number 149 | February 2012

# bulletin

→ space for europe


www.esa.int

European Space Agency

# 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, Romania, Spain, Sweden, Switzerland and the United Kingdom. Canada is a Cooperating State.

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

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

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

The ESA headquarters are in Paris.

The major establishments of ESA are:

ESTEC, Noordwijk, Netherlands.

ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

Chairman of the Council: D. Williams

Director General: J.-J. Dordain


←

On cover:
Vega, ESA's new small launch vehicle, lifts off on its maiden flight on 13 February from Europe's Spaceport at Kourou, French Guiana (ESA/CNES/Arianespace/Optique Video CSG)

esa

# bulletin

number 149 | February 2012

The *ESA Bulletin* is an ESA Communications production.

**Published by:**
ESA Communication Department

ESTEC, PO Box 299
2200 AG Noordwijk
The Netherlands
Tel: +31 71 565 3408

Email: contactesa@esa.int

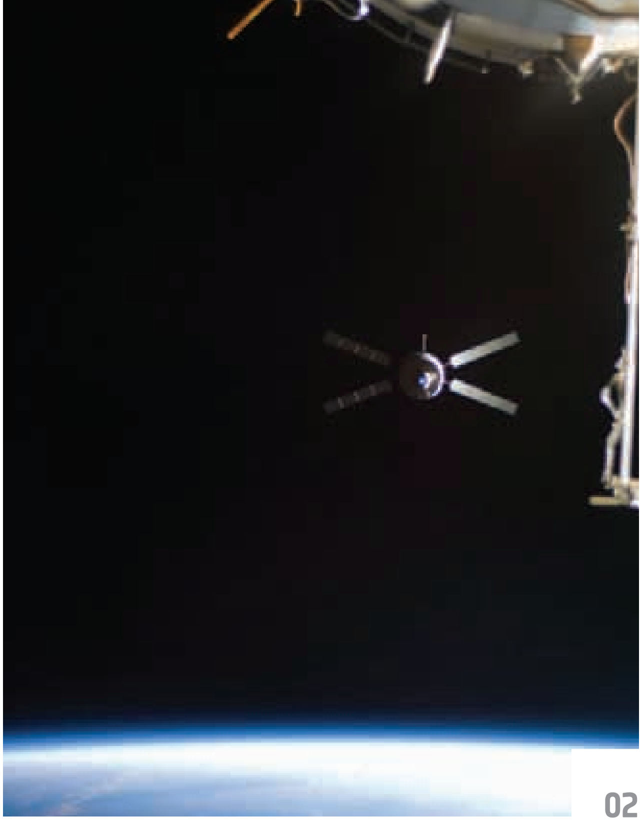
**Editor**
Carl Walker

**Designer**
Ornella Catalano

**Organisation**
www.esa.int/credits


ISSN 0376-4265 | e-ISSN 1608-4713

→ contents

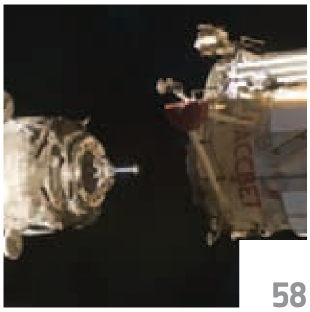

02


12


22


38


51



58

↑

ATV *Johannes Kepler* seen leaving the ISS in 2011

# → EUROPEAN HAT-TRICK

## The flight of ATV *Edoardo Amaldi*

**Massimo Cislaghi and Nadjejda Vicente**
Directorate of Human Spaceflight and Operations, ESTEC, Noordwijk, the Netherlands

**Even with the completion of ESA's second Automated Transfer Vehicle mission still fresh in our minds, the latest in the series of European space freighters is ready to go.**

The third Automated Transfer Vehicle, ATV *Edoardo Amaldi*, will be launched next month and soon after attached to the International Space Station (ISS) for nearly half a year. This February, only a few weeks before launch, all systems are 'go'. All kinds of contingencies have been tackled during the final simulations, and the last checks are taking place. Excitement in the ATV team is growing.

Following in the footsteps of its predecessor *Johannes Kepler*, ATV *Edoardo Amaldi* will serve as a cargo carrier, storage facility and 'tug' vehicle for the ISS. On top of its Ariane 5 launcher, ATV *Edoardo Amaldi* is set to start its voyage to the ISS and it is loaded with 6.6 tonnes of cargo, more dry cargo in its hold than on previous missions.

"It might seem that this is a carbon copy of the ATV-2 flown just a few months ago, but ATV-3 is bringing much more to the space transportation scene," says ESA's ATV-3 Mission Manager Massimo Cislaghi. "The much shorter turnaround time and a greater late cargo loading capability make the ATV-3 mission a great hat-trick for Europe."

## Time pressure

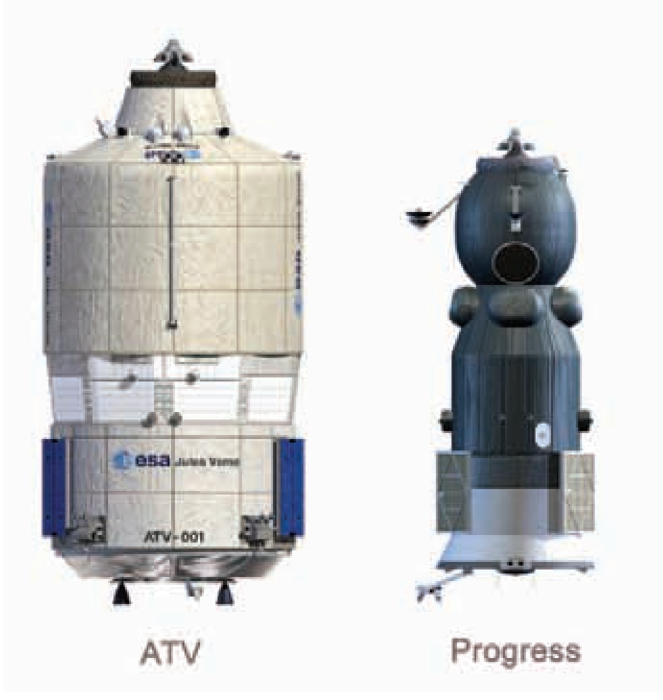
The main challenge for ATV *Edoardo Amaldi* is about to be accomplished: it is the first of the ATV series to be processed and launched within the target rate of one per year. The production and integration chain worked at full capacity to be on time.

"Since ATV *Johannes Kepler* was launched to the Station one year ago, and even months before that, we have been working under high time pressure," explains Massimo Cislaghi. European teams and industry got to the starting line on time even if many of the post-flight technical recommendations were available only at a very late stage of this prelaunch campaign.

The rush is for a good reason. The retirement of the Space Shuttle in July 2011, the end of an era for the US space programme, has led to a new scenario. From that moment on, the supplies for the ISS are uploaded on unmanned, expendable cargo vehicles provided by the Station's international partners.

"Before the new US commercial resupply service vehicles become operational, ensuring the annual launch rate is vital for the Space Station logistics, especially at a time when there is no Shuttle replacement ready in the near future," notes the ATV-3 Mission Manager.


↑ The ATV *Edoardo Arnaldi* mission logo




↑ Comparison of size of ESA's ATV and the Russian Progress supply vehicles

Europe's ATV has the largest upload capability of all ISS visiting vehicles, and it is the only one, besides the Russian Progress spacecraft, that can provide refuelling, attitude control and reboost functions. With ATV, Europe contributes in kind towards its share of the operational costs of the ISS.

The most challenging European spacecraft to date is about to start its third voyage to the ISS, ready not only to supply the astronauts with food and more research equipment, but also to help in adjusting the orbit of the ISS. Maintaining this orbit will be vital, especially during the forthcoming period of high solar activity. The atmospheric density in the ISS altitude range will increase, creating a larger drag that needs to be actively compensated.

## What's inside?

Permanently inhabited since 2000, the ISS relies on logistics vehicles such as ATV to upload cargo as well as propellant to maintain its orbit. However, the various needs of the ISS change with every mission.

"For ATV-2 we had quite an amount of propulsive support propellant, whereas for ATV-3 we have much more dry cargo: almost 800 kg more this time," explains Kirsten MacDonell, ESA ATV Cargo Integration Engineer. The volume available has also increased, from six cargo racks on the first ATVs to eight racks on *Edoardo Amaldi*. Every cubic centimetre of the cargo carrier is used to full capacity.

← Loading dry cargo in ATV *Edoardo Amaldi* in 2011 (ESA/CNES/Arianespace – Optique video du CSG)

Most of the cargo has been in place since November, but the very last packages will be loaded only three weeks before launch. With ATV already in the vertical position on top of its Ariane 5 launcher, ESA will use a special access device to load last-minute cargo items through the hatch that will eventually connect the spacecraft to the ISS in space.

Late loading is a delicate operation, 'something very unique' according to Kirsten. Compared to ATV *Johannes Kepler*, the amount of late cargo has been doubled. Sixty bags holding about 500 kg will be stored, and these will include the precious 'crew care packages', traditionally prepared by the astronauts' families with personal gifts. "This expanded late access is definitely a first for ATV-3, showing great flexibility of ESA in adapting the cargo to the ISS needs," says Kirsten.

The most important item in the cargo planned for ATV *Edoardo Amaldi* is the spare Fluids Control Pump Assembly (FCPA), a critical piece of the system that recycles urine into drinkable water for the ISS. "It is perhaps the most valuable cargo we have on ATV-3 because it could affect the life support systems. If the only FCPA available right now in orbit breaks down, the astronauts will still have enough water for some time, but the Station wouldn't work at full efficiency," notes Kirsten.

Like assembling a giant puzzle, the interior of ATV has been carefully laid out over the last months, taking into account the centre of mass in order to avoid disturbances to the sophisticated onboard guidance and control systems. The cargo team have calculated where to store each bag optimally and use barcode labelling to make it easier to keep track of the various items taken into the ISS.

↑ Using a special access device, last-minute cargo is loaded through the hatch that will eventually connect ATV to the ISS

## → What's inside ATV?

| | |
|---|---|
| ISS propulsive support | 3150 kg |
| Refuelling propellant | 860 kg |
| Water | 285 kg |
| Gas (oxygen and air) | 100 kg |
| **Total fluid cargo** | **4395 kg** |
| Main dry cargo | 1665 kg |
| Late-loading dry cargo | 535 kg |
| **Total dry cargo** | **2200 kg** |


↑ Above, ATV shown in its fairing on Ariane 5; top, the Ariane launchpad at Kourou, French Guiana

## From rainforest to space

The edges of the Amazonian tropical rainforests will once again be the setting for an ATV launch. The Ariane 5 heavy-lift launcher will take off from Europe's Spaceport in Kourou, French Guiana, breaking its own record for the second time. Weighing more than 20 tonnes at launch, ATV *Edoardo Amaldi* will be the heaviest spacecraft ever to be lifted by any vehicle of the Ariane rocket family.

"Even after witnessing around 50 launches here, and even knowing exactly what is going on during the countdown, this launch will still be a very spectacular and emotional one," admits Dominique Siruguet, the ATV Campaign Manager in Kourou.

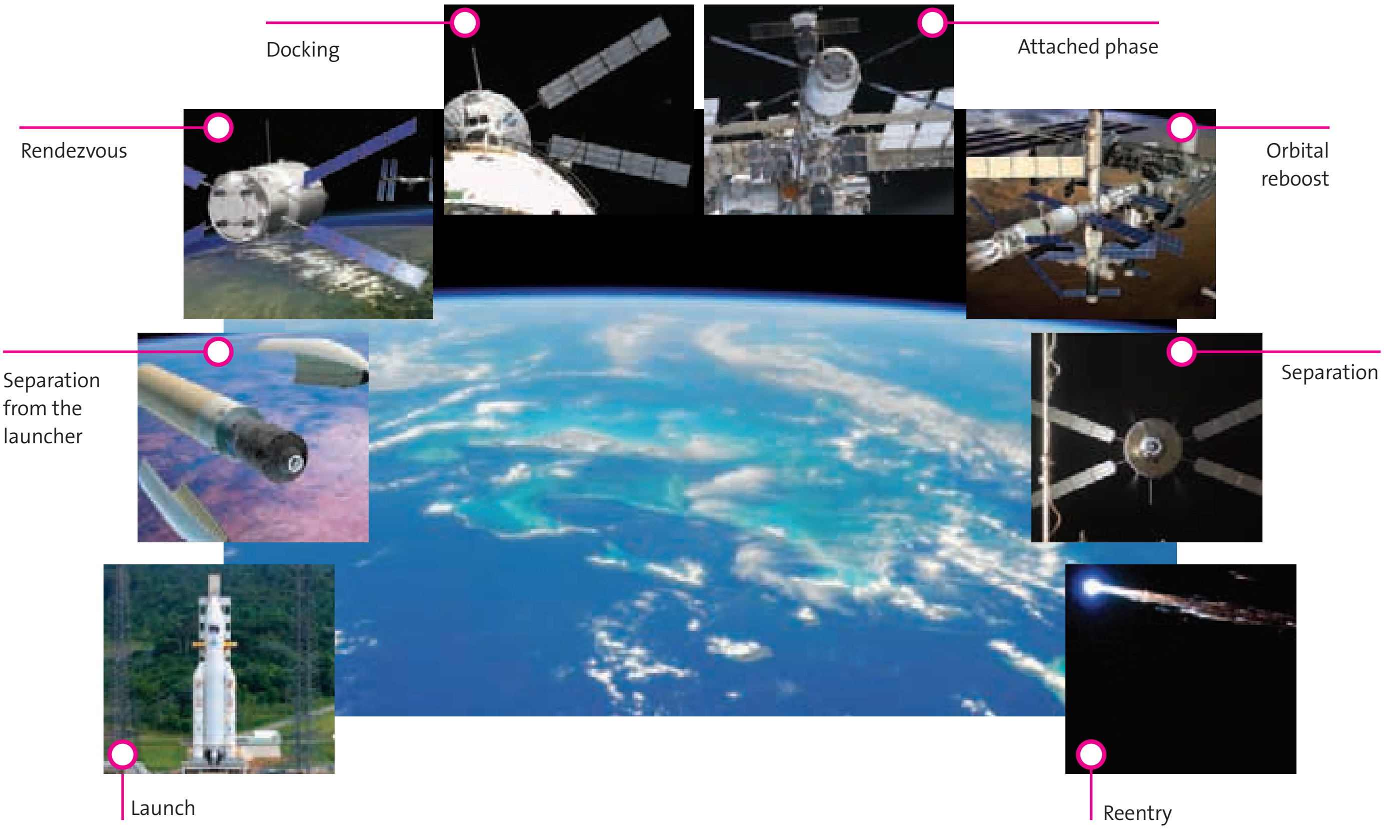
Before the rocket moves to the launch pad, teams on site will make sure that *Edoardo Amaldi* and the Ariane 5 can recognise each other's commands perfectly, and that the optical sensors for docking are working properly.

The ATV launch window opens and lasts for ten days. The countdown will start ten hours before launch, and there is no margin for even a one-minute delay. "If there is a problem with the vehicle, I'm the guy who presses the 'red button' in the last minutes. I'm confident that it won't happen, but we are well prepared to set the ATV in a safe configuration if necessary," says Dominique.

## A beautiful courtship in space

About an hour after lift-off, *Edoardo Amaldi* separates from the rocket and its high-precision navigation system guides the spacecraft on a rendezvous trajectory towards the ISS. An onboard startracker identifies different star constellations in the sky to calculate the

## → ATV MISSION CYCLE




vessel's orientation in space, and a GPS receiver gives positional information. Together, these are the modern equivalent of centuries-old navigation techniques.

ATV *Edoardo Amaldi* will need a few days to reach a 'hold position', some 30 km behind the ISS. Both objects are moving at around 28 000 km/h in Earth orbit but, from this point on, *Edoardo Amaldi* will start performing a series of predefined manoeuvres, piloting itself and gradually closing the distance to the ISS.

During the last 250 m, ATV's state-of-the-art automatic rendezvous system employs a videometer's eye-like sensors. These analyse the behaviour of its own laser beam returned from a target, installed on the ISS more than ten years ago. The 20-tonne ferry will manoeuvre itself and dock with the ISS to a precision of within 6 cm.

### Under control

Without major modifications after the last mission, ATV operations have become more robust. New procedures and specific training for contingency situations emerged during the preparations for *Edoardo Amaldi*.

"The key word is safety—this governs all operations," explains Jean-Michel Bois, Head of the Operations Division at the ATV Control Centre (ATV-CC) in Toulouse, France. "The Automated Transfer Vehicles are very safe by design, but also from an operational point of view. We are extremely careful in every step."

There are at least three levels of safety to protect the ISS and its crew. If there are any last-minute problems, the approach can be stopped by ATV's computer, the ground controllers in Toulouse or the ISS crew, with the vehicle sent away in a safe manner. In a worst-case scenario, it is possible to trigger a programmed sequence of anti-collision manoeuvres, fully independent of the main navigation system.

The hazards of high solar activity, such as solar flares, have already been foreseen by ESA's engineers. During the 'free-flying' phase of the ATV mission, solar flares do not affect the spacecraft. However, during the rendezvous phase, the GPS systems, both on the ATV and on the ISS, need to work with maximum accuracy. After the maiden flight of ATV *Jules Verne*, new software was installed in the Russian GPS system to exclude ionospheric perturbations, so as to match the level of precision required during the earlier stages of the rendezvous.

Space debris could also jeopardise the mission, but the flight dynamics team at ATV-CC is constantly checking with space surveillance networks that track possible hazards. If any object passes nearby, a new trajectory and set of manoeuvres for ATV will be calculated automatically.

"Our mission doesn't end when ATV docks to the Station. Apart from the critical phases, we need to be ready to support any contingency during the attached phase," adds Jean-Michel. For those five months, any problem inside ATV-3 could be solved with the support of the crew on board.

## Old friends

After two years of training, ESA astronaut André Kuipers knows almost all there is to know about how to deal with *Edoardo Amaldi*. On the ISS since the end of December, he will welcome Europe's third ATV during his PromISSe mission. André will be the prime operator overseeing the rendezvous and docking.

With crewmate Oleg Kononenko, Expedition 31 commander, André will monitor ATV as it approaches the ISS, ready to interrupt the approach if necessary. The rendezvous and docking manoeuvres require a complex set of skills and very efficient communication between the two crewmembers. Oleg was in orbit during the maiden flight of ATV *Jules Verne* and is more than familiar with ATV.

The ISS does not have a window facing ATV's approach path, but André can observe it via a camera mounted on the aft end of the Zvezda module. "Only when you see in the video the huge mass of the vehicle approaching the ISS with the sunlight reflected by the solar panels, do you realise how real it is and what a challenge the whole mission is," recalls Jean-Michel.

After contact, hooks are closed, ATV's docking probe is retracted, and then the data and electrical connections are made. As soon as all interfaces are established, the crew can open the hatch and enter the pressurised part of ATV.

## A matter of propulsion

There are three main features that make ATV's propulsion system unique: first, it is compatible with human spaceflight requirements; second, it operates almost completely automatically (with some engines being used during the whole mission), and third, its sheer size.

The scale of ATV, together with the complexity of manoeuvres it can perform, results in one of the largest and most sophisticated propulsion systems ever built. Besides guiding ATV to and from the ISS, the engines of this European spacecraft can perform ISS attitude control, regular orbital reboosts and can enable occasional manoeuvres to avoid collisions with space debris.

"ATV is definitely the most complex propulsion system we have ever designed and flown in space from Europe. I would even say worldwide, as far as satellite propulsion is concerned," says Fabio Caramelli, who has been checking the propulsion system – first in Europe and then in Kourou – during the ATV launch campaign.

Of all the vessels that deliver cargo to the ISS, ATV can bring the largest quantity of fuel. ATV *Edoardo Amaldi* is indeed

↑ André Kuipers and Oleg Kononenko during training on ATV systems and procedures

## → Who was Edoardo Amaldi?

The official name of ESA's third ATV spacecraft pays tribute to the Italian physicist and spaceflight pioneer Edoardo Amaldi. He was a leading figure of Italian science in the 20th century, particularly in fundamental experimental physics. In the 1930s, Amaldi was member of a group of young Italian scientists, known as the 'Via Panisperna Boys', famous for the discovery of 'slow neutrons'. That achievement would later make possible the nuclear reactor.

From his initial studies in nuclear physics, he did pioneering work in the field of cosmic rays and then devoted himself to the new field of particle physics. Near the end of his career, he turned again to emerging scientific areas working on the experimental search for gravitational waves.

Amaldi contributed directly to the realisation of national and international projects, such as the Electron Synchrotron for the Instituto Nazionale di Fisica Nucleare (INFN) and the European Organization for Nuclear Research (CERN). He was one of the few who, in the post-war years, prompted action towards the creation of a space organisation with a European character, ultimately leading to the foundation of the European Space Research Organisation (ESRO), a fore-runner to ESA.

Amaldi was a strong believer in the open nature of science and the need for international cooperation. His contribution as one of the founding fathers of European space research is recognised by this ATV mission not only with his name, but also a by a copy of a letter written by Amaldi in 1958 that will fly on the spacecraft to the ISS.

This unique historical document reflects his ambitious vision of a peaceful, non-military European space organisation. Once his words fly into space, as he states in the letter, to 'attract the liveliest part of the new generation,' his dream will have come true.

focused on delivering propellant: its main payload is nearly four tonnes of fuel in different forms to restock the ISS reserves. The engines of its predecessor, ATV *Johannes Kepler*, achieved the biggest orbital boost used in spaceflight since the Apollo missions to the Moon when they raised the ISS orbit by more than 40 km.

This system has been fine-tuned for ATV *Edoardo Amaldi*, a spacecraft that Fabio considers at this stage in its development to be 'more than a teenager, it is already an adult' and is he is very confident about the success of the mission.

Fabio still remembers the excitement of the second ATV deorbiting, when the spacecraft was sent on destructive reentry into Earth's atmosphere. "I was quite surprised to see that the propulsion system was still working on reentering the atmosphere, trying to keep the vehicle under control. That was a real proof to me of how good the propulsion system is."

> **"Once Amaldi's words fly into space, to attract the liveliest part of the new generation, his dream will have come true."**

### A long-distance relationship

Only two months after the end of the ATV *Johannes Kepler* mission, staff at ATV-CC were busy preparing and simulating operational scenarios for the next mission. Even if operating ATV for its third mission is a routine activity, Massimo Cislaghi insists, "Relaxation is not an option. The local staff have been working at full speed since last September following a well-deserved, but unfortunately very short, rest from the heavy work pressure of the ATV-2 mission."

No one doubts that such a short turnaround, a first for an ESA mission, would have been impossible without the esprit de corps that joins everyone involved in the ATV project. Whether 400 kilometres up with the spacecraft, or on the ground when it passes overhead, everyone feels part of the team.

For pre-launch and launch operations, ATV-CC coordinates with the Guiana Space Centre, in charge of launch and deployment of the vehicle. For the rest of the mission, and especially for rendezvous, docking and departure, ATV-CC is in constant communication with the mission control centres in Moscow and Houston. During the prelaunch campaign, the entire ATV-CC team underwent joint integrated

↑ The ATV Control Centre (ATV-CC) in Toulouse, France

simulations in which the three control centres involved (Moscow, Toulouse and Houston) trained together.

The ATV project involves about 2000 people from ESA and European industry. "It's not only one specific team or agency. ATV missions are some of the most complex systems led by Europe, and there are also multicultural and multiagency ingredients. We are all in this together," notes Jean-Michel Bois.

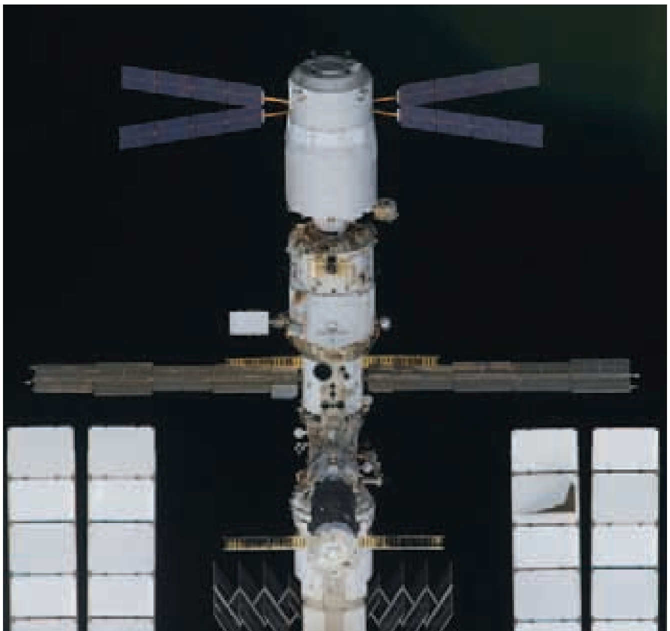
ATV *Edoardo Amaldi* was developed and built under ESA contract by a European industrial consortium led by EADS Astrium. During the highly active phases of an ATV flight – from launch to docking, and from departure to reentry – a dedicated 60-person team works together to coordinate all procedures.

"Emotionally speaking it is very important to get everyone together in one room. This is really a team," explains Jean-Michel Bois. During the attached phase, fewer operators are needed, but the control centre is manned 24 hours a day. "We are more organised and efficient. I have less and less inputs of lessons learned, we have improved a lot," says Jean-Michel.

For Fabio Caramelli, he says, "The three years I've spent with the ATV project have been the best ones of my career from any point of view."

## Trilogy complete, but the saga continues

After about five and a half months, *Edoardo Amaldi* will undock from the ISS. Its engines will deorbit the spacecraft on a steep flight path that causes it to



↑ ATV *Johannes Kepler* docked to the ISS as seen from the Space Shuttle *Discovery* STS-133 in February 2011 (NASA) break apart and burn up harmlessly in the atmosphere over an uninhabited area of the Pacific Ocean. More than six tonnes of ISS waste can be destroyed during the reentry.

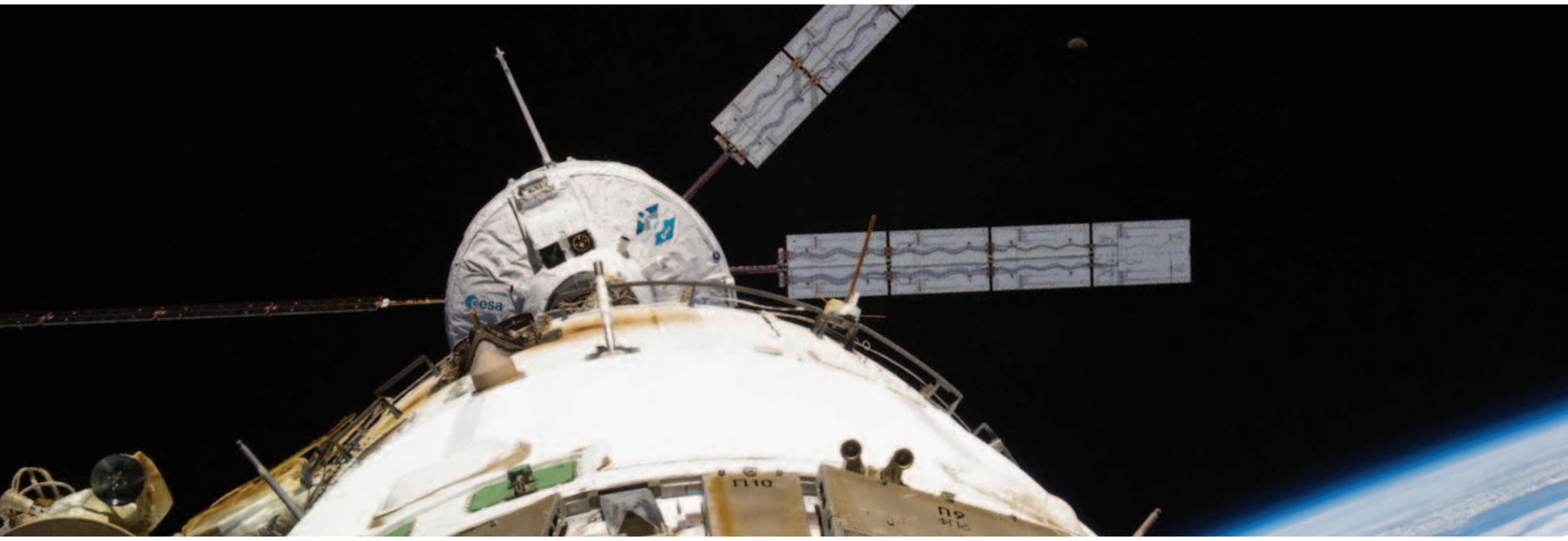
"Some people may think that we are building the same type of vehicle each time, but ATV is upgraded for every mission to increase its flexibility. For ATV-4 (now called ATV *Albert Einstein*), for example, a new type of internal lift will allow a greater amount of late-load cargo to be installed," says Kirsten MacDonell.

ATV *Edoardo Amaldi*, supported by ESA teams and industry, is about to make another giant step for European space transportation. As Massimo Cislaghi puts it, "We are all part of a very exciting human and space adventure. ATV is Europe's ticket to space." ■

## → ATV facts

| | |
|---|---|
| **Launch site** | Kourou, French Guiana |
| **Launch date** | 23 March |
| **Launcher** | Ariane 5 ES |
| **Undocking** | 27 August 2012 |
| **Mission duration** | 171 days |

- Heaviest spacecraft ever launched by ESA and on an Ariane rocket
- Three times the payload of a Russian Progress-M spacecraft
- Largest reboost capability of any vessel visiting the ISS
- Largest and most sophisticated flight software ever developed by ESA



## → Keep in touch with ATV

Since first launched in 2008, ESA's ATV blog has become an extremely popular source of information. It is now permanently linked and regularly cited by top-level media and space enthusiast sites around the world, as well as social media.

Almost 250 000 page views in 2011, plus millions of content impressions via Facebook and Twitter, confirm the success of its formula: an editorial 'human touch' with quotes, interviews, video and comments published in a friendly and informal style. The blog has also won a reputation for being the authoritative source for mission updates as they happen. Even the ATV Mission Director gives answers to visitor questions directly!

All aspects of the ATV mission are covered, from the launch campaign, astronaut training, liftoff and docking, through to the attached and reentry phases. The blog provides quick, real-time updates during critical parts of the mission. Last year, during the ATV *Johannes Kepler* docking, the blog was visited by over 23 000 readers in just six hours.

**Follow the ATV-3 mission at:**
ESA's ATV blog: http://blogs.esa.int/atv/
ESA's ATV website: www.esa.int/atv
Related Twitter accounts: @esa, @esaoperations, @astro_andre, @AstroPettit, @ESA_nl


Decision-makers need to be convinced of the benefits that GMES can create for national and local communities (Flavioka@stock.xchang)

# → GLOBAL MONITORING FOR ENVIRONMENT AND SECURITY

## GMES Space Component getting ready for operations

Josef Aschbacher, Maria Milagro-Pérez, Antonio Ciccolella, Thomas Beer,
Alessandra Tassa, Wolfgang Rathgeber and Giancarlo Filippazzo
Directorate of Earth Observation, ESRIN, Frascati, Italy

**Next to Galileo, Global Monitoring for Environment and Security (GMES) is one of the two European Union flagship programmes in space, and another example of how space policy can contribute to improving European citizens' lives.**

While the future of Galileo is secured through the EC's proposal to provide sufficient operational funding within the general budget of the EU, the long-term future of GMES has yet to be secured. Unexpectedly, last year the EC proposed to finance GMES outside the EU Multi-Annual Financial Framework (MFF), which covers the period 2014–20, suggesting instead to organise the required funding through a new intergovernmental mechanism.

In the GMES Space Component, the Sentinels and ground segment are currently in the final stages of their development and are getting ready for launch from 2013 onwards. Pre-operational data delivery from existing national and third party missions is well under way. What is most urgently needed now is securing the operational funds and consolidating the governance including Sentinel ownership and data policy.


← From left, Vittorio Prodi, Chaiman of the Sky & Space Intergroup, European Parliament, Antonio Tajani, Vice-President of the EC, responsible for Industry and Entrepreneurship, and Jean-Jacques Dordain, ESA Director General, before the Conference on EU Space Policy in Brussels, November 2011

## Why GMES was initiated?

The EU and ESA have developed the GMES initiative as Europe's answer to the vital need for joined-up information about our environment, to understand better climate change, and to support the civil security of European citizens.

Through a unique combination of satellite, atmospheric and Earth-based monitoring systems and models to convert observations into information services, GMES will provide vital new insight into the state of the land, sea and air, providing policymakers, scientists, businesses and the public with accurate, up-to-date, global information.

The GMES initiative was born in 1998 in Baveno, on the shore of Lake Maggiore in northern Italy, when the main national space agencies, ESA, the EC and Eumetsat came together to discuss how these challenges could be met.

Since then, significant achievements have been made: pre-operational services in the main environmental domains have been developed and the first elements of the necessary space observation infrastructure are close to completion. The first satellites will be ready for launch from 2013 onwards, and the programme will become operational in 2014.

## What is GMES?

To accomplish its objectives, GMES has been divided into three main components: 'Space', '*In situ*' and 'Services'.

The Space Component, led by ESA, comprises five types of new satellites called Sentinels, which are being developed by ESA specifically to meet the observational requirements of GMES services. In addition, access to data from the 'Contributing Missions' ensures that European space infrastructure is fully used for GMES. An integrated ground segment infrastructure enables access to data from Sentinels and Contributing Missions.

> **GMES will provide us with crucial imagery and data on the environment, which will enable us to understand better and mitigate climate change. It will also make our agriculture and fishery more efficient. This in turn will guarantee better food quality and food security. It will also be of great help in crisis response in emergency situations during natural or manmade disasters.**
>
> J.M. Barroso, President of the European Commission, November 2011

The *In situ* component, under the coordination of the European Environment Agency (EEA), is composed of atmospheric and Earth-based monitoring systems, and based on established networks and programmes at European and international levels and on ad hoc measurement campaigns enabling to collect environmental data from, for example, field instruments, vessels, aircraft or observation balloons.

The EC is in charge of implementing the services component and of leading GMES politically. GMES services will provide essential information in five main domains, atmosphere, ocean and land monitoring, as well as emergency response and security. Climate change has been added as a new GMES service and cuts across all these domains. In terms of security, GMES is a purely civil system addressing civil security needs.

GMES is moving from its research and development phase towards operations sequentially. Although defined to start from 2014 onwards, linked with the availability of operational funding, the operational programme integrates individual elements into the overall system as they reach their respective operational stages.

## Who are the users of GMES?

Based on global observations, GMES services, developed in close collaboration with users, will provide essential information in three Earth-system domains (atmosphere, marine and land) and three cross-cutting domains (emergency management, security and climate change).

These services, once operational, will provide standardised multi-purpose information common to a broad range of EU policy-relevant application areas:

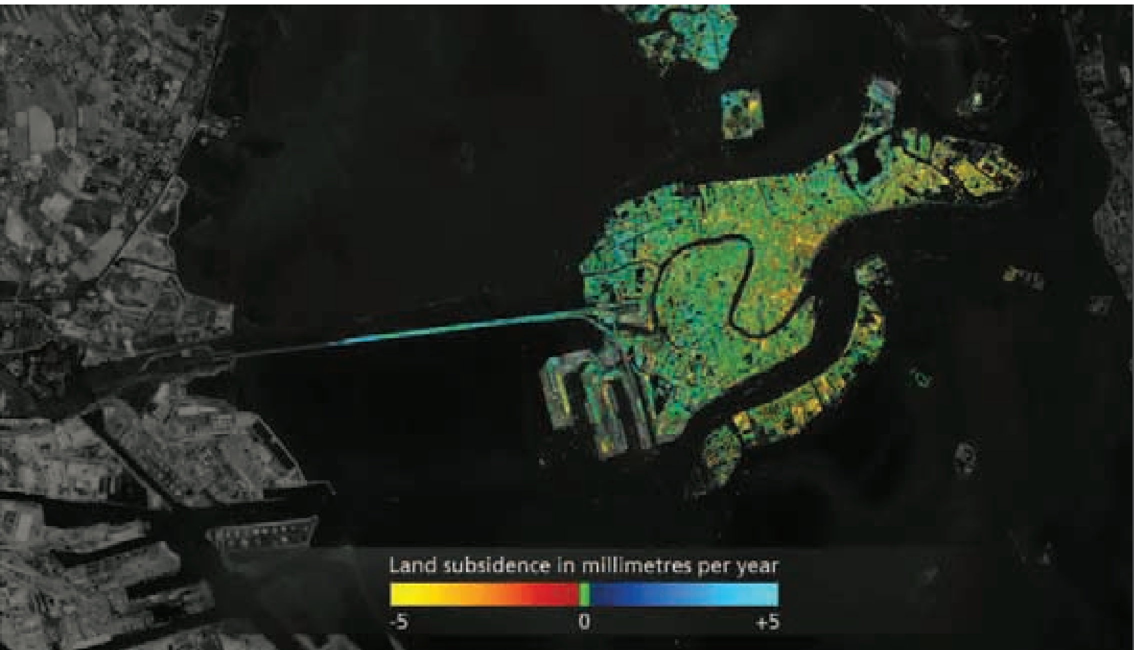
- GMES Marine Monitoring Service: focused on areas such as marine safety and transport, oil spill monitoring, water quality, weather forecasting and the polar environment.
- GMES Land Monitoring Service: focused on areas such as water management, agriculture and food security, land-use change, forest monitoring, soil quality, urban planning and natural protection services.
- GMES Atmosphere Monitoring Service: focused on areas such as air quality, ultraviolet radiation forecasting, greenhouse gases, ozone layer and climate change studies.
- GMES Emergency Management Service: provides information to mitigate the effects of natural and manmade disasters, floods, forest fire, earthquakes and to support humanitarian aid.
- GMES Security Service: provides support in areas such as peacekeeping efforts, maritime surveillance and border control.

The data gathered within these services will also feed Climate Change activities.

In addition to the above services, GMES serves other users such as public entities in Member States at national, regional or local level (for example, environmental agencies, mapping bodies, emergency services, urban planning bodies), European agencies (such as the European Environment Agency, the European Maritime Safety Agency, the European Centre for Medium-Range Weather Forecasts, Eumetsat and the European Union Satellite Centre), private business and individual citizens. A large variety of commercial industry segments will also benefit through the development and provision of operational geo-services.

At a regional level, GMES is already used to monitor air quality, map coastlines, regional areas and urban expansion and to manage marine and agricultural resources. GMES also plays a key role in disaster management and prevention.

On air quality, for instance, GMES currently provides daily (three-day) air quality forecasts and historical records of key industrial pollutants such as ozone, nitrogen dioxide, sulphur dioxide and aerosols for the major cities and regions of Europe. The forecasts form the basis for the management of health risks of citizens suffering from asthma or other symptoms. The




← Very high resolution map of land subsidence in Venice (mm/year), with data collected from May 2008 to April 2010 showing over 1.5 million point measurements (ESA/DLR) historical records support regulation of the EU's Air Quality Directives that are implemented by regional authorities of national governments. A fully operational Air Quality Service in Europe could not be sustained without GMES.

In another domain, the GMES Emergency Response Service has been activated more than 50 times in Europe between September 2010 and September 2011. Crisis situations associated with the floods in Poland and Hungary in 2011 were supported by this service. Geo-information products and situation maps specifically dedicated to the preparedness and recovery phases of these events were delivered. Loss of this GMES service would increase the risks to lives and livelihoods of European citizens.

↑ Floods of the Hérault in south-eastern France in November 2011 monitored with GMES Contributing Missions (COSMO-SkyMed and SPOT-5, SAFER)

## Socio-economic benefits of GMES

According to the EC staff working paper Memo/11/469, '*Money where it matters – how the EU budget delivers value to you*', published in conjunction with the EU MFF proposal, GMES could provide economic benefits of around €6.9 billion per year for industry, or 0.2% of EU annual Gross Domestic Product (GDP). Natural and manmade catastrophes in Europe, America, Asia and Africa, coupled with increased security needs, have further reinforced the case for improved monitoring systems.

GMES has great potential for businesses in the services market, which will be able to make use of the data it provides free of charge. Over the period 2006–30, the potential GMES benefits accumulated would be comparable to 0.2% of the EU current annual GDP. The benefits from all the GMES services in full use would equal €130 billion (2005 prices) or around €6.9 billion per year.

Obviously there are different methods that can be used when assessing the socio-economic benefits of GMES. Matters are complicated by the fact that some of the effects are not quantifiable. It is useful to perform a meta-analysis of studies that have been carried out.

The ESPI Report 39, '*The Socio-Economic Benefits of GMES*' published in November 2011 follows this line by comparing a study by PricewaterhouseCoopers (PwC) and another one by Booz&Co. An important result is that both studies, although employing different approaches, reach similar conclusions regarding the order of magnitude of potential socio-economic benefits of GMES.

> **"€1 invested in GMES brings a macro-economic return of €10"**

The PwC study establishes three categories of potential GMES benefits: efficiency benefits, European policy formulation benefits and global action benefits, and assesses them separately. The Booz&Co study, based on a literature review, looks at different funding levels and performs an impact analysis in the areas of climate change, environment and security and industrial development.

Moreover, it differentiates between static and dynamic scenarios. A dynamic scenario, unlike a static one, allows for interaction between relevant ecosystems in the realm of GMES. From both studies, a benefit–cost ratio of about 10 can be derived. This means that for every €1 spent by the European taxpayer on GMES, a public return of €10 can be expected.

In short, the European dimension of GMES will lead to economies of scale, facilitate common investment in large infrastructures, foster coordination of efforts and observation networks, will enable harmonisation and inter-calibration of data, and provide the necessary impetus for the emergence of world-class centres of excellence in Europe.

In addition to these economic benefits, GMES will provide strategic benefits by providing Europe with better information globally and therefore allowing Europe to assume a stronger role on the political stage and the global marketplace.

## GMES Space Component led by ESA

The objective of the GMES Space Component (GSC) programme is to fulfil the space-based observation requirements in response to European policy priorities and GMES users needs in the environmental and security domains. The Space Component comprises two types of satellite missions, ESA's five families of dedicated Sentinels and missions from other space agencies, called Contributing Missions.

This component is coordinated by ESA, based on ESA's more than 30 years experience in developing and operating satellites as well as providing access to third party missions to users.

*GSC Space Segment*

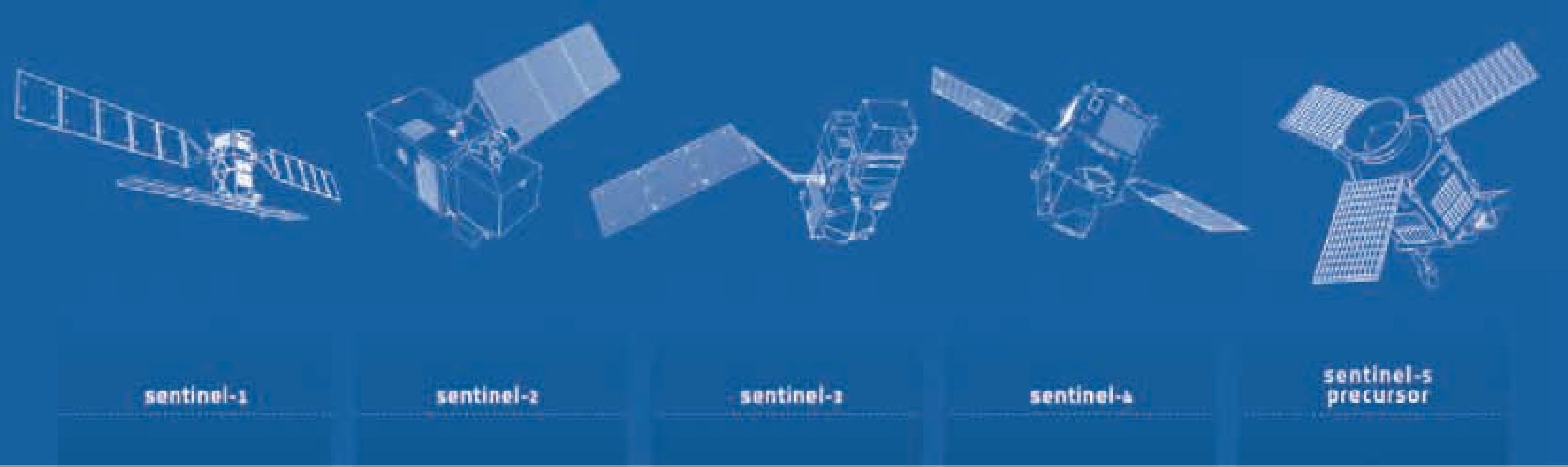
While the Sentinel satellites are currently developed specifically for the needs of the programme, the Contributing Missions are already providing a wealth of data for GMES services, and will continue to deliver complementary data after the Sentinels are in orbit. They are operated by national agencies or commercial

↓ GMES Optical Contributing Missions: Operational time periods (ESA)

| OPTICAL MISSIONS | PRINCIPAL OWNERS | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Low Resolution (res > 300 m)** | | | | | | | | | | | | | | | | |
| Envisat (AATSR/MERIS) | ESA | In orbit | In orbit | In orbit | | | | | | | | | | | | |
| Sentinel-3 (SLSTR) A | ESA | | | | Approved | Approved | Approved | Approved | Approved | Approved | Approved | | | | | |
| Sentinel-3 (SLSTR) B | ESA | | | | | Approved | Approved | Approved | Approved | Approved | Approved | Approved | | | | |
| Sentinel-3 (SLSTR) C, ... | ESA | | | | | | | | | | | Planned | Planned | Planned | Planned | Planned |
| SPOT-4/-5 (VGT) | CNES | In orbit | In orbit | In orbit | | | | | | | | | | | | |
| **Medium Resolution 1/2 (30 m < res ≤ 300 m)** | | | | | | | | | | | | | | | | |
| PROBA-V | ESA/BELSPO | | | Approved | Approved | Approved | | | | | | | | | | |
| Sentinel-3 (OLCI) A | ESA | | | | Approved | Approved | Approved | Approved | Approved | Approved | Approved | | | | | |
| Sentinel-3 (OLCI) B | ESA | | | | | Approved | Approved | Approved | Approved | Approved | Approved | Approved | | | | |
| Sentinel-3 (OLCI) C, ... | ESA | | | | | | | | | | | Planned | Planned | Planned | Planned | Planned |
| **High Resolution 2 (10 m < res ≤ 30 m)** | | | | | | | | | | | | | | | | |
| SPOT-4 | CNES | In orbit | | | | | | | | | | | | | | |
| UK-DMC 2 | DMCII | In orbit | In orbit | In orbit | In orbit | | | | | | | | | | | |
| Deimos-1 DMC | Deismo | In orbit | In orbit | In orbit | In orbit | | | | | | | | | | | |
| Sentinel-2 A | ESA | | | | Approved | Approved | Approved | Approved | Approved | Approved | Approved | | | | | |
| Sentinel-2 B | ESA | | | | | | Approved | Approved | Approved | Approved | Approved | Approved | Approved | | | |
| Sentinel-2 C, ... | ESA | | | | | | | | | | | Planned | Planned | Planned | Planned | Planned |
| **High Resolution 1 (4 m < res ≤ 10 m)** | | | | | | | | | | | | | | | | |
| RapidEye-5 S/C | RapidEye | In orbit | In orbit | In orbit | In orbit | In orbit | | | | | | | | | | |
| RapidEye Follow-on | RapidEye | | | | | Planned | Planned | Planned | Planned | Planned | Planned | Planned | | | | |
| Venμs | CNES-ISA | | | | Approved | Approved | Approved | Approved | | | | | | | | |
| **Very High Resolution 2 (1 m < res ≤ 4 m)** | | | | | | | | | | | | | | | | |
| SPOT-5 | CNES | In orbit | In orbit | In orbit | | | | | | | | | | | | |
| SPOT-6, -7 | Spot Image | | | Approved | Approved | Approved | Approved | Approved | Approved | Approved | Approved | Approved | Approved | Approved | | |
| Seosat / Ingenio | CDTI | | | | Approved | Approved | Approved | Approved | Approved | Approved | Approved | | | | | |
| Seosat / Ingenio-2 | CDTI | | | | | | | | | | Planned | Planned | Planned | Planned | Planned | Planned |
| **Very High Resolution 1 (res ≤ 1 m)** | | | | | | | | | | | | | | | | |
| Pléiades-1, -2 | CNES | | Approved | Approved | Approved | Approved | Approved | Approved | Approved | Approved | | | | | | |
| DMC3 | DMCII | | | | | Approved | Approved | Approved | Approved | Approved | Approved | Approved | | | | |
| Deimos-2 | Deimos | | | | Approved | Approved | Approved | Approved | Approved | Approved | Approved | | | | | |
| **Hyperspectral missions** | | | | | | | | | | | | | | | | |
| EnMap | DLR | | | | | Approved | Approved | Approved | Approved | Approved | | | | | | |
| Prisma | ASI | | | Approved | Approved | Approved | Approved | Approved | | | | | | | | |

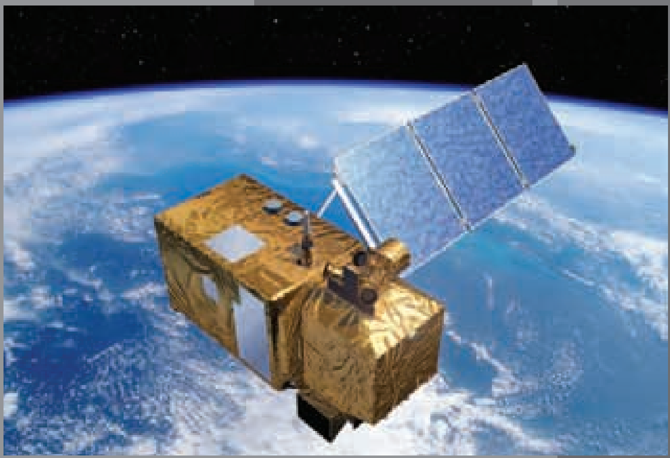
In orbit — Approved — Planned

N.B. Bars indicate estimated time of mission operations in years




↑ Sentinel-1

↑ To be launched in 2015, Sentinel-5 Precursor will be a satellite with a UV/IR spectrometer, developed to avoid a gap between Envisat and the launch of Sentinel-5 on a MetOp Second Generation satellite



↑ Sentinel-2

↑ The Sentinel-4 mission consists of two instruments carried on the Meteosat Third Generation Sounder satellite, to be launched in 2019

↑ Sentinel-3

entities within ESA or EU Member States, Eumetsat or other third parties. The conditions under which their data are made accessible to GMES (e.g. Ordering mechanisms, processing level, delivery timeliness, data licensing, etc.) are contractually stipulated with the mission owners.

The evolving constellation of Contributing Missions, with their own ground segment, is interfaced through the Coordinated Data Access System (CDS) to provide data to users.

The GMES dedicated missions include the development of a series of two spacecraft of the Sentinel-1, Sentinel-2 and Sentinel-3 missions. The first will be launched in 2013. These missions carry a range of technologies, such as radar and multi-spectral imaging instruments for land, ocean and atmospheric monitoring:

- Sentinel-1: a C-band Synthetic Aperture Radar (SAR) sensor to provide a high revisit time all-weather day-and-night supply of imagery and ensures continuity of ERS-2/Envisat SAR data. It supports services related to the monitoring of Arctic sea-ice extent, routine sea-ice mapping, surveillance of the marine environment (including oil-spill monitoring and ship detection for maritime security), monitoring of land-surface for motion risks and mapping to support humanitarian aid and crisis relief actions.

- Sentinel-2: a medium-resolution optical sensor, to provide continuity of SPOT- and Landsat-type data for services related to, for example, land management by European and national institutes, the agricultural industry and forestry, as well as disaster control and humanitarian relief operations.

- Sentinel-3: a suite of instruments to measure sea-surface topography, sea- and land-surface temperature and ocean- and land-surface colour with high-end accuracy and reliability in support of ocean forecasting systems, and for environmental and climate monitoring.

- Sentinel-4/-5: spectrometer instruments at high temporal and spatial resolution to be carried on Eumetsat satellites (Meteosat Third Generation and MetOp Second Generation, respectively), which will benefit services to monitor air quality, stratospheric ozone, solar radiation and climate monitoring. Taking the planned launch date for MetOp-SG (2019) into account, a Sentinel-5 precursor mission is being developed for launch in 2015, in order to fill the gaps between Envisat and Sentinel-5 for atmospheric monitoring.

Studies are also performed for the evolution of the GSC system, in response to user requirement evolutions and technology developments. For low-inclination altimetry, a Jason-CS mission is being developed, which is a further development of CryoSat-2 and continues measurements obtained currently by Jason-2/3.

***GSC Ground Segment***

The Ground Segment, through which the data are streamed and made available to GMES services, completes the Space Component. It is composed of Core and Collaborative Ground Segments.

The Core Ground Segment, having GSC-funded functions and elements, provides the primary access to Sentinel Missions and coordinates access to complementary EO data from Contributing Missions.

The GSC Core Ground Segment interfaces with the GSC Collaborative Ground Segment, which is comprised of elements funded by third partners, i.e. not via the ESA/EU funded GSC programme. It provides complementary access to Sentinel missions, e.g. through specific data acquisition, processing, dissemination or specific data products.

ESA ensures integrity and coordination of the GMES Space Component. Within the GSC Core Ground Segment, ESA will:

- assume the overall technical coordination related to EO data access, including interfaces to GMES Contributing Missions and the coordination of ground segment interface/standard developments;

- operate the Core Ground Segment for the Sentinel-1 missions, for the Sentinel-2 missions and for Sentinel-3 missions (for the land user community) and the operations of the Coordinated Data Access System (performed by existing facilities or industry under contract of ESA);

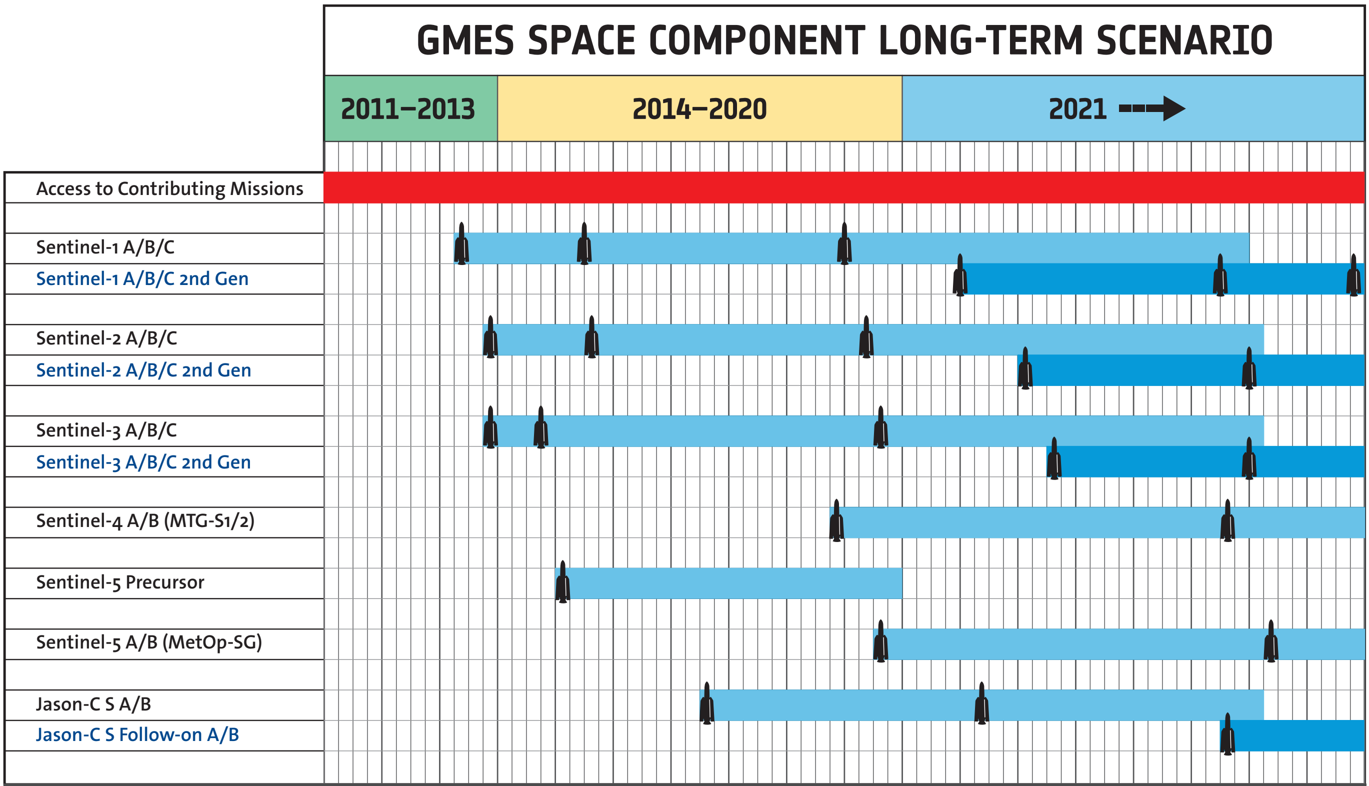
- ensure the technical integration of new missions and the technical evolution of the Core Ground Segment, while maintaining its operational services;

- ensure coordination of Ground Segment aspects with Eumetsat for the marine part of Sentinel-3, for Sentinel-4 and for Sentinel-5 missions.

## Users need long-term guaranteed observations

Continuity of observations is the prerequisite for an operational service. This principle is clearly visible in meteorology. A similar goal is to reach such an operational status for environmental monitoring.

The user-driven nature of the GMES Space Component programme and the prerequisite of its affordability and




↑ Simplified Long–Term Scenario graph

sustainability impose that the forecast of the long-term operational needs are based primarily on periodically updated requirements of the GMES services user community. Once operational services are in place, the evolution of their requirements will continue to drive the GSC.

At the same time, industrial and technology development will impact the GSC capabilities and influence the way the system fulfils the user needs. The baseline technology for the space segment should remain stable for a period ranging between 10 and 20 years per satellite generation (depending on the kind of mission), in analogy to other operational Earth observation programmes such as Meteosat, SPOT, MetOp, Landsat or NOAA/AVHRR.

Regarding the ground segment, more frequent adjustments will be made to take account of advances in computational facilities and user interface technologies due to the shorter cycles of technology renewal.

Therefore, it is essential in GMES to preserve the co-existence of mechanisms enabling the long-term operations of series of satellites, together with mechanisms enabling development activities considering the introduction of new technologies.

## Stimulating growth

Access to Sentinel data is governed by the Sentinel data policy, which is formulated within the framework of a wider GMES data and information access policy.

Under the EU’s responsibility, the overall GMES Data and Information Policy has the following objectives:

- Promoting the use and sharing of GMES information and data
- Full and open access to information produced by GMES services and data collected through GMES infrastructure, subject to relevant international agreements, security restrictions and licensing conditions, including registration and acceptance of user licenses
- Strengthening Earth observation markets in Europe, in particular the downstream sector, with a view to enabling growth and job creation
- Contributing to the sustainability and continuity of the provision of GMES data and information
- Supporting the European research, technology and innovation communities

These objectives, which also apply to the Sentinel data policy aim at maximising the beneficial use of Sentinel data for the widest range of applications and intend to stimulate the uptake of information based on Earth observation data for end users. Thus it responds directly to the increasing demand for Earth observation data in the context of climate change initiatives and in support for the implementation of environmental and security policies.

The principles of the Sentinel Data Policy are:

- In principle, anyone can access acquired Sentinel data; in particular, no difference is made between public, commercial and scientific use and in between European or non-European users (registration is required).
- The licences for the Sentinel data itself are free of charge.
- The Sentinel data – as far as generated out of the Core Ground Segment – will be made available to the users via a 'generic' online access mode, free of charge. 'Generic' online access is subject to a user registration process and to 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 affecting data availability or timeliness, specific operational procedures will be activated.

The principles of this policy have been defined by ESA and the EC and were approved by ESA Member States in September 2009. In 2012, the EC is expected to issue a legal act on the overall GMES Data and Information Policy, of which the Sentinel Data Policy will be one specific element. For the Contributing Missions, the data policy of the mission owners will be respected for the purpose of providing data to GMES service users.

## Funding – the main challenge today

ESA and EU Member States have funded the development of the GMES Space Component. To date, around €2.3 billion have been invested, of which ESA Member States provided 72% and the EU 28%. The EU provided an additional €0.7 billion for the services domain while ESA Member States provided €0.2 billion during the initial period for the build-up of GMES services.

Details of the GSC co-funding, including technical, managerial and financial issues, are laid down in an agreement between ESA and the EU on the GSC implementation, concluded in February 2008 and amended in January 2009 and June 2011.

GSC funding is expected to be complemented after decisions made at the ESA Ministerial Council in 2012 to complete the GSC build-up, and by the next EU MFF for the years 2014–20, in order to achieve the operational configuration of the GMES Programme. An average amount of €834 million per year has been identified for the operation of the overall GMES programme. The portion needed for the GSC is described in the GSC Long-term Scenario prepared by ESA and amounts to about €640 million per year.

However, in June 2011, the EC unexpectedly suggested to finance GMES outside its next MFF, citing the risk of potential cost overruns in the operational phase, albeit confirming the overall funding need of €834 million per year.

Any EU funding instrument outside the MFF budget has already been criticised by several key EU Member States, Members of the European Parliament, European users, in particular the EEA, international research organisations and a number of business and industry associations. The ESA Council Chair, on behalf of ESA Council, also raised concerns and urged decision-makers to move GMES back on budget, i.e. within the MFF. The Chair also stated that in the absence of EU commitments for the availability of operational funding beyond the middle of 2014, ESA would be instructed not to launch the Sentinel satellites.

It shall also be pointed out that the risk of cost overruns within the operational phase is marginal, since these costs can be capped at the pre-estimated level, as listed in the GSC Long-term Scenario, and the operational performance of the GSC overall system will be performed within the limits of the available budget.

Nevertheless, the EC proposal for the next MFF will undergo an intense negotiation process until the end of 2013 involving the EU Council and European Parliament.

## GMES is unique

The combination of space and *in situ* observations to create information services through a comprehensive system, as currently built up through GMES, is unique. It provides not only strategic information and significant socio-economic benefits to Europe, but also demonstrates how Europe can work together by pooling expertise and resources to achieve a common goal. GMES also creates new business opportunities and new high-end jobs in many disciplines, most of them outside the space domain.

Decision-makers need to be convinced of the benefits that GMES can create for national and local communities. For GMES to become fully operational, and allowing Europe to reap these benefits, an adequate funding level within the EU MFF is essential. To achieve this, GMES needs political support, today more than ever.

Hylas-1 after fuelling at the launch site in Kourou, French Guiana

# → HYLAS-1

## Satellite broadband for Europe

**Jose Maria Casas, Andrea Cotellessa and Andrew Murrell**
Directorate of Telecommunications and Integrated Applications

**Ulrich Sterzl**
Directorate of Procurement, Financial Operations and Legal Affairs

**Hylas has validated a new way of operating in the satellite telecommunications sector – where ESA and satellite operators join forces and shares resources, to provide more rapid access to space for new products and technologies.**

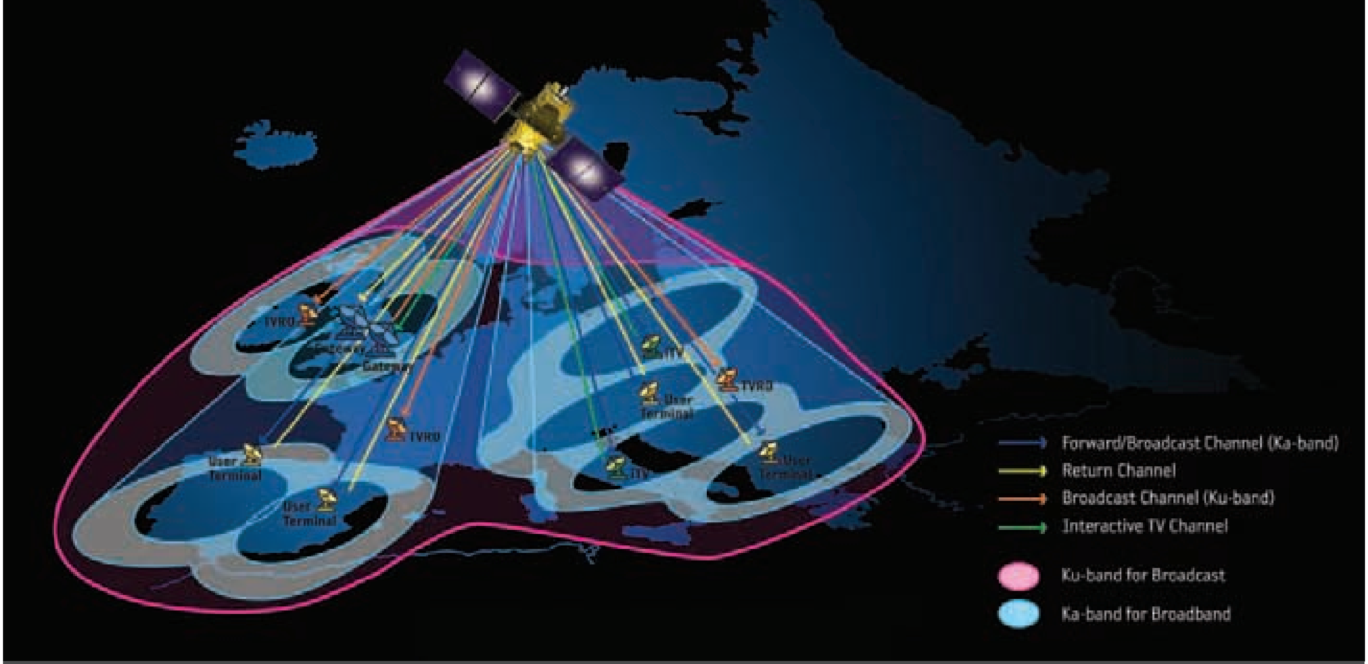
The Hylas project was ESA's first Public–Private Partnership, resulting in the launch and commissioning of a full satellite telecommunication (satcom) system. The Hylas-1 satellite is providing broadband connectivity to underserved areas in key European regions.

### Setting the scene

The role of ESA in satcoms is to support the competitiveness of European industry and to provide solutions that meet the needs of European citizens. There a few projects where these objectives been met as successfully as in the Hylas project.

In the early 2000s, there was a global awareness of the need to provide internet connectivity to a wide range of people that were beyond the reach of terrestrial networks or were in places where the quality of terrestrial services left a lot to be desired.

Of course, telecommunications satellites were an obvious alternative and, in many cases, they were used as a last resort. Most telecommunications satellites are designed for broadcast television (a broad single beam), and their coverage area is typically a continent, or a region encompassing several countries. So when they are used to deliver internet services, the data downloaded by a user are in fact transmitted over a full continent with an extraordinary waste of power and spectrum.




↑ Map showing how 'spot beam' technology on Hylas-1 is used to aim narrow beams at selected areas in Europe

The way around this is to use 'spot beam' technology, where satellites are designed to aim narrow beams at selected areas, allowing the same radio frequencies to be reused in different places, thus increasing the channel capacity.

The concept of large-capacity multi-spot beam systems had been subject to a vigorous development under ESA's ARTES programme between 1999 and 2002. Plans had been introduced to support the initial deployment of these systems after the ESA Ministerial Council of 2001. But by 2002 however, the internet 'bubble' had burst, and there was a reluctance of satellite operators to enter in a business that was tainted by the collapse of so many 'dot.com' businesses.

Nevertheless, multispot beams have remained a subject of interest for the sector because of their ability to optimise the use of satellite resources, so that a given multispot beam satellite can carry tens of times more traffic than their conventional predecessors. Spot beam solutions create a different problem of system dimensioning however: not all spots are equally populated and therefore not all of them require the same power and bandwidth.

To tackle this issue, ESA and industry (Astrium UK) initiated a development allowing full flexibility in the definition of the frequency plan and bandwidth of each satellite transponder and also on the assignment of power to its power amplifiers (TWTAs). This development was named the Generic Flexible Payload.

> **"Products become available more quickly for use in the largest, most competitive and most profitable sector of the space industry."**

In early 2005, ESA was approached by Avanti, a relatively small service provider in the UK, with the proposal to develop, implement and launch a satellite to be called 'HYLAS' (Highly Flexible Satellite) that would allow the validation of the Generic Flexible Payload technology and promote, and quick start, the development of broadband access to internet across Europe.

Hylas was born from the vision of Avanti's management who, realising the sound fundamentals of the internet demand, put forward a project that ESA was able to include in its ARTES programme, supporting European industry and introducing new services demanded by European society.

## Public–Private Partnership

The Public–Private Partnership (PPP) model makes available to satellite operators new products and equipment that have been developed by industry in the framework of other ESA programmes (most notably under the Advanced Research in Telecommunications Systems programme, ARTES).

It goes without saying that the world of satcoms, as in other sectors, is averse to technological risks and prefers flight-proven solutions for the satellites that populate the orbits around Earth.

New technologies, unproven in orbit, represent a financial risk for the satellite operators that may affect the timeliness of deployment of new satellites as well as their reliability over the mission lifetime. This automatically results in a reduced capacity to generate revenues for the large capitals that are invested in a typical satellite procurement activity.

In the PPP model elaborated by ESA, the new technologies developed under ESA programmes are provided to the operators at the end of a rigorous qualification programme on the ground, in full compliance with the applicable industrial standards of the satcom market, under the financial and technical coverage of ESA.

This allows satellite operators to embark the newly developed products on their own satellites and to benefit from the improved performances with a much-reduced financial exposure. In this win-win scenario, the effectiveness of the ESA research and development programmes is tremendously augmented, such that Member States' satcom industry products become available more quickly for use in the largest, most competitive and most profitable sector of the space industry.

The pivotal element in Hylas partnership is represented by the satellite's communication payload, in Ka- and Ku-band, entirely based on Astrium's Generic Flexible Payload architecture. The design, development, manufacturing and testing of these payloads has been funded by ESA. The rest of the spacecraft, the 'platform module', was procured by Avanti Communications under their Hylas procurement contract placed with Astrium UK.

For this specific mission, Astrium UK exploited their strategic partnership with Antrix Corporation, designing the satellite around the small geostationary I-2K bus, flown by the Indian Space Research Organisation (ISRO) in previous INSAT and GSAT missions.

Moreover, as an integral part of the Hylas contract, Avanti Communications undertook to set up all the necessary ground infrastructure to control Hylas during its 15-year mission lifetime and to access and manage the communication network components for the provision of the different communication services.

## Challenges of the partnership

The technical side of the project offered many challenges, but the contractual side certainly proved no less challenging in its own right. At the outset, some basic questions had to be answered.

Firstly, Avanti Communications was a relatively young company with only few staff, undertaking to shoulder approximately two thirds of the total project cost, a figure with nine digits. To attract investors or/and lenders providing the entire company contribution before contract signature was not to be expected, resulting in a substantial residual risk for ESA in view of the completion of the project.

So should ESA team up with Avanti Communications at all? Should ESA space-qualify other companies' highly innovative components and provide the remaining third of the total cost? Were the risks associated with the Generic Flexible Payload development commensurate with the business plan, such that the start of commercial operation and the revenue stream for our partner could be achieved in a financially viable time?

Next, what kind of contractual relationship should it be? A recent example (Amazonas) existed where ESA had placed the contract for a telecommunications satellite payload and then handed over the result to a satellite operator.

Then, would a partnership agreement be needed or a contract, or both? Would the ESA Legal or Procurement Departments (or both) be involved? An ESA Council Document on Public–Private Partnerships dated October 2000 existed but left, quite wisely as it turned out, plenty of freedom.

And finally, would Hylas count as an ESA mission for which an Ariane launcher would need to be given priority (which appeared unaffordable at contract signature)?

## Fastest and leanest

The leanest and fastest contractual solution imaginable had to be adopted to make Hylas happen, and the number of ESA requirements (technical, managerial and contractual) with which an ESA partner must comply had to be kept to the minimum, while still safeguarding ESA interests.

ESA's contract conditions for co-funded contracts had been written originally with the aim of supporting industry-conceived developments, but were not suited to guarantee timely delivery of a commercial satellite. The project therefore decided to let the future satellite operator place, on commercial terms and conditions, that contract as well as the contract for the launch service, and to enter into a co-funding contract in which the satellite operator undertook to set up the satellite system and pilot-operate it. All partnership aspects were to be included in the latter contract.

This contractual structure became the role model for all of ESA's telecommunication satellite PPPs entered into since, such as Alphasat (with Inmarsat), SmallGEO (with Hispasat) and EDRS with Astrium Services.

Last not least, thanks to an excellent cooperation with Avanti's CEO, Mr David Williams, and CTO, Mr David Bestwick, the time from proposal submission to signature of the Preliminary Authorisation to Proceed (with IPC approval in between) was only 62 days, and to signature of the contract less than eight months.

The contractual side of Hylas demanded further interventions to ensure the partnership would remain solid and tight long after contract signature. In summer 2007, another funding slice needed to be secured; the lenders demanded that the satellite operator be given the completely unrestricted right to choose the launcher, which initially ESA did not approve.

In the meantime, the harbingers of the 'credit crunch' and global financial crisis appeared on the horizon, and creative funding instruments suitable to Avanti Communications were disappearing quickly. It was only hours before the lenders' deadline that a Contract Change Notice enabling the closing of a loan was signed. After a substantial increase of the Hylas budget in 2009, an Ariane 5 was ultimately chosen.

ESA had certainly not been conceived with the primary objective to act as partner in PPPs for commercial telecom satellite projects but, through what officially counts as its first PPP, it has demonstrated that it can muster in all disciplines the capabilities and flexibility required.

Some particularities of the Hylas contract:

- Ownership of the satellite system remains with the satellite operator, only in cases justifying contract termination would ESA take over.
- Joint control over the bank account holding the satellite operator's initial financial contribution.
- Choice of the launcher, to be preceded by a competitive tender action, was the satellite operator's privilege; ESA retained the right to impose the use of an Arianespace launcher against payment of any price difference.
- 60% of ESA's contribution payable only as from Launch Readiness Review onwards.
- The total number of Contract Change Notices was 14, of which three included an increase of ESA's financial contribution.

## Indian spice on European technology

The novel elements of Hylas were not limited to only the financial set-up. The spacecraft carries a very advanced communications payload based on the Generic Flexible Payload architecture developed by Astrium.

Unlike on conventional telecommunication satellites, this payload is capable of being reconfigured in orbit by telecommands to adjust the transmission plan and the transmitted levels of powers according to the evolving traffic demands in the various service areas. The development of this new payload represented the main contribution of ESA to the Hylas partnership.

Besides, the size and power demand of the Hylas payload (160 kg and 2000 W) were less than optimal for the accommodation on a Eurostar-3000 satellite platform (the mainstay of Astrium's telecom geostationary Earth orbit platforms) and therefore less financially attractive for Avanti.

However in 2005, with the specific aim of gaining competitiveness in the lower end of the geostationary platforms market (below 4000 W), Astrium had entered into an agreement with Antrix Corporation, the commercial arm of ISRO, to offer satellite operators telecommunication satellites based on the I-2K and I-3K class of Indian geostationary platforms. An I-2K platform was selected to carry the Hylas advanced telecommunications payload and maintain compatibility with the ISRO GSLV launch vehicle.

## The Hylas system

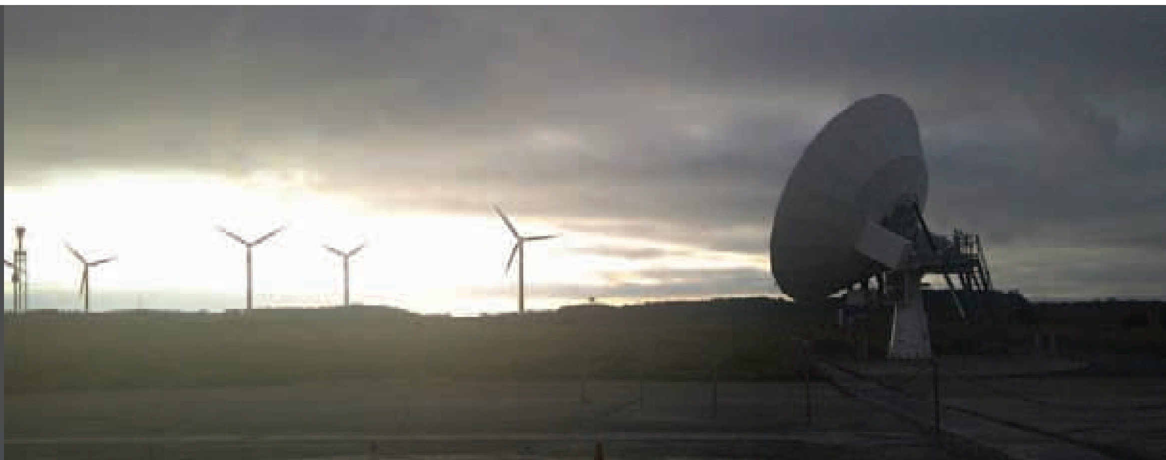
Hylas is the first multi-spot beam Ka-band system designed and launched in Europe to provide broadband access over a selected number of European regions. The satellite footprint consists of eight spot beams, generated by a dual reflector single feed per beam (SFPB) antenna system.

Two of the beams can be selected as gateway beams, with only one active at any one time, to provide the required connectivity to the internet backbone. The Hylas system is a 'star network', in which the gateway beam works as a conduit for the traffic to all the other beams of the system.

The Hylas Ground Segment is the Earth-based part of the mission and hosts all those elements that make sure the satellite is kept under control at all times and that the communication services can be provided to the users.

The Ground Segment has three main parts: a) the Satellite Control Centre for the control of the satellite and its orbit; b) the Common Elements, which include shared infrastructure and software, such as the gateway stations and antennas, the Network Operations Centre, satellite resources management and back-office tools; and c) the Service Segment, which provides satellite broadband services and includes the hubs and the terminals.

Avanti procured the Satellite Control Centre (SCC) through a contract awarded to Inmarsat. The Hylas SCC is hosted in the Inmarsat facilities and is based on the I4S systems; Inmarsat's own satellite fleet management product. Telemetry and



→ The 9.3 m antenna of the Hylas-1 gateway station, Goonhilly, in Cornwall, UK

Telecommand ground stations for Hylas are also part of the Inmarsat infrastructure and are hosted in the Fucino teleport in Italy, run by Telespazio.

The Satellite Common Elements group a set of functionalities that are distributed over a number of different locations and that utilise different hardware and software components. Avanti have placed contract with British Telecom to set up Hylas-1 gateway stations in two locations in Cornwall: Goonhilly and Land's End. The two sites are conveniently separated geographically to offer the diversity to maintain the high availability required for a Ka-band satellite network, even in the presence of adverse weather conditions. Both sites host a 9 m Ka-band antenna system, procured from GDSatcom.

Goonhilly is the primary site and hosts a state-of-the-art facility – the hubs that provide the connectivity services to the Hylas-1 users. A Radio over Fibre link allows a switchover of gateway services to Land's End if needed because of severe rain fade or routine maintenance.

The Internet traffic is routed over the fibre backbone into redundant core network switches out to the Internet. The gateway stations are also connected to London, where Avanti have set up their Network Operations Centre. This is where Avanti actually controls the entire system. As a broadband service provider they will manage installation, provide support services and host all the back-office billing and accounting services. Avanti will also support resellers of their broadband services from their London facilities. This facility will be responsible for analysing the satellite performances and (re)allocating satellite resources by means of the in-orbit flexibility of the spacecraft communication payload, as required by the traffic demands in the various spot beams.

The Service Segment includes the satellite hubs and the user terminals for the provision of the broadband services for consumers and enterprise users. Avanti has contracted Hughes Network to supply the hubs and the several thousands terminals that are planned to be deployed in each of the eight Ka-band spot beams that form the Hylas-1 coverage.

> **"The in-orbit testing phase has been a complete success and puts us in a strong position for future growth."**
>
> David Williams, CEO, Avanti

## "Bravo a toute l' equipe"

This was the handwritten annotation by ESA Director General Jean-Jacques Dordain, on the letter of congratulations to the ESA Hylas-1 Project Team. In the true spirit of a partnership, this represents the real essence of the Hylas project, the three key players all contributed substantially to the final success.

ESA, Avanti and Astrium have faced a series of problems and challenges for the first time in an unprecedented context. In all those circumstances, in which specific issues were pulling the partners in different directions to protect their vested interests, the partnership always remained solid, allowing solutions to be found in a timely manner.

Hylas is the opening paragraph of an entirely new chapter of ESA history in telecoms that will be soon populated with stories of completion of other partnership programmes that are now being developed.

> **"ESA's cooperation with Avanti Communications is a prime example of a creative fast-track for demonstrating and reaping the benefits of satellite high technology."**
>
> Magali Vaissiere, Director of Telecommunications and Integrated Applications, ESA

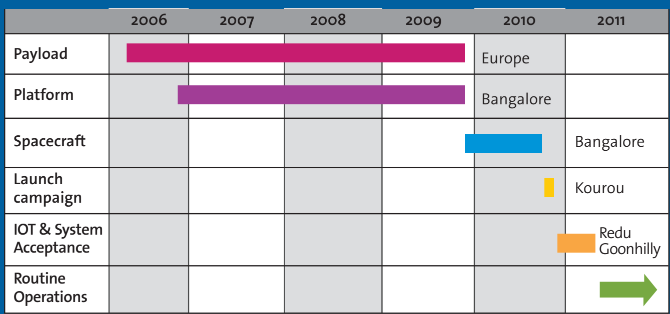
↑ Avanti's David Williams and ESA's Magali Vaissiere celebrate the launch of Hylas-1 at Kourou, French Guiana

# → A BRIEF HISTORY OF HYLAS

Hylas-1 is the first telecom satellite launched in the framework of an ESA partnership programme, and comes almost ten year after Artemis, the last telecom satellite launched by ESA in 2001.

To date, Hylas-1 is the fastest telecom satellite project ever performed in ESA: from the contract signature in April 2006 to end of commissioning in March 2011, activities were completed in less than five years.

The major effort in the programme was the design, development, production and qualification of the units that constitute the GFP payload. These activities took place at the Astrium site in Portsmouth, UK, in the period from contract signature until October 2009 when the last payload (SCACE) completed the ground test programme.



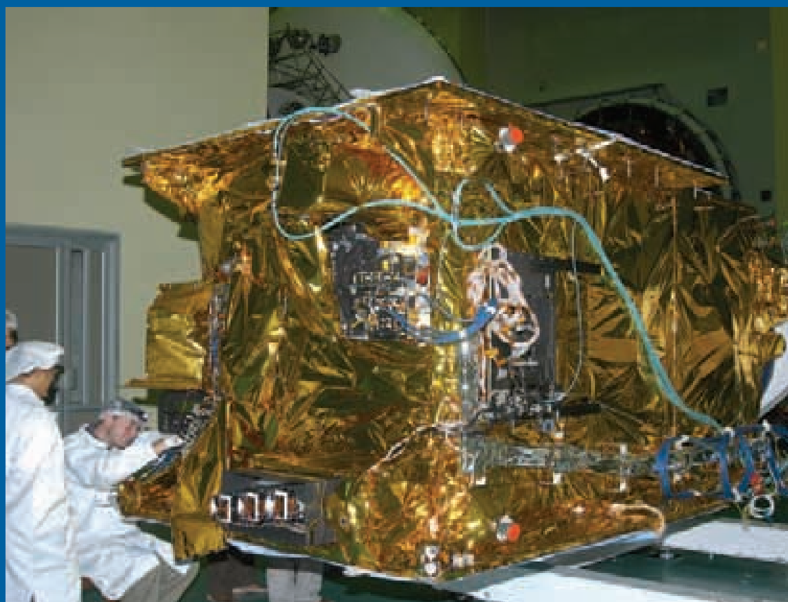

↑ The Hylas project master schedule

Earlier on, Tesat's development had been completed, as had production of the linearised travelling-wave tube amplifiers (TWTAs), another new technology to reach geostationary orbit for the first time with Hylas-1.

Meanwhile in India, ISRO was busy ensuring the full compatibility between the selected I-2K platform and the payload as it was coming off the draughtsman's board. This resulted in the initial satellite design being augmented into a heavier version with the required space, power and dissipation performances dictated by the payload.

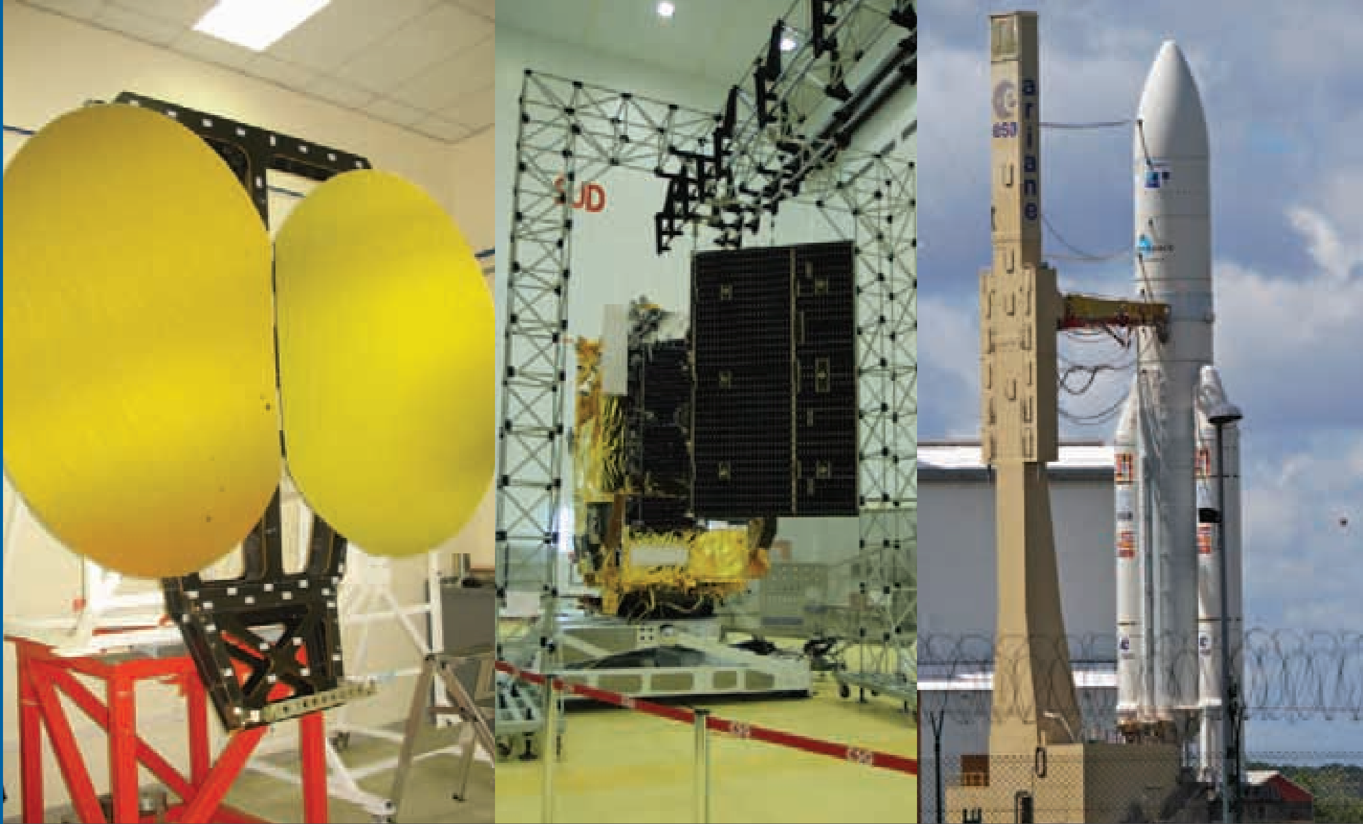
The Hylas payload, hosted on the two 'north' and 'south' radiators and on the Earth Viewing Platform, was integrated and tested in Portsmouth, on the flight panels manufactured and shipped from India by ISRO. On completion of payload integration and performance testing in the UK, the three panels were shipped back to ISRO in Bangalore, India, to be integrated with the rest of the spacecraft.

The satellite integration campaign started in November 2009 and progressed swiftly through the ground test programme that included thermal vacuum, sine and acoustic tests at ISRO facilities in Bangalore. The test campaign concluded with the final satellite functional tests in the Compact Antenna Test Facility in Bangalore, where antenna performances and satellite auto-compatibility were checked.



↑ Hylas-1 seen prior to thermal vacuum testing at ISRO Bangalore (ISRO)

↓ Hylas-1 Ka-band antenna seen during tests in ISRO Bangalore, India. Note the balloon used to support it during a test unfolding (ISRO)




↑ From left, Hylas-1 Ka-band Deployable Reflector Assembly; solar array deployment testing at Europe's Spaceport at Kourou; rollout of Ariane 5 flight V198 in November 2011

In October 2010, the spacecraft was flown on an Antonov-225 transport aircraft to Kourou for the final preparation for launch.

On 26 November, Hylas-1 was launched on Ariane 5 flight V198 on a bright sunny afternoon, a mere 412 milliseconds into the launch window. Hylas-1 separated from the launcher after 34 minutes into the selected geostationary transfer orbit and deployed its solar arrays as part of the initialisation sequence.

Hylas-1's orbit was raised from the Ariane transfer orbit to the geostationary arch with three burns of its liquid-fuel apogee motor, performed from the ISRO Master Control Facility (MCF) in Hassan, India, supported by the Launch and Early Operations network that included stations in Canada, Australia, South Africa and India. On 30 November, Hylas-1 was in geostationary orbit.

The In-Orbit Test (IOT) campaign was run from the MCF in Hassan for the platform part and from the SCC at Inmarsat for the payload part. The payload IOT campaign measurements were performed by Redu Space Services (RSS) at the ESA Redu ground station in Belgium, supported by a collocated team of engineers from Astrium, ESA and Avanti. The actual IOT preparations had started long before and had to resolve the problem of the lack of suitable Ka-band facilities in Europe for the class of performances required by modern Ka-band multi-spot beam systems, like Hylas-1.

The solution was found in an existing Ka-band antenna, TMS-6, from the Artemis programme, which was upgraded by RSS with contributions from ESA's ARTES programme.

On 14 March 2011, Avanti took over the in-orbit operations from Astrium/ISRO and began the final stage of the system validation: the System Acceptance Test. During this phase, Avanti performed a long series of tests on their Ground Segment infrastructure with Hylas-1 in the loop. The tests took three weeks to complete with the test team located at Goonhilly. Hylas-1 and the associated ground infrastructure were cleared to start routine operations on 4 April, just short of five years into the contract.

After one year in space, Hylas-1 is performing very satisfactorily with its eight Ka-band spot beams powered up and with users in all of the European regions in the satellite's coverage.


↑ Payload In-Orbit Test Facilities at ESA's Redu ground station in Belgium

# → Payload technology

## The need for flexibility

The Hylas payload is the first to employ a new architectural concept called the Generic Flexible Payload (GFP), developed by EADS Astrium with funding from ESA via the ARTES programme.

In a conventional telecommunications payload, a transponder's receive frequency, bandwidth and transmit frequency are all fixed during the satellite design phase, typically several years before entering into service. During the lifetime of a satellite, evolving business and political landscapes, the emergence of new technologies and applications, or even a change of orbital location or owner, can alter the operational requirements on the payload. With the expected lifetime of current commercial satellites exceeding 15 years, the ability of to adapt to these changing needs over the satellite's lifetime would be highly advantageous.

The GFP architecture allows the satellite's frequency plan to be redefined throughout the mission lifetime by commands from the ground. When combined with new power amplifier technology that allows a satellite's transmit power to be redistributed over service regions, the payload can reallocate flexibly the most critical resources of radio spectrum and transmit power, according to specific needs at the time.

## The solution

The GFP solution works by converting the frequency of all signals received by the satellite to a common Intermediate Frequency (IF), approximately 6 GHz, with an electronic unit called the Agile Integrated Down-converter Assembly (AIDA). Variants of AIDA have been produced that cover the Ku-FSS, Ku-BSS and Ka-bands. For payloads that use C-band uplink frequencies, no AIDA is required because the received signal is already at the IF.

Extensive connectivity is inherent to the GFP architecture: the IF output signals from the AIDA are all input to a sold-state switch matrix, called the Routing And Switching Equipment (RASE). The RASE allows connectivity to be established between any pair of satellite uplink and downlink beams. In addition, the RASE allows communications links to be operated in 'Broadcast' mode whereby a single uplink signal can be transmitted in multiple downlink beams simultaneously.

***SCACE***

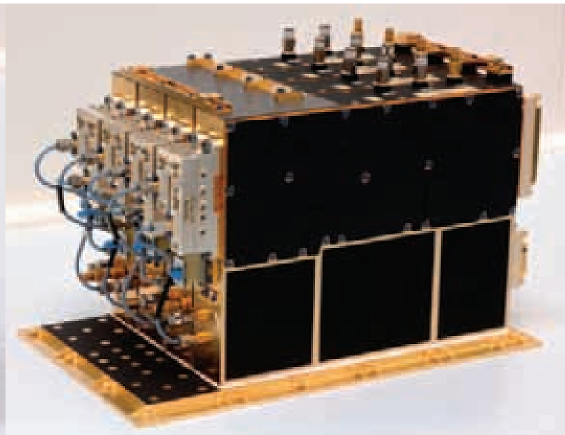
Having established the desired end-to-end connectivity path through the payload, the uplink signal is then 'conditioned' by a device that constitutes the heart of the GFP concept, called the Single Channel Agile Converter Equipment (SCACE).

The SCACE comprises three main elements/functions:

- A reconfigurable band-pass filter that allows the transponder uplink centre frequency and bandwidth to be independently adjusted under control from the ground.
- A gain control element that allows the link to be operated in either Fixed Gain Mode (FGM) where the gain of the overall transponder can be adjusted via ground control, or Automatic Level Control (ALC) mode. In ALC mode, variations in the receive signal strength (for example, because of rain fading) are automatically compensated for by adjustment of the satellite transponder gain.
- A variable frequency converter to translate the signal to the desired transmit frequency.

For Hylas-1, the required transmit signal is amplified prior to retransmission by an In-Orbit Adjustable Microwave Power Module (IOA-MPM). This equipment allows the transmit signal power to be adjusted while maintaining near-constant efficiency and was used on a spaceflight for the first time with Hylas-1. This innovation (developed by Tesat) enables the available satellite power to be reallocated between transponders as demanded by evolving operational conditions.

→ AIDA Engineering Model, Ku-band FSS and BSS (Astrium)



← Hylas-1's Single Channel Agile Converter Equipment, SCACE, Flight Unit (Astrium)

↑ The IOA-MPM Qualification Unit and flexible Travelling Wave Tube Amplifier by Tesat (ESA/Tesat-Spacecom)

## Enabling technologies

The Hylas payload equipment incorporates a number of technical innovations that allow a very high degree of functionality to be contained within highly integrated, compact, analogue sub-assemblies. This equipment is based on the Modular Microwave Hybrid Technology (MMHT) concept, developed by Astrium under a series of ESA-funded ARTES projects.

With this approach, the high-frequency elements of the design are realised by embedding active and passive circuit elements within multi-layer ceramic substrates housed within hermetically sealed cavities. Low-frequency and DC bias circuits are mounted on the outside of the structure to form complete functional blocks (or 'hybrids') such as frequency converters, amplifiers and agile frequency synthesisers.

Another 'first-flight' technology used within the GFP hybrids is the 'transponder-bandwidth-defining' ACT filter (Active Channelisation Technology). This type of filter is formed using a plated ceramic material with a high dielectric constant that allows high-frequency discrimination to be realised within a much lower volume. Used in conjunction with state-of-the-art microwave semi-conductor die, the resulting GFP hybrids represent a significant advance in terms of analogue RF functionality and performance for space applications. ■

## → Hylas data sheet

| | |
|---|---|
| Launch vehicle | Ariane 5 ECA (V198) |
| Launch site | Guiana Space Centre, Kourou, French Guiana |
| Orbital location | Geostationary at 33.5° West / 326.5° East |
| Operational lifetime | 15 years |
| Payload | ▪ Repeaters:<br>Six flexible Ka-band forward link transponders<br>One flexible Ka-band return link transponder<br>Two flexible Ku-band transponders<br>▪ Antennas:<br>One deployable 1.6 m diameter reflector antenna generating a linearly polarised shaped Ku-band beam with European coverage. One single-feed-per-beam antenna system with two deployable elliptical antennas – each measuring 1.6 x 1.35 m – generating eight circularly polarised Ka-band spot beams, each covering a key European market |
| Spacecraft bus | ISRO 1-2K (three axis stabilised) |
| Launch mass | 2541 kg (1109 kg dry mass) |
| Size | 4.2 x 2.6 x 2.5 m; deployed solar array span 9.0 m; deployed antenna span 6.0 m |
| Power supply | Two Sun-tracking wings each comprising two (2.54 x 1.53 m) solar panels, made up of triple-junction gallium arsenide cells; two batteries each comprising 20 lithium-ion cells with a 32 Ah capacity |
| Commercial operator | Avanti Communications |
| Prime contractor | EADS Astrium |
| Platform subcontractor | Indian Space Research Organisation (ISRO)/Antrix |
| Satellite control centre | Inmarsat HQ, London, controlled with the Inmarsat I4S control system |
| Network operations centre | Avanti Communications HQ, London |
| Gateway stations | Primary: Goonhilly (UK); Back-up: Land's End (UK) |

↘

REXUS rocket on
launch tower

# → REACHING FOR THE SKIES

## Flying student experiments to the edge of space

Helen Page & Roger Walker
Directorate of Policies, Planning and Control, ESTEC, Noordwijk, The Netherlands

**In a programme now entering its fifth year, over 400 European students have already had the chance to fly their own experiments to the edge of space.**

The REXUS/BEXUS programme (Rocket and Balloon Experiments for University Students) offers opportunities for student experiments to be flown on sounding rockets and stratospheric balloons. Each year, two rockets and two balloons are launched, carrying up to 20 experiments designed and built by student teams.

Students experience the full life-cycle of a space project, beginning with researching the idea and defining the design, continuing with building and testing, participating in the flight campaign and completing with data analysis and reporting. Throughout the project, the students develop a valuable understanding of space project methods and gain

↑ A REXUS launch

confidence in the practical skills necessary for the assembly, integration and testing of flight hardware and software.

## A unique experience

The possibility to participate in a launch campaign with teams from across Europe is a unique and unforgettable opportunity. Many students choose to base their university projects or theses on their REXUS/BEXUS experiments.

Students are also encouraged to document their progress, to develop an outreach programme and to present their experiment to experts in conferences and to the public through media such as the internet or their local press.

ESA has been involved in this German/Swedish programme since 2007 by identifying and sponsoring student teams to take advantage of the Swedish share of the payload allocation. ESA's Education Office provides coordination and financial support and experts from ESA's Directorate of Technical and Quality Management act as mentors to review the students' progress and offer advice throughout the course of their projects. This activity contributes towards ESA's long-term objective to ensure the existence of a qualified workforce for the future of the European space sector.

↑ A team of Czech students monitor their experiment data during a flight in the BEXUS-6 and -7 campaign in 2008 (SNSB/R. Schederin)

↑ ESA experts help students with last-minute troubleshooting in the BEXUS-6 and -7 campaign (SNSB/R. Schederin)

## → Programme partners

The REXUS/BEXUS programme is realised under a bilateral Agency Agreement between the German Aerospace Center (DLR) and the Swedish National Space Board (SNSB). Through the collaboration with ESA, the Swedish share has been made available to students from all ESA Member or Cooperating States.

EuroLaunch, the cooperation between SSC Esrange Space Centre and DLR's Mobile Rocket Base (MORABA), is responsible for the campaign management and operations of the launch vehicles. Experts from DLR, SSC and ESA provide technical and logistical support to the student teams throughout the project.

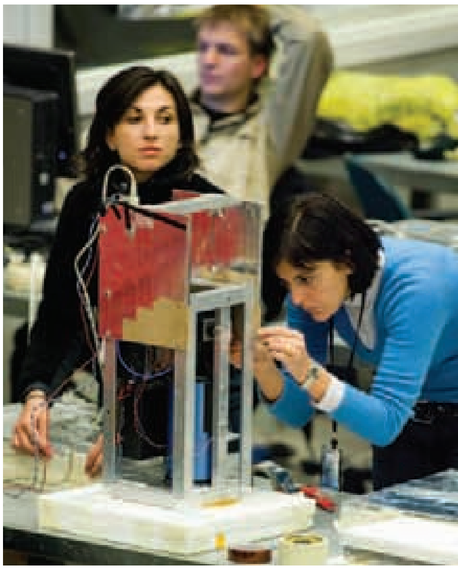
### Programme outline

The programme is targeted at student teams from universities and higher education colleges across Europe. Each year, two rockets and two balloons are launched in March and October respectively, carrying up to 20 student experiments..

The application process for participation opens in September each year, with the experiment selection being finalised before Christmas. From that point, the students' projects take about nine months for BEXUS and 14 months for REXUS to be ready for launch from the Esrange Space Centre in northern Sweden.

Sponsorship is available for the student teams to attend a training week, project reviews and the launch campaigns, with expert guidance available throughout the project. Dedicated lectures and workshops are offered on topics relevant to the project stages. Financial support for the development of experiments is possible to a limited extent.

Since the students themselves are responsible for designing, building and operating their experiment, they are advised to form an interdisciplinary team that includes knowledge of mechanics, electronics and experimental methods, alongside scientific expertise. Guidance from a professor or an institute is highly recommended.



← Students from the Sapienza University of Rome prepare their experiment for flight in the BEXUS-6 and -7 campaign (SNSB/R. Schederin)

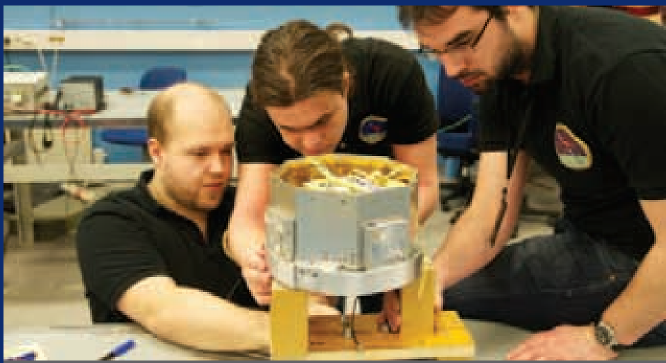
### The experiments

Since 2008, 46 student experiments have already flown, with nine more currently under preparation for the REXUS campaign in March 2012. Many of the experiments have a scientific focus, in research fields such as atmospheric physics, radiation, magnetic fields, fluid physics, microgravity and materials science. Other teams have flown technology demonstrations investigating aspects of aerodynamics, propulsion, communications, deployment systems and more.

## CASE STUDY 1: SQUID (Spinning QUad Ionospheric Deployer)

KTH Royal Institute of Technology, Stockholm, Sweden
Launched: 23 February 2011 on REXUS-10

The SQUID team designed and built a miniaturised version of a wire boom deployment system, which could also conduct measurements of the lower magnetosphere. Four wire booms were deployed on ejection from the rocket and sensors measured the electrical and magnetic field properties during the descent, as well as the inflight dynamics of the wire boom system.

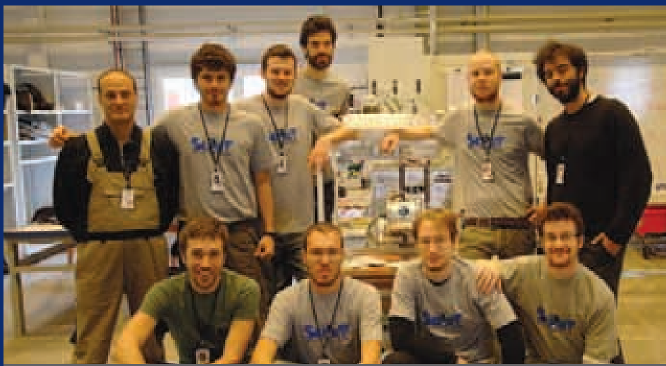


↑ Final assembly of the SQUID experiment

## CASE STUDY 2: SCRAT (Spherical Compact Rechargeable Air Thruster)

University of Padua, Italy
Launched: 9 October 2010 on BEXUS-10

SCRAT tested a rechargeable, low-thrust cold gas actuator for use on 'lighter than air' vehicles. The propulsion system used compressed air collected directly from the surrounding atmosphere as propellant, thereby eliminating the need to store fuel on board. A complete evaluation of the thruster's performance at varying altitudes and atmospheric conditions was performed, from which peak thrust and total impulse profiles were derived.



↑ The SCRAT team with their experiment

## CASE STUDY 3: CRIndIons (Cosmic Ray Induced Ionisation)

Lulea University of Technology, Sweden, Charles University & Czech Technical University, Prague, Czech Republic
Launched: 11 Oct 2009 on BEXUS-09.

CRIndIons conducted high-precision, *in situ* measurements of atmospheric cosmic-ray-induced ionisation yield, using semiconductor pixel detectors of the Medipix family for the first time for radiation imaging in the stratospheric environment. The detectors operated as an 'active nuclear emulsion', demonstrating how particle track types distribution (components of mixed radiation field) changes with altitude. Performance of the detectors was evaluated for further design implications of proposed use on satellites.

← CRIndIons experiment components inside housing (J. Urbář)

↑ BEXUS balloon at the Esrange Space Centre, 45 km from Kiruna in northern Sweden

# → BEXUS

A BEXUS stratospheric helium balloon can reach an altitude of up to 35 km. Depending on the wind speed, a flight lasts between two and five hours. This includes about 45 minutes of ascent and 30 minutes of descent. A standard balloon has a volume of 12 000 $m^3$ and a diameter of 14 m. The total length of the balloon system varies between 65 and 100 m. The gondola beneath the balloon can carry between 40 and 100 kg of experiment payload.

# → REXUS

The REXUS vehicles are unguided, solid-propellant, single-stage rockets that can reach an altitude of up to 100 km. Five experiments per rocket can be accommodated, with a total mass of 30 kg. REXUS offers experiment time of up to three minutes during its ballistic flight. With the use of a 'yo-yo' despin system, it is possible for experiments to experience around 150–180 seconds of reduced gravity. In this configuration it is also possible to eject the nose cone of the rocket during the flight, thereby exposing the experiment underneath to the atmosphere.

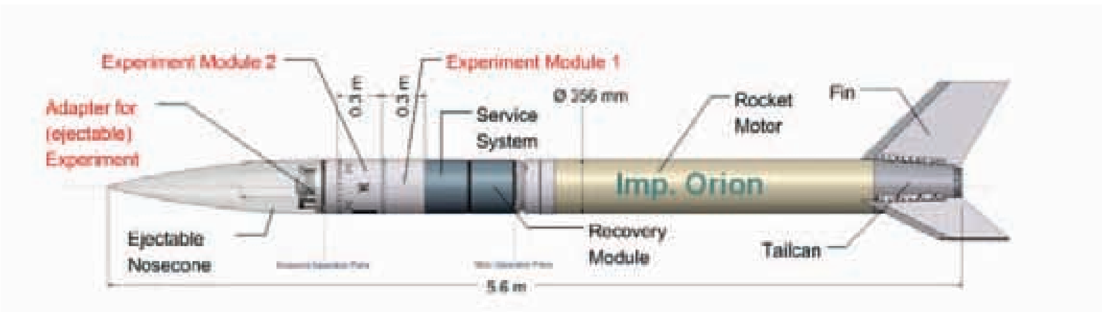
## Experiments in preparation for REXUS campaign, March 2012

### REXUS-11

- **GGES** (Gravity Gradient Earth Sensor)
  EPFL, Lausanne, Switzerland
- **CaRu** (Experiment on Capillarity under microgravity shown with Runge pictures)
  TU Dresden, Germany
- **RAIN** (Rocket-deployed Atmospheric probes conducting Independent measurements in Northern Sweden)
  KTH Royal Institute of Technology, Stockholm, Sweden
- **ADIOS** (Advanced Isolation on Sounding Rockets)
  FH Aachen, Germany

### REXUS-12

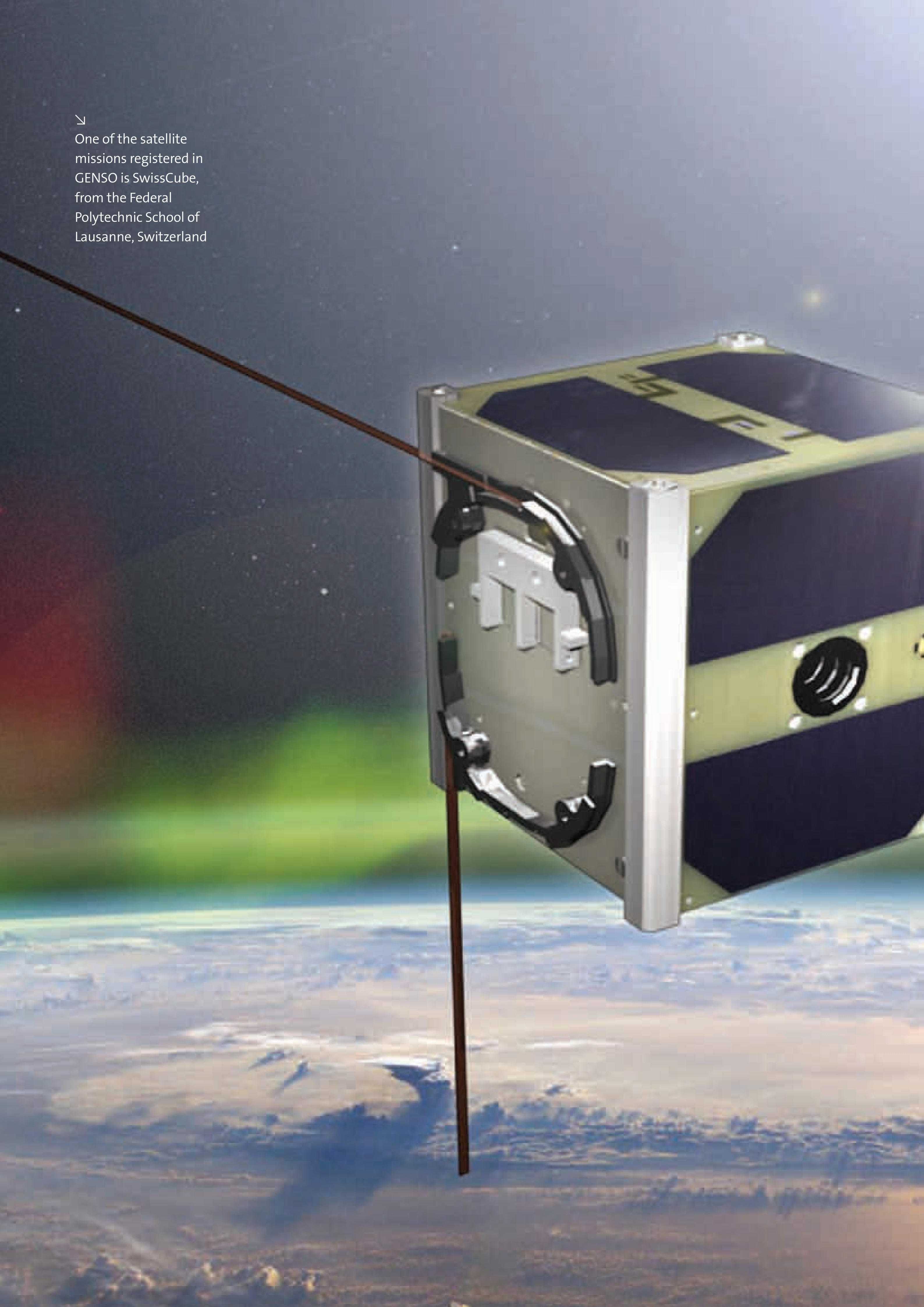
- **Suaineadh** (Deployment and stabilisation of a spinning net)
  University of Strathclyde and University of Glasgow, UK, and KTH Royal Institute of Technology, Stockholm, Sweden
- **REDEMPTION** (REmoval of DEbris using Material with Phase Transition: IONospherical tests)
  University of Bologna, Italy
- **SPACE** (Suborbital Particle Aggregation and Collision Experiment)
  TU Braunschweig, Germany
- **SOMID** (Solid-borne Sound Measurement for the Independent Detection of Events on Space Vehicles)
  University of the German Federal Armed Forces
- **Telescobe** (Demonstration of a telescopic boom system)
  Dublin Institute of Technology, Ireland




↗ The 'Improved Orion' REXUS rocket

**More information**

- www.rexusbexus.net
- Email: rexus-bexus@esa.int



↘
One of the satellite missions registered in GENSO is SwissCube, from the Federal Polytechnic School of Lausanne, Switzerland

# → CONNECTING STUDENTS WITH SPACE

## GENSO pre-operational activities and preparation for GEOID/HumSAT operations

**Antonio Castro, Helen Page, Roger Walker & Francesco Emma**
Directorate of Policies, Planning and Control, ESTEC, Noordwijk, The Netherlands

**Fernando Aguado, A.J. Vazquez**
University of Vigo, Vigo, Spain

**Operators of educational spacecraft now have greater access to their satellites, through a worldwide network of education and radio amateur ground stations linked together via the internet.**

Developed in an ESA-funded project, GENSO (standing for 'Global Educational Network for Satellite Operations') is a distributed system connected via the internet designed to allow the operation and control of educational satellites.

Mission controllers of university satellites can normally gather around 20 minutes of data per day with their own university ground stations. GENSO will give them free access to potentially hundreds of stations around the globe and increase their data return to many hours per day. It will also allow them to command their spacecraft from the other side of the world.

GENSO offers many benefits for the operation of small satellites in low Earth orbit (LEO). The key challenge for missions operating in LEO is that the spacecraft is above the horizon of a ground station for only a few minutes each day. For the rest of the time, missions rely on manually collected beacons from other ground station operators or simply have to wait for the spacecraft to pass overhead again.

GENSO extends the timeframe for communication with a LEO satellite from the normal value of about 20 minutes a day, up to a theoretical maximum of 24 hours a day by tunnelling the traffic over the internet. This applies not only to the downloading of telemetry, but also the transmission of telecommands.

This system offers the capability to plan and schedule use of ground station resources, predict the trajectories of spacecraft over the ground station and automate tracking and hardware control during a pass. Downlinked mission data are provided to the mission controllers within a few minutes of the end of the pass. A real-time communications link for transmission of telecommands and reception of telemetry is also possible.

It has the potential to offer many additional services for participating missions and ground stations through the application of novel scientific approaches. The open source nature of the project will allow individuals to develop any number of enhancements to the system.

While the dramatically increased communication timeframe is one of the major benefits of GENSO, many other advantages can be envisaged such as spacecraft orbit deviation measurements and access to a satellite within minutes in case of emergency, no matter where the satellite is located in its orbit.

GENSO will allow rapid orbit determination after launch, long before organisations such as NORAD are able to provide reliable orbit information, and there will be significantly extended mission lifetimes and returns on investment, due to increase frequency of downlinks, faster orbital path ('Two-line element', TLE) determinations after launch and the possibility to contact the satellite independently of its position.

## The GENSO concept and GEOID/HUMSAT

GENSO is an ESA project, coordinated by ESA's Education Office, to implement a global network of ground stations in support of educational, amateur and non-commercial satellites that would optimise the outcome and return of these satellites.

The software development was carried out in a cooperative effort of universities and radio amateurs worldwide. In fact, the software applications that facilitate the data sharing were developed in 'Java' by an international team of students from universities in Europe, Japan and the USA.

The International Space Education Board, a body that fosters cooperation in education and also involves other space agencies, such as CNES, JAXA, NASA and the Canadian Space Agency, endorses GENSO.

## → ESA Education Office

Responsible for the Agency's corporate education programme, ESA's Education Office is bringing together young Europeans, aged from 6 to 28, helping them to gain and maintain an interest in science and technology.

Our long-term objectives are to contribute to the creation of a knowledge-based society and to ensure a qualified workforce for ESA and the European space industry, which will keep up Europe's lead in space activities.

These are achieved by organising activities designed for specific age groups, keeping the educational community informed about these developments and providing inspirational materials that assist teachers and students with the learning process.

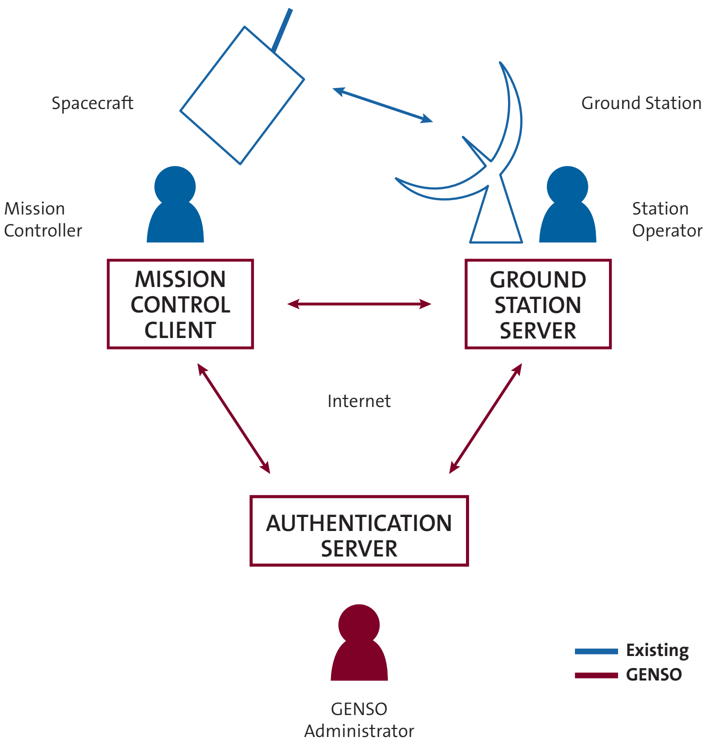
The project is based on the idea of sharing of 'idle' resources. The typical situation is a university building a spacecraft and having its own ground station for supporting operations. These ground stations are used daily but only for very short periods, being idle most of the time. GENSO offers the possibility to exchange spare ground station time with other participants in the network having the same situation.

By sharing spare time with other ground stations located elsewhere, operators can complement and enlarge the contact time with their own spacecraft. Increasing the spacecraft contact time maximises the spacecraft scientific and educational return.

↑ Antenna of the ground station at the University of Vigo in Spain (M. Gil Biraud)

The aim of GENSO is to achieve near-global coverage; therefore GENSO is open to any non-commercial entity worldwide interested in taking part in the initiative. GENSO is made possible because education satellites are permitted to use amateur radio frequencies.

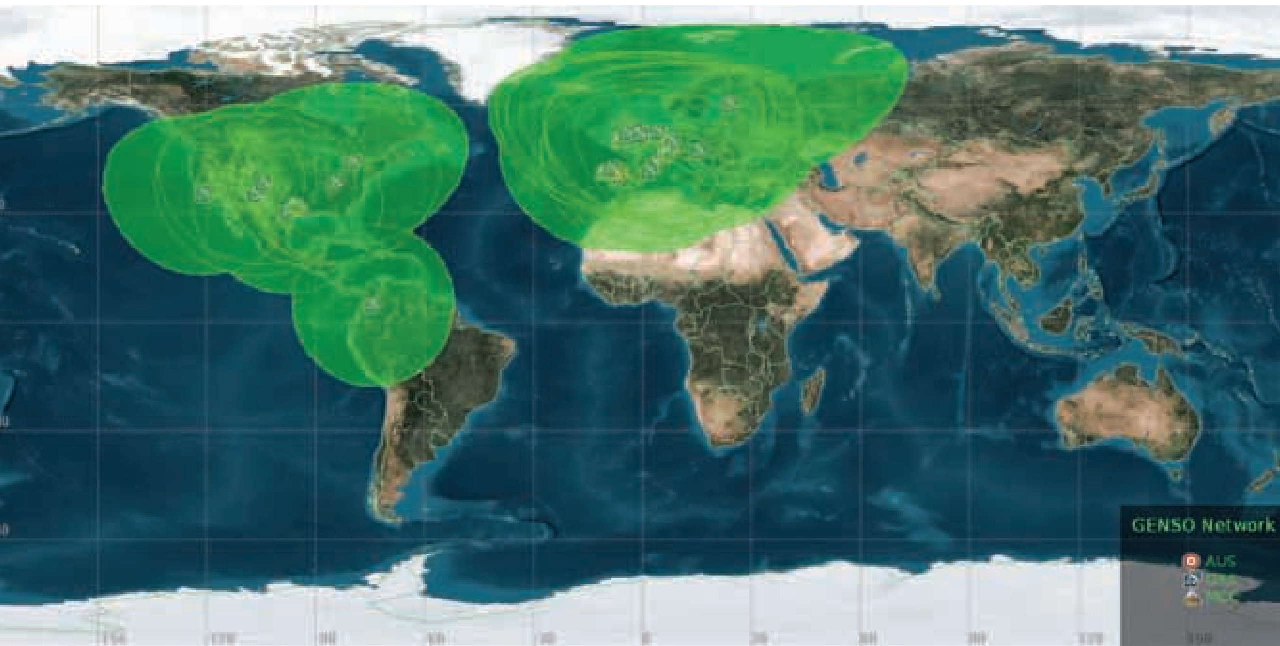
The GENSO concepts, of sharing resources worldwide and providing close to global coverage, are the key elements for obtaining frequent access to the GEOID/HumSAT constellation. HumSAT is the international Humanitarian Satellite constellation project, and GEOID (GENSO Experimental Orbital Initial Demonstration) will be a demonstrator for GENSO functionality and performance in a real environment while supporting the HumSAT constellation system operations.




↑ GENSO architecture

## How does GENSO work?

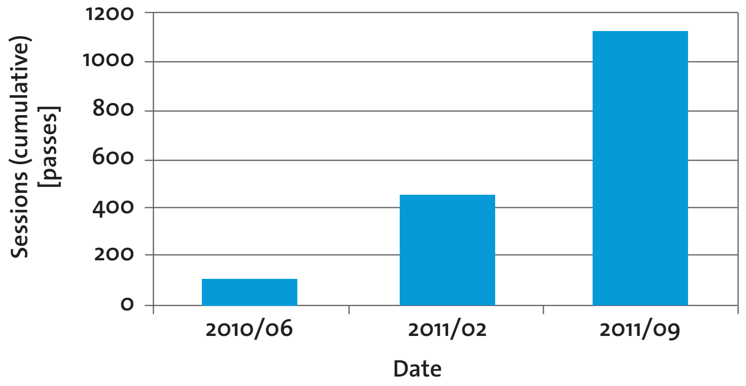
The GENSO architecture is based on three different components interconnected through the internet. The Ground Station Server (GSS) is located in the ground stations, and controls the hardware during the satellite passes. The Mission Control Client (MCC) is located in the Satellite Control Centres, and provides the link to the satellite through one of the GENSO stations. An Authentication Server (AUS) is located on the GENSO Operations Node, and provides authentication for all entities in the network and the keys to establish secure links between GSSs and MCCs.




← GENSO coverage map for LEO orbits

The software is designed to allow several mutually redundant GENSO Operations Nodes worldwide to manage and coordinate the access between spacecraft operators and ground stations. Today, only the GENSO European Operations Node has been assigned, to the University of Vigo in Spain, under an ESA competitive call.

The GENSO network services are non-guaranteed and can support real-time concurrent telemetry and telecommands, real-time telemetry only and offline telemetry services. In the last case, spacecraft telemetry is stored in the GENSO ground station and retrieved at a later stage by the spacecraft operators. In all cases, telemetry can be received as digital data or as audio files or streaming.



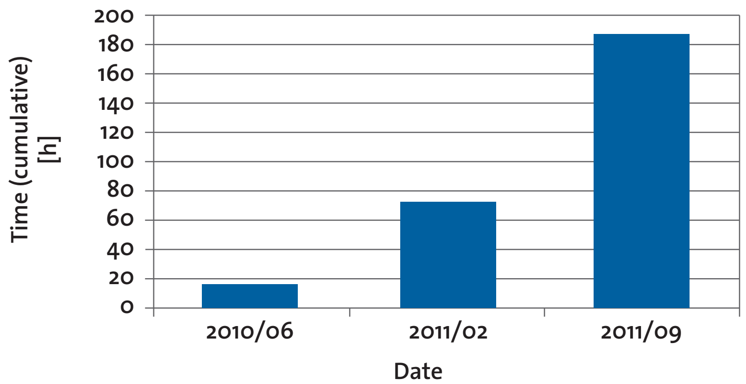

↑ GENSO stations passes providing telemetry services

## Initial GENSO Pre-Operational Activities

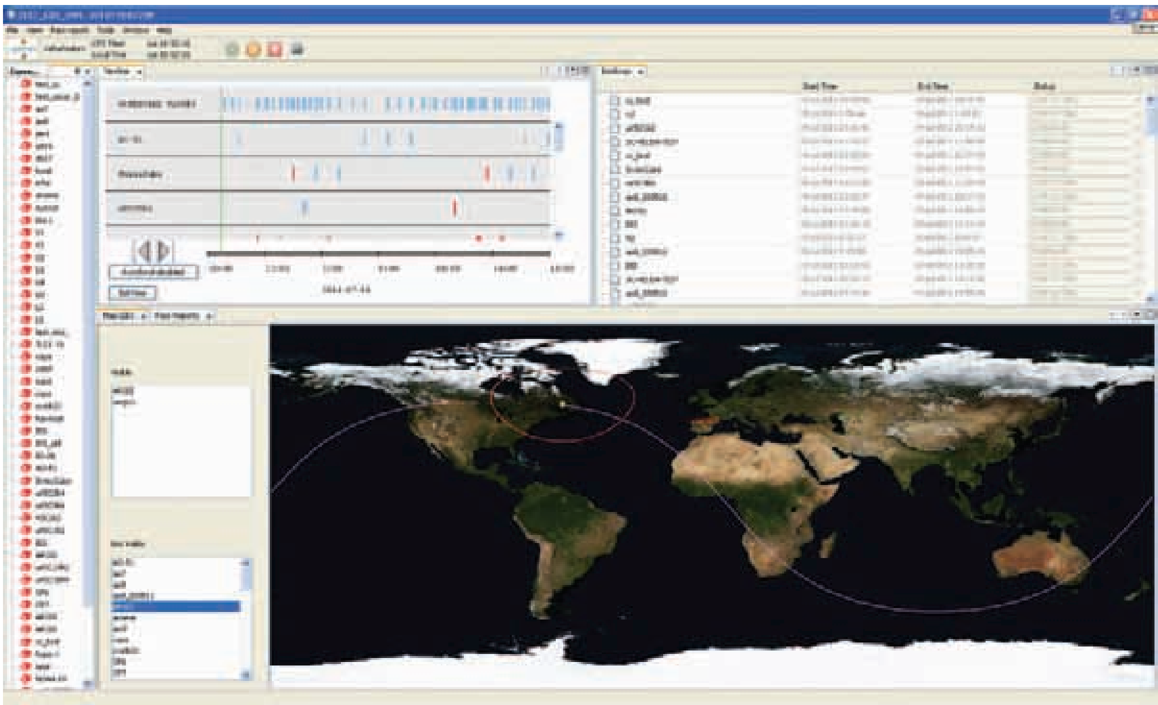
Release 1 has been deployed and used in supporting some missions. Release 2 is undergoing testing and it is expected to be deployed and operational by early 2012. It includes enhancements in user interface and some additional functionality.

Currently, 22 ground stations (GSS) are registered in the GENSO network, with 14 being active. Some are used for test purposes only, being the rest available for the community in a pre-operational state. Five satellite control centres (MCC) are registered, with three being regularly used, either for testing or supporting mission operations. At the moment only one AUS exists in the network, the GENSO European Operations Node, coordinating the system-level testing and pre-operation activities.

In the last 20 months, including tests and pre-operations, the GENSO network has performed tracking activities in almost 14 000 passes for a total of around 2500 hours. Out of these, 1124 passes provided telemetry services for several




↑ GENSO Stations Telemetry Support Time



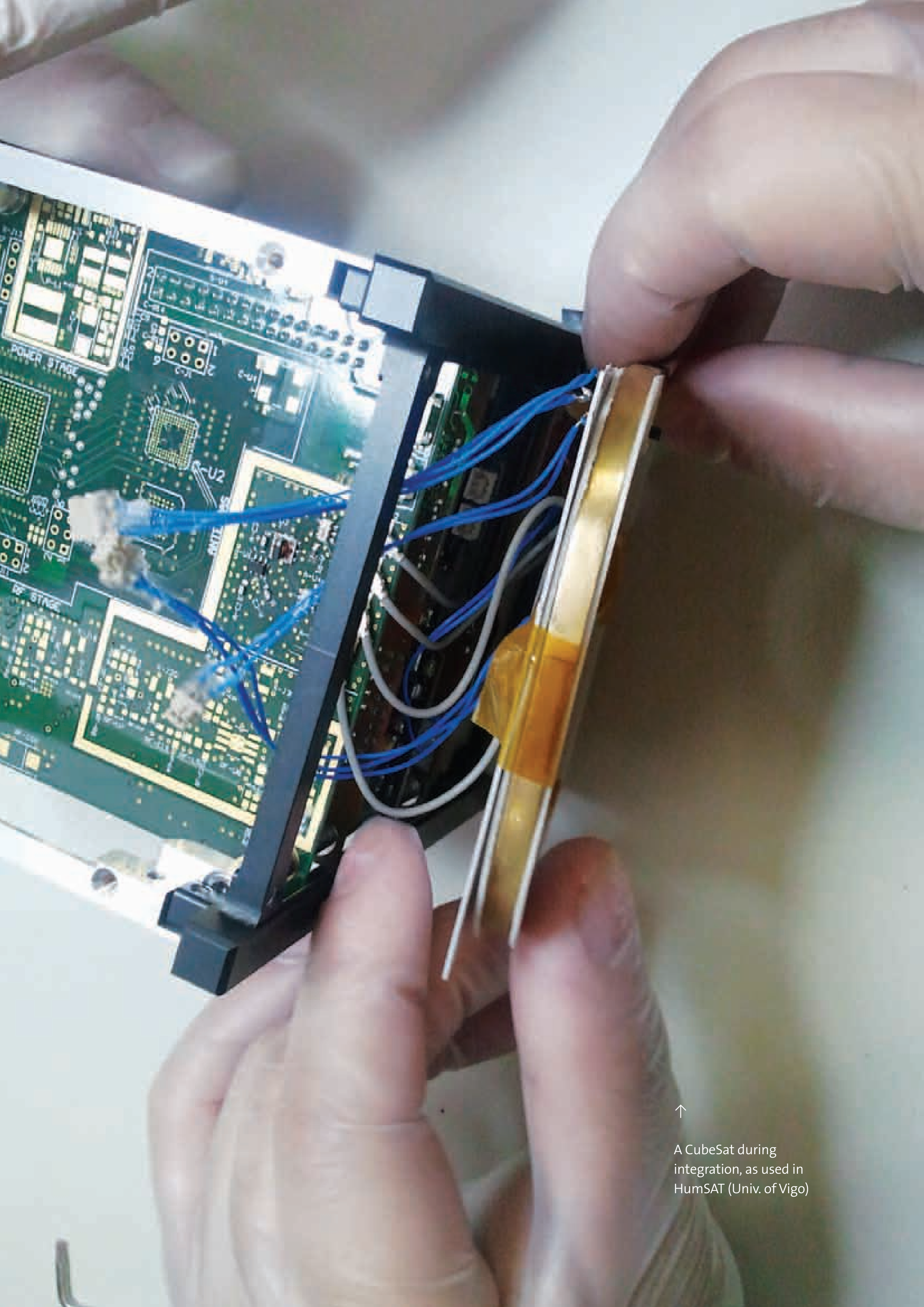
← Screenshot of the GENSO ground station software, showing the groundtrack of a satellite spacecraft, amounting almost 184 hours of support. During this 20-month period, the maximum number of passes taken by a single ground station in the GENSO network was 227.

GENSO is currently supporting the following missions and testing activities:

- Operational activities were performed early 2011 in support of NASA's ELaNa missions.
- FASTRAC-1 and FASTRAC-2 satellites, a joint project of the University of Texas at Austin and the Air Force Research Laboratory.
- The International Space Station and the amateur satellite AO-51 are regularly tracked for testing purposes.
- European university CubeSat missions launched on the maiden flight of ESA's new Vega rocket, including PW-Sat, XaTcobeo and Masat-1.

GENSO is the baseline ground station network for the GEOID/HumSAT constellation, providing near-global coverage. GEOID is the initial HumSAT component and will also serve to further validate the GENSO concept. ■

| ORGANISATION (country) | COMPONENT (satellite) |
|---|---|
| Aalto University (Finland) | GSS |
| California Polytechnic State University (USA) | GSS |
| Delft University of Technology (The Netherlands) | MCC (Delft) |
| ESOC (Germany) | GSS |
| ESTEC (The Netherlands) | GSS |
| Federal Polytechnic School of Lausanne, Space Centre (Switzerland) | MCC (SwissCube) |
| Federal Polytechnic School of Lausanne, Space Centre (Switzerland) | GSS |
| Graz University of Technology (Austria) | GSS |
| International Space University (France) | GSS |
| Isis Space (The Netherlands) | GSS |
| MyGroundStations.com (UK) | GSS |
| Polytechnic University of Catalonia (Spain) | GSS |
| Radio Amateur – G3VZV (UK) | GSS |
| Radio Amateur – G4DPZ (UK) | GSS |
| Radio Amateur – KA0SWT (USA) | GSS |
| Sergio Arboleda University (Colombia) | GSS |
| University of Applied Sciences, Heidelberg (Germany) | GSS |
| University of Kentucky (USA) | GSS |
| University of Montpellier (France) | GSS |
| University of New Mexico, Configurable Space Microsystems Innovations & Applications Centre (USA) | GSS |
| University of Surrey, Surrey Space Centre (UK) | GSS |
| University of Texas at Austin (USA) | MCC (FASTRAC 1) |
| University of Texas at Austin (USA) | MCC (FASTRAC 2) |
| University of Texas at Austin (USA) | GSS |
| University of Valladolid (Spain) | GSS |
| University of Vigo (Spain) | AUS |
| University of Vigo (Spain) | MCC (Test Satellites) |
| University of Vigo (Spain) | MCC (Xatcobeo) |
| University of Vigo (Spain) | GSS |
| University of York (UK) | GSS |




↑

A CubeSat during integration, as used in HumSAT (Univ. of Vigo)

# → HANDS-ON EXPERIENCE

## The HumSAT system and the ESA GEOID Initiative

**Antonio Castro, Roger Walker & Francesco Emma**
Directorate of Policies, Planning and Control, ESTEC, Noordwijk, The Netherlands

**Fernando Aguado & Ricardo Tubio**
University of Vigo, Vigo, Spain

**Werner Balogh**
UN Office for Outer Space Affairs, Vienna, Austria

**A unique training opportunity, the GEOID/HumSAT project is a first-class educational tool for engineering and science students, as well as for universities interested in the space sector.**

An activity of ESA's Education Office, the GENSO Experimental Orbital Initial Demonstration, or 'GEOID', will allow university students from ESA Member and Cooperating States to participate in a worldwide initiative for the implementation of a 'CubeSat'-based constellation of satellites, called HumSAT (Humanitary Satellite). CubeSats are a type of miniaturised satellite for space research that usually have a volume of about 10 $cm^3$, a mass of around 1 kg and use off-the-shelf electronics components.

Beyond its educational objectives, the project will build an infrastructure to allow services in developing countries and supporting climate-monitoring activities. In addition, there are research opportunities in science and technology for participating universities in Europe, fulfilling the two main areas of interest for universities: research and education.

HumSAT is an international educational initiative for building a constellation of nano-satellites providing worldwide communication capabilities to those areas without infrastructure.

The system will provide data-relay services for sensors distributed around the world. Two types of sensors will exist in the system: one-way sensors, to transfer information to a remote user; and bi-directional sensors, to allow the transmission and reception of information offline from a remote user.

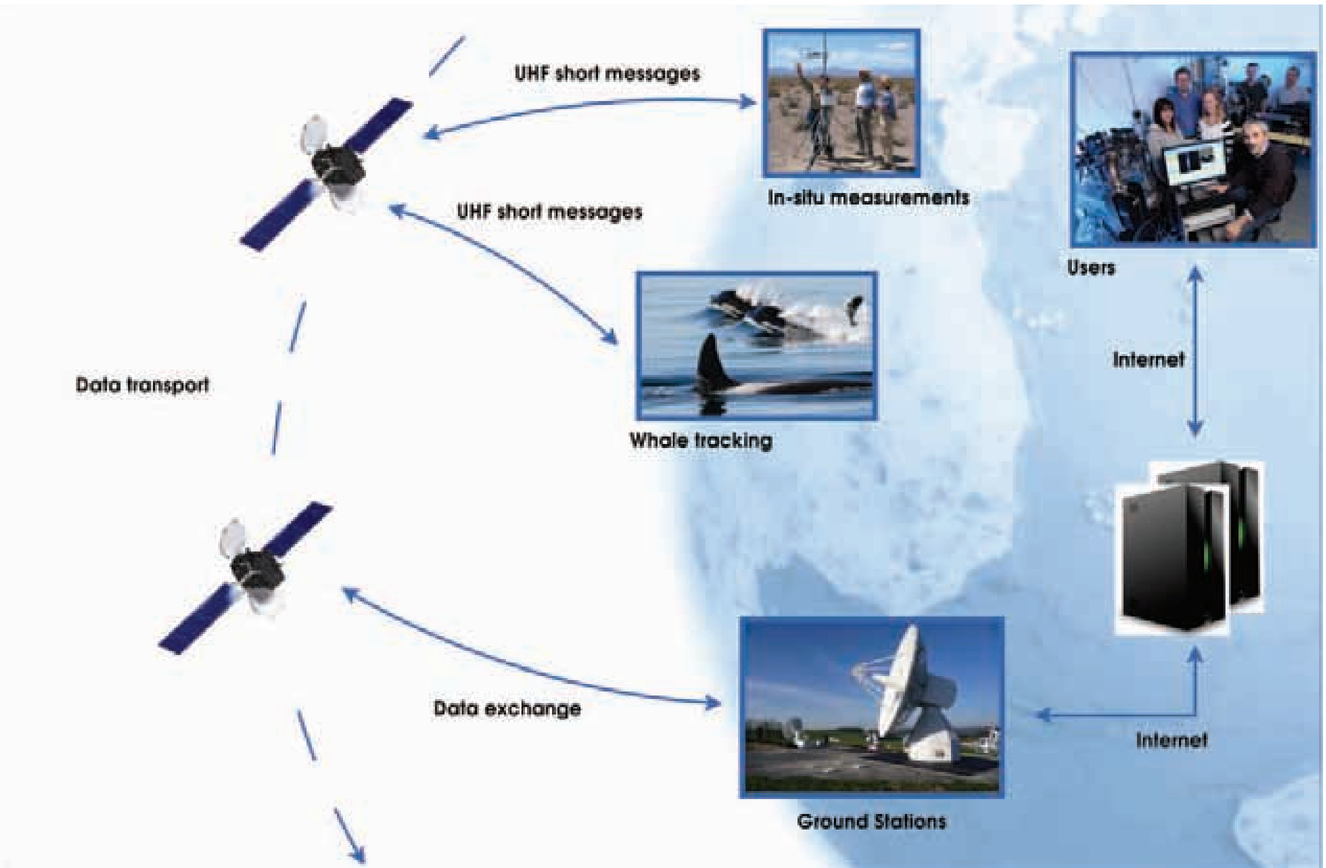
HumSAT will be made up of a swarm of low-Earth orbit CubeSats, with a store-and-forward functionality. Spacecraft operations will be supported using the GENSO (Global Educational Network for Satellite Operations) ground station network – a worldwide chain of ground stations operated by universities and radio amateurs. Its user segment will be composed of autonomous systems (mainly sensors) that will send and receive short messages (32 bytes per message) in the UHF amateur radio band, and can be deployed globally.

HumSAT spacecraft passing over a region will receive the messages uplinked from the sensors and store them until they are downloaded to the corresponding spacecraft control centre that will forward them to the central archiving server, located at the University of Vigo in Spain. Owners of the deployed sensors will be able to download their data in the central archive through the internet, as well as uploading the data that has to be forwarded to the sensors.

The store-and-forward communications service provided by HumSAT will be free, non-guaranteed and exclusively for non-commercial applications. With a modular and scalable construction, the addition of new elements to the system (spacecraft, ground stations and sensors) will be possible at any point without impacting the existing performance of the system. Scalability and incremental performance of the system are key drivers in the design of the system.

## HumSAT history

The Humanitary Satellite Network Project was initially conceived and designed by the University of Vigo, Spain, California Polytechnic State University (Cal Poly), USA, and the Autonomous National University of Mexico and the Regional Centre for Space Science and Technology Education for Latin America and the Caribbean, affiliated to the United Nations (CRECTEALC) (Mexico).




↑ HumSAT system concept

The project obtained the support of ESA, the UN Office for Outer Space Affairs (UNOOSA) and the International Astronautical Federation. ESA started its educational programme called GEOID (GENSO Experimental Orbital Initial Demonstration), in which students from universities in Member States were invited to participate by developing spacecraft as part of the HumSAT system.

GEOID will be the European contribution to HumSAT, to serve as validation test-bed for the GENSO network and with the University of Vigo designated as the prime contractor for the definition of the system and the GENSO European Operations Node.

HumSAT has also been incorporated as part of the activities of the Basic Space Technology Initiative (BSTI) of UNOOSA under the framework of the United Nations Programme on Space Applications. BSTI was established in response to the growing interest in countries that have previously mainly been passive users of space technology and its applications, and that are now also interested in establishing their own national capabilities in basic space technology development. The initiative aims to promote international cooperation and information exchange and, ultimately, to contribute to sustainable development.

| University | Participation in GEOID |
|---|---|
| Brno UT (CZ) | GENSO station |
| Czech TU (CZ) | CubeSat, GENSO station and sensor developments |
| Narvik University (NO) | CubeSat |
| Politecnico di Torino (IT) | Satellite, GENSO station and sensor development |
| Polytechnic University of Madrid (ES) | GENSO station, portable station and array antenna development |
| TU Cluj-Napoca (RO) | GENSO station |
| University of Alcala (ES) | CubeSat, GENSO station and sensor development |
| University of Rome (IT) | CubeSat, GENSO station and sensor development |
| University of Strathclyde (UK) | GENSO station |
| University of Vigo (ES) | CubeSat, GENSO station and sensor development |

↑ The European universities participating in GEOID/HumSAT with their developments and contributions to the system

Initially, GEOID will consist of:

- Six satellites (five are CubeSats)
- Nine new GENSO stations
- New ground station developments: portable station and array antenna.
- Five sensor developments, with the following applications: temperature, radiation, sliding lands, wireless sensor network demonstrators and biomedical applications.

Outside Europe, some 20 universities from 11 different countries have already expressed their interest in participating in HumSAT, bringing a total of 19 satellites.

## Educational objectives

The objectives of the GEOID/HumSAT project are fully in line with similar activities carried out by the ESA Education Office. The project offers students hands-on technical experience on all aspects of space missions during their complete lifecycle, from design to operational phases.

It is managed according to space standards (limited to the needs of the project and CubeSats) and follows the same procedures and methods as in any other ESA project. This approach will also provide participating students with the experience and insight on standards, management and review processes that are inherent to any ESA project.

A directly derived benefit of this process is the need for developing all design, implementation and testing documentation associated with the process. This will result in a knowledge base that is expected to remain in the university once students leave, and should be a building block for future satellite developments at the university, allowing the possibility to build more-complex or larger satellites.

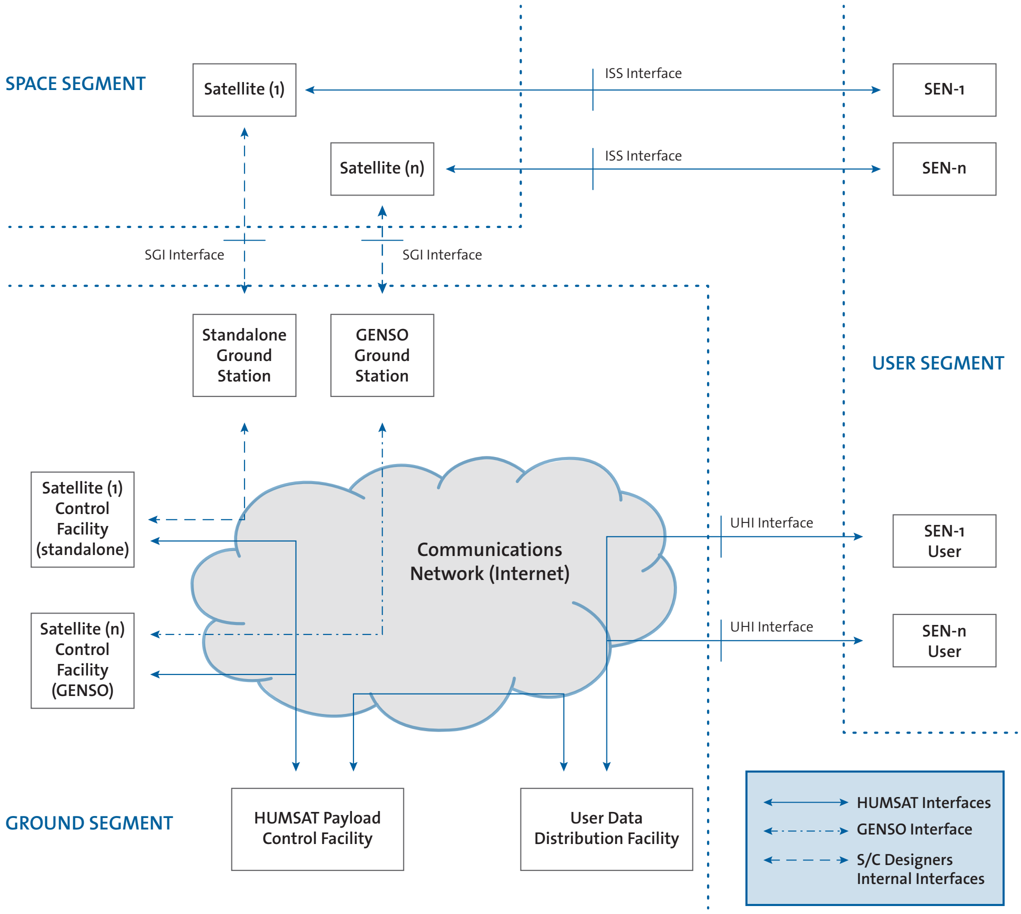
Based on its global scale, the project will offer additional benefits. Its global component will promote international cooperation in the space sector; and will offer students and universities the possibility to collaborate and share their experience with other universities, institutions and space agencies worldwide.

## HumSAT system architecture

***Space segment***

Composed of a group of spacecraft forming the backbone of the HumSAT system, with most satellites following the CubeSat standard. Their sizes will range from 1-unit (10 x 10 x 10 cm, 1 kg) to 3-unit (10 x 10 x 30 cm, 3 kg). Some participants plan to develop other small satellites not based

→ The HUMSAT architecture is composed of three parts: space segment, ground segment and user segment




on the CubeSat standard. Satellites will operate indistinctly on the VHF, UHF or S-bands, according to each specific design.

Since CubeSats do not have a propulsion system, the space segment will be a ‘swarm’ constellation. The swarm will have to be as spread as possible through different low-Earth orbits in order to provide as wide coverage as possible. This can be achieved by ‘piggyback’ launching the CubeSats on different launchers as much as possible. Satellites will be built and operated independently by different universities, however they are developed according to common interface definitions and operated in a coordinated manner in order to achieve the target system performance.

The compatibility of all HumSAT spacecraft with the deployed sensors is guaranteed through their compliance (of both sensors and spacecraft) with a common interface specification that has been developed for this purpose, including a new ground-to-space protocol definition for the data transfer between sensors and spacecraft.

*Ground segment*
These are all the facilities required for the control of the spacecraft, and for managing all the data exchange between users and sensors. The ground station network will be the GENSO network, although other stand-alone ground stations could be used as well. All communications with the ground stations and the users will be via the internet.

A set of satellite control facilities will be used to control and operate each of the spacecraft. Depending on the nature of the ground station that these facilities will use for establishing the communications link with the spacecraft to be commanded (i.e. whether it is a GENSO-based ground station or a stand-alone one), they will have to implement different interfaces and functionalities.

A central HumSAT Payload Control Facility, at the University of Vigo, will coordinate all schedules and passes to be taken. This facility also establishes the planning for sending data to the sensors, assigning ground stations and spacecraft to be used. It also keeps all information related to the deployed sensors, their identifiers, actual status and location.

A User Data Distribution Facility will store the sensor data and will interface with final users, allowing them to access their data through the internet. Security mechanisms will be implemented for ensuring the confidentiality of the sensor data.

*User segment*
This will be composed of the sensors deployed by users all over the world, and by the facilities or additional components and devices that they will require for processing the data received from sensors, or for generating the data to be sent back to them. All sensors will communicate with the spacecraft using a standard predefined radio interface.

For ensuring the compatibility of the spacecraft developed by each university with the common spacecraft/sensor interface, test sensors will be developed by the University of Vigo to ensure the radio-frequency and data compatibility during the spacecraft testing.

## System-level interfaces

The interconnection of all these components is done through the following interfaces.

- ***Space-to-Sensor Interface*** (SSI) is the standard interface between sensors deployed by users and spacecraft. It provides communications capabilities in the UHF amateur satellite band at 437 MHz. The definition of this interface includes the definition of the parameters for the physical link and a custom medium-access protocol (MAC protocol) for guaranteeing communications among spacecraft and sensors in a shared medium. This interface includes a new development of a protocol for the data uplink and downlink between satellites and sensors.

- ***Space-to-Ground Interface*** (SGI) is the communications interface between spacecraft and the ground station that is defined by each spacecraft development team. In some cases, like the spacecraft developed by the University of Vigo, it will be based in the ECSS standards tailored to the needs of the project. In case GENSO ground stations are used, this interface shall also meet all those requirements for the spacecraft to remain compatible with the ground stations of the GENSO network.

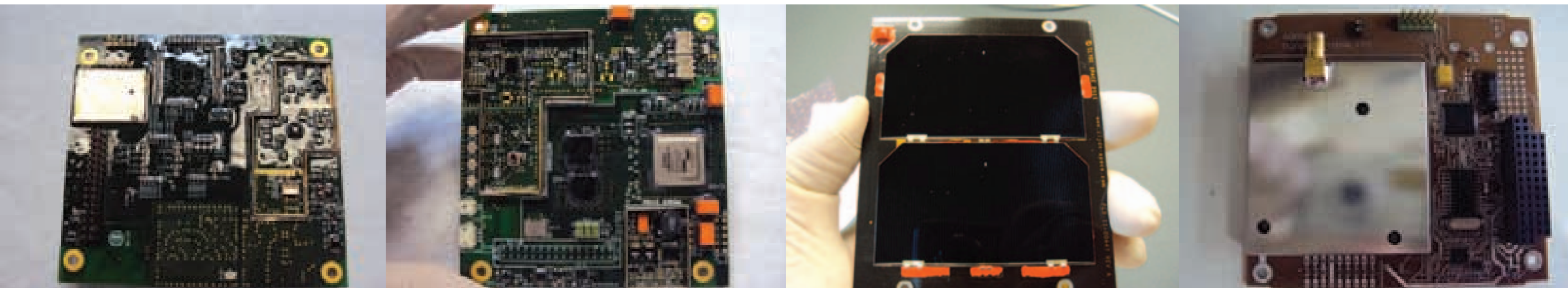
- ***User-to-HumSAT Interface*** (UHI) is an interface that will allow users to access to the services provided by the HumSAT system through the internet. Including secure access and guaranteeing the data confidentiality for each user.

- **Satellite Control Centres-to-Ground Stations Interface** will allow spacecraft operators to connect to their own ground stations, as well as to GENSO remote stations. It will be based either on the use of the internet or a local area network for interconnecting these two facilities within the same university. For connections established with remote ground stations in the GENSO network, its specific interface requirements will have to be implemented in order to obtain the full-duplex real-time audio link requirements, as well as offline downlink capabilities.

- ***HumSAT Payload Control Facility-to-Satellite Control Centres Interface*** defines the data exchange between each of the Satellite Control Centres for each of the spacecraft with the central HumSAT Payload Control Facility (in Vigo). Data gathered by spacecraft from sensors is downloaded by each of the Satellite Control Centres and the forwarded to the Payload Control Facility. Also the data to be delivered to the sensor that needs to be uplinked using one of the spacecraft will be sent from Payload Control Facility to the corresponding Satellite Control Centre for the designated spacecraft. This interface is standardised and the same for all satellite developers.

## Spacecraft Development Framework

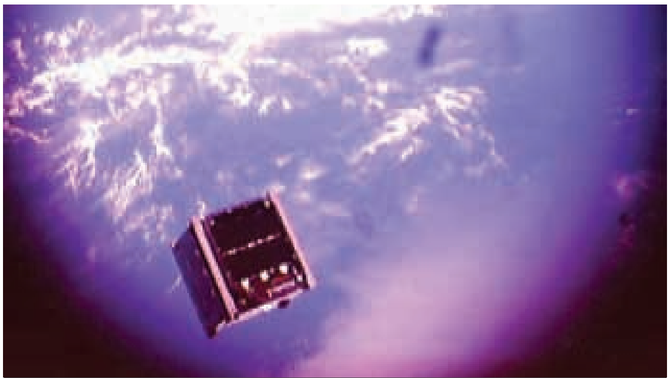
The different availability of resources and development times employed by each of the participating universities imposes the scalability of the system and an incremental



↑ Parts of a Cubesat: two sides of a Reconfigurable Software Radio Payload, a side panel with solar cells, and a telemetry, tracking and control subsystem (Univ. of Vigo) service provision as a design driver for HumSAT. This requires that the addition of new system components do not impact the functionality and performance of the existing ones. Based on this need, one of the objectives of HumSAT is to establish a development framework for universities to independently design spacecraft, ground stations and/or sensors that could be added to the system, preserving its compatibility and increasing its overall performance. The spacecraft of ESA's GEOID initiative will provide a demonstration of the system as well as being the European contribution.

Therefore, the development framework to be established will consist of an initial top-level design into which different heterogeneous components with different schedules could be fitted:

- Spacecraft are expected to be independently developed by different universities, and launched according to their own schedule and in the orbit they can afford. Minimum interface requirements will be imposed on them.



↑ Amazing photo of a Cal Poly CubeSat in orbit taken from another CubeSat, AeroCube 2 (Cal Poly)

- Each of the development teams is expected to develop its own ground station and they will be encouraged to add their ground station to the GENSO network. For this purpose, the specific interface requirements allowing for remote service provision will need to be implemented in the station control systems.

- Sensors will be deployed independently by users. The spacecraft interface will be imposed, but they are free to develop the applications, mange their use, select their location and define the amounts of data transmitted or received.

The constellation formed by spacecraft compatible with HumSAT will not be a pre-designed one, but a set of spacecraft freely launched in different flight opportunities without pre-defined orbital positions or orbit control system. This is because CubeSats do not have propulsion and rely, for cost reasons, on piggyback launches whose orbits are defined by their primary passengers.

## The project so far

By July 2011, the HumSAT project had completed its preliminary definition in Phase-A. Phase-B would be completed by November. The objective is to establish a framework for spacecraft developers and final users to start making their designs compatible with the HumSAT system preliminary specification. The first HumSAT satellite and sensors will be available as demonstrators from the University of Vigo in early 2012 and they will be launched during the second quarter of 2012.

Student participation in this project will ultimately contribute to the Education Office's objective of supporting the efforts for the creation of a qualified workforce in space engineering and science for the European space industry and for ESA. ■

## → HumSAT summary

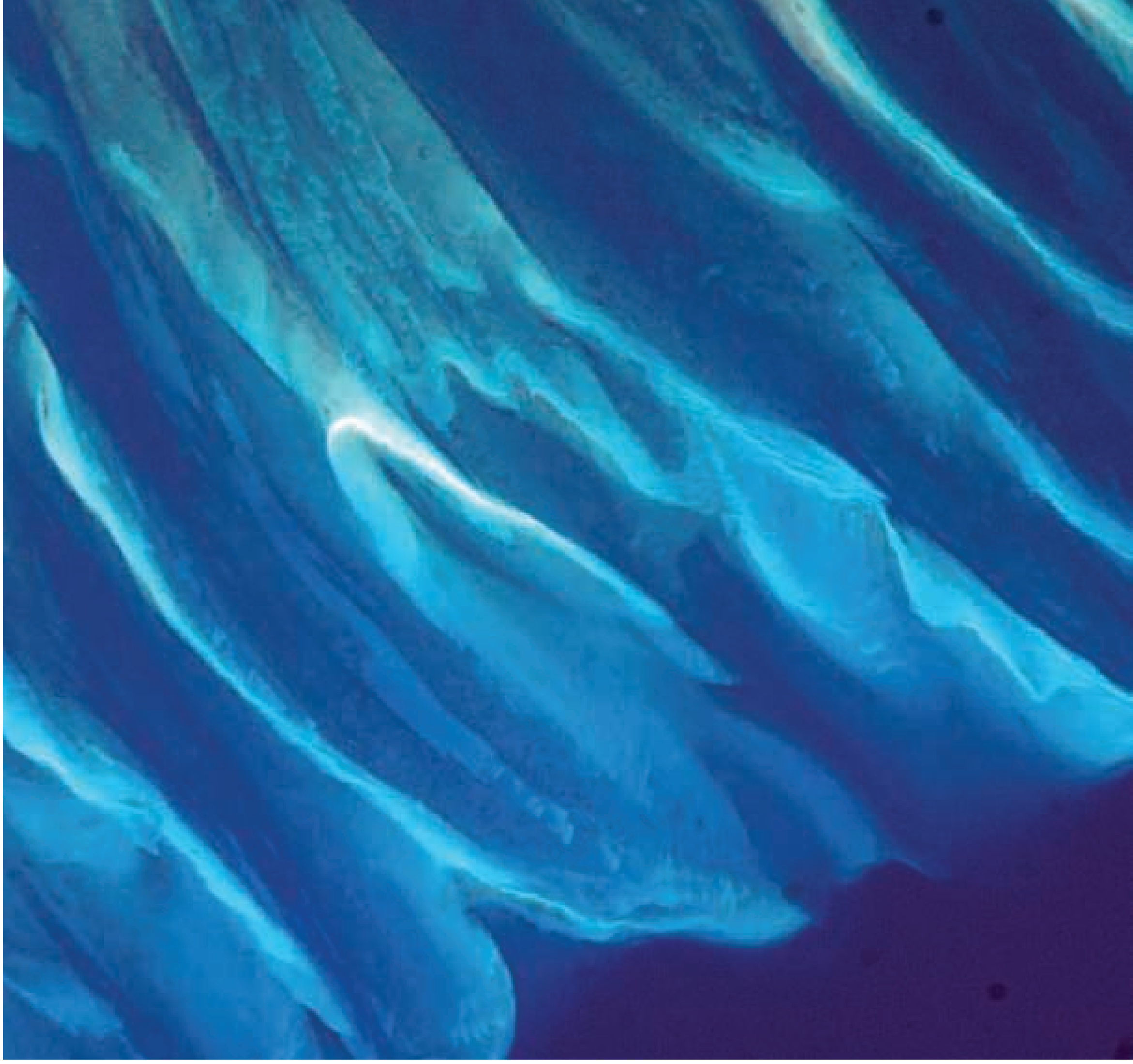
- A highly-scalable, low-cost 'swarm-like' constellation of heterogeneous spacecraft
- A free non-guaranteed service of store-and-forward data for non-commercial uses
- Initial constellation set up mostly, but not exclusively, by satellites based on the CubeSat standard, mainly by universities and their students gaining hands-on space project experience
- Main applications will be non-commercial, mainly scientific and humanitarian support
- Ground segment mostly based on the use of the global GENSO network
- HumSAT/GEOID and GENSO are open for participation to any interested non-commercial organisation worldwide

# → 2011 IN PICTURES

**Some of the most memorable moments and inspirational images of space taken last year.**

Preceding page, Soyuz lifts off for the first time from Europe's Spaceport in French Guiana, 21 October, carrying the first two Galileo satellites

→ Sandbanks under the sea as seen from the ISS, taken by Paolo Nespoli on 27 January during the MagISStra mission (ESA/NASA)



→ Expedition 27 crew members pose for a photo on the ISS in honour of the 50th anniversary of the spaceflight of Yuri Gagarin on 12 April. A portrait of Gagarin is at centre, with cosmonaut Dmitri Kondratyev, astronaut Cady Coleman, cosmonauts Alexander Samokutyaev and Andrei Borisenko, astronauts Ron Garan and Paolo Nespoli (NASA/ESA)

← A new image of the Andromeda galaxy is a composite of two photos – one is the most detailed image of this galaxy ever taken at infrared wavelengths, captured by ESA's Herschel space telescope, and the second, taken in X-ray light by ESA's XMM-Newton, shows dying stars shining X-rays into space (ESA/PACS/SPIRE/EPIC/MPE)

← Mars Express returned this image from its flyby of the largest martian moon Phobos on 9 January, when the ESA spacecraft passed the moon at a distance of 100 km (ESA/DLR/FU Berlin)

→ One of the most impressive views of the year, taken by Paolo Nespoli as his Soyuz TMA-20 spacecraft departed the ISS in May, the first time an ATV (*Johannes Kepler*) and a Space Shuttle (*Endeavour*) had been photographed docked to the ISS (ESA/NASA)


→ One of the Expedition 27 crew captured this image of ESA's ATV *Johannes Kepler* docking with the ISS in February, note the Moon in the background (ESA/NASA)

← The latest images from Mars Express in released in November included this one of Tharsis Tholus, an extinct volcano that has been battered and deformed over the aeons. Viewed by the spacecraft's High Resolution Stereo Camera, the colours represent heights of the surface. By Earth standards, Tharsis Tholus is a giant, over 125 km wide and towering 8 km above the surrounding terrain, yet on Mars, it is just an average-sized volcano (ESA/DLR/FU Berlin)

← The record-breaking simulated mission to Mars has ended with smiling faces after 17 months. Mars500's six brave volunteers stepped out of their 'spacecraft' on 4 November and were welcomed by the waiting scientists – happy that the venture had worked even better than expected (IBMP\O.Voloshin)

↑ Space Shuttle *Atlantis* is seen as it launches on 8 July from pad 39A at NASA's Kennedy Space Center, Cape Canaveral, Florida. This launch of *Atlantis*, STS-135, is the final flight of the US Space Shuttle programme ((NASA/B.Ingalls)

↑ André Kuipers' Soyuz TMA-03M spacecraft was rolled out by train on its way to the launch pad at Baikonur Cosmodrome, Kazakhstan, on 19 December. The launch took place on 21 December, carrying the Expedition 30 crew of Kuipers, Oleg Kononenko and Don Pettit to the ISS (ESA/NASA)

# → NEWS IN BRIEF


↑ With the three Expedition 30/31 crew members on board, including ESA's André Kuipers, the Soyuz TMA-03M spacecraft (left) eases toward its docking with the ISS. The Soyuz docked at the Russian-built Mini-Research Module 1 (also known as Rassvet, Russian for 'dawn') on 23 December 2011 (NASA)

# Promising start

**ESA's fourth long-duration mission to the ISS began on 21 December, when the Soyuz rocket carrying ESA astronaut André Kuipers and crewmates Oleg Kononeko and Don Pettit lifted off from Baikonur Cosmodrome in Kazakhstan.**

After circling Earth for two days, the three astronauts joined the Expedition 30 crew when their Soyuz TMA-03M spacecraft docked with the Station. They will work aboard the ISS for five months and return to Earth in May.

During his PromISSe mission, André will conduct more than 25 ESA experiments and around 20 for NASA and Japan's space agency, JAXA, including human research, biology, fluid physics, materials science and radiation research and technology.

His mission also features a strong educational aspect centred on the theme 'Spaceship Earth'. The lessons from space will educate children in science, technology, engineering and mathematics, as well as illustrating the requirements for life on Earth.

↑ ESA astronaut André Kuipers and crewmates Oleg Kononeko and Don Pettit board their spacecraft at Baikonur Cosmodrome in December

During a live TV event in January, the Prime Minister of the Netherlands, Mark Rutte, and students from the Technical University of Delft enjoyed speaking with André about life on the ISS. Mr Rutte chatted with André and acted as master of ceremonies as the students asked questions.

Mr Rutte asked André how he had settled in on the Station. "It is wonderful," replied André. "I have adjusted well to life in space and it is really starting to feel like home." Life in space is similar to life back on Earth, according to André – when they are not working the astronauts play music, eat dinner together and look out of the window from time to time.

↑ Astronaut André Kuipers answering questions on the International Space Station during a live event at the University of Delft with Dutch Prime Minister Mark Rutte

André talked about the Spaceship Earth project: "One of the most important things is to motivate schoolchildren. At that age, children become inspired and interested. If only a small number of students are influenced to continue their careers in science or engineering, then that is a good result of this mission."

Former astronaut Thomas Reiter, now ESA's Director of Human Spaceflight and Operations, and Franco Ongaro, ESA Director of Technical and Quality Management, talked with the Dutch Prime Minister at the event about the important role of space for society.

# Station support

**A two-year contract was signed with Astrium in December to provide Industrial Operations Team support to ESA's human spaceflight activities.**

Under the contract, Astrium will oversee an industrial consortium responsible for providing all services related to the European components of the International Space Station.

Astrium's responsibilities include mission control, astronaut training, maintenance and logistics, extensions for new space experiments, ground station operations, communication systems and data transfer.

↑ J. Schaper (left), Dr Michael Menking, Astrium's Senior Vice President for Orbital Systems & Space Exploration (centre), in Bremen, Germany, for the signing ceremony with Thomas Reiter

ESA and Astrium have also agreed to implement a series of measures over the next few years aiming to reduce the costs of the programme by some 30% between now and 2016.

ESA's Director of Human Spaceflight and Operations, Thomas Reiter, said, "In Astrium, ESA has found a reliable partner to serve as prime industrial contractor and consortium leader. The company is uniquely placed to manage the operation and utilisation of the International Space Station through its experience in human spaceflight."

# World's space-faring countries meet

**Representatives from 28 countries, the European Commission and ESA met in Lucca, Italy, for the Third International Conference on Exploration in November.**

The conference, co-organised by ESA, the Chair of the ESA Ministerial Council – Italy – and the European Commission, highlighted the importance of space exploration and its direct benefit to humankind.

These leaders, including ESA Director General Jean-Jacques Dordain, affirmed that, 50 years since humans first ventured into orbit, space exploration provides many benefits to society. Space exploration fuels discoveries, addresses global challenges through innovative technology, builds global partnerships by sharing challenging and peaceful goals, inspires younger generations, and provides economic expansion and new business opportunities.

Representatives endorsed the Lucca Declaration, which recognises the benefit of a continuing dialogue on future space exploration to help identify potential areas for international cooperation.

It is expected that further discussions will cover joint missions and collaboration on research, and could lead to greater cooperation in areas such as access to space, innovation and space technologies, the use of current and future low-orbit infrastructures, and future human and robotic presence further out in space.

The government representatives in Lucca made a commitment to begin open, high-level policy dialogue on space exploration at government-level for the benefit of humankind. The United States offered to host the next meeting.


↑ Jean-Jacques Dordain, ESA Director General, during the Lucca conference

# Galileo in good health

**The first satellite in Europe's state-of-the-art global navigation system Galileo appears healthy, transmitting test signals received by ESA's ground station in Redu, Belgium.**

The first two Galileo satellites were launched on a Soyuz rocket from Europe's Spaceport in French Guiana on 21 October. They are currently being tested to check that their highly sophisticated navigation payloads are operating as planned. Testing started on the first Galileo satellite, progressing to the second satellite early this year.

Galileo is an initiative of the European Commission and ESA to provide Europe with an independent global satellite navigation system. The Galileo system combines the best atomic clock ever flown in space for navigation – accurate to one second in three million years – with a powerful transmitter to broadcast precise navigation data worldwide.

# Gaia spreads its wings

**ESA's Gaia star-mapper has passed a critical test ahead of its launch in 2013: the satellite's sunshield was deployed for the first time in October.**

Gaia's sunshield is an essential component of the mission. It keeps the satellite in shadow, maintaining the scientific instruments at a constant temperature of around –110°C. The sunshield is about 10 m across, which is too large for the launch vehicle fairing, so it has been built with a dozen folding panels that will be deployed after launch.

Since the sunshield is designed for the weightlessness of space, it cannot support its own weight on Earth. So, during this test at Astrium in Toulouse, France, support cables and counterweights simulated weightless conditions and provided a realistic trial.

During its expected lifetime of five years, Gaia will take a census of a billion stars – roughly 1% of all of the stars in our Milky Way galaxy. It will observe each star about 70 times, each time recording its brightness, colour and, most importantly, its position.

By comparing Gaia's series of observations, astronomers will

# Satellites help to grow perfect grapes

**ESA's 'GrapeLook' service shows how satellite technology can benefit agriculture, using data from space to help grape growers decide how much to water vineyards, and when.**

← Vine monitoring in the Grapelook project (C. Jarmain/ UKZN)

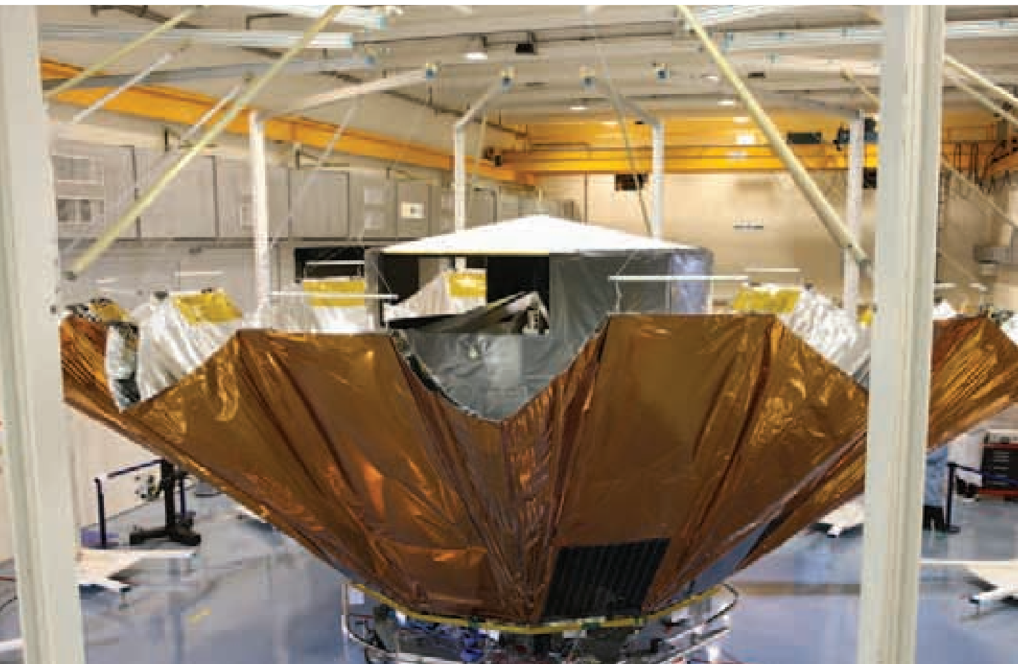
To use the water most efficiently, growers need information on crop production and water consumption. GrapeLook uses satellite remote sensing to monitor how much water is released from the plants, how much biomass is grown and how efficiently the water is being used overall.

The service uses technology that combines Earth observation data and field measurements. Moisture readings are sent in real time to a processing centre via a satellite link. Once the information is processed, the maps are put online for the grape growers and water managers through a Google Maps-based website.

GrapeLook was tested this year with selected grape growers in South Africa. The growers connected regularly to the website to check the status of their vineyards. Participants agreed that GrapeLook was useful for monitoring water stress, crop growth and identifying irrigation problems.

The system helped to identify more efficient practices and would help in reducing labour and other costs. It should increase the amount of grapes being harvested and raise the quality of the wine – all the while using less water.

The service was developed by WaterWatch (NL), supported by ESA's Integrated Applications Programme and co-funded by the Department of Agriculture of Western Cape in South Africa, in collaboration with the University of KwaZulu-Natal and with support of the Department of Agriculture, Fisheries and Forestry and the Dutch Embassy.



Gaia Deployable Sunshield Assembly seen being deployed in Toulouse (Astrium)

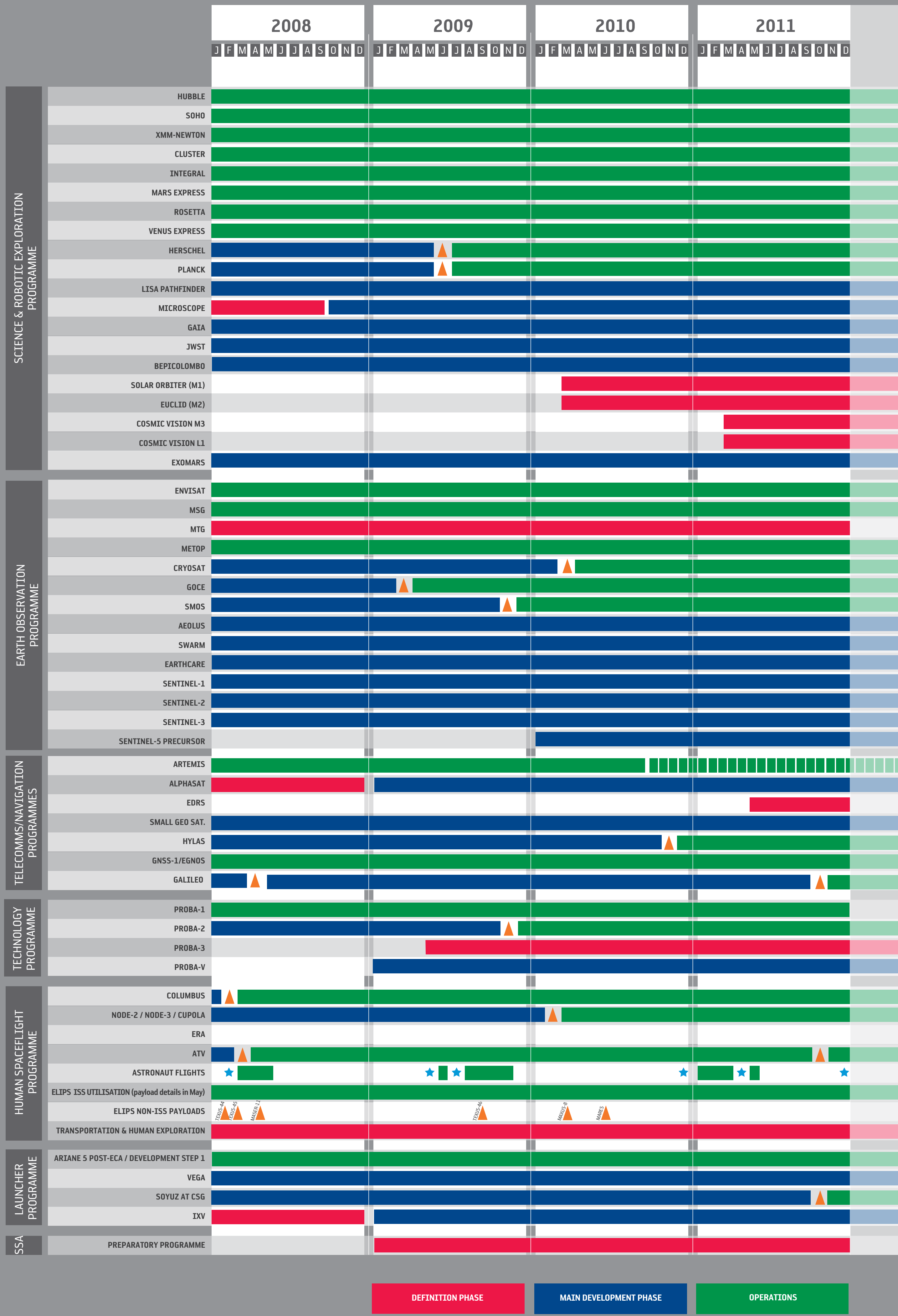
precisely measure the apparent movement of each star across the heavens, enabling them to determine its distance and true motion through space. The unprecedented results will allow astronomers to trace the history of the Milky Way.

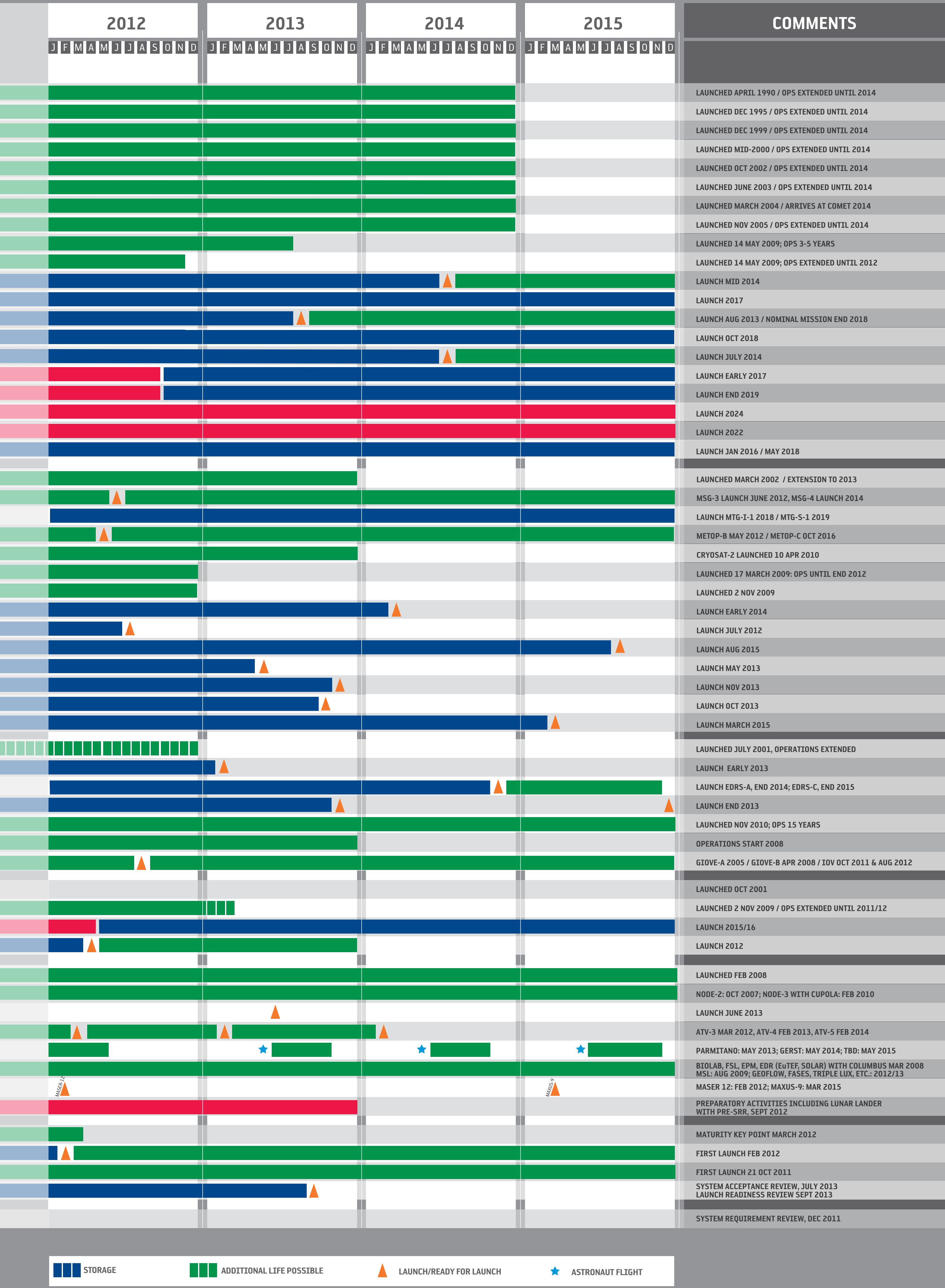
The Gaia sunshield was developed and manufactured by Sener in Spain. The satellite's prime contractor is Astrium SAS in France.

# → PROGRAMMES IN PROGRESS

**Status at end of January 2012**

The first Vega, flight VV01, lifts off at 11:00 CET (07:00 local time) on 13 February from its new launch pad at Europe's Spaceport in French Guiana


2008
2009
2010
2011
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
SOHO
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
ROSETTA
VENUS EXPRESS
HERSCHEL
PLANCK
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
SOLAR ORBITER (M1)
EUCLID (M2)
COSMIC VISION M3
COSMIC VISION L1
EXOMARS
EARTH OBSERVATION PROGRAMME
ENVISAT
MSG
MTG
METOP
CRYOSAT
GOCE
SMOS
AEOLUS
SWARM
EARTHCARE
SENTINEL-1
SENTINEL-2
SENTINEL-3
SENTINEL-5 PRECURSOR
TELECOMMS/NAVIGATION PROGRAMMES
ARTEMIS
ALPHASAT
EDRS
SMALL GEO SAT.
HYLAS
GNSS-1/EGNOS
GALILEO
TECHNOLOGY PROGRAMME
PROBA-1
PROBA-2
PROBA-3
PROBA-V
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS
NODE-2 / NODE-3 / CUPOLA
ERA
ATV
ASTRONAUT FLIGHTS
ELIPS ISS UTILISATION (payload details in May)
ELIPS NON-ISS PAYLOADS
TEXUS-44
TEXUS-45
MASER-11
TEXUS-46
MAXUS-8
MARES
TRANSPORTATION & HUMAN EXPLORATION
LAUNCHER PROGRAMME
ARIANE 5 POST-ECA / DEVELOPMENT STEP 1
VEGA
SOYUZ AT CSG
IXV
SSA
PREPARATORY PROGRAMME
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS


2012
2013
2014
2015
COMMENTS
J F M A M J J A S O N D
LAUNCHED APRIL 1990 / OPS EXTENDED UNTIL 2014
LAUNCHED DEC 1995 / OPS EXTENDED UNTIL 2014
LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 2014
LAUNCHED MID-2000 / OPS EXTENDED UNTIL 2014
LAUNCHED OCT 2002 / OPS EXTENDED UNTIL 2014
LAUNCHED JUNE 2003 / OPS EXTENDED UNTIL 2014
LAUNCHED MARCH 2004 / ARRIVES AT COMET 2014
LAUNCHED NOV 2005 / OPS EXTENDED UNTIL 2014
LAUNCHED 14 MAY 2009; OPS 3-5 YEARS
LAUNCHED 14 MAY 2009; OPS EXTENDED UNTIL 2012
LAUNCH MID 2014
LAUNCH 2017
LAUNCH AUG 2013 / NOMINAL MISSION END 2018
LAUNCH OCT 2018
LAUNCH JULY 2014
LAUNCH EARLY 2017
LAUNCH END 2019
LAUNCH 2024
LAUNCH 2022
LAUNCH JAN 2016 / MAY 2018
LAUNCHED MARCH 2002 / EXTENSION TO 2013
MSG-3 LAUNCH JUNE 2012, MSG-4 LAUNCH 2014
LAUNCH MTG-I-1 2018 / MTG-S-1 2019
METOP-B MAY 2012 / METOP-C OCT 2016
CRYOSAT-2 LAUNCHED 10 APR 2010
LAUNCHED 17 MARCH 2009: OPS UNTIL END 2012
LAUNCHED 2 NOV 2009
LAUNCH EARLY 2014
LAUNCH JULY 2012
LAUNCH AUG 2015
LAUNCH MAY 2013
LAUNCH NOV 2013
LAUNCH OCT 2013
LAUNCH MARCH 2015
LAUNCHED JULY 2001, OPERATIONS EXTENDED
LAUNCH EARLY 2013
LAUNCH EDRS-A, END 2014; EDRS-C, END 2015
LAUNCH END 2013
LAUNCHED NOV 2010; OPS 15 YEARS
OPERATIONS START 2008
GIOVE-A 2005 / GIOVE-B APR 2008 / IOV OCT 2011 & AUG 2012
LAUNCHED OCT 2001
LAUNCHED 2 NOV 2009 / OPS EXTENDED UNTIL 2011/12
LAUNCH 2015/16
LAUNCH 2012
LAUNCHED FEB 2008
NODE-2: OCT 2007; NODE-3 WITH CUPOLA: FEB 2010
LAUNCH JUNE 2013
ATV-3 MAR 2012, ATV-4 FEB 2013, ATV-5 FEB 2014
PARMITANO: MAY 2013; GERST: MAY 2014; TBD: MAY 2015
BIOLAB, FSL, EPM, EDR (EuTEF, SOLAR) WITH COLUMBUS MAR 2008
MSL: AUG 2009; GEOFLOW, FASES, TRIPLE LUX, ETC.: 2012/13
MASER 12: FEB 2012; MAXUS-9: MAR 2015
PREPARATORY ACTIVITIES INCLUDING LUNAR LANDER
WITH PRE-SRR, SEPT 2012
MATURITY KEY POINT MARCH 2012
FIRST LAUNCH FEB 2012
FIRST LAUNCH 21 OCT 2011
SYSTEM ACCEPTANCE REVIEW, JULY 2013
LAUNCH READINESS REVIEW SEPT 2013
SYSTEM REQUIREMENT REVIEW, DEC 2011
STORAGE
ADDITIONAL LIFE POSSIBLE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

## KEY TO ACRONYMS

| | |
|---|---|
| AM - Avionics Model | MoU - Memorandum of Understanding |
| AO - Announcement of Opportunity | PDR - Preliminary Design Review |
| AU - Astronomical Unit | PLM - Payload Module |
| CDR - Critical Design Review | PRR - Preliminary Requirement Review |
| CSG - Centre Spatial Guyanais | QM - Qualification Model |
| ELM - Electrical Model | SM - Structural Model |
| EM - Engineering Model | SRR - System Requirement Review |
| EQM - Electrical Qualification Model | STM - Structural/Thermal Model |
| FAR - Flight Acceptance Review | SVM - Service Module |
| FM - Flight Model | TM - Thermal Model |
| ITT - Invitation to Tender | |

## → HUBBLE SPACE TELESCOPE

In a sky survey made in near-infrared light, Hubble has spotted five galaxies clustered together. They are so distant that their light has taken 13.1 billion years to reach us. These galaxies are among the brightest galaxies at that early stage of the Universe's history. They are also very young: we are seeing them just 600 million years after the Universe's birth in the Big Bang. Galaxy clusters are the largest structures in the Universe, comprising hundreds to thousands of galaxies bound together by gravity. This developing cluster, or 'protocluster', seen as it looked 13 billion years ago, presumably has grown into one of today's massive cities of galaxies, comparable to the nearby Virgo cluster of more than 2000 galaxies.

These observations demonstrate the progressive build-up of galaxies and provide further support for the hierarchical model of galaxy assembly, in which small objects accrete mass or merge to form bigger objects over a smooth and steady, but dramatic, process of collision and collection.

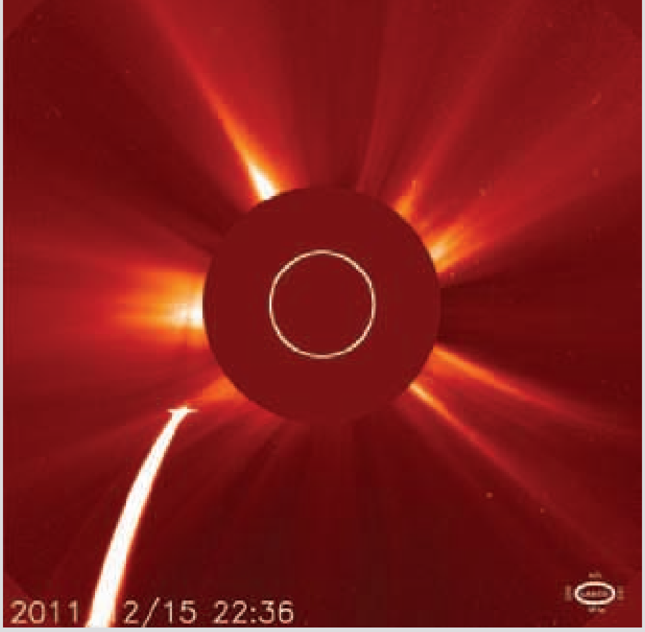
The observations are part of the 'Brightest of Reionizing Galaxies' (BoRG) survey, which uses Hubble's WFC3 to search for the brightest galaxies around 13 billion years ago. The distance to the newly found galaxies was estimated using their colours. Astronomers now plan to follow up with spectroscopic observations, which will help them precisely calculate the cluster's distance. These observations will also yield the velocities of the galaxies and show whether they are gravitationally bound to each other.

## → SOHO

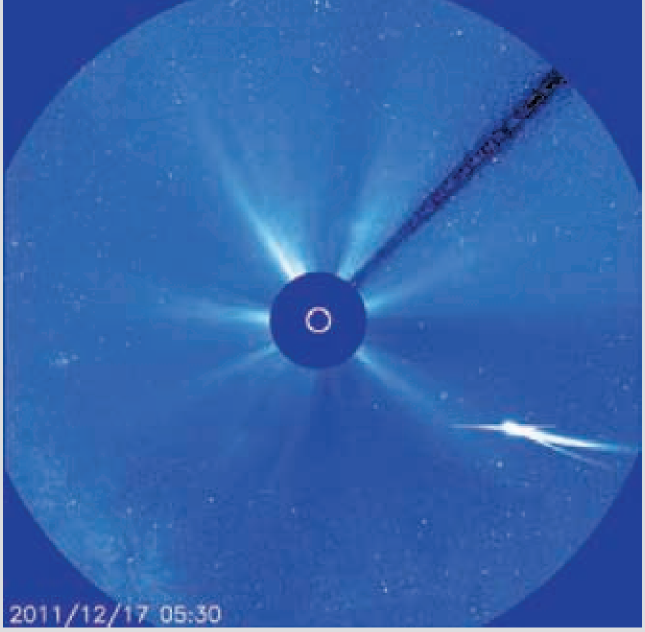
Announced on SOHO's 16th launch anniversary on 2 December, the discovery of Comet C/2011 W3 (Lovejoy) took all experts by surprise. It survived its close encounter with the Sun and emerged intact after plunging through the several million degree solar corona. It was discovered by Australian amateur astronomer Terry Lovejoy who, as an early pioneer of discovering SOHO comets over the internet, can now claim to be the first person to discover a sungrazing comet from both ground and space-based telescopes.

As other ground-discovered Kreutz-group comets, Comet Lovejoy was predicted to get bright, and it did not disappoint. It turned into a truly spectacular object and attracted enormous interest by the public. On 15 and 16 December (the day before and after perihelion passage), the SOHO web server alone set two single-day records for page views (2 878 750 and 3 037 971) and data downloaded (1.95 and 1.97 TB, respectively). The LASCO and UVCS instruments on SOHO made special observations of this event. The measurements should provide outgassing rates and the size of the nucleus. But there are many questions that still puzzle scientists, such as what caused Comet Lovejoy to lose its tail inside the Sun's atmosphere and then regain it later? And how did Comet Lovejoy survive at all?


This composite Hubble image, taken in visible and near-infrared light, shows five galaxies clustered together just 600 million years after the Universe's birth in the Big Bang. The circles pinpoint the galaxies and the close-up images, taken in near-infrared light, show the galaxies (Univ. of Cambridge/Univ. of Colorado/STScI/BoRG)




Comet Lovejoy approaching its close encounter with the Sun seen by SOHO/LASCO on 15 December




Comet Lovejoy after its close encounter with the Sun seen by SOHO LASCO on 17 December, note the two distinct tails (ion and dust)

## → CASSINI-HUYGENS

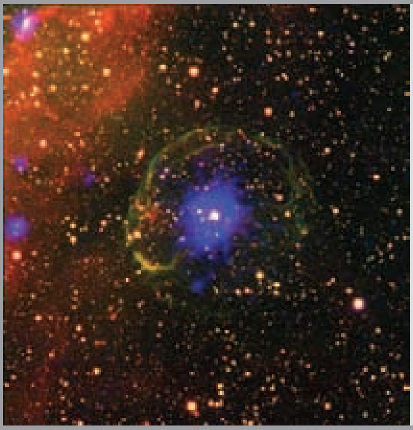
Previous analysis of the Huygens Chromatograph Mass Spectrometer data had revealed an atmospheric depletion in noble gases heavier than argon. A recent study explains this puzzling depletion by suggesting that the heavier noble gases are trapped efficiently into surface 'clathrates hydrates' (a water ice lattice) given the thermodynamic conditions at the atmosphere/surface interface of Titan. However, for this process to work, fresh lava from cryo-volcanic activity needs to be present, possibly resulting in a layer a few metres thick of clathrate compounds retaining the primordial noble gases as they are progressively removed from Titan's atmosphere. This study adds indirect new clues to a possible cryo-volcanic activity on Titan's surface in the recent past, while direct evidence has not been found so far.

An analysis of Radio and Plasma Wave experiment data, obtained during four Enceladus flybys, reveals the composition of the ambient plasma, inferring electron and ion density as well as the ion bulk speeds. Plasma properties in the 'plumes' of Enceladus have been derived (the plumes are geyser-like features containing water vapour, icy grains and neutral atomic or molecular particles ejected from cracks in the south pole of the moon). It appears that the plasma in the plume is depleted in electrons, which are attached to nanometre- and micrometre-sized particles. A strong dust–plasma coupling is observed, as the dust volume number density implies an inter-grain distance smaller than the Debye length. Such conditions, prevailing around Enceladus as well as in the E ring as a whole, define the existence of a 'dusty plasma', a rarely observed phenomena, as opposed to 'dust in a plasma' which is much more frequent in interplanetary space.

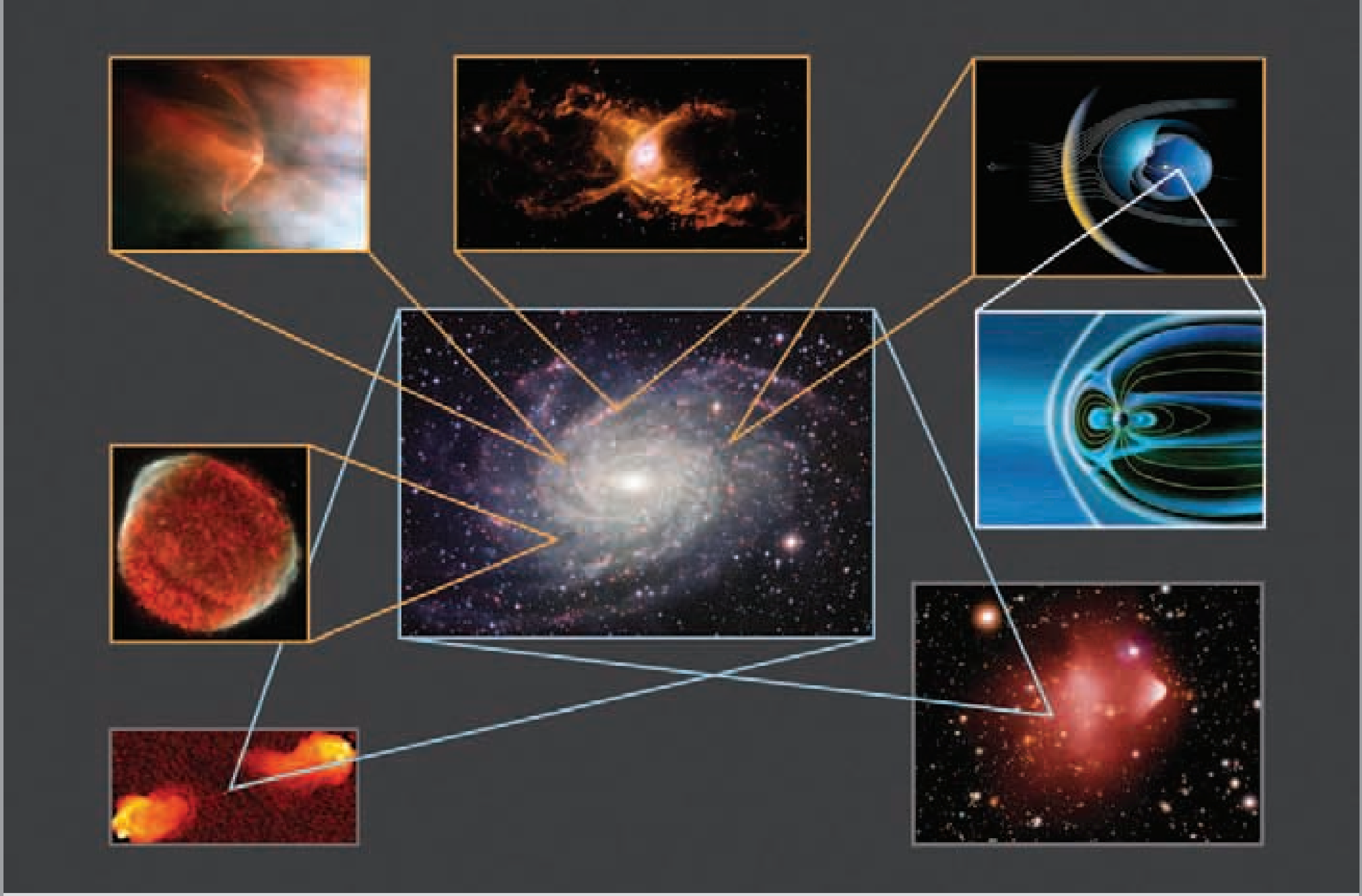
In addition, the cold ions have a bulk velocity close to the Keplerian speed expected at the Enceladus radial distance from Saturn. In particular, the data show that there is no wake in the direction of Enceladus' motion, which would be expected if the plasma moved with a 'rigid' co-rotational speed driven by Saturn's magnetosphere rotation, greater than the local ion sound's speed. These observations of strong dust–plasma coupling is a significant step toward understanding the modulations of the Saturn Kilometric Radiation and the associated difficulties to measure Saturn's rotation period.

## → XMM-NEWTON

Astronomers have discovered a very slowly rotating X-ray pulsar still embedded in the remnant of the supernova that created it. This unusual object was detected on the outskirts of the Small Magellanic Cloud, a satellite galaxy of the Milky Way, using data from a number of telescopes, including ESA's XMM-Newton. A puzzling mismatch between the fairly young age of the supernova remnant and the slow rotation of the pulsar, which would normally indicate a much older object, raises interesting questions about the origin and evolution of pulsars.



A composite false-colour image of the newly discovered X-ray pulsar, combining the X-ray view from XMM-Newton with optical data from NOAO's Cerro Tololo Inter-American Observatory (ESA/Univ. of Potsdam/IAA/CTIO/Univ. of Illinois)



Some astronomical sources where shocks have been detected: clockwise from top left, a bow shock around the very young star LL Ori in the Great Orion Nebula; shock waves around the Red Spider planetary nebula; the bow shock created by the Solar System as it moves through the interstellar medium of the Milky Way; Earth's bow shock, formed by the solar wind as it encounters our planet's magnetic field; a bow shock in the hot gas of the merging galaxy 'Bullet Cluster'; shock-heated shells of hot gas on the edge of the lobes of the radio galaxy Cygnus A; very thin shocks on the edge of the expanding supernova remnant SN 1006. Galaxy NGC 6744 in the centre gives a rough idea of the relative scales of the shock waves present across the Universe

## → CLUSTER

2011 was the most productive year for Cluster science, with more than 220 articles published in refereed literature. A recent highlight was the estimation of Earth's bow shock thickness, made with multiple spacecraft, and how this result enables a better understanding of other physical phenomena across the Universe.

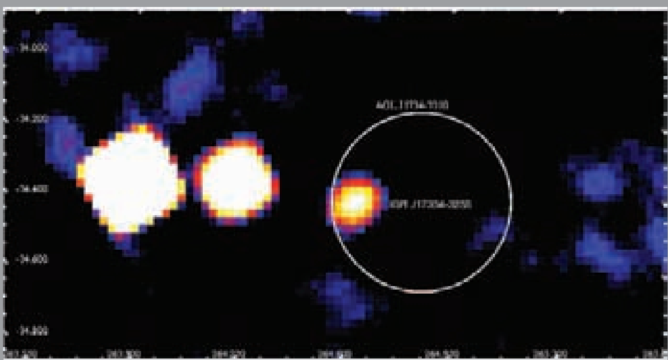
In the Solar System, the Sun expels a fast-moving flow of electrically charged particles, called the solar wind. As it encounters Earth's magnetic field, a permanent shock wave is created in front of our planet. This 'bow shock' is an extraordinary laboratory to directly probe plasma dynamics and to explore scales that are inaccessible on the ground or by astronomical observations. Cluster's new results in this local environment are applicable on much larger scales. Shocks are also found around exploding stars, young stars, black holes and whole galaxies. Space scientists suspect that these may be the origin of the high-energy cosmic rays that fill the Universe.

Using the Cluster Active Archive, this study found evidence that electrons experience a sharp rise in temperature across the bow shock within only 17 km. Such a sharp transition is close to the limit set by plasma theory and could hardly be any steeper, implying that the shock layer is as thin as it can be. Such shock thicknesses mean far more efficient acceleration is possible and this mechanism may be a solution to the injection problem in cosmic accelerators. If a shock can be this thin, particles 'surfing' along it may be accelerated to a sufficiently high energy threshold where they can then be fed to different mechanisms that accelerate them to even higher energies, well beyond 1 GeV, such as those reported in cosmic ray studies. These results show how local studies in the Solar System can have a major impact on the understanding of cosmic particle acceleration, a ubiquitous phenomenon active on a wide range of scales across the Universe.

In early 2012, Cluster made special manoeuvres to allow Guest Investigator (GI) operations. The Cluster GI Programme will identify new and compelling uses of the Cluster scientific payload from proposals from the scientific community. The first GI configuration implemented in 2012 will examine turbulence in the solar wind, using a pair of Cluster spacecraft separated by only 40 km, first aligned with the Sun/Earth direction then perpendicular. The other spacecraft will be kept at larger separation for context measurements. In May, the spacecraft will be put in a multiscale configuration to examine reconnection at the magnetopause and, later in the year, they will then be put in their largest separation so far to examine boundary wave phenomena.

## → INTEGRAL

Blazars, or 'blazing quasi-stellar objects', are very compact quasars and are among the most energetic phenomena in the Universe. Very high energy observations by the AGILE and Fermi spacecraft have recently indicated the existence of a possible population of transient high-energy (MeV/GeV) sources in the galactic plane and characterised by fast flares lasting only a very few days. Notably, no 'blazar-like' counterparts are known within their error circles, so they could represent a completely new class of high-energy galactic fast transients. The task of identifying their counterparts at lower energies remains very challenging, mainly because of their large error circles.



A significance map from Integral/IBIS in the 18–60 keV band. IGR J17354-3255 is inside the error circle determined for AGL J1734-3310

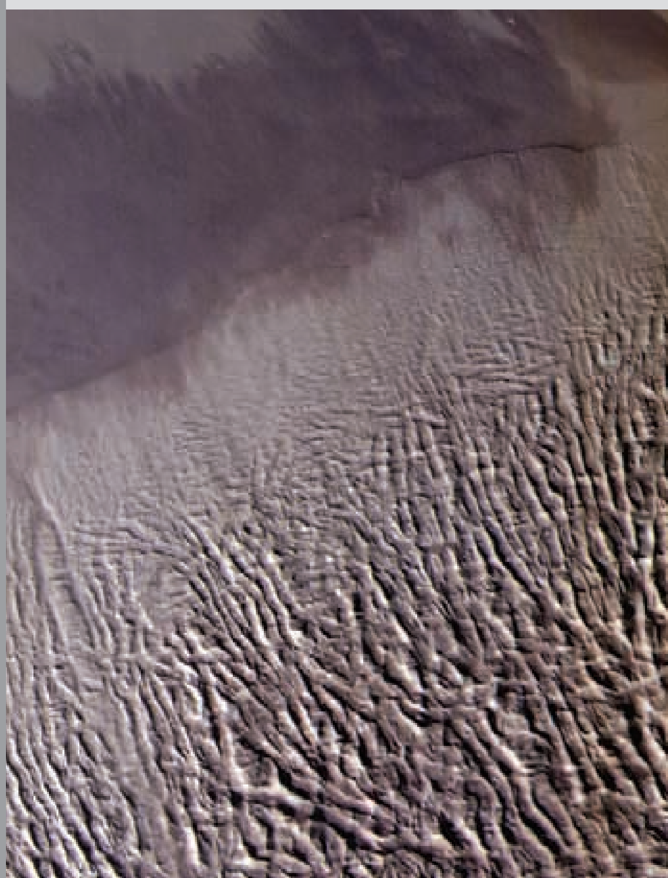
Integral observations are particularly suited to search for reliable best candidate counterparts. In particular, recent results suggest that reliable best candidate counterparts could be found among the members of Supergiant Fast X-ray Transients (SFXTs), merely based on intriguing hints such as spatial correlations and common transient behaviours on similar, though as yet not simultaneous, short timescales. The currently proposed associations represent an important first step towards obtaining reliable test cases on which to concentrate further efforts to obtain quantitative proofs for a real physical association. So far, the best test case is represented by the recently proposed association between IGR J17354-3255 and AGL J1734-3310.

IGR J17354-3255 is an unidentified hard X-ray source that Integral found could be an intermediate SFXT while monitoring it in the hard X-ray band 18–60 keV. Several flares have been detected with typical durations from a few hours to a few days. The flares are mainly clustered around the closest passage of the likely neutron star compact object during its 8.4-day orbit around the companion donor star. Interestingly, IGR J17354-3255 is the only hard X-ray source inside the error circle of the unidentified transient source AGL J1734-3310. AGILE detected several recurrent high-energy flares lasting 1–2 days, and in particular two were quasi-simultaneous with hard X-ray activity detected by Integral/IBIS from IGR J17354-3255, providing a possible quantitative proof for a real physical association. Further studies of IGR J17354-3255/AGL J1734-3310 with AGILE and Integral are under way. If confirmed, the implications of SFXTs producing MeV/GeV emission are huge, both theoretically and observationally, and would add a further extreme characteristic to this already extreme class of transient sources.

## → MARS EXPRESS

An excellent workaround solution for the problem with the Mars Express Solid State Mass Memory was found. Science operations had been suspended in mid-October, but have now resumed.

A recent image taken by the High Resolution Stereo Camera on Mars Express from an altitude of 360 km. It shows the northern border of the 'aureole' that surrounds the famous Olympus Mons, the highest volcano in the Solar System. Two distinct geological areas are clearly seen: the ancient lava flows of the Amazonis Planitia at the top, which are overlaid by the aureole at the bottom. The different colours on the lava flows are from dark sand at the surface covered with a brighter dust



MARSIS had a successful north polar nightside campaign between June and October, despite many orbits missed due to the mass memory issue and solar events, which can result in a denser ionosphere disturbing the propagation of the radar wave. The polar regions of Mars are of particular interest because climate variations affect the quantities of water ice and dust found in the polar deposits. This campaign is one of the major scientific activities of the current mission extension. So far, the lowest point in the orbit had only been over the north pole during martian summer (daylight). The new data have higher signal-to-noise (better deep detections) and higher lateral resolution than previous MARSIS north polar observations. A first estimate of refractive index implies that the composition is not pure water ice.

## → ROSETTA

Analysis of data from the flyby of asteroid (21) Lutetia revealed key information in understanding the evolution of Solar System bodies through internal heating. Lutetia has one of the highest densities of any known asteroid: 3400 kg/m$^3$, implying that it contains significant quantities of iron. In spite of this, the asteroid has not formed a dense iron core, as is the case for the terrestrial planets. Its surface composition remained primordial and does not show the rocky material expected for a fully differentiated body. This can only be explained if the asteroid was subjected to some internal heating early in its history, but did not melt completely and so did not end up with a well-defined iron core.

## → VENUS EXPRESS

Tessera is a 'complex ridged' surface feature seen on venusian plateau highlands. VMC infrared images have revealed that, through analysis of surface emissivity, this tessera material cannot be basaltic as had been generally believed. It could be 'felsic', meaning having high silica content like, for example, granite. If so, this has important implications on the geochemical environment in the early history of Venus. These VMC results are also supported by data from the Virtis instrument.

A new photochemical model of the Venus middle atmosphere has been constructed based on data from Venus Express and from ground-based observations. It is a significant improvement of earlier models and does, in particular, model well the drop of $H_2O$ and $SO_2$ at the top of the cloud layer. A remaining difficult area to solve is the lower cloud boundary, where more data from Venus is required in order to better understand the physical conditions. The model includes more than 150 different chemical reactions. An important conclusion is the finding that variations in the $SO_2/H_2O$ ratio do not need volcanism to be explained. This is, however, debated and is not yet fully accepted by the general Venus community.

A precise comparison of the rotational position of geological features in Virtis images and the corresponding expected longitude has revealed that the rotation period of Venus deviates from the value approved by the International Astronomical Union. The new value, 243.023 ± 0.002 days, is slightly higher than the value established by the Magellan radar mission in 1992. The new value corresponds to an average over the period 1992 to 2008 and there is a possibility that short-term variations in the rotation rate have caused the Magellan value to be lower than the value averaged over a longer time. A highly accurate value is of importance for achieving correct pointing for new observations and for potential future landing missions.

## → HERSCHEL

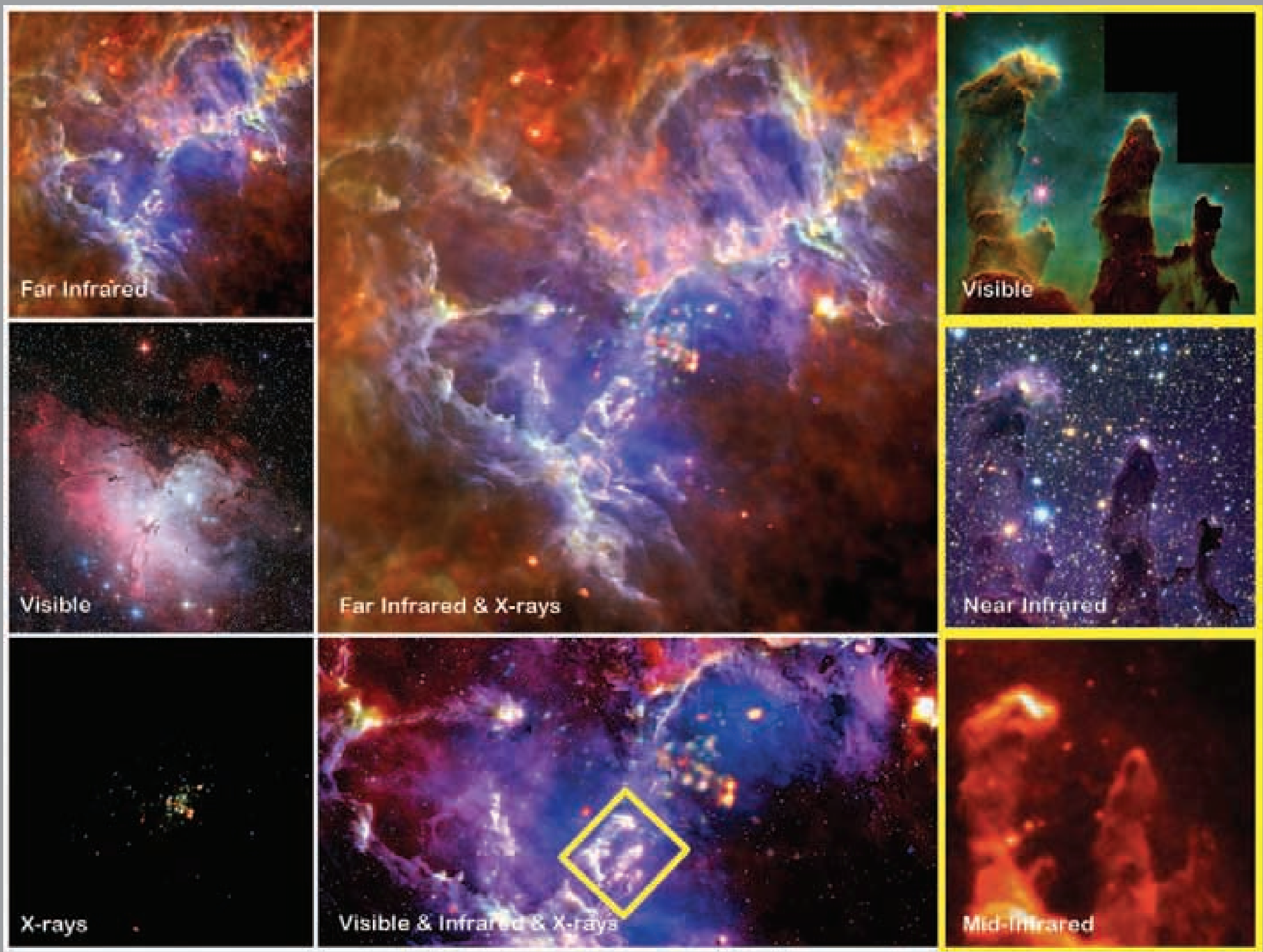
Herschel continues to perform routine science phase observing. With very few exceptions, all key programme observations have been made, as well as more than half of the observations selected in 2010 in the first call for observing proposals while in flight. In 2011, the remaining available observing time was allocated in the second and last call. Herschel flight operations will continue until all superfluid helium has been exhausted, which is predicted to occur in February 2013.

Herschel is the first space observatory to target the poorly observed far-infrared and submillimetre part of the spectrum, opening it up for detailed study with its large telescope. In doing so, Herschel often provides striking new views of well-known targets, revealing them in light literally never seen before.

A good example is the M16 'Eagle' nebula, roughly 6500 light-years away. Herschel has imaged a much larger area of the sky around M16 using both the PACS and SPIRE instruments. The central part of the resulting image at 70 mm (blue), 160 mm (green), and 250 mm (red) wavelengths shows the famous 'Pillars of Creation' as seen by the Hubble Space Telescope in 1995 and a wide area around them.

Each colour shows a different temperature of the dust, from around 10 degrees above absolute zero (10K) for the red, up to around 40K for the blue. Capturing the nebula in Herschel's far-infrared wavelengths allows astronomers to see inside the pillars and structures in the region, this time glowing in their own light emitted at these long wavelengths because of the very low temperature of the gas and dust. This beautiful image very clearly illustrates how the powerful radiation from young stars has been sculpting and illuminating the surrounding gas and dust,

The Eagle Nebula as never seen before. Hubble's 'Pillars of Creation' image of the Eagle nebula became one of the most iconic images of the 20th century. ESA's Herschel has shed new light on this enigmatic star-forming region. This image was used in the BBC's Stargazing Live TV show which aired on 16–18 January. Amazon UK said they saw an almost six-fold increase in sales of telescopes after first show in this series (ESA/PACS/SPIRE/HOBYS)




A composite of X-ray, optical, near-, mid- and far-infrared images of M16. The 'Pillars of Creation' are only a small part of the huge nebula region shown in far-infrared by Herschel (ESA/PACS/SPIRE/HOBYS/EPIC/MPG/ESO/VLT/ISAAC/AIP)

resulting in a huge hollowed-out cavity and the famous pillars, each several light-years long, which take on an ethereal ghostly appearance. The gas and dust provide the material for the star formation that is under way inside this enigmatic nebula.

## → PLANCK

In early December, Planck's spin rate of 1 rpm was increased by 40% for around one week. This operation, which had not been originally planned, was designed to acquire additional calibration information for Planck's scientific payload.

Planck has now completed its fifth survey of the entire sky. On 16 January, the High Frequency Instrument (HFI) ran out of the coolant needed to keep its detectors at their operating temperature of 100mK. Since then, the HFI has no longer produced scientifically useful data. However, the Low Frequency Instrument (LFI) continues to operate and will keep surveying the sky for around eight months. During this period, the HFI will also remain switched on because one of its coolers is required to service part of the LFI.

Planck was originally designed with a minimum requirement of acquiring two full sky surveys. The fact that this technologically complex mission has been able to complete five full surveys without interruptions and with all its payload operating testifies to the high quality of the work by the many engineering and scientific teams that developed the satellite.

## → COROT

COROT continues to operate after more than five years in space. The teams are requesting from the French space agency CNES a further mission extension beyond April 2013.

More than 250 objects, of several dozens of types, have been observed asteroseismologically. In the exoplanet programme, COROT has covered 58 square degrees of sky and acquired 125 064 light curves that have been released to the public. The COROT team have detected a total of 3760 possible transits, most of which are found to be transiting stellar systems. Most of these can be identified through the long duration of the light curves, allowing detection of the secondary transit or by analysing the light curve modulation. With some objects, the transit is observed only once (mono-detections), possibly representing long-period planets. The remaining candidates are investigated through the follow-up process using photometric and spectroscopic ground-based observations.

More than 625 candidates have been screened out this way, while 27 confirmed planets varying in mass from around 10 Earth masses to 60 Jupiter masses have been reported.

Image of NGC 2264 cluster taken by the VLT (ESO)

Several more planets are indicated, while 34 000 light curves are currently being analysed by the science team. Note that in each field, a number of transit candidates have not been 'solved', i.e. not determined if they represent bona fide exoplanets or 'false-positives'. This is mainly because the faintness of the host stars does not allow a proper spectroscopic radial velocity determination. They remain potential planets.

From December to January, COROT participated in a multi-spacecraft campaign (COROT, Spitzer, Chandra and MOST), as well as with many ground-based telescopes (especially the Very Large Telescope in Chile). The target was the 106 year-old cluster NGC 2264 (also known as the 'Christmas Tree' or 'Madonna' nebula). The instruments observed continuously about 4000 stars of different masses, so at several stages of formation, in wavelengths from infrared to X-rays. The main objectives were to study the interaction between stars and surrounding matter, rotation and magnetic activity, characterisation of stellar structure using asteroseismology, and search for planetary and stellar transits.

COROT is observing the field LRa01 again, first observed in 2007. This field contains four confirmed planets including the first positively identified 'rocky' planet, COROT-7b. This latter system potentially contains two more planets in the 'super-Earth'/'hot Neptune' mass category. Simultaneously, a radial velocity campaign with ESO's 3.6 m telescope is being carried out. It is expected to pick up more planet candidates in this field, since many mono-detections were observed here and may represent long-period planets. If the operational phase of COROT is extended again, more repeat observations of LRa01 may provide a unique sampling over nine years.

## → PROBA

Proba-2 celebrated its second birthday in space on 2 November and entered the first mission extension phase. All ground and flight segment elements have been working as normal since commissioning, including the scientific instrumentation – observing the Sun continuously.

The SWAP imager has produced more than 400 000 images of the Sun, each of them available in calibrated form to scientists, space weather forecasters and the interested public in less than four hours after acquiring the image. The LYRA radiometer produces a daily, calibrated data file sampled at 20 Hz containing the measured solar irradiance at four different wavelengths.

As well as observations of large flares and coronal mass ejections, now reported more often because of the increased activity of the Sun, Proba-2 also observed Comet Lovejoy in December.

## → GAIA

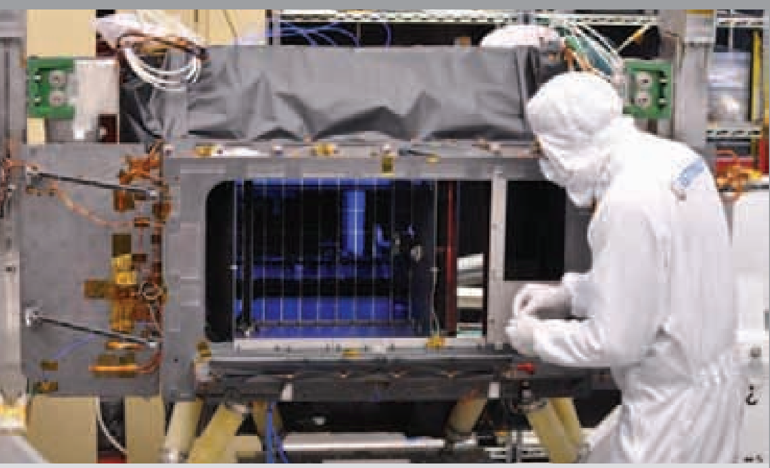
Mechanical qualification tests of Protoflight Model 1 were completed, including the Service Module FM, the Payload Module dummy inside the Thermal Tent FM and the Deployable Sun Shield FM. The sun shield was deployed before and after the tests. The activities on the sun shield are finished and the hardware is stored. It will be integrated for the last time on the spacecraft at the launch site. Six of the 12 thrusters of the cold-gas micro-propulsion system have been delivered.

Alignment of the two telescopes is progressing; the wave-front error of the first telescope is now almost at the required value while the second telescope needs some additional tuning. The focal length difference was further reduced and it is close to the required value.

Integration of the Focal Plane Assembly FM is complete and the system is ready to start the environmental tests (mechanical and then thermal). Concerns about the alignment of the Basic Angle Monitor (the instrument which will accurately measure in orbit the variation of the two telescopes' lines of sight) have been resolved. The fine optical measurements on Radial Velocity Spectrometer showed that the system needs a realignment of one of its prisms.

The Mission Operation Centre at ESOC and the Science Operation Centre at ESAC are in development. The third System Validation Test, with the spacecraft AM commanded from ESOC using the flight procedures, took place in December. So far, more than 400 flight operation procedures have been validated. The Ground Segment Implementation Review took place at the end of 2011.

Work with Arianespace proceeds as planned. The first releases of the launch campaign plan, including the detailed timeline and of the safety submission are available. The Galileo launch in October confirmed that the launch site and launcher configuration for Gaia are ready.



The Gaia Focal Plane Assembly fully integrated in the clean room (Astrium SAS)

## → LISA PATHFINDER

Environmental testing of the spacecraft FM was completed in November. The integrated system functional tests and the first System Validation Test (SVT-1) were performed. Only some closed-loop system functional tests need to be performed before the start of spacecraft hibernation. Functional verification activities are being finalised, both at the Real Time Test Bench and the Software Verification Facility.

The LISA Pathfinder Science Module Flight Model after completion of the On-Station Thermal Vacuum Test at IABG, Ottobrunn (IABG/Astrium)

Tests on the FEEP micro-propulsion system are proceeding. The new emitter configuration, together with the ceramic accelerator shield, is so far providing excellent results. Tests will continue until mid 2012.

The American Disturbance Reduction System payload flight hardware has been integrated on the Science Module (SCM) for more than one year. All units of the LTP, except the LTP Core Assembly, which is subject to the necessary redesign activities of the caging mechanism, have been delivered and tested by the LTP Architect and subsequently integrated and tested on the SCM. After that two new launch lock mechanism concepts have been designed and tested at breadboard level, one of the two, the Cage and Vent Mechanism (CVM), has been chosen for qualification and FM manufacturing. The contracts have begun and the new CVM is expected in early 2013.

The baseline launch vehicle is Vega, the third of the planned VERTA launches. As a back-up option, Rockot is being considered. The PDR for Rockot was held, while the Vega PDR will take place after the maiden flight.

## → BEPICOLOMBO

The Mercury Planetary Orbiter (MPO) STM is being prepared for mechanical tests. All spacecraft modules, the Mercury Transfer Module (MTM) STM and Sunshield FM, are at ESTEC to join in the mechanical tests of the composite

Structural Models of the BepiColombo MPO, MTM and MMO and Flight Model of MOSIF being prepared for mechanical tests at ESTEC

spacecraft. The MPO FM was delivered and the MTM FM was ready for delivery just before the end of the year. These events mark the start of the flight spacecraft integration campaign. Equipment and subsystem CDRs have started. Two more MPO instrument EMs were delivered and completed pre-integration to the Engineering Test Bench at Astrium. All scientific instruments are now ready to support the system functional tests. The Engineering Test Bench completed the first run of integrated system tests with the payload EMs. Another five MPO instrument CDRs were conducted and the remaining review is scheduled for early 2012.

JAXA handed over the mechanical test model of the Mercury Magnetospheric Orbiter (MMO). The FM mechanical and electrical interface check is ongoing at JAXA and is nearing completion according to plan. The MMO System CDR was completed.

The Ground Segment Design Review was concluded. The contractor for the spacecraft simulator was selected and procurement of the control centre computer hardware was initiated.

## → MICROSCOPE

In December, CNES finally approved the start of implementation phase. The ESA project is resuming activities for procurement of the cold-gas micro-propulsion system. The next step will be the selection of the industrial contractor. This will be based on the ITT released in 2011 and on the responses already received by the bidders.

## → EXOMARS

Work on the ExoMars baseline mission continued, including the Trace Gas Orbiter and Entry, Descent and Landing Demonstrator Module to be launched in 2016, as well as studies on the joint rover to be launched in 2018. The work was supported through an Authorisation to Proceed issued by ESA for October to December.

A number of major programmatic events took place in this period that will mould the future of the ExoMars programme while maintaining the 2016 mission launch date. Ongoing budget difficulties in NASA, which were first reported in early 2011, have resulted in the formation of a group of ESA, NASA and Roscosmos heads agreeing to study the possibility of a broadening of cooperation to include Roscosmos in the ESA ExoMars and NASA Mars Exploration programmes. All parties agreed the need to tailor cooperation to maintain the existing launch dates of 2016 and 2018 for the ExoMars programme.

A trilateral programme and technical meeting was held in Paris in December. It was agreed to study further various payload configurations of European, US and Russian instruments for the 2016 Orbiter Module, with preliminary discussions on a broader scientific and technical cooperation for 2018 and beyond.

ESA is seeking a Proton launcher for the 2016 mission while Russia is looking into flying instruments on the 2016 mission and starting a longer-term cooperative programme for 2018 and beyond. Completion of this study and issue of a feasibility report is targeted for January to allow the agencies to decide on a future broad trilateral or focused bilateral cooperation.

Up to the end of December, joint studies between ESA and NASA for the 2018 mission continued and planning was consolidated to permit project start on the NASA side in the first half of 2012. Basic arrangements for sharing the joint rover and responsibilities for the 2018 mission are agreed. Some final architectural decisions concerning solar or nuclear power and the division of labour for the overall integration and test flow need to be agreed. The final architecture for the joint rover will be fixed in early 2012 at a NASA Mission Concept Review in which ESA will participate.

## → SOLAR ORBITER

The PDR began in December. Contract negotiations were completed with the prime contractor and Phase-B2/C/D started.

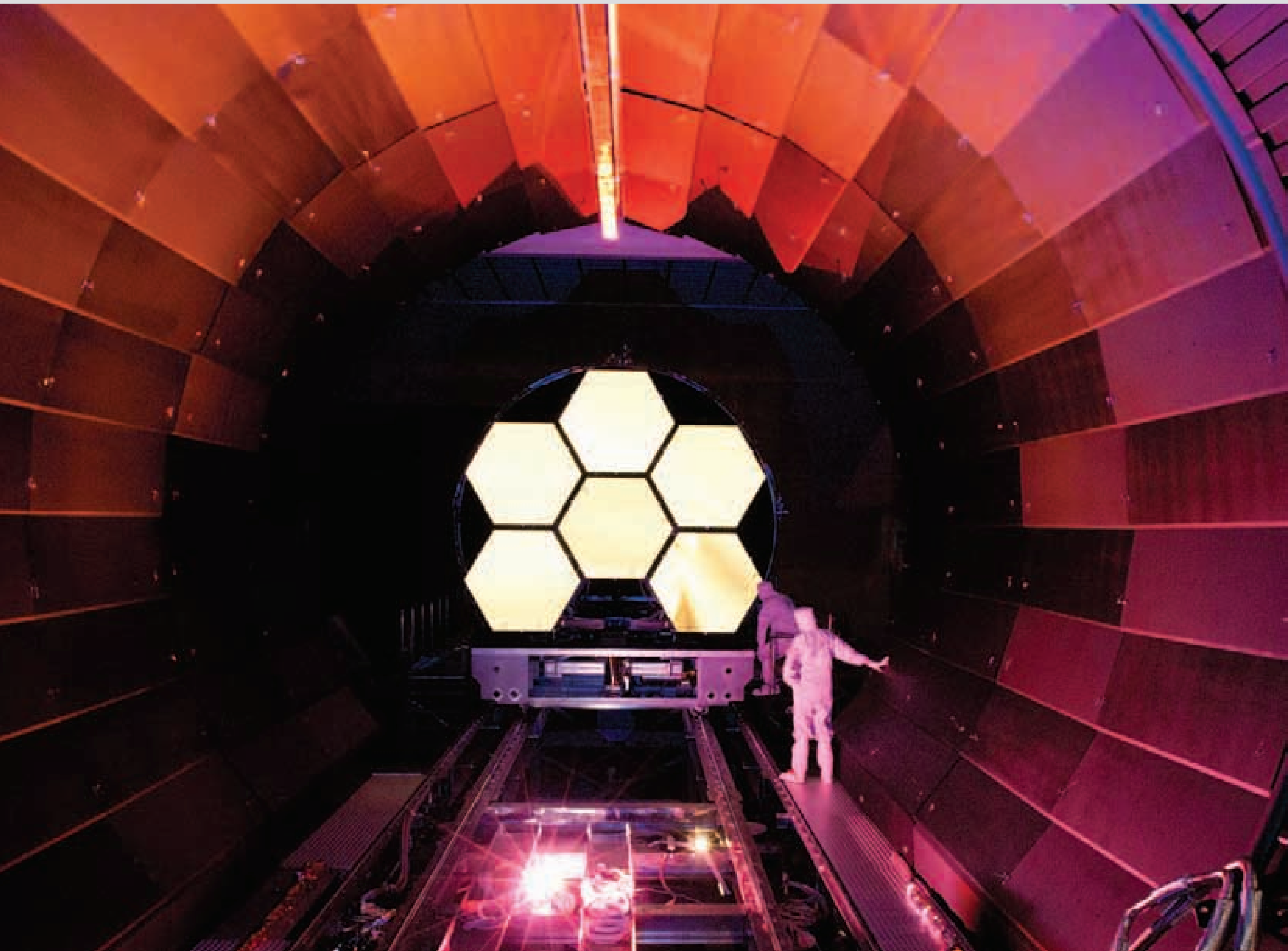
Sub-system level procurement activities continued and most subsystem contractors have been selected. Procurement activities up to completion of the overall industrial consortium will take up to mid 2012. Technology development work continues on the High Temperature Materials definition (for high-temperature multilayer insulation for the back of the antennas, heat shield, front shield, feed-through coatings, etc.)

The technical baseline design presented for PDR is well advanced and in line with the mission requirements. The procurement process is well underway to agree the way forward towards a European-led SPICE instrument (still with involvement of US institutes) to replace the NASA-funded original instrument. Similarly, procurement is under way with the University of Kiel for replacement of the Suprathermal Ion Sensor (part of the Energetic Particle Detector instrument suite led by the University of Alcalá).

The ESA Coordinated Parts Procurement Agency (CPPA) contract (for the benefit of the instruments only) has begun.

The Mission Implementation Requirements Document has been agreed, constituting a sound basis for the development of the Mission Implementation Plan in 2012. The Operations Interface Requirements Document and Space-to-Ground Interface Control Document have been agreed and updated, and form part of the ESA requirements baseline. The Consolidated Report on Mission Analysis (CReMA) has been updated.

Roll-out of the last six primary mirror segment assemblies for JWST from final cryo-verification test (Ball Aerospace)



The ESA/NASA MoU and Joint Project Implementation Plan were agreed and NASA conducted its 'gate review', confirming funding beyond Phase-A for its contribution to the payload as reduced earlier in 2011.

Technical definition of the launch vehicle interface is advancing. Results of the first Coupled Load Analysis and a Trajectory and Separation Conditions analysis were delivered by NASA.

## → JAMES WEBB SPACE TELESCOPE

The final cryo-verification test of the last set of six flight pimary mirror segments was completed. The predicted performance of the primary mirror, composed of 18 segments, is well within specification. This is a major project milestone. NASA JWST has received full funding for 2012, according to the new plan leading to launch in October 2018.

The NIRSpec flight instrument has been fully disassembled from the optical bench. No additional cracks have been found, and no cracks have been found in the main load carrying interfaces. The problem is limited to interfaces on the bench carrying light auxiliary equipment. The flight spare bench has been 'woken up' and is now in final preparation before the instrument reintegration starts.

The MIRI Acceptance/Pre-Shipment Review began in December. A potential problem on the instrument sensitivity was identified. Causes have been traced to the detector system or incomplete data processing.

## → ENVISAT

The mission proceeds normally, however the GOMOS (Global Ozone Monitoring through Occultation of Stars) instrument anomaly has degraded further.

ERS-2's deorbit and passivation had an indirect benefit of improving knowledge on Envisat fuel consumption. As a result, the fuel availability is slightly larger than predicted. This will be used to perform more orbit manoeuvres in 2012 that will allow technically Envisat to operate longer than estimated a few years ago. Such an approach keeps open the possibility to operate Envisat until 2015, if ESA Member States agree to extend mission operations beyond the currently approved extension to 2013.

## → GOCE

Released in October, the third generation of gravity field models and derived parameters demonstrate that GOCE is changing our understanding of the high-resolution gravity field. As a consequence, the application of such information in Earth sciences is advancing rapidly. Significantly improved results in terms of ocean dynamic topography and ocean currents have shown that GOCE delivers a much sharper view of all the main ocean current systems. In terms of solid Earth physics, new results based on both gravity models as well as the world-first three-dimensional gravity gradient data are emerging. Five ESA-funded projects have been started, aimed at increasing the impact of the mission beyond its nominal mission objectives.

Meanwhile, GOCE and its payload continue to operate flawlessly despite the increased solar activity. With funding through 2012, ESA is working on a plan for operations into 2013, funded through the fourth period of the Earth Observation Envelope Programme.

## → SMOS

The first mission reprocessing is being carried out and reprocessed data should be available to users by March.

## → CRYOSAT

Both space and the ground segment continue to operate, acquiring and generating science data systematically. The new version of the ground processors is about to be released, marking a leap in quality in the products distributed to the scientific community. This will be followed by the start of the first reprocessing campaign.

In spring, the first results of seasonal changes in sea-ice thickness of the Arctic basin will be presented. Although the mission was designed to measure trends of Earth's ice fields, interest from the oceanographic and marine gravity community in CryoSat data is very high.

## → AEOLUS

The first laser transmitter flight unit was shipped to Selex Galileo, in Florence, Italy, for a six-week vacuum test campaign. In parallel, the integration of the second flight unit is under way in Selex Galileo, Pomezia.

The transmitting and receiving optics are being refurbished at Astrium, Toulouse. New optical elements with improved UV coatings (higher laser-induced damage thresholds) are being assembled into their precision mounts. Laser-induced damage tests are being conducted in DLR, Stuttgart, and Laser Zentrum, Hannover, on the few remaining samples of the flight optics batches, to confirm adequate margins for flight. All precision jigs for the final alignment have also been completed.

A new software version is under procurement from SciSys UK Ltd., to extend the existing command and control functions for the in situ cleaning subsystem and to operate the Aladin instrument in a more stable continuous mode.

## → SWARM

The third satellite will complete its thermal vacuum test and magnetic characterisation at IABG, Munich, in early 2012. All three satellites have been tested together in the acoustic chamber, and all three will soon be ready for the stack test with the launcher adapter (fit check and shock test).

Acceptance tests of the three EFI instruments, demonstrating the correct implementation of the interfaces, have been completed with two of them already mounted onto their satellite. The last one will be integrated in January.

Ground segment preparation activities are proceeding according to plan.

## → EARTHCARE

Preparations for Phase C/D are now complete. The detailed design, based on the spacecraft PDR configuration, is progressing and avionics equipment EMs are being assembled and tested. The procurement process under the Best Practices scheme is now completed for the prime contractor (Astrium GmbH), the Multi-Spectra Imager (SSTL/TNO), the Broad-Band Radiometer (SEA/RAL) and nearing completion for both base platform (Astrium UK) and ATLID (Astrium France).

Development of the three ESA instruments is progressing well. The CDR of the Broad-Band Radiometer has started and the PDR for the ATLID transmitter (Selex Galileo) is complete. Assembly of both cameras of the MSI Engineering Confidence Model is proceeding and qualification testing of the detectors is ongoing.

In Japan, refurbishment of the Cloud Profiling Radar structural elements following the earthquake in 2011 is complete and the SM mechanical test campaign is about to resume. The Overall Configuration and Interface Design Review of the ground segment, also covering JAXA elements, has started in preparation for the Ground Segment PDR later in the year.

## → METEOSAT

### Meteosat-8/MSG-1

Satellite performance is normal, providing the Rapid Scan Service (one picture every five minutes of the northernmost third of Earth, in 12 spectral channels), complementing the full-disc mission of the operational Meteosat-9/MSG-2.


Two of the three Swarm satellites at IABG, Ottobrunn, Germany

### Meteosat-9/MSG-2

Eumetsat's operational satellite at 0° longitude is in very good health, performing the full-disc mission (one image every 15 minutes in 12 spectral channels), as well as the data collection, data distribution and search and rescue missions.

## → MSG-3

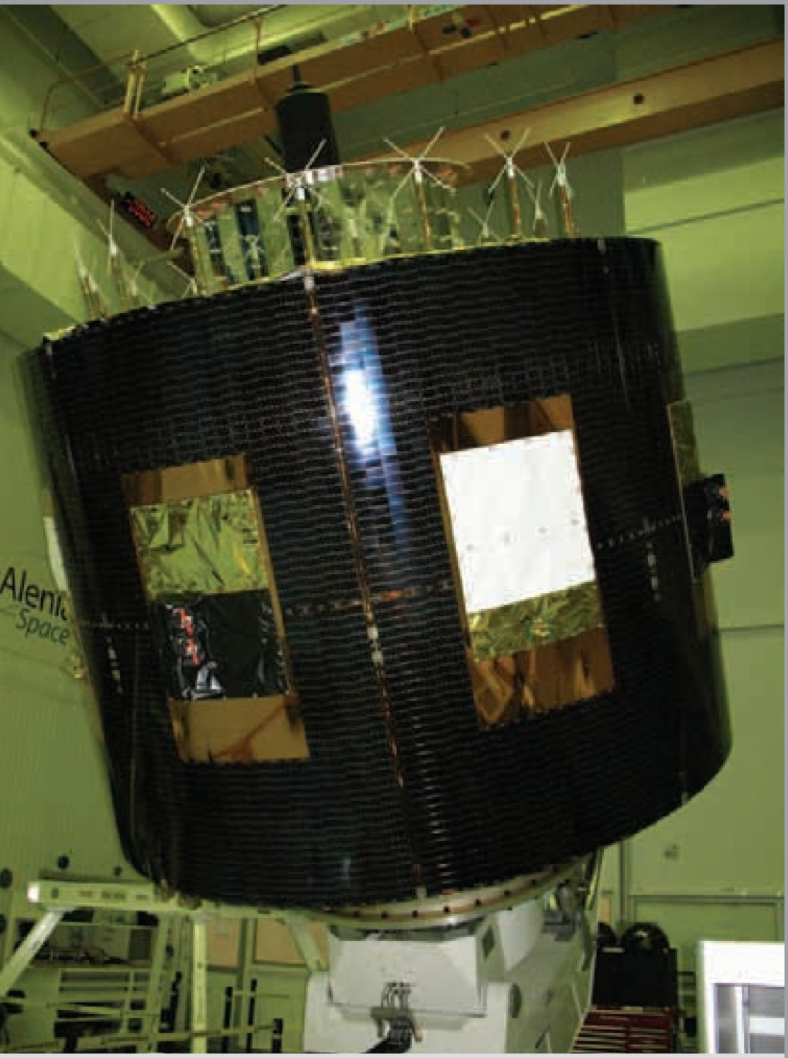
MSG-3 has completed 'Mass, Centre of gravity, Inertia' (MCI) measurements and fine balancing (to an accuracy of ± 100 g for a dry mass of more than 1 tonne) and rehearsal of launch site procedures. Next is the System Validation Test to confirm compatibility with the control centres (ESOC for LEOP and Eumetsat for normal operations). Final reviews at ESA and EUMETSAT will pave the way for the launch. MSG-3 will depart for Kourou at Easter, and launch is planned for mid June to mid July.

## → MSG-4

Re-assembly of the Scan Drive Unit will start in March. The Eumetsat Council approved the launch of MSG-4 in early 2015, followed by in-orbit storage. The schedule of MSG-4 is compatible with this launch date.

## → MTG

The Baseline Design Review was held in November. While good progress was made in consolidation of the overall MTG satellites, further progress is needed before undertaking the formal satellite PDR, mainly on MTG-S satellite and IRS instrument aspects, to ensure a stable system baseline design.



MSG-3 on the MCI measuring machine (Thales Alenia Space France)

The datapack delivery for the satellite PDR for both MTG-I and MTG-S is scheduled for May, with a collocation in June. The PDRs for the FCI and IRS instruments and the Common Platform are also planned in 2012.

Of 35 ITTs/RFQs released, about two thirds of these procurement actions are now completed. Of particular note was the release of the schedule-critical ITTs for the Lightning Imager instrument and the FCI/IRS Scan Assemblies. The remaining ITTs will be released before the middle of 2012.

Finally, the introduction of Astrium Germany into the Core Team is now well advanced which should allow ESA to be ready for the full MTG Contract signature, with Thales Alenia Space France by the middle of February.

## → METOP

### MetOp-A

The satellite and all instruments continue to perform excellently in orbit. Eumetsat increased the High Rate Picture Transmission service coverage area from January 2011; this change will last until MetOp-B is declared operational. GOME-2 is producing very good scientific data, but the unexpected throughput loss can still lead to some science limitation in the extension of the mission from October. GOME-2 throughput has been stable over the last 15 months with very small degradations for specific frequency ranges. MetOp-A completed its five-year mission on 19 October and extended operations are already confirmed, at least, up to the MetOp-B end of commissioning.

### MetOp-B

All instruments are integrated on the Payload Module (PLM) and tested. All tests on the Service Module (SVM) were completed as planned. The final satellite-level tests were completed in October and November, including flight software verification and a System Validation Test combining satellite, Eumetsat ground segment and ESOC ground systems.

The MetOp-B satellite Flight Acceptance Review (FAR) was completed in November, and the MetOp-C Satellite FAR Part 1 was run in parallel. Launch preparations are progressing well, with the Final Mission Analysis Review completed in January. The launch campaign starts on 27 February, for a launch in May.

### MetOp-C

After their long storage, MetOp-C modules (PLM, SVM and Solar Array) were assembled as the MetOp-C satellite. The satellite's functional and mechanical (sine vibration and acoustic) tests were completed in early 2011. The satellite was then disassembled with the modules completing the final test verifications before re-entering storage. Several instruments were removed for calibration. GOME-2 is at TNO for calibration.

MetOp-C is planned for launch in October 2016, but needs to be ready as a back-up for MetOp-B in late 2013.

## → SENTINEL-1

Phase-D continues with the integration of flight units into the flight subsystems as planned.

Propulsion flight equipment for the platform was delivered at Thales Alenia Space, Italy. The 14 tiles of Sentinel-1A SAR instrument antenna are in different stages of assembly, integration and tests at Astrium Germany. All Transit/Receive Modules and the antenna structure have been delivered, and the Antenna Centre Panel is assembled with the first flight tiles. The SAR EM testing and production of flight units are in progress at Astrium UK.

Optical Communication Payload (OCP) development is in progress. The OCP is manufactured by TESAT (DE) and delivered in kind by DLR.

The Preliminary Mission Analysis for Sentinel-1A launch was completed with Arianespace for a Soyuz launch from French Guiana.

## → SENTINEL-2

The prime contractor for the Multi-Spectral Imager, Astrium France, started integration of the two VNIR and SWIR focal planes, using the recently delivered VNIR and SWIR detectors and their optical filters. The three mirror FMs that were polished to specification will be integrated within the silicon carbide telescope baseplate and aligned.

At satellite-level, Astrium Germany starts the Engineering Functional Model (EFM) test campaign, including integration of the Video and Compression Unit (VCU), Mass Memory and Formatting Unit (MMFU), GPS Receiver, Star Tracker, and Inertial Measurement Unit (IMU). The last equipment to be integrated on the EFM was the OCP EM, delivered by DLR and TESAT (DE).

The EFM test programme uses a version of the onboard software allowing the integration and operations of the MSI currently represented by its VCU electronics. The qualified platform PFM (with propulsion system, thermal hardware and flight harness) is integrated on the multipurpose satellite trolley at Astrium in Friedrichshafen. Satellite PFM Assembly Integration and Testing resumes in April with the arrival of the Power Conditioning and Distribution Unit PFM.

Two launch service contracts have been signed with Eurockot (for Sentinel-2A, backup to Sentinel-2B) and with Arianespace (Sentinel-2B, backup to Sentinel-2A). The Payload Data Ground Segment (PDGS) prime contract is approaching PDR, and the Ground Segment CDR was rescheduled to September 2012 to take into account the development status of the PDGS. The first Satellite Validation Test campaign, in which the satellite EFM will be remotely operated by the flight control team at ESOC, is being prepared by Astrium Germany for March.

## → SENTINEL-3

Phase-C/D development activities are proceeding with the CDR completed and all flight hardware released for manufacturing and several flight units already available.

At platform level, integration of propulsion hardware is ongoing. The satellite structure arrived at the platform contractor in December, allowing integration of propulsion hardware on the main structure. Integration of flight avionics will start in March.

The SLSTR STM testing was completed in October, confirming the validity of the current thermo-mechanical design. SRAL and MWR PFM integration has started and the OLCI EM testing is ongoing.

Negotiations for launch services (Eurockot with Rockot for Sentinel-3A, Arianespace with Vega for Sentinel-3B) have been completed and both contracts have been signed, so launch service preparation activities can begin. The Eurockot contract began at the end of 2011, and Arianespace's contract


Sentinel-3 Sea and Land Surface Temperature Radiometer (SLSTR) STM entering the thermal chamber at IABG (IABG)

Artist impression of Sentinel-5 Precursor (Astrium)

starts in early 2012, in order to have full support from both launch services in the satellite qualification campaign.

## → SENTINEL-5 PRECURSOR

Phase-B2/C/D/E1 activities began at Astrium UK in October. The Payload Data Ground Segment was awarded to DLR Oberpfaffenhofen and the Flight Operations Segment activities will be taken care of by ESOC. ESA Best Practice procurement activities for major satellite sub-systems have started. The system-level PDR is scheduled for June.

Phase-B/C/D for TROPOMI is proceeding, subsystem and unit-level PDRs are nearly complete with final PDR scheduled for February.

## → ALPHABUS AND ALPHASAT

Alphasat payload test activities are ongoing in Toulouse. Major programme milestones for 2012 are the delivery of the optical laser terminal and the satellite thermal vacuum test campaign.

The Alphabus Extension programme is on track. After the successful SSR, the programme is moving towards the CDR scheduled in June 2013.

In the Alphasat ESA/Inmarsat Applications initiative, a first activity has been started with AnsuR Technologies (NO), and a second call for proposals will be issued shortly.

## → VEGA

The launch campaign began on 7 November with the transfer of the P80 first stage to the launch pad. On 2 December, the Zefiro 23 second stage was integrated on the first stage, followed by the Zefiro 9 third stage on 9 December. On 16 December, the fourth stage, the AVUM storable liquid propellant stage, was added to complete the mechanical integration of the main launcher element.

The upper composite, comprising LARES, ALMASat-1, seven CubeSats, the payload adapter and the fairing, was added to the top of the launcher on 24 January.


Delegates of the Joint Board on Communications Satellite Programmes visit Alphasat in Toulouse in September

On 26 January, a full launch rehearsal was carried out. This was one of the last critical milestones of the launch campaign, a major step in securing the scheduled launch window. The rehearsal simulated the actual countdown sequence by retracting the gantry and preparing all ground systems as in a real launch. All operations performed during launch, such as communication with the telemetry stations, synchronisation with the payload countdown sequence and even military deployment, were simulated in this exercise.

LATE NEWS: On 11 February, the Launch Readiness Review took place, confirming the final status of the entire launch system, including the vehicle and the ground infrastructure.

Soyuz lifts off from Kourou starting flight VS02 to launch a six-satellite payload on 16 December (ESA/CNES/Arianespace/Optique Video CSG)


Vega flight VV01 on the eve of launch

On 13 February, the first Vega lifted off at 11:00 CET (07:00 local time) on its flawless qualification flight VV01. Vega is ready to operate alongside Ariane 5 and Soyuz, extending the family of launchers available at Europe's Spaceport in Kourou, French Guiana. Europe now covers the full range of launch needs, from small science and Earth observation satellites to the largest spacecraft such as ATV to the ISS.

## → SOYUZ AT CSG

In preparation for the second Soyuz launch from CSG, (the first in ST-A configuration), the Soyuz launcher and upper composite were transferred to the launch zone on 12 December. A full launch rehearsal on took place on 13 December (for the launcher) and 15 December (for spacecraft and Fregat). The Flight Readiness Review took place on 15 December. The first Soyuz ST-A launch took place on 16 December with six satellites on board (Pléiades, SSOT and four Elisa satellites).

## → FUTURE LAUNCHERS PREPARATORY PROJECT

**Intermediate eXperimental Vehicle (IXV)**
Phase-D/E1A, covering flight and ground segment deliveries, is progressing. The proposal for Phase-E1B, including launch service preparation, has been received. The CDF study on potential evolution will be completed in early 2012.

**Next Generation Launcher (NGL)**
After the first milestone (Key Point 1) in System Studies, Phase-2 is in progress. The baseline configurations (technology, architecture, staging) of the four launch system concepts (HHSC, HHGG, PPH, CH) were agreed. These configurations include also the boosted variants, which allow for less thrust in the first-stage engine. Key Point 2 was scheduled for December. Concurrent activities continue to investigate alternative technologies and architectures.

Phase-B of SCORE-D (Stage COmbustion Rocket Engine Demonstrator) is nearing PDR. A workshop on the Health Monitoring System took place in November. In upper-stage propulsion, the storable propulsion project is preparing the technologies needed for pressure-fed engines of thrust 3–8 kN. The PDR was completed in October. The industrial proposal for the continuation of the activity is under negotiation. SCORE-D development Key Point was scheduled for December.

In Cryogenic Upper Stage Technologies (CUST), industrial activities are progressing with the CDR of the Propellant Preconditioning/Propellant Management Device. Two cryogenic payloads simulating Propellant Management Devices were launched as inflight experiments on the TEXUS 48 suborbital rocket on 27 November.

## → HUMAN SPACEFLIGHT

ISS research was carried out at a reduced level from mid-September because of the unmanned Progress 44P failure in August. Following the 44P accident investigation, which determined the failure to be a one-off manufacturing error, there was a successful Progress launch in October followed by two successful manned Soyuz launches in November and December to the ISS. The ISS is back at full strength with six permanent crewmembers with the arrival of ESA astronaut André Kuipers (NL), Oleg Kononenko and Don Pettit on 23 December. With a full crew, more time can be dedicated to science activities (35–45 hours per week).

The launch of TEXUS 48 in November carrying CUST Propellant Management Device experiments (Thilo Kranz/DLR)

The crew of Soyuz TMA-03M, Don Pettit, Oleg Kononenko and André Kuipers

In addition to his research activities, André Kuipers has been involved in many other system and experimental tasks since his arrival. Besides standard orientation and familiarisation, he will service the Advanced Resistive Exercise Device (ARED) in the European-built Node-3, sample water from the Water Recovery System racks in Node-3 and sample ISS air. He will also be a subject of, and will undertake, a selection of NASA experiments.

The Mars500 crew safely arrived 'back on Earth' on 4 November after 520 days in isolation. The mission gained excellent scientific results, which are important for operations and psychological management of long-duration missions with an international crew in confined conditions. After a media conference in Moscow on 8 November, the six crewmembers went through an exhaustive series of debriefings, tests and evaluations to collect final mission data.

The Mars500 crew meets the press at RIA Novosti on 8 November (ESA/IBMP/O. Voloshin)

## → ISS DEVELOPMENT/ EXPLOITATION

**ATV *Edoardo Amaldi***

The ATV Proximity Communications equipment used for communications and control of the ATV from the ISS was installed in the Russian Service Module in December. Ground fuelling of ATV *Edoardo Amaldi* started in January. Launch is scheduled for March.

Technicians prepare for loading hydrazine propellant into ATV *Edoardo Amaldi* at Kourou in January


ATV *Edoardo Amaldi* is moved to the Final Assembly Building in Kourou, on 7 February. The massive vessel dwarfs the workers carefully guiding it out of its transport container

## → UTILISATION

The Announcement of Opportunity (AO) for Climate Change Studies on the ISS received 16 proposals representing 309 science team members. All of the proposals are within the scope of the AO and consist of consortiums of multinational teams. The peer evaluation and preliminary assessment, in conjunction with ESA Earth Observation experts, has started.

**European research using the Columbus laboratory**

The ROALD-2 (ROle of Apoptosis in Lymphocyte Depression) experiment was launched on Soyuz TMA-03M and completed after two days of processing in two KUBIK incubators on 26 December. ROALD-2 will expand on the initial ROALD experiment from 2008 in determining the role of the lipid 'anandamide' in the regulation of immune processes in human lymphocytes and in the cell cycle under weightless conditions.

The European Physiology Module (EPM) facility was active on 23 November for another session of the 'Passages' experiment, this time with a new subject: Expedition 30 Commander Dan Burbank. The experiment uses a light shield attached to a multipurpose laptop connected to the front of the EPM. The Passages experiment is designed to test how astronauts interpret visual information in weightlessness using virtual reality stimuli, such as traversing through a virtual door.

Vessel Imaging sessions were carried out by Expeditions 29 and 30 between October and December. The experiment was implemented in conjunction with NASA's Integrated Cardiovascular Experiment and consists of an echography scan together with ECG and heart rate measurements. Flow velocity changes in the aorta and the middle cerebral and femoral arteries are used to quantify the cardiovascular response to fluid shifts in the body during long-term exposure to weightlessness with the aim to optimise countermeasures.

André Kuipers was the subject for the Space Headaches experiment, which he had already started in Soyuz after launch, filling in daily questionnaires to help determine the incidence and characteristics of headaches occurring in astronauts in orbit.

Runs of the Geoflow-2 experiment resumed in the Fluid Science Laboratory in November and December. Four no-rotation runs and two low-rotation runs were completed. Geoflow-2 is investigating the flow of an incompressible viscous fluid held between two concentric spheres rotating about a common axis as a representation of a planet. This is important for astrophysical and geophysical problems such as global scale flow in the atmospheres, oceans and liquid nucleii of planets.

From right, ESA astronaut Luca Parmitano (IT) in training for Expedition 36 with Russian cosmonaut Fyodor Yurchikhin and NASA astronaut Karen Nyberg (GCTC/S. Remezov)

### Additional European research on the ISS

The Microgravity Science Glovebox (MSG) celebrated 10 years in space, reaching an operational lifetime of 10 000 hours. Two of the three experiments that form part of the SODI (Selectable Optical Diagnostic Instrument) experiment series were processed. SODI-Colloid 2 was the first of these experiments consisting of runs for determination of the colloids aggregation (crystal formation) temperature, and 'demixing runs', where temperatures above the critical point are applied to the sample cells. Initial downlinked data is positive. The Colloid experiment covers the study on growth and properties of advanced photonic materials within colloidal solutions. The focus is on materials that are promising candidates for new types of optical components.

A few days after completion of the Colloid-2 experiment, the SODI-DSC (Diffusion and Soret Coefficient Measurements for Improvement of Oil Recovery) experiment was installed and started in MSG. SODI-DSC is supporting research to determine diffusion coefficients in different petroleum field samples and refine petroleum reservoir models to help lead to more efficient extraction of oil resources. The experiment was completed and removed from MSG.

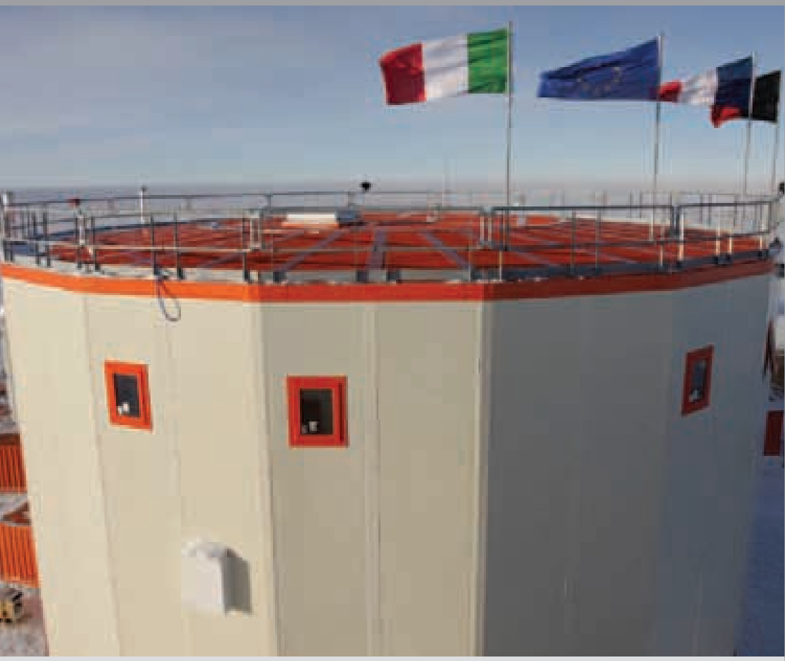
The ALTEA-Survey (Anomalous Long Term Effects in Astronauts) experiment collected 112 days of data before the hardware stopped transmitting health and status information and is inactive. The ALTEA experiments aim at obtaining a better understanding of the light flash phenomenon as witnessed by astronauts, and more generally the interaction between cosmic rays and brain function. The three-dimensional survey of the radiation environment in the US laboratory will soon be followed by the corresponding measurements of different shielding materials with the ALTEA detectors on the ISS.

The Thermolab experiment in conjunction with NASA's VO2 Max (Maximum Volume Oxygen) experiment were undertaken by Expeditions 29 and 30. This experiment uses the ESA-developed Portable Pulmonary Function System to investigate thermoregulatory and cardiovascular adaptations during rest and exercise in the course of long-term exposure to weightlessness.

The Vessel Identification System (VIS), also known as the Automatic Identification System (AIS), has been functioning on the ISS since December 2010 with telemetry being received by the Norwegian User Support and Operation Centre in Trondheim via ESA's Columbus Control Centre in Germany. The VIS is testing ways to track global maritime traffic from space by picking up signals from standard AIS transponders carried by ships.

## → NON-ISS RESEARCH

The 55th ESA Parabolic Flight campaign took place from 14 to 25 November, with nine experiments, including three in physical sciences and six in life sciences.



Concordia Base in Antarctica (PNRA/IPEV)

After the deferral of the TEXUS-48 (DLR) launch to 27 November, the launch of the MASER-12 sounding rocket mission was scheduled to take place in February with three ESA physical science projects and two life science experiments.

An Announcement of Opportunity for medical, physiological and psychological research using the Concordia Antarctic Station as 'human exploration analogue' was published with proposals expected in January. Proposals accepted could be implemented as early as the 2013 winter-over season.

## → CREW TRANSPORTATION AND HUMAN EXPLORATION

### Expert

The Qualification Review was concluded on 3 November for flight on Volna, its original launch system but, for various reasons, Volna might not be used as the launch vehicle. Meetings with launch service providers have been held to identify an alternative launcher. None of the systems (standard version) offer the atmospheric reentry conditions required, and additional analyses are needed to find launchers able to adapt to unconventional launch conditions. While waiting for a decision on the launch campaign, Expert will be kept in storage in a controlled environment at Thales Alenia Space Italy.

### Lunar Lander

The configuration of the spacecraft is under consolidation, with specific attention to the tank design and to the launcher adapter interface aspects. An intense effort has also been made on navigation techniques and on the overall Guidance, Navigation and Control functional architecture.

The breadboarding activities are progressing. The hot-firing tests of the 220N ATV engine have been completed and the results from the hydraulic flow tests are positive. The preliminary navigation test plan has been established and the activities related to avionics are under definition.

**ESA is organising a global ISS Symposium in Berlin, 2–4 May, to review key accomplishments made to date, looking at fundamental and applied research, actual or potential spin-offs for the benefit of humankind, as well as looking at the future of research on the ISS. Joining will be representatives from the five ISS partner agencies and other spacefaring nations, the international science community, space experts, astronauts, engineers and representatives from industry, academia and media. A small group of students from across Europe will be invited, and limited places will be available for the public with an interest in space activities.**

**For more details, see www.isssymposium2012.com**

ESA astronaut Alexander Gerst (DE) at the NASA Neutral Buoyancy Lab in Houston, preparing for his mission to the ISS in 2014 on Expeditions 40 and 41 (NASA)

Each of the payload definition studies initiated through the General Studies Programme has been through an Instrument Requirements Review.

## → SPACE EXPLORATION

The NASA ISECG (International Space Exploration Coordination Group) Global Exploration Workshop took place in San Diego in November with ESA participation, followed by a meeting of ISECG representatives to initiate work on the benefit assessment of exploration.

## → EDUCATIONAL ACTIVITIES/ OUTREACH

ESA co-sponsored the YouTube SpaceLab competition, which challenges 14–18 year old students from around the world to design a science experiment to be performed on the ISS. Around 2000 video submissions were received and the dedicated YouTube site recorded 17 million hits. Sixty proposals, including 21 European ones, have been selected as finalists, which will be marked by the YouTube community and a panel of judges that includes ESA astronaut Frank De Winne, NASA's Associate Administrator for Human Exploration and Operations William Gerstenmaier, Professor Stephen Hawking, Cirque du Soleil's founder Guy Laliberté, NASA's Associate Administrator for Education Leland Melvin and JAXA astronaut Akihiko Hoshide.

## → SPACE SITUATIONAL AWARENESS

The System Requirements Review was completed on 2 December after an extensive review process that included, in addition to ESA staff, the SSA User Representatives Group and the SSA Programme Board. The SRR Board endorsed the plan of the Programme Office to proceed immediately with the contractual activities for the subsequent Architectural Design phase (two parallel contracts).

The SSA Programme Security Instruction (PSI) and its important Classification Guide for the first surveillance radar demonstrator was agreed in December. The SSA PSI will be presented to the ESA Council in March for approval.

The Eighth Space Council took place in December in Brussels, where the importance of protecting critical space infrastructure was emphasised again.

The development of the first SSA surveillance radar demonstrator in close monostatic technology is progressing well. Significant progress was made in the study of the overall network of telescopes required for the survey and follow-up of space debris and Near Earth Objects (NEOs).

The Space Surveillance and Tracking (SST) Centre for the test and validation of advanced data processing and analysis has been installed in ESAC in Spain. In parallel, the first iteration of collision warning software has been deployed. The first combined tracking campaign between numerous European sensors has been performed and the analysis received. The future operational system requirements have been consolidated and will be used as the baseline for the architectural studies to be completed during 2012.

The establishment of the initial Space Weather (SWE) Service Coordination Centre at the Belgian Institute of Space Aeronomy was finalised. Expert Service Centres (ESCs) for solar weather, ionospheric weather, space radiation and geomagnetic conditions have been established to provide federated SWE services based on existing national assets in Europe.

The definition of the SSA NEO segment is proceeding as planned. The existing NEODyS impact warning service of the University of Pisa is now supported by ESA. In 2011, two NEOs were discovered by the NEO segment using ESA's 1 m Zeiss telescope on Tenerife.

# → ESA PUBLICATIONS

## Brochures

**Agenda 2015: A Document by the ESA Director General**
(December 2011)
BR-303 // 64 pp
E-book online

**Commemorative Colloquium in Honour of George P. van Reeth**
(December 2011)
BR-299 // 78 pp
E-book online

**SpaceWire: Making Links, Building a Market** (October 2011)
BR-298 // 8 pp
E-book online

**Galileo IOV: Afbau der Europäischen Navigationssatelliten-Konstellation** (December 2011)
BR-297/DE // 16 pp
E-book online

**Galileo IOV: Birth of the European Satellite Navigation Constellation** (September 2011)
BR-297/EN // 16 pp
E-book online

**The ESA History Project** (February 2011)
BR-294 // 94 pp

**ESRIN: ESA's Eye on Earth** (January 2012)
BR-291 // 8 pp
E-book online

**Earth Explorers: Satellites to Understand our Changing Earth**
(January 2012)
BR-289 (3rd ed.) // 8 pp
E-book online

## Special Publications

**GIOVE Experimentation Results** (October 2011)
SP-1320 // 124 pp
Price: €30

**Sustainable Development 2009–10 Report** (January 2011)
SP-1319 // 72 pp
Price: €20

## Conference Proceedings

**Proc. 20th Symposium on European Rocket and Balloon Programmes and Related Research, 22–26 May 2011, Hyère, France**
(October 2011)
SP-700 // 683 pp (book)
Price: €60

**Proc. 5th IAASS Conference 'A Safer Space for a Safer World', 17–19 October 2011, Versailles, France** (February 2012)
SP-699 // CD
Price: €60

**Proc. 14th European Space Mechanisms & Tribology Symposium (ESMATS 2011), 28–30 September 2011, Constance, Germany**
(September 2011)
SP-698 // CD
Price: €50

**Proc. Fringe 2011, 19–23 September 2011, Frascati, Italy**
(February 2012)
SP-697 // CD
Price: €60

**Proc. 4th International GOCE User Workshop, 31 March – 1 April 2011, Munich, Germany** (July 2011)
SP-696 // CD
Price: €40

**Proc. DASIA 2011 Conference, 17–20 May 2011, San Anton, Malta**
(August 2011)
SP-694 // CD
Price: €60

## Annual Report

**ESA Annual Report 2010** (December 2011)
96 pp
E-book online

## Newsletters

**All About ESA: Space for Europe**
EN, FR, IT, DE, ES, NL // 14 pp
No charge

# → HOW TO ORDER

Selected ESA publications and conference proceedings can be ordered online at **www.spacebooks-online.com**

| | | |
|---|---|---|
| **ESA brochures*** (BR-xxx) | available as 'e-books', online only. | |
| **Periodicals and selected monographs** | also available for download at no charge at: | **www.esa.int/publications** |
| **ESA *Bulletin* subscriptions**<br>***Annual Report* requests** | contact **esapub@esa.int** or write to | ESRIN Communication Office,<br>Casella Postale 64, 00044 Frascati, Italy |
| **Public relations material** | (General ESA literature, posters, photographs, films, etc.) | ESA Communication Department<br>8–10 rue Mario Nikis, F-75738 Paris Cedex 15, France<br>Tel: +33 1 53 69 71 55 Fax: +33 1 53 69 76 90 |

** under special conditions (e.g. for educational purposes) and on ESA approval, ESA brochures (BR-xxx) can be ordered as hard copies. Please contact us for these requests at* **esapub@esa.int** *or write to ESRIN Communication Office, Casella Postale 64, 00044 Frascati, Italy*

**ESA Member States**

Austria
Belgium
Czech Republic
Denmark
Finland
France
Germany
Greece
Ireland
Italy
Luxembourg
Netherlands
Norway
Portugal
Romania
Spain
Sweden
Switzerland
United Kingdom

**An ESA Communications Production**