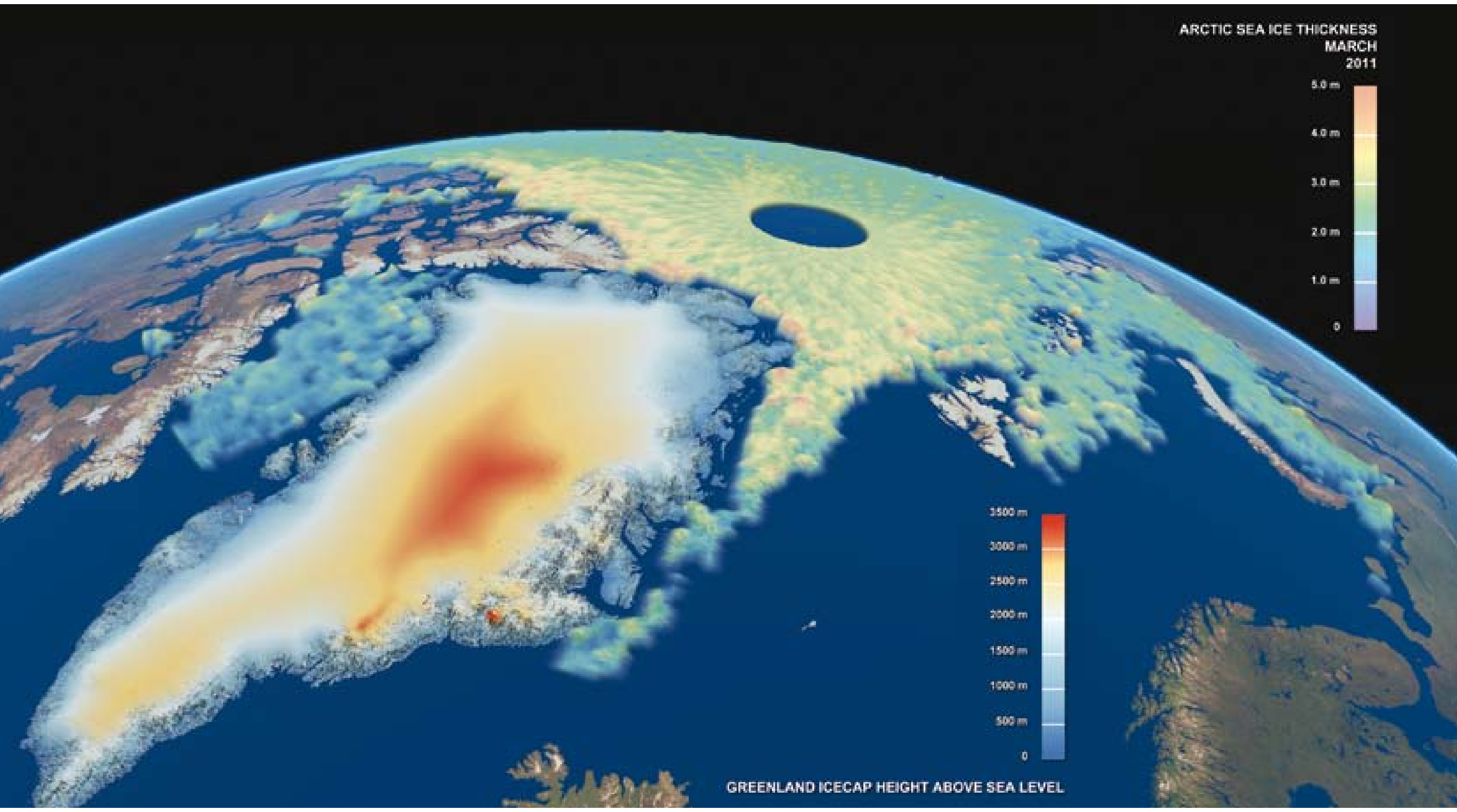
Rendered increasingly accessible by the melting of ice, the Arctic is being transformed from a region of primarily scientific interest into one attracting a complex set of environmental, security and commercial concerns.

The growing of commercial activities and use of the region's resources make infrastructure, mapping, accurate weather forecasting and climate applications key issues.

Satellites can offer unique opportunities to monitor this environment, facilitate navigation and communications, improve marine safety and help build the infrastructure needed in the Arctic to meet the region's challenges.

Mr Frederiksen noted the stronger autonomy and the new role of Greenland within the Kingdom of Denmark and with European institutions. He expressed his strong commitment to developing more networks, connections and institutional actions of his country towards an improved and reliable space system that could contribute to increasing facilities, services and industrial applications in the region.

↑ Mr Jens Frederiksen (fourth from left) and Mrs Lida Skifte Lennert (third from right) at ESRIN on 29 August



↑ Map of Arctic sea-ice thickness, as well as the elevation of Greenland Ice Sheet, for March 2011 from CryoSat-2 satellite data (NSIDC/CPOM/UCL/Leeds/ESA/PVL)

First MetOp-B data from polar orbit

The MetOp-B weather satellite, launched on 17 September, is performing well and is on its way towards replacing the ageing MetOp-A as prime operational satellite in polar orbit, after a six-month commissioning phase.

Four of the instruments on the MetOp-B were activated in September and are delivering data. The Advanced Scatterometer (ASCAT) and Microwave Humidity Sounder (MHS) are innovative European instruments. ASCAT delivers information on near-surface wind speed and direction over the global oceans and soil moisture over land, while the MHS delivers information on atmospheric humidity in all weather conditions.

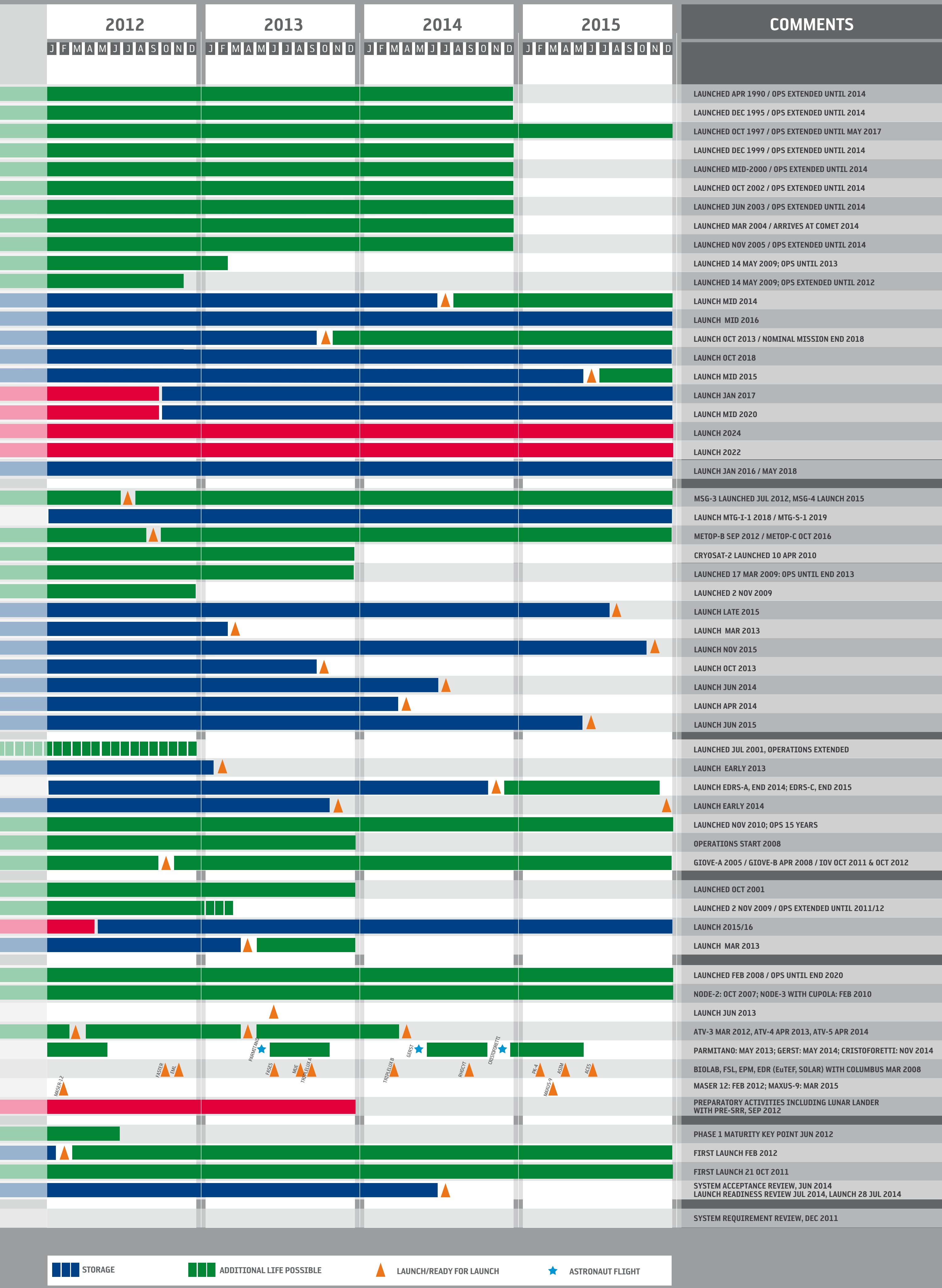
The Advanced Microwave Sounding Unit-A provides temperature soundings in all weather conditions. The Global Navigation Satellite System Receiver for Atmospheric Sounding instrument is delivering data that are used to provide atmospheric temperature and humidity profiles by measuring the bending of GPS signals through the atmosphere.

Temperature and humidity soundings, wind at the ocean surface, and soil moisture are essential inputs to numerical weather prediction models, the basis of modern weather forecasting. The all-weather wind measurements provided by ASCAT are used worldwide to track mid-latitude storms and tropical cyclones. These instruments also contribute to the long-term datasets needed for climate studies and monitoring.

→ PROGRAMMES IN PROGRESS

Status at end of October 2012


2008
2009
2010
2011
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
SOHO
CASSINI-HUYGENS
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
ROSETTA
VENUS EXPRESS
HERSCHEL
PLANCK
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
SOLAR ORBITER (M1)
EUCLID (M2)
COSMIC VISION M3
JUICE (L1)
EXOMARS
EARTH OBSERVATION PROGRAMME
MSG
MTG
METOP
CRYOSAT
GOCE
SMOS
AEOLUS
SWARM
EARTHCARE
SENTINEL-1
SENTINEL-2
SENTINEL-3
SENTINEL-5 PRECURSOR
TELECOMMS/NAVIGATION PROGRAMMES
ARTEMIS
ALPHASAT
EDRS
SMALLGEO
HYLAS
GNSS-1/EGNOS
GALILEO
TECHNOLOGY PROGRAMME
PROBA-1
PROBA-2
PROBA-3
PROBA-V
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS
NODE-2 / NODE-3 / CUPOLA
ERA
ATV
ASTRONAUT FLIGHTS
ELIPS ISS UTILISATION
ELIPS NON-ISS PAYLOADS
TRANSPORTATION & HUMAN EXPLORATION
LAUNCHER PROGRAMME
ARIANE 5 POST-ECA
VEGA
SOYUZ AT CSG
IXV
SSA
PREPARATORY PROGRAMME
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS


2012
2013
2014
2015
J F M A M J J A S O N D
COMMENTS
LAUNCHED APR 1990 / OPS EXTENDED UNTIL 2014
LAUNCHED DEC 1995 / OPS EXTENDED UNTIL 2014
LAUNCHED OCT 1997 / OPS EXTENDED UNTIL MAY 2017
LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 2014
LAUNCHED MID-2000 / OPS EXTENDED UNTIL 2014
LAUNCHED OCT 2002 / OPS EXTENDED UNTIL 2014
LAUNCHED JUN 2003 / OPS EXTENDED UNTIL 2014
LAUNCHED MAR 2004 / ARRIVES AT COMET 2014
LAUNCHED NOV 2005 / OPS EXTENDED UNTIL 2014
LAUNCHED 14 MAY 2009; OPS UNTIL 2013
LAUNCHED 14 MAY 2009; OPS EXTENDED UNTIL 2012
LAUNCH MID 2014
LAUNCH MID 2016
LAUNCH OCT 2013 / NOMINAL MISSION END 2018
LAUNCH OCT 2018
LAUNCH MID 2015
LAUNCH JAN 2017
LAUNCH MID 2020
LAUNCH 2024
LAUNCH 2022
LAUNCH JAN 2016 / MAY 2018
MSG-3 LAUNCHED JUL 2012, MSG-4 LAUNCH 2015
LAUNCH MTG-I-1 2018 / MTG-S-1 2019
METOP-B SEP 2012 / METOP-C OCT 2016
CRYOSAT-2 LAUNCHED 10 APR 2010
LAUNCHED 17 MAR 2009: OPS UNTIL END 2013
LAUNCHED 2 NOV 2009
LAUNCH LATE 2015
LAUNCH MAR 2013
LAUNCH NOV 2015
LAUNCH OCT 2013
LAUNCH JUN 2014
LAUNCH APR 2014
LAUNCH JUN 2015
LAUNCHED JUL 2001, OPERATIONS EXTENDED
LAUNCH EARLY 2013
LAUNCH EDRS-A, END 2014; EDRS-C, END 2015
LAUNCH EARLY 2014
LAUNCHED NOV 2010; OPS 15 YEARS
OPERATIONS START 2008
GIOVE-A 2005 / GIOVE-B APR 2008 / IOV OCT 2011 & OCT 2012
LAUNCHED OCT 2001
LAUNCHED 2 NOV 2009 / OPS EXTENDED UNTIL 2011/12
LAUNCH 2015/16
LAUNCH MAR 2013
LAUNCHED FEB 2008 / OPS UNTIL END 2020
NODE-2: OCT 2007; NODE-3 WITH CUPOLA: FEB 2010
LAUNCH JUN 2013
ATV-3 MAR 2012, ATV-4 APR 2013, ATV-5 APR 2014
PARMITANO: MAY 2013; GERST: MAY 2014; CRISTOFORETTI: NOV 2014
BIOLAB, FSL, EPM, EDR (EuTEF, SOLAR) WITH COLUMBUS MAR 2008
MASER 12: FEB 2012; MAXUS-9: MAR 2015
PREPARATORY ACTIVITIES INCLUDING LUNAR LANDER WITH PRE-SRR, SEP 2012
PHASE 1 MATURITY KEY POINT JUN 2012
FIRST LAUNCH FEB 2012
FIRST LAUNCH 21 OCT 2011
SYSTEM ACCEPTANCE REVIEW, JUN 2014
LAUNCH READINESS REVIEW JUL 2014, LAUNCH 28 JUL 2014
SYSTEM REQUIREMENT REVIEW, DEC 2011
STORAGE
ADDITIONAL LIFE POSSIBLE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

KEY TO ACRONYMS

AM - Avionics Model	LEOP- Launch and Early Orbit Phase
AO - Announcement of Opportunity	MoU - Memorandum of Understanding
AIT - Assembly, integration and test	PDR - Preliminary Design Review
AU - Astronomical Unit	PFM - Proto-flight Model
CDR - Critical Design Review	PLM - Payload Module
CSG - Centre Spatial Guyanais	PRR - Preliminary Requirement Review
EFM - Engineering Functional Model	QM - Qualification Model
ELM - Electrical Model	SM - Structural Model
EM - Engineering Model	SRR - System Requirement Review
EQM - Electrical Qualification Model	STM - Structural/Thermal Model
FAR - Flight Acceptance Review	SVM - Service Module
FM - Flight Model	TM - Thermal Model
ITT - Invitation to Tender	

→ HUBBLE SPACE TELESCOPE

Hubble outreach activities engage both scientists and the general public. Hubble has made over a million observations since launch, but only a small number are attractive images — and even fewer are actually seen by anyone outside the small groups of scientists that publish them. However, there are still many hundreds of beautiful images, scattered among the vast amount of valuable, but visually unattractive, scientific data, that have never been enjoyed by the public. These pictures are called Hubble's 'hidden treasures', and a few months ago the public were invited to look through Hubble's science archive to help find these in the very successful Hidden Treasure Contest. The response was impressive, with almost 3000 submissions. More than a thousand of these images were fully processed: a difficult and time-consuming task.

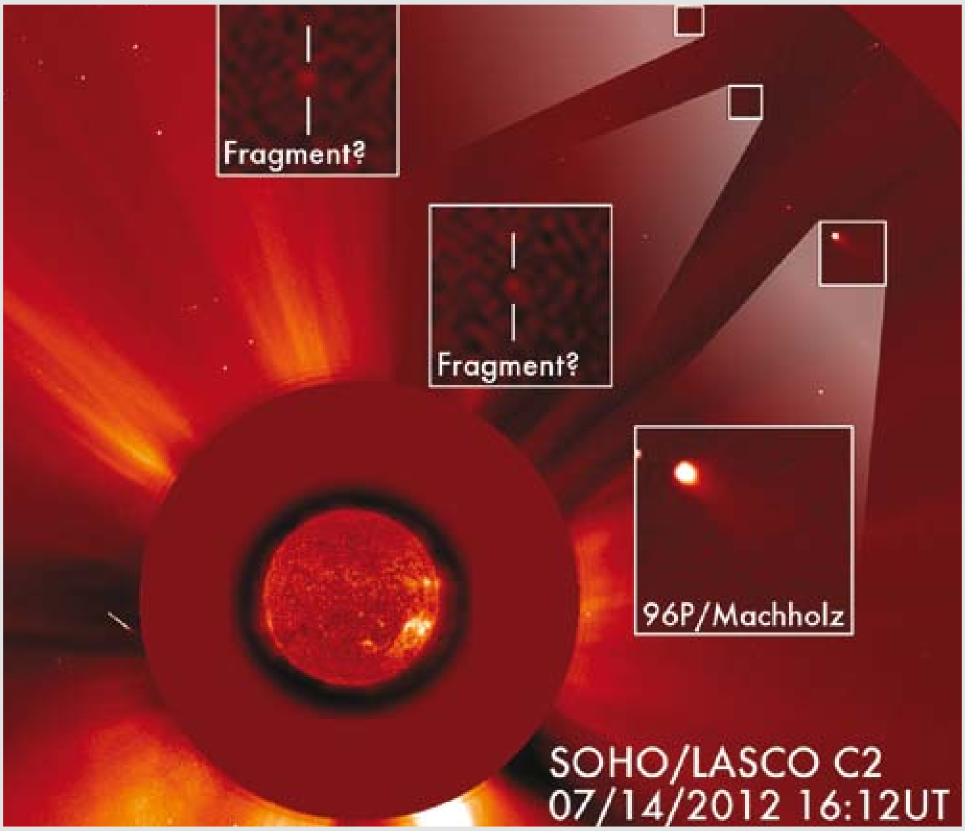
Hubble also continues to produce amazing scientific results. Among the most recent, astronomers saw dramatic changes in the upper atmosphere of a faraway planet. French astronomer Alain Lecavelier des Etangs (CNRS-UPMC) and his team used Hubble to observe the atmosphere of exoplanet HD 189733b during two periods in 2010 and 2011, as it was silhouetted against its parent star. While backlit in this way, the planet's atmosphere imprinted its chemical signature on the starlight, allowing astronomers to decode what was happening on scales that are too tiny to image directly. The observations were made to confirm what the team had seen previously in a different planetary system: the evaporation of an exoplanet's atmosphere.

→ SOHO

When Comet 96P/Machholz made its fourth appearance for the LASCO cameras, it was thought that it could not hold many more surprises. This just shows how wrong you can be about comets! On 14 July, as Comet Machholz entered the view of LASCO C2, two of SOHO's ever-diligent comet hunters spotted a pair of much smaller, fainter comets a few hours ahead of Machholz. At first they thought that these were unrelated, but upon closer inspection, it became obvious that these two tiny objects were in fact fragments of Comet Machholz, forging out ahead of their parent body.

Fragmentation events like this are not that uncommon, particularly for Comet Machholz, but it is the first time this particular comet has been seen directly doing this! It is not known exactly when this fragmentation happened,

A mosaic of the winning images in the Hubble 'Hidden Treasures Contest' (ESA/Hubble/ESO)



Fragments of Comet Machholz seen by SOHO in July (ESA/NASA)

but given that the comets are some 1.4 million km ahead of their parent, it is most likely to have been about one orbit ago during their previous passage by the Sun. For them to be separated like this, they must have split apart at different speeds, about 25 m/s according to rough calculations. Assuming these fragments survive, they should precede Comet Machholz by half a day or more on its next return in late 2017.

Quasi-periodic oscillations from a disrupted star being devoured by a supermassive black hole (NASA)

→ XMM-NEWTON

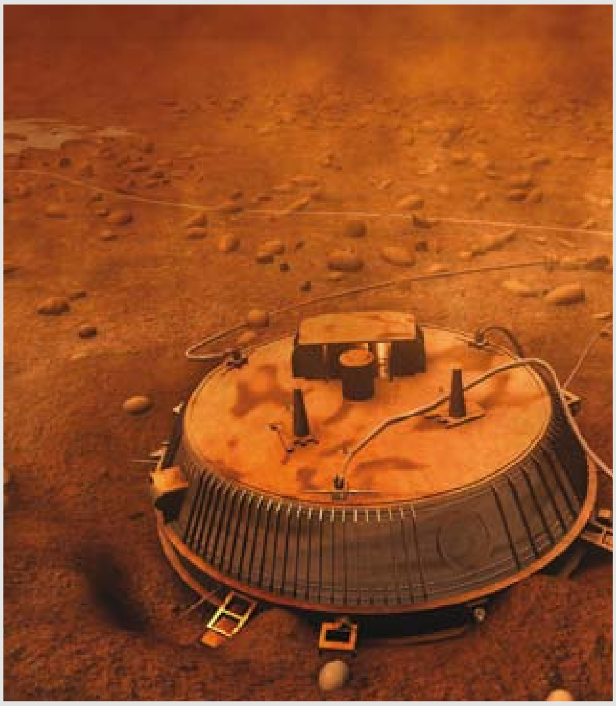
Astronomers have detected telltale luminosity fluctuations in the X-ray signal from a star that was torn apart and devoured by a supermassive black hole at the centre of a distant galaxy. The fluctuations, which have a period of 200 seconds, originate from the innermost stable orbit around the black hole and represent the last signal sent by the debris of the disrupted star before disappearing beyond the black hole's event horizon. This discovery, based on data from XMM-Newton and the Japanese/US Suzaku space observatories, has allowed astronomers to probe the details of matter accretion onto a supermassive black hole in the distant Universe in a unique way.

→ CASSINI-HUYGENS

A new combined analysis of the Huygens HASI, SSP and DISR instrument data on landing has been performed to reconstruct the motion of the probe just after it touched down. Not only does this work give insights into the details of this historic moment, but it also gives a 'dynamic' feeling of the landing, as well as a better understanding the physical properties of Titan's surface.

The initial impact punched through a thin icy layer and dug a 12 cm hole in a wet sand-like material (owing to liquid hydrocarbons), bouncing back and sliding tens of centimetres away from the initial touchdown position. The probe then performed a 30–40 cm slide across the surface, tilted by about 10° in the direction of motion.

A spike in the acceleration data suggests that, during the first wobble, the probe likely encountered a pebble protruding by around 2 cm from the surface of Titan. Overall, the probe's dynamical behaviour suggests a recent spell of dry weather at the time of the landing because fluffy dust-like material was thrown up on landing. This material was probably covering the damp near-subsurface material.



ESA's Huygens probe on Titan

→ CLUSTER

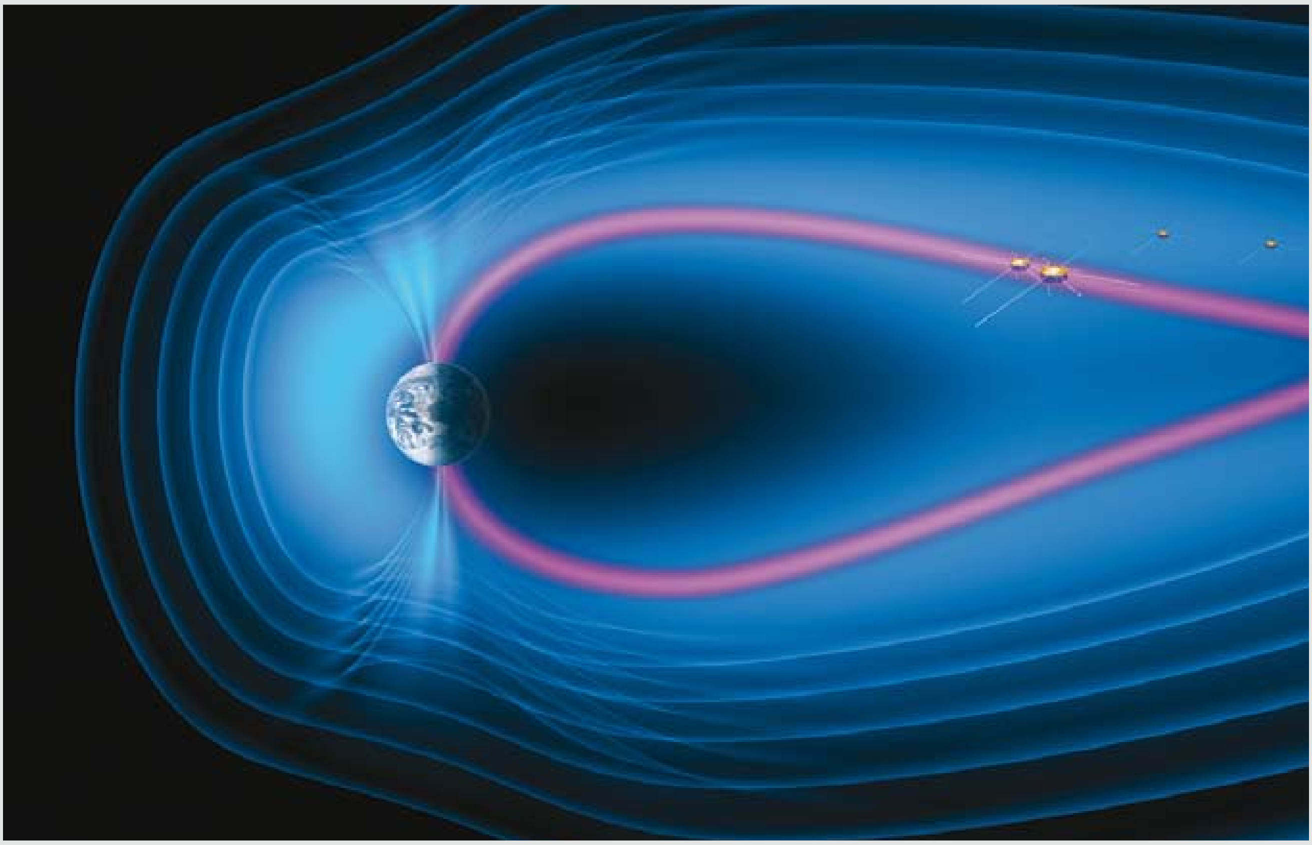
A recent science highlight concerns 'lower hybrid waves', a special kind of wave that develops at thin plasma boundaries in space and in the laboratory.

In space, particle interactions are not a trivial problem. In plasma, there is a state that is referred to as 'collisionless', meaning the density and energy of particles and ions are such that individual collisions between them are extraordinarily rare. Therefore, the exchange of matter and energy between different plasma regions, as well as the acceleration of particles, must take place via mechanisms other than collisions.

In fact, plasma has a very interesting feature that distinguishes it from an ordinary gas: while remaining neutral as a whole, local differences may develop in the distribution of its positive and negative charges. These inhomogeneities give rise to electric and magnetic fields and, in turn, the oscillations of such fields produce waves. Whereas particles in collisionless plasma hardly ever impact one another, they interact with these waves via the electromagnetic force and may gain or lose energy in the process.

Lower hybrid waves play an important role in the dynamics of electrons and in the transfer of energy between regions in the magnetosphere. These waves were the focus of a recent Cluster study, using observations during a special multiscale configuration of the Cluster spacecraft in 2007, where two spacecraft were separated by only 40 km with the other two spacecraft at much larger distances. This configuration allowed scientists to calculate for the first time the velocity and wavelength of the waves, resulting in good agreement with theory and presenting evidence of the key role that these waves play in the acceleration of electrons.

Cluster's Guest Investigator (GI) special operations continue. Such an open call to scientists is the first one for an operating Solar System space mission. During the summer, the Cluster spacecraft were placed into a multiscale formation to investigate flow breaking on the night side of Earth, where large volumes of plasma impinge on the dipolar field lines of the magnetosphere. The next target is the magnetopause and the focus will be on large-scale wave generation there. To achieve the GI observation goals, the spacecraft are being separated by the largest distance so far in the mission, around 20 000 km at the magnetopause.



The Cluster spacecraft shown as they flew in Earth's magnetotail on 31 August 2007: two of them separated by only a few tens of kilometres in the thin boundary of the magnetosphere (purple). Using data from this event, scientists have for the first time characterised 'lower hybrid drift' waves

→ INTEGRAL

During observations in the direction of IGR J17544-2619 and the galactic bulge performed on 16 and 17 September, a bright new transient source was detected. The location of this source is consistent with the newly discovered transient Swift J174510.8-262411. The early average broadband 5–500 keV spectrum can be well fitted by a power-law with exponential cut-off at high energies. The source presents a monotonically increasing flux in all bands, increasing within few days from about 70 mCrab (16 September) to about 1 Crab (19 September). A Crab is a standard astrophotometrical unit for measurement of the intensity of astrophysical X-ray sources. One Crab is defined as the intensity of the Crab Nebula at the corresponding X-ray photon energy.

Because of the rapid flux increase, the high value of the energy cut-off and the absence of thermonuclear bursts, it can be argued that Swift J174510.8-262411 might be a new black-hole transient.

An Target of Opportunity follow-up began on 18 September, and observations began in the evening of the same day. Following a request by the Principal Investigator all scientific data are being made public and immediately available to the scientific community.

→ MARS EXPRESS

The spacecraft and instruments are working normally. On 6 August, the spacecraft recorded signals from NASA's Mars Science Laboratory (MSL) for about 28 minutes then lost contact, as expected, just a few moments before touchdown on Mars. The signal recordings include information on MSL's velocity and direction. They record the sequential critical events during the descent of the NASA rover. This will help to reconstruct the probe's trajectory, refine models of the martian atmosphere and assess landing accuracy.

An article in *Astronomy & Astrophysics*, 'New astrometric observations of Deimos with the SRC on Mars Express', reports on six years of observations of the martian moon.

These false-colour images taken by Mars Express show a region called Tenuis Cavus close to the martian north pole at three different times around the start of summer in Mars' northern hemisphere. They clearly illustrate the seasonal effects on Mars, and especially the action of the approaching summer with the evaporation of local ice. The white parts are water ice, brown areas are mixed sand and dust, while dark parts are volcanic sand (ESA/DLR/FU Berlin)

More than 100 super-resolution images were acquired and used for astrometric measurements of Deimos. Positions with accuracies between 0.6 and 3.6 km were obtained. Comparisons with current orbit models indicate that Deimos is ahead or falling behind its predicted position along its track by as much as 5 km. The data can be used to improve the location of the moon, which is important for studying its origin and evolution. Precise orbit data may also help in planning future Deimos exploration missions.

→ ROSETTA

The spacecraft has been in hibernation since 8 June 2011 while moving further into the outer Solar System. Rosetta reached the aphelion of the current orbit at 5.29 AU from the Sun in early October.

The science and operations teams are continuing the detailed preparation of the rendezvous, landing, and comet escort. A number of operational analyses of the comet phases have been performed including the definition of the reference trajectory up to a sample lander delivery. The orbits required during the various phases of comet activity are being calculated and evaluated together with the teams of the science payload to cope with the requirements for the scientific measurements during the comet rendezvous phase in 2014/15.

Rosetta is set to wake up on 20 January 2014, at an Earth distance of 5.39 AU and 4.49 AU away from the Sun, to rendezvous with Comet 67P/Churyumov-Gerasimenko.

→ HERSCHEL

Observing will continue until Herschel runs out of its superfluid helium coolant, which is predicted to occur in March 2013. Although the end of observing is a very important milestone, it is not the end of the Herschel mission. The science ground segment will continue to support Herschel observers for many years. In parallel, the final Herschel 'legacy' of data, documentation and software will be produced for posterity, and Herschel will be important for decades to come. A 'readiness review' for transition into this new mission phase is imminent.

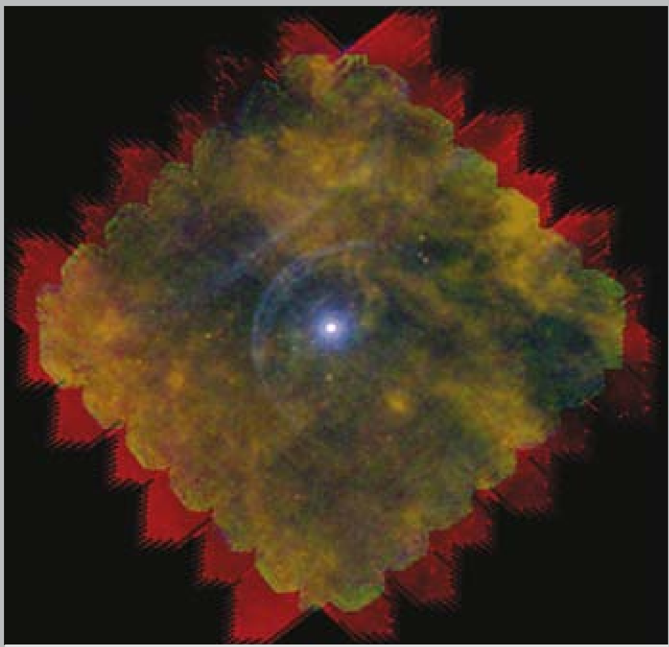
→ We are made of star stuff

We have often heard the phrase, "We are stardust." But how did the 'stardust' get into us?

The elements of life, such as carbon, nitrogen, oxygen and sulphur, are produced in stellar nuclear furnaces and are then injected into the interstellar medium, from which new generations of stars and planetary systems form containing these elements. But how does this happen?

When stars run out of hydrogen in their centres, they swell up enormously, start burning heavier elements (manufacturing the 'elements of life'), become unstable and variable, sometimes pulsating and shed material into surrounding space. The closest and most spectacular example of such a star is the second brightest star in the constellation of Orion, called Betelgeuse, at a distance of about 600 light-years.

This star is the prototype of a 'red oxygen-rich supergiant'. If placed in the position of our Sun, it would engulf all four inner planets of our Solar System and the asteroid belt. Betelgeuse has been studied with a variety of observational techniques over many years, and its variability was first described by John Herschel (son of William Herschel) in 1840.



A Herschel composite image of the star Betelgeuse showing the interaction between material ejected by the star and the motion of the star at about 30 km/s with respect to the surrounding medium. This can be seen as multiple bowshock arcs confined by ram pressure. An intriguing linear structure, the origin of which is still not clear, can also be seen at upper left (ESA/Herschel/PACS/MESS)

→ PLANCK

The spacecraft continues to operate very stably and satellite operations are smooth and generally uneventful. The Low Frequency Instrument (LFI) continues to operate normally and is now starting on its seventh full-sky survey. The High Frequency Instrument (HFI) is running because it is needed to operate the 4K cooler and maintain the temperature of the LFI's reference loads. Since December, the HFI is also acquiring technical data on each of the bolometers, allowing the effects of a non-linearity arising in onboard analogue-to-digital converters to be estimated. These data, which are important for gain calibration, are laborious to acquire. This activity will continue until at least this November.

→ COROT

After more than 2100 days in orbit, COROT continues to operate normally. It does so without one of the data processing units that failed in 2009, resulting in the loss of half of the field of view. More stars can, however, be observed in the resulting field. It has been shown that in order to maximise the output of COROT, the optimum integration time (owing to magnitude and detectable transit depth limitations), is less than 100 days, as opposed to about 180 days. This means that COROT can observe twice as many fields as originally foreseen, making the loss of science negligible.

Other instruments and performance remain within the requirements. Only marginal use has been made of consumables on board. Based on the good condition of the satellite and the scientific case within the proposal prepared by the COROT Science Committee, CNES has decided to extend the mission from 2013 to 2016.

On 1 October, the satellite stopped observing in the direction of the galactic centre (only accessible during the summer) and was turned to point in the opposite direction for the winter 2012/13 observations. There will be at least two runs during the winter. The first began taking data on 2 October. The second winter run is expected to begin taking data in the first half of January 2013.

The priority for the asteroseismology segment this winter is to follow a number of very massive and luminous (O-type) stars for a long time (around 100 days). For this kind of star, it will be attempted to detect faint variation modes caused by waves penetrating all the way through the centre of the star. This gives information about the nuclear reactions in the core. In exoplanetology, there have been 29 confirmed planets found by COROT. A number of other newly discovered and studied planets are in the final stages of confirmation.

Recent results include the confirmation of earlier indications about the high stellar activity (starspots, flares, etc.) among solar-type stars. Our Sun appears to be a rather quiet star in comparison. Other results include data on stellar variability of very hot stars that provide detailed information about the centres of these stars, and studies of the micro-variability (within parts per million) of solar-type stars where the data allow determination of physical parameters and ages with unprecedented precision.

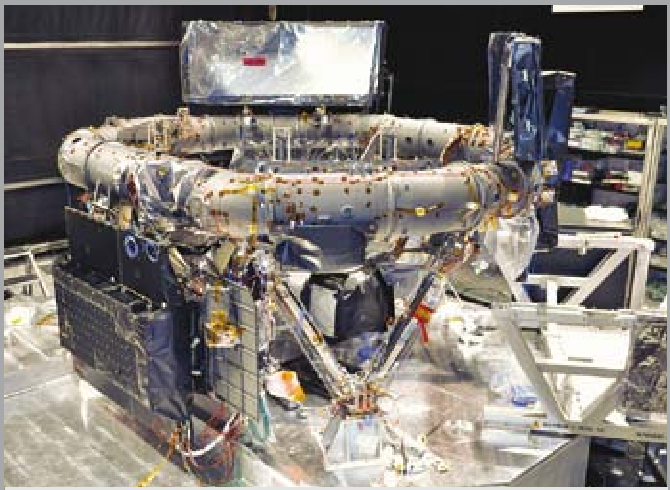
→ GAIA

The mechanical acceptance test of the PLM FM took place at Intespace in September. The optical measurements after the test showed perfect stability. The PLM was transported to Centre Spatial Liège (CSL) where the thermal balance/thermal vacuum test is planned for November/December.

The new optical filter for the Radial Velocity Spectrometer (RVS) is spectrally excellent and the high spatial frequency wave-front error defect has been removed. The replacement on the RVS (and PLM) will take place at CSL in October.

The SM FM completed the thermal tests at Intespace in August. The following fit check with the launcher adaptor and the clamp band release test were also carried out without problems.

Work with the operation and science ground segments is progressing. The fourth System Validation Test with the Mission Operations Centre was completed in September. The Science Operation Centre took part in this test. This completes the SVT campaign using the spacecraft AM. The next SVTs will be performed on the FM. Gaia is on track for launch at the end of 2013.



The Gaia Payload Module Flight Model during the mechanical acceptance tests at Intespace (Astrium)

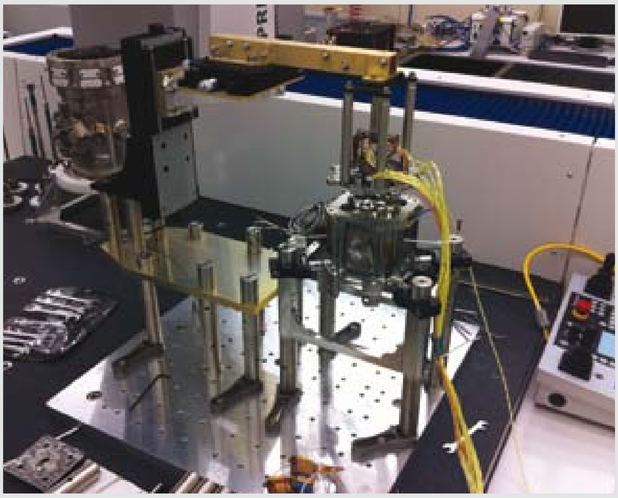
→ LISA PATHFINDER

The Propulsion Module and Science Module were put in storage after system environmental tests and the Qualification Review Part 1. The industrial team is busy finalising a full version of the flight software and performing functional verification activities.

Following the CDRs of the launch lock mechanism and of the Inertial Sensor Head, manufacturing, assembly and test activities have continued as planned. The launch lock features eight fingers holding the cubical gold/platinum test mass in its eight corners. A QM was integrated inside the Inertial Sensor Head, while the finger FMs were being completed. Once in orbit, the eight fingers retract so that two opposite-side plungers gently hold the test mass; these plungers will then release the test mass into a drag-free condition. For this operation, both plungers must be co-aligned accurately to within a few microns. This intricate alignment process was completed for all FMs in September.

For the cold-gas micropropulsion system, the operational and redundancy schemes, the orientation of the thruster and the amount of propellant were confirmed so that industry can continue with parts procurement and system engineering leading to a CDR in spring 2013.

The baseline launch vehicle is Vega, on the third VERTA launch. The Interface Control Document for the back-up launcher Rockot was signed in September.



LISA Pathfinder: the Qualification Model of one of the opposite-side plungers integrated on top of the test mass in a Class 100 cleanroom and with the aid of a micron-accurate measuring machine at CGS (I). On the top-left corner, an empty Vacuum Enclosure awaits to be completed with mechanisms and test mass

LISA Pathfinder: a Development Model of the actuator for the launch lock eight fingers sits on top of the Qualification Model of the Vacuum Enclosure after a fit check. Inside already sit the various mechanisms and the test mass

→ BEPICOLOMBO

The MPO FM spacecraft integration proceeded as planned with the thermal hardware and chemical propulsion system. The spacecraft was transported to the Westcott Ltd (UK) facilities where it completed the proof pressure tests. The spacecraft then returned to Astrium Ltd, Stevenage, for the completion of the works on the mechanical and propulsion bus before transportation to Thales Alenia Space in Turin. The first large-scale test after modification of the thermal design was concluded, demonstrating the performance of the reworked high-temperature multi-layer insulation. A second large-scale test will verify thermal interfaces to equipment outside the spacecraft. The mechanical test programme on the spacecraft STMs in the launch composite configuration was completed, including vibration, shock and acoustic tests. The System CDR began.

The first System functional and electromagnetic compatibility tests, actively supported by the instrument engineers, were completed on the spacecraft Engineering Test Bed. The instrument teams are busy to complete their instrument qualification activities and to finalise the FM procurement to be followed by integration and test programme with a high priority.

The Japanese spacecraft STM was shipped back to JAXA after completion of system-level mechanical test campaign at ESTEC. The MMO EM arrived at Astrium, Friedrichshafen, for functional verification on the Engineering Test Bed. The first flight units have been delivered to JAXA and integration onto the MMO FM is scheduled for November.

BepiColombo in integrated launch configuration on the vibration table at ESTEC

Work on the Ariane 5 launch services is proceeding and the preliminary mission analysis review started. The ground segment mission control system deliveries are on schedule and acceptance testing continues. Launch is planned for the Mercury launch opportunity in mid-2015.

→ MICROSCOPE

The procurement of the Myriade standard equipment is ongoing at CNES (Myriade is a microsatellite product line developed jointly by Astrium and CNES since 1998). The procurement of the satellite's specific equipment (platform structure, solar panels, de-orbit system) is starting. The procurement of the ESA-provided micropropulsion, based on the Gaia cold-gas system, has also started. The production of the thruster FMs is expected to start in October.

→ EXOMARS

Work continued on the Trace Gas Orbiter (TGO) and Entry, Descent and Landing (EDL) Demonstrator Module (EDM) to be launched in 2016. For the 2018 mission, the industrial team has been ramped up to support the pace of development for the ESA rover with Roscosmos.

Significant progress on the 2016 mission has been achieved with a transition to manufacturing and preparations for the system AIT of the EDM STM as well as fabrication of the principal PFM structures of the TGO. A number of important achievements occurred, including: EDM Back Cover elements fabricated, Surface Platform CDR, Surface Platform Crushable Structure test programme completed and parachute ejection systems were tested.

On the TGO, the Central Tube FM composite tube was fabricated, propulsion system Engineering Verification Model fabrication was completed and the Interface Control Document for the NOMAD instrument was finalised.

For the 2018 mission, industry has been preparing a Phase-B proposal to establish a baseline within the international cooperation involving Roscosmos and their primary industrial contractor Lavochkin. Meetings have been held to discuss the architecture and the responsibilities of each partner. A proposal for the Phase-B study is expected for kick-off in November. A team of European industries and Russian organisations will combine to form the technical team that will design and implement the 2018 mission.

Rover developments are proceeding, particularly in the areas of the Drill, Sample Preparation and Distribution System (SPDS) and the payload. The 2 m drill development is now beginning an EQM-type testing programme, while the SPDS is moving towards an end-to-end test of the mechanism breadboards that have been produced to date. This will provide a verification of the overall Analytical Laboratory Drawer concept where the main life-seeking instruments are accommodated along with a complex *in situ* laboratory preparation facility.

The Pasteur Payload complement has been rescoped and a special technical session with the remaining instruments (MOMA, Micro-Omega and Raman) took place at ESTEC. The combined team of ESA, industry and scientific instrument groups arrived at a design for the new configuration.

Preparations for the ExoMars ground segment are proceeding in support of the 2016 launch date and a Requirements Review was started to verify the completeness and understanding of the needs for the ExoMars 2016 mission.A large part of the 2016 ground segment will also be used for the 2018 mission, which will be reviewed after the 2018 mission Phase-B study has started.

The large international cooperation planned for ExoMars has advanced significantly with many bilateral meetings at all levels of the project and ESA. Agreements on the basic responsibilities of each agency have been achieved and the finalisation of the agreement between ESA and Roscosmos on cooperation in robotic exploration of Mars and other bodies in the Solar System is nearing completion.

→ SOLAR ORBITER

The prime contractor is working in the B2-2/Advanced C/D-phase. Following completion of the spacecraft and mission PDR, several sub-system PDRs have been completed and several more are ongoing.Surface-treated materials have been tested at ESTEC under simultaneous high temperature and high ultraviolet flux, and then under successive electron and proton fluxes, to investigate their suitability for high-temperature multi-layer insulation for the back of the antennas, heatshield front and feed-through coatings. Results were very promising and are under review.

Nine of the ten Instrument PDRs have been held. One more, for the SPICE spectrometer is scheduled to start in October. The second Payload Steering Committee meeting was held to coordinate any funding, programmatic and technical decisions among the national organisations that act as funding agencies in the scientific payload complement.

→ JAMES WEBB SPACE TELESCOPE

NASA activities continue in accordance with the new project plan for launch in October 2018. The first two primary mirror assemblies have been delivered to NASA Goddard Spaceflight Center for integration. The second flight instrument, the Fine Guidance Sensor from CSA, has also been delivered for integration.

The reintegration of NIRSpec onto the flight spare optical bench is nearing completion. All optical elements have been integrated and the measured instrument optical quality is excellent.NASA has restarted the manufacturing of microshutter chips and plans to build a fully assembled flight spare Micro-Shutter assembly. The aim is to improve performance and exchange at the end of 2014 while the planned detector exchange takes place.

The formal delivery process of the MIRI instrument to NASA was closed. To resolve the pending instrument sensitivity issue, a second detector test campaign at JPL has been concluded. The outlook for recovery is positive.JWST will be launched on an Ariane 5 ECA. In the launcher definition phase, two pending issues have been resolved. Arianespace have confirmed the feasibility of the roll scenario during injection to overcome a thermal issue for JWST and the launch opportunities have been significantly enlarged by minor tweak of the operational orbit.

→ EUCLID

Euclid is the second 'Medium' mission of the Cosmic Vision Science Programme. It is devoted to investigate the nature and origin of the unseen Universe: 'dark matter', five times more abundant than the ordinary matter made of atoms, and 'dark energy', causing the accelerating expansion of the Universe. The 'dark Universe' is reckoned today to amount at 95% of the total matter-energy density. Euclid will survey about 40% of the sky, looking back in cosmic time up to 10 billion years. A smaller part (1%) of the sky will look back to when the Universe was only few million years old. This three-dimensional survey will allow us to map the extent and history of dark matter and dark energy.

Preparation for the Implementation Phase is proceeding. The ITT to industry for the phased procurement of the PLM was issued in July and the prime contractor ITT is in preparation. The procurement of the Near Infrared Spectrometer-Photometer (NISP) detectors is managed by ESA, while the NISP instrument is provided by the European scientific consortium (Euclid Consortium). The procurement of the CCD detectors of the Visible Imager (VIS) is also managed directly by ESA and will start in November. The VIS instrument is also provided by the Euclid Consortium.

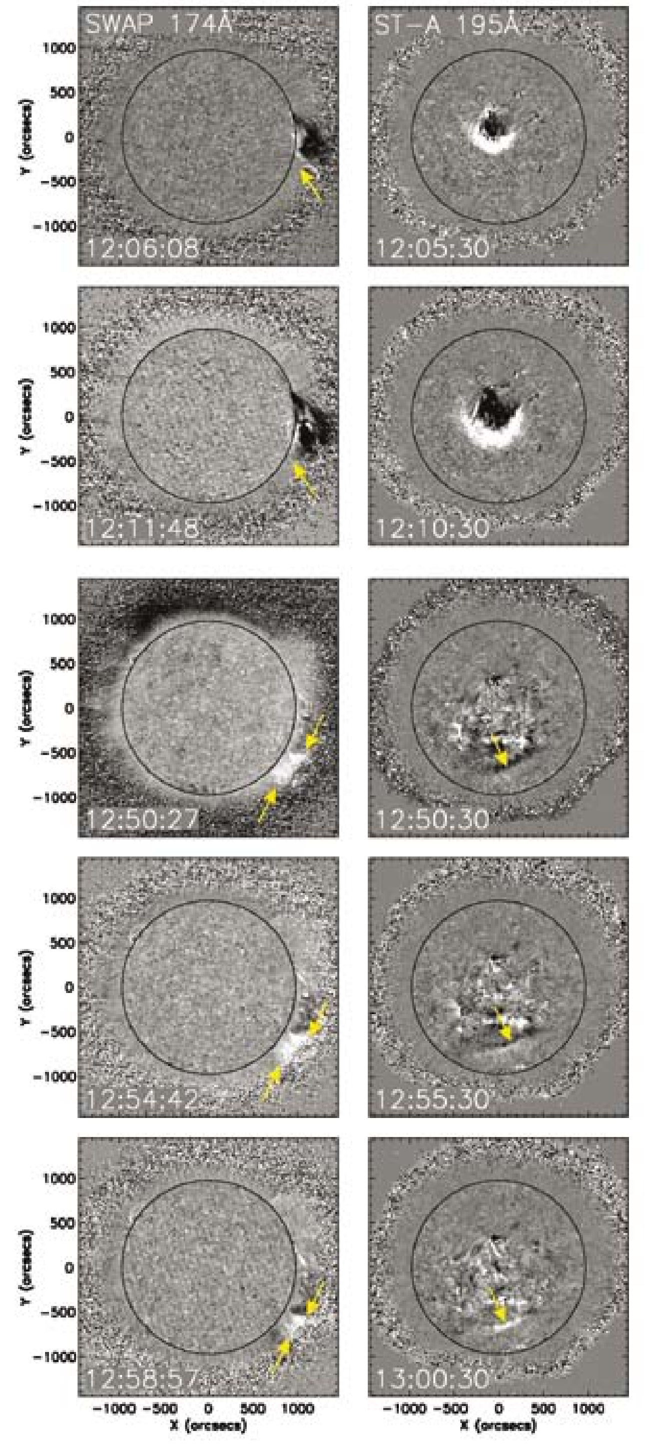
The Euclid science ground segment controls the processing of the Euclid data and is split into a part under ESA responsibility, the Science Operations Centre at ESAC and a part developed by the Euclid Consortium. The mission operations are under the responsibility of ESOC. The launch is planned for mid-2020 on a Soyuz/Fregat from Europe's Spaceport in French Guiana. Euclid will be put in a large 'halo' orbit around the second Sun–Earth Lagrange point and the mission will last six years.

→ PROBA-2

With a relatively quiet Sun in this period, measured sunspot values and solar background noise were lower than predicted. This resulted in a quiet observation period for the SWAP imager and the LYRA radiometer, because instrument campaigns are often related to increased solar activity, i.e. large solar flares or coronal mass ejections.

The solar corona is the outer part of the Sun's atmosphere, dominated by magnetic fields, and reaching out millions of kilometres into space. Strangely, the temperature increases from several thousands of degrees at the solar 'surface' (the photosphere) to millions of degrees in the corona. The corona is continuously active, sometimes with quite large events, for example outbursts of plasma into space, called Coronal Mass Ejections (CMEs). Dr I. Kienreich and colleagues from the University of Graz, Austria, analysed several of these CMEs propagating through the corona and space with an initial velocity of 300–500 km/s. This propagation through the corona is referred to as extreme-ultraviolet (EUV) waves.

By combining data from two spacecraft, STEREO-A and Proba-2, and extracting 3D information from the propagating wave images, Dr Kienreich and his team could follow



Differential images from Proba-2 SWAP (left) and STEREO-A EUVI (right). The first two rows show the early evolution of the primary wave (yellow arrows). The last three rows show the evolution of the reflected wave. Note the two satellites observed the event from different locations in space. STEREO-A observed the event on the solar disk, whereas Proba-2 observed the event on its limb (Univ. Graz/I. Kienreich)

the waves in the corona and their reflections on 'coronal holes'. Coronal holes are areas of open magnetic field lines, stretching out into space. This is a first firm confirmation that EUV waves interact with other parts of the corona in such a way that they follow the rules of reflection that we know and observe in waves on Earth. As a consequence, this allows solar scientists to further characterise these EUV waves.

→ ADM-AEOLUS

Detailed root-cause analyses have been completed for the sub-millimetre spot damages on the ultraviolet optics that participated in the long-duration laser test. The results of these analyses have allowed agreements with optical element suppliers and experts on laser damage testing to ensure that the new ultraviolet optics are produced with the appropriate precautions and screened with adequate test procedures.

In parallel to the new optics procurement, development activities continue on the flight laser transmitters and on the instrument transmitting optics. In addition, the equipment deliveries for the Aladin *in situ* cleaning system are nearing completion.

→ SWARM

The FAR was completed with some work outstanding. The three Swarm satellites are now ready for launch and are stored within their containers. Each container is purged with nitrogen during the storage period. A pre-shipment review was completed in early September, where the majority of actions from the FAR were closed. A workshop was held in Frascati in July with the 12 pilot projects that will support the validation of the instruments and scientific data products.

Launch has been delayed until March 2013 following the failure of the upper stage of a Proton rocket. ESA is still expecting, from the Russian Ministry of Defence, the launch manifest for the year 2012/13 for Rockot launchers indicating the launch date for Swarm.

→ EARTHCARE

The industrial consortium is proceeding with the detailed design phase and preparing for the series of equipment, sub-systems and instruments CDRs. The prime contractor has begun integration of the spacecraft EFM and started testing after receiving the initial integration version of the central software. The initial tests focus on the spacecraft avionics and an incremental approach will be followed to accommodate the staggered deliveries of the EMs of the remaining spacecraft units.

The ATLID instrument transmitter STM manufacturing is ongoing and the test readiness review is planned for October. The Power Amplifier EQM tests are ongoing and the Master Oscillator production has been initiated. The Beam Steering Mechanism Assembly PDR was completed and the detailed design is progressing.

All FM microbolometers of the Broadband Radiometer were delivered by Institut National D'Optique and the testing of the first instrument telescope at the National Physical Laboratory (UK) was completed and the spectral response characterised. The instrument control unit EM was manufactured and is in testing.

Manufacturing of the Engineering Confidence Model of the Multi-Spectral Imager is proceeding. The Visible, Near-and Shortwave infrared camera is complete and being prepared for delivery by Nederlandse Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek (TNO). The ECM Thermal Infrared Camera assembly was completed and the unit its undergoing optical, electrical and mechanical test campaign.

In Japan, integration of the Cloud Profiling Radar (CPR) EM was completed by NEC Toshiba Space and the instrument is being tested by JAXA. In parallel, the CPR Electrical Interface Simulator is being assembled to allow representative testing of this instrument as part of the satellite EFM programme.

First image from MSG-3 (Eumetsat)

→ METEOSAT

Meteosat-10/MSG-3

The spacecraft was launched on 5 July from Europe's Spaceport in French Guiana. The Launch and Early Orbit Phase was performed under the responsibility of ESOC and the handover to Eumetsat took place on 16 July. The first image was taken on 7 August. Commissioning by Eumetsat is continuing normally. MSG-3 should start its operational phase at the beginning of 2013.

MSG-4

The dismounting of the SEVIRI instrument from the spacecraft in order to exchange the failed Mirror Scan Drive Unit was authorised and should start in September. The SEVIRI refurbishment activities and reintegration in the spacecraft will last until the end of 2013. Following the decision by Eumetsat Council, the objective is to prepare MSG-4 for a launch at the beginning of 2015, followed by in-orbit storage.

→ MTG

The Preliminary Design Review (PDR) for the MTG-I (Imager) and MTG-S (Sounder) satellites concluded with the Board meeting held in July. Currently, the Common Platform PDR

MSG-3 launch on an Ariane 5 from Europe's Spaceport, 5 July (ESA/CNES/Arianespace/Photo-Optique Video CSG)

is on-going with the Board meeting scheduled for late October, while the PDR for the Infrared Sounder instrument is planned for October/November. By the end of the year all PDRs relating to the MTG satellites and associated main elements (platform and instruments) will have been held.

In parallel, with the technical baseline consolidation, the Best Practice Procurement activities are approaching their completion with approximately 90% (by value) of anticipated ITTs/RFQs released. For approximately 80% of the procurements, the preferred suppliers have been selected, with negotiations either on-going or completed. Of particular note was the selection of the Scan Assembly, Central Tube and the Solar Array Drive Assembly.

It is now anticipated that the majority of the remaining ITTs will be released before the end of 2012, which will allow the formal price conversion process for Phase C/D to start with the goal to complete in early 2013.

Five days before launch, MetOp-B is inside the fairing connected to the third stage of the Soyuz rocket, ready to be integrated with the first and second stages

→ METOP

MetOp-A

The satellite continues to perform very well. GOME-2 is producing very good scientific data, but the unexpected throughput loss behaviour can still lead to some science limitation during the extended mission lifetime, i.e. after MetOp-B was declared operational. The GOME-2 throughput has been stable over the last 24 months with very small degradations at specific frequency ranges. MetOp-A completed its five-year in-orbit life on 19 October 2011 and extended operations are confirmed, at least, up to the end of commissioning of MetOp-B in April 2013.

MetOp-B was launched from the Baikonur Cosmodrome on 17 September to monitor the weather and provide data for climatology

Fantastic view of MetOp-B during encapsulation inside the Soyuz fairing, this was a last view of MetOp-B on the ground

MetOp-B

After six years in storage, MetOp-B was launched on 17 September into polar orbit about 820 km above Earth. The launch campaign was impacted by the missing agreement between the Russian and Kazakhstan governments on the launcher boosters 'drop zone' and consequently lasted around seven months instead of the normal three. This delay imposed several extra activities on the satellite, mainly with respect to limited life items. All activities were performed as planned and the team spirit between all parties was key in guaranteeing the quality and maintaining the schedule in the final preparations for launch.

The Launch and Early Orbit Phase was completed as planned within the first three days in orbit, with the manoeuvre after separation performed with only a small change required owing to the accurate insertion orbit provided by Soyuz/Fregat. On 20 September, the satellite was handed over from ESOC to the Eumetsat operations team in good health and in the required configuration and orbit.

The Satellite In-Orbit Verification (SIOV) phase, under ESA responsibility, started on 21 September. The first ten days of SIOV were critical for the instruments – to switch on, perform the first functional tests and to configure several instruments in 'decontamination' mode, which is designed to ensure that the first days of outgassing of the satellite will not impact the scientific performances of the optical instruments. This phase was completed, with some instruments already delivering excellent quality data in a trial phase.

MetOp-C

After the satellite's functional and mechanical (sine vibration and acoustic) tests were performed in 2011, each module (PLM, SVM and Solar Array) is in storage. Annual reactivation/tests are planned to keep the modules under tight control and to perform trend analysis to guarantee good health when the satellite is launched. MetOp-C is planned for launch on a Soyuz/Fregat from Europe's Spaceport in French Guiana in February 2018.

→ SENTINEL-1

Almost all flight equipment has been delivered for the final AIT campaign with the prime contractor Thales Alenia Space Italy, Rome. The spacecraft internal harness is already integrated, with integration of the following flight units ongoing: batteries, avionics, propulsion subsystem, power subsystem and payload data handling and transmission subsystem. Assembly and test of the solar array wing has also been completed, ready for integration onto the satellite.

The SAR antenna has progressed with integration and testing at Astrium GmbH, Germany. The two antenna wings completed their environmental and deployment test campaigns in September. The SAR electronics subsystem EM (Astrium Ltd, UK) was delivered in July and is undergoing end-to-end instrument testing. The manufacture and testing of the flight units is progressing.

The definition of the commissioning phase is in progress with the preparation of the tools and ground equipment to be used (including the Calibration and Performance Analysis Facility, the Calibration Transponder, and Prototype SAR Processor).

In launcher activities, a quality status meeting reviewed the major quality and reliability aspects concerning the launch vehicle (Soyuz at CSG).

→ SENTINEL-2

The payload instrument PFM development is proceeding with the fully integrated Visible and Near-infrared (VNIR) and Shortwave Infrared (SWIR) focal planes ready, including their struts for integration within the telescope. In parallel, the instrument telescope silicon carbide structure was integrated, including the installation and alignment of the three mirrors, and the installation of optical shields, thermal hardware and struts for integration within the telescope.

Satellite AIT activities are concentrating on the EFM that integrates critical equipment, such as the onboard computer, remote interface unit and GPS receiver. The first system test conducted on the satellite PFM will be the power system test using the FM power conditioning and distribution unit and EM batteries.

Two launch service contracts signed with Eurockot (Sentinel-2A on Rockot) and with Arianespace (Sentinel-2B on Vega) are undergoing the Preliminary Mission Analysis Review (PMAR). The PMAR for Eurockot should be complete in December and for Arianespace for spring 2013.

Image quality activities conducted under the responsibility of CNES are progressing. The second Satellite Validation Test campaign, during which the satellite EFM will be remotely operated by ESOC, is scheduled for December. The Optical Communication Payload FM development conducted under the responsibility of DLR is ongoing at TESAT to be ready for Sentinel-2A by spring 2013. Final procurement actions of the Sentinel-2 Payload Data Ground Segment are being finalised in order to support the Ground Segment CDR in March 2013.

A preparatory symposium held in April at ESRIN gathered more than 300 Sentinel-2 research and development user communities addressing all aspects of mission applications in land cover, forestry and agriculture.

→ SENTINEL-3

Phase-C/D manufacturing and AIT are under way at all stages. Integration of the last satellite elements FMs (SLSTR and OLCI) started. This marks a significant step in the programme with five PFM test campaigns running in parallel on the four instruments and the platform. Among the major achievements, the completion of the platform electrical integration, the release of the first fully validated version of the flight software and the first Satellite Validation Test led by ESOC.

At instrument level, several OLCI FM elements completed testing (Focal Plane Assembly, the Video Acquisition Module and Electronics Unit) and were delivered in July for testing at instrument level. The SRAL PFM instrument testing is also continuing to plan and FM elements needed for the second instrument are completing acceptance. Instrument PFM delivery has been shifted to early 2013 to allow the repair of one electronics board. Testing of the MWR Radiometer Electronics Unit was completed and both Radiometric Processing Modules were delivered. The SLSTR flight structure was delivered to the Optical Mechanical Enclosure contractor and integration of the PFM started. All flight detectors were delivered, confirming good performance.

On the launcher side, activities related to the Rockot Preliminary Mission Analysis Review (PMAR) are proceeding. The same review for the Vega launcher was started with Arianespace, with a slightly shifted schedule that should allow completion of this PMAR in early 2013. Rockot is the baseline launcher for the Sentinel-3A while Vega is the baseline launcher for the Sentinel-3B.

→ SENTINEL-4

Sentinel-4 is an operational mission with the objective to monitor key air quality trace gases (NO_2, O_3, SO_2 and HCHO) and aerosols over Europe at high spatial resolution with a fast (hourly) revisit time in support of the GMES Atmosphere Services.

The Sentinel-4 system consists of an ultraviolet/visible/near-infrared (UVN) imaging spectrometer embarked on Eumetsat's geostationary MTG-S platforms and relies on the use of subsets of data from the Infrared Sounder on the same platforms and from the Flexible Combined Imager on the MTG-I platforms. Key features of the Sentinel-4 instrument are the spectral range from 305 nm to 500 nm with a spectral resolution of 0.5 nm for the UV visible, and 750 nm to 775 nm with a spectral resolution of 0.12 nm in the NIR. The Sentinel-4 instrument is undergoing its PDR.

→ SENTINEL-5 PRECURSOR

The satellite/system-level PDR and overall Ground Segment Requirements Review were concluded. Following the PDR, the former ceiling price for the spacecraft and system activities was converted into a fixed price resulting in a formal start of the satellite/system Phase-C/D during summer. Requests for

Quotations have been issued for launcher study proposals from Arianespace (Vega) and Eurockot (Rockot).

Level-2 Product proposals are expected from a consortium of research institutes in the Netherlands, Germany, Belgium and the United Kingdom.

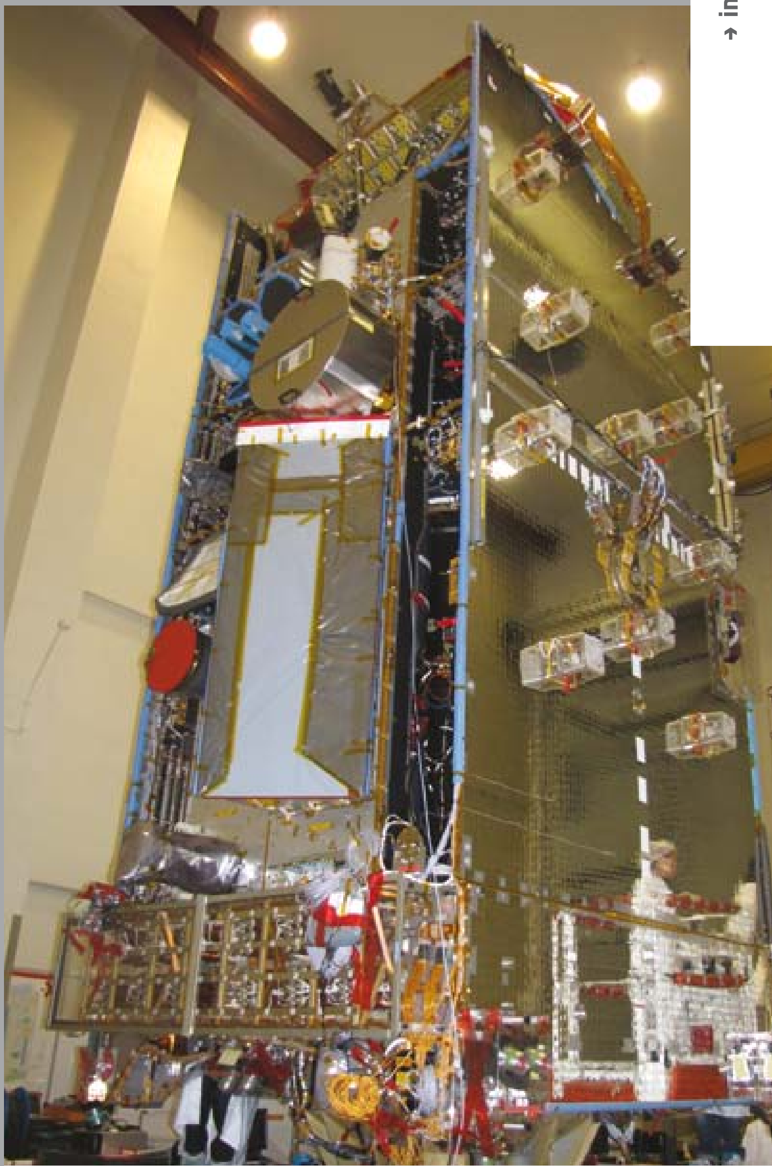
Regarding the Tropospheric Monitoring Instrument (TROPOMI) payload, CDRs for payload sub-systems continue up to the end of the year with a TROPOMI-level CDR in early 2013. CDRs for UVN Demodulator Module, TROPOMI EGSE and Telescope Support Structure have already been concluded.

The first flight hardware for TROPOMI delivered by SRON are the immersed gratings for the SWIR spectrometer. These gratings will be the first of their type to be used in space. The high-tech gratings developed by SRON signify a breakthrough for international space technology.

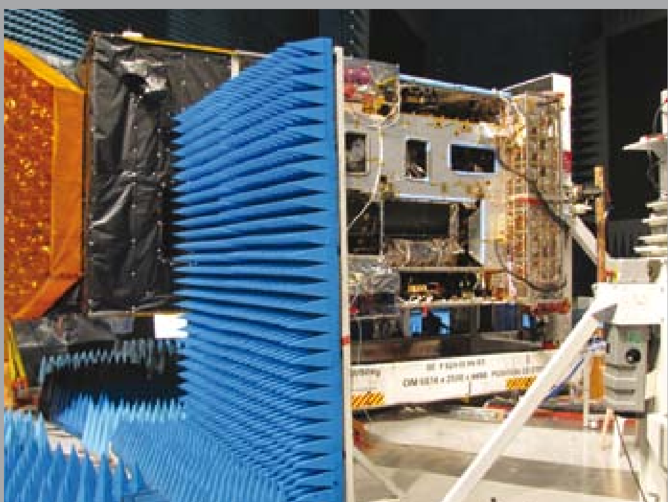
→ ALPHASAT

The spacecraft is in the test centre in Toulouse being prepared for thermal vacuum testing, which is scheduled to start in November. All ESA-furnished Technology Demonstration Payloads were fully tested and an important end-to-end polarity test demonstrated the ability of the Laser Communication Terminal to properly interpret spacecraft and sensor data to point its laser telescope at the right target. Final tests are being conducted on the Inmarsat commercial payload. Launch on an Ariane 5 is planned for early 2013.

In the frame of the ESA/Inmarsat Ground Segment initiative, a new activity has just started that will make use of Alphasat and Inmarsat-4 satellites to provide improved aeronautical safety services. One result of the studies already supported by this initiative is Inmarsat's 'FleetBroadband Multi-Voice service', launched in June, which allows up to nine simultaneous telephone calls to be made through a single FleetBroadband terminal on vessels at sea.



View of Alphasat being prepared for thermal vacuum testing. The Earth-pointing face of the spacecraft, hosting the four ESA Technology Demonstration Payloads, is visible on the left. The large radiative panel (North face) is on the right



Alphasat in the anechoic chamber at Intespace, Toulouse

→ ALPHABUS

The Alphabus Extension programme, aiming to significantly increase the possible mass of embarked payloads on the Alphabus platform, is on track for a CDR in April 2013. Good progress was made on the development of a number of technologies, including the Deployable Radiator and the Antenna Module.

→ ARIANE 5 POST-ECA

The M4R Vinci test campaign started in July and will go on until November. The Vinci M5 engine assembly will start in mid-October.

→ VEGA

The implementation of the recommendations to improve the radio frequency visibility during the first part of the mission was assessed. An improvement of the ground station network at Kourou was started with the procurement of a complementary portable telecommand station.

On the ground segment, the first part of the Ground Segment Qualification Review (GSQR) was performed while activities related to the revalidation of ground segment means, the closure of campaign anomalies and the preparation of final data package for the GSQR (part 2) are ongoing.

On VERTA, the architecture for the additional telemetry kit for VV02 in the upper composite was finalised with the introduction of a localisation chain based on GPS, and the use of video cameras for monitoring the separation of stages.

On the launch system, the VV01 Return of Experience Steering Board took place in July. An Organisational Note for VERTA campaigns was signed in July between ESA and Arianespace. The Launch System Qualification Review will take place in November, followed by the VV02 FRR at the end of November. Start of the VV02 campaign is scheduled for 29 November with the transfer of the P80 stage to the Mobile Gantry.

→ FUTURE LAUNCHERS PREPARATORY PROGRAMME

Intermediate Experimental Vehicle (IXV)

The IXV Phase-D/E1A and E1B are progressing, including the manufacturing and qualification of the flight and ground segments and the preliminary mission analysis activities. Among the several manufacturing and qualification activities, it is worth mentioning the completion of the parachute qualification and the progress on the descent and landing system synthesis test with integration of the vehicle at CIRA premises. Scenarios for the implementation of the Phase-E/F (i.e. the mission into space) are being developed.

Next Generation Launcher (NGL) preparation

In System studies, the third phase, addressing the HH Boosted configurations (both in Staged Combustion and Gas Generator variants) as well as on the PPH concepts, was completed in July. As a priority for the continuation of the study, the impacts of some variations of the Mission Statement, in particular targeting an earlier qualification flight (in line with scenario B, the evolution of European family of launchers) will be studied. Dedicated activities have been initiated with preliminary results presented in September, showing the interest in some other concepts (e.g. HH type based on use of a Vulcain 2, twin-engine first stage or quadrilateral engine first stage).

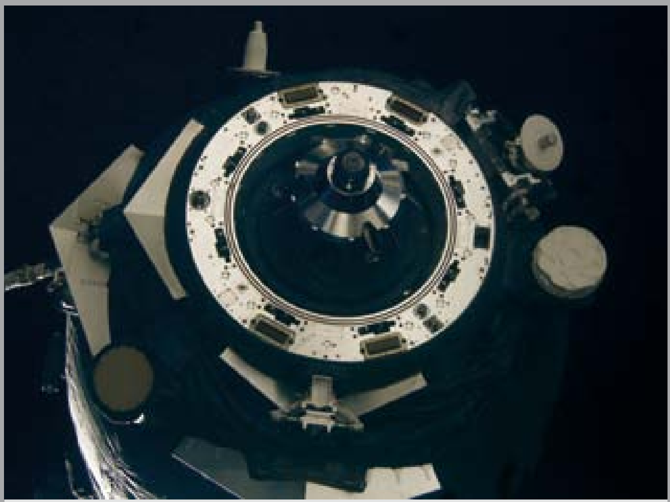
In Propulsion, after the different sub-systems' Feasibility Reviews, Phase-B of the Stage Combustion Rocket Engine Demonstrator is progressing towards the PDR in October. In Cryogenic Upper Stage Technologies (CUST), the industrial activities are progressing with, in particular, the completion of the test campaign for one of the Propellant Management Device concepts.

View inside the JAXA H-II Transfer Vehicle (HTV-3) docked to the ISS (NASA/ESA)

View of HTV-3 after capture and berthing on the ISS arm on 27 July (NASA/ESA)

→ HUMAN SPACEFLIGHT

ISS highlights included the undocking of the ATV *Edoardo Amaldi*, the undocking/redocking by the Progress 47P logistics spacecraft to test a new Kurs rendezvous and docking system antenna, and the final undocking of Progress 47 on 30 July. Progress 48 (with 2.6 tonnes of ISS cargo) was launched on 1 August, docking six hours later, the first time a four-orbits-to-docking procedure had been undertaken rather than the usual 34 orbits which takes two days to dock after launch. This is testing a shortened transit plan that may be incorporated for future Soyuz launches. The third Japanese H-II Transfer Vehicle (HTV-3) was launched from the Tanegashima Space Centre in Japan on 21 July and was captured by the Station's main robotic arm and berthed to the ISS on 27 July, delivering 3.5 tonnes of pressurised cargo



The unpiloted Russian Progress 47 resupply spacecraft temporarily undocks from the ISS Pirs Docking Compartment on 22 July to perform a series of docking tests (NASA/ESA)

One of the last images taken inside ATV *Edoardo Amaldi* by the ISS crew just before hatch closure and undocking. The location of stowed waste was documented before departure to verify centre-of-gravity calculations (NASA/ESA) and 1.1 tonnes of unpressurised cargo. HTV-3 was unberthed from the ISS on 12 September and made a destructive reentry into Earth's atmosphere on 14 September.

→ ISS TRANSPORTATION

The ATV *Edoardo Amaldi* mission was concluded on 28 September, with the undocking from the ISS and then a reentry into Earth's atmosphere on 3 October. In June, July and August, ATV thrusters had been used to reboost the ISS to a higher orbital altitude to set up phasing for Soyuz TMA-03M and TMA-04M landings and Progress 48P and 49P launches. ATV-3 had also been used for turning the ISS by 180° degrees so the Russian Service Module faced forwards for the Progress 48P docking at the beginning of August. These new manoeuvres save propellant and decrease the loads imparted on the ISS. Total propellant consumption was around 18 kg instead of 160 kg, which would be required with the standard manoeuvre. Extensive cargo transfer activities between the ATV and the ISS had taken place before ATV undocking, including propellant and water from ATV tanks and using ATV gas supplies to refresh/repressurise the ISS cabin atmosphere. Vehicle integration and operations preparation activities are also ongoing for ATV-4 and ATV-5.

→ ISS UTILISATION

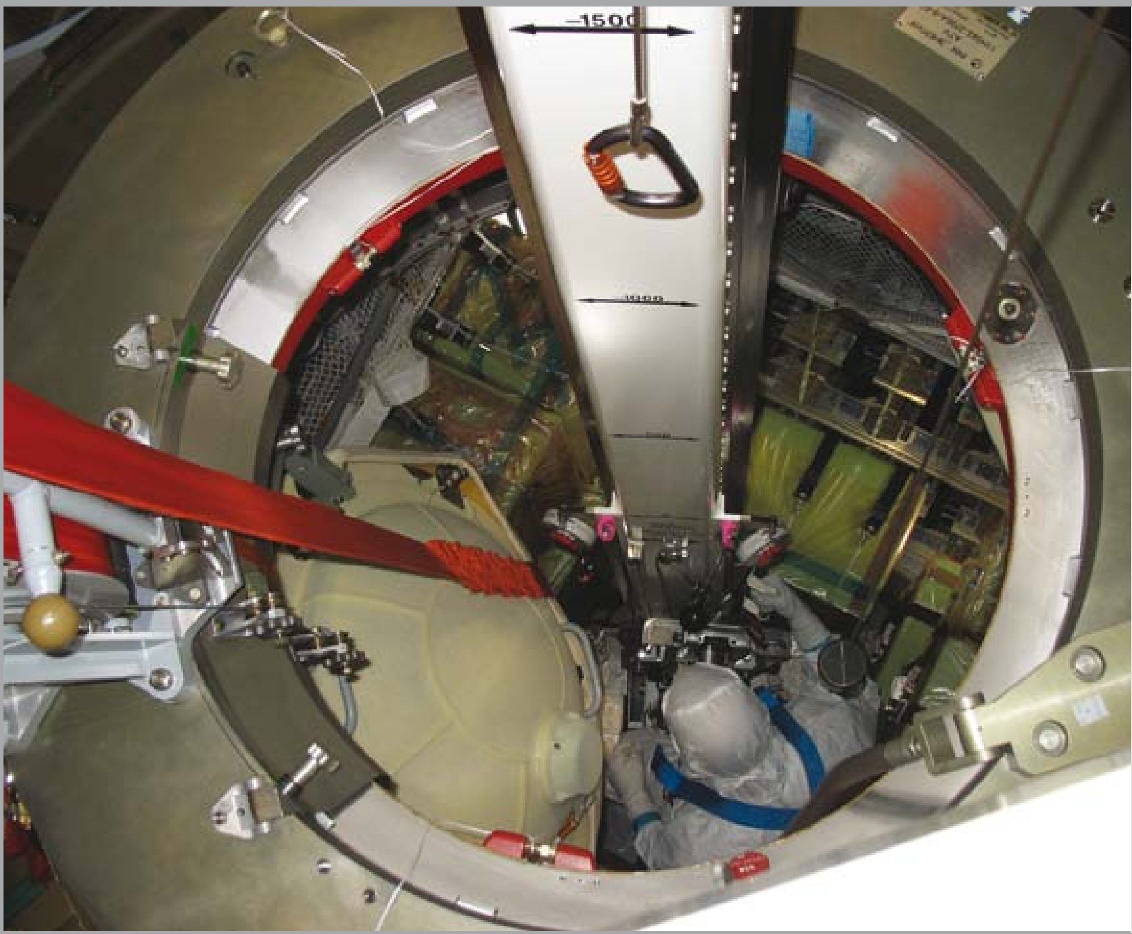
European research on the ISS

Following the end of the European PromISSe mission of ESA astronaut André Kuipers (NL) on 1 July, the European ISS science programme has been continuing with the assistance of the Expedition 32/33 crew members in orbit.

Human research

Within cardiopulmonary research between July to September, NASA astronaut Joe Acaba continued as a subject ESA's Vessel Imaging experiment in conjunction with NASA's Integrated Cardiovascular experiment, consisting of an echography scan together with ECG and heart rate measurements. NASA astronaut Sunita Williams and JAXA astronaut Akihiko Hoshide also became new subjects of the joint experiments that help to quantify the cardiovascular response to fluid shifts in the body during long exposure to weightlessness and aim to optimise countermeasures for adverse effects of spaceflight.

Additional experiments in this area were undertaken using the Portable Pulmonary Function System to record a variety of pulmonary measurements during varying degrees of exercise on the CEVIS ergometer. This formed part of ESA's Thermolab and EKE experiments in conjunction with NASA's



Test inside ATV *Albert Einstein* (ATV-4) of the new Late Cargo Access Means (LCAM) in Kourou. The new LCAM will allow larger and heavier last-minute cargo to be loaded, 75 kg of Triple Cargo Transfer Bags instead of the previous capability of 25 kg Double Bags

NASA astronaut Sunita Williams performs a VO2 Max experiment while using the CEVIS cycle ergometer (NASA/ESA)

Maximum Volume Oxygen (VO2 Max) experiment. Sunita Williams completed her first sessions of the experiments in August and September. Thermolab is investigating thermoregulatory and cardiovascular adaptations among crew members, while EKE aims to develop a diagnostic tool for improved assessment of endurance capacity in orbit and the development of a physiological model for oxygen transport.

Thermolab sensors were also used in a new ESA experiment, Circadian Rhythms, with Hoshide as the first subject. Hoshide completed three sessions of the experiment between 30 July and 8 September, with 36 hours of continuous data gathering. Its objective is to get a better basic understanding of alterations in circadian rhythms in humans during long spaceflights. This will provide insights into the adaptation of the human autonomic nervous system in space over time, and will help to improve physical exercise, rest and work shifts, as well as fostering adequate workplace illumination from the occupational healthcare point of view in future space missions.

Another new ESA experiment, Reversible Figures, started in the area of neuroscience with Sunita Williams as the first test subject. Williams carried out the first three sessions of the experiment in July, August and September. The experiment is investigating the adaptive nature of the human neurovestibular system in the processing of gravitational information related to 3D visual perception. It involves the comparisons of pre-flight, in-flight, and post-flight perceptions with regards to ambiguous perspective-reversible figures to assess the influence of weightlessness. The experiment uses hardware connected to a laptop and a dedicated astronaut-worn visor.

Joe Acaba also continued the 'Space Headaches' experiment, filling in weekly questionnaires that are being analysed on ground to help determine the incidence and characteristics of headaches occurring within astronauts in orbit. Acaba completed his final (17th) questionnaire on 13 September before his return on Soyuz TMA-04M.

ESA's immunology research continued within the Immuno experiment, which is determining changes in stress and immune responses, during and after a stay on the ISS. Russian cosmonauts Gennady Padalka and Sergei Revin were subjects of the experiment in July and September, providing blood and saliva samples to check for hormones associated with stress response and for carrying out white blood cell analysis in addition to filling in a stress test questionnaires.

Fluids research

The remaining four flash disks of data for the SODI-Colloid 2 experiment were returned to Earth with TMA-04M in September to undergo analysis by the science team. Colloid 2 was one of the three experiments undertaken in the ESA-developed Microgravity Science Glovebox in the US laboratory using the Selectable Optical Diagnostic Instrument (SODI). The Colloid experiment covers the study on growth and properties of advanced photonic materials within colloidal solutions.

Radiation research

The Dose Distribution inside the ISS 3D (DOSIS 3D) experiment has been continuing using the active radiation detectors located in the European Physiology Modules (EPM) facility and passive radiation packages at different locations around the Columbus laboratory. Monthly downlinks of data from the active detectors have been carried out via the EPM facility and good data has been confirmed by the science team. The set of passive detectors (ten Passive Detector Packages and one Triple Detector Package) were uninstalled by Sunita Williams on 11 September and returned to earth with Soyuz TMA-04M on 17 September. The passive detectors are used in order to undertake 'area dosimetry', i.e. to measure the spatial radiation gradients inside the Columbus laboratory while the two active DOSTEL detectors are making time-dependent radiation measurements. DOSIS-3D will build on the DOSIS experiment by combining data gathered in Columbus with those from other modules of the ISS.

Data acquisition continued for the ALTEA-Shield experiment in the 'shielding' configuration since its relocation to EXPRESS Rack 3 in Columbus on 8 June. The shielding part of ALTEA-Shield is testing the two different types of shielding materials (and different thicknesses of each material) against cosmic rays. On 9 August, 54 cumulative days of science data had been collected using the polyethylene shielding tiles that were being tested. This meets the minimum requirements (40 days) for this part of the experiment. At that point, Hoshide exchanged the polyethylene tiles for Kevlar tiles. To 21 September, the Kevlar tiles had been tested for 43 cumulative days. This follows the ALTEA-Survey part of the ALTEA-Shield experiment series that had made a 3D survey of the radiation environment in the US laboratory.

Solar Research

ESA's SOLAR facility carried out four more data acquisition periods during Sun 'visibility windows' between 20 June and the end of September, each period lasting just under two weeks. The SOLAR payload facility has been studying the Sun's irradiation with unprecedented accuracy across most of its spectral range for more than four years on orbit. An extension to the payload's time in orbit could see its research activities extend up to early 2017 to monitor the whole solar cycle with unprecedented accuracy.

Technology research

ESA's Vessel Identification System (commonly known as the Automatic Identification System, AIS) has been functioning on the ISS for more than two years with telemetry being received by the Norwegian User Support and Operation Centre in Trondheim via ESA's Columbus Control Centre in Germany. Upgraded software for the system's NORAIS receiver on the ISS was uplinked and updated on 26 June.

The first steps in advance of ESA's Multi-purpose End To End Robotic Operations Network (Meteron) experiment took place on the ISS in August. The goal of Meteron is to set up a test-bed to allow astronauts on the ISS to simulate robotic exploration scenarios, tele-operating robots on the ground from the ISS.

Operations and checkout activities were configures by Sunita Williams and connection was established between the ISS laptop located in the Columbus laboratory and ESOC using the new Disruption Tolerant Network (DTN) communication technique. A software patch is needed before continuing with activities, which will establish the initial communications network for ESA's Meteron experiment. The first test will be made on 31 October (operating a small rover at ESOC).

Files were downlinked from the Erasmus Recording Binocular 2 (ERB-2) high-definition 3D video camera via the European Drawer Rack on the ISS in September. The ERB-2 files were produced by André Kuipers in January and February during the PromISSe mission. The extensive amounts of data cover different activities, from general life on the ISS, maintenance and research activities, as well as training on exercise equipment such as the T2 treadmill and Advanced Resistive Exercise Device in Node-3.

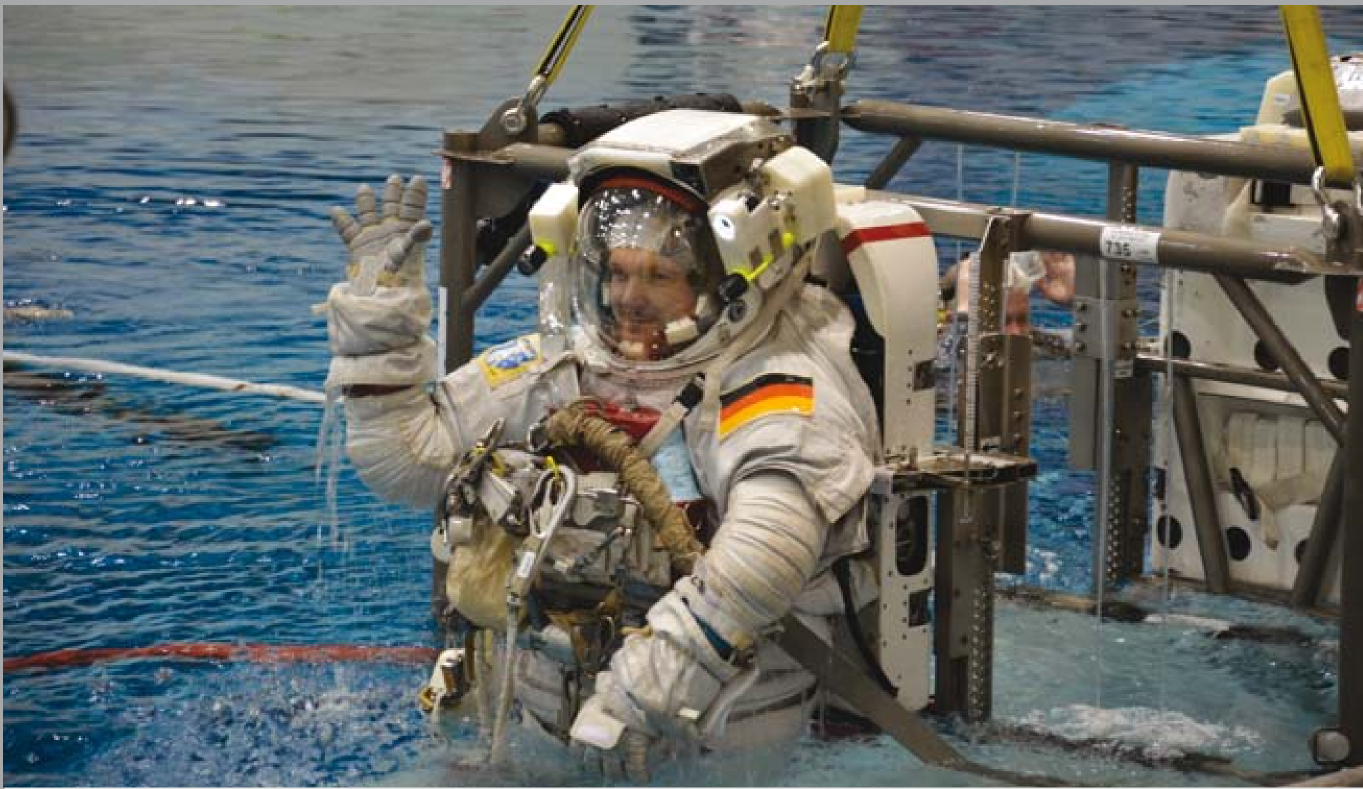
→ ASTRONAUTS

André Kuipers has been involved in post-flight activities including rehabilitation, baseline data collection for human research investigations and public relations activities.

Luca Parmitano (IT), scheduled for launch in late May 2013 as a member of ISS Expeditions 36/37, is back-up flight engineer for Canadian astronaut Chris Hadfield. Hadfield will fly to the ISS in December as a member of Expeditions 34/35. Parmitano finished training at EAC as an ESA Columbus specialist and in ATV rendezvous and docking, and has started ESA payload training. Parmitano is also fully trained for US extravehicular activities (EVA), robotics and 'track and capture' for visiting logistics vehicles (for example HTV, Cygnus or Dragon).

Alexander Gerst (DE), scheduled for launch in May 2014 as a member of Expeditions 40/41, is receiving refresher training on Columbus systems and payload racks. He is also being trained at NASA on systems in the US segment of the ISS, robotics and EVA procedures.

Alexander Gerst in Soyuz training at Star City, Moscow (ESA/Roscosmos)



ESA astronaut Alexander Gerst in the neutral buoyancy pool in Houston (NASA)

NASA astronaut Karen Nyberg and ESA astronaut Luca Parmitano, both Expedition 36/37 flight engineers, take part in an EVA planning session in the ISS mock-up/trainer at NASA Johnson Space Center (NASA)

Astronauts Andreas Mogensen and Soichi Noguchi take part in the CAVES 2012 training course (ESA/V.Crobu)

Samantha Cristoforetti (IT), scheduled for launch in November 2014 as a member of Expedition 42/43, finished the ESA Pre-Assignment Training in August and has started ISS increment training.

Andreas Mogensen (DK) became a 'troglonaut', one of an international team of astronauts taking part in a six-day ESA caving exercise in Italy. Astronauts from each ISS Partner agency (ESA, NASA, JAXA, CSA and Roscosmos) got a taste of what it might be like working as a safe and effective team on a long spaceflight. During the exercise they honed their leadership and group skills while working in a typical multicultural team as found on the ISS. With 'cavewalking' being similar to spacewalking, space protocols were used for example in correct use of tools and safety procedures. The team carried out research activities, as they would during an ISS mission, but in this case covering cave meteorology, geology, biology and microbiology.

A number of international astronauts have been training at EAC since July. Cosmonauts Oleg Kotov (Expeditions 37/38) and Mikhail Tyurin (Expeditions 38/39) received training on ATV rendezvous, docking and ingress) in preparation for ATV-4 in 2013. NASA astronaut Kevin Ford (Expeditions 34/35) made final preparations for ESA tasks on his long-duration mission starting in October. NASA astronauts Michael Hopkins (Expeditions 37/38) and Richard Mastracchio (Expeditions 38/39) received training on Columbus operations and payloads. JAXA astronaut Koichi Wakata (Expeditions 38/39) was trained as a Columbus Specialist and on Columbus payloads.

Non-ISS research

Preparations for the 57th ESA Parabolic Flight Campaign in October are under way. This campaign will cover 11 experiments (four in physical sciences, four in life sciences and three student experiments). Preparations are also under way for the second Joint European Partial-g Parabolic Flight (JEPPF) campaign for partial-gravity, gravity-dependent and microgravity experiments. This joint ESA/CNES/DLR-organised campaign is a reflight of 11 of the initial set of 13 experiments.

This years's Concordia Antarctic station winter-over season will finish in October and the next winter-over season is in the final planning phase. The 2013 crew are due to fly to Concordia in November and will begin their winter-over period from February 2013.

The Investigations into Biological Effects of Radiation (IBER) project completed two beam times in August using the particle accelerator facility at the GSI Helmholtz Centre for Heavy Ion Research in Darmstadt, Germany. IBER is assessing the risks related to radiation in various exploration scenarios, with a programme of experiments on biological materials.

A new medium-duration bed-rest campaign is due to start in November. The campaign will be undertaken over three periods, one in 2012 and two in 2013, with each period incorporating a 21-day bed-rest period with the same 12 subjects in each. The study builds on previous campaigns, to test countermeasures for the effects of (simulated) weightlessness on the human body.

The campaign will test a nutritional supplement (potassium bicarbonate and whey protein) and an exercise protocol (resistive vibration) to determine if the supplement improves the effect of the exercise. Each period will have a control group taking no exercise and without a supplement, a group taking just exercise and a final group taking exercise plus the nutritional supplement. The campaign will take place at the Medes Space Clinic in Toulouse, France.

Two drop-tower campaigns are being planned for November and December. The first campaign will be for the Chondrule 2b investigation (a focused study on particle rotation and photophoresis). The next campaign is a student campaign from the Magdeburg University and forms part of the 'Drop Your Thesis 2012' campaign.

→ TRANSPORTATION/EXPLORATION

International Berthing and Docking Mechanism (IBDM) and International Docking System Standard (IDSS)

Discussions have taken place with NASA and CSA for the possible definition of a joint development of a new docking system based on the IBDM. A revised design for the International Standard, which would be compatible with the Russian APAS soft-docking diameter, was developed by European industry in the summer. The final definition is to be detailed in a further phase.

NASA is completing an internal review on its equivalent docking system to assess current design and the decision to evolve it to a new international standard for soft docking. A Technical Meeting of the five ISS Partners was called by NASA in October at ESRIN, where an agreement in principle for the adoption of the narrow soft-docking ring is expected.

Advanced Return Vehicle (ARV)

The System Concept and Programmatic Review was completed with the final delivery of the revised data package. The ARV Phase-A final presentation was held in ESTEC on 6 September.

Expert

Funding was provided by the ESA General Studies Programme (GSP) to support Thales Alenia Space Italy in carrying out analyses to identify an alternative launch system. The availability of alternative launch systems on the Russian side appears doubtful because of the evolution of the Russian Ministry of Defence policy not to use military systems for civil space missions. A Technical Assistance Agreement to evaluate Expert launch options with US industry and NASA was approved by the US Department of State. Technical discussions with Orbital Sciences for the evaluation of alternative launch vehicles have started.

The 146 m ZARM drop tower, at the University of Bremen, is one of the tallest and best-known drop tower facilities in Europe and the home of ESA's 'Drop Your Thesis' campaigns (J. Howaldt)

Lunar Lander

The Call for Declarations of Interest for payloads on the Lunar Lander was issued and a total of 63 high-quality proposals for instruments and experiments were received from international teams. The evaluation of the results and preparation for a possible AO in 2013 through a Lunar Lander Science Definition Team has started.

The Phase-B1 mission study is in progress. The industrial team is operational, with about 20 companies. Lunar Lander design activities have been working towards the Pre-SRR for October/November. All breadboarding activities are now under way in propulsion, navigation, avionics, LIDAR and thermal control.

Lunar Polar Sample Return (LPSR)
Lunar exploration has been declared a top priority in Russia. LPSR is the next major mission after the ongoing Luna-Glob and Luna-Resurs missions, with a launch no earlier than 2020. In a broad cooperation agreement on exploration, encompassing the Moon, Mars and Jupiter, Roscosmos has invited ESA to assess possibilities for participation in LPSR and the Luna-Resurs lander mission (launch after 2017). The discussions with Roscosmos are focusing on the definition of potential contributions to these two missions, including a drill derived from ExoMars and a hazard detection and avoidance system developed for Lunar Lander.

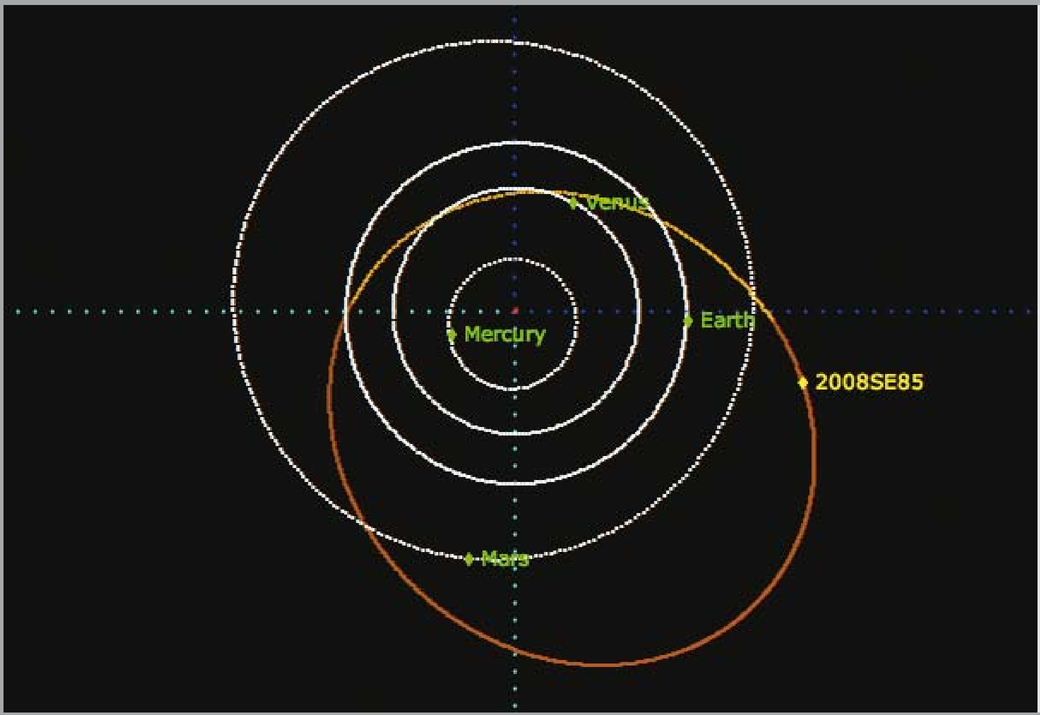
Exploration
The ESA Strategic Guidelines for Exploration document was presented at the 10th meeting of ESA's Human Spaceflight and Exploration Science Advisory Committee and the 42nd meeting of the ESA Human Spaceflight Programme Board in September. An ESA internal review of roadmaps for future human spaceflight and exploration developed within the context of the ESA Scenario Studies, funded by the European Transportation and Human Exploration Preparatory Programme, took place in August and September.

→ SPACE SITUATIONAL AWARENESS (SSA)

SSA Architectural Design
The second SSA Architectural Design contract with INDRA (ES) for the future SSA/Space Surveillance and Tracking (SST) and SSA/Near-Earth Objects (NEO) segments began in July. The work led by Astrium GmbH under the first contract progressed satisfactorily. High-level architecture options were presented to ESA by the consortium in September. Negotiation with industry for a second SSA Architectural Design contract for the Space Weather (SWE) segment is ongoing.

SSA/SST
The factory acceptance test for the next-generation conjunction prediction and reentry prediction systems was concluded. Work is now under way to test these new capabilities within the ESA SSA Integration and Reference Environment at ESAC. Steps are also being taken to leverage European industry experience in operational space surveillance and tracking in order to supply real-life data. These data products that provide indication of conjunction predictions will then be used to test and validate the development of an efficient and automated data processing chain for catalogue generation.

SSA/SWE
The first Space Weather precursor services provided by the Expert Services Centres for Solar Weather, Ionospheric Weather, Space Radiation Environment and Geomagnetic Conditions have been available for the end users for testing and validation since August. The SWE Service Coordination Centre (SSCC) in the Space Pole in Brussels has been providing user support during this time and helped new users with the registration to the services and with more detailed questions related to the services and space weather in general. Contracts for establishing new services for ionospheric weather in the north-polar region, ground-



The orbit of asteroid 2008SE85. This NEO was discovered in 2008, and 'rediscovered' by an amateur astronomer during a regular observation slot sponsored by ESA's Space Situational Awareness programme (ESA/Deimos)

A new radar designed to test methods for finding orbital debris that can be hazardous to space navigation was installed near Santorcaz, about 30 km from Madrid in Spain

based H-alpha solar monitoring service and European ionosonde and neutron monitor service were started in August. Initial versions of the new services are expected to be available in early 2013.

SSA/NEO

The NEO Data Centre is being set up at ESRIN. A local front-desk operator is the first contact point for queries related to the NEO services. During relatively short test observations, the 1 m Optical Ground Station telescope discovered two NEOs and rediscovered a potentially hazardous asteroid that was considered 'lost' since 2008 (2008SE85). Several contracts related to the NEO segment began, including a contract on a robotic follow-up telescope demonstration test-bed and a contract on NEO impact effects and mitigation measures.

SSA Ground Segment Engineering

Excellent progress was achieved with the mono-static breadboard radar, developed under a contract with INDRA and the Fraunhofer Institute for High Frequency Physics and Radar Techniques (DE). The radar was moved to its final location near Madrid, where it will be prepared for the Site Acceptance Test in November.

For the bistatic breadboard radar, Phase-2 of the contract, aiming at developing the breadboard radar, began and the consortium led by ONERA (FR) is working on the PDR for November.

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