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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, Portugal, 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: M. Lucena

Director General: J.-J. Dordain

←

The Cat's Eye Nebula (NGC 6543) was discovered by William Herschel in 1786. Hubble observations revealed it to be one of the most complex nebulae known of its kind, with 11 rings of gas making up the Cat's Eye and remarkable structures such as knots, jets and bubbles. In the centre, there is a hot bright star that lost its outer envelope producing the nebula about 1000 years ago (NASA/ESA/STScI/AURA) esa

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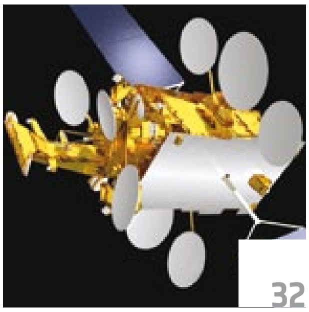

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Hubble seen from Space Shuttle *Discovery*, STS-103, during Servicing Mission 3A in 1999 (two ESA astronauts were on this flight, Jean-François Clervoy and Claude Nicollier)

→ SEEING WITH HUBBLE-VISION

20 years of science with the Hubble Space Telescope

Antonella Nota
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Bob Fosbury and Colleen Sharkey
Space Telescope European Coordinating Facility, Garching, Germany

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The NASA/ESA Hubble Space Telescope is one of the greatest scientific projects of all time. For 20 years, Hubble has opened our eyes to the wonders of our 'planetary' backyard and beyond, and has made a number of fundamental discoveries in astronomy and physics.

Named after the renowned astronomer Edwin P. Hubble, this space-based observatory has revolutionised astronomy by providing unprecedented deep and clear views of the Universe, ranging from our own Solar System to extremely remote fledgling galaxies that formed not long after the 'Big Bang', billions of years ago.

Launched on 24 April 1990, Hubble has been greatly extended in its scientific powers through new instrumentation installed during five servicing missions with the Space Shuttle. Its primary mirror is 2.4 m in diameter, not large by ground-based standards, but giving amazing performance in space.

The Universe is transparent to visible light over journeys lasting thousands of millions of years. However, just before this light arrives at telescope mirrors on Earth, it must travel through our turbulent atmosphere and the fine cosmic details become blurred.

→ Edwin Powell Hubble (1889–1953) was first to show that the Universe is expanding and is considered by many to be the father of observational cosmology

Putting a telescope in space is one way of avoiding this problem. From its vantage point 575 km above Earth, Hubble can detect light with 'eyes' five times sharper than the best ground-based telescopes under normal conditions. As well as collecting visible light from its orbit high above the atmosphere, Hubble can also observe the infrared and ultraviolet wavelengths that are filtered out by the atmosphere.

NASA's partner for Hubble

From hardware and astronauts, to groundbreaking science, the European influence in the Hubble project has been vast and vital. ESA has a nominal 15% stake in the mission and has provided, among other things, the Faint Object Camera and the first two sets of solar panels that powered the spacecraft until 2002.

Just as important as ESA's financial and technical contributions is that of the people who support the telescope and use it to investigate the Universe. There are many astronomers in Europe who use Hubble, but the two main centres for Hubble science employ dedicated groups of full-time astronomers.

→ Space Telescope European Coordinating Facility

Based at the headquarters of the European Southern Observatory in Garching, near Munich, ST-ECF developed and maintains the European copy of the full Hubble archive and has worked with the STScI and the Canadian Astronomy Data Centre on many of the archive developments, including the Hubble Legacy Archive that contains a wide range of 'science-ready' data products.

The ST-ECF group has worked on a series of Hubble science instrument projects and, in recent years, has become responsible for the 'slitless spectroscopy' modes offered by most of Hubble's cameras.

→ The Space Telescope Science Institute in Baltimore, USA

A group of 15 European astronomers works at the Space Telescope Science Institute (STScI) in Baltimore, Maryland (USA) while another group runs the Space Telescope European Coordinating Facility (ST-ECF), near Munich, Germany, to provide a direct connection to European astronomers.

ESA's contribution entitles European astronomers to 15% of the telescope's observing time, but this fraction has reached over 25% when robust and scientifically compelling proposals have been made.

ESA's Hubble Space Telescope Project Scientist and Mission Manager at STScI, Antonella Nota, has a long history with Hubble. An astronomer originally from Venice, Italy, she spent ten years supporting Hubble instrument science operations – starting as head of the Faint Object Camera Group, then head of the Observatory Support Group and as head of the NICMOS (Near-Infrared Camera and Multi-Object Spectrometer) Group.

"It is an enormous benefit to ESA and to the European community to have European scientists at STScI. Their unique knowledge has been fundamental for instrument calibration and user support. Their presence at senior levels in the organisation ensures that the views of the European scientific community are well represented. As many of them eventually return to Europe, the expertise they acquire working directly with Hubble is often put to use in Europe at universities and other research institutions, where many of them now hold leading positions," said Antonella.

← Antonella Nota, ESA's Hubble Space Telescope Project Scientist and Mission Manager at STScI

From their orbital vantage point, these modes are extremely sensitive and allow the spectroscopic analysis of objects fainter than can be achieved from the ground, even with much larger telescopes. The measurements of many of the 'high-redshift' supernovae that spawned the idea of an accelerating Universe and the existence of 'dark energy' were made with Hubble's slitless spectrographs.

For Servicing Mission 4, ST-ECF provided much of the processing needed to set up and calibrate the slitless spectroscopic modes of the new Wide Field Camera 3. This camera has two infrared spectroscopic modes that offer a unique and very powerful capability to map the history of star formation over most of the age of the Universe.

Since the late 1990s, the group also has been producing much of the European outreach and public relations products for this joint ESA/NASA mission. It has introduced a number of innovative products, such as the highly popular Hubblecast, available through iTunes, and the FITS Liberator software that enables Photoshop users around the world to process Hubble image data. Many amateur astronomers as well as professionals benefit from this work.

→ Helmut Jenkner, Deputy Head of the ESA HST Mission at STScI

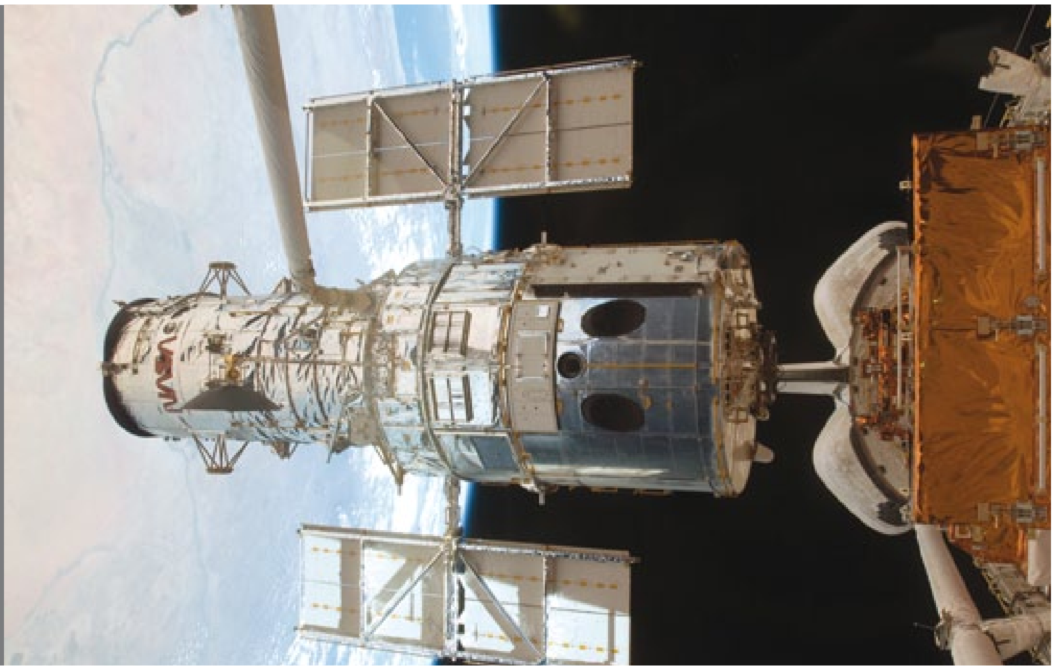
Some of the ESA astronomers at STScI were deeply involved in the design and execution of Servicing Mission 4 in 2009. Helmut Jenkner, the Deputy Head of the HST Mission at STScI, was in the NASA Goddard Space Flight Center control room during the spacewalks. During long shifts, day and night, Helmut represented ESA and the European community when major decisions were made about the observatory.

"For me, Servicing Mission 4 was certainly the most exciting period in my 27 years on the Hubble programme, as its success promises exceptional science for years to come," said Jenkner.

Other ESA astronomers were involved in the commissioning activities of the instruments, such as the optimisation campaign for the Advanced Camera for Surveys (ACS). ESA's Linda Smith, an expert on star clusters and starbursts galaxies, is the team leader at STScI for ACS and the Wide Field Planetary Camera 2 (WFPC2, now 'retired' to the National Air and Space Museum in Washington DC).

During her 15 years as an astronomy professor at University College London, Smith made frequent visits to STScI but decided several years ago to take a leave of absence from teaching to work full-time at the Institute. She liked it so much she gave up her professorship to focus completely on Hubble.

With her team, Linda led the ACS optimisation campaign, preparing calibration files and test runs at NASA's Goddard Space Flight Center. "We had to prepare for the possibility that ACS wouldn't work as well as it used to," said Linda. "You're aware that all of the work could be in vain. I thought people were going to be so disappointed but it was so exciting! Straight 'out of the box', it worked better than we could have even hoped!"



→ Servicing Mission 4: Space Shuttle *Atlantis*'s remote manipulator arm lifts Hubble from the cargo bay before releasing the orbital observatory to resume observations of the Universe

> **“I hadn’t expected this image for ACS to be so amazing. The large, orangeish arc is incredible and everybody on the team is proud to be working on such a capable instrument.”**

The ACS Early Release Observation (the first Hubble picture released after SM4) was the culmination of months of hard work and preparation, so seeing the image for the first time was exciting and satisfying for Linda. It was a stunning picture of Abell 370, a galaxy cluster that highlights the phenomenon known as ‘gravitational lensing’.

“I hadn’t expected this image for ACS to be so amazing. The large, orangeish arc is incredible and everybody on the team is proud to be working on such a capable instrument,” said Linda.

Now that Hubble is working better than ever, Linda is looking forward to doing more research using this observatory and to making ACS available for other Hubble researchers.

Marco Chiaberge’s affiliation with STScI dates back to 2001 when he was an ESA post-doctoral researcher. He returned to his native Italy to work at the Institute of Radio Astronomy in Bologna before rejoining STScI in 2005. Chiaberge led one of the teams that analysed the first data from ACS after SM4, which involved long late-night hours and lots of patience.

Now that the camera is functioning again, Chiaberge and his team have to get to know the ‘new’ ACS. He serves as the calibration lead, ensuring that the instrument is optimally set up for observers. An expert on so-called ‘active galactic nuclei’ (galaxies with black holes at their centres), he looks forward to working with the improved Hubble to pursue new research, peering deeper into the Universe to study distant galaxy clusters.

← Part of one of the first images returned by Hubble’s newly repaired Advanced Camera for Surveys, peering nearly five billion light-years away to resolve intricate details in the galaxy cluster Abell 370 (NASA/ESA/SM4 ERO team/ST-ECF)

Space Shuttle *Discovery* lifts off on 24 April 1990, carrying the STS-31 crew of five and the Hubble Space Telescope into space

Danny Lennon, the Deputy Head of the STScI Instrument Division, was also very busy orchestrating the instrument commissioning activities during SM4, while at the same time closely following the first in-flight tests of the Cosmic Origin Spectrograph. An ultraviolet spectroscopy expert by training and scientific interests, Lennon joined the STScI staff in 2009, just in time to dive into and enjoy the most exciting moments.

→ History of Hubble

The idea of sending a telescope into space was first proposed long before the first satellites were launched. German rocket scientist Herman Oberth suggested a space-bound telescope as early as 1923 in his book *Die Rakete zu den Planetenräumen*.

It took many years before technology caught up with Oberth's idea. The American scientist Lyman Spitzer proposed a more realistic plan for a space telescope in 1946 and lobbied for his idea for almost 30 years. In the 1970s, NASA and ESA took up the idea and proposed a 3-m space telescope. The NASA/ESA Memorandum of Understanding was signed in October 1977. After funding began to flow in 1977, Hubble was downsized to 2.4 metres, but still started to attract significant attention from astronomers.

The precision-polished mirror was finished in 1981 and the assembly of the entire spacecraft was completed in 1985. The plan called for a launch on NASA's Space Shuttle in 1986 but, just months before the scheduled launch, the *Challenger* disaster caused a delay of the entire Shuttle programme.

Hubble was finally launched in 1990 and the tension built up as astronomers examined the first images through Hubble's eyes. It was soon realised that Hubble's mirror had a serious flaw. A focusing defect prevented Hubble from taking sharp images – the mirror edge was too flat by a mere fiftieth of the width of a human hair.

1977
NASA/ESA Memorandum of Understanding signed

1981
Precision-polished mirror completed

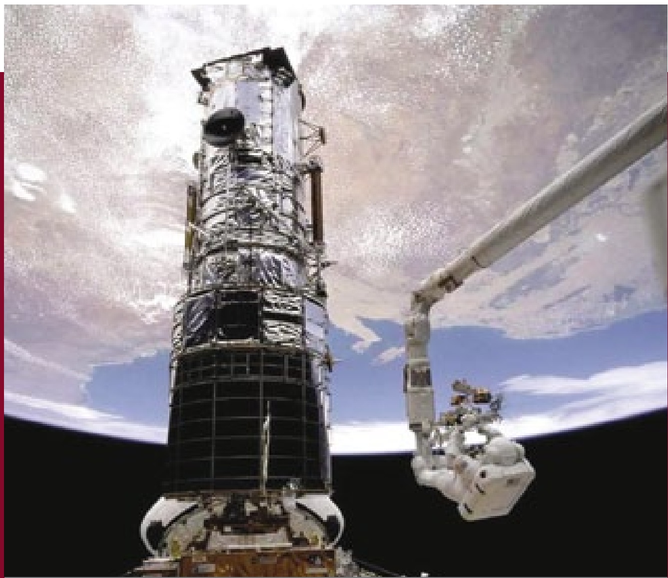
1985
Assembly of complete spacecraft finished

1986
***Challenger* disaster caused a delay in Shuttle programme**

1990
Hubble was launched but its mirror had a serious flaw: a focusing defect

"During SM4 we had to carry out 'aliveness tests' of each instrument immediately following its installation or repair by the astronauts. Our elation and excitement grew as, one after another, the aliveness tests were declared successful. The catchphrase of SM4 became 'It's alive!', heralding the emergence of a new and improved Hubble," said Lennon.

Although floating silently above us, Hubble depends on its teams on both sides of the Atlantic Ocean. A great deal of public relations effort goes into the promotion of Hubble, but the beauty of its images alone is enough to lure people into a fascination with space. Hubble's new lease on life is set to provide even more amazing images and data, increasing our knowledge of the Universe. ■



↑ During Hubble's first servicing mission STS-61, astronaut Story Musgrave is anchored on the end of the Remote Manipulator System arm, ready to install protective covers on the magnetometers

Over the following months, scientists and engineers from NASA and ESA worked together and came up with a superb corrective optics package that would restore Hubble's eyesight completely. A Shuttle crew carried out the repairs necessary to restore the telescope to its intended level of performance during the first Hubble Servicing Mission (SM1) in December 1993.

SM1 captured the attention of both astronomers and the public at large to a degree that no other Shuttle mission since has achieved. Meticulously planned and brilliantly executed, the mission succeeded on all counts. It will go down in history as one of the highlights of human spaceflight. Hubble was back in business.

Since SM1, four other Servicing Missions have been carried out: during SM2 in 1997, two new instruments were installed; in SM3A in 1999, many of Hubble's crucial technical systems were exchanged; and in 2002 came SM3B when Hubble again was fitted with new science instruments. Following SM4, Hubble is now expected to work long into the new decade, with strong hopes for an overlap with its successor, the James Webb Space Telescope, which is currently under construction by NASA, ESA and the Canadian Space Agency, and due for launch in 2014.

→ ESA astronaut Claude Nicollier using one of the Hubble power tools, during the second of three STS-103 extravehicular activities in 1999

1993
First Hubble Servicing Mission (SM1) in December 1993

1997
During SM2 two new instruments were installed

1999
SM3A: Many of Hubble's crucial technical systems were exchanged

2002
SM3B: Hubble again was fitted with new science instruments

2009
SM4: Fifth and last Shuttle Servicing Mission

Astronauts John Grunsfeld (left) and Andrew Feustel work in the light and the dark during their seven-hour spacewalk on SM4, the mission's fifth and final session of extravehicular activity to refurbish Hubble

→ Servicing Mission 4

During the ambitious NASA Servicing Mission 4 in May 2009, the Space Shuttle *Atlantis* STS-125 rendezvoused with Hubble, captured it with the Shuttle's robot arm and placed it in its payload bay. The STS-125 astronauts performed on-orbit repairs on two important science instruments.

With the Space Telescope Imaging Spectrograph (STIS) and Advanced Camera for Surveys (ACS) still in place on Hubble, the STS-125 spacewalkers attempted – for the first time ever – to repair instruments in orbit. These instruments were never designed to be fixed in space.

Astronomers the world over watched anxiously as the astronauts performed 'space surgery' on their treasured telescope, knowing that the period following the mission would be critical to the future success of Hubble.

A team of ESA engineers kept a watchful eye on Hubble's large solar panels – the lifeblood of the spacecraft – as they turned and made way for spacewalking astronauts. Although the ESA-supplied solar panels were replaced in 2002, the new ones are still connected to European solar array drive mechanisms.

Led by Michael Eiden, ESA HST Project Manager for the Science and Robotic Exploration Directorate, the team of four worked 12-hour shifts to provide 24-hour coverage for the entire mission, supervising the positioning of the panels and ensuring the integrity of the solar array hardware.

"We were elated with the performance of ESA's Solar Array Drive Electronics and Solar Array Drive Mechanisms – they performed flawlessly," said Eiden. "I have worked on all of the servicing missions, but to be able to support the last mission to this extraordinary telescope was particularly gratifying."

← The ESA Hubble team during shift handover. Michael Eiden (far left) and Udo Rapp (far right) work the orbit shift, while Lothar Gerlach (second from left) and Manfred Schmid (middle) work the planning shift

↑ ESA HST Project Manager for the Science and Robotic Exploration Directorate Michael Eiden shares a handshake with NASA Goddard Mission Operations Manager Keith Walyus

← The ESA HST team with ESA HST Project Scientist & Mission Manager Antonella Nota

During the spacewalks, the astronauts delivered two new instruments, a camera and a spectrograph. The Wide Field Camera 3 (WFC3), which replaced the workhorse WFPC2, is the first single instrument on Hubble to be able to image across infrared, visible and ultraviolet wavelengths.

The Cosmic Origins Spectrograph (COS) will help astronomers to determine the chemical composition and evolution of the Universe. Both instruments use advanced technology to improve Hubble's potential for discovery dramatically and to enable observations of the faint light from the young stars and galaxies in the Universe.

The astronauts were also able to repair the Advanced Camera for Surveys (ACS) and the Space Telescope Imaging Spectrograph (STIS), both affected by power failures. A dramatic moment occurred when the astronauts had to conquer a stubborn bolt on a handrail attached to STIS before taking on the task of removing 111 screws to access the instrument's power supply card. After trying multiple options without success, managers on the ground advised astronaut Mike Massimino to use 'brute force' to break off the handrail, so he could proceed with the removal of the cover plate.

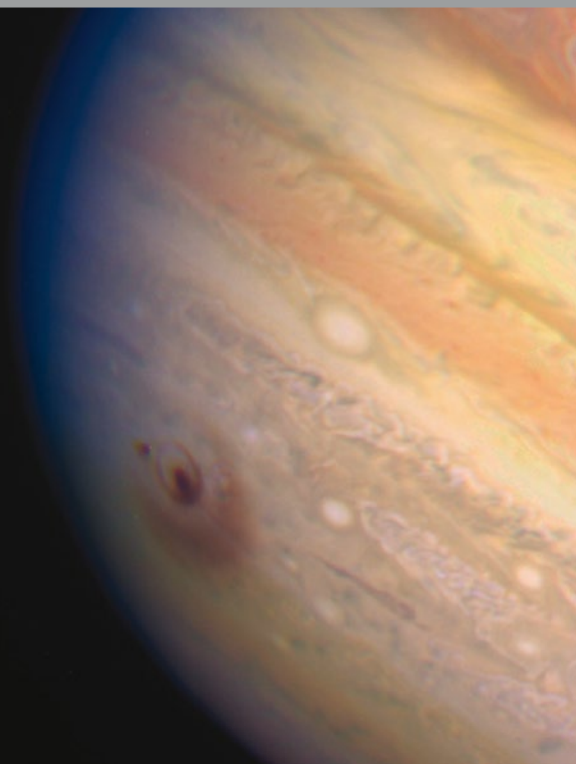
ACS's powerful imaging capabilities at both ultraviolet and optical wavelengths are now both available again, although its High Resolution Channel could not be fixed. ACS provides the perfect complement to the powerful new WFC3, and the duo will be vital for the study of dark energy and dark matter.

After a 13-day mission, all mission objectives were accomplished during five spacewalks that totalled 36 hours, 56 minutes. Hubble was revitalised, now more capable than ever. ■

→ TOP 20 OF SOME OF THE MOST AMAZING HUBBLE IMAGES

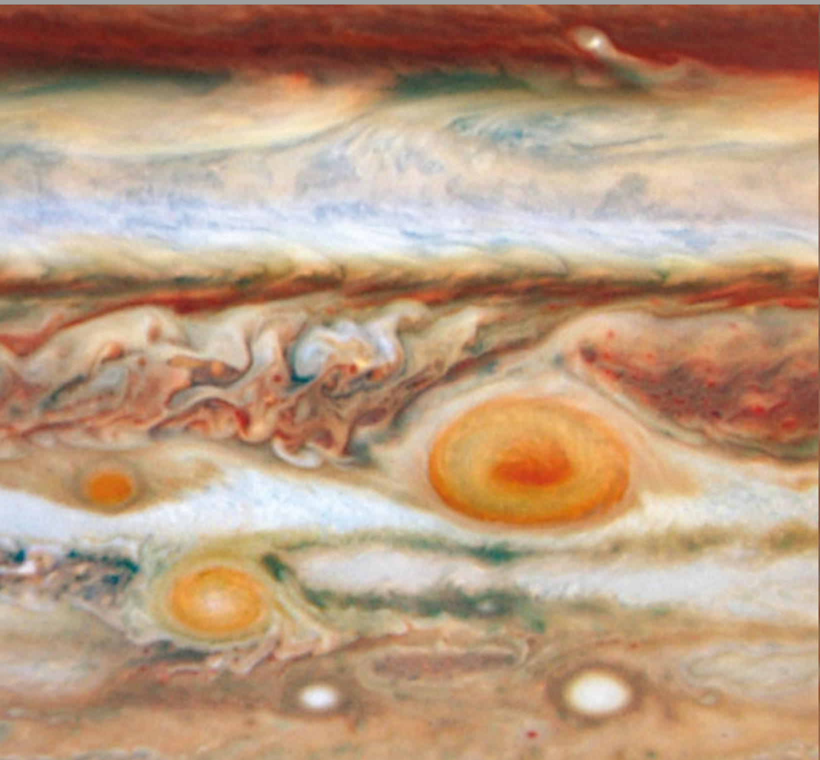
↓ **20.** Mars seen in 1999, with dark sand dunes around the polar ice cap, and a large cyclonic storm churning nearby. Early morning clouds can be seen along the left limb of the planet (Univ. Colorado/Cornell/SSI/NASA/ESA)

↓ **19.** A true colour image of Jupiter reveals the impact sites of fragments 'D' and 'G' from Comet Shoemaker-Levy 9 (MIT/NASA/ESA)

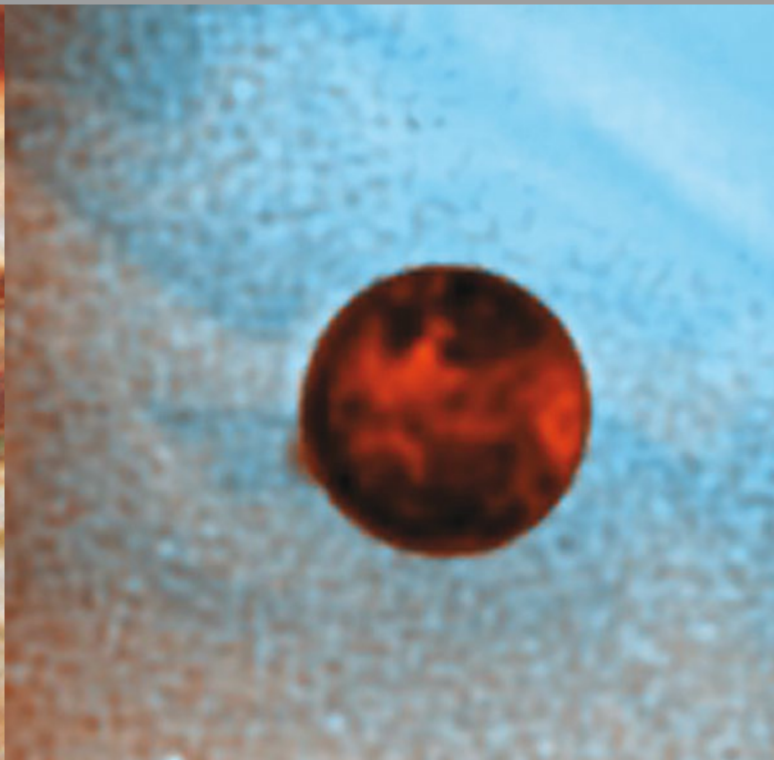


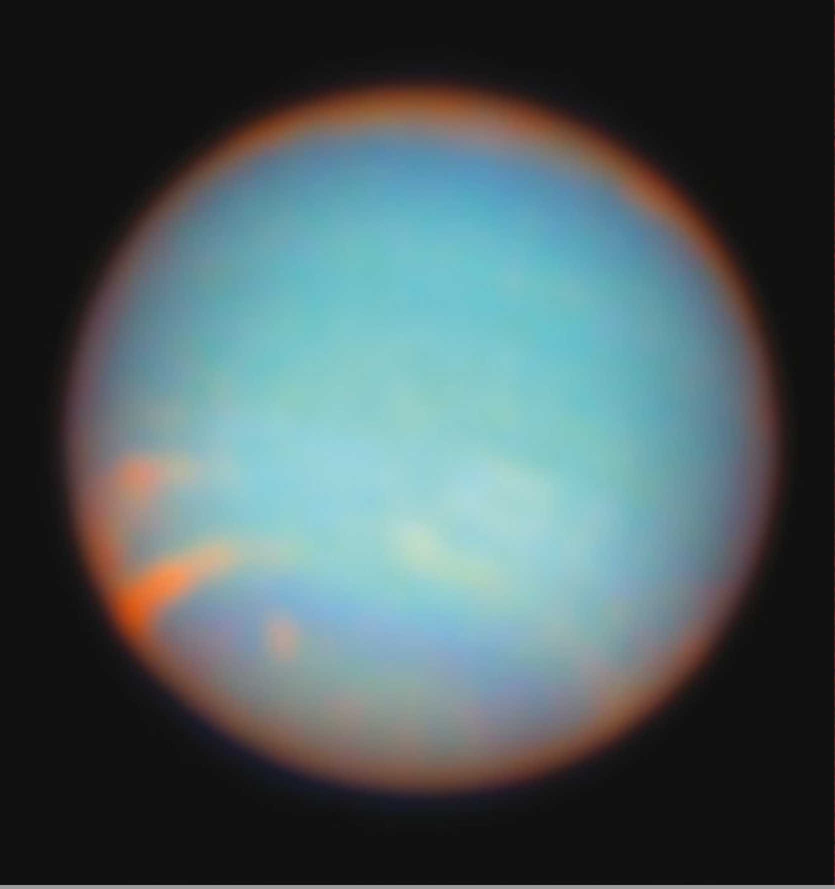
↓ One of the Universe's most stately and photogenic galaxies, the Sombrero galaxy, M104 (NASA/ESA/STScI/AURA)

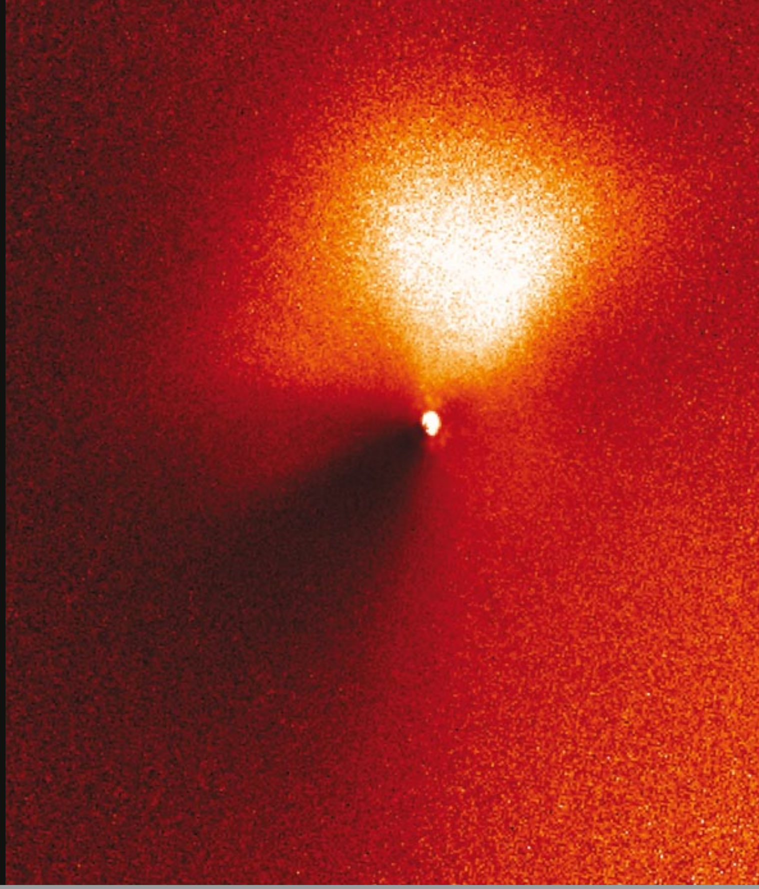
↓ **18.** A third red spot has appeared alongside its cousins, the Great Red Spot and Red Spot Jr., in the turbulent atmosphere of Jupiter (NASA/ESA/Univ. Calif., Berkeley)



↓ **17.** A 400-km-high plume of gas and dust from a volcanic eruption on Io, Jupiter's large innermost moon, taken by the Hubble WFPC2 in 1996 (NASA/ESA/Lowell Obs.)

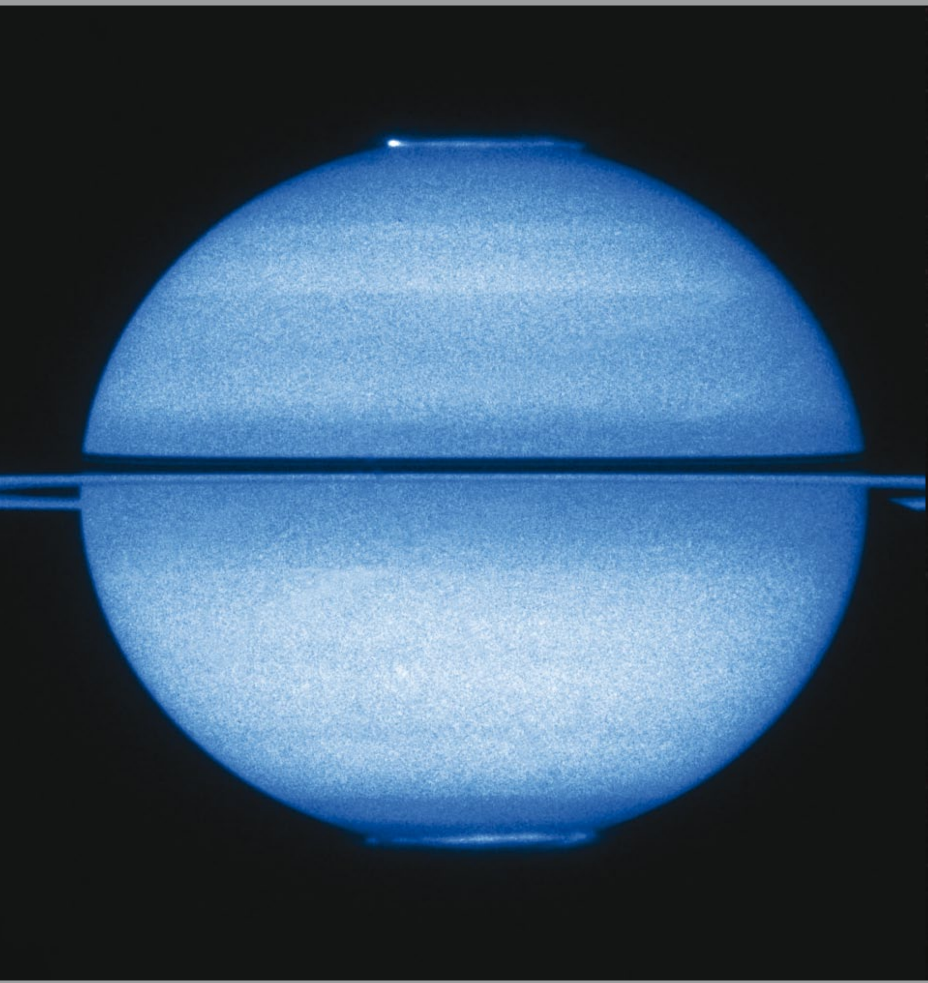


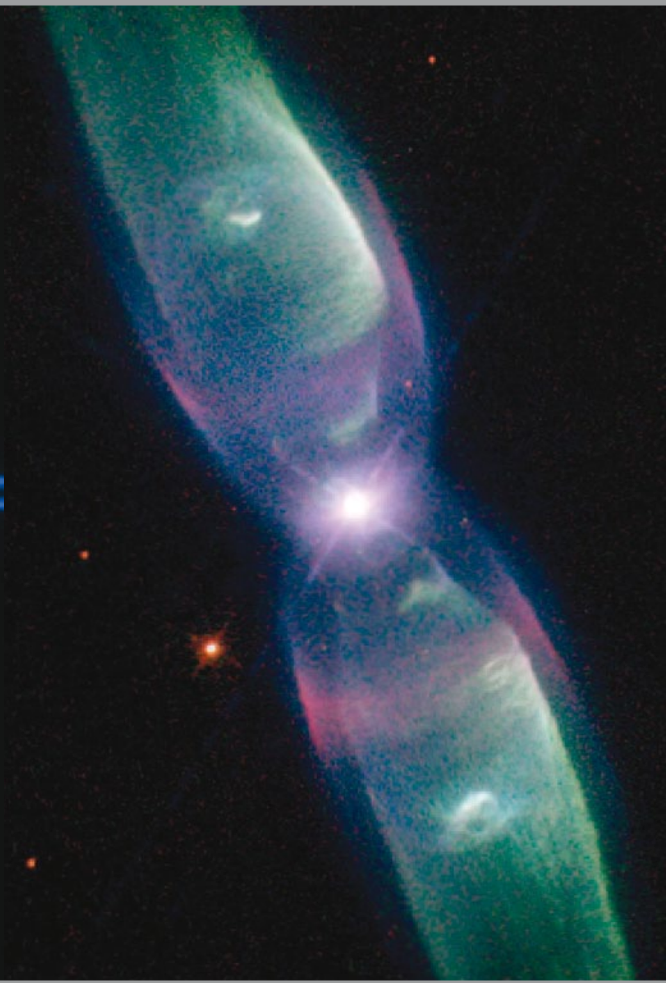




↑ **16.** Atmospheric features seen on Neptune taken through colour filters on the Advanced Camera for Surveys in 2003 (NASA/ESA/Univ. Ariz.)

↑ **15.** Hubble captures the gaseous outburst from Comet 9P/Tempel 1, after being hit by the Deep Impact spaceprobe (NASA/ESA/Johns Hopkins Univ./App. Phys. Lab)



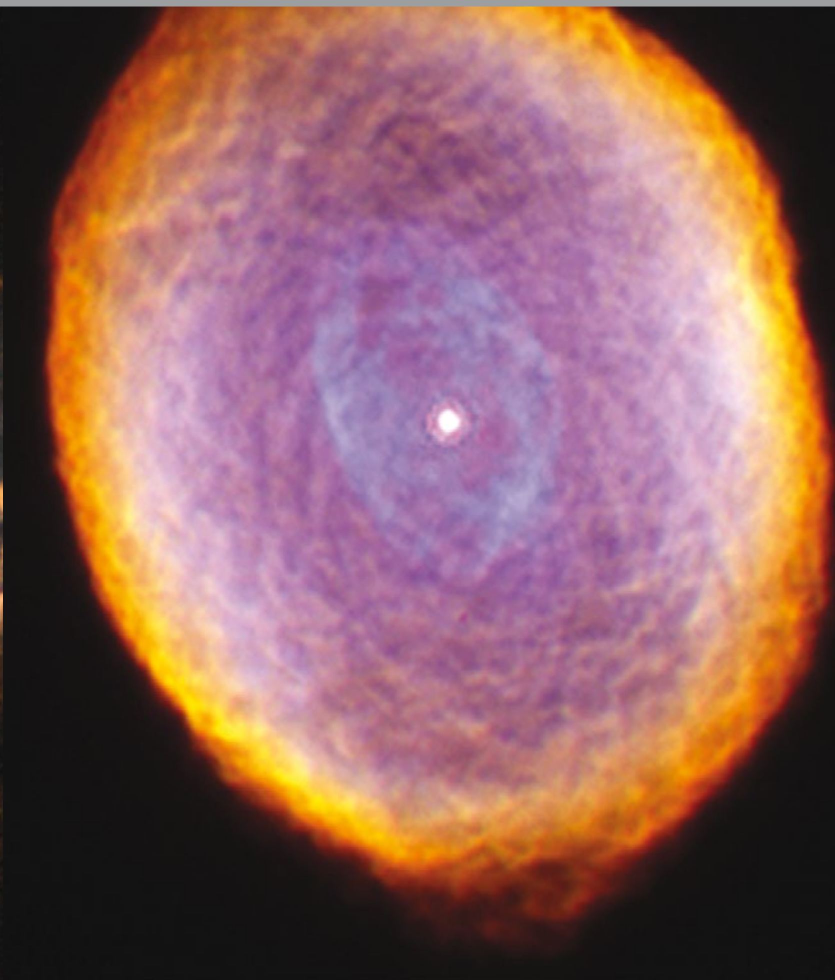


↑ **12.** A unique image from 2009 features Saturn with its rings edge-on and both poles in view, offering a stunning view of its almost symmetrical aurorae, Saturn's own 'northern' and 'southern lights' (ESA/Univ. Leics.)

↑ **11.** M2-9, the 'Twin Jet Nebula', is a striking example of a 'butterfly' or a bipolar planetary nebula (Univ. Wash./Leiden Univ./Stockholm Univ./NASA/ESA)

↑ **14.** NGC 6826's eye-like appearance is marred by two sets of red 'fliers' that lie horizontally across the image. Taken in 1996 with Hubble WFPC2 (Univ. Wash./USNO/Cornell/Univ. Florence/Arcetri Obs./NASA/ESA)

↑ **13.** The 'Eskimo' Nebula, NGC 2392 (NASA/ESA/STScI/ST-ECF)



↑ **10.** The glowing eye of planetary nebula NGC 6751 (NASA/ESA/STScI/AURA)

↑ **9.** The 'Spirograph' Nebula, planetary nebula IC 418 (NASA/ESA/STScI/AURA)

→ **8.** Hourglass' 'Nebula, the young planetary nebula MyCn18 (JPL/ NASA/ESA

→ **7.** Supernova 1994D shining just to the left of galaxy NGC 4526 (NASA/ESA/ Key Project/ High-Z Supernova Search)

→ **6.** Blobs of cold cosmic dust lie around the giant elliptical galaxy NGC 1316 (NASA/ ESA/STScI/ AURA)

→ **5.** The doomed star, Supernova 1987A, spotted two decades ago, was one of the brightest exploding stars in more than 400 years. This Hubble image shows a ring with dozens of bright spots in the region around the supernova in 1996 (NASA/ESA/Harvard-Smithsonian Center for Astrophysics)

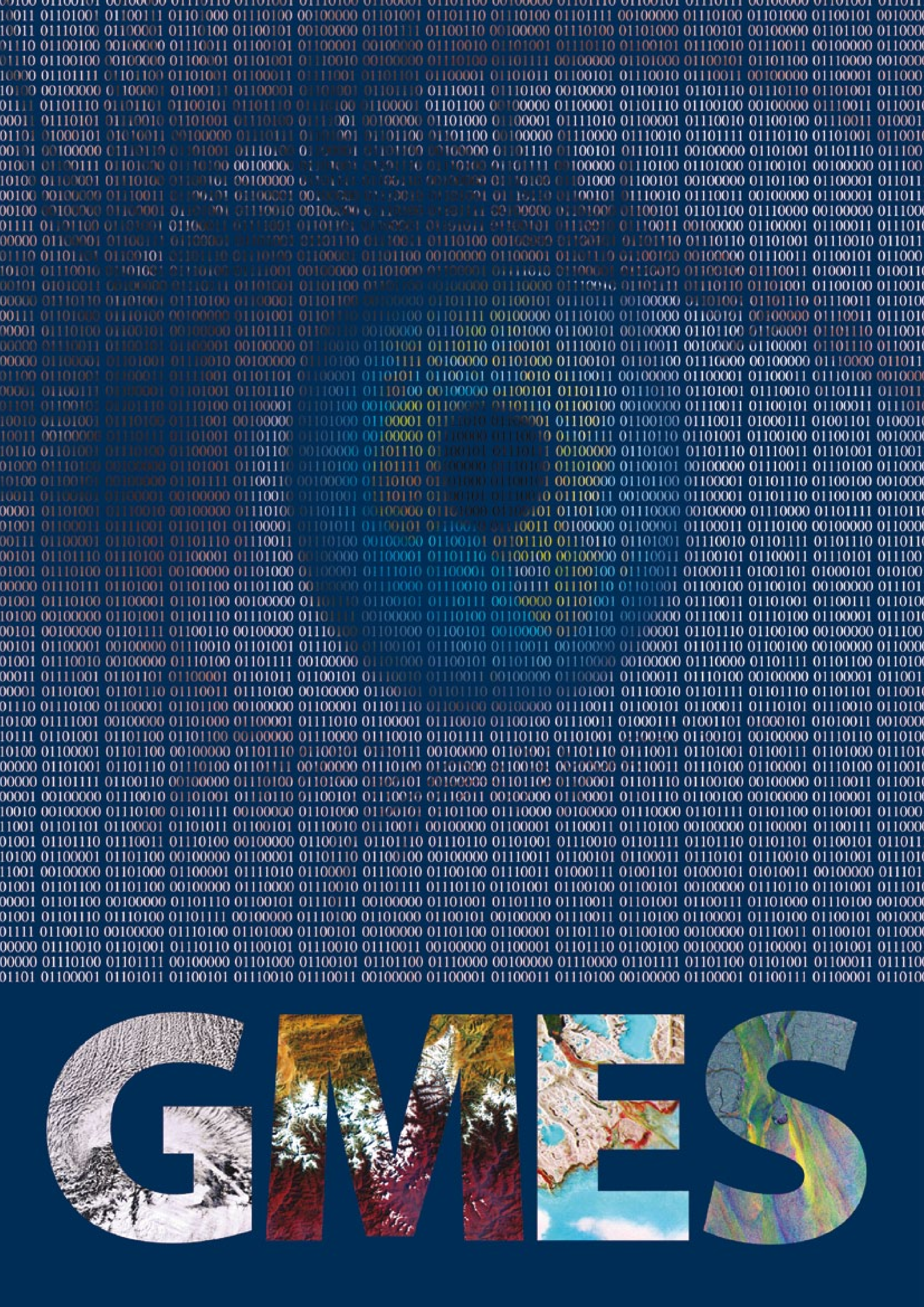
→ **4.** The planetary nebula NGC 6302 taken by Hubble WFC3 after Servicing Mission 4 (NASA/ESA/ERO)

↑ **3.** The massive group of young stars is only a few million years old and resides in 30 Doradus, the 'Tarantula' Nebula, the largest stellar nursery in our local galactic neighbourhood. Taken by Hubble WFC3 after Servicing Mission 4 (NASA/ESA/ERO)

↑ **2.** In January 2002, a moderately dim star called V838 Monocerotis in the constellation Unicorn suddenly became 600 000 times more luminous than our Sun. This made it temporarily the brightest star in our Milky Way. The light from this eruption created a unique phenomenon, known as a 'light echo', when it reflected off dust shells around the star, and it may represent a stage in a star's evolution that is rarely seen (NASA/ESA/STScI)

↖ **1.** And finally, possibly one of the most fascinating images ever taken: more than 12 billion years of cosmic history are shown in this unprecedented, panoramic, full-colour view of thousands of galaxies in various stages of evolution.

This mosaic is made of images taken in September and October 2009 with WFC3 after Servicing Mission 4 (and 2004 with ACS) and covers a portion of the southern field of a deep-sky study (GOODS) by several observatories to trace the formation and evolution of galaxies (a slice of space that is equal to about a third of the diameter of the full Moon). Such a detailed view of the Universe has never before been assembled in such a combination of colour, clarity, accuracy and depth. It shows over 7500 galaxies stretching back through most of the Universe's history (NASA/ESA/Ariz. State Univ./Univ. Virginia/Carnegie Obs./Univ. Calif., Riverside/Univ. Calif., Davis/Ohio State Univ./STScI)


GMES

→ OBSERVING EARTH, FOR A SAFER PLANET

GMES Space Component: status and challenges

Josef Aschbacher, Thomas Beer, Antonio Ciccolella, M. Pilar Milagro & Eleni Paliouras
GMES Space Office, ESRIN, Frascati, Italy

Managing natural resources and biodiversity, supporting rescue teams after natural disasters, predicting the spread of oil spills, adapting to sea-level rise, monitoring the chemical composition of our atmosphere, planning new roads and bridges: all depend on accurate information delivered in time to make a difference.

GMES (Global Monitoring for Environment and Security) is the European initiative for setting up a wide capability for Earth observation, and is the most ambitious Earth observation programme to date.

The idea is to pull together observations from satellites, airborne sensors and ground stations and, when appropriate, combine them with models to get timely and accurate information especially relating to the environment and security. In other words, it will provide a comprehensive picture of the 'health' of Earth at any moment.

GMES has the goal of delivering operational information services for environment and security in six areas: Land, Marine, Atmosphere, Emergency Response, Security and Climate Change. To accomplish this, GMES has been organised into three main components: Services, Space and *In situ* Components.

ESA Member States have invested significantly in the set up of GMES by creating and funding the ESA optional GMES Space Component (GSC) Programme. The programme is co-funded by the European Commission. The majority of the GSC build-up is ensured, with only minor elements remaining to be funded.

→ GMES Space Office

The GMES Space Office, located at ESRIN (Frascati), is the focal point in preparing programmatic aspects of GMES for ESA's Directorate of Earth Observation Programmes and ESA itself. It also interfaces with key external organisations, in particular the European Commission (EC) that leads the overall GMES programme.

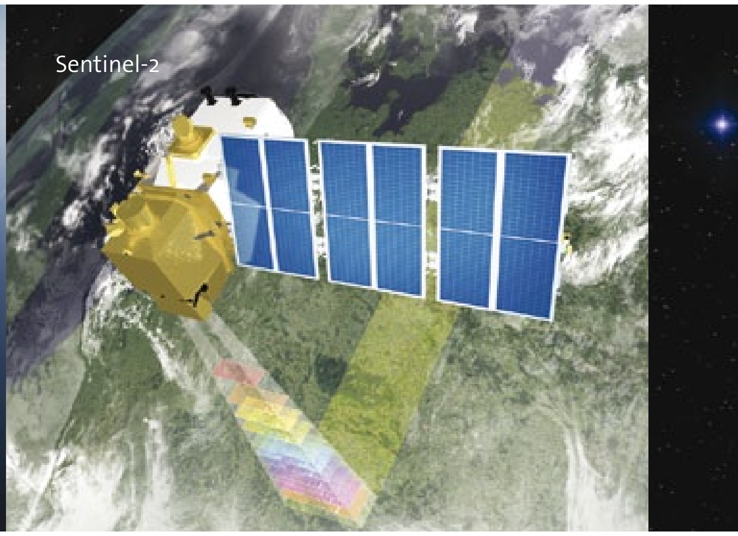
Preparing and funding the operational phase is the responsibility of the EC as overall GMES leader. This is envisaged through an EU operational GMES programme in the next EU Financial Framework starting in 2014. This is the biggest challenge ahead and the most critical factor for GMES – including the Space Component – to succeed.

GMES Space Component

The GMES Space Component programme will fulfil space-based observation requirements responding to European policy priorities. To achieve this, two types of missions will provide the essential space-based information: the Sentinels, developed specifically for GMES, and the GMES Contributing Missions, owned by various national and/or commercial entities and built for their own use but providing valuable complementary observation capacity to GMES.

Integrating these diverse resources into the one homogenous architecture of the overall GMES Space Component is a clear challenge, both technically and programmatically. The integrated ground segment enables this. It operates and provides access to Sentinel data, and interfaces with Contributing Missions in order to obtain a coordinated data stream to GMES services.


Sentinel-1


Sentinel-2

> **We must guarantee the success of our flagship projects Galileo and GMES. GMES is now making a critical transition from research to operations. Both represent long-term commitments for the EU. We must ensure that long-term funding or governance issues do not get in the way of their success.**
>
> JM Barroso, President of the EC

→ Sentinel missions

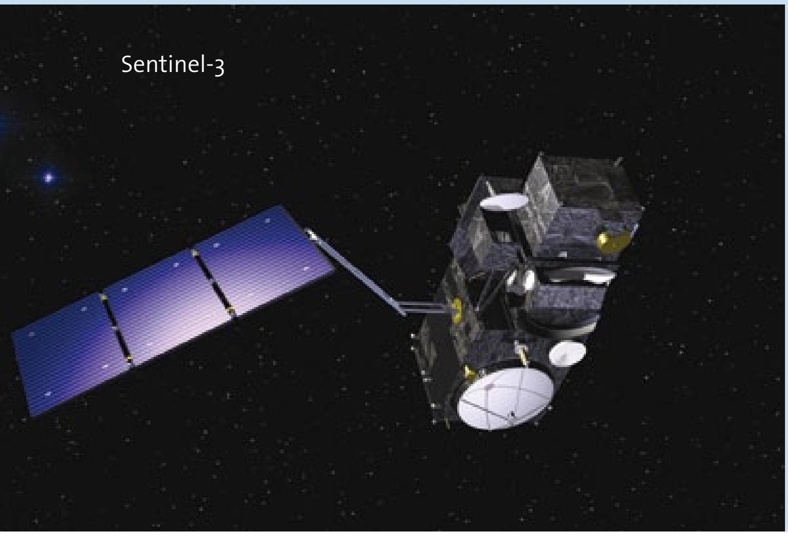
The backbone of the ESA GSC Programme are the Sentinel missions. Five families of Sentinels are being developed today. In addition, the Jason-CS mission is expected to become part of the GSC programme after the next ESA Ministerial Conference in 2012.

Sentinel-1

A C-band imaging-radar mission, providing all-weather, day-and-night imagery, with improved revisit frequency and coverage. The radar operates in four modes, with the interferometric mode as the default mode. The instrument operates at ground resolutions of 5 m and higher. The interferometric mode has a swath width of 250 km, enabling global coverage about every two days in mid-latitudes with the nominal two-satellite configuration. The first satellite will be launched at the end of 2012.

Sentinel-2

A multispectral imager mission, with 13 spectral bands and resolutions of 10, 20 and 60 m. With a swath width of 290 km, it offers a high repeat cycle of six days at the equator and three days in mid-latitudes in the two-satellite configuration. The large number of channels and high revisit time offer a major improvement compared to today's land mapping missions. The first satellite will be launched in 2013.



Sentinel-3

Sentinel-3

A satellite carrying a suite of different instrument packages, the Sea and Land Surface Temperature (SLST) radiometer to measure surface temperatures, the Ocean and Land Colour Instrument (OLCI) to measure ocean chlorophyll activity and land surface vegetation, and the Radar Altimeter (RA) package to measure sea-surface topography for primarily marine dynamics and climate change studies. The OLCI and SLST offer almost daily coverage in mid-latitudes, with a ground resolution of 300 m. The first satellite will be launched in 2013.

Sentinel-4 & Sentinel-5

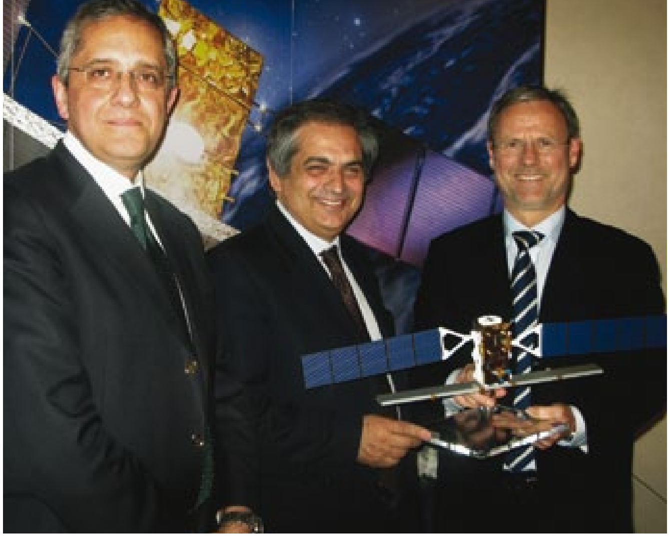
Instrument packages devoted to atmospheric composition monitoring, from geostationary and polar orbit respectively, to combine high temporal and geometric resolutions. The former, to be launched in 2018, is planned to fly on the MTG mission while the latter will fly on post-EPS, to be launched in 2020. The Sentinel-5 precursor mission, planned for launch in 2014, will bridge the data gap between Envisat and Sentinel-5 in atmospheric observations.

Jason-CS

This satellite will carry a radar altimeter package to continue the high-precision, low-inclination altimetry missions of Jason-2 and 3. It will complement the high-inclination measurements on Sentinel-3 to obtain high-precision global sea-surface topography for the marine and climate user community. The satellite is planned for launch in 2017.

←

EC President JM Barroso highlights GMES as key European space programme at the 'Space conference' held in October 2009 in Brussels (EC)



←

A step forward for GMES: Luigi Pasquali, CEO of Thales Alenia Space Italy (left), Enrico Saggese, President of the Italian space agency ASI and Volker Liebig, ESA's Director of Earth Observation (right) celebrating the contract awarded to Thales Alenia Space to build Sentinel-1 B and 3 B

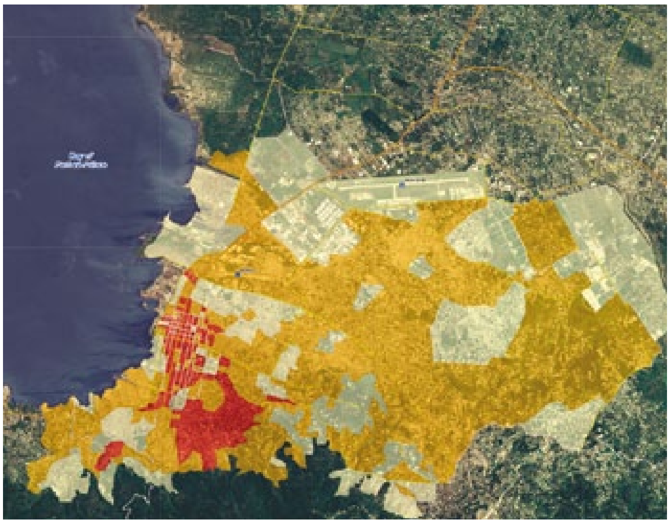
GMES Contributing Missions

Around 30 Earth observation missions, operated by European national or multinational organisations, are in orbit today or will be flying within the next few years. A portion of this vast resource of satellites and sensors can be made available to GMES, after having satisfied their prime national, security or commercial customers.

The missions include investments made via public, commercial and Public-Private partnership financing.

The Sentinel missions have been designed to be complementary to European Contributing Missions, as known at the time of the adoption of the GSC Programme in 2005. Therefore, these two resources provide complementary observations with a large variety of sensors and relatively high observation frequency.

↓ The pyramids of Giza, just 20 km outside Cairo, seen by TerraSAR-X in July 2007. The radar beam makes it possible under certain conditions to recognise structures below ground level, especially in arid areas with loose types of soil. This opens up new options for archaeology and constitutes yet another application for TerraSAR-X data (DLR)



←

Damage evaluation map based on satellite data over the Port-au-Prince area of Haiti, following the magnitude 7 earthquake and aftershocks that hit the Caribbean nation on 12 January 2010, based on data from SPOT-5, ALOS and GeoEye-1 satellites (CNES, JAXA, GeoEye, SERTIT)

The list of Contributing Missions will evolve over time. Typical examples today include the German TerraSAR-X, Tandem-X, Enmap and RapidEye missions, the French SPOT and Pleiades satellite series, the Italian Cosmo-Skymed and Prisma missions, the Spanish SeoSAR, SeoSAT and DMC-Deimos missions, the UK DMC mission, the ESA/Belgian Proba mission as well as Eumetsat's MSG and MetOp missions.

The Canadian Radarsat missions (Radarsat, RSC) are also included, given the Cooperating State agreement with ESA. In addition, other non-European missions are added depending on a case-by-case basis. Several smaller, R&D missions are also provided to GMES, though within the limits of their respective data access and dissemination schemes.

Currently data from these missions are obtained based on competitive bulk procurement contracts ESA has concluded or is concluding with the respective mission operators. The data policies of the suppliers are respected. GMES covers the cost to obtain these data for use by approved GMES services today.

In order to establish a longer-term and more stable data access regime, the Sixth Space Council in May requested ESA and the EC to start formal dialogues with those Member States that own satellite missions in order to discuss long-term data access schemes for the period from 2014 onwards. This process is ongoing and its findings will be reflected in the future governance of the GMES Space Component.

Sentinel data policy – 'free and open'

The Sentinels are funded by ESA and EU Member States. Therefore they can define a data policy that is in fully in line with the objectives of GMES. The EC and ESA have defined Sentinel data policy principles, which should eventually lead to a Sentinel data policy:

- Anybody can access all Sentinel data. In particular, no difference is made between public, commercial and scientific use.
- The licenses for the Sentinel data itself are free of charge.
- The Sentinel data will be made available to the users via a generic online access mode, free of charge. Generic online access is subject to user registration and the acceptance of generic terms and conditions.
- Additional access modes and the delivery of additional products will be tailored to specific user needs and therefore subject to tailored conditions.
- In the event security restrictions apply to specific Sentinel data that affect data availability or timeliness, specific operational procedures will be activated.

These Sentinel data policy principles were approved by ESA Member States in September 2009. EC approval is expected in 2010.

GMES history

The GMES initiative began some 12 years ago when the main national space agencies, ESA, the EC and Eumetsat, started to discuss opportunities for Europe to establish an environmental and security information system. It became apparent that in an increasingly integrated world, where access to global information determines a region's political and strategic position, it was necessary to establish a system that supports European and national policies through adequate information. Since then, the first ideas have developed into reality, with the launch of the first operational satellites within the next years.

→ GMES milestones

1998 'The Baveno Manifesto' founds the GMES initiative, presented at Baveno, Italy

2000 GMES partnership formed between Member States, space agencies, industry representatives, user organisations and the EC

2001 ESA Ministerial Council, Edinburgh: first GMES services are funded by ESA Member States (in parallel, EC funds GMES services through FP6)

2001 EU Summit, Gothenburg: Heads of State and Government request that 'the Community contributes to establishing by 2008 a European capacity for Global Monitoring for Environment and Security'

2004 EC Communication, 'GMES: Establishing a GMES capacity by 2008' introduces an Action Plan for a GMES capacity by 2008

2004 EC/ESA Framework Agreement signed, providing the basis for cooperation in space, including GMES

2005 ESA Ministerial Council, Berlin: optional ESA GMES Space Component (GSC) Programme adopted and first funds committed to specific GMES space hardware

2007 European Space Policy adopted, recognising GMES as a flagship of the European Space Policy, next to Galileo

2008 GMES Forum in Lille, France: five Core Services are officially launched: Marine monitoring, Land monitoring, Atmosphere monitoring, Emergency response and Security

2008 EC Communication, GMES: We care for a Safer Planet' establishes a basis for financing, operational infrastructure and management of GMES

2008 EC-ESA Agreement on GMES provides legal basis for EC FP7 contribution to GSC Programme
ESA Ministerial Council, The Hague: major ESA funding for GSC build-up

2010 GIO Regulation: EC proposes regulation for GMES Initial Operations (GIO), providing legal basis and EC funding for an operational GMES programme

2012+ Sentinel launch: Sentinel-1A scheduled for launch, followed by successive Sentinel launches to complete operational space-based observation capacity

2014+ EU Operational GMES Programme: aimed at ensuring long-term sustainability of operational programme

Funding the GMES Space Component

The GSC programme is organised in two overlapping phases, the build-up phase and operational phase. The current build-up phase coincides with the timeframe defined in the ESA GSC Programme Declaration, which lasts from 2006 until 2017. The operational phase is defined in accordance with the availability of operational funding from the EU, which is expected from 2014 onwards. This may not necessarily coincide with the operation of the Sentinel missions, which will commence after the Initial Orbit Validation period following each satellite's launch. Because these periods vary from Sentinel to Sentinel, and in order to define an operational period for programmatic purposes, this is linked with the establishment of the EU operational GMES Programme and the related funding for GMES including the GMES Space Component.

The GMES Space Component has been funded in successive steps. The first part of €268 million (2008 e.c.) was obtained at the 2005 ESA Ministerial Conference. This was supplemented by another €522 million (2008 e.c.) from ESA Member States in 2007 through subscriptions outside the frame of a Ministerial Conference. In 2008 and 2009, EC funding was committed through the signature of the EC/ESA Agreement on GMES and its First Amendment. The EC contribution amounts to €626 million (2008 e.c.), provided through its Seventh Framework Programme. At the 2008 Ministerial Council, ESA Member States provided an additional €831 million (2008 e.c.). This brings the total GSC Programme funding to €2.3 billion (2008 e.c.), of which ESA Member States provide 72% and the EC 28%.

The EC has provided additional funding for GMES services and the *in situ* component in the order of €500 million.

For the GSC Operations phase, the EC is expected to take responsibility for financing the operational capacity, which includes the procurement of recurrent Sentinel satellites, access to Contributing Missions and routine Sentinel operations. ESA Member States are expected to contribute by financing R&D activities for the evolution of the GSC such as the development of next-generation satellites and ground segment infrastructure.

The EU GMES Operations Programme is expected to start in January 2014. In order to implement tasks attributed by the EC to ESA for the GSC operation a new agreement will need to be signed. The negotiation and approval process is expected to last about one year, therefore making EC funds effectively available for GSC operations from 2015 only. Because the first three Sentinels will be in orbit in 2013, it is necessary to bridge this period and to prepare transitional funding (GMES Initial Operations, GIO). The different elements concerned are the operation of the Sentinel-1, 2 and 3 A units, the launcher procurement for the Sentinel-1, 2 and 3 B units, advance procurements of critical parts and elements for the Sentinel-1, 2 and 3 C units and data access to Contributing Missions during the year 2014.

The total amount is €563 million (c.e.c.). It is important to note that these are not programme cost overruns, but necessary outstanding investments that would mostly occur in the next Financial Framework. Not being able to organise these funds in a timely manner will lead to a significant delay in providing the full operational service as well as incurring additional costs in the order of at least €400 million. The EC Regulation (*COM(2009) 223 final*), which is currently being negotiated by the European Parliament and EU Council, would cover part of these costs. However, according to current discussions, these amounts are by far not sufficient. Additional efforts are needed.

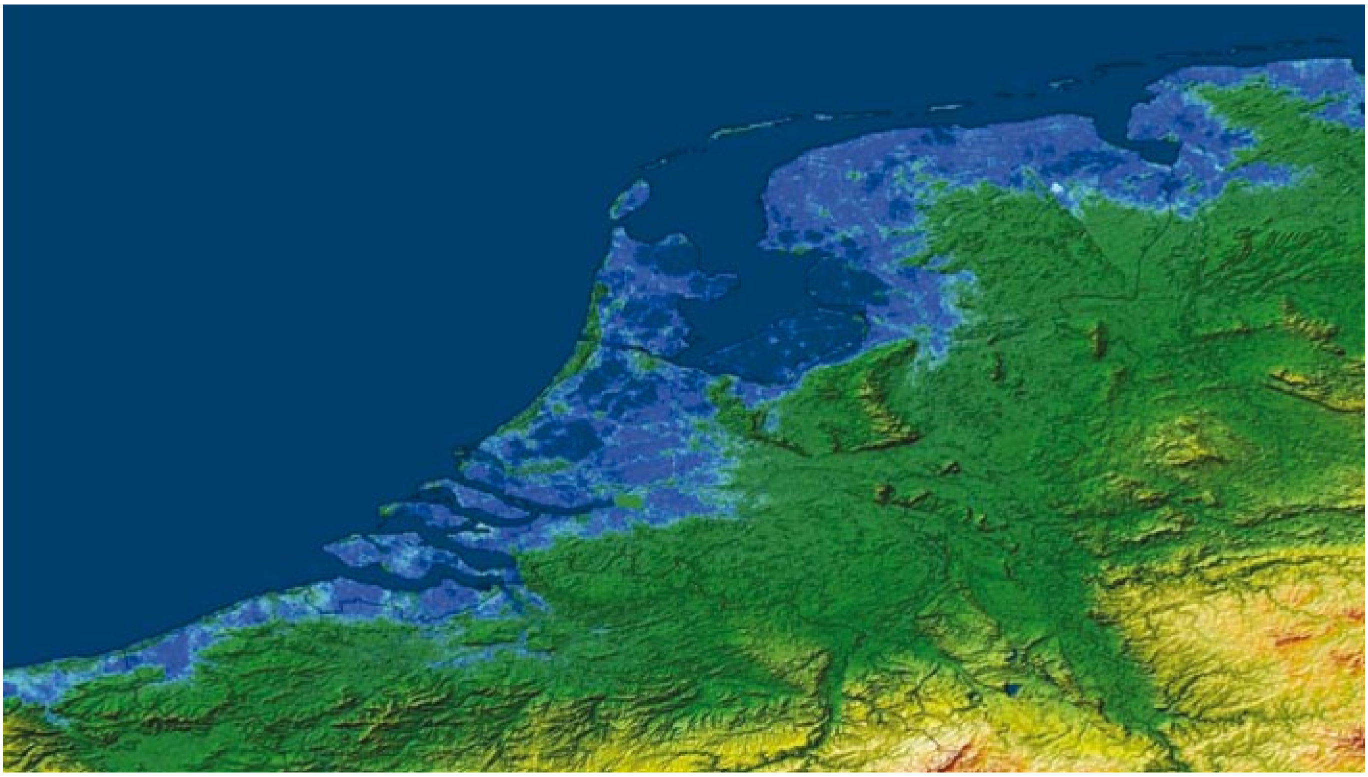
Governance of GMES and the GMES Space Component

The EC issued a Communication on '*GMES: Challenges and Next Steps for the Space Component*' in October 2009 *(COM(2009)589 final*), in which the respective roles of the European Union (EU), the EC and ESA within GMES in general, and within the GSC in particular, are addressed.

New terminology and concepts have been introduced. The EC leadership of the overall GMES programme has been reiterated, declaring the intention to be the GMES Programme Manager and to organise itself accordingly. ESA has been reconfirmed as the Coordinator of the GMES Space Component ('GSC Coordinator') while the European Environment Agency is proposed to coordinate the *In situ* Component.

ESA's function as GSC Coordinator has been described at a high level in several policy documents related to European Space Policy, including several Space Council Orientations, in EU and ESA policy documents and in EC Communications related to GMES. Based on the most recent EC Communication, a more detailed document was discussed at the EO Programme Board in February 2010, and updated for the May 2010 meeting, further explaining the role of ESA as GSC Coordinator. Accordingly, ESA would take prime responsibility – and be accountable – for the overall performance of the GSC throughout its lifetime.

Based on endorsed EU user needs, the GSC Coordinator will derive, and agree with the EC, space-based observation requirements, define the content of the GSC, define the end-to-end GSC architecture and be responsible for the development of dedicated infrastructure, i.e. the Sentinels and corresponding ground segment.



↑ Possible sea-level rise impacting the costs of in the Netherlands and Germany. Digital elevation data was used to create this traditional topography map, onto which two layers are overlaid showing possible sea-level rises of 0.65 m (dark blue) and 1.3 m (light blue) (ESA/EAPRS/De Montfort Univ.)

↓ Non-exhaustive list of Synthetic Aperture Radar and Optical GMES Contributing Missions. The list is indicative and will evolve in order to keep up with new user requirements

	GMES CONTRIBUTING MISSIONS	PRINCIPAL OWNER	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Medium / High Resolution	Sentinel-2A	ESA						approved	approved	approved	approved	approved	approved	approved				
	Sentinel-2B	ESA										approved	approved	approved	approved	approved	approved	approved
	Sentinel-2C	ESA												planned	planned	planned	planned	planned
	SPOT 4	CNES	in orbit	in orbit	in orbit	in orbit												
	SPOT 5	CNES	in orbit	in orbit	in orbit	in orbit	in orbit											
	SPOT Follow-on	InfoTerra/Astrium							approved	approved	approved	approved	approved	approved	approved	approved		
	RapidEye - 5 S/C	RapidEye	in orbit	in orbit	in orbit	in orbit	in orbit	in orbit	in orbit									
	RapidEye Follow-on (TBC)	RapidEye							planned	planned	planned	planned	planned	planned				
	UK-DMC & UK-DMCII	DMCII	in orbit	in orbit	in orbit	in orbit	in orbit	in orbit										
	Deimos-1 DMC	Deimos		in orbit	in orbit	in orbit	in orbit	in orbit										
	Seosat / Ingenio	CDTI							approved	approved	approved	approved	approved	approved	approved			
	EnMap (Hypersp.)	DLR						approved	approved	approved	approved	approved						
	PRISMA	ASI				planned	planned	planned	planned	planned								
	Venus (Hypersp.)	CNES-ISA					approved	approved	approved	approved								
Very High Resolution	Pléiades 1 & 2 (VHR)	CNES			approved	approved	approved	approved	approved	approved	approved							
	HiRos (TBC)	DLR							planned	planned	planned	planned	planned					
SAR missions	ERS-2 (C-Band)	ESA	in orbit	in orbit	in orbit													
	Envisat ASAR (C-Band)	ESA	in orbit	in orbit	in orbit	in orbit	in orbit	in orbit										
	Sentinel-1A	ESA					approved	approved	approved	approved	approved	approved	approved					
	Sentinel-1B	ESA									approved	approved	approved	approved	approved	approved	approved	
	Sentinel-1C	ESA											planned	planned	planned	planned	planned	planned
	TerraSAR-X (X-Band)	DLR	in orbit	in orbit	in orbit	in orbit	in orbit	in orbit										
	TerraSAR-X -2 (X-Band)	DLR						planned	planned	planned	planned	planned						
	TanDEM-X (X-Band)	DLR			approved	approved	approved	approved	approved	approved								
	Cosmo-Skymed (X-Band) -S/C 1,2,3	ASI	in orbit	in orbit	in orbit	in orbit	in orbit											
	Cosmo-Skymed (X-Band) -S/C 4	ASI			approved	approved	approved	approved	approved									
	Cosmo-Skymed 2nd gen (X-Band)	ASI						planned	planned	planned	planned	planned	planned	planned	planned	planned	planned	planned
	Radarsat-2 (C-Band)	CSA	in orbit	in orbit	in orbit	in orbit	in orbit	in orbit	in orbit									
	RCM (C-Band)	CSA							approved	approved	approved	approved	approved	approved	approved			
	SeoSAR/PAZ (X-Band)	CDTI					approved	approved	approved	approved	approved	approved						

in orbit   approved   planned

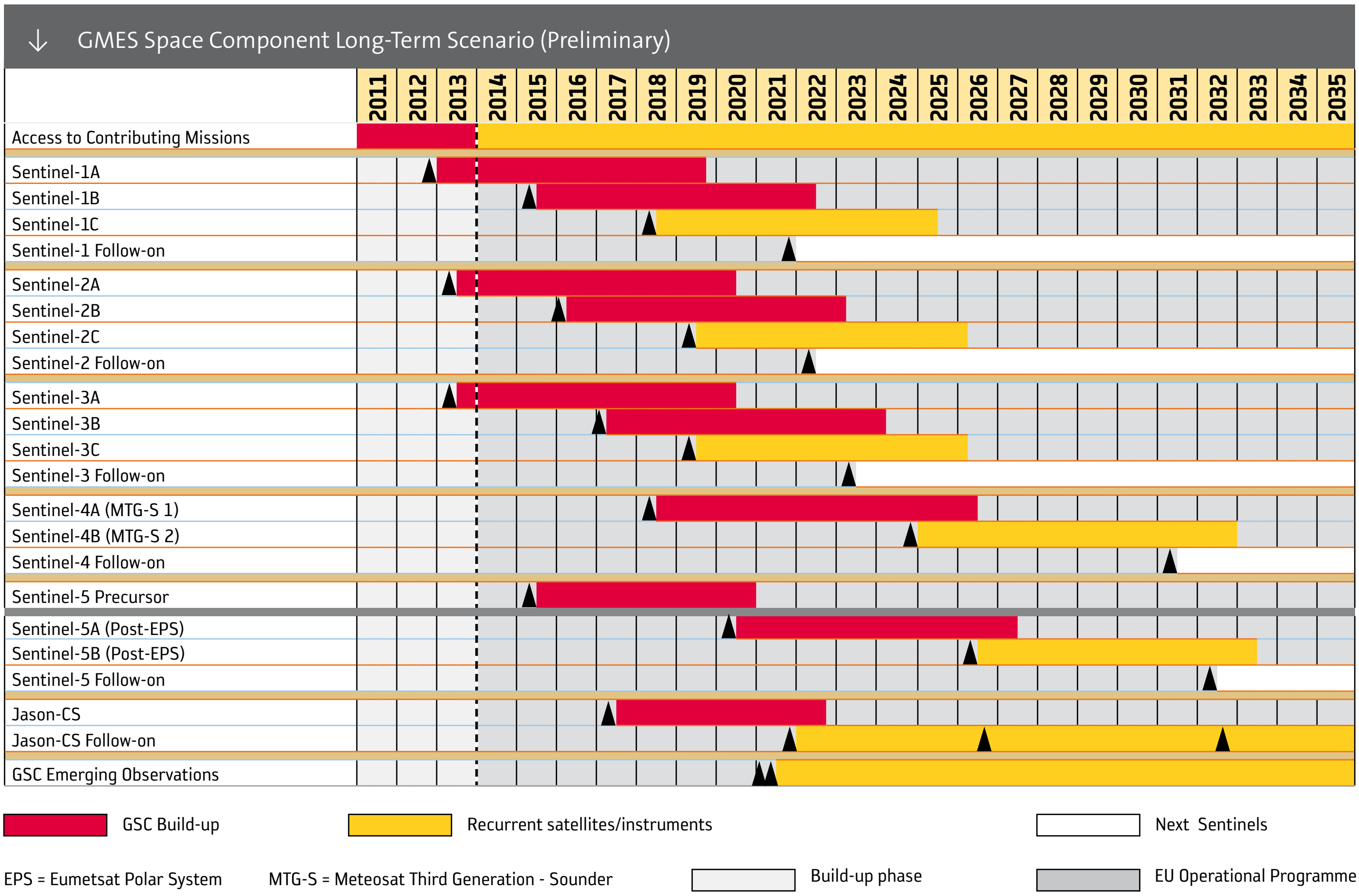
Apart from being the development agency for the GSC, ESA will also procure recurrent elements funded by the EU on its behalf, ensure the operation of Sentinel missions and organise the access to Contributing Missions.

Regarding the GSC operation, EU and ESA Member States have already identified Eumetsat as the operator of the marine part of Sentinel-3 and of Sentinel-4 and 5, while ESA was identified as *ad interim* operator of Sentinel-1, 2 and the land part of Sentinel-3; it does not exclude that this function might also become permanent.

The ESA tasks will be carried out through industrial contracts in the EU/ESA Member States. Flight operations will be performed at the European Space Operations Centre (ESOC), Darmstadt, and payload operations will be managed from ESRIN, ESA's centre for Earth observation in Frascati. The ground segment build-up and operations rely on a decentralised approach whereby the main facilities are also developed and operated in individual Member States.

The overall coordination of GMES activities will be ensured through a newly established GMES Partners Board, which is to be chaired by the EC and comprises the EU Member States as members, and Switzerland, Norway and several European organisations including ESA as observers. The Partners Board is an advisory body. Budget and implementation decisions are made at the respective decision bodies of the funding organisations, in particular the ESA Programme Board for Earth Observation and Council for funds from ESA Member States and the respective EC Programme Committees for funds provided by the EU. The ESA and EU decision bodies have met jointly, and may continue to do so on an ad hoc basis if joint decisions on GMES issues involving the GMES Space Component are required.

This set-up, to govern issues related to the GSC build-up and initial operations, is currently in place and is expected to cover the period up to the end of 2013. It may be modified once the EU GMES Operational Programme is in place from 2014 onwards.



Major challenges still ahead

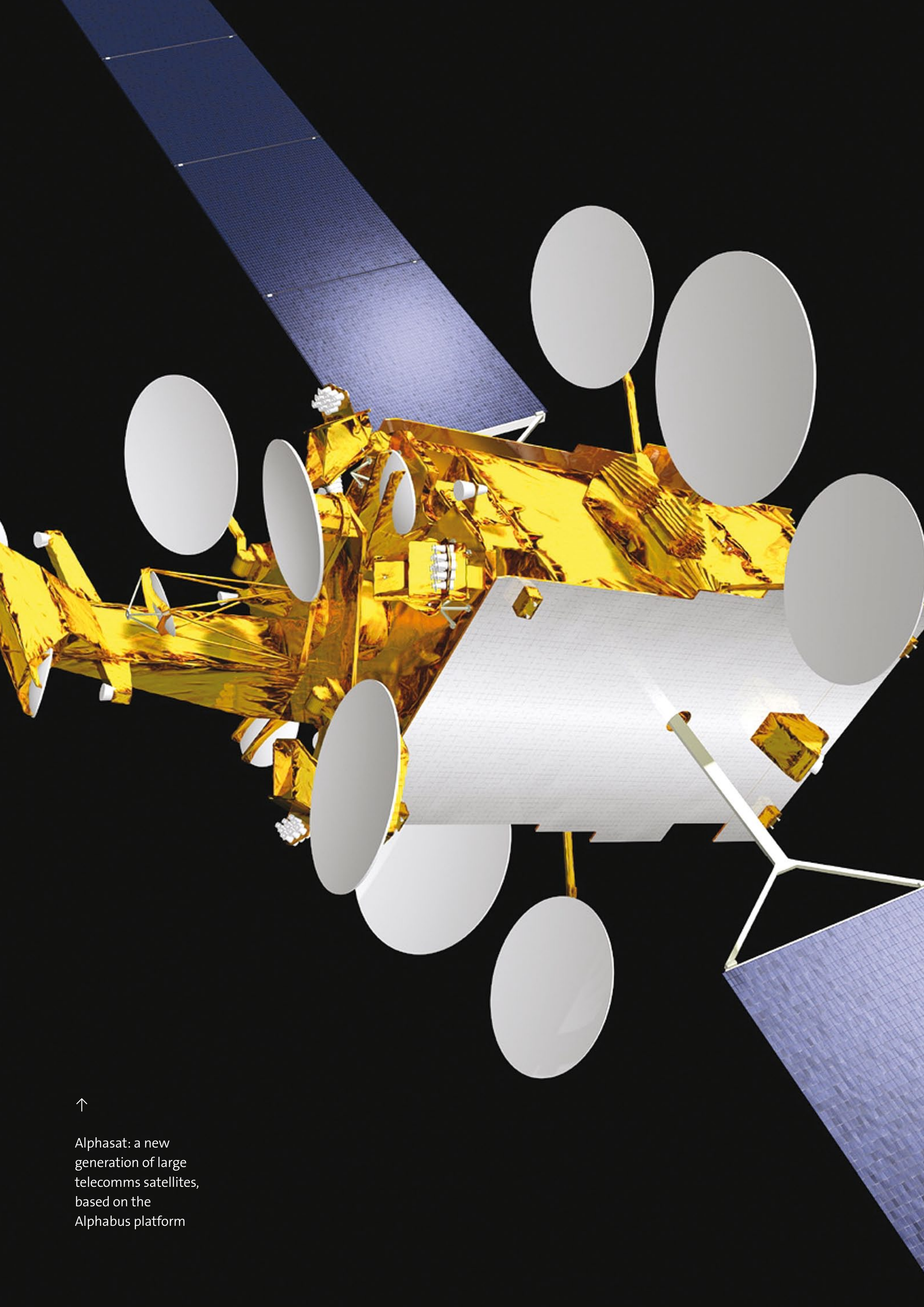
GMES and the GMES Space Component have progressed reasonably well over the past years. The excellent cooperation between the two key organisations, the EC and ESA, together with their respective Member States, has been instrumental in this achievement. It also confirms that a balanced approach between 'user-pull' and 'technology-push' is required, as neither of them would succeed alone in obtaining a long-term sustainable space applications programme that serves European and national policy needs.

Once operational, GMES will be unique in the world. GMES will provide what is done successfully today in meteorology, namely to combine satellite and *in situ* observations with forecast models, to obtain information services needed by institutions and individual citizens alike. GMES will extend this concept to domains such as agricultural monitoring and food supply forecasting, fisheries, ship-routeing, urban planning, climate change studies, emergency response, humanitarian aid, external EU actions, border surveillance or maritime security, to name just a few.

Such an integrated Earth observation system does not exist in any other country or region. Europe will prove that the combined efforts of all its Member States, coupled with strong institutional leadership, will lead to major societal and economic benefits for its citizens.

The biggest challenge, however, is to ensure the programme's sustainability. Sufficient funds need to be allocated in the next EU Financial Framework in order to allow the full operation of GMES including the GMES Space Component. As significant funding is required it will necessitate the full political support of the EU Member States. ESA and its Member States can and will certainly assist in the best possible way, although it can only do so within the institutional limits given that the prime responsibility for GMES lies with the EU.

ESA and its Member States have clearly identified what is needed for the GMES Space Component. The GSC Long-term Scenario was acknowledged by the Space Council as the basis for developing a long-term funding strategy up to 2030. The same document was elaborated in close consultation with the ESA Programme Board for Earth Observation and ESA Council. The EC has taken on board the financial estimates required for the GSC operation in its recent GMES Communication. But ensuring that they will actually be obtained in the next Financial Framework remains a challenge as the need for space-related funding will be weighed against other needs of the EU, such as agriculture, regional development, etc. Therefore the GMES community must be adamant in presenting a unique and strong mandate to the EC and EU, and their Member States in order to succeed in the negotiation of a strong GMES budget in the next EU Financial Framework.



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Alphasat: a new generation of large telecomms satellites, based on the Alphabus platform

→ ALPHABUS

Europe's solution for the high-power satcom market

Andreas Mauroschat
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Marc Patier
Thales Alenia Space, Toulouse, France

There are times when size really does matter, especially when it comes to 'satcom', or satellite telecommunications. Larger and more complex satellites are required by a demanding market, and Alphabus is Europe's answer to meet this need.

European citizens, along with telecom users all over the world, want to be able to connect to others at all times and at a reasonable cost – whether by video, voice or email – from any location, whether on a train, in a car, on a boat, or on top of a mountain. They want to receive more high-definition television channels or radio stations, and soon they will want to watch their favourite sporting events in 3D. This demand requires more power, capacity and size from our telecommunication satellites.

ESA and the French space agency CNES are driving the developpment of a new European high-capacity satellite platform, Alphabus, which will be able to compete in the worldwide satcom market. This co-operation brings together two of Europe's biggest players in the European satellite business, working side-by-side to complement the existing European telecommunications platform product lines significantly beyond their current capabilities.

The Alphabus market

Telecommunication satellite systems provide telephony, internet, radio, video and data services to millions of people around the world. One of the biggest markets that satcom continues to serve is television broadcasting. According to recent statistics, more than 21 000 TV channels are transmitted by telecom satellites, reaching more than 200 million homes.

There are around 25 communication satellites sold per year worldwide. However, the market predicts that in the coming years, 10–15% of those orders will be for sophisticated high-power satellites to meet the ever-growing demand of large satellite operators wanting to provide extensive broadcasting and broadband multimedia services, as well as mobile communications, at competitive prices.

This high-end of the market requires larger satellites than those available today in Europe. Alphabus is Europe's answer to meet this market demand. Alphabus will make new applications possible, including the next generation of mobile and broadband services, digital radio broadcasting and high-definition TV.

Alphabus is being jointly developed by EADS Astrium and Thales Alenia Space as co-prime contractors, leading a European-wide industrial consortium.

The Alphabus platform

Typically, communication satellites consist of two main parts: the 'platform' (or service module) which, in simple terms, supplies the mechanical and thermal control, together with electrical power, attitude control and data handling to the second part, known as the 'payload'.

After the transfer into geostationary orbit (36 000 km away from Earth), the platform keeps the satellite in this orbit, pointed towards Earth while providing a stable thermal environment for the payload by radiating heat generated into space.

Telecom payloads receive signals from Earth, process and amplify them and then transmit them back to Earth. More signals require more power, more thermal dissipation and more antennas and radio-frequency equipment to be accommodated in satellites. This requires bigger platforms with higher capacities. This is the need that Alphabus will serve.

While being a new satellite platform, Alphabus takes full benefit from the long heritage of the two industrial partners, primarily the Spacebus and Eurostar families, respectively from Thales Alenia Space and EADS Astrium, with the inclusion, where appropriate, of new technologies fully qualified through the Alphabus programme.

→ Alphabus performance summary

Alphabus has been developed to support large payloads with power levels ranging from 12 kW up to 18 kW, and a payload mass of up to an impressive 1500 kg.

It can accommodate a large amount of payload equipment with a large thermal rejection capability. As an example, it can hold 190 transponders, allowing the transmission of more than 1000 television channels and more than 200 000 audio channels. Alphabus can cope with large 'antenna farm' configurations, of up to 12 antennas with rigid reflectors of up to 3.5 metres in diameter.

Payload power	12–18 kW
Payload mass	Up to 1500 kg
Satellite launch mass	Up to 8800 kg
Dimensions (Alphabus satellite)	Height up to 9 m; Width (including solar array) about 40 m
Number of transponders	Up to 190
Number of antennas	Up to 12 reflectors; including two large reflectors of up to 3.5 m, or four up to 2 m
Antenna pointing accuracy	Up to 0.05° half-cone using antenna tracking

→

A typical Alphabus multimedia satellite with a large antenna farm and a full six-panel solar array configuration

Maximum launch vehicle compatibility

Alphabus has been designed to fit inside the 5 m fairings on Ariane 5 and Atlas 5, but remains also compatible with a 4 m fairing on Proton. Alphabus is compatible with an Ariane 5 ECA dual launch configuration at the low end of the range and up to 8800 kg on Ariane 5 single launch or Atlas 5 at the high end.

↓

Alphabus is compatible for launch on European Ariane 5 (a), Russian Proton (b) or US Atlas 5 (c) launchers

a

b

c

↑ Static qualification test stand (MMST) for the Alphabus central tube and the primary structure at Inta (Spain)

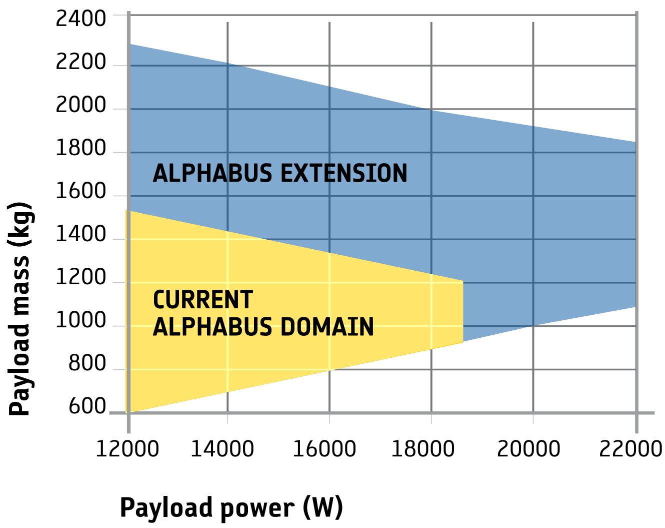
Qualification status

All Alphabus elements have been qualified or are on the verge of being qualified. The static qualification of the Alphabus central tube and the primary structure has been achieved using a dedicated test set-up at Inta (Spain) on a special mock-up satellite structure. Both electrical and data handling systems were extensively tested and validated using test beds including engineering and qualification model hardware. The overall Alphabus platform qualification will be completed in 2010.

Alphabus Extension Programme

The Alphabus Extension Programme will address long-term market opportunities for the very high-end of communication satellites by ensuring continued growth of Alphabus to accommodate top-range payloads with the following objectives:

- Payload power up to 22 kW, compared to 18 kW for the nominal Alphabus product range
- Enhanced thermal rejection capability thanks to the introduction of the deployable panel radiator
- Payload mass up to 2000 kg at 18 kW payload power (see below graph)
- Number of repeaters: up to 230 transponders compared to 190 transponders for the nominal Alphabus product range
- Antenna accommodation up to 12 antennas, unchanged with respect to the nominal Alphabus product range
- Compatibility with a Proton launcher with 4 m fairing



↑ Typical payload mass and power performances

The Alphabus extension programme will include the development and qualification of the following main features:

- An advanced solar array which will have the new 3G 30% efficiency solar cells with an adapted panel size compatible with a 4 m Proton fairing, even for maximum payload power configuration
- A power subsystem with increased capabilities of the Power Supply Regulator, battery and thermal unit
- Extended onboard memory capabilities within the Satellite Management Unit to cope with highly complex payloads
- A deployable panel radiator based on high-performance loop heat-pipes
- A second-generation power processing unit for the control of the plasma propulsion thrusters
- Lifetime extension of the PPS 1350-G plasma thrusters through the development of an advanced cathode
- A European xenon pressure regulator
- An advanced high-accuracy pressure transducer for more accurate prediction of the remaining fuel for a better end-of-life prediction
- A fully qualified antenna module with associated production toolings
- Enhanced solar array drive electronics

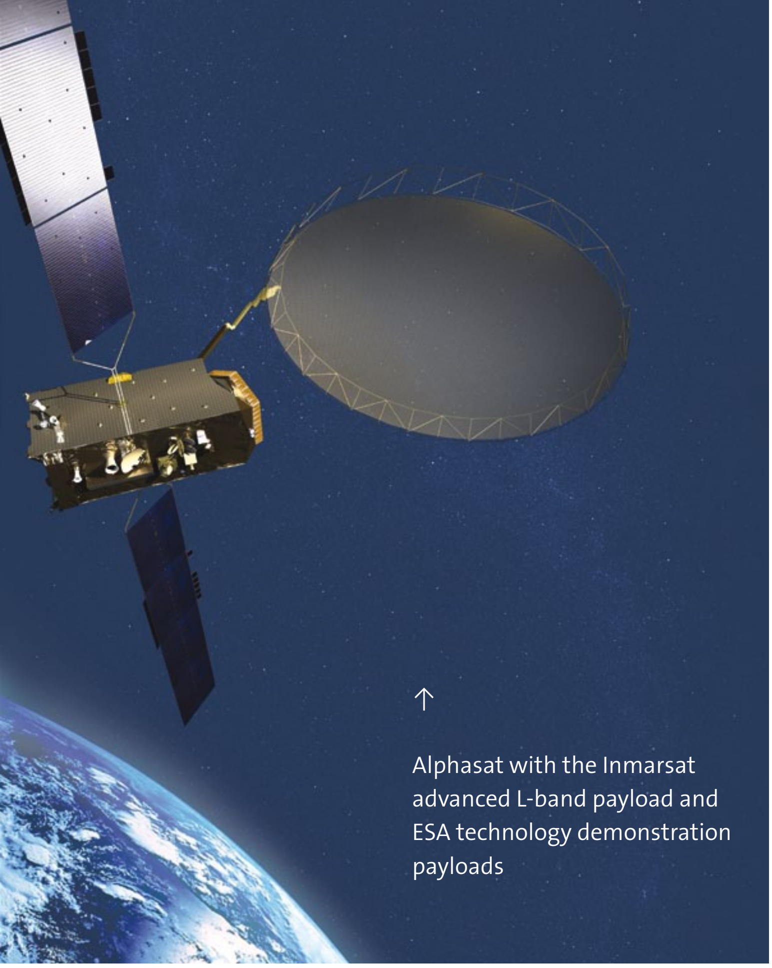
The full contract is expected to be placed with EADS Astrium and Thales Alenia Space in the second quarter of 2010.

Alphasat

In parallel with the development and qualification of the new Alphabus platform, ESA saw the unique opportunity to offer operators, service providers and industrial groups the possibility to fly their payloads on the first Alphabus platform.

In 2005, ESA issued an Announcement of Opportunity that encouraged proposals from the satcom industry. After an extensive evaluation process, ESA and Inmarsat Global signed an agreement for the implementation of Alphasat at the end of 2007. Launch of Alphasat on an Ariane 5 is planned for 2012.

Through this cooperation, Inmarsat effectively becomes the first commercial customer for the Alphabus platform. Together, Alphasat and the Alphabus platform create the Alphasat satellite, also named by Inmarsat, 'Alphasat I-XL'. With this partnership, objectives from both parties are met: Inmarsat's objective to benefit from the Alphabus capability and use Alphasat to extend its current satellite fleet, and the ESA/CNES objective to facilitate an early first flight and in-orbit validation of Alphabus.



Alphasat with the Inmarsat advanced L-band payload and ESA technology demonstration payloads

Inmarsat has introduced the Broadband Global Area Network (BGAN) service, developed with the support of ESA through its Advanced Communications in Telecommunications Systems (ARTES) Programme. With the use of three satellites, the BGAN family of services provides a wide range of high data rate applications to mobile user terminals for aeronautical, land and maritime markets.

With the Alphasat mission, Inmarsat will extend BGAN's capabilities, both in performance and capacity for which an additional 2x7 MHz of L-band spectrum will be used, not available on current Inmarsat's satellites, thereby offering enhanced services to mobile users, using for example hand-held devices like 'smart' phones.

The satellite is intended to be placed at the orbital position of 25 degrees East to provide coverage centred over Africa and additional coverage to Europe, the Middle-East and parts of Asia.

EADS Astrium is the industrial prime contractor for the development of the Inmarsat I-XL satellite, including its advanced L-band mission.

Key to the implementation of this payload is the advanced integrated processor, being developed by EADS Astrium in the UK under ESA contract, which will provide payload flexibility enabling full coverage reconfiguration and flexible power allocation.

The flexibility of the Alphabus platform design allows the accommodation of a special 'geo-mobile' configuration with a 90-degree change to the satellite flight orientation and the addition of a large deployable antenna of 11 m diameter.

Along with the operational payload from Inmarsat, the Alphasat mission will also include four Technology Demonstration Payloads (TDP). These include:

TDP 1 – An advanced laser communication terminal to demonstrate geostationary-orbit to low-Earth-orbit optical communication links at 1064 nm, complemented with a Ka-band payload, developed by TESAT (Germany)

TDP 5 – Two experimental Q-V Band communication payloads to assess the performance of these bands for future commercial applications, developed by Thales Alenia Space (Italy) and Space Engineering (Italy)

TDP 6 – An advanced star tracker with active pixel detector, developed by Jenoptik (Germany)

TDP 8 – An environment effects facility to monitor the geostationary orbit radiation environment and its effects on electronic components and sensors, developed by Effacec (Portugal)

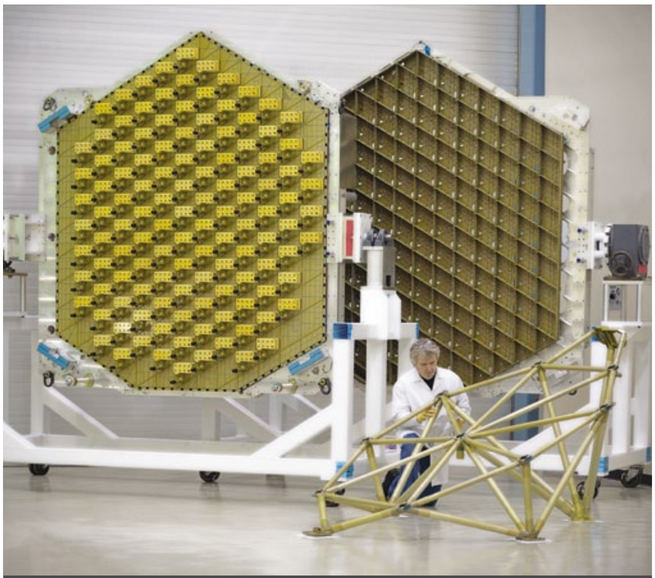
The Alphabus/Alphasat activities of ESA are implemented within the framework of element 8 of the ESA's ARTES programme.

Alphabus today

Alphabus has come a long way since 2002, when the cooperation between ESA and CNES started to develop the large platform. Phase C/D began in September 2005, the Critical Design Review was closed in February 2008, and the Alphabus Qualification Review in the second half of 2010 will mark the achievement of a major objective of this important programme.

→ Key milestones of the Alphabus/Alphasat programme

	ALPHABUS	ALPHASAT
Start of ESA/CNES cooperation	2002	
Early system design and critical technology developments	2002–2005	
Preliminary Design Review	May 2005	
Start of platform phase C/D development	Sept. 2005	
Hardware Design Review	Jan. 2006	
Start of satellite programme		Nov. 2007
Critical Design Review	Feb. 2008	
Alphabus Qualification Review	Oct. 2010	
Launch		2012



↑ The L-band feed array under development in MDA (Canada)

In parallel, the Alphasat contract was started in November 2007 on the basis of the Alphabus protoflight model. Work on the Alphabus/Alphasat flight hardware is progressing according to plan in all areas:

Service Module

The mechanical integration of the Alphabus SM was completed in the satellite integration facilities of Thales Alenia Space Cannes at the end of 2009. The SM assembled in Cannes consists of the main structure, central tube, internal deck and other structural elements carrying the chemical propulsion system with the main apogee boost motor, the pressure control assembly with three helium tanks and the two large propellant tanks inside the central tube, as well as part of the plasma propulsion system and its xenon tanks.

On 26 January 2010, the SM was shipped from Thales Alenia Space Cannes to EADS Astrium Toulouse, where it will be completed. In the meantime, the flight harness was installed, and the mechanical and electric integration of data handling equipment (SMU, PFDIU and PLIU), and the power system regulator was completed. The SM was powered up for the first time in February.

Repeater Module

The RM activities are progressing well. Both the manufacturing and assembly of the North and South RM halves were completed in Thales Alenia Space Turin and delivered to EADS Astrium Portsmouth for payload integration.

Next steps

On completion of the payload integration, the RM will be shipped to Toulouse where it will be coupled with the SM. The complete satellite will undergo environmental testing before being shipped to Kourou for launch in 2012.

A successful Public-Private Partnership

Alphabus/Alphasat is the first large operational programme involving a commercial satellite operator implemented by ESA in cooperation with CNES under a Public-Private Partnership scheme with Inmarsat. An innovative overall programme structure was established for the common development of the new satellite platform, by EADS Astrium and Thales Alenia Space, under a joined ESA/CNES management scheme.

With the Alphabus product reaching qualification completion, and the first platform model to be delivered to its first customer this year, this challenging programme is on its way to unprecedented success. Alphabus/Alphasat has successfully combined the European satcom industry to bring this ambitious project to completion, following ESA's vision to enhance the competitiveness of European industry. Partnering with a private operator allows the in-orbit validation and exploitation of innovations developed by ESA.

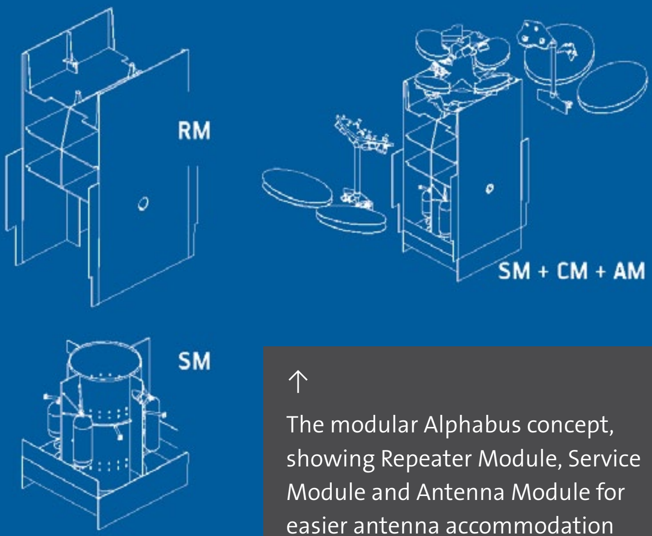
In 2010, EADS Astrium and Thales Alenia Space are now proposing the qualified Alphabus platform for future high-power satellite opportunities on the world market. ■

↓ ESA Member States delegation inspects the Alphabus Service Module at Thales Alenia Space in Cannes in January

→ Technical features

Alphabus structure

The Alphabus platform is based on a scalable and modular design allowing parallel integration and tests of the standardised Service Module (SM) as well as the mission-specific three-floor Repeater Module (RM).



↑
The modular Alphabus concept, showing Repeater Module, Service Module and Antenna Module for easier antenna accommodation and efficient assembly and test

The SM is built around a large central tube (1.6 m) embedding two large propellant tanks with a maximum capacity of 4200 kg, and provides the mechanical interface with the launch vehicle for a launch mass of up to 8,800 kg.

↑
The Half Repeater Module under assembly in Thales Alenia Space Turin (Italy)

The RM itself is split in two halves, allowing parallel integration of the repeater units with an accommodation capacity doubled compared to what is available today. It is mounted on top of the SM.

The use of an 'ultrastable' antenna module structure for the Earth-facing side allows the efficient mechanical alignment of the antennas and their accurate pointing towards Earth. It can also include lateral arms to hold large antenna reflectors on the lateral sides of the satellite, if required by the mission. The antenna module structure is under development by RUAG Space (Switzerland).

The overall physical configuration of Alphabus built on these three modules – the SM, RM and the antenna module – allows for maximum payload unit accommodation.

The overall structure has been developed by Thales Alenia Space Cannes (France). The central tube was developed by EADS Casa (Spain) and is based on state-of-the-art carbon fibre placement technology offering high strength and low mass.

←
Alphabus SM after mechanical integration in Thales Cannes, ready for transport to EADS Astrium Toulouse

↑
Alphabus four-panel solar array wing, developed by EADS Astrium Ottobrunn (Germany), in deployed configuration

RUAG Space (Switzerland) developed various structural panels. The RM structure thermal control integration and assembly were performed by Thales Alenia Space Turin (Italy).

Thermal control

The Alphabus platform configuration is designed to provide both physical and thermal separation between the mission-specific RM and the SM, minimising the design and analysis required to adapt the platform to a dedicated mission. The SM thermal design uses 3D heat pipe network linking the East/West and the North/South panels. A 3D surface heat pipe networks are also installed on the backside of the North/South panels and on the shelves of the RM. A high level of payload thermal dissipation is ensured by adaptation of the fixed radiators surface.

Large solar array for high-power capabilities

The solar generator, inherited from Eurostar E3000, is scalable from four to six panels per wing. The 10 m^2 panels are fitted with triple junction solar cells from Azur Space (Germany) and will benefit from the continuous efficiency improvements of gallium arsenide (GaAs) cell technology. When needed, the fifth and sixth panels are deployed laterally from the third in-line panel.

During launch and early orbit operation, one panel per wing is deployed and provides sufficient power for the satellite electrical power balance. The solar array was developed by EADS Astrium in Ottobrunn (Germany). The low-shock release mechanism was designed also by EADS Astrium Ottobrunn and developed by RUAG Space. The high-power solar array drive mechanism was developed by EADS Astrium Stevenage (UK).

Electrical propulsion: a low-risk baseline

The Electrical Propulsion subsystem is based on four plasma thrusters used for north/south on-orbit 'stationkeeping' of the satellite. The system is an evolution of an existing design and consists of proven hardware with flight heritage. The plasma thruster, PPS 1350-G, was developed by Snecma (France), and its control electronics (Power Processing Unit, PPU), come from Thales Alenia Space ETCA (Belgium).

Two thruster orientation mechanisms, developed by Thales Alenia Space Cannes, hold two thrusters each and allow orientation in two perpendicular directions. The system includes two off-the-shelf xenon fuel tanks of 68 litres each; however, larger xenon tanks each of 105 litres are being developed at Thales Alenia Space in Italy.

↑ The PPS 1350-G plasma propulsion thruster developed by Snecma (France)

↑ The PPS 1350-G thrusters in operation

↑ The Chemical Propulsion Module developed by Astrium Lampoldshausen (Germany)

Chemical propulsion: a high propellant capacity

The Alphabus Chemical Propulsion System (CPS) is a helium-pressurised bipropellant system using monomethylhydrazine (MMH) as the fuel and mixed oxides of nitrogen (MON-3) as the oxidiser. It has a 4200 kg total propellant mass capacity scalable down to 3500 kg, with 16 reaction control thrusters and a 400 N apogee engine. EADS Astrium Lampoldshausen (Germany) is responsible for the CPS subsystem and provides the reaction control thrusters and apogee engine along with most CPS components. A new high-efficiency 500 N apogee engine is being developed at EADS Astrium Lampoldshausen.

The titanium carbon-fibre over-wrapped propellant tanks were developed by MT Aerospace. With a volume of up to 1925 litres and a dry mass of less than 85 kg, they are among the world's largest yet lightest satellite tanks ever built.

← Integration of one of the two main propellant tanks, developed by Man Technology Aerospace (Germany), into the Alphabus SM at Thales Alenia Space Cannes

The system includes three helium tanks of 90 litres each from EADS Astrium Aquitaine (France). An upgrade to a larger tank configuration of two tanks of 150 litres each is planned. The development of the larger helium tanks is in progress at Thales Alenia Space in Italy.

Electrical power architecture: a cost-effective solution

The overall electrical configuration has been designed to allow efficient powering of payload units. A primary 100 V regulated power bus with structure return is distributed to payload units with aluminium bus bars protected through decentralised fuse boxes. The 100 V Power Supply Regulator (PSR) and the lithium ion modular battery configuration allows for efficient power regulation. The PSR was developed by EADS Astrium (France). The battery modules and their latest generation 'G5' lithium ion battery cells were developed by Saft (France) for Alphabus. The fuse box was developed by EADS Astrium Crisa (Spain).

Data handling

The data handling subsystem uses maximum synergy with EADS Astrium and Thales product lines. It is composed of the onboard computer, the Satellite Management Unit (SMU), the Data Bus Network (DBN) and the Platform Interface Unit (PFDIU), inherited from the Thales Alenia Space Spacebus® 4000. The modular concept of the PFDIU is scaled to platform needs, embedding interfaces for Plasma Propulsion Mechanism control, propulsion hardware control, heater lines, pyrotechnic lines, and up to eight antenna 2-axis pointing mechanism controls under a fine-tracking control loop. The DBN will use 1553 and OBDH/RS485 data buses.

The SMU was developed by Thales Alenia Space (France and Italy); the PFDIU was developed by Thales Alenia Space (France) and Thales Alenia Space ETCA (Belgium). This data handling system is complemented by a Payload Interface Unit, which is inherited from EADS Astrium's Eurostar E3000 and allows for Payload Unit TM/TC devices with discrete or Low Speed Serial Bus interfaces.

The on-board software was developed by Thales Alenia Space Cannes and validated by Critical Software (Portugal).

Attitude Determination and Control System

The very accurate and flexible Alphabus Attitude Determination and Control System (ADCS) is inherited from the zero-momentum, four-reaction-wheel control concept of the Spacebus® 4000, with three-axis determination using a star tracker and an accurate on-board orbit propagator and precise on-board time. It also includes a gyroscope and a coarse sun sensor. The reaction wheel has been developed by RCD (Germany) in different versions (angular momenta of 18, 25 and 50 Nms); a new active pixel sensor-based star sensor was developed by Galileo Avionica (Italy); a new Hemispherical Resonator Gyroscope was developed by Sagem (France) with Syderal (Switzerland) and a new coarse sun sensor was developed by TPD TNO (The Netherlands).

Antenna Tracking System for high-accuracy antenna pointing

Alphabus is designed to accommodate an Antenna Tracking System (ATS) based on radio-frequency sensing in order to reach 0.05° half-cone target performance. Up to eight antennas can be controlled by the ATS. This system allows for individual pointing control of each antenna, compared to the standard ADCS body control, hence compensating for each beam-specific error with a higher control bandwidth. An onboard closed loop is implemented in the onboard software.

→ Alphabus equipment suppliers and equipment qualification status

EQUIPMENT	SUPPLIER	QUALIFIED
STRUCTURE		
Central tube	EADS CASA	✓
Primary structure	Thales Alenia Space Cannes	✓
Secondary structure	Ruag Space (Switzerland), Thales Alenia Space Cannes (France), EADS CASA (Spain)	✓
ELECTRICAL POWER SYSTEM		
Solar array	EADS Astrium Ottobrunn (Germany)	✓
Low-Shock Release Unit for solar array deployment	Ruag Space (Switzerland), EADS Astrium Ottobrunn (Germany)	✓
Power System Regulator	EADS Astrium (France)	✓
Battery modules based on 5th-generation lithium ion technology	Saft (France)	✓
High-power Solar Array Drive Mechanism	EADS Astrium Stevenage (UK)	✓
High-power equipment	EADS Crisa (Spain)	✓
CHEMICAL PROPULSION SYSTEM (CPS)		
Apogee boost motor to transfer satellite into geostationary orbit	EADS Astrium Lampoldshausen (Germany)	✓
Reaction control thrusters for keeping satellite on station	EADS Astrium Lampoldshausen (Germany)	✓
Propellant tank	MT Aerospace (Germany)	✓
Helium tank (90 litre)	EADS Aquitaine (France)	✓
New helium tank (150 litre) under development	Thales Alenia Space Turin (Italy)	
Propellant and helium filters	Sofrance (France)	✓
Pressure transducers	Bradford Engineering (The Netherlands)	✓
Various CPS items	EADS Astrium Lampoldshausen (Germany)	✓
ELECTRICAL PROPULSION SYSTEM (EPS)		
Xenon tank (68 litre)	Off-the-shelf	✓
New xenon tank (105 litre) under development	Thales Alenia Space Turin (Italy)	
Various EPS propulsion items	Ampac (UK and Ireland)	✓
Plasma thrusters, PPS 1350-G	Snecma (France)	✓
Power Processing Unit, Filter Unit and Hot Interconnection Boxes	Thales Alenia Space ETCA (Belgium)	✓
Thruster Orientation Mechanism (TOM)	Thales Alenia Space Cannes (France)	✓
ATTITUDE DETERMINATION AND CONTROL SYSTEM		
High-momentum reaction wheel	RCD (Germany)	✓
Coarse Sun sensor	TPD TNO (The Netherlands)	✓
Hemispherical resonator gyroscope	Sagem (France) with Syderal (Switzerland)	✓
Active pixel sensor-based star tracker	Galileo Avionica (Italy)	✓
DATA HANDLING SYSTEM		
Satellite Management Unit	Thales Alenia Space (France and Italy)	✓
Platform Data Interface Unit	Thales Alenia Space (France and Belgium)	✓
Payload Interface Unit	EADS Astrium (France)	✓

→ WHAT CAN 'SPACE' BRING TO 'ENERGY'?

'Space & Energy' supporting EU policies

Isabelle Duvaux-Béchon
Future and Strategic Studies Office
DG's Policy Office, ESA Headquarters, Paris, France

Iñigo Sabater
Energy Technologies and Research Coordination,
DG Energy, European Commission

Not energy for satellites, but energy on Earth. ESA's Space & Energy' project is looking at how satellites, technologies and related operational services can help energy production, transportation, consumption and security.

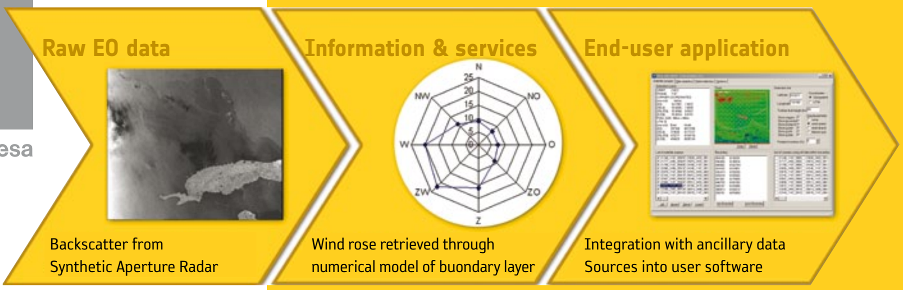
Satellites, with their unique positions, continuous availability and the high-performance technologies developed in their construction, can provide answers that, while of course not solving all the energy problems on Earth, can significantly help citizens, businesses and regional and national authorities.

From Earth observation satellites, the data of past years can be used to support the identification of adequate locations for the installation of wind or solar energy power plants.

Meteorological satellites allow more weather forecasting, which helps the prediction of short-term production and the integration of these renewable energy plants into the global 'smart grid' of the electricity network.

Telecommunications and navigation satellites can support efficient and secure transportation, or operations and maintenance of power grids. Space-based observations can increase geomagnetic information used for efficient surveying, drilling and large-scale electrical networks. The laboratories on the International Space Station can host experiments aimed at developing new materials and fuels, or characterising potential reservoirs to trap carbon dioxide, for example. Technologies developed for the harsh space environment can be transferred to innovative high-efficiency, low-consumption solutions for Earth energy systems.

→ The EO value chain: turning Earth observation data into information services

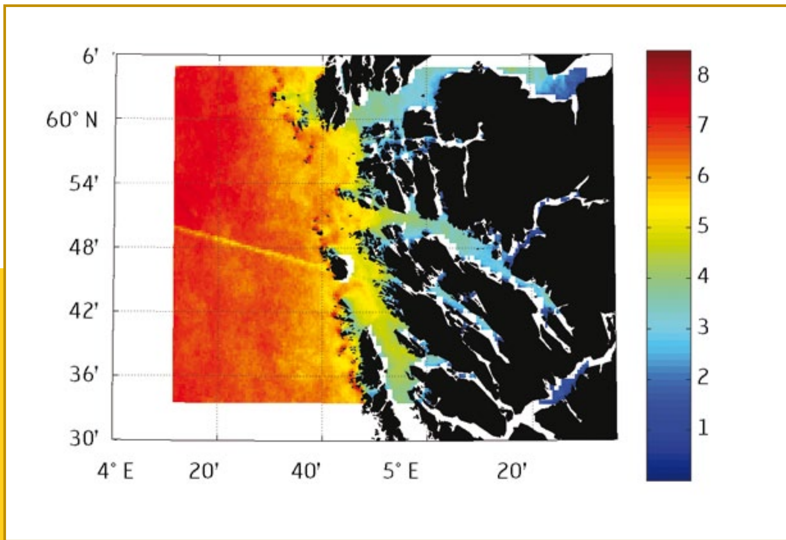


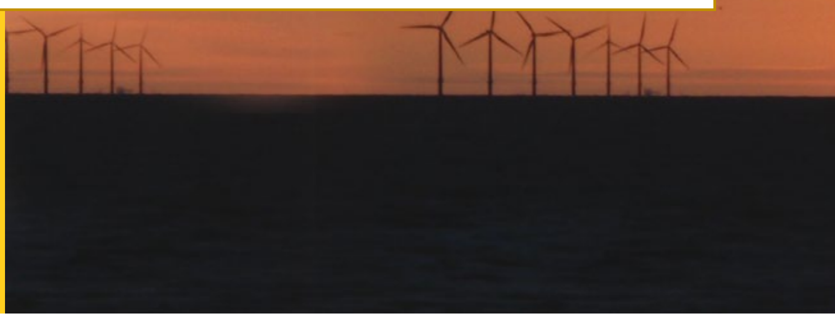
The utility of Earth observation (EO) data comes from the information that can be extracted from them. Turning data into information is not a simple task and often requires coupling with other sources of data, integration into numerical models and software, and timely delivery in a user-friendly way via geographical information systems. The EO value chain illustrated shows how value-adding companies transform raw data from radar (e.g. backscatter) into wind information products directly usable by renewable energy managers (e.g. wind rose at mast height, energy yield curve) and then integrate them within third-party software, which are widely used in the renewable energy sector (e.g. the Wind Atlas Analysis and Application Programme, WASP)

There are already several applications in existence. The 'Space & Energy' project started in ESA in 2009 with the aim of creating an inventory of such applications and possible future ones, identifying those that could be interesting and proposing them to the EU (the then Directorate General Transport & Energy (DG-TREN) of the European Commission, now DG Energy).

The EU had already developed a series of challenges and plans, so when we analysed these at ESA it could be seen that each of the projects identified and listed below would very likely support one or more of the challenges or plans. When ESA started discussions with the European Commission, this impression was confirmed and we were convinced that we had to work together to build a common plan and propose it to our stakeholders. →

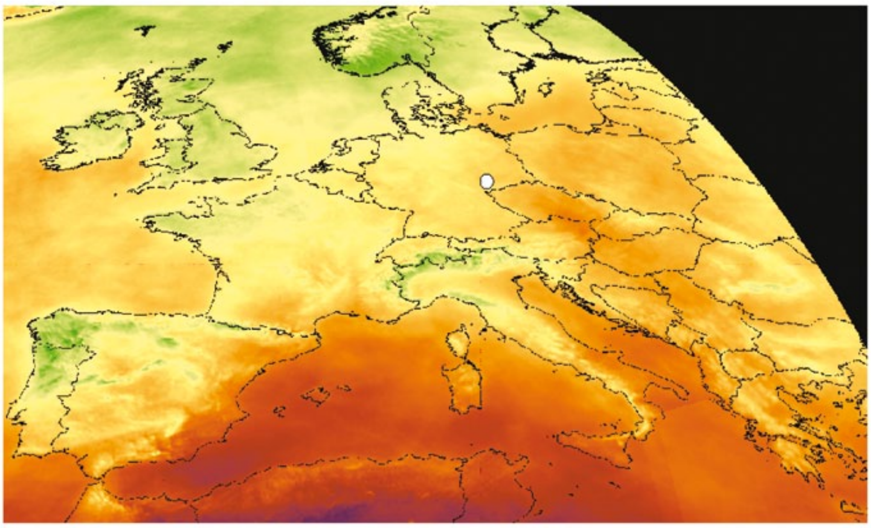
The 'Space & Energy'





→ Wind energy

Coastal wind magnitude measured from space. The magnitude and variability of coastal wind resources can be assessed by using complementary Earth observation sources of ocean wind data, including global data from scatterometers at 25 km resolution, which provide a suitable temporal sampling, and regional data from Synthetic Aperture Radar at 100 m resolution, which provide the spatial details at the coast (NERSC)



→ Solar energy

Ground irradiance measured from space. Sensors on geostationary satellites, such as the Meteosat Second Generation, supply radiance observations every 15 minutes with up to 1 km resolution. Timely delivery of data allows rapid detection of weather and dust conditions to help improve the performances of photovoltaic plants. The image corresponds to monthly mean global irradiance based on Meteosat-7 satellite for April 2000 (Univ. Oldenburg)

The 'other' kind of solar power — solar thermal power — offers more choices to integrate with the grid to provide reliable power. Instead of directly converting the Sun's rays into electricity, solar thermal plants use mirrored surfaces to concentrate sunlight to produce high temperatures. This is why they are also called Concentrating Solar Power (CSP) plants (Sky Inc.)

→ Hydropower

Snow cover from space as seen by the Envisat's Medium Resolution Imaging Spectrometer instrument in December 2008

By processing EO images and combining this information with ground measurements of snow thickness, it is possible to estimate the 'Snow Water Equivalent', which approximates the potential hydropower stored in snow

Working Group

For many years, studies and analyses have been regularly made to identify whether ESA satellites, data and technologies, as well as applications based on them, could have even more uses than were initially planned. This is the case at the 'individual' level for the transfer of technologies and setting up of specific services with dozens of examples of successful development support, transfers and incubation of small- and medium-sized enterprises. ESA has started to analyse systematically given subjects in a trans-disciplinary way, across all Directorates, to identify the projects that can be involved.

The 'Space & Energy' theme is already part of the Integrated Applications Programme, but it does not cover all possibilities because it is aimed only at those applications that involve telecommunications applications. Widening the approach and integrating other domains allow a global and efficient in-house analysis and better discussions with potentially interested partners.

Space is seen as a tool and ESA programmes and activities are being proposed in fields that are not traditionally 'space-oriented', with the aim to maximise the benefits derived from Member States' financing and, by thinking 'out-of-the-box', to bring space to the service of European citizens on matters of global interest.

Until a new programme is defined and created within a specific Directorate, the coordination of these studies is entrusted to the Director General's Policy Office. For example, such structured work is taking place with security, with a dedicated Office, and work started on 'Space & the Arctic' in February.

For 'Space & Energy', an ESA Inter-directorate Working Group met in 2009 to investigate how ESA's programmes, technologies and activities could support the EU policies related to energy. Coordinated by the DG's Policy Office, this Working Group brought together representatives from Earth Observation, Telecommunications & Integrated Applications, Human Spaceflight, Technical & Quality Management, Operations & Infrastructure, and Resources Management & Industrial Matters. Each

Directorate analysed what type of activity it could provide to support the EU's objectives and the degree of maturity in each activity.

Based on the EU policies and technology challenges in this field, some 15 potential projects were identified and informally presented to the European Commission for a first analysis. Discussions in a workshop held on 15 January 2010 confirmed the Commission's interest in pursuing this direction and defined some priorities.

ESA's initial proposals

These projects are organised in line with the themes of interest to the EU and show the variety of the proposals and the number of subjects for which space could contribute to the solution (the objectives behind each of these ideas are shown in separate tables):

Space applications for energy policy enforcement

- Earth observation services in support of renewable energy sector and carbon capture and storage
- Benchmarking and promoting best practices in energy efficiency and sustainability

Space applications for energy systems management

- Intelligent integrated grid monitoring, management and control
- Intelligent planning, monitoring and diagnostic applications
- Pipeline remote monitoring system
- Prediction of disruptive geomagnetically induced currents in networks
- Small-scale power plant management and integration with electricity grid
- Space infrastructure as enabling factor to increase the safety of nuclear end-to-end energy production

Transfer of technology

- Adaptation of high-efficiency solar cells and modules handling and testing methods
- Transfer of power conversion innovative solutions

Long-term research (of potential benefit to the other subjects)

- Improved heat exchangers
- Processes for cleaning crystalline silicon (c-Si) for photovoltaic cells
- Analysis of diffusion and Soret coefficients
- Solid nano-structured metal powder fuel
- Lightweight high-efficiency thermoelectric material to convert waste heat into electricity
- Space solar power plant system

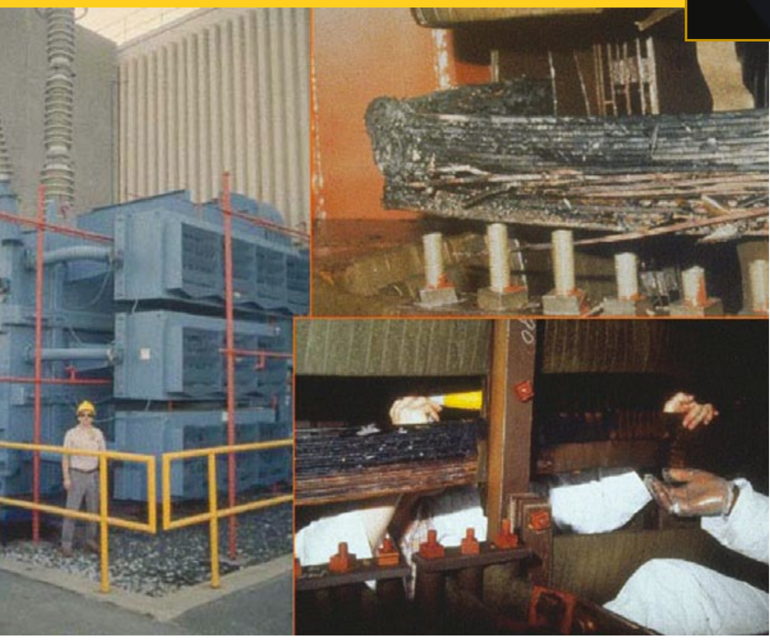
These projects vary considerably in their size or planning. They build on past expertise and projects, but some are new in what they propose, while others are a follow-up of former programmes, or development or an extension to the whole Europe of a specific application. But they all can contribute to help solve one or more of the challenges facing Europe in the energy sector. They are not 'endorsed' by the EU, but they will be discussed further and could, in some cases, be implemented immediately.

By combining the specific features of these projects, support to most of the EU technology challenges and plans can be provided at a cost that is marginal compared to the initial ESA investment made for the development of satellites, instruments or technologies, and marginal compared to the budgets in the energy sector. The key EU technology challenges and the EU SET-Plan Roadmap are shown in separate tables.

→ Geomagnetic storms

This image obtained by the NASA TIMED Global Ultraviolet Imager shows an aurora, superimposed over an Earth image, produced by a major geomagnetic storm that occurred in April 2006 (Johns Hopkins Univ., Applied Physics Lab)

Geomagnetically induced currents melted the internal windings of a 500 kV transformer in the Salem Nuclear plant in New Jersey, USA. These currents were caused by a geomagnetic 'superstorm' in March 1989 (J. Kappenman, Metatech)



The collaborative work

After the Directors General of the two organisations confirmed the interest to go ahead and investigate further the projects that could be relevant to the EU, the concept was presented to the FP7 Energy Programme Committee on 1 October. The EC's Directorate General Transport & Energy and ESA were encouraged to proceed in the analysis and to organise meetings with the national experts to validate the ideas.

On 15 January, more than 50 experts gathered at ESA Headquarters, from Member States of both ESA and the EU, from the technology platforms, from industry, from various EU Directorates and from ESA. The keynote speeches are available on the EU's web site

Agreed joint conclusions from the workshop

- There was broad consensus among the experts that space applications and technologies can significantly contribute to improve security of supply and support the transition to a low-carbon economy, while creating new opportunities for growth and jobs. Actually, there are already concrete but incipient examples that illustrate the potential benefits of this cooperation (for instance, the space surveillance of energy infrastructures, the space-based assessment of renewable resources, the transfer of technology in sectors such as photovoltaics or hydrogen, or research on innovative motor fuels).

- Space can be used not only to support policy formulation and enforcement, but also for management of energy systems. Current space technologies (Earth observation, GMES, space-based positioning, Galileo, and satellite telecommunications) can provide services in support of energy system management (both in renewable energy sources and in traditional oil-carbon and nuclear sectors).

These services can support all the phases of energy production and supply, ranging from the exploration phase, production, transport to exploitation and distribution networks. They can be implemented in the short term, some already in 2010. For example, there is the potential contribution of space assets to the management of future, complex energy grids with many renewable energy plants. An integrated (space and terrestrial) system could increase the reliability and the stability of wide complex grids.

- Satellite technologies could provide enormous opportunities to enhance the planning, design and long-term monitoring of energy systems (including pipelines) and critical energy infrastructure.

- Present space technologies have a track record of success and future ones have large potential to be transferred to the Earth environment. The space environment can support research on novel materials, fuels or technologies for the long-term evolution of our energy systems.

- A structured project in technology transfer would help to find the right players and pass the right information between sectors that do not know each other. It would help governments to get the maximum from investments in research and development, and even joint research and development could be envisaged.

- At the workshop it was evident that energy and space stakeholders are not alike and had little tradition of working together. However, the discussion proved useful in identifying potential areas for cooperation. Many participants underlined the value of giving continuity to these discussions in a structured and systematic way. Existing networks (for example, EC, ESA, Member States, Technology Platforms, International Energy Agency) could be activated and brought together to understand better their detailed requirements, discuss what space can bring and translate all this into concrete actions.

- In particular, in long-term research, given the large number of topics already identified for these two categories of research, it was stated that ESA should build links with the European Energy Research Alliance and other research organisations in Europe. Detailed expert discussions should be promoted to define an R&D programme that could justifiably be sponsored by the EC that could accept the inclusion of space as an enabling technology.

A way forward: an exploratory plan on energy and space

The workshop also identified elements that have now to be implemented. Cooperation between energy and space sectors is certainly considered relevant, and it is multifaceted (for example, policy versus research, short-term versus long-term), so several actions could be envisaged. These could take the form of an 'exploratory' plan, covering the most relevant actions stemming from the workshop.

Such an exploratory plan would assess the merit of establishing a longer-term cooperation between the two sectors (a 'Programme'), to develop and put space technologies and application at the service of our energy policy objectives. This has already happened in other sectors, for instance in environment (GMES) and in transport (Galileo).

A possible target would be the next ESA Ministerial Council, where ESA, with EC support, may be in a position to propose a 'Space and Energy Programme' stemming from the results of this exploratory plan.

The exploratory plan could include:

1. *Pilot actions to test and demonstrate concepts*
Candidates are: energy efficiency in buildings, biofuel sustainability, carbon capture and storage, infrastructure monitoring and renewable energy sources monitoring. Some projects can start very soon because they are mature enough. They include projects directly using space data and assets, and transfer of space technologies.

2. *Exploratory studies*
Candidates are space services for legislation enforcement, management of energy services (grids and resources), exploration, development of energy-dedicated satellite services (e.g. Ener-SAT).

3. *Coordination actions for outreach*
Workshops and conferences to support the previous actions and engage key players in the energy and space sectors, support the dissemination of existing technologies already transferred (or ready to be) and of data from satellites for ground operators.

→ Key EU technology challenges for the next 10 years

Challenges to meet 2020 targets

- Make second-generation bio-fuels competitive alternatives to fossil fuels, while respecting the sustainability of their production
- Enable commercial use of technologies for carbon dioxide capture, transport and storage through demonstration at industrial scale, including whole system efficiency and advanced research
- Double the power generation capacity of the largest wind turbines, with offshore wind as the lead application
- Demonstrate commercial readiness of large-scale photovoltaic and concentrated solar power
- Enable a single, smart European electricity grid able to accommodate the massive integration of renewable and decentralised energy sources
- Bring to mass market more-efficient energy conversion and end-use devices and systems, in buildings, transport and industry, such as poly-generation and fuel cells
- Maintain competitiveness in fission technologies, together with long-term waste management solutions

Challenges to meet the 2050 vision

- Bring the next generation of renewable energy technologies to market competitiveness
- Achieve a breakthrough in the cost-efficiency of energy storage technologies
- Develop the technologies and create the conditions to enable industry to commercialise hydrogen fuel-cell vehicles
- Complete the preparations for the demonstration of a new generation (Gen-IV) of fission reactors for increased sustainability
- Complete the construction of the ITER (International Thermonuclear Experimental Reactor) fusion facility and ensure early industry participation in the preparation of demonstration actions
- Elaborate alternative visions and transition strategies towards the development of trans-European energy networks and other systems necessary to support the low-carbon economy of the future
- Achieve breakthroughs in enabling research for energy efficiency: e.g. materials, nano-science, information and communication technologies, bioscience and computation

Fruitful collaboration

The practical implementation of these recommendations has now to be discussed and put in place. Different ways will be explored concerning the financing of these activities and the governance of the collaboration.

Nothing is yet defined or excluded, and the activities can take the form of parallel complementary activities or can be delegated to ESA. Financing can come from the Seventh EU Framework Programme (FP7) or specific energy financing. We will review all the possible tools in order to be as efficient as possible, and to be able to start the pilot actions as soon as possible.

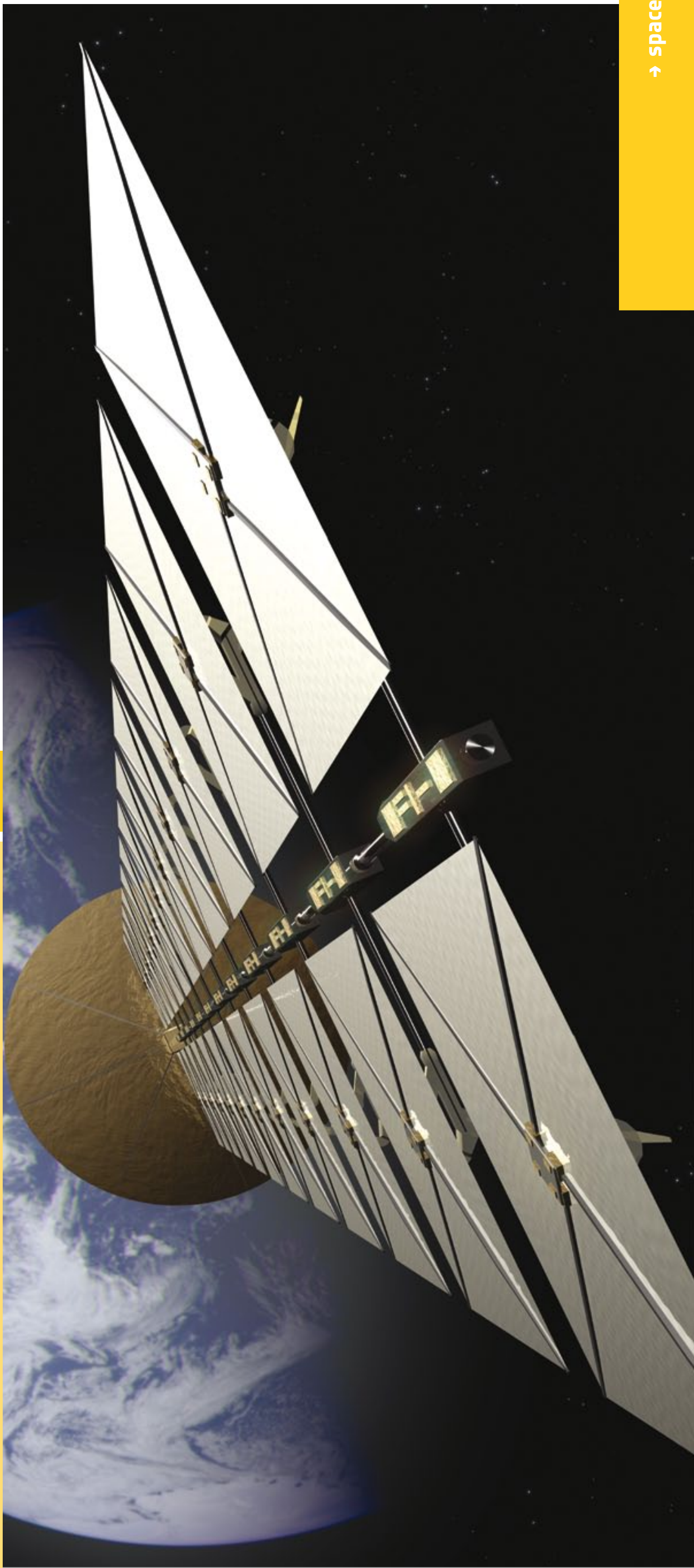
The change in the structure of the EC, and of the Commissioner and Director General in charge of Energy has delayed implementation, but the merit of pursuing this cooperation is recognised by ESA and the EC.

We look forward, on both sides, to a fruitful collaboration, based on the successful assets of the European space programme and for the ultimate benefit of European citizens. ■

EU Strategic Energy Technology (SET) Plan Roadmap on low-carbon energy technologies

The SET Plan has defined an ambitious roadmap, to which ESA believes it can equally contribute in many different areas:

- Up to 20% of the EU's electricity will be produced by wind energy technologies by 2020.
- Up to 15% of the EU's electricity will be generated by solar energy in 2020. However, if the DESERTEC vision is achieved, the contribution of solar energy will be higher, especially in the longer term.
- The electricity grid in Europe will be able to integrate up to 35% renewable electricity in a seamless way and operate along the 'smart' principle, effectively matching supply and demand by 2020.
- At least 14% of the EU's energy mix will be from cost-competitive, sustainable bio-energy by 2020.
- Carbon capture and storage technologies will become cost-competitive within a carbon-pricing environment by 2020–25.
- While existing nuclear technologies will continue to provide around 30% of EU electricity in the next decades, the first Generation-IV nuclear reactor prototypes will be in operation by 2020, allowing commercial deployment by 2040.
- By 2020, 25 to 30 European cities will be at the forefront of the transition to a low carbon economy.



↑ An artist's concept for a reference solar-power-from-space system in orbit

→ The objectives of the projects proposed by ESA

Earth observation services in support of sustainable low-carbon energy production and use

To expand and grow prospects for increasing the volume of low-carbon energy production both within the energy industry and European Member States specifically for the implementation of EU Energy policies, plans and directives. This includes:

- primary production of renewable energy sector (main renewable energy sources: solar, wind, wave, hydro, biofuels)
- increased exploitation of solar energy in buildings infrastructures within major European cities
- new technologies for carbon sequestration and storage.

Benchmarking and promoting best practices in energy efficiency and sustainability

- To become a benchmark, with EU's support, for energy/environmental issues relating to sites and buildings, thus promoting to European citizens best practices that correspond to EU policies in this field.

Intelligent integrated grid monitoring and control

- To improve reliability and efficiency of the current grid, reduce grid maintenance and operation costs, integrate space and non-space intelligent sensors to provide new monitoring and control capabilities (e.g. video, temperature, humidity) to prepare transition to smart grid.

Intelligent planning, monitoring and diagnostics

- Applicability of advanced technology for space asset monitoring and management linked to EU's Energy Programme for Recovery and Renewable Energy Source Monitoring.

Pipeline Remote Monitoring System (PRMS)

- To develop a Europe-wide satellite-based system for the monitoring of gas flow from major pipelines: gathering information in real-time on the flow conditions in any particular stretch of pipeline, and providing, in particular, alert and monitoring capability in cases of incident/accident. This information will be used by gas companies to select appropriate gas sources and routes to maintain uninterrupted gas supply.

Prediction of disruptive geomagnetically induced currents in large-scale electrical networks

- To design, implement and validate services to predict and forecast geomagnetically induced currents in large-scale power distribution electrical networks (such as national power grids, cathodic protection system of oil/gas pipelines) based on a combination of ground-based and space-based sensors.

Small-scale power plant management and integration with electricity grid

- To facilitate the integration of different scale production power plants in the electricity grid, contributing to the stability of the overall electrical system
- To provide management tools that allow transition from current management models to a new model based on a mixture of large-scale (fossil fuel and nuclear fission mainly) and microscale power generation (e.g. renewable sources such as solar, wind energy, etc.)
- Design and deploy a new integrated control system suitable for the interaction between grids and microscale power plants.

Space infrastructures as an enabling factor to increase the safety of end-to-end energy production (for AREVA, the multinational energy company)

- To improve tracking capabilities by geo-localisation and identification of packages of nuclear/chemical materials in the overall AREVA production cycle
- To develop resilient system tools to manage the handling of packages of nuclear/chemical materials to meet the overall applicable European safety standards, including a resilient telecommunication network.

High-efficiency solar cells: transfer of knowhow and conversion technology

- To use high-efficiency solar cell technology and knowhow already developed by ESA in terrestrial concentrator photovoltaic plants.

CELSIUS: enhanced heat exchangers

To tackle different problems involved in heat transfer systems in an integrated manner towards the rational, knowledge-based improvement of heat transfer systems in industry and the development of new ones for highly specific applications.

The main objectives of CELSIUS are:

- To pool together, and develop as required, knowledge, expertise and tools in thermo- and hydrodynamics, materials design and systems engineering that closely interrelate in heat transfer systems
- To enable a breakthrough in heat transfer efficiency by optimising existing concepts and designing, prototyping and validating new ones in order to promote industrial and residential energy savings.

Processes for cleaning crystalline silicon (c-Si) for photovoltaic (PV) cells

The feedstock of the PV-silicon industry that used to be the leftovers of the electronics industry is not available anymore to the c-Si PV industry. With starting materials composed of only 98% silicon, much process development work needs be done to devise commercially competitive ways of cleaning the raw materials and for this, research on the formation and influence of the metallic inclusions needs to be performed.

Analysis of diffusion and Soret coefficients

In order to improve the long-timescale modelling of the behaviour of multi-component fluids in a thermal gradient, some research effort needs to be made. Such knowledge is particularly important in physical systems where mass diffusion processes are not negligible compared to convective ones, as is often the case in porous media. Situations are encountered by the petroleum industry (initial state of a reservoir) and in the CO_2 sequestration (geological storage).

Solid nano-structured metal powder fuel (PyroMet)

- To develop a totally new and different class of fuel, based on solid nano-structured metal powder with very large surface areas. A number of metals are combustible, have high energy densities, and are relatively cheap and easy to store, and are widely available around the globe (e.g. Al, Mg, Fe). PyroMet will focus on the safe production and the controlled combustion of these metal powders for a variety of industrial uses:
- next-generation space propellants
- internal combustion engines, as an alternative to petrol and diesel (To develop and deliver the first automotive engine fuelled by nano-structured metals, and emitting zero CO_2, zero particulates and lower NO_x. The nano-structured metal powder can be collected after combustion, and subsequently deoxidised. The project will therefore explore important fuel-recycling approaches, especially those using renewable sources.)
- other potential applications, such as power generation turbines for electricity production, and as an energy storage medium for solar power facilities.

Lightweight high-efficiency thermoelectric material to convert waste heat into electricity (THERMOMAG)

To develop a new class of lightweight high-efficiency thermoelectric materials, based on Mg_2Si compounds, able to convert waste heat directly into electricity, by exploiting the 'Seebeck' effect. This technology can be applied in the aviation sector (aircraft and aero-engine compressor stages), in the automotive sector (benefiting from using thermoelectrics on exhaust pipes and radiators), in industrial plants (e.g. steel-making blast furnaces, aluminium smelters, cement factories and power stations).

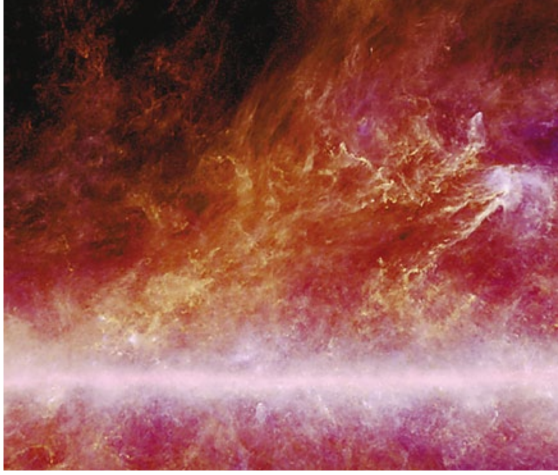
Integrated space and terrestrial solar power plant system

To design a reference solar-power-from-space system to complement the growing European terrestrial solar power plant infrastructure. ■

→ NEWS IN BRIEF

NASA astronaut
George Zamka looks out
from a window
of the newly-installed
Cupola of the International
Space Station

Planck sees cold dust



↑ Planck's view of dust structures above the plane of the Milky Way

Giant filaments of cold dust stretching through our galaxy, the Milky Way, are revealed in a new image from ESA's Planck satellite. Analysing these structures could help to determine the forces that shape our galaxy and trigger star formation.

The image shows the filamentary structure of dust in our solar neighbourhood – within about 500 light-years of the Sun. The local filaments are connected to the Milky Way, which is the pink horizontal feature near the bottom of the image. Here, the emission is coming from much further away, across the disc of our galaxy.

The image has been colour-coded to show different temperatures of dust. White-pink tones are a few tens of degrees above absolute zero, whereas the deeper colours are at around –261°C, only about 12 degrees above absolute zero. The warmer dust is concentrated into the plane of the galaxy whereas the dust suspended above and below is cooler.

What gives these structures these particular shapes is not well understood. There are many forces that to help shape the molecular clouds into these filamentary patterns, for example, the rotation of our galaxy, gravity, radiation or particle jets from stars, and magnetic fields also play a role, although to what extent is presently unclear.

ESA's Herschel space telescope can be used to study such regions in detail, but only Planck can find them all over the sky. Launched together in May 2009, Planck and Herschel are both studying the coolest components of the Universe. Planck looks at large structures, while Herschel can make detailed observations of smaller structures, such as nearby star-forming regions.

This new image is a combination of data taken with Planck's High Frequency Instrument (HFI), recorded as part of Planck's first all-sky survey at microwave wavelengths, and an image taken in 1983 with the IRAS satellite.

Windows on the world

Astronauts aboard the International Space Station opened the shutters on the seven Cupola windows in February, providing them with the first views of Earth from their new observation deck.

Cupola is an observation and control tower with six side windows and a top window, all equipped with shutters to protect them from passing space debris and micrometeoroids and closed when not in use.

Almost exactly two years after the Columbus laboratory was added to the ISS, Node-3 and Cupola were installed by the crew of Space Shuttle *Endeavour* STS-130 between 8–17 February.

The new module, complete with the biggest window ever launched, means the astronauts will have better life-support systems, more exercise facilities and a wider view on space for monitoring, observing and relaxing.

↑ NASA STS-130 astronaut Steve Robinson inside Cupola, relaxing with a guitar and an Earth view in the background

To Mars and back – as real as it gets

A crew of six, including two Europeans, will soon begin a simulated mission to Mars in a mock-up that includes an interplanetary spacecraft, a Mars lander and martian landscape. The Mars500 experiment, as long as a real journey to Mars, is the ultimate test of human endurance.

↑ Mars500 candidates receive training on use of spacesuits

Their mission is to mimic a full mission to Mars and back, as accurately as possible without actually going there. Mars500 will be the first full-duration simulated mission to Mars, starting in a special facility in Moscow this summer.

The Europeans will join a crew of three Russians and one Chinese participant for a total of 520 days: 250 days for the trip to Mars, 30 days on the surface and 240 days for the return journey. All the food and water needed for the 'journey' will have to be loaded into the 'spacecraft' before 'departure'.

There will even be a simulated landing when, after about 250 days, the crew will be split in two, and three 'cosmonauts' will move into a separate area to walk on a mock-up surface of the Red Planet wearing modified Russian Orlan spacesuits.

The three ESA candidates are Colombian-Italian Diego Urbina (26), Belgian Jerome Clevers (28) and Romain Charles (30) from France. Two of the four will take part in the final 520-day mission.

"Mars is the ultimate goal of the global human exploration programme. In addition to developing the necessary space infrastructure for exploration missions, ESA also has an ongoing programme of ground-based analogues and ISS research activities to make sure that our astronauts are as prepared as possible for the physical and mental demands of long-duration missions, and to develop countermeasures for any adverse effects such missions. The Mars500 isolation study is a major milestone in this, and the cooperation between ESA and Russia in this experiment is also an asset," said Simonetta Di Pippo, ESA's Director of Human Spaceflight.

Third ATV named after Edoardo Amaldi

ESA's third ATV has been named after the Italian physicist and space pioneer Edoardo Amaldi at a ceremony in Rome in March, attended by his son, Prof. Ugo Amaldi.

Europe's ATV space freighter proved its maturity in 2008, when ATV *Jules Verne* completed a demonstration flight to the International Space Station, carrying 4.5 tonnes of food, water, fuel, supplies and equipment, and served as a propulsion module for six months before finally undocking and entering Earth's atmosphere over the southern Pacific.

ATVs are key to the ISS's logistics and operations and are an excellent demonstration of Europe's capability in creating a space infrastructure for human spaceflight and exploration.

After this flawless first flight, the second ATV, *Johannes Kepler,* is being completed for launch later this year.

Now the third ATV has been named after the Italian physicist and space pioneer Edoardo Amaldi.

Edoardo Amaldi was one of a small number of visionary scientists who in the post-war years prompted the process that led to the founding of ESRO, a predecessor of ESA.

He was a leading figure in Italian science in the 20th century, particularly in fundamental experimental physics.

Satellite data improving aviation safety

Thousands of planes were grounded across Europe in April due to the spread of volcanic ash following the eruption under Iceland's Eyjafjallajökull glacier.

Volcanic eruptions eject large amounts of ash and trace gases, such as sulphur dioxide, into the atmosphere, often reaching the altitudes of scheduled flights. When flying through a volcanic ash cloud, ash particles can enter jet engines and could result in engine failure. The ash can also limit the view of pilots and severely damage aircraft structures, clogging sensors, scratching or 'sandblasting' cockpit windows, landing light covers and leading edges of tails and wings.

The total cost of damage sustained by aircraft due to volcanic ash clouds from 1982 to 2000 is estimated at $250 million.

Every year there are about 60 volcanic eruptions, but ground-based monitoring is carried out on only a limited number of these volcanoes. In fact, most volcanoes, especially those that are in remote locations, are not monitored at all on a regular basis.

Therefore, observations of sulphur dioxide (SO_2) and aerosols derived from satellite measurements in near-real time can provide useful complementary information to assess, on a global level, possible impacts of volcanic eruptions on air traffic control and public safety.

↑ Jet turbine blades in a Boeing 747 engine, showing damage caused by ash (BA/Captain Eric Moody)

Ensuring that volcanic cloud hazards are addressed, Volcanic Ash Advisory Centres (VAACs) were established in 1995 to gather information regarding volcanic ash clouds and to assess the possible hazard to aviation.

To assist the VAACs in their tasks, ESA started the Support to Aviation Control Service (SACS) to deliver SO_2 email alerts to them in near-real time. For each alert, a dedicated map around the location of the SO_2 peak value that triggered the alert is produced and published on a dedicated web page, specified in the email.

In addition to VAACs, more information (derived from the Sciamachy instrument on ESA's Envisat, GOME-2 and IASI on MetOp, OMI on EOS-Aura and AIRS on Aqua) is delivered to vulcanological observatories, healthcare organisations and scientists in affected areas.

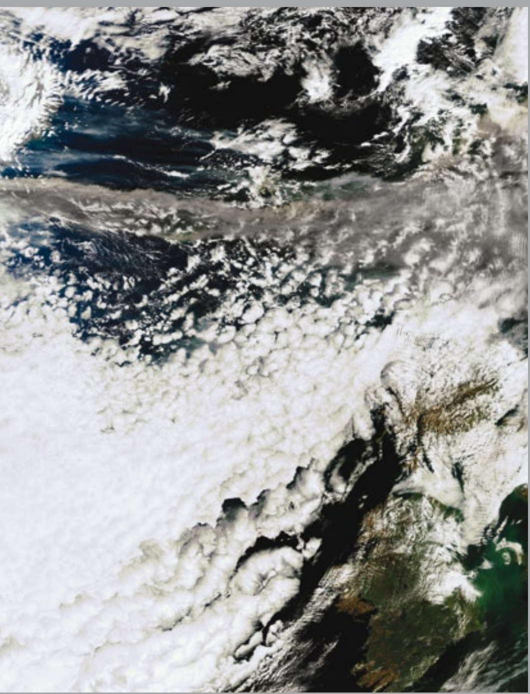
First images from ESA's water mission

In less than four months since launch, the first calibrated images are being delivered by SMOS. These images of 'brightness temperature' translate into clear information on global variations of soil moisture and ocean salinity to advance our understanding of Earth's water cycle.

Launched on 2 November, the Soil Moisture and Ocean Salinity (SMOS) mission is improving our understanding of the water cycle by making global observations of soil moisture over land and salinity over oceans. By mapping these two variables, SMOS will not only advance our understanding of the exchange processes between Earth's surface and atmosphere, but will also help to improve weather and climate models. In addition, the data from SMOS will have several other applications in areas such as agriculture and water resource management.

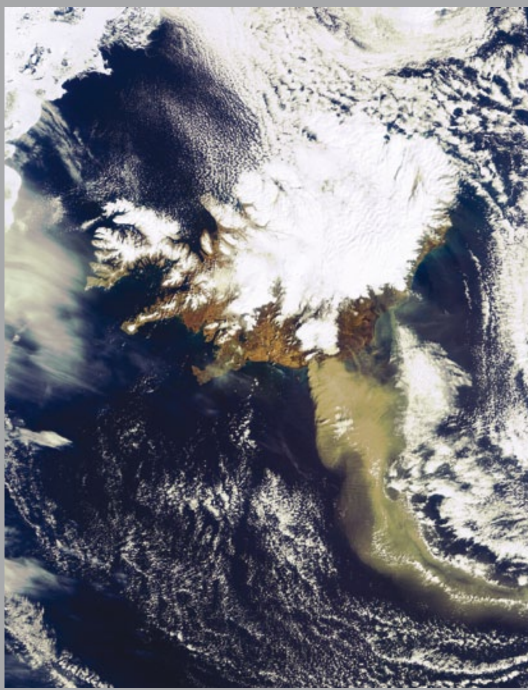
SMOS captures images of 'brightness temperature', which then are processed to give information on soil moisture and ocean salinity. Brightness temperature is a measure of the radiation emitted from Earth's surface. During the commissioning phase, considerable effort is put into improving the quality of these images of brightness temperature before using them as input for the soil moisture and ocean salinity data products. ESA is now in a position to show the first results, which are very encouraging.

Since it was launched, engineers and scientists from various institutes in Europe have been busy commissioning the SMOS satellite and instrument. This commissioning phase, which will continue until the end of April, initially involved testing the satellite platform and the all-important MIRAS



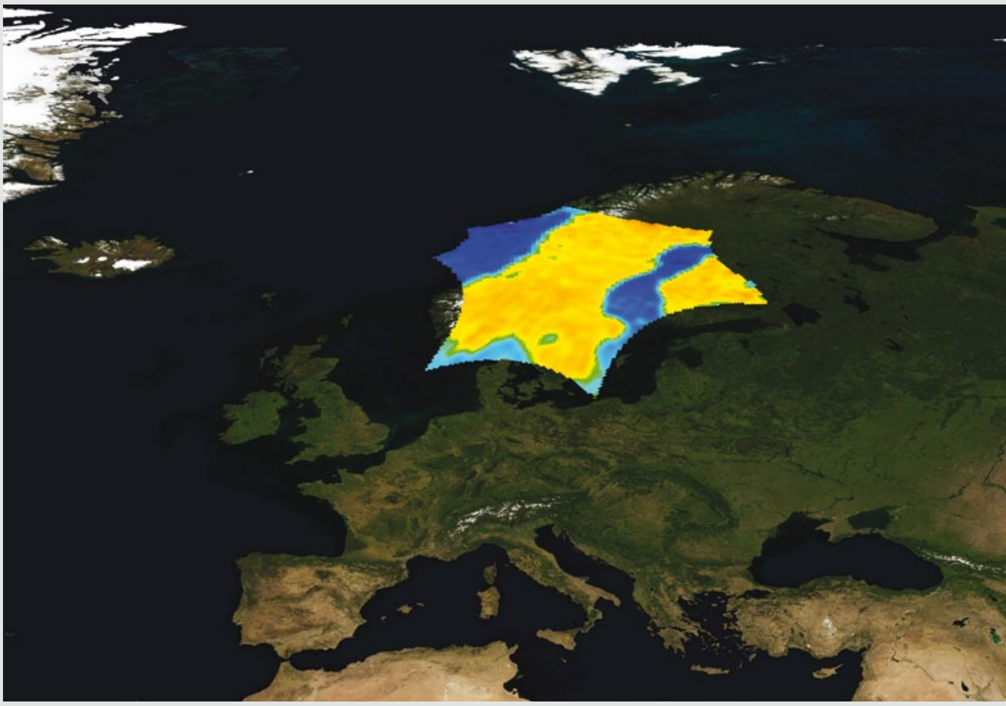
← 15 April 2010: taken at 13.25 CEST by ESA's Envisat satellite, the vast cloud of volcanic ash sweeps across the UK from the eruption in Iceland, more than 1000 km away. Carried by winds high up in the atmosphere, the cloud of ash from the eruption of the volcano under the Eyjafjallajökull glacier in southwest Iceland led to the closure of airports throughout the UK and Scandinavia, with further closures later across northern Europe. The ash, seen as the large grey streak, is drifting from west to east at a height of about 11 km

→ 19 April 2010: taken at 14.45 CEST by Envisat, a second heavy plume of ash from the Eyjafjallajökull volcano is seen travelling in a roughly southeasterly direction. The plume, visible in brownish-grey, is approximately 400 km long



instrument, developed by EADS-CASA in Spain under contract to ESA. Both platform and instrument have shown excellent performance during their first four months in orbit.

Achim Hahne, ESA's SMOS Project Manager, said, "Our development team is extremely happy and proud to see the real performance of the SMOS system in orbit. We are only half-way through the in-orbit commissioning phase and it is rewarding to see these first very promising calibrated products delivered by SMOS."



→ Image of brightness temperature over Scandinavia from SMOS

CRYOSAT-2 LAUNCH SPECIAL

ESA's CryoSat-2 delivered its first data just hours after ground controllers switched on the satellite's sophisticated radar instrument for the first time.

CryoSat-2 was launched on 8 April and has been performing exceptionally well during these critical first few days in orbit. Europe's first mission dedicated to studying variations in our planet's ice cover entered polar orbit just minutes after launch, marking the start of three days of intense activity.

Mission controllers at ESA's European Space Operations Centre (ESOC) monitored CryoSat-2 around the clock to ensure the satellite's systems and payload were functioning normally.

The CryoSat-2 satellite was launched at 15:57 CEST, 8 April, on a Dnepr rocket provided by the International Space Company Kosmotras, from the Baikonur Cosmodrome in Kazakhstan. The signal confirming that it had separated from the launcher came 17 minutes later from the Malindi ground station in Kenya.

Three days later, on 11 April, ESA's Flight Director Pier Paolo Emanuelli declared that the formal Launch and Early Orbit Phase (LEOP) was complete. "The satellite is in excellent condition and the mission operations team quickly resolved the few problems that came up. It's been a very smooth entry into orbit, precisely as planned," he said.

CryoSat-2's primary instrument, the Synthetic Aperture Interferometric Radar Altimeter (SIRAL), was switched on for the first time and started gathering the first radar echo data later that day. SIRAL's first data were acquired and were downloaded and processed at ESA's Kiruna ground station in northern Sweden.

"We switched SIRAL on and it worked beautifully from the very start. Our first data were taken over the Antarctic's Ross Ice Shelf, and clearly show the ice cover and reflections from underlying layers.

↑ Richard Francis, ESA's CryoSat-2 Project Manager (left), Klaus Köble, CryoSat-2 Project Manager from EADS Astrium and Pier Paolo Emanuelli, ESA's Flight Director (right) give the 'thumbs up' after the SIRAL instrument was switched on and delivering its first data on 11 April (ESA/J. Mai)

These are excellent results at such an early stage and are a tribute to the hard work of the entire CryoSat community," said Prof. Duncan Wingham, CryoSat's Lead Investigator.

The satellite is now in a polar orbit, reaching latitudes of 88°, bringing it closer to the poles than earlier Earth observation satellites. This covers an additional 4.6 million square kilometres, an area larger than all 27 European Union member states put together.

CryoSat-2's sophisticated instruments will measure changes at the margins of the vast ice sheets that lie over Greenland and Antarctica and in the marine ice floating in the polar oceans. By accurately measuring thickness change in both types of ice, CryoSat-2 will provide information critical to scientists' understanding of the role ice plays in the Earth system.

"The combined ground teams proved the value of months of extensive training and preparation and the satellite has shown to be a high-quality machine with very few problems. The launch and orbit injection have been almost flawless and we are looking forward to an extremely productive mission," said Richard Francis, ESA's Project Manager for CryoSat-2.

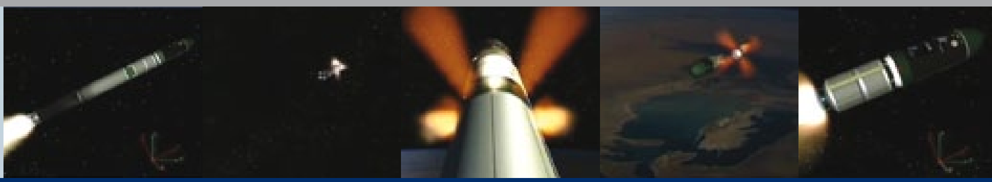
With LEOP complete, ground experts will now put CryoSat-2 through an exhaustive commissioning phase lasting several months, during which the systems on board the satellite and on the ground will be optimised to provide the best-ever ice thickness data from space.

"We are very happy with the first calibration results from SIRAL. The data are now being processed and made available almost immediately to the commissioning teams. We are now optimising the data-processing system and results will be released once we have accumulated enough data," said Tommaso Parrinello, ESA's CryoSat Mission Manager.

Marking a significant achievement for ESA's Earth observation programme, CryoSat-2 is the third of its Earth Explorer satellites to be placed in orbit within a little over 12 months. CryoSat-2 follows on from the Gravity field and steady-state Ocean Circulation Explorer (GOCE) mission, launched in March 2009, and the Soil Moisture and Ocean Salinity (SMOS) mission, launched last November.

↑ 'Gunnar', a polar bear, officially badged on duty as a mascot at ESOC on 8 April

↑ Valeria Bozzi, CryoSat-2 engineer, working at her console at ESOC during the launch event



→ PROGRAMMES IN PROGRESS

Status at April 2010


2006
2007
2008
2009
J F M A M J J A S O N D
J F M A M J J A S O N D
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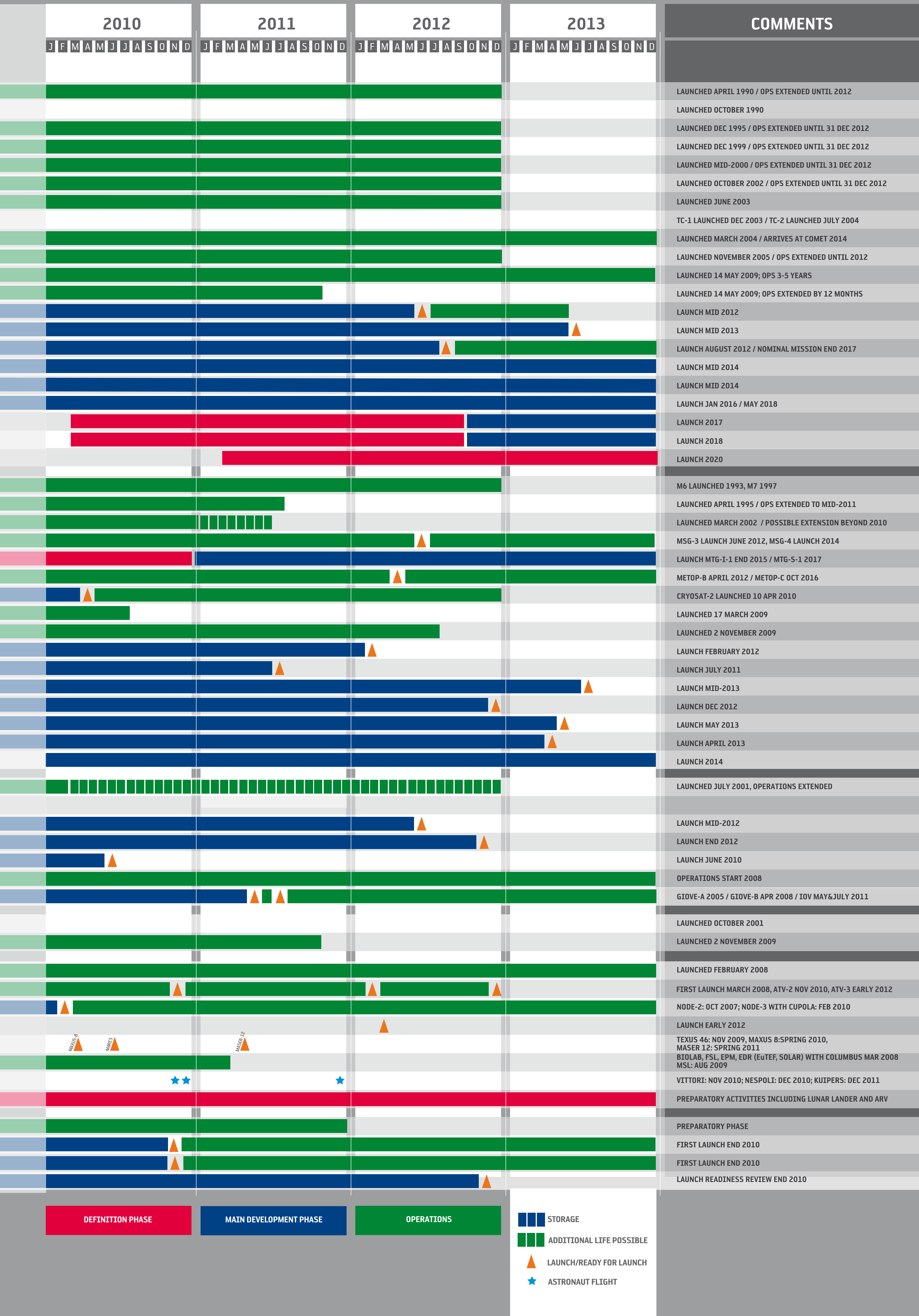
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
ULYSSES
SOHO
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
DOUBLE STAR
ROSETTA
VENUS EXPRESS
HERSCHEL
PLANCK
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
EXOMARS
COSMIC VISION M1
COSMIC VISION M2
COSMIC VISION L1
EARTH OBSERVATION PROGRAMME
METEOSAT-6/7
ERS-2
ENVISAT
MSG
MTG
METOP
CRYOSAT
GOCE
SMOS
ADM-AEOLUS
SWARM
EARTHCARE
SENTINEL-1
SENTINEL-2
SENTINEL-3
SENTINEL-5 PRECURSOR
TELECOMMS/NAV. PROGRAMMES
ARTEMIS
ALPHABUS
ALPHASAT
SMALL GEO SAT.
HYLAS
GNSS-1/EGNOS
GALILEO
TECH. PROG.
PROBA-1
PROBA-2
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS
ATV
NODE-2 / NODE-3 / CUPOLA
ERA
EMIR/ELIPS
FOTON-M3
TEXUS-44
TEXUS-45
MASER-11
TEXUS-46
MFC
ASTRONAUT FLT.
TRANS. & HUMAN EXP.
LAUNCHER PROG.
ARIANE 5 POST-ECA
VEGA
SOYUZ AT CSG
IXV


2010
2011
2012
2013
COMMENTS
J F M A M J J A S O N D
LAUNCHED APRIL 1990 / OPS EXTENDED UNTIL 2012
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LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 31 DEC 2012
LAUNCHED MID-2000 / OPS EXTENDED UNTIL 31 DEC 2012
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LAUNCHED JUNE 2003
TC-1 LAUNCHED DEC 2003 / TC-2 LAUNCHED JULY 2004
LAUNCHED MARCH 2004 / ARRIVES AT COMET 2014
LAUNCHED NOVEMBER 2005 / OPS EXTENDED UNTIL 2012
LAUNCHED 14 MAY 2009; OPS 3-5 YEARS
LAUNCHED 14 MAY 2009; OPS EXTENDED BY 12 MONTHS
LAUNCH MID 2012
LAUNCH MID 2013
LAUNCH AUGUST 2012 / NOMINAL MISSION END 2017
LAUNCH MID 2014
LAUNCH MID 2014
LAUNCH JAN 2016 / MAY 2018
LAUNCH 2017
LAUNCH 2018
LAUNCH 2020
M6 LAUNCHED 1993, M7 1997
LAUNCHED APRIL 1995 / OPS EXTENDED TO MID-2011
LAUNCHED MARCH 2002 / POSSIBLE EXTENSION BEYOND 2010
MSG-3 LAUNCH JUNE 2012, MSG-4 LAUNCH 2014
LAUNCH MTG-I-1 END 2015 / MTG-S-1 2017
METOP-B APRIL 2012 / METOP-C OCT 2016
CRYOSAT-2 LAUNCHED 10 APR 2010
LAUNCHED 17 MARCH 2009
LAUNCHED 2 NOVEMBER 2009
LAUNCH FEBRUARY 2012
LAUNCH JULY 2011
LAUNCH MID-2013
LAUNCH DEC 2012
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LAUNCH APRIL 2013
LAUNCH 2014
LAUNCHED JULY 2001, OPERATIONS EXTENDED
LAUNCH MID-2012
LAUNCH END 2012
LAUNCH JUNE 2010
OPERATIONS START 2008
GIOVE-A 2005 / GIOVE-B APR 2008 / IOV MAY&JULY 2011
LAUNCHED OCTOBER 2001
LAUNCHED 2 NOVEMBER 2009
LAUNCHED FEBRUARY 2008
FIRST LAUNCH MARCH 2008, ATV-2 NOV 2010, ATV-3 EARLY 2012
NODE-2: OCT 2007; NODE-3 WITH CUPOLA: FEB 2010
LAUNCH EARLY 2012
MAXUS-8
MASER-12
TEXUS 46: NOV 2009, MAXUS 8:SPRING 2010,
MASER 12: SPRING 2011
BIOLAB, FSL, EPM, EDR (EuTEF, SOLAR) WITH COLUMBUS MAR 2008
MSL: AUG 2009
VITTORI: NOV 2010; NESPOLI: DEC 2010; KUIPERS: DEC 2011
PREPARATORY ACTIVITIES INCLUDING LUNAR LANDER AND ARV
PREPARATORY PHASE
FIRST LAUNCH END 2010
FIRST LAUNCH END 2010
LAUNCH READINESS REVIEW END 2010
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS
STORAGE
ADDITIONAL LIFE POSSIBLE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

KEY TO ACRONYMS

AM	Avionics Model	MoU	Memorandum of Understanding
CDR	Critical Design Review	PDR	Preliminary Design Review
ELM	Electrical Model	QM	Qualification Model
EM	Engineering Model	SM	Structural Model
FAR	Flight Acceptance Review	SRR	System Requirement Review
FM	Flight Model	TM	Thermal Model
ITT	Invitation to Tender		

→ HUBBLE SPACE TELESCOPE

Hubble is now back in full science operations with a full complement of instruments following Servicing Mission 4 in 2009. The first scientific results are already appearing. For example, Hubble has discovered the smallest Kuiper Belt Object (KBO) to date. This small body, less than 1 km across, provides the first evidence for the existence of a population of comet-sized bodies in the Kuiper Belt.

This object is very faint at magnitude 35, 100 times fainter than what Hubble can image directly. In fact, this small KBO was detected by the Fine Guidance Sensors (FGS), which are the instruments that Hubble uses for pointing. The FGS are so sensitive that they can see the effects of a small object passing in front of a star. This causes a brief occultation and diffraction signature in the FGS data as the light from the background guide star is bent around the intervening foreground KBO.

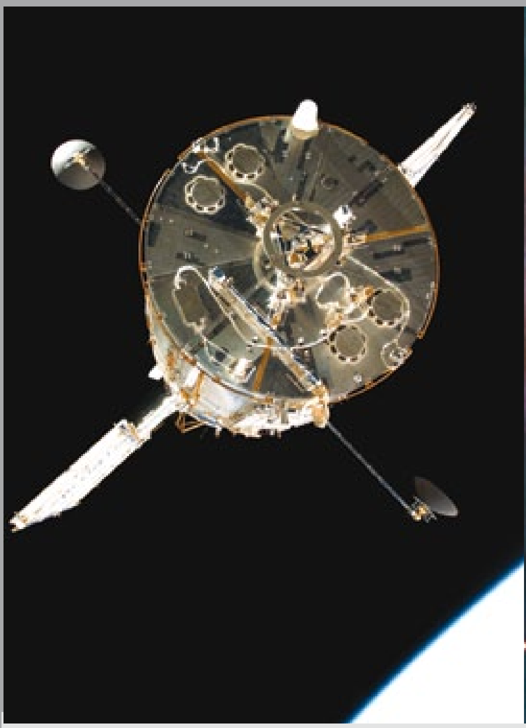
Launched in 1990, Hubble celebrated its 20th anniversary on 24 April.

→ SOHO

What is the origin of the 11-year solar magnetic cycle? The late onset of the new solar cycle and the unusually deep minimum between cycles 23 and 24 took all the experts by surprise, which suggests that there is a fundamental lack in our understanding of the origin of the solar activity cycle.

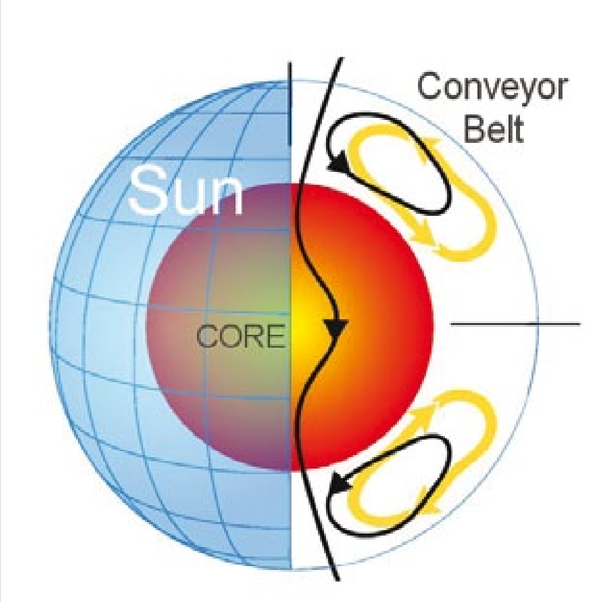
The Sun's meridional circulation is believed to play a key role in determining the strength of the Sun's polar magnetic field, which in turn determines the strength of the sunspot cycles (this circulation is a massive flow pattern inside the Sun that transports hot plasma near the surface from the solar equator to the poles and back to the equator in the deeper layers of the convection zone).

One class of dynamo models predicts that a stronger meridional flow produces weaker polar fields, whereas another class of models predicts stronger polar fields (and a shorter sunspot cycle) for the same flow.



An unusual view of Hubble in orbit, taken from the Space Shuttle STS-125 at the end of Servicing Mission 4 in 2009

This image was released to celebrate Hubble's 20th anniversary. Hubble's Wide Field Camera 3 observed this cloud of cold interstellar gas and dust rising from a stellar nursery in the Carina Nebula, 7500 light-years away, in February 2010 (NASA/ESA/M. Livio/Hubble Heritage Team/STScI)



The Sun's meridional circulation, a large-scale flow that transports solar plasma from the equator to the poles and back, like a giant conveyor belt (Science@NASA)

Analysing more than 60 000 full disk magnetogrammes registered by the MDI instrument on SOHO between May 1996 and June 2009, scientists have measured the latitudinal profile of this flow and its variations over a solar cycle by tracking the motions of small-scale magnetic flux concentrations, which are carried away by the meridional flow like leaves on a river. They found an average flow that is poleward at all latitudes up to 75 degrees and that the flow was faster at sunspot cycle minimum than at maximum, and substantially faster on the approach to the current minimum than it was at the last solar minimum. This finding poses new constraints on solar dynamo models and may help to explain why the last solar minimum was so peculiar.

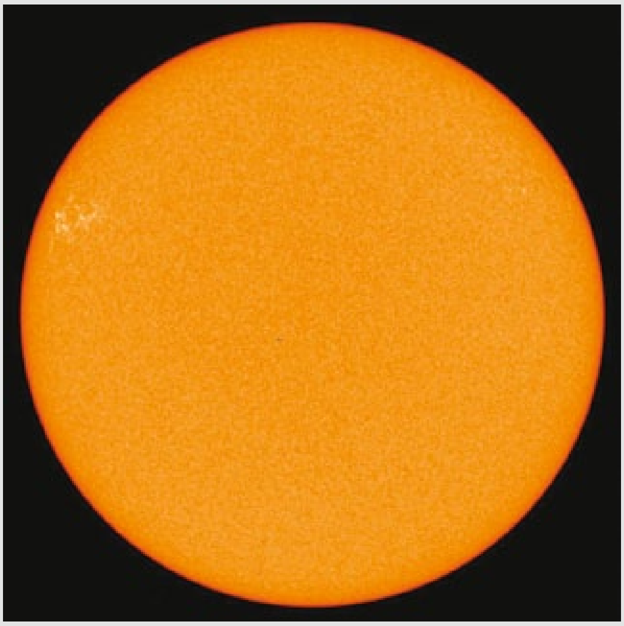


Image of the Sun from the Michelson Doppler Imager (MDI) on SOHO, taken on 21 April 2010, still unusually free of sunspots. As of 23 April, the Sun was officially 'spotless' for eight days in a row (ESA/NASA)

→ XMM-NEWTON

Clusters of galaxies are the largest bound structures in the Universe and can contain many thousands of galaxies, many or all of which contain supermassive black holes. Between these galaxies there is hot gas that emits intense X-rays, making galaxy clusters some of the brightest sources in the X-ray sky. However, just what keeps this gas hot and how it is moving are among the key questions in astronomy today. XMM-Newton has been used to determine, for the first time, the turbulent velocity of the hot gas in the core of a cluster of galaxies (Abell 1385) by measuring very accurately the widths of spectral lines with the RGS spectrometer – the broader the lines, the faster the gas is moving. The XMM-Newton constraint is of key interest in understanding how supermassive black holes interact with the cluster gas and create the large-scale structure seen in clusters.

→ CASSINI–HUYGENS

NASA has extended the Cassini mission to 2017, calling the extension the 'Cassini Solstice Mission'. During its planned 14-year operational period at Saturn, Cassini will span two seasons at Saturn (one Saturn year is 29 Earth years), allowing further study of seasonal effects on Titan, Saturn and Saturn's magnetosphere, but also global seasonal effects in the Saturnian system.

→ CLUSTER

Early this year, the Cluster mission completed its second auroral acceleration region campaign and preliminary data show some exciting results. In one case, two of the satellites were able to sample for the first time the altitude (spatial) variation of electron distributions in the region, when they were located on the same magnetic field line. The other satellites provided a temporal measurement of the evolution of the region.

The satellites are now moving to the dayside magnetosphere to examine the magnetopause, magnetosheath and bow-shock. The Cluster Active Archive continues its success and now has almost 1000 users. The 11th Cross-calibration meeting was held in April in Goslar, Germany, showcasing the great efforts the instrument teams are putting into providing the best high-resolution space plasma data archive to date.

Cluster continues to advance our understanding of space plasma physics. Although not in its original core science targets, the inner magnetosphere is becoming a major focus of Cluster science. A recent paper focused on the creation of so-called 'killer electrons' in the near-Earth space environment. 'Killer electrons' are highly energetic particles trapped in Earth's outer radiation belt. Their name derives from the fact that, due to their energy, they can penetrate the thick shielding of satellites and cause microscopic strikes that can damage and sometimes destroy vital onboard electronic components.

Theories show that several physical processes can accelerate electrons to these harmful energies; the predominant processes are interactions with waves. Using Cluster, along with data from SOHO, Double Star and other geosynchronous orbit spacecraft, scientists were able to track the effect of the impact of a large interplanetary shock wave on the magnetosphere, Earth's protective bubble. Almost immediately after the impact, the radiation belt fluxes started to increase, with Cluster data indicating a two-step acceleration process: first shock-related then wave-related enhancement.

The inner magnetosphere will be a prime focus of Cluster science in the next years, due to the inclination and apogee lowering resulting from the evolution of the orbit, so stay tuned for more!

→ DOUBLE STAR

The Chinese and European operations, project science and instrument teams are now in the archiving phase of the mission, which began with the reprocessing of the raw dataset.

→ INTEGRAL

Operations continue smoothly with the satellite, instruments and ground segment all performing nominally. At the time of writing the spectrometer SPI is being annealed following the usual half-year rhythm.

→ MARS EXPRESS

During February and March 2010 the Mars Express orbit was changed to guarantee in future a better balance between the illumination conditions required by all instruments. This new orbit, a so-called '88:25 resonance', was achieved by making using two main manoeuvres.

As it turned out, this also gave an opportunity to fly by the moon Phobos at very close range several times. This was possible because Mars Express orbits Mars in a highly elliptical polar orbit that brings it close to Phobos every five months. It is the only spacecraft currently in orbit around Mars whose orbit reaches far enough from the planet to provide such close-up views of the largest martian moon.

The final manoeuvre needed to steer close to Phobos on 3 March 2010 showed a slight (but within normal range) over-performance, implying Mars Express would arrive 20 seconds late and at a distance from the surface of around 60 km (instead of the promised 50).

As predicted, there was an occultation of Mars Express by Phobos, meaning a loss of the radio signal right at the time of a very important measurement of the influence of Phobos on the Mars Express radio frequency signal (this radio science experiment would measure the Phobos gravity field with unprecedented accuracy). A special procedure was carried out that effectively delayed mission events with respect to the Phobos flyby, guaranteeing a clean and uninterrupted radio science measurement of the gravity field, although this did increase the distance from the surface to 62 km.

The full Phobos flyby campaign consisted of a spectacular series of twelve close passes between 16 February and 26 March. With two manoeuvres, performed on 21 and 22 March, Mars Express was put into its final orbit.

During the other flybys (at higher altitudes), all the Mars Express instruments were operating. The collected data will help to understand the origin of Phobos, which is still a matter of debate.

Phobos as seen by the High Resolution Stereo Camera on Mars Express on 10 March (ESA/DLR/FU Berlin)

→ ROSETTA

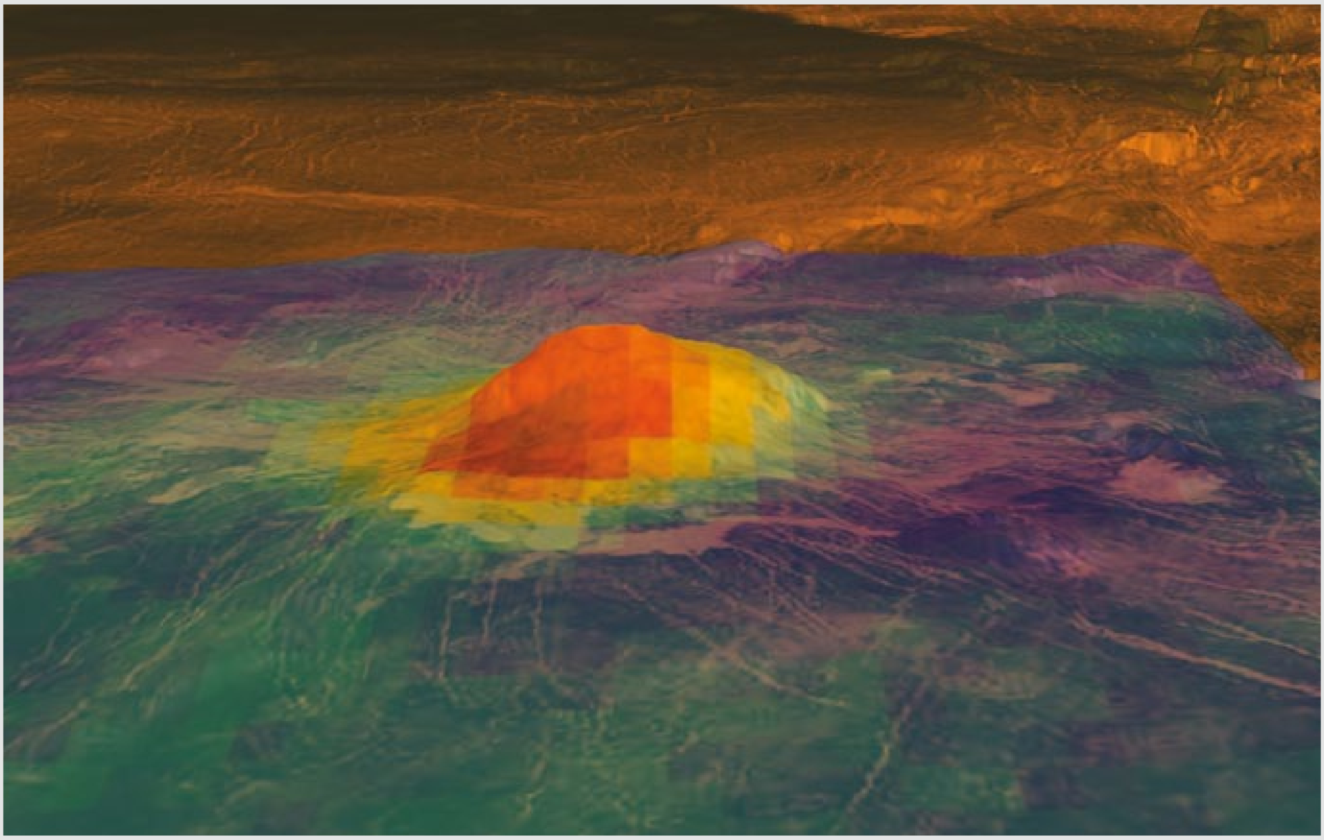
Rosetta is on its way to perform its second close encounter with an asteroid of the main asteroid belt between Mars and Jupiter. The flyby at (21) Lutetia will take place on 10 July, with closest approach at 15:45 UTC. Rosetta will pass the asteroid with a relative velocity of 15 km/s at a minimum distance of 3160 km. The selected flyby strategy allows continuous observations of the asteroid before, during and after closest approach. Most of the scientific instruments on Rosetta will be switched on for investigations. Imaging and spectral observations will be obtained covering ultraviolet to sub-millimetre wavelengths. A number of *in situ* measurements will be made of the asteroid as well as of its direct environment.

The target (21) Lutetia is a large asteroid with an estimated diameter of about 95 km. It has been classified to be either of C-type or of M-type, meaning that remote-sensing observations have shown features that hint at characteristics of carbonaceous chondrite (a type of meteorite that contains organic chemicals and water), but also to a metallic surface composition. This contradiction makes (21) Lutetia an extraordinarily interesting object for close inspection from space.

→ VENUS EXPRESS

Venus Express continues to run smoothly. The natural evolution of the orbit is reducing the pericentre altitude (i.e. the closest approach) by 1–3 km per day. This is compensated for by regular orbit maintenance manoeuvres but also gives opportunities to probe the upper atmosphere by measuring the atmospheric drag through precise orbit tracking. Another technique, measuring the torque caused by asymmetric forces on the spacecraft during pericentre passes, has been tried recently. These two independent techniques have revealed that the atmospheric density in the 170–180 km range is significantly lower than earlier thought.

Data from VIRTIS infrared measurements of thermal radiation, combined with altimetric and gravity data from the Magellan spacecraft, have shown that some areas of volcanic origin have surface ages as young as 250 000 years, or possibly even younger. These major results were published by S. Smrekar et al, in *Science* in April. The mountains Idunn Mons, Innini Montes and Hathor Montes were found to have distinctly higher thermal emissivities, which indicates a low state of weathering and therefore a fresh surface.



3D image of the Imdr Regio on Venus, showing a higher emissivity at Idunn Mons (centre) compared to the surrounding terrain. The image is a combination of a SAR image from Magellan in grey and emissivity from VIRTIS on Venus Express in colour (JPL/INAF/DLR/NASA/ESA)

These results are of great importance since they provide an answer to the long-standing question about the resurfacing of Venus. It is well established that the general age of the surface of Venus is between 500 and 1000 million years old, or geologically speaking, very young. But the big question was if there has been a gradual modification region by region, by volcanism and other processes, or if all places were overturned more or less simultaneously in a global cataclysm. The new results indicate that the former case is the more likely, making Venus more Earth-like and easier to understand.

→ HERSCHEL

For SPIRE and PACS, Herschel entered its Routine Science Phase. The Science Demonstration Phase was mostly completed for these instruments with only a few observations remaining to be done.

Using the redundant branch of the instrument's signal electronics chain, HIFI recovery has been successful. Following a partial repeat of the Commissioning Phase activities and a full Performance Verification Phase, the instrument is being given approximately 50% of the available observing time to complete its Science Demonstration Phase in time for the Call for Open Time proposals that will be issued in May 2010.

Also in May 2010, about two weeks before this Announcement of Opportunity, the ESLAB 2010 symposium will be held at ESTEC, Noordwijk, to present the Herschel 'first results'. Almost 400 attendees had registered before registration closed. 153 papers have been submitted for publication in the Herschel special issue of *Astronomy & Astrophysics*. These first written scientific publications of Herschel results will appear in Summer 2010.

→ PLANCK

The Planck spacecraft, payload and ground segment operations continue to work nominally, providing excellent data. By mid-April, Planck had completed eight months of routine operations and in this time has surveyed the sky with no gap in the survey strategy. On 16 April, full coverage of the sky was reached for detectors LFI 24, 27 and 28. Full coverage for the remaining detectors at all wavelengths will be achieved by 3 June.

→ COROT

COROT continues to operate normally after over 1250 days in space and its mission has been extended to May 2013. On 9 April the telescope was pointed towards its 14th field. The satellite is currently in a very productive phase, with over 500 scientific articles published since operations began in March 2007.

Herschel's infrared view of the Rosette nebula. The bright smudges are dusty cocoons containing massive protostars. The small spots near the centre of the image are lower-mass protostars (ESA/PACS/SPIRE/HOBYS)

Among recent results, the first 'temperate planet', CoRoT-9b, i.e. a planet where the blackbody temperature is consistent with the possibility of the existence of liquid water, has been discovered. The planet itself is of the gas-giant type but investigations are in progress to find out if it has any large moons. Another recent observation was the detection of 'p-mode' oscillations in a solar-type star that also possesses a planet.

→ AKARI

Akari has issued two new all-sky survey infrared catalogues, surpassing the predecessor IRAS in sensitivity, wavelength coverage and spatial resolution after 25 years. The Akari-IRC Point Source catalogue contains around 70 000 objects in two bands (9 and 18 microns), and the Akari-FIS Bright Source Catalogue contains over 430 000 celestial sources in four infrared bands centred at 65, 90, 140, and 160 microns.

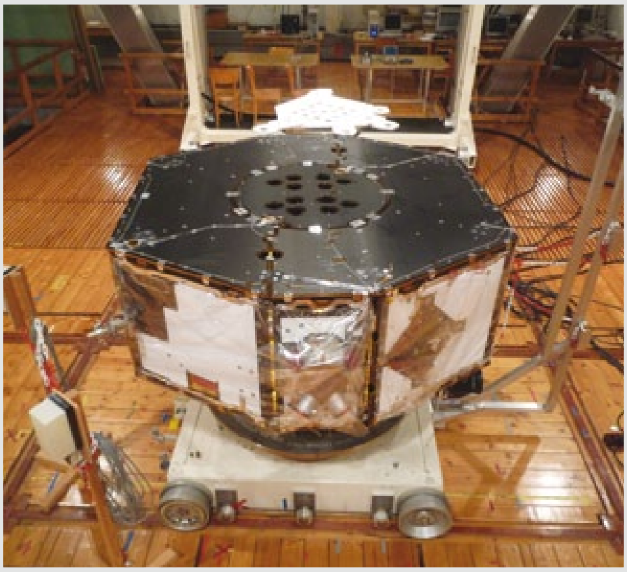
All-sky surveys are an essential tool for astronomers. The large numbers of objects that are detected in these surveys lend themselves to classification and statistical analysis of celestial bodies. The astronomical census that results from a multi-wavelength, all-sky survey provides a firm framework on which to build a deeper understanding of the formation and evolution of galaxies, stars and planetary systems.

→ LISA PATHFINDER

The Science Module has completed the system magnetic test in the special wooden facility in IABG, Munich. Now the spacecraft FM has been shipped back to Astrium Ltd, Stevenage, UK. Some FM units have been temporary disassembled from the spacecraft to allow further unit testing. They will all be put back on the spacecraft later this year, when most of the LISA Technology Package (LTP) units will also be integrated.

The propulsion module FM structure, propulsion components and units have all been delivered. The integration is nearly finished and the module will be shipped to IABG for the Transfer Orbit Thermal Balance/Thermal Vacuum test at the end of April. In parallel, a Science Module SM (based on a flightworthy structure and equipped with many flight units) is finishing integration before shipping to IABG. The two modules will be mated at the test facility and tested in launch configuration. The verification of the onboard software is continuing on the Software Verification Facility (SVF) and on the two parallel Real-time Test Benches at Astrium Ltd for the Attitude Control and System Control aspects and in Astrium GmbH for the Drag-Free Attitude Control.

The work to define the changes required for the caesium slit thruster unit was nearly complete and a series of material and accelerator tests have started. This extensive test campaign is aimed at the definition of the best thruster configuration to be subsequently submitted to the qualification tests.



LISA Pathfinder Science Module Flight Model during the system magnetic test in the special magnetic facility in IABG, Munich, in February

The American Disturbance Reduction System payload flight hardware is mechanically and electrically integrated on the Science Module. The suppliers of the various parts of the European LISA Technology Package (LTP) delivered all the ELM units to Astrium GmbH and they have been extensively tested on the Real-time Test Bench or on the Optical Measurement test facility at the Albert Einstein Institute in Hanover.

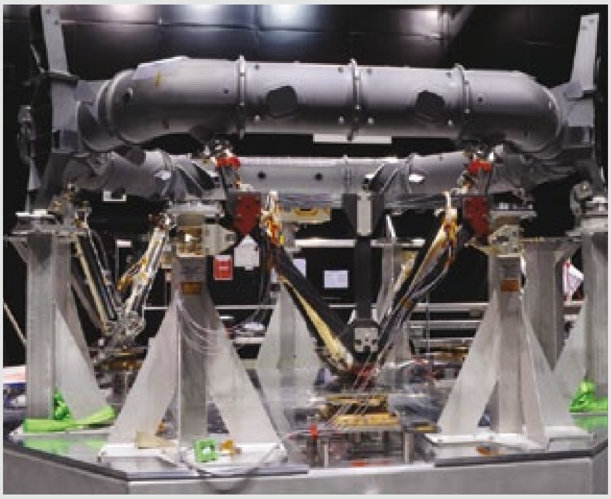
During the last months, the Laser Assembly and Phasemeter Unit and the Optical Bench FMs have also been delivered and are being accepted by the LTP integrator. The inertial sensor with the caging mechanism, the electrode housing and the vacuum system together with the Phasemeter photodiodes and the UV light unit remain the most critical items, due to their technological challenges.

The launch is not expected to take place before mid-2012.

→ GAIA

The Gaia assembly integration and test activities are gaining momentum at Astrium SAS and Astrium Ltd, UK.

In Toulouse, the assembly of the Payload Module SM is ongoing. The three bipods, the isostatic interfaces between the optical bench and the Service Module, are under



The Gaia Payload Module optical bench ('torus') with the first two bipods integrated in the cleanroom at Astrium SAS, Toulouse

integration. The folding optical structure, a very complex structural element in silicon carbide that will support part of the optics, has passed all mechanical tests and is ready to be glued on to the primary structure (the 'torus'). The key elements of the Focal Plane Assembly SM have been delivered, therefore allowing integration to start. The Focal Plane EM is being prepared for thermal vacuum testing.

At Astrium Ltd, Stevenage, the integration on the Service Module FM of the chemical propulsion subsystem, elements of the micro-propulsion subsystem and thermal hardware is progressing. Activities on the spacecraft Avionics Model continue, with the first engineering model units of the instrument integrated and tested.

The design consolidation of the Deployable Sun Shield is continuing and a new design of the blanket-holding mechanism has been tested. Additional tests are still needed before it can be confirmed that the planned combination of local modifications will enable the current baseline deployment concept to be kept. In parallel, a back-up solution with motors is being studied.

The new micropropulsion thruster (cold gas), with modified design, completed the tests in thermal vacuum, showing nominal performances. A second thruster is being assembled to confirm that performances are repeatable.

The Payload Module CDR was completed. For the first time, the expected accuracies (astrometry, photometry and radial velocity) were presented, considering all end-of-life radiation effects and a proposed calibration approach. The performances were reviewed by the scientific community and will be consolidated for the forthcoming spacecraft CDR.

→ MICROSCOPE

The integration of the Sensor Unit QM is ongoing. The first drop-test is planned at ZARM's freefall tower in mid-June. The FM2 of the Front-end Electronic Unit was delivered following the Proto-flight Model 1 delivery last month, and functional tests on both models are now running. The payload software included in the payload Interface Control Unit is under validation.

Activities on the proportional micropropulsion thruster (cold gas) are continuing, both at satellite level and subsystem level. A survey of the technical options to fulfil the mission needs was presented to a CNES Review Board.

→ JAMES WEBB SPACE TELESCOPE

The NASA JWST project has passed the Mission CDR, pending resolution of a few issues. The Engineering Development Unit primary mirror segment has been repolished to null-out the measured cryo-deformation at operating temperature (40K) and it now exceeds specifications. Out of the 21 Primary Mirror Segment Assemblies, 15 are fully assembled for initial test

The JWST NIRSpec Engineering Model being unpacked at NASA Goddard Spaceflight Center

Incoming inspection JWST MIRI Structural Model at NASA Goddard Spaceflight Center

operations and 11 have already completed the cryogenic hit map testing.

The ESA contribution to JWST consists of the launch of JWST with an Ariane 5 ECA, two out of four scientific instruments, i.e. the Near-Infrared Spectrograph (NIRSpec) developed by ESA and the Mid-Infrared Instrument (MIRI) developed by a consortium of European institutes, and support to the science operations.

The NIRSpec full-scale Development Model was delivered to NASA in February. Integration of the flight instrument is proceeding well. Three flight subsystems remain to be delivered: the detector system, the microshutter system and the grating wheel assembly.

The MIRI SM was delivered to NASA in March. The completion of the MIRI flight subassemblies is proceeding. The two flight dichroics/grating wheels have completed their acceptance tests and been integrated into the spectrometer, which is now ready for delivery to Rutherford Appleton Laboratories (UK) for instrument integration. Two subsystems remain to be delivered: the input calibration optics, which are in final testing before delivery, and the Detector System, which is currently undergoing some investigations due to data dropouts.

Activities on the launcher are progressing: a Final Couple Load Analysis has been started to confirm the launcher system performance.

→ BEPICOLOMBO

The spacecraft development is proceeding in the C/D phases with detailed design activities on system and equipment level. Approximately 40% of the equipment has passed the PDR and manufacturing of the SM and ELM hardware is ongoing. Performance characterisation tests on candidate solar cell assemblies at high temperature and high solar intensity were completed, as well as structural analyses for the solar array substrates. This allowed final selection of the substrate materials and final selection of the solar cell type and configuration is imminent. This milestone permits a starting the solar array qualification programme.

The critical area remains the mass and this is being closely monitored. Although margin is still available, the dry mass has grown as a consequence of final detailed equipment designs. Mass risks remain on equipment that has not yet passed PDR. A number of items of equipment are driving the overall schedule owing to the complexity, late definition of detailed interfaces and procurement schedules of some long lead-time items. Some recovery measures are being implemented and others are under investigation.

The instrument general requirements were mostly completed for the FM phase. The MPO Payload Acceptance Reviews for the SM started in March 2010 and the complete set of SMs will be delivered in July for integration in August/September. In parallel, the EMs are being completed and tested against the spacecraft interface simulator at the instrument premises, in order to ensure a smooth delivery and acceptance in autumn 2010.

The TM test of the Japanese MMO at one Solar Constant (SC) was completed at the Tsukuba Space Centre in Japan. The TM is awaiting shipment to ESTEC for the ten SC test in the Large Space Simulator, now shifted to September.

The Ariane 5 preliminary mission analysis review is being held and the coupled loads analysis was started.

Launch is planned for the Mercury launch opportunity in mid-2014.

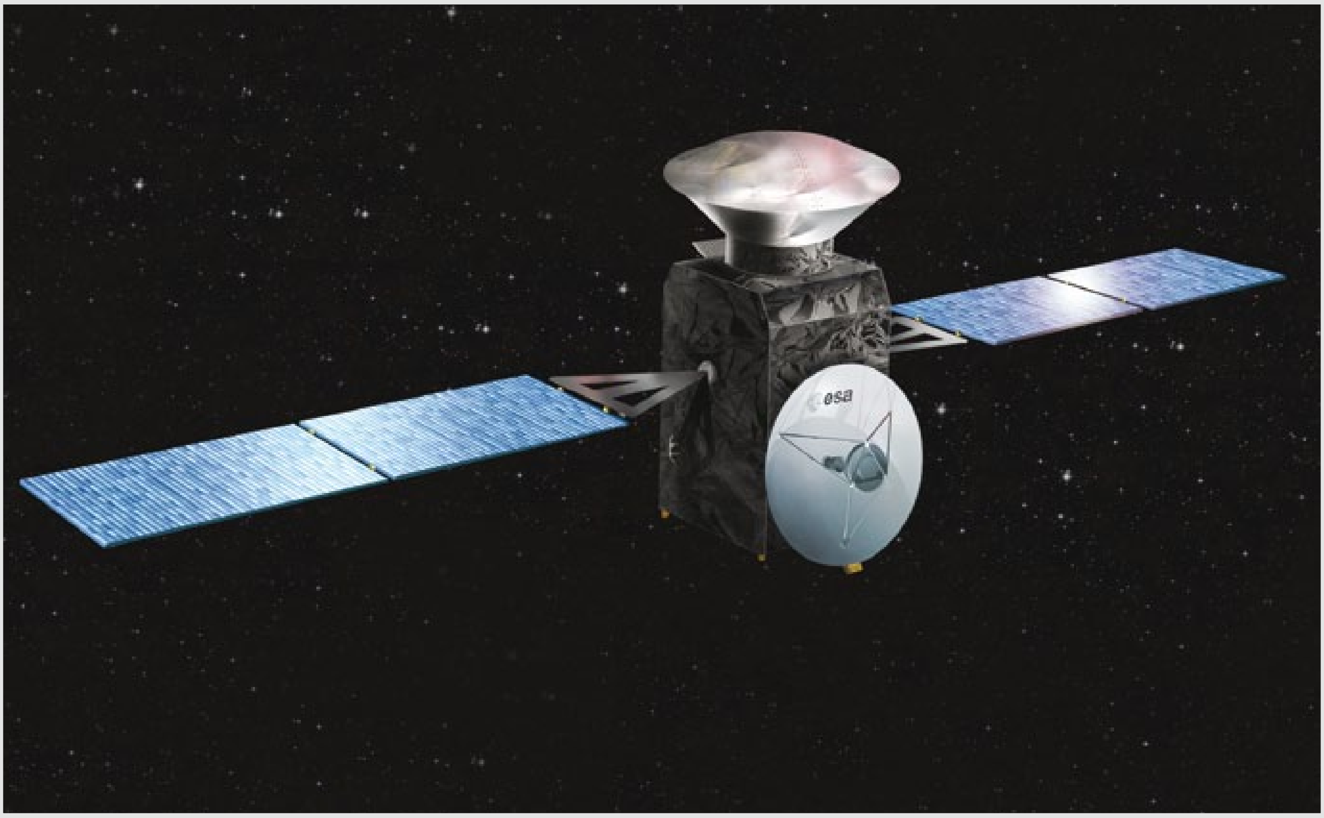
→ EXOMARS

The ExoMars programme now consists of two cooperative missions with NASA, using NASA-provided launchers in 2016 and 2018. The changes to the baseline documentation and industrial structure necessary to support the new architecture for the programme have been implemented. The first tangible product of the newly established joint exploration cooperation with NASA has been the issue of the Joint Announcement of Opportunity (AO) for Trace Gas Instruments for the 2016 Orbiter mission. The AO was publicly released on 15 January, open to proposals from US and European principal investigators.

Negotiations with the European industrial team were started in preparation for the next phase of activities to start on 1 April. One year of detailed design work is foreseen, with a System PDR to be completed on 13 December followed by delivery of an industrial price proposal for the implementation phases (C/D/E1).

Substantial design work at system and sub-system level has been completed for the Orbiter Module and the Entry, Descent and Landing Demonstrator Module. These two modules make up the Spacecraft Composite, which will be launched to Mars in January 2016.

The Rover Module is the main contribution from ESA on the 2018 mission, with NASA providing a second rover and the spacecraft to transport and land the rovers on Mars. The schedule of the development of the Rover has been modified substantially to align the development with that of NASA. The Rover Module technology developments will proceed to reduce known risk areas, such as the software, the sample processing system for the Pasteur Payload and the drill system.



The Spacecraft Composite for the ExoMars 2016 mission, for orbital trace gas investigations and demonstration of entry, descent and landing technologies

→ SMOS

The commissioning of the MIRAS instrument and the ground data processing is continuing as planned.

After the initial debugging and tuning of the processor, Level 1 data products have been released to the calibration/validation science team. The instrument is switched on a weekly basis between dual polarisation and full polarisation modes, in order to allow scientists to evaluate the respective merits of the two modes in their impact on Level 2 data products. In parallel, instrument calibration tuning, in particular for the frequency of the local oscillator, are continuing.

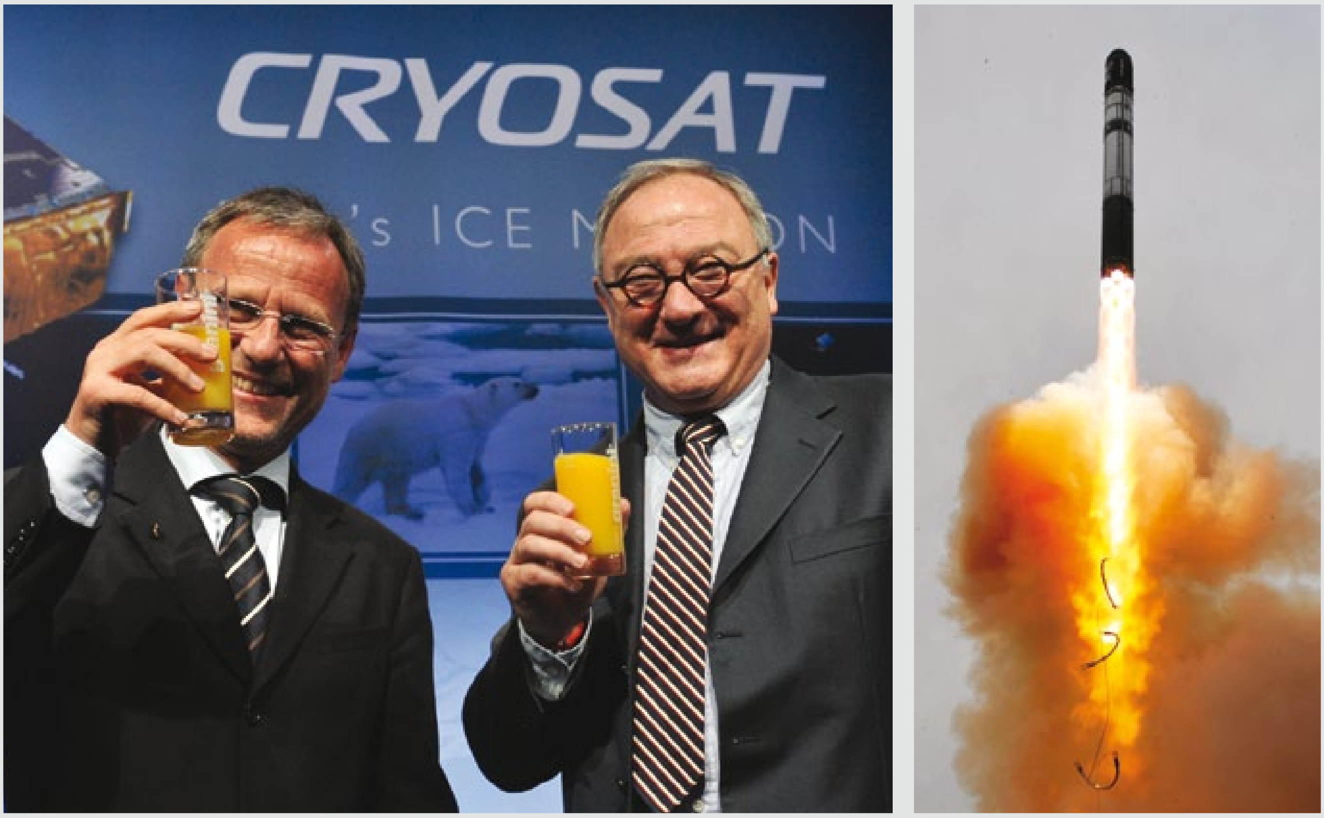
In reaction to the radio-frequency interference from the ground which has been detected, two solutions for mitigation are being pursued: the formal route through the national and international telecommunication authorities, and a practical one of looking into ways to minimise and possibly completely remove the impact of ground interference by signal processing. In the case of Spain, significant improvements of the situation are already reported.

→ CRYOSAT

The launch campaign in Baikonur proceeded according to schedule until one week before the planned launch on 25 February. At that point the launch service provider announced a delay in order to make a software modification on the launch vehicle, required to improve the fuel consumption in the second stage.

The spacecraft, which had already been integrated onto the launcher in the silo, was then removed and returned to the integration facility for storage. The launch campaign resumed on 23 March and went exactly according to plan, leading to a launch on 8 April 2010.

The orbital injection was very precise, with an altitude only 108 m higher than the target orbit. The satellite telemetry signal was received at the Malindi ground station in Kenya. The period immediately after launch, called the Launch and Early Orbit Phase (LEOP), also went very smoothly and the satellite's payload, the SIRAL radar, was switched on three days after launch. The first results from this are extremely promising: one early comment was that they were so good that they looked like simulations.



ESA Director for Earth Observation Volker Liebig (left) and Jean Jacques Dordain, ESA Director General, celebrate the launch of CryoSat-2 at ESOC on 8 April (ESA/J. Mai). Right, CryoSat-2 launch on Dnepr rocket (ESA/S. Corvaja)

→ ADM-AEOLUS

The Aeolus satellite platform has passed the Qualification Review and is now ready for storage. Now the programme activities are concentrated on completion of the transmitter laser and implementation of the contamination prevention gas system.

Integration of the first FM of the ALADIN laser is continuing, but has been stepped back until the root causes of slow energy losses observed on the EM are determined.

In parallel, modifications on ALADIN and the platform are being designed and tested to avoid the darkening of the transmission optics from trace amounts of organic material. This involves partial sealing of the laser and transmitter optics, as well as addition of the gas handling system to the platform to generate a low-pressure gas environment for the high power optics.

→ SWARM

The FM of the structure for the second satellite, equipped with the cold-gas propulsion subsystem, was delivered. Delivery of the third structure is planned in May. Meanwhile, the integration of the first satellite is keeping pace with equipment/instrument deliveries. Qualification testing of the satellite boom has been completed.

Back-up plans have been put in place in order to mitigate the delivery delay of the Accelerometer (ACC) and the Electrical Field instrument (EFI) instruments against the assembly, integration and test activities at satellite level.

The ground segment development is ongoing. The first satellite system verification test (SVT) was performed in March with positive results. No blocking points were detected by ESOC in executing the foreseen procedures, and the problems encountered during this test were processed as normal work. This test is confirming the level of maturity of the satellite software with regard to ESA command and control requirements.

Rockot has been selected as the baseline launch vehicle for the Swarm mission. Technical activities began in March, followed by the official contract signature between ESA and Eurockot on 9 April.

The development schedule of the adapter/dispenser, specific to Swarm, coupled with the delay in starting activities, gives a likely launch date in mid-2012. Ways to improve the planning are being discussed with Eurockot.

The optical bench of the second Swarm satellite as mounted on the characterisation facility, developed specifically for Swarm at the Calar Alto Observatory in Spain, for the calibration of the Euler angles

→ EARTHCARE

The EarthCARE industrial team closed the PDR in spring 2010. Most actions resulting from the PDR have been completed for the base platform, Broadband Radiometer, Multi-Spectral Imager and Avionics.

The ATLID bistatic configuration has been further detailed to allow preparation for the ATLID Instrument PDR, started at the end of March with a presentation and the release of the data package. In parallel, support activities to confirm assumptions regarding laser-induced contamination mitigation have been started.

The Cloud Profiling Radar activities in Japan are progressing for the SM and for the EM, which underwent thermal vacuum testing in March.

Equipment procurement under the Best Practices scheme continued during the last quarter but the procurement of the structure and solar array has been delayed to ensure that the ATLID Instrument PDR outcome confirms the spacecraft-to-ATLID interfaces and budgets.

MetOp PLM-1/PLM-3 taken out of storage at Astrium GmbH

→ METOP

All MetOp-A instruments continue to perform excellently in orbit. The HRPT continues to be operated in a restricted coverage area and LRPT operation was discontinued by Eumetsat.

MetOp-B and MetOp-C

Following finalisation of the integration activities on the Payload Module (PLM-1) for Metop-B, further testing has been completed. The thermal vacuum set-up pre-test was completed in February as planned and the actual thermal vacuum test was delayed to July 2010, due to unavailability of the Large Space Simulator (LSS) at ESTEC.

With the Service Module (SVM-1) for MetOp-B taken out of storage in April, industrial activities have been restarted. MetOp-B is planned for launch in April 2012.

PLM-3 will also be taken out of storage in April, allowing Astrium GmbH, Friedrichshafen, to continue working while waiting for the LSS to become available for the PLM-1 thermal vacuum test.

The satellite assembly and integration activities (PLM and SVM) are planned to start at the end of 2010. MetOp-C is planned for launch in October 2016.

→ METEOSAT

Meteosat-8/MSG-1

MSG-1 is in good health with instruments performing normally. It continues to provide the Rapid Scan Service, complementing the full-disc mission of the operational Meteosat-9.

Meteosat-9/MSG-2

Meteosat-9 is Eumetsat's operational satellite at 0° longitude, performing the full-disc mission (one image every 15 minutes on 12 spectral channels). Satellite and instruments are performing excellently.

MSG-3

MSG-3 is in long-term storage in Thales Alenia Space Cannes. A change request has been issued to industry to cover all satellite activities, starting after leaving storage in spring 2011 up to return to Europe after the launch campaign.

MSG-4

Assembly of the new SEVIRI Drive Unit (DU) is close to completion. Once the qualified DU is available, dismounting activities on the satellite will be started. After reintegration of the DU, the satellite will be submitted to mechanical, acoustic and reference testing.

→ METEOSAT THIRD GENERATION

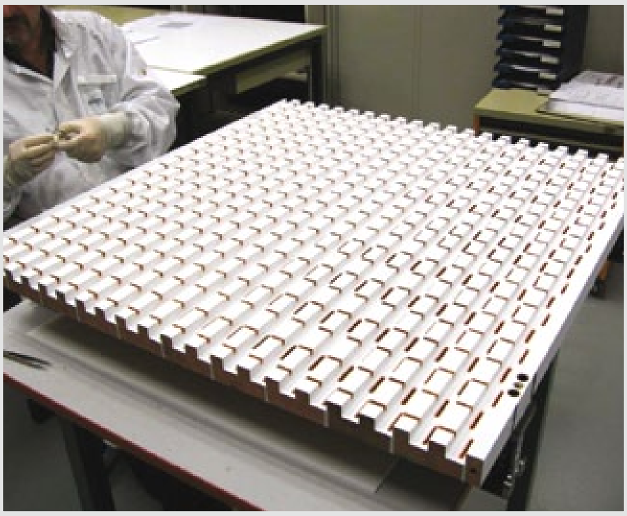
Following the Technical Evaluation Board recommendation of the preferred supplier, the project started negotiations with the selected consortium. These have been successful and the necessary improvements to the industrial offer agreed.

More detailed negotiations are scheduled for May with a view to submitting the Contract Proposal for Phases B2, C/D (and support to Phase E) to the Industrial Policy Committee at the end of June.

→ SENTINEL-1

The contract and associated rider 2 between the prime contractor, Thales Alenia Space Italy, and their main subcontractor, Astrium GmbH, were signed in April.

Procurement of the launcher for Sentinel-1A has progressed, following the Tender Evaluation Board recommendation for the procurement of launch services for a Soyuz from Kourou. Negotiations are ongoing. Consolidation of the Optical Communication Payload interfaces progressed with the activities defined at the Interface Requirements Review (IFRR). The freeze of the interfaces between the Laser Communication Terminal and Sentinel-1 is planned before the Sentinel-1 CDR.



Sentinel-1 SAR Tile Structural Model (Astrium GmbH)

Significant progress has been made on the Waveguide Radiators (under Astrium GmbH), with the qualification process completed and the required production rate demonstrated. Integration of the Tile SM was completed and this is currently undergoing environmental qualification tests.

The production lines of the SAR Antenna Electronic Front-end modules (under Thales Alenia Space Italy) have been relocated back to L'Aquila, one year after the earthquake. The ELM models are undergoing their assembly, integration and test campaign.

→ SENTINEL-2

Equipment CDRs are being conducted at platform and payload instrument level, with the objective of organising the Payload Instrument CDR and the Satellite CDR before the end of 2010. Critical payload instrument detection chain equipment and components (EMs) are now being delivered to initiate the instrument EM test programme.

A first version of the basic onboard software was tested on a breadboard of the onboard computer, using the satellite EGSE that was already delivered.

The Optical Communication Payload delivered as a costumer-furnished item from DLR to complement the satellite operational X-band data transmission system is under an Interface Requirements Review.

The two Sentinel-2 launcher preparatory contracts are being finalised, in time for the issue of the launch service procurement ITT in June 2010.

At system level, the Sentinel-2 Ground Segment PDR is planned for autumn 2010. This review will allow the release of the Flight Operations and Payload Data Ground Segments procurement activities.

→ SENTINEL-3

Sentinel-3 C/D detailed design activities are under way, with several lower-level equipment CDRs already completed and the remaining planned for the summer. Instrument and Satellite CDRs will follow later in the year. At Ground Segment level the Sentinel-3 Ground Segment PDR is ongoing.

Contractually, the execution of the procurement tasks through competitive ITTs is proceeding in all fields. At Space Segment level, out of around 120 procurement contracts to be placed, only five have still to be started while few others are in the final stages of negotiation.

Manufacturing of both EM and SM hardware has started for most of the subcontractors and, in a few cases where reuse of already qualified or time-critical hardware is involved, manufacturing of flight hardware has started. Testing at EM and STM assembly levels has also started.

On the launcher side, support studies are still taking place with both the Vega and Rockot organisations, while the ESA documentation to support the selection of the nominal Sentinel-3 launcher through an ITT process is being prepared. The ITT will be issued before the summer.

On satellite issues, the mass is still critical but remains under the 1250 kg launch capability of Vega and Rockot, including adequate system and maturity margins at this point of development. The energy and power margins are positive for the nominal satellite mode throughout the mission lifetime, including life extension.

There are no major technical issues for the SAR Radar Altimeter, where antenna and some lower-level CDRs have been completed. On the Ocean Land Colour Instrument, the development of the Scrambling Window Assembly was accelerated to secure the performance and schedule of the subsystem. On the Microwave Radiometer, the SM test campaign is almost complete, allowing confirmation of the selected design. Manufacture of the Sea and Land Surface Temperature Radiometer Structural and Thermal Model (STM), started in January.

Finally, a staggered release of structural elements (e.g. skins, individual panels, inserts) was chosen because a number of analyses still had to be concluded. Other subsystems progressed well, several reaching readiness for STM testing, among them the flip mechanism and the blackbodies, while the Visible Calibration (VISCAL) unit is about to reach this level.

→ SENTINEL-5 PRECURSOR

The ITT for the Sentinel-5 Precursor system and spacecraft was published in October 2009. Two offers were received and evaluated in April 2010. The Tropospheric Ozone-Monitoring Instrument (TROPOMI) payload will be provided as an In-kind Contribution by the Netherlands and its development has reached PDR level. The procurement for the TROPOMI payload complement, led by the TROPOMI prime contractor Dutch Space and financed by ESA, began in March. The sub-assembly ITTs have also been published.

→ GALILEO

Both GIOVE-A and B satellites are fulfilling their mission and sending regular data, used not only by ESA's Navigation Laboratory, but also by scientific institutes around Europe.

Jean-Jacques Dordain, ESA Director General, René Oosterlinck, ESA's Director of Galileo and Navigation-related Activities, and Jean-Yves Le Gall, Chairman of Arianespace, at the signing of the contract for Galileo launch services in January

Galileo IOV

The EM is now complete, the two platforms – satellite and payload – have been mounted and the spacecraft is undergoing the full range of tests. The four In-orbit Validation satellite platforms are now at Thales Alenia Space Italy at various levels of integration.

Galileo FOC

Towards Galileo's fully operational capability (FOC), three major contracts were signed on 26 January at ESTEC: with OHB Germany, who teamed up with Surrey Satellite Technology Ltd (UK), which was assigned the construction of 14 satellites; with Arianespace for five Soyuz launches from Kourou; and with Thales Alenia Space Italy for system activities support.

→ VEGA

The mitigation plan related to the Vega Flight Programme Software is being implemented. The executable prototypal code and relevant documentation has been delivered.

The modification of the Z9A igniter was fully modelled and implemented, leading to igniter tests and a motor firing test in May.

Following signature of the Customer Service Improvement contract, system activities for the multiple payload missions have been started.

The P80 Thrust Vector Control qualification test campaign has been completed, allowing the start of the qualification review. Activities related to the Ground Segment are proceeding with the completion of integrated tests and the acceptance of the mechanical subsystems.

→ SOYUZ AT CSG

After all the containers for the structural elements of the mobile gantry were delivered to the Soyuz launch area, the first containers with the mobile platforms were delivered in January.

Structure levels from 0–39 m are now fully integrated. The level 39–45 m has been fully integrated on the ground, ready for lifting. The mobile platform levels at 18, 21 and 24 m are integrated in the mobile gantry and the remaining ones are ready on the ground. The covered roof of the mobile gantry will be in place by early May.

On the Russian systems, mounting activities are completed (gas system pipelines in the launch table ring) or near completion (liquid oxygen/liquid nitrogen store).

For Soyuz Launch System qualification, the technical qualification phase relevant to Mechanical (MECA-1) and gas (GAZ-1) campaigns are near completion. Final acceptance reviews are scheduled in April for GAZ-1 and May for MECA-1.

A Consultation Committee is planned in May with participation of the Russian team at CSG, to mark the delivery of the mobile gantry structure to the European site and the consolidation of planning until launch.

→ FUTURE LAUNCHERS PREPARATORY PROGRAMME

Next Generation Launcher (NGL)

Negotiations on system activities, which will cover further investigations of the selected concepts for Next Generation Launcher, are close to completion.

As part of the High Thrust Engine (HTE) Demonstrator activities, in parallel to the activities at technology level, the Preliminary Requirement Review for the HTE Demonstrator was completed in March. The next milestone, the Architecture Key Point, was set with the objective to select a reference architecture (in particular in terms of HTE functional cycle and mechanical architecture).

A HTE industrial day, hosted at DLR Lampoldhausen, gave the opportunity to share the achievements and perspectives of the HTE Demonstrator with industrial partners and Future Launchers Participating States in February.

Activities on the Storable Propulsion demonstrator began in March. The development of Cryogenic Upper Stage Technologies (CUST) has had its first reviews, in particular for the 'sandwich common bulkhead' technologies, for which a sample test campaign was also initiated.

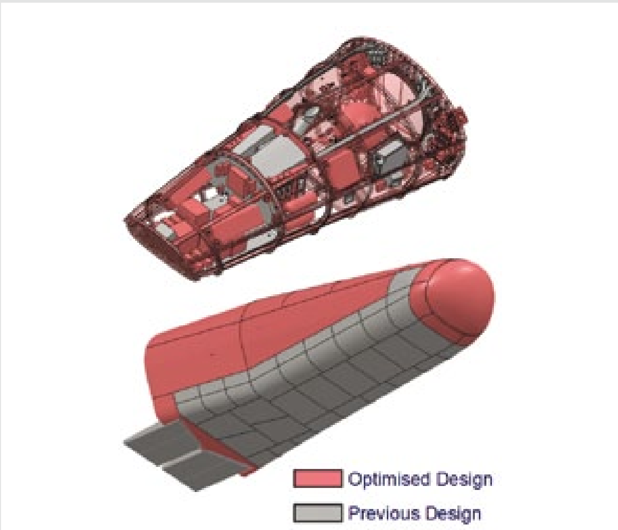
In materials and structures, activities relevant to advanced technologies are being developed under direct contract between ESA and technology providers. The activities related to composite structures, such as feeding lines, tanks and primary structures are now in place with industry.

Intermediate eXperimental Vehicle (IXV)

Industrial activities are progressing with the consolidation of the design baseline for the reentry demonstrator, reviewed at the Consolidation Key Point following the data package delivery from industry in January.

Significant progress has been made in several areas and interesting design optimisations and improvements have been introduced with respect to the previous design baseline. In particular, the redesign of the Cold Structure, based on large Carbon-Fibre Reinforced Polymer sandwich panels, the thermal protection and the avionics, contributed to significant design improvements and mass savings. No technical or programmatic 'showstoppers' have been identified, and the activities are proceeding to the CDR by the end of 2010.

Negotiation for technology support to the ceramic thermal protection to be used on IXV has concluded, and the contract is being approved.



The new Intermediate eXperimental Vehicle (IXV) design baseline, a key milestone at the start of the full development phase of the IXV, which is due to make its first flight three years from now

Astronaut Nicholas Patrick near the Cupola module during the STS-130 mission's final spacewalk

→ HUMAN SPACEFLIGHT

The heads of the International Space Station (ISS) agencies from Canada, Europe, Japan, Russia, and the United States met in Tokyo, Japan, on 11 March to review the status and long-term perspectives of the ISS cooperation.

With the assembly of the ISS nearing completion and the capability of supporting a permanent crew of six established, they noted that there are no identified technical constraints to continuing ISS operations beyond the current planning horizon of 2015 to at least 2020, and that the partnership is currently working to extend the certification of the on-orbit ISS elements to 2028.

The heads of agencies expressed their strong mutual interest in continuing operations and utilisation for as long as the benefits of ISS exploitation are demonstrated. They acknowledged that a US fiscal year 2011 budget consistent with NASA's budget request would allow the USA to support the continuation of ISS operations and utilisation activities to at least 2020. They emphasised their common intent to

International Space Station heads of agencies meet in Japan, from left: Keiji Tachikawa (JAXA), Charles Bolden (NASA); Anatoli Permirov (RSA), Jean-Jacques Dordain (ESA) and Steve MacLean (CSA)

The European-built Cupola module, being used for Earth observation by JAXA astronaut Soichi Noguchi, Expedition 22 Flight Engineer

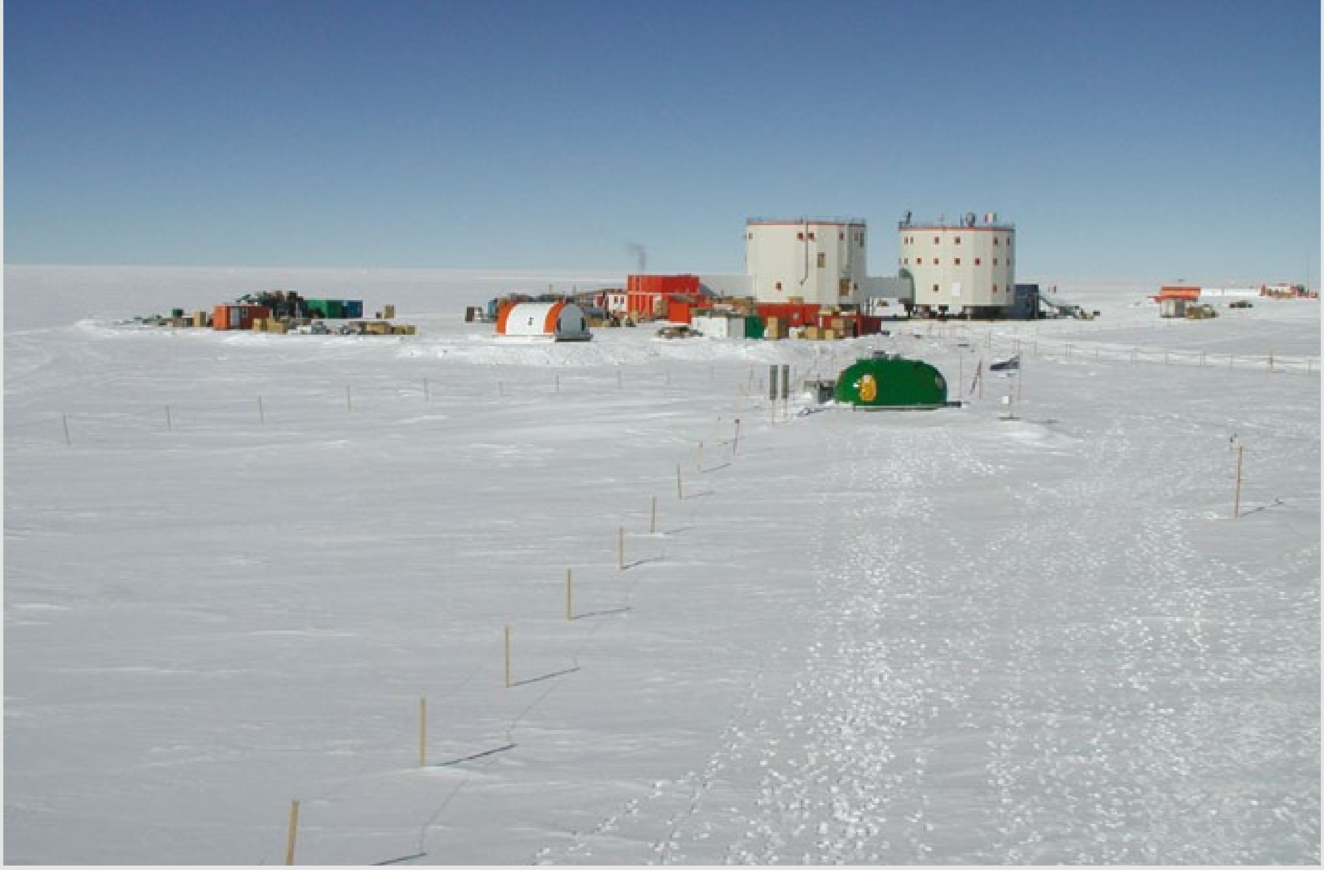
The Alpha Magnetic Spectrometer during environmental testing in the Large Space Simulator at ESTEC

undertake the necessary procedures within their respective governments to reach consensus later this year on the continuation of the ISS to the next decade.

The success of the ISS programme was also recognised with the ISS being awarded the 2009 Collier Trophy. The Collier Trophy is considered the top award in aviation, and the ISS programme was selected for 'the design, development, and assembly of the world's largest spacecraft, an orbiting laboratory that promises new discoveries for mankind and sets new standards for international cooperation in space'.
ISS programme managers were honoured with *Aviation Week*'s 53rd Annual Laureate Award in the space category for the completion of the project in 2009 with the addition of the last major modules and the expansion of the permanent crew to six.

Space Shuttle *Endeavour* was launched in February, carrying the last two European-built ISS modules on flight STS-130: Node-3 (Tranquility) and Cupola. Almost two years after the Columbus laboratory's installation, Node-3 was installed on the ISS on 12 February.
Then, on 17 February, the shutters on the seven Cupola windows were opened, providing the first views of Earth from this new observation deck.

One of the most exciting scientific instruments designed for space, the Alpha Magnetic Spectrometer (AMS), arrived at ESTEC, Noordwijk, in February for final environmental testing before its scheduled launch on the Shuttle STS-134 flight.



Concordia Station in Antarctica (Y. Frenot/IPEV)

The AMS will help us to better understand fundamental issues relating to the origin and structure of the Universe by observing 'antimatter' and 'dark matter'. The experiment is led by Nobel laureate Prof. Samuel Ting of the Massachusetts Institute of Technology (MIT), USA. A large part of the experiment however, was built in Europe.

ESA received a very good response to the Call for Ideas for climate change studies from the ISS, issued at the end of October 2009, with high-quality proposals being presented.

The initial four European Mars500 candidates meet the press in March: Romain Charles, Jerome Clevers, Arc'hanmael Gaillard and Diego Urbina

A report and preliminary assessment of the 45 proposals was presented to delegations on 16 February at ESTEC.

In addition, the peer evaluation by the European Science Foundation of the proposals received in response to the three ELIPS research solicitations (AO-2009/ILSRA-2009/ BR-2009) has been completed. The feasibility assessment is ongoing.

Meanwhile, the European science community has been invited to propose medical, physiological and psychological experiments for the Antarctic Concordia Station after a new Announcement of Opportunity on 20 January.

In March, ESA selected four European candidates for the 520-day Mars500 simulated mission to Mars. Following medical checks, however, only three of the four European candidates, Jerome Clevers (BE), Romain Charles (FR) and Diego Urbina (IT), are now undergoing final training. Two of these candidates will be selected to join an international crew of six, with one Chinese and three Russian participants. This first full-duration simulated mission to Mars starts on 3 June 2010.

ESA's Maxus-8 sounding rocket mission was launched on 26 March from Kiruna in northern Sweden carrying four microgravity research modules on a spaceflight that included 12 minutes of microgravity. This eighth Maxus campaign will help with the production process of new lightweight aero-engine turbines and new catalysts for chemical reactors and hydrogen fuel cells.

→ SPACE INFRASTRUCTURE DEVELOPMENT/ISS EXPLOITATION

Completion of ATV *Johannes Kepler* (ATV-2) is on course for the pre-shipment review on 4 May. Shipping to the launch site is scheduled for 10 May, with the start of the launch campaign on 25 May, to be ready for launch by 30 November. In addition, the ATV Control Centre, the ATV-related upgrades on the ISS, the launcher and the launch facilities will be ready to meet this date. The precise launch date will be determined in July, depending on traffic to the ISS and the opening of a suitable docking window, but also considering the Ariane 5 launch schedule.

ATV-3 has been named after the Italian physicist and space pioneer Edoardo Amaldi. The launch readiness date for ATV *Edoardo Amaldi* is now set for January 2012 because of the need for thermal vacuum testing of the Equipped Avionics Bay.

The European Robotic Arm (ERA) is a robotic servicing system that will be used in the assembly and servicing of the Russian segment of the ISS. ERA will operate from the Russian Multipurpose Laboratory Module (MLM), on which it is installed during launch. Roscosmos has resumed activities for the MLM, aiming for a launch in March 2012. ESA presented the updated ERA programme status to delegations on 2 March, and the Joint Project Plan (that establishes all the required activities necessary to meet the target launch date) was signed in Tokyo by ESA and Roscosmos on 10 March.

Logo of ATV-3, ATV *Edoardo Amaldi*

→ UTILISATION

Following completion of the ISS Increment 21 and 22 experimental programmes with excellent results (physiology experiments, SODI-IVIDIL, MSL etc.), the experimental programme of Increments 23 and 24 has started and will run until September.

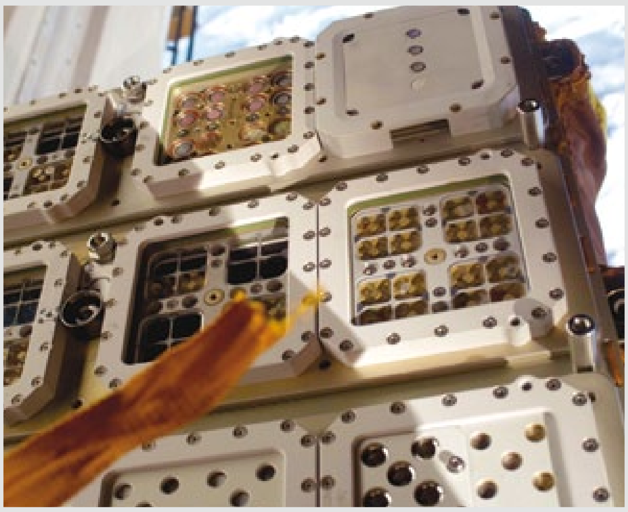
External payloads

The SOLAR platform has continued to operate normally for the SOLACES and SOLSPEC spectroscopic measurements. The SOLAR facility celebrated two years of successful operations on 15 February. It has already produced excellent scientific data during a series of Sun observation cycles. As a result, the overall operation period has been extended to 2013 in order to capture the whole solar cycle transition.

The Expose-R exobiology mission has been extended to the autumn, allowing a scientifically beneficial addition of 50% to the open-space exposure time. The European Technology Exposure Facility (EuTEF) community gathered at ESTEC, Noordwijk, in March to present the preliminary results of the mission and to celebrate its success. EuTEF was an external platform attached to the Columbus laboratory for one and half years, hosting a set of eight scientific and technology payloads and one temperature monitoring unit. Its success and the continued interest from the multi-disciplinary user community clearly demonstrates the need for continued availability of such a versatile external ISS experiment platform.

ISS biology

The Biolab facility has been prepared to perform the next WAICO-2 experiment, which was launched on Shuttle flight STS-131 (19A) on 5 April.



The Expose-R exobiology unit mounted outside the ISS

Human physiology and performance

Following the success of several human physiology experiments (SOLO, CARD, 3D-Space) on the ISS, an extension of the in-orbit pre-positioned kits (SOLO and CARD) to February 2012 has been agreed.

The Portable Pulmonary Function System is currently supporting ESA's ThermoLab and EKE experiments in combination with NASA's VO2Max experiment.

In addition, the European Physiology Modules facility was activated on 7 January in support of the monthly DOSIS data downlink and PASSAGES, a new neuroscience experiment testing how astronauts interpret visual information in weightlessness.

Materials research

Preliminary analysis of the first two processed MICAST and CETSOL sample cartridges showed promising results. In the meantime, four more samples were processed and downloaded on the STS-130 (20A) return flight on 21 February.

The FOCUS experiment from the EC SURE call, studying foam formation and stability in weightlessness with a view to ultralight and strong metallic foams in the future, was also uploaded and completed.

Fluid physics

The Microgravity Science Glovebox was reactivated on 11 January with the remaining runs of the SODI instrument's Influence of Vibrations on Diffusion in Liquids (IVIDIL) experiment, completed on 20 January. This has provided scientists with fascinating images of the behaviour of liquid mixtures under the influence of vibration.

In addition to SODI-IVIDIL, the next SODI experiments are Diffusion and Soret Coefficient Measurements for Improvement of Oil Recovery (DSC) and Colloid. DSC was uploaded on the Progress 36P flight and ISS Flight Engineer Soichi Noguchi (JP) completed the set-up of the SODI by installing the DSC cell array no. 1 and the first flash disk on 15 February. It was decided to return parts of SODI with STS-130 (19A) for ground repair as well as the DSC cells for refill. The Colloid experiment cell assembly will be launched on the Shuttle flight STS-132 (ULF-4).

Non-ISS missions

The 52nd ESA Parabolic Flight Campaign in is preparation, to be held between 26 April and 7 May, with a mix of physical and life sciences experiments. Following the debut of ESA's 'Fly Your Thesis!' programme in 2009, four teams of university students were selected to conduct their microgravity experiments. The inclusion of a fourth flight to enable the new ESA candidate astronauts to undergo training under microgravity conditions is also planned.

ASTRONAUTS

The OasISS mission is in its post-flight phase, with technical and experiment debriefings taking place. Crew training for ISS Expeditions 24 to 30 is progressing on schedule. ESA astronauts Roberto Vittori and Paolo Nespoli are training for their planned missions later this year (STS-134 and Soyuz TMA-20 respectively). André Kuipers continues his mission training for the ESA ISS Increment starting at the end of 2011, Expeditions 30/31, on board Soyuz TMA-03M. ESA's new astronauts continue their basic training.

Astronaut Roberto Vittori in training at NASA Johnson Space Center for his flight on STS-134

Paolo Nespoli

André Kuipers

→ CREW TRANSPORTATION AND HUMAN EXPLORATION

Advanced Reentry Vehicle (ARV)

Work on the ARV Phase A has been progressing under a 'Preliminary Authorisation to Proceed' to prepare the Preliminary Requirement Review, planned for April. Negotiations for the finalisation of the main contract were completed, with Astrium GmbH signing on 17 March. The Request for Quotations and ITTs were released to several subcontractors expected to contribute at system level. The ARV vehicle concept is being developed, while the interface aspects and the mission requirements are being discussed. Several interactions have taken place with the ISS partners for a more detailed assessment of the ISS needs in the 2016–20 period.

International Berthing Docking Mechanism (IBDM)

The engineering Development Unit of the IBDM is undergoing tests with an active control loop at the INTA facilities in Torrejon (ES). Preparation for the software and driving avionics for an improved configuration continues. In parallel, the International Berthing Docking Standard Working Group continues to work on the detailed configuration for the new docking system standard.

A Technical Interchange Meeting in April will ratify the provisional agreement of the new standard by confirming the mechanism geometry and associated load criteria. NASA has taken steps to include the standard docking system in the development of the new common docking adaptors for the ISS, and the NASA Associate Administrator for Space Operations, William Gerstenmaier, visited the INTA facilities on 15 April.

Expert

Phase D of the Expert testbed development is ongoing. Actions resulting from the vehicle CDR were closed and vehicle manufacturing started. Agreements with the national institutions contributing to funding for the experiments have been prepared for signature and the experiment FMs are being delivered for integration. The main vehicle subsystems are completed. The ceramic nose cap and flaps, cold structure and some elements of the avionics and software have been delivered to the prime contractor, Thales Alenia Space, for vehicle integration and testing by the summer.

Lunar Lander activities

The objectives for the first Lunar Lander mission have been defined and prioritised, on the basis of the proposals received in response to the Lunar Lander Request for Information. The scientific objectives of ESA's first Lunar Lander, a precursor mission to human exploration of the Moon, were presented during the meeting of the Life Sciences and Physical Sciences Working Groups (LSWG/PSWG) on 11 February. The members of the LSWG and PSWG expressed their satisfaction with the excellent work and papers presented by the Lunar Exploration Definition Team.

ESA's new astronauts experience a launch simulation from the Main Control Room at ESOC in Germany

It was also emphasised that the model proposed by the ESA Lunar Lander team, as a baseline for the upcoming Phase B1, adequately covers the range of relevant issues to be addressed by such a precursor mission in the preparation for future human exploration.

On this basis, a Soyuz-class Lunar Lander mission has been defined for the Phase B1 industrial study. The Lunar Lander mission was presented to delegations on 3 March.

The Phase B1 ITT was released on 29 March, and an information day for the Lunar Lander project took place on 14 April at ESTEC, Noordwijk.

Human exploration technology

For the Advanced Closed Loop System (ACLS, for air revitalisation), six activity proposals in the framework of the General Support Technology Programme (GSTP-5) were submitted following the final consultation on the content. The proposals were approved at the March Industrial Policy Committee meeting. These activities will be instrumental in preparing the ACLS system for a full flight system in the future. ESA and NASA have agreed in principle on the launch and resources of ACLS on the ISS with final details to be defined later.

The MELiSSA Food Characterisation Phase 1 results have been received and are undergoing analysis. Phase 2, which will produce, integrate and test two Food Characterisation Units, is under final preparation. The activities at the MELiSSA Pilot Plant in Barcelona are going to plan.

The activity on In Situ Resource Utilisation is progressing with the first trade-off of technologies completed. The current phase will concentrate on the design and development of a breadboard model for later testing of the carbo-thermal reduction process for oxygen reclamation from a material similar to the lunar regolith.

The ITT for Energy Provision and Management has been released and proposals are expected in May. The activity will develop fuel cell technologies for larger power density applications, such as a manned lunar base or a pressurised lunar rover, both of which need power in the 10 kW range.

International architecture development and scenario studies

The Tender Evaluation Board for the Exploration Scenario Studies took place on 19 March. Significant progress has been made towards finalisation of the work on the International Space Exploration Coordination Group (ISECG) Reference Architecture for Human Lunar Exploration, and work on the development of the ISECG Global Exploration Roadmap has been initiated.

A White Paper on the role of the ISECG in advancing global exploration was completed to inform an ISECG meeting at senior management level by mid-2010.

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