

number 153 | February 2013



# bulletin

→ space for europe



## European Space Agency

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

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

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

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

The ESA headquarters are in Paris.

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ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

Chairman of the Council:  
D. Williams (to Dec 2012)

Director General: J.-J. Dordain



On cover:  
Soyuz flight VSO3 lifts off from Europe's Spaceport in French Guiana on 12 October 2012, on its mission to place the second pair of Galileo satellites into orbit



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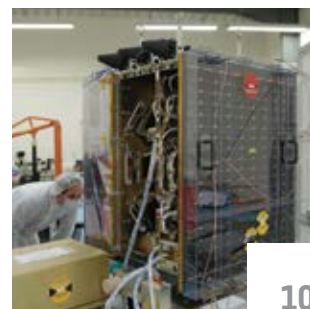
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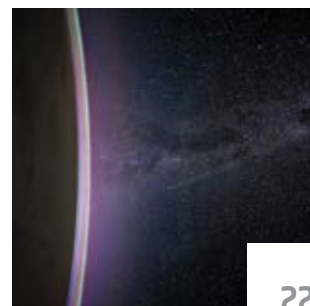
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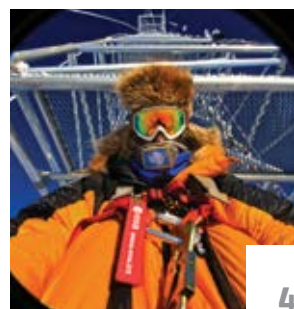
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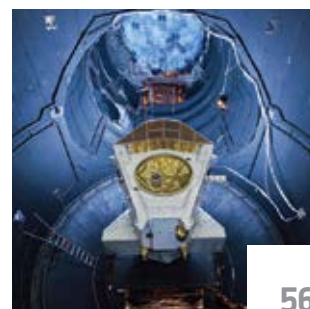
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NASA's Orion spacecraft will be using a Service Module built in Europe, based on ESA's Automated Transfer Vehicle technology

# → BOLDLY GOING WHERE NO EUROPEAN HAS GONE BEFORE

## ESA's Service Module for Orion

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**ESA and NASA plan to send astronauts farther into space than ever before, in Orion spacecraft powered by European Automated Transfer Vehicle technology.**

When it blasts off atop the Space Launch System rocket in 2017, NASA's Orion spacecraft will be using a Service Module built in Europe, derived from ESA's Automated Transfer Vehicle (ATV). ATVs have been resupplying the International Space Station (ISS) since 2008. The fourth in the series, ATV *Albert Einstein*, is being readied for launch this year from Europe's Spaceport in French Guiana.

ATV is a versatile showcase of European space capability, performing many functions during a mission to the ISS. The space freighter is used to reboost the ISS and can even push the Station out of the way of space debris. While docked, ATV becomes an extra module for the astronauts, and at the end of its mission it takes waste materials away from the Station.

ESA and NASA signed an agreement last December for the provision of a Service Module for the Orion's Exploration Mission-1 in 2017. The agreement maps out a plan for ESA to fulfil its share of operational costs and additional supporting



services for the ISS by providing the Orion Service Module and necessary elements of its design. The plan was given the go-ahead at ESA's Ministerial Council last November and allows European industry to capitalise ATV technology while significantly cutting research and production costs for NASA.

NASA plans to make a first unmanned test flight in 2017, meaning that ESA will have to deliver the first Service Module in 2016 – a tight schedule but the people behind ATV are used to delivering a model each year. The first Service Module will be delivered as part of ESA's contract for International Space Station utilisation, with an option for a second module to be exchanged in kind for other services still to be identified. Sending European astronauts on Orion is, of course, on the wishlist of the European space community.

## The flights

The first Orion flight will be Exploration Flight Test-1 in 2014, in which an uncrewed Orion will launch on a Delta IV heavy rocket and fly to an altitude of around 5700 km above Earth's surface, farther than a manned spacecraft has gone in 40 years. For Flight Test-1, the system will not include a Service Module, but only a structural test adapter built by Lockheed Martin that connects the capsule to the launcher. The main objective of this mission is to test the Crew Module at re-entry speeds representative of returns from beyond low-Earth orbit missions.

The first European Service Module will fly on Exploration Mission-1, the first flight of the Orion spacecraft on NASA's new Space Launch System (SLS). This mission will be an



↑ The NASA/ESA Orion Partnership news conference in Houston, 16 January 2013 (from left): William Gerstenmaier, NASA Associate Administrator for Human Exploration and Operations; Thomas Reiter, ESA Director of Human Spaceflight and Operations; Mark Geyer, Orion Program manager; and Bernardo Patti, ESA Manager of ISS Operations (NASA)



↑ The first Orion spacecraft in orbit attached to a Delta IV upper stage during Exploration Flight Test-1 (NASA)

uncrewed lunar flyby, returning to Earth's atmosphere at 11 km/s – the fastest reentry ever. Provided these missions go well, Exploration Mission-2 will then launch an Orion with a crew of four astronauts into space in 2021.

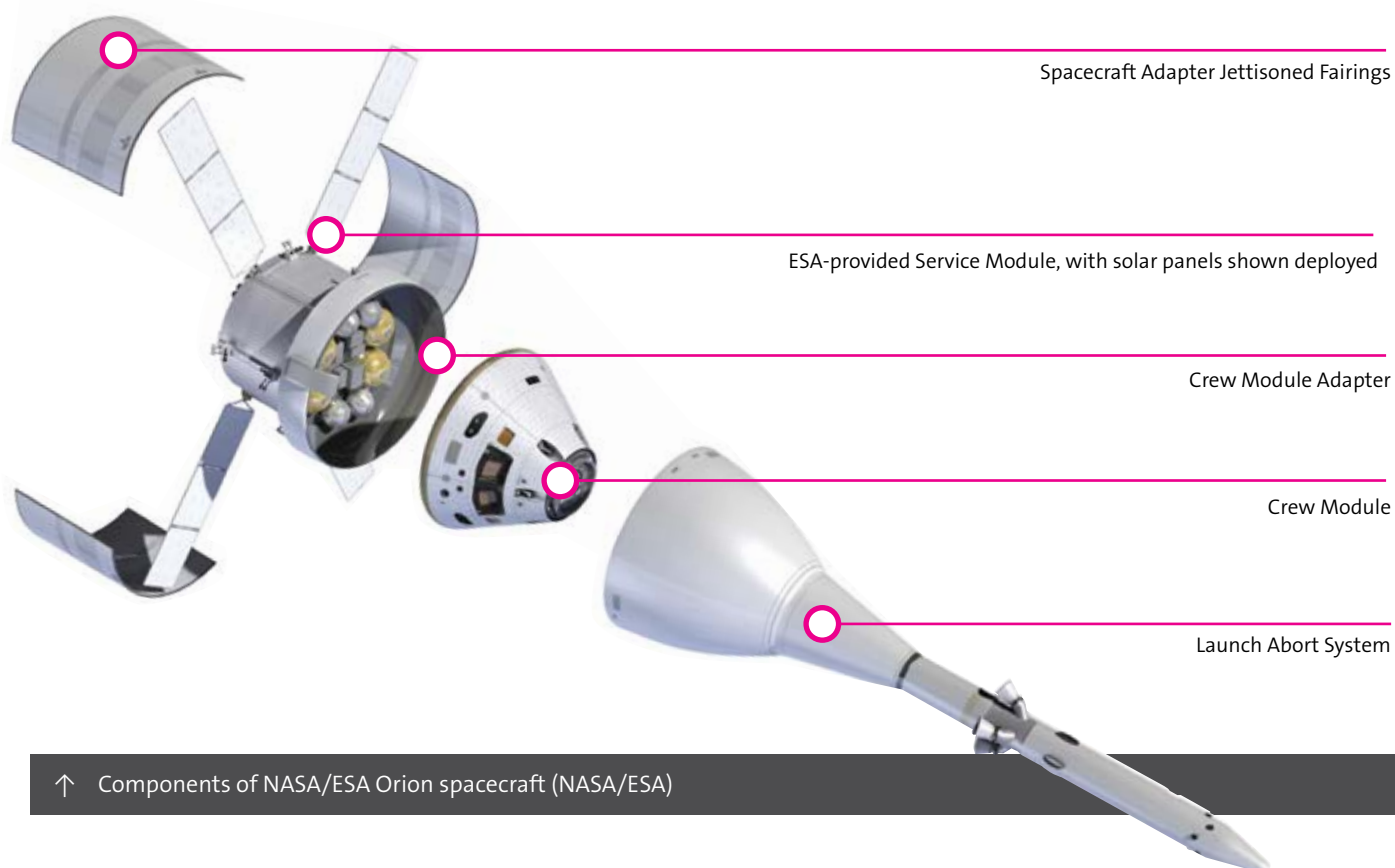
Thomas Reiter, ESA's Director of Human Spaceflight and Operations, said, "The cooperation with NASA in the critical path of a human-rated transportation system, which will take astronauts beyond low Earth orbit, opens a new page in the transatlantic relationship. It's a strong sign of trust and confidence in our capabilities, and an important contribution to the future of human exploration."

Nico Dettmann, Head of ESA's ATV Programme Department, said, "ATV has proven itself on three flawless missions to the Space Station and this agreement is further confirmation that Europe is building advanced, reliable spacecraft."

Dan Dumbacher, NASA's Deputy Associate Administrator for Exploration Systems Development, agrees: "It is a testament to the engineering progress made to date that we are ready to begin integrating designs of an ESA-built Service Module with Orion. Space has long been a frontier for international cooperation as we explore. This latest chapter builds on NASA's excellent relationship with ESA as a partner in the International Space Station, and helps us move forward in our plans to send humans farther into space than we've ever been before."

## The Orion vehicle

Orion is the name given to the Multi-Purpose Crew Vehicle, a crewed spacecraft that will transport up to four astronauts from Earth's surface to a nearby destination or staging point and bring the crew safely back to Earth at the end of a mission. Orion consists of a Crew Module, a Crew Module Adapter, a Service Module, a Spacecraft Adapter, Spacecraft Adapter Jettisoned Fairings and a Launch Abort System.



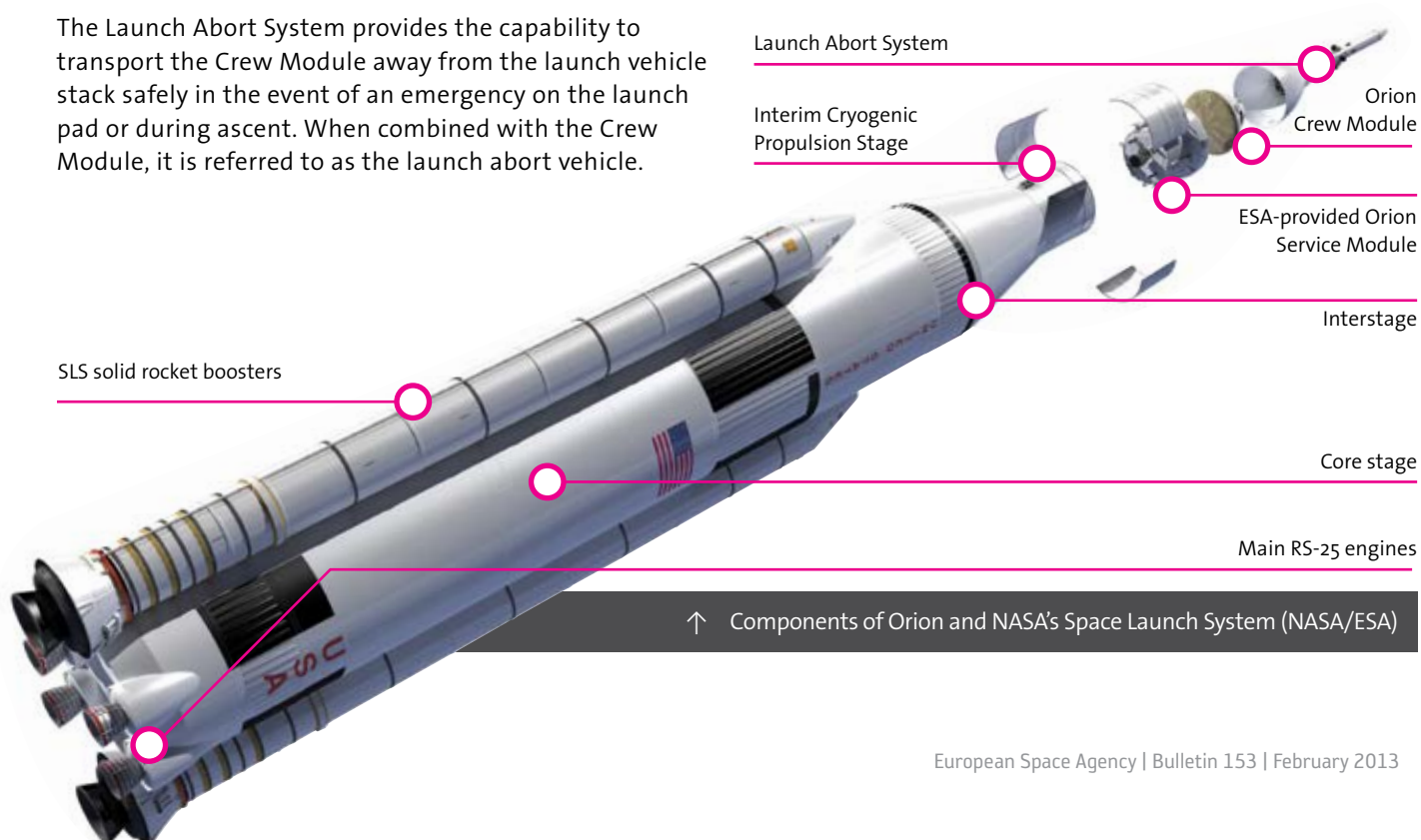
This vehicle will provide all services necessary to support a crew during all phases of a given mission, from launch operations to Earth entry, descent, landing and recovery (for shorter duration (1–21 days) missions or until a crew transfers to another space vehicle). Orion astronauts will wear launch, entry and abort (LEA) suits to protect them during these operations. The LEA suit does not provide any in-orbit extravehicular activity capability.

### Launch Abort System

The Launch Abort System provides the capability to transport the Crew Module away from the launch vehicle stack safely in the event of an emergency on the launch pad or during ascent. When combined with the Crew Module, it is referred to as the launch abort vehicle.

### Crew Module

The Crew Module is the command, control, communications and navigation centre for all in-space operations. This module supports up to four astronauts and consists of a closed, environmentally controlled cabin that provides the habitable volume. The cabin is enclosed by the backshell and heatshield, which protect it during reentry into Earth's atmosphere. The Crew Module is supported by the Service Module systems for most mission durations.



Pre-launch and post-landing crew access is through the side hatch on the starboard side of the Crew Module. The hatch opens outward to the left side for egress, and is sized for ingress and egress by crewmembers wearing a pressurised suit. During docked operations and in post-landing contingency scenarios, crew access is through the docking hatch. Egress aids are provided for post-landing emergency egress.

The Crew Module includes crew accommodation for eating, sleeping, hygiene and stowage of tools, hardware, supplies and cargo. Interfaces for pressure suits, communications, and biomedical data are provided for each astronaut. Interfaces for power, vehicle displays and controls, vehicle data and communications are also provided.

### Crew Module Adapter

This adaptor provides the structural, mechanical, electrical and fluid interface between the Crew Module and the Service Module. It houses communication equipment, sublimators for thermal heat rejection, and power and data control/interface electronics.

### Service Module

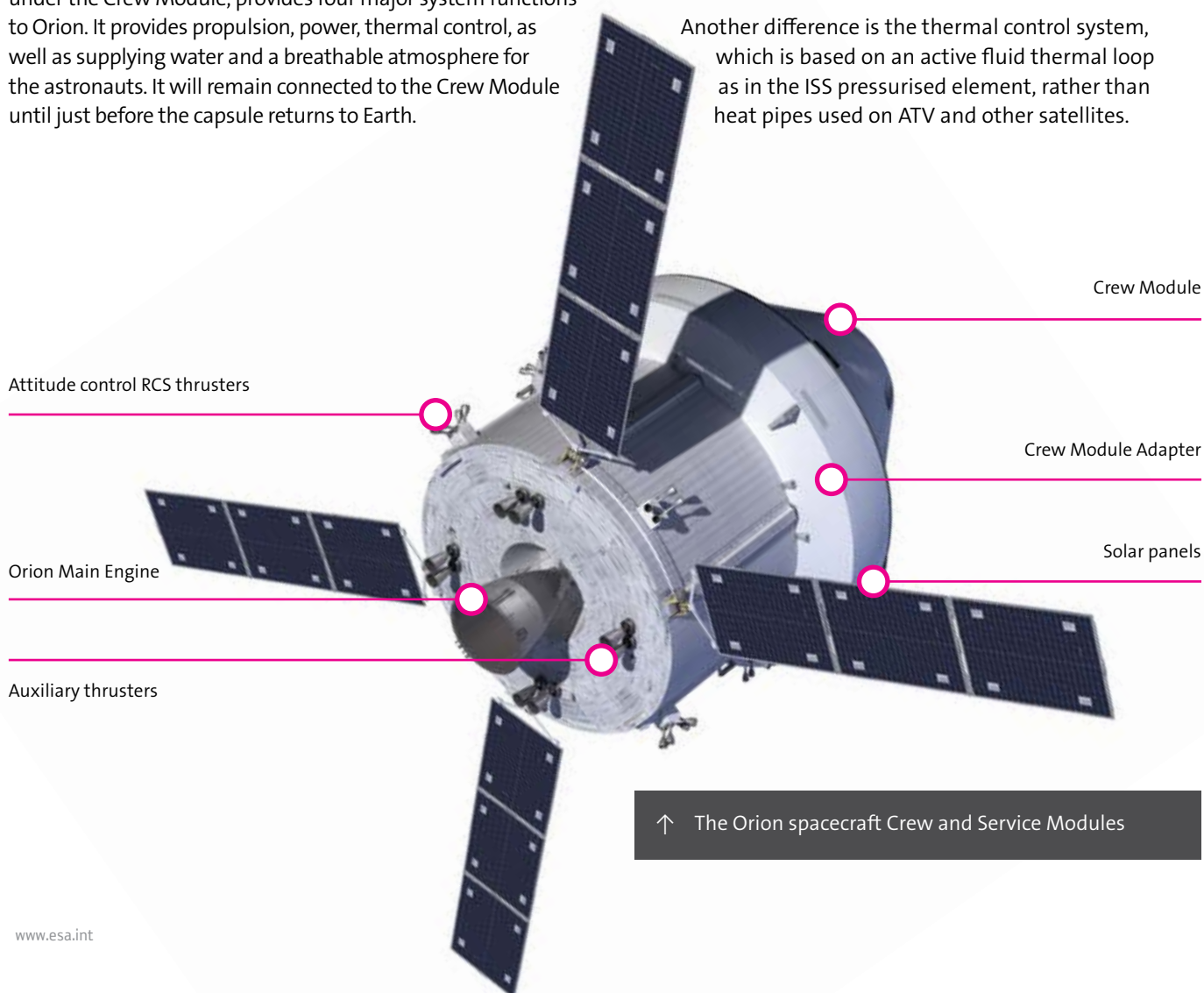
The European ATV-derived Service Module, sitting directly under the Crew Module, provides four major system functions to Orion. It provides propulsion, power, thermal control, as well as supplying water and a breathable atmosphere for the astronauts. It will remain connected to the Crew Module until just before the capsule returns to Earth.

The Service Module will be 2.7 m long and 4.5 m wide, similar to the present ATV but a quarter of the length. Although ATV's solar panel configuration will remain, they will get a significant upgrade. Slightly shorter and wider, the new solar panels for the Service Module will use gallium arsenide technology and supply more electricity, up to 11 kW – enough to power the energy needs of a typical household. These newer solar panels offer 30% efficiency converting solar energy, compared to ATV's current solar panels, which manage around 17%.

The Service Module houses the Orion Main Engine and engine thrust vector control, the reaction control system and auxiliary thrusters, and the fuel, oxidiser and pressurant tanks for the propulsion system. These provide the in-space propulsion capability for orbital transfer, attitude control and high-altitude ascent aborts.

The Main Engine is one of the main differences with the current ATV design, which does not have such an engine. The Orion Main Engine is an increased performance version of the rocket engine used by the Space Shuttle for its Orbital Manoeuvring System. This engine will supply around 26 kN of thrust in addition to eight smaller engines (compared to ATV's four). The smaller engines will supply a total of 490 N, enough to get Orion back to Earth if needed.

Another difference is the thermal control system, which is based on an active fluid thermal loop as in the ISS pressurised element, rather than heat pipes used on ATV and other satellites.



↑ The Orion spacecraft Crew and Service Modules





↑ Launch of Orion on the Space Launch System vehicle from Kennedy Space Center, Florida (NASA)

Additionally, thermal radiators surround the propulsion tanks and, like the Crew Module, the Service Module's passive thermal control design incorporates multi-layer insulation blankets, thermal coatings and micrometeoroid/orbital debris shielding.

The Service Module may provide additional volume and other resources for selected missions, for example by accommodating science, engineering demonstrations, development test objectives, or deployment of lunar infrastructure equipment during the cruise and lunar orbit phases of lunar missions. This volume provides electrical power distribution, network access for command and control interfaces, and structures and mechanisms.

## Spacecraft Adapter

The Spacecraft Adapter provides the interface to the launch vehicle during launch and ascent. This adapter attaches the aft end of the Service Module to the launch vehicle and includes the structural interface, separation mechanisms and umbilical connectors for communication between the launch vehicle and the Orion. When the launch vehicle burns out, the Orion spacecraft separates from the Spacecraft Adaptor.

## Spacecraft Adapter Jettisoned Fairings

The Service Module is enclosed by three fairing panels, which protect the solar arrays, radiators and thrusters during launch and ascent. The fairings may be jettisoned during the ascent phase or following main engine cutoff of the launch vehicle.

## The missions

The official name of Orion is 'Multi-Purpose Crew Vehicle', meaning that the spacecraft can be used to complete different missions. A number of the possible mission descriptions, called Design Reference Missions, have been created to provide the context in which an ESA-provided Service Module and Spacecraft Adapter may be required to operate. Note that these plans are only intended to help define the Service Module's spaceflight capabilities; they may not necessarily represent missions that will actually be flown.

### 1) *Uncrewed beyond Earth orbit mission (lunar flyby)*

This mission uses a single SLS launch with an interim cryogenic propulsion stage and lunar Orion to go



↑ The Orion spacecraft in low Earth orbit (NASA/ESA)



Orion in lunar orbit  
(NASA/ESA)

beyond Earth orbit and test critical mission events as well as demonstrate spacecraft performance in relevant environments. The initial SLS configuration places an uncrewed Orion in low Earth orbit. The interim propulsion stage engine fires to raise its low Earth orbit, and again for a trans-lunar injection burn.

The trans-lunar injection manoeuvre puts the Orion on a free-return trajectory that is targeted for a lunar closest approach altitude of 100–200 km. The Orion performs a lunar flyby and then returns to Earth. The trajectory is designed to achieve a high-speed atmospheric entry to demonstrate the Orion entry, descent and landing systems. Orion's return velocity will be 11 km/s.

## 2) *Crewed beyond Earth orbit mission (lunar orbit)*

An SLS configuration with an interim cryogenic propulsion stage will be used to launch a crewed lunar Orion into low Earth orbit. The interim propulsion stage engine fires to raise its low Earth orbit, and again for a trans-lunar injection burn. When approaching a high lunar orbit, the Orion provides the lunar orbit insertion burn to put the spacecraft into an elliptical high altitude lunar orbit.

A high lunar orbit is used because the Orion is performing both the lunar orbit insertion and trans-Earth injection burns. The Orion's elliptical lunar orbit will be between 100–200 km at its lowest point and around 1000 km at its highest. The Orion will remain in lunar orbit for several

The future? A manned habitat orbiting an asteroid, served by the joint NASA/ESA Orion spacecraft (NASA/ESA)





days and then will perform a trans-Earth injection burn to begin the return to Earth.

### 3) *Crewed lunar vicinity/lunar surface mission*

This mission could include a 'Lunar Surface Sortie', which lands four crewmembers on the surface of the Moon in the equatorial or polar regions and returns them to Earth. Two launch vehicle stacks are used in this scenario, the first SLS launch puts a Lunar Lander with a cryogenic propulsion stage into low Earth orbit, while the second SLS puts the manned Orion into low Earth orbit.

Instead of docking the Orion with the Lander around Earth (as was done in Apollo), this plan uses a dual lunar orbit rendezvous mission design that performs rendezvous, operations, docking and undocking in low lunar orbit. Just before separation of the Lander, the Orion is configured for uncrewed operations. In general, this preparation will not consist of any major powerdowns, since the Orion must be fully operational and fault-tolerant to ensure readiness for the initial separation burn from the Lunar Lander, possible emergency rendezvous or a normal return from the lunar surface. Things to be powered down include internal crew interfaces, displays, lighting, etc.). The crew prepares the spacecraft communications systems for remote commanding from the Lander or Earth, and stow equipment in preparation for the later return of the crew and cargo.

The crew transfers into the Lunar Lander and descends to the Moon's surface. The Lunar Lander would provide habitation for up to seven days duration on the surface. Deep-space extravehicular activity suits will be required for surface operations.

### 4) *ISS backup capability mission*

This mission provides an alternative means of delivering crewmembers and cargo to the ISS if other vehicles are unable to perform that function. Currently, this is just an analysis, awaiting decisions from the ISS partner agencies on whether this backup will be needed. Orion's design is optimised for exploration, but since this capability must be available if needed, assessments must be performed to determine the cost, schedule, and technical impact of implementing crew rotation and cargo delivery to the ISS.

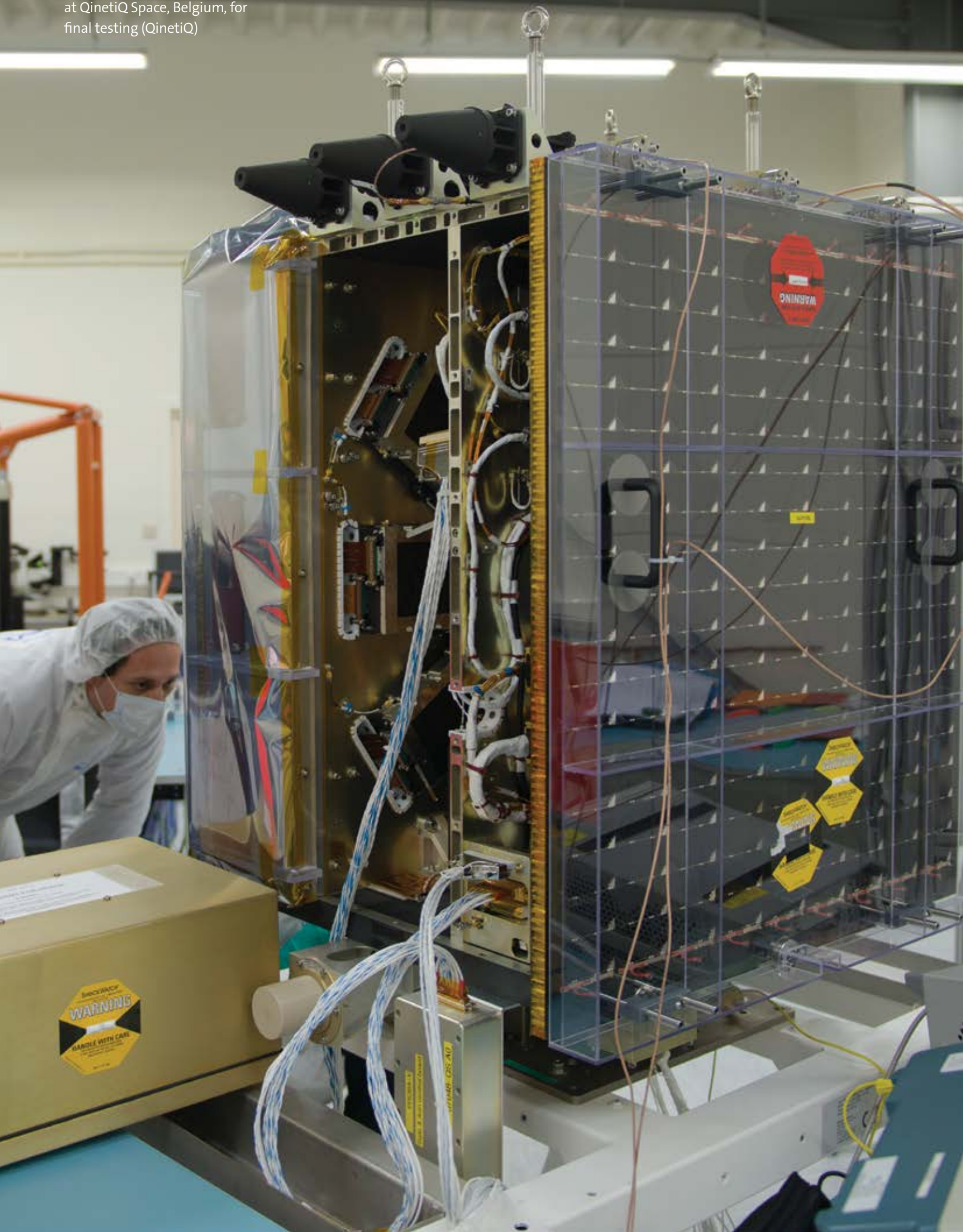
Orion should support a crew for at least four active mission days, plus two more days as contingency. After orbit insertion, the Orion performs rendezvous, proximity operations and docking with the ISS. Orion will remain at the ISS in a quiescent mode for up to 210 days (which includes 30 days for contingency) and spend one day undocking and returning to Earth. Contingency days are intended to address cases such as a launch delay of the next crew, or delayed departure due to landing site conditions. ■



Main parachute test on the Orion Crew Module (NASA)



Proba-V on the cleanroom bench  
at QinetiQ Space, Belgium, for  
final testing (QinetiQ)



## → 'V' FOR VEGETATION

### The mission of Proba-V

Sean Blair

Communications Department, ESTEC, Noordwijk, The Netherlands

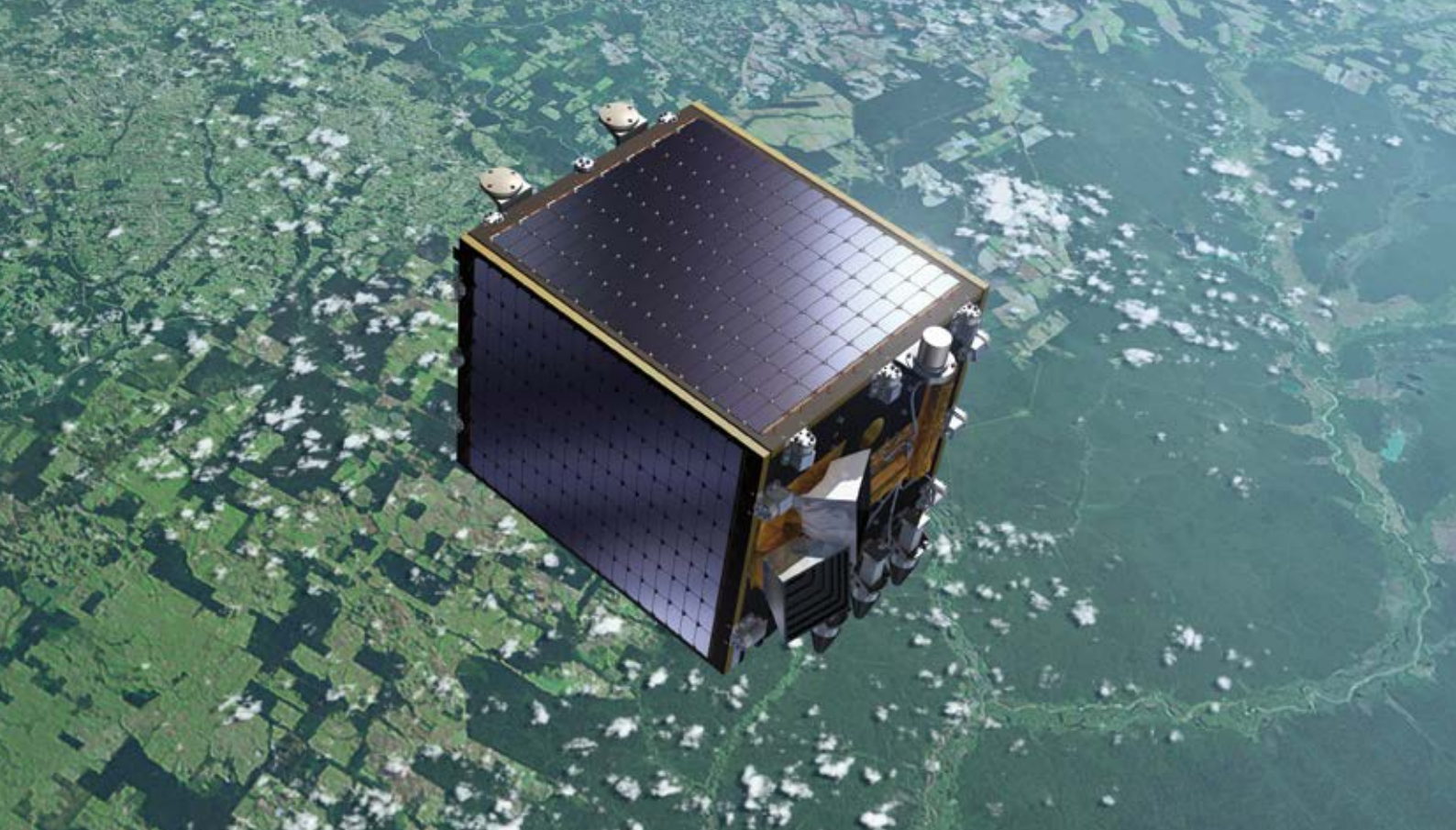
**ESA's Proba-V minisatellite is now assembled and being readied for space. With a launch this April, this miniature Earth observer is designed to chart global vegetation every two days.**

Resting on a cleanroom bench, it appears to be just a box of electronics, about the same size as a modest network server or an office fridge. Yet when ESA's Proba-V minisatellite goes into orbit this spring, it will be able to build up a continuous daily picture of the state of vegetation across most of planet Earth: complete coverage of high latitudes each day, with 90% of equatorial regions covered within those same 24 hours.

Within two days all of our planet's land surface will be imaged. Once cloud cover is accounted for, a complete composite of Earth's land cover should be available to the scientific community, and a significant number of operational data users, every ten days. Not bad for a cubic metre's worth of electronics.

With Proba-V, ESA's small satellite series has finally come of age. Over the last decade, 'Proba' has become synonymous with small high-performance satellites, designed around innovation. Initially, the two previous satellites in the 'Project for Onboard Autonomy' series were demonstration missions, overseen by ESA's Directorate of Technical and





↑ Proba-V's Vegetation instrument has been specifically designed for global environmental and agricultural monitoring

Quality Management, and intended to give promising technologies an early chance to fly in space.

These satellites were quickly repurposed as operational missions when the high-quality data from their pioneering experimental payloads were recognised by users. Launched in 2001, Proba-1 was used for hyperspectral environmental monitoring and Proba-2, launched in 2009, made solar observations and monitored space weather. Proba-V is different: it will begin as an operational mission as soon as its commissioning is complete, supplying data to an existing – and eagerly waiting – user community.

## Highly prized scientific workhorse

The 'V' in Proba-V stands for 'vegetation', the mission is needed to extend the dataset of the long-established Vegetation instrument flown on the French Spot-4 and Spot-5 satellites, launched in 1998 and 2002, respectively. Spot-5's Vegetation instrument is still operational today.

Vital uses of Vegetation data include day-by-day tracking of extreme weather effects, alerting authorities to crop failures, monitoring inland water resources and tracing the steady spread of deserts and deforestation.

### Proba-V facts and figures

Launch date	April 2013
Mass	140 kg
Orbit	Sun-synchronous polar, 820 km altitude, 10:30 a.m. local time at the descending node
Instrument	New version of Spot Vegetation instrument
Guest technology payloads	GaN amplifier in communication subsystem; Energetic Particle Telescope; Satram radiation monitor; ADS-B aircraft signal detector; fibre optics photonics experiment
Prime contractor	Qinetiq Space (BE)
Sentinel-5 precursor	Will carry a UV/VIS/NIR/SWIR spectrometer payload to avoid a data gap between Envisat and replacement of the MetOp series of Earth observation satellites
Payload developer:	OIP Space Systems
Ground Station	Mission control centre in Redu (BE) with a northerly data reception station, and a processing and archiving centre at VITO (BE)
Launcher	Vega



“Remote sensing has emerged as a key technology for ensuring sustainable land use,” explained Tanja Van Achteren of VITO, the Flemish government environmental research centre responsible for the current Vegetation instrument’s data processing.

“This is an instrument that has been specifically designed for global environmental and agricultural monitoring, with a very wide 2250 km field of view across blue, red, near-infrared and mid-infrared spectral bands. It can distinguish between different land cover types and plant species, including crops, revealing their state of health, as well as detect water bodies and vegetation burn scars.

“Its current 1-km spatial resolution is relatively coarse compared to other satellite sensors but, in exchange, Vegetation provides a detailed daily snapshot of land cover across a continental scale on a near-daily basis.”

There are Earth observation satellites that offer much higher resolution imagery, but the price paid for this sharpness is a reduced field of view, not unlike trying to read a map while peering through a drinking straw. Geostationary satellites, observing from a fixed point relative to their surface, offer a wider view comparable to Vegetation – but only for a third of Earth’s surface, and with their perspective on higher latitudes growing progressively more distorted.

So the Vegetation instrument, born two decades ago, belongs to a narrow class of wide-swath multispectral imagers, including NASA’s MODIS and the MERIS instrument that operated aboard ESA’s Envisat satellite for a decade from 2002. Co-financed by Belgium, France, Italy, Sweden and the European Union and designed by the French space agency CNES, the wide-eyed Vegetation has ended up as a highly prized scientific workhorse for global change studies.

“Vegetation data products have around 10 000 registered users around the globe, and have contributed to hundreds of scientific papers,” added Tanja Van Achteren. Together with complementary data from the instruments mentioned above, Vegetation is, for example, a leading source of key European and global vegetation data products (such as Leaf Area Index and Normalised Density Vegetation Index) provided to environmental researchers through the Geoland2 project, backed by the EC’s Seventh Framework Programme.

These products are harnessed in turn for scientific and operational activities that range from climate impact assessments and surface water resource management to agricultural monitoring (feeding, for example, the MARS Bulletin on European Union crop production forecasts) and food security estimates.



↑ Landcover of Africa as seen by Spot Vegetation

## Running out of time

But despite its valued perspective on the living Earth, the original Vegetation design is an instrument running out of time. Spot-4 ended Vegetation observations last year, while the Vegetation mission of its twin satellite Spot-5 is projected to end by mid-2014. The Spot satellite family has now been commercialised by Astrium to concentrate solely on high-resolution imagery from small satellites. No room was available for another Vegetation instrument on the Spot-6 mission that was launched in September 2012.

This meant that the nearly 15-year Vegetation dataset looked set to end – at least until the instrument’s community of users spoke up. Expressing themselves through the Vegetation International Users Committee (IUC), they argued that extended data continuity was essential to fully exploit the global capacity of such a crucial spaceborne instrument.

“The further a dataset can be extended, the more valuable it becomes,” argues Tanja Van Achteren. “Certainly in the case of climate studies you need at least 30 years to begin seeing the underlying trends – so the argument for extending Vegetation observations beyond the life of the Spot-5 platform really speaks for itself.”

The idea took shape among discussions between scientists, before being developed further. “The concept was quickly adopted by the Belgian authorities,” said Jean-Paul Malingreau, Chair of the Vegetation IUC.

“They saw in this new mission the opportunity to significantly contribute to global science.”

The Belgian Federal Science Policy Office, Belspo, began discussions with ESA on creating a Vegetation follow-on. “The single most important requirement was that it would have to be built and flown quickly,” recounted Karim Mellab, ESA’s Project Manager for Proba-V. “Any new instrument has to be fully cross-calibrated with Spot-5’s already-orbiting Vegetation instrument to ensure the radiometric and geometric quality and compatibility of its data.”

“So the mission was targeting a very narrow time window in space terms, with less than three years from start to launch. That in turn led us consider to a small satellite platform – because, generally speaking, the smaller the mission, the cheaper and faster it can be mounted.”

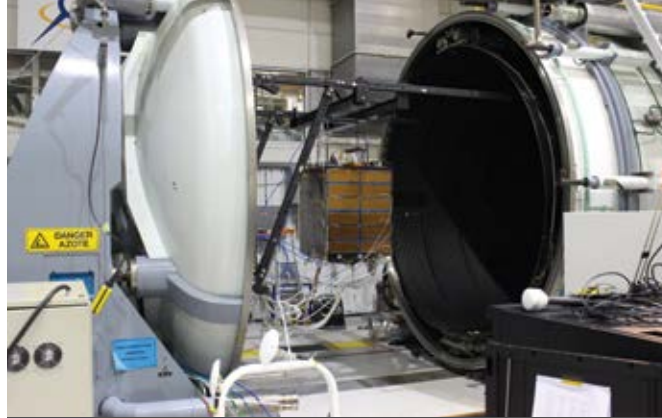
The idea took shape for a spacecraft built in Belgium, because the Proba minisatellite platform – produced by the QinetiQ Space company – was identified as the best available fit for this new instrument. “To meet such a rapid schedule, we reused as much design heritage from Proba-2 as possible,” explained the company’s Frank Preud’homme.

With QinetiQ Space the overall mission prime contractor, VITO stepped up from its original data processing and distribution role to serve as principal investigator for the redesigned instrument while also taking responsibility for its user segment, overseeing the image data processing, archiving and distribution as well as the inflight calibration and validation. QinetiQ Space subcontracted Belgian company OIP Sensor Systems to build the redesigned Vegetation instrument.

## Putting the world in a box

Devising a way to fit a view of the whole world into a small box has been no easy task, but necessity is the mother of invention. Engineered to fly on a Spot satellite platform the size of a van, the original 130 kg Vegetation instrument was in fact much larger and heavier than the whole Proba satellite.

To fit inside the available space and mass budget of Proba would mean shrinking the design significantly. This miniaturisation process meant harnessing all the technological advances that had taken place since the instrument was first designed in the early 1990s.



↑ Proba-V Flight Model enters the test chamber at Intespace for thermal/vacuum testing

Back then, only a combination of heavy glass lenses could yield Vegetation’s 101° field of view, and separate glass lenses were required for each of its four spectral bands. Its sensitive shortwave infrared detectors also demanded a heavy, power-hungry cooling system. The drive to lose mass led designers to swap glass for lighter aluminium mirrors, which have the additional advantage of observing across all spectral bands without the need for duplication.

These mirrors are arranged within a compact ‘three-mirror anastigmat’ (TMA) design – but need to be curved in just the right ‘aspherical’ shape. Achieving this required a manufacturing technique of nanometre-scale precision, known as ‘single-point diamond turning’, by Belgium-based specialist AMOS.

At first, it was uncertain whether this could be achieved at all. But in 2009, a prototype TMA telescope, produced through ESA’s General Support Technology Programme which helps develop space hardware to flight readiness, proved the concept.

To reduce the size of the mirrors needed in Proba-V’s Flight Model, the instrument has been subdivided into three telescopes with overlapping views of 34° each – hence the distinctive triple slits seen on the satellite’s Earth-facing side. The three telescopes feed through to a single set of detectors.

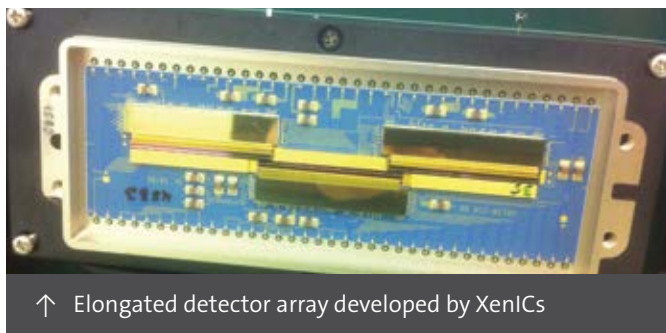
Belgian company XenICs developed a 2709-pixel-long linear array to cover the shortwave infrared channel, composed of three 1024 detectors originally designed for terrestrial applications. These arrays were mechanically butted together, overlapping to ensure full swath coverage.

Because these detectors have been built from indium gallium arsenide, they deliver the high sensitivity needed

“

**The further a dataset can be extended, the more valuable it becomes.**

”



↑ Elongated detector array developed by XenICs

while still at ambient temperature. This is important because the slimmed-down instrument has to make do without any active methods of controlling its temperature.

“The risk is that temperature-driven mechanical deformation might put the telescopes out of optical alignment as the satellite passes from sunlight to darkness,” said Davy Vrancken, QinetiQ Space Project Manager for Proba-V.

“So the instrument rests on an optical bench made of the same aluminium as the mirrors themselves, linked in turn to the star trackers used to orient the satellite. All this aluminium will expand and contract in the same way, keeping the telescopes aligned even as their temperature changes.”

Temperature-driven deformation is kept to a minimum anyway, because the instrument and its optical bench are kept isolated from the rest of the satellite by low-conducting titanium struts and shrouded in a dozen sheets of multilayer insulation.

“Even so, we have also created a detailed model of the very slightest temperature effects on the instrument throughout its orbit. This will enable us to compensate for these effects on the instrument’s geometrical accuracy during image processing, to provide the very best possible data quality,” commented Frank Preud’homme.

“Both instrument and mission development proceeded on an ‘end-to-end’ basis,” said Karim Mellab. “As part of this, a System Performance Simulator allowed us to estimate the quality of the data delivered to users as the engineering process unfolded. If necessary, we could go back and retrofit the mission design to enhance quality.”

## Substantial improvement

Proba-V’s Vegetation instrument offers a substantial improvement in data characteristics over its two predecessors: 1 km-resolution data products will still be offered, but 300 m resolution imagery will now be available as well, along with an additional uncorrected product available at spatial resolutions of 100 m in visible and near-infrared (VNIR) and 200 m shortwave infrared

(SWIR) across a limited swath within its central nadir-looking telescope.

To be compatible with its predecessor, Proba-V’s 820 km polar orbit is Sun-synchronised, giving a local 10:30 time on the ground to give optimal illumination conditions for continuity of measurements. “In terms of spectral bands, there will, however, be a very slight shift in the mid-infrared band; this will enable a better distinction of water bodies,” added Frank Preud’homme.

The minisatellite will remain ‘always on’ over Earth’s land surfaces, producing large amounts of data to store and downlink for such a modest platform. A novel 16-gigabit flash memory system will give sufficient onboard storage capacity using data compression, downlinking data once per orbit to a northern latitude ground station – ESA’s Kiruna site in the Swedish Arctic during the commissioning phase – via a high-bandwidth X-band antenna.

The raw data will be relayed automatically to VITO, where it will be processed on a near realtime basis into one-day and ten-day products (plus, if requested, the raw 100 m resolution product). These products will then be sent out via VITO, this distribution being managed by ESRIN, ESA’s Earth observation centre in Italy.

Once its six-month commissioning is complete and the mission performance is qualified, Proba-V will be transferred from ESA’s Directorate of Technical and Quality Management to the Directorate of Earth Observation. In particular, its results will support Europe’s flagship Global Monitoring for Environment and Security (GMES) initiative, developing operational environmental monitoring services to support European policies and improve the quality of life of European and global citizens, as well as application development projects and research projects in continuation of previous Vegetation-based scientific projects, along with those employing Envisat MERIS data products.

Like its Proba predecessors, the satellite will be controlled from ESA’s Redu Centre in Belgium’s Ardennes forest. The satellite is designed to operate as autonomously

↓ Under test at ESTEC, the Structural/Thermal Model of Proba-V’s Vegetation instrument – specifically designed for global environmental and agricultural monitoring





as possible, so is overseen by a small team. Redu is also where Proba-V's additional 'techno-demo' payloads will be operated from, testing promising technologies in space.

With a planned 2.5-year lifetime (with the potential to double to five years), Proba-V is sometimes regarded as a 'gap filler' mission: ESA's Sentinel-3 mission, supporting GMES, is planned for launch in April 2014 and will produce Vegetation-compatible data products. But, if Proba-V proves a success, it might well make the case for a successor, on

a complementary basis to the Sentinels. Such a 'Proba-Vb' is currently the subject of extensive discussions within the Proba-V International Users Committee; it also the topic of a VITO study, supported by ESA's 'Programme de Développement d'Expériences scientifiques' (PRODEX) technology development programme.

Sean Blair is an EJR-Quartz writer for ESA

## → Seeing red

The Vegetation instrument observes Earth's land surfaces in a spectral region extending from visible light to the invisible near- and mid-infrared. This enables measurement of what is called the 'red edge'. The reason why plants appear green in visible light is because the chlorophyll in each leaf absorbs red light to perform photosynthesis. But move into the near-infrared, this strong absorption suddenly shifts to strong reflectivity from the rest of the leaf's internal structure. Plant matter therefore reflects back in the near-infrared much stronger than other non-organic surfaces.

The resulting 'red-edge' value – the contrast in brightness between the visible red and invisible near-infrared – is the basis for various vegetation indices commonly employed by environmental scientists, as well as being used directly to estimate the chlorophyll content of the vegetated area being observed.

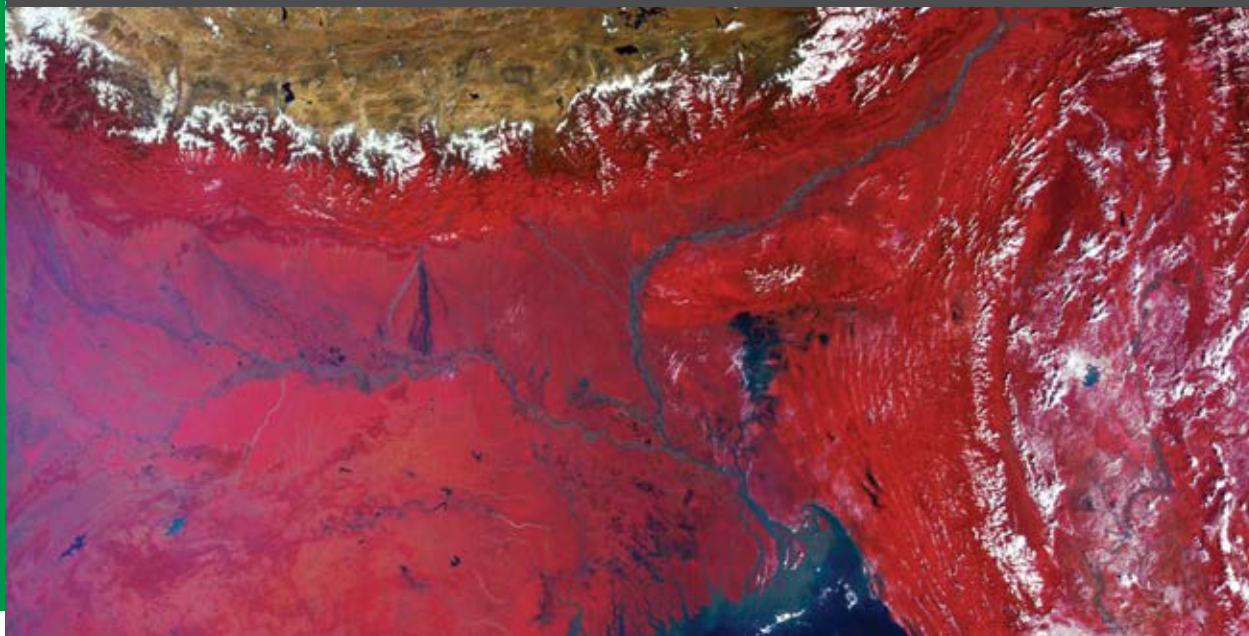
Reflectivity at mid-infrared wavelengths is influenced by the presence of water and plant material cellulose and lignin, and so can be used to derive information on vegetation health and stress due to factors, such as drought or soil salinity, as well as biomass estimates.

Vegetation stress is typically indicated by a decrease in near-infrared reflectivity with a corresponding brightening at mid-infrared.

The following biophysical parameters are made available by the EC through a series of environmental and climate monitoring projects, specifically based on Vegetation instrument data:

- **Normalised Difference Vegetation Index (NDVI)** – the difference in reflectivity between visible red and near-infrared
- **Fraction of vegetation cover (FCover)** – the fraction of vegetation per unit area observed
- **Leaf Area Index (LAI)** – the total area of (one-sided) photosynthetic tissue per unit area observed
- **Fraction of photosynthetically active radiation (fAPAR)** – the fraction of incoming solar radiation being absorbed by vegetation cover
- **Dry Matter Productivity (DMP)** – the increase in dry matter biomass over time
- **Burnt areas** – forest and other vegetation fire scars
- **Water bodies and seasonality** – tracking the presence and extent of water bodies, in Africa only (in combination with NASA's MODIS instrument)

↓ The Brahmaputra and Ganges river delta in India and Bangladesh as seen in infrared from space (CNES/VITO)



## → Proba-V's fellow passenger

Proba-V will share its flight to orbit with Estonia's first satellite, ESTCube-1, a 1-kg nanosatellite 'CubeSat' designed, built and operated by the students of several Estonian universities and led by the University of Tartu with Tartu Observatory.

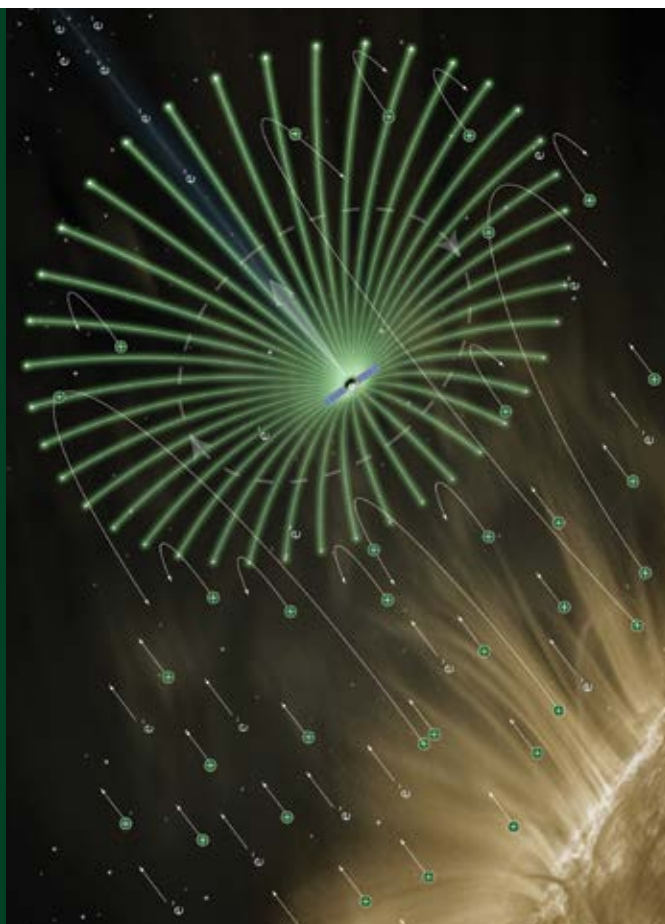
The mission will demonstrate a mini-prototype of a new type of solar sail, and is part of ESA's Plan for Cooperating States cooperative agreement with Estonia, a one-year programme of activity as a prelude to the country joining ESA as a Member State.

An electric solar sail, or 'e-sail' bears little resemblance to the more usual sail concepts, shaped like a web-like net. But when electricity is applied through the e-sail, the resulting electrostatic forces repel charged plasmas found in space – including the Sun's solar wind – to generate momentum. E-sail technology is being developed through the EU's Seventh Framework Programme by a partnership of nine institutes across five countries.

"The plasma in low orbit is quite slow moving relative to Earth, so the idea is to use e-sails as brakes to deorbit satellites, which is what we're testing with ESTCube-1," explained Pekka Janhunen, Finnish Meteorological Institute, inventor of the e-sail concept. "It should be a very different story for future satellites beyond Earth's magnetic field, where the fast-flowing solar wind will give quite a kick, offering a nearly free ride across the Solar System."

ESTCube-1 will unfurl a 10-m long single-strand e-sail to demonstrate its potential as a compact and economical deorbiting method. It will measure the resulting force acting on the e-sail as it comes into contact with space plasma.

International regulations state that satellites must deorbit within 25 years of their end of life to reduce space debris. Typically this means reserving propellant for this purpose, shortening the working life of the mission. But by gradually slowing a satellite, the hope is to deorbit small satellites within two to three years instead. The e-sail is particularly useful for nanosatellites, because there are

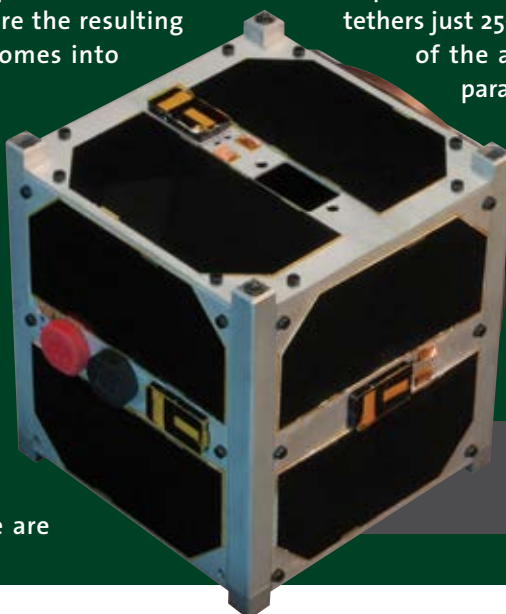


↑ The electric solar sail concept (Antigravite/Szame)

currently no existing technologies for deorbiting these objects in the 1–3 kg range.

Tethers, put to various uses including power generation, have historically had a mixed record in space – about half have snapped or failed to deploy. The project is borrowing techniques from the microelectronics industry to make tethers just 25–50  $\mu\text{m}$  thick – half the diameter of the average human hair – based on parallel subwires interlinked together.

So even if all but one subwires in the tether get cut, by a micrometeoroid for example, then the e-sail should continue to function. A longer, 100 m e-sail tether will be flown on a Finnish student CubeSat, Aalto-1, later in the year.



← The Estonian ESTCube-1 nanosatellite (E. Kulu)



## → Hitching a ride

The Proba series offers early spaceflight opportunities for new technologies from European companies. So Proba satellites carry as many technology demonstration packages as possible.

The two previous Proba missions were the first to fly subsequently influential innovations, such as the first lithium-ion battery for space, the first gallium arsenide solar cells, the first APS-based startracker and the first LEON-2 FT microprocessor, ESA's latest generation of space computer chips.

With its main Vegetation instrument taking up around a third of its total volume, Proba-V had less room to spare for 'techno-demo' payloads than its predecessors, but the team still did their very best to accommodate as many other items as possible.

"We were able to add an extra couple of payloads by taking out the weights used to keep the satellite's centre of gravity in balance with its centre of geometry," says Frank

Preud'homme of QinetiQ Space. "We thought, why not fly more working items instead of just metal blocks?"

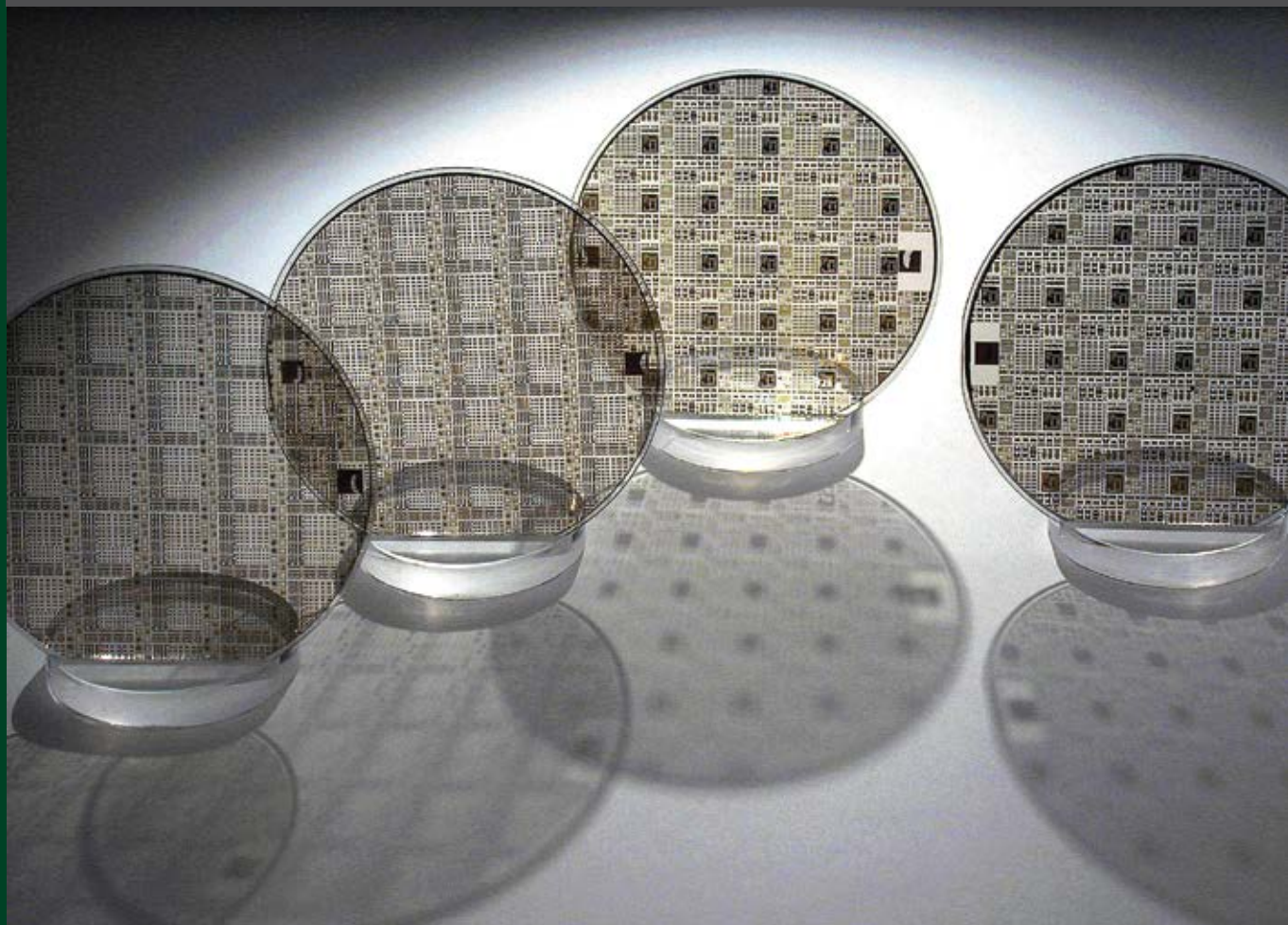
### First GaN hardware in space

Proba-V's X-band communication system will include an extra amplifier based on new gallium nitride (GaN) technology instead of standard gallium arsenide. Already in everyday use in light-emitting diodes, GaN is attracting great interest in the world of integrated circuits.

ESA has identified GaN as a key enabling technology for space: its high power capacity makes it the most promising semiconductor since silicon. GaN operates reliably at much higher voltages and temperatures than silicon or gallium arsenide, offering a five- to ten-fold increase in communications signal strength without requiring active cooling systems. As an additional advantage for space missions, it is also inherently radiation resistant.

The X-band transmitter on Proba-V is produced by Syrlinks in Germany, with the GaN amplifier coming from TESAT in Germany. This amplifier is among the earliest outputs

↓ Gallium nitride (GaN) circuits on silicon carbide wafers: GaN as a key enabling technology for space







↑ Proba-V will be carrying technology demonstration packages, offering early spaceflight opportunities for new technologies from European companies

of an ESA-led European consortium to manufacture high-quality GaN devices for space uses: the 'GaN Reliability Enhancement and Technology Transfer Initiative' (GREAT2). This innovative amplifier also has an adjustable power output, so its use should help to conserve the small satellite's power consumption while also providing extra redundancy.

## Global aircraft detection

The German Aerospace Center DLR has developed an instrument to detect Automatic Dependent Surveillance – Broadcast (ADS-B) signals from aircraft. The ADS-B system is being phased in around the world, with all aircraft entering European airspace to be equipped with it by 2015.

The system involves aircraft broadcasting their position, altitude, velocity and other measurements on an automatic basis every second or so. Currently air traffic controllers on the ground rely on radar contacts to gain an overview of air traffic. But with ADS-B transmissions, aircraft remain continuously visible, not only to controllers, but also to other suitably equipped aircraft. ADS-B requires no costly ground infrastructure to implement – so sparsely-populated countries such as Australia have been enthusiastic early adopters.

The idea with this payload is to take up an ADS-B system as is, foregoing any costly equipment upgrades, and investigate if it is technically feasible to receive ADS-B signals in orbit. Proba-V will demonstrate how many aircraft can be observed worldwide and which types – different-sized aircraft are assigned ADS-B systems with differing signal strengths.

Over European airspace and other high-traffic regions, adjacent ADS-B signals might well overlap, but space-based ADS-B holds potential for monitoring sparsely trafficked areas not covered by ground-based radar, such as oceans or polar regions. Enlarging coverage in this way should boost overall air traffic capacity as well as safety and security.

The principle of detecting ADS-B signals from above rather than below has been proved by a DLR experiment carried on a high-altitude balloon, but Proba-V will assess the feasibility of detecting signals from 820 km up in orbit. DLR is working

with industrial partner SES Astra on a space-based ADS-B service using a constellation of satellites for global coverage – one of a number of such initiatives in the planning stages around the world.

## Measuring space radiation

Space may be a vacuum, but it is far from empty: particles of different energies and charges are thrown out from the Sun or arrive from deep space, or are captured and accelerated within radiation belts of Earth's magnetic field. Proba-V will carry a pair of instruments to survey space radiation levels, the main cause of satellite anomalies and malfunctions, and a potential health risk to astronauts.

Developed by QinetiQ Space and the Centre of Space Radiation in Belgium, the shoebox-sized Energetic Particle Telescope (EPT) will record the charge, energy and angle of incoming charged particles along a broad range of energies across a wide 50° field-of-view. Unlike simpler radiation monitors previously flown in space, the EPT can separate out particles from their energies for much more accurate sampling of the radiation flux.

A second radiation monitor, known as SATRAM (Space Application of Timepix-based Radiation Monitor) is contributed by CSRC and the Czech Technical University. These two radiation monitors will be well placed when Proba-V is launched this spring: the Sun's 11-year cycle of activity is forecast to peak to the next 'solar maximum' by the middle of 2013.

## Fibre optics under test

The Norwegian T&G Elektro and Spanish DAS Photonics companies have contributed to the payload known as HERMOD (High Density Space Form Connector Demonstration) to test the capacity of a novel multi-line optical fibre and connector design to operate reliably in the space environment.

Light-based fibre optics offer numerous improvements on metal wiring for future space missions, including increased bandwidth, reduced mass and decreased sensitivity to temperature, radiation and electromagnetic interference.

The payload electro-optics generate different digital signals to pass through four different optical cables made of 12 fibres and then compare the returned message to the initial one, counting up the number of errors over time.

Already employed in terrestrial sectors including the oil industry, these multi-line optical fibres were already being ground-tested for space as part of ESA's General Support Technology Programme when the opportunity arose to fly on Proba-V. A crash effort brought the payload to flight readiness within six months.



↑ ESA's first Vega rocket stands ready for launch

## → Voyaging on Vega

Proba-V will be launched into orbit on the second Vega flight. Vega made its maiden flight on 13 February 2012 and is ESA's newest rocket, able to carry small and medium-sized satellites, increasing the flexibility and competitiveness of Europe's launcher family.

This spring marks the start of the VERTA (Vega Research and Technology Accompaniment) programme, intended to demonstrate the flexibility and versatility of the Vega launch system. At a planned minimum of two launches per year, the programme will allow the smooth transition of Vega into commercial exploitation.

After Proba-V, VERTA flights will launch the ADM-Aeolus wind-mapping mission, the LISA Pathfinder technology demonstrator and the Intermediate Experimental Vehicle reentry test vehicle. Between 2014 and 2016, Vega will launch ESA's Sentinel-2 and Sentinel-3 missions, as the start of its commercial operations.

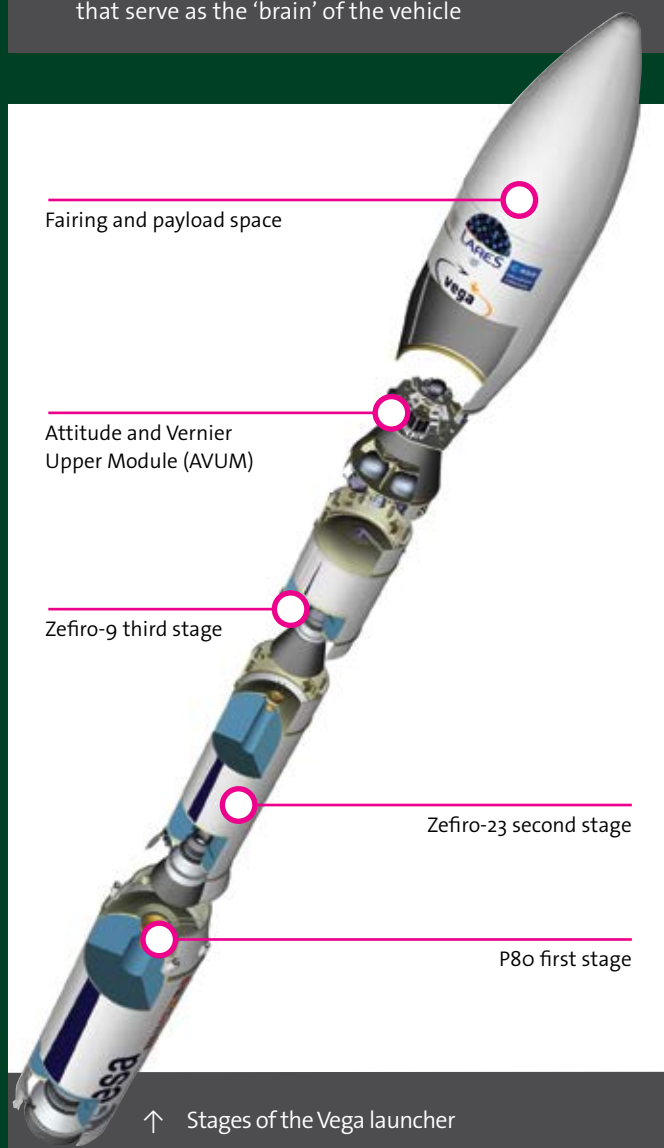
ESA's Directorate of Technical and Quality Management, overseeing the Proba-V mission, has collaborated closely on Vega development with ESA's Directorate of Launchers and Italy's Avio company. Like any other ESA project, the Vega team had at their service the specialist engineering teams and laboratories of ESA's technical centre ESTEC in Noordwijk, the Netherlands. This collaboration beat the odds for an inaugural rocket launch, with a perfect first flight, establishing Vega for its long working life to come.

- Vega incorporates a wide range of new materials to keep its own mass low: the lighter Vega is, the more payload it can haul into orbit. Its skin is woven from carbon fibre reinforced polymer then baked solid, a material more typically found in the structures of Formula 1 cars. The resulting vehicle is three times lighter than equivalent metal-bodied rockets, but with a strength-to-weight ratio almost five times greater than steel or aluminium.
- The nozzles of the new rocket face some of the most demanding performance requirements of all. The P80 first stage, the Zefiro-23 second stage and Zefiro-9 third stage nozzles are all made from carbon-carbon and of carbon-phenolic composite material. These composites have a tendency to 'ablate' – or flake away – at very high temperatures, so much so that carbon phenolic is sometimes used as a heat shield for reentering spacecraft: this flaking effect comes in handy as a way of dumping frictional heat. Robust dynamic testing was needed to ensure the nozzles would not behave the same way under stress.
- Guided by decades of experience building and flying Ariane launchers, its first three solid-fuel stages are derived from Ariane 5's strap-on boosters. A reignitable liquid-propellant





↑ View inside the Attitude and Vernier Upper Module, a reignitable liquid-propellant fourth stage containing the avionics that serve as the 'brain' of the vehicle



↑ Stages of the Vega launcher

fourth stage, the Attitude and Vernier Upper Module (AVUM) is as much a spacecraft as it is a launch stage. This stage completes delivery of Vega payloads into orbit, as well as hosting the avionics and thrusters used to control the entire stack's roll throughout its flight.

- New electromechanical actuators are used for the thrust control system of the second, third and fourth stages, controlling their direction during flight. This is the first time these actuators are being used on a European launcher – in place of the bulkier hydraulic thrust vector control system used on Ariane 5. Each stage has two actuators for moving the rocket nozzle, an electronic control unit called the Integrated Power Distribution Unit and a lithium-ion battery, all linked by a cable harness. Controlling the system is a HBRISC2 processor, capable of surviving radiation as it rises spaceward, while maintaining simultaneous control of the pair of actuators.
- Keeping a launcher correctly oriented as it rises through the air is like balancing a pen upright on your finger, made more complicated by the fact that it is not a single item but four joined stages accelerating at hypersonic speed. Vega's 100 000 lines of flight software is not particularly large when compared to the latest satellite missions – with a flight computer running on 1990s-era ERC-32 microprocessors – but failure is never an option. Astrium contributed the flight control software for the first Vega flight, this responsibility passing to the Vega prime contractor ELV for future launches. To control all three axes of flight and take into account external influences, such as wind, the software algorithm has been 'tuned' through thousands of simulated flights into orbit over a period of years.



Capturing the  
'overarching' aspect of  
HISPAC's Grand Science  
Themes: this view from  
the ISS includes elements  
spanning the space  
sciences (the stars of  
the Milky Way), Earth  
sciences (Earth's surface  
and thin atmosphere)  
and even how cosmic  
radiation interacts with  
Earth's magnetic field  
with an auroral glow  
(NASA/ESA)





## → GRAND SCIENCE

### Setting the stage for ESA programmes of the future

**Marc Heppener and Anders Jordahl**

Director General's Cabinet, ESA Headquarters, Paris, France

**Eike Kircher and Matthew R. Bullock**

Directorate of Technical & Quality Management, ESTEC, Noordwijk, the Netherlands

**ESA is taking steps towards an integrated, long-term vision for the Agency on science and its enabling technologies, transcending the objectives of ongoing programmes and activities, and setting the stage for ESA programmes of the future.**

ESA's High-level Science Policy Advisory Committee (HISPAC) has identified a number of overarching scientific themes, called the 'Grand Science Themes' that will help to focus the key science and technology priorities of ESA.

HISPAC consists of independent and highly regarded European science and technology experts with the remit to reflect on interdisciplinary science and technology

themes and ideas. Established by ESA's Director General Jean-Jacques Dordain in July 2007, the committee advise him directly on long-term science policy issues. HISPAC has a key role in identifying long-term scientific developments that will be of benefit and importance to the science and technology activities of ESA.

In defining its Grand Science Themes, HISPAC intentionally took a long-term perspective beyond the defined science objectives of already approved ESA programmes, such as the mandatory Science Programme, the Earth Observation Envelope Programme and the ELIPS programme for life and physical sciences in space. At the same time, the Grand Science Themes should offer a logical continuation

and integration of those objectives into synergistic, overarching scientific themes for ESA.

As guiding principles, HISPAC wanted to ensure that these Grand Science Themes were scientifically rich, inspirational and extensive. They would be synergistic between ESA's different scientific programmes and cross-linked with enabling technologies of value across ESA, and they would also be linked to societally important themes, for example, medicine, land use, traffic monitoring, sustainable materials and processes.

The Grand Science Themes formed the backbone of one of the three strategic objectives in the Director General's proposal 'Space for Competitiveness and Growth' at the ESA Ministerial Council in 2012. As part of the long-term support for these themes, ESA's Future Technology Advisory Panel (FTAP) has recommended a number of cross-cutting enabling technologies. HISPAC and FTAP will now take their work further to provide an encompassing framework for decisions on future technologies and science missions.

## One science-led ESA

In the words of the Director General, HISPAC should work 'unconstrained by considerations of funding, ESA's internal Directorate structure, the existing approved programmes and politics'. The identification of synergies and overarching scientific objectives for ESA is the core task of HISPAC, as well as developing strategies to foster these.

HISPAC therefore focuses on a timescale beyond the currently approved programmes. Yet its advice has an impact on a much shorter timescale, because of the need to prepare for opportunities in the long term. HISPAC is not charged with defining specific missions, but concentrates on science and technologies that will support broad areas of ESA's activities.

HISPAC contributes to the vision of the Director General to promote not only 'One ESA', but also 'One Science-led ESA'. This means an agency-wide, coherent and comprehensive approach to science and technology as a whole. In this context, the term 'science-led' is understood to encompass a very wide range of activities within ESA and includes pure science, applied science and science-related aspects of technology.

HISPAC's members are mindful of the importance of developing themes that are of clear relevance for the benefit of the citizens of Europe and the world. In parallel with this responsibility, HISPAC engages with issues in fundamental science and curiosity-led research that may have a very much longer pay-back time for both science and society than more obviously societally oriented themes.

HISPAC takes inputs from the established ESA Science Advisory Structure's Working Groups and Committees, which are the source of specific science advice for the selection of missions and the approved programmes. This 'bottom-up' approach to the definition of science and technology priorities is fostered by the Working Groups and Science Advisory Committees, which have an impressive membership of world-ranking scientists in the space sciences. The Chairs of the ESA Science Advisory Committees are also members of HISPAC.

The Science Advisory Structure was reformed in 2009 following extensive discussions within HISPAC and subsequently with the Science Advisory Committees, the Programme Boards and the Executive. The structure today regroups the required disciplinary expertise across the different ESA Directorates, streamlining the advice and promoting the identification of wider themes and cross-disciplinarity.

Working Groups provide scientific advice to all the Science Advisory Committees, encouraging synergies across all programmes. To further support synergies, a Director General/Directors' Sub-Committee for Science was set up. The science advisory structure formally includes also more recent programmatic fields of science relevance, in particular, the satellite navigation activities.

## HISPAC's Grand Science Themes

### *Grand Science Theme 1: Terrestrial and cosmic climate*

As with the other Grand Science Themes, even the name carries a clear interdisciplinary message. It links the climate on Earth with other climate systems found in the Universe in a broad sense.

Terrestrial climate includes the study of all aspects of local and global climate, such as the atmosphere, hydrosphere, cryosphere, biosphere and anthroposphere. Since all these

“

**A first step towards an integrated, long-term vision for ESA on science and its enabling technologies.**

”



aspects are interconnected both physically and in the models used to understand and predict global change, the overall subject of study is often referred to as Earth System Science. It is clear that for successful monitoring and understanding of this system, global coverage, intercomparability of data and long time-series are essential, all pointing to the need for observations from space.

Moving out from our home planet, we encounter the radiation input of the Sun and aspects of what is called 'space weather': solar wind and other cosmic particles, magnetic fields and plasmas, and how these interact with Earth's atmosphere. It is interesting to note that navigation satellites can provide important contributions to the study of our upper atmosphere, complementary to the data from solar observatories and other satellites.

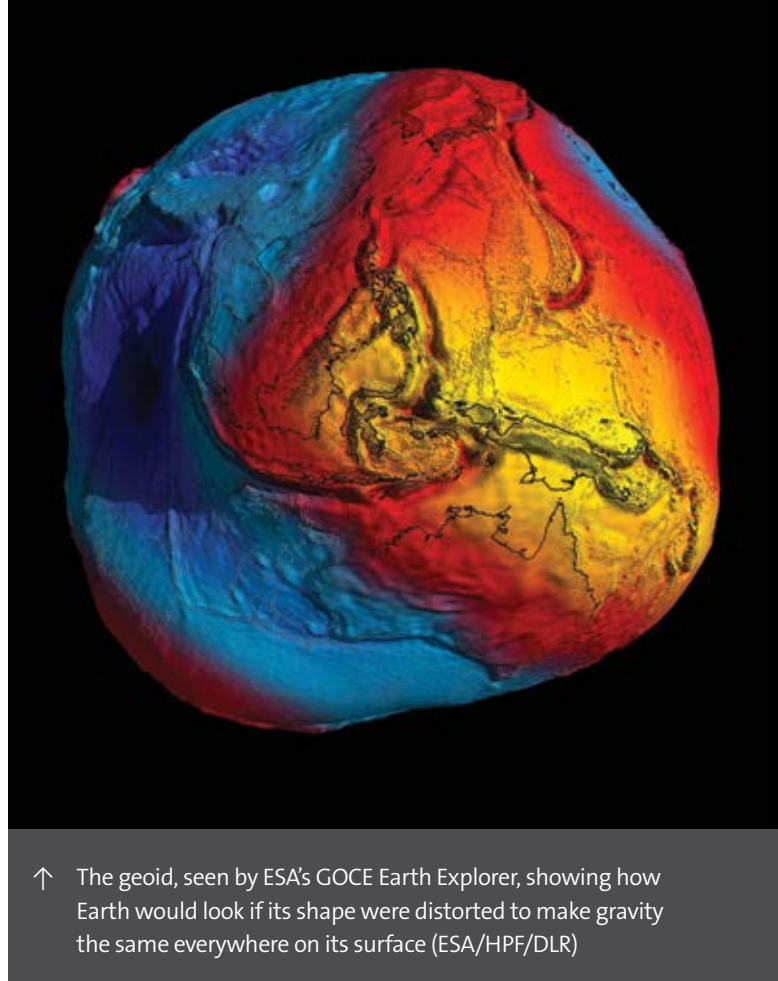
However, the physics of our terrestrial climate is not unique. With the knowledge and understanding gained from these studies, we can also look at other planets in our Solar system. In fact, looking at the climate of Earth-like planets such as Venus and Mars can provide very valuable information on our own climate and how to improve its modelling. At the same time, these data provide information on the possibility of life under extreme conditions, such as may have existed or even still exist on, for example, Mars or in the oceans of Europa. Data can come from remote observations or local measurements, including cometary landers, searching for signs of prebiotic molecules.

Going beyond our own Solar system, we encounter other planetary systems, each with their own climate. Almost 1000 extrasolar planets, or 'exoplanets', are now known and the discoveries of new ones, including Earth-like planets, are being made at a high rate using ground-based and space telescopes. Future missions with even higher resolution and spectroscopic capabilities can yield information on the atmospheric composition and climates of such exoplanets, providing a unique opportunity to study large samples of planetary systems with quite different planetary atmospheres from those within the Solar system.

Finally, once the properties of large samples of exoplanets have been obtained, we can start looking broadly at the comparative planetology of planets and systems of planets. The prospect is to start understanding the role of life in them, and the possibility of finding habitable or inhabited worlds other than our Earth.

### ***Grand Science Theme 2: Understanding gravity***

Gravity is the force of nature that we are most familiar with in our daily lives, and yet it is possibly the most elusive theoretically of the forces known to us. Understanding gravity and its effects, both microscopically and on the scale of the Universe, is one of the great challenges facing physicists.



↑ The geoid, seen by ESA's GOCE Earth Explorer, showing how Earth would look if its shape were distorted to make gravity the same everywhere on its surface (ESA/HPF/DLR)











Starting with the effects of gravity on the largest scales, observations of the large-scale structure and expansion of our Universe since its origin in the Big Bang seem to require the presence of ingredients beyond the ordinary types of matter that make up most of the visible parts of the Universe. These observations appear to need the existence of 'dark matter' and 'dark energy', the nature of which have not yet been determined by observation and experiment.

To account for the observations of the large-scale isotropy of the Universe and the existence of large-scale fluctuations in the distribution of galaxies, theorists have postulated a period of rapid 'inflation' in the very early Universe. The search is now on to find evidence for these features of our Universe. Whatever the outcome, the resolution of these great problems will greatly enhance our understanding of cosmology, fundamental forces, elementary particles and physics in general.

Another intriguing aspect of gravitational physics is that the theory of general relativity predicts the existence of large-scale gravitational waves travelling through the fabric of our Universe, in the same way that light waves are linked to the electromagnetic forces. These gravitational waves are very difficult to detect, since their wavelengths are measured in millions of kilometres, and their amplitudes in fractions of the radius of an atom. Yet, when we would be able to observe them directly, a completely new window on the Universe would be opened, allowing us to observe different signatures of the massive energetic phenomena in our Universe, such as the coalescence of two supermassive black holes.

## CURRENT POTENTIAL HABITABLE EXOPLANETS

Compared with Earth and Mars and ranked in order of Similarity to Earth

CURRENT POTENTIAL HABITABLE EXOPLANETS							ESI	
							1.00	0.64
								
							Earth	Mars
#1	#2	#3	#4	#5	#6	#7	Recently Excluded	
Earth Similarity Index (ESI)								
0.82	0.79	0.75	0.74	0.68	0.67	0.50	0.72	0.49
								
Gliese 581 g*	Gliese 667C c	Kepler-22 b	Tau Ceti e*	Gliese 163 c	HD 40307 g*	Gliese 581 d	HD 85512 b	Tau Ceti f*
Discovery Date								
Sep 2010	Nov 2011	Dec 2011	Dec 2012	Sep 2012	Nov 2012	Apr 2007	Sep 2011	Dec 2012

\*planet candidates

\*planet candidates

↑ Potential habitable planets known (as at 18 February) in solar systems other than our own (PHL/UPR Arecibo)

In all of these studies, Einstein's theory of general relativity plays an essential role, so it is therefore very important to validate this theory to the very highest level of accuracy. Two techniques for doing this are on the horizon. The first is to observe phenomena in situations where the gravitational field is very strong, such as in the early Universe or in the vicinity of black holes. The other is to make use of ultra-cold atom devices to test the equivalence principle and to make ultra-precise timing measurements.

These cold atom devices are also recognised as a future technology priority by ESA's Future Technology Advisory Panel. Although already existing on Earth, operating them in microgravity conditions in space will allow further improvement of the accuracy with which time can be measured. A realistic goal would be to achieve an accuracy of one part in  $10^{18}$ , equivalent

to roughly one second over the entire age of the Universe. Such devices will open up a wealth of new science, such as those mentioned earlier, but also improved measurements of the gravitational constant, quantum metrology, alternative ways of detecting gravity waves, and so on. In addition, there are new applications, such as improved accuracy of navigation systems and high-precision gradiometers.

With gradiometers, the mass distribution of Earth and the other planets can be measured from space. This information is important for the understanding of the geology and history of the interior of the planet. On Earth, in addition, precise knowledge of the gravity field is an essential parameter in explaining global ocean circulation, which in itself is again important for modelling and understanding heat transport in the oceans as one of the parameters determining global climate.



A Hubble Space Telescope composite image shows a ghostly 'ring' of dark matter in galaxy cluster Cl 0024+17. Although dark matter is invisible to us, this ring-like structure is evident in the blue map of the cluster's dark matter distribution. The map is superimposed on a Hubble image of the cluster (NASA/ESA/John Hopkins Univ.)





←  
Scientists have discovered communities of previously unknown species living on the seafloor near Antarctica clustered around hydrothermal vents. This discovery is certainly exciting for biologists, but it's also important for astrobiologists. It begs the question — if life can thrive in the deep, dark oceans without sunlight, could similar life thrive elsewhere in our Solar System or the Universe? (NOAA)

Finally, in microgravity (more accurately, the quasi-absence of gravity while in free-fall, such as is generally experienced during spaceflight) we can study processes in fluid physics of material sciences that would otherwise be masked by gravity-induced convection. This allows precise measurements to be made of the fundamental physical properties of materials, understanding transport phenomena and precisely controlled solidification. Innovative materials with important novel properties can be designed based on this knowledge.

### ***Grand Science Theme 3: Life in the Universe***

This theme addresses questions of profound scientific and philosophical importance, and future space missions can cast light on them. Where did life come from? How was it created? What conditions are required? Is it widespread throughout the Universe, or unique to Earth? Where can we look for it? How do we infer or detect its presence? How did it evolve on Earth? Can we travel in space, and how far or for how long? How do space and spaceflight affect our daily lives, our society and our view of the grander scheme of things?

Comets, asteroids and the interstellar medium may all harbour prebiotic molecules, such as amino acids, that are the building blocks of life as we know it. A key question is how did this early chemistry work and how could it lead to the development of the first self-reproducing systems. Is liquid water, as many think, the essential ingredient for life and can we use that proposition for identifying likely places where life could exist?

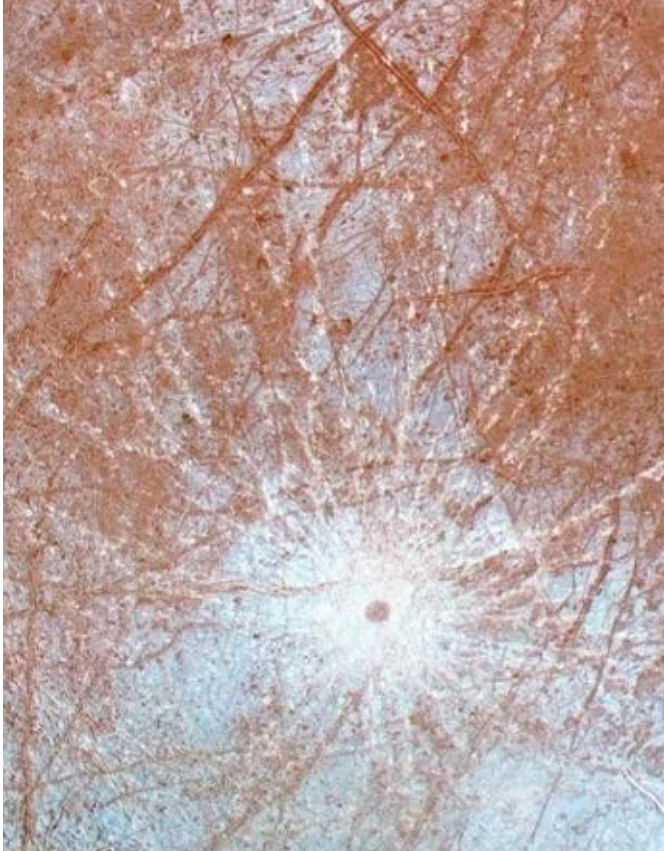
What are the other essential environmental ingredients in planetary atmospheres or oceans that are a prerequisite to generate and support life, and how many exoplanets would fulfil life-sustaining conditions? What can we learn from existing organisms on Earth, known as 'extremophiles', that are able to

live under extreme conditions such as the ocean floor, in small bubbles of liquid water in Antarctic ice, in ultra-dry deserts, or in salt and alkali lakes?

We do not know how life emerged on our own Earth: whether it is indigenous or whether it or its prebiotic ingredients were migrating, for example, on comets or through the interplanetary transport of material ejected after a cometary impact.

Then we have the issue of life and gravity. Was a '1-g' environment essential for the emergence of life on Earth and if not, what range of gravity levels are compatible with life processes? For higher life forms, such as bacteria, plants, insects and animals, we want to understand what role gravity plays in their functioning, and if and how they can adapt to different gravity conditions.

**These results transcend the objectives of ongoing programmes and activities and set the stage for ESA programmes of the future.**



The surface of Jupiter's moon Europa: could life have formed and even exist today? The primary ingredients for life are water, heat and organic compounds from comets and meteorites. Europa has all three. Research suggests that there is plenty of oxygen available in the subsurface ocean of Europa to support oxygen-based metabolic processes for life similar to that on Earth. In fact, there may be enough oxygen to support complex, animal-like organisms with greater oxygen demands than micro-organisms (NASA/JPL/Univ. Arizona)

Human spaceflight, while now more or less common, is at present restricted to low-Earth orbit. We want to know if we can travel farther, but for that we need to understand the limitations of humans in long-duration space travel, which includes exposure to microgravity, a harsh radiation environment and endless monotony. Finally, because we now live in a world where the age-old confinement to our planetary surface has rapidly disappeared within one generation, what impact does that have on our global economy, politics, health and beliefs?

#### ***Grand Science Theme 4: Cosmic radiation and magnetism***

This theme relates to the interaction of elementary particles with electromagnetic fields. Magnetism is a phenomenon that exists on scales from planets, stars and supernovae up to entire galaxies and clusters of galaxies, although the latter have only one millionth of the field strength of Earth's magnetic field. These large-scale fields may be generated by processes in the early Universe and so could be linked to fluctuations in the cosmic microwave background radiation. Alternatively, they might be generated and expelled from the nuclei of active galaxies.

Strong magnetic fields play an important role in the dynamics of collapsing rotating supernovae and in the energy dissipation of neutron stars. The sunspots and flares on the Sun are associated with the dynamical effects of magnetic fields and result in the acceleration of charged particles, which are the cause of aurorae and can disrupt radio communication on Earth. Earth's magnetic field not only protects us against the effects of cosmic particles coming from the Sun or the interstellar medium, but it can also reveal information of the geological history of our planet.

The study of the (point) sources and energy distribution of these cosmic particles will give new insights in cosmology and stellar evolution. At very high energies, conditions can be reached that are unattainable even in the largest accelerators imaginable on Earth and our own atmosphere can serve as an efficient detector.

Finally, turning to the need to protect future space travellers from over-exposure to radiation, it is recognised that the most dangerous part is the component from the interstellar medium. Whereas solar wind particles and eruptions have a higher intensity, it is easier in general to provide shielding against these than against the much higher-energy cosmic particles from elsewhere. One of the protection strategies is to mimic the protection provided by Earth by surrounding a space capsule by a magnetic field strong enough to deflect these particles.

#### ***Grand astronomical challenges***

HISPAC also identified a series of challenges related to enabling new observations or space missions. These are not Grand Science Themes as such, but they do represent interesting science closely linked to technological breakthroughs. This category includes, for example, the need for new observation points in our own Solar system, such as out of the ecliptic plane, at Lagrangian points, taking vantage points to use the Sun as a gravitational lens, or physically on the surface of comets or asteroids.

It also addresses the study of, and protection strategies against, space debris and near-Earth objects. Lastly, it includes the challenges associated with long-distance space travel, for example, propulsion, communication and even possibilities for hibernation of astronauts, a field that is starting to attract the practical attention of Earth-based laboratories and clinics today.

#### **Identifying enabling technologies for future science missions**

Behind any science mission or scientific discovery are enabling technologies. These technologies have made new types of scientific missions possible and have allowed major evolutions from one generation of science missions to the next. The Future Technology Advisory Panel (FTAP)





ESA astronaut Christer Fuglesang makes a spacewalk during construction of the International Space Station. During extravehicular activities in low Earth orbit, astronauts are protected by Earth's magnetic field. For missions farther out into space, such as to Mars or beyond, astronauts would need more protection, for example, through magnetic shielding (NASA/ESA)

prepares recommendations on technologies that will enable breakthroughs in future science missions. It is an ad hoc panel with an initial three-year mandate, bringing ESA scientific advisory structure representatives together with external technology experts, selected for their broad technical knowledge. They work together to capture a transverse view of scientific needs and to identify, select and assess enabling technologies and make recommendations.

Its activities build on an interactive and progressive process, guided by three objectives for identifying enabling technologies.

- Is the enabling technology advanced with respect to the start of the art?
- Is it fundamental in fostering scientific progress?
- Is it applicable to a range of scientific (and non-scientific) applications?

The panel completed its first cycle in 2011–12. Building on an initial list of 64 enabling technologies, the panel has pre-selected seven technologies for further assessment. After this assessment, FTAP has recommended to reinforce R&D actions for cold atom devices (optical clocks and atom interferometry) and large ultrastable structures (a cluster consisting of large monolithic mirrors and ultrastable deployable structures).

It also proposes to refine dossiers in its next cycle for lasers, infrared detectors, formation flying and autonomous rendezvous.

FTAP has also recommended the initiation of the 'Technology Challenges' initiative. This initiative targets technological needs where solutions have not been identified. The technology solutions could be considered as 'game changers' because, in some cases, they could enable profound scientific breakthroughs. ■

↓ Once the preserve of science fiction, through films such as *2001: a Space Odyssey* and *Alien*, hibernation or 'suspended animation' may one day become an important enabler of deep space travel. While a crewed

journey to Mars is expected to take about nine months, even a one-way mission to the Jovian or Saturnian system would take several years. Hibernation is a Grand Astronautical Challenge (20th Century Fox)





## → Enabling technology clusters for future science missions

### Cold atom devices

Using cold atom devices in space will further improve the accuracy of time measurements, and in addition foster fundamental physics (by improving measurements of the gravitational constant, quantum metrology), Earth science (with higher-precision gradiometers) and navigation science.

The main time reference on the ground, today, is a cold atom device (an atomic clock): the caesium 'Fountain' clock (operating in several sites worldwide). The standard relies on the atomic resonant excitation frequency that occurs in the microwave frequency range (just under 9.2 billion cycles per second or 9 192 631 770 Hz).

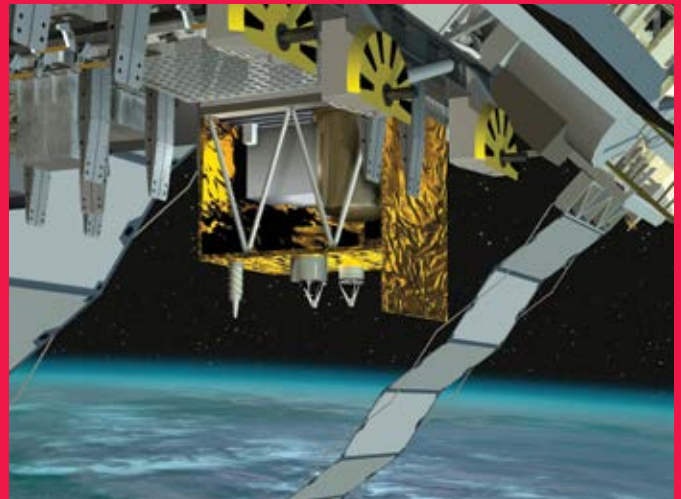
Work is already being done to put this type of technology to space. The Atomic Clock Ensemble in Space (ACES) will take cold atom clock technology into space for space-to-ground comparisons of clocks. ACES is a facility that will be flown to the ISS in 2015–16, which includes PHARAO, a caesium-based 'space' clock. An important performance feature of this system is its time accuracy and stability of  $10^{-16}$  (i.e. the clock would roughly drift by 1 second in over 10 million years). Adapting this technology, to go from a laboratory on the ground to flight in space (reducing its mass, volume and power consumption, while coping with extreme launch and space environments) has been a considerable challenge.

But the effort has its rewards, since taking cold atom devices into space offers advantages for science. In space, longer clock cycle times are possible because of microgravity (atoms are in freefall longer); in addition, the space environment offers reduced levels of mechanical disturbances and kinetic energy (temperature) and systematic errors. This lowers the noise in the atomic sample and makes the local clock oscillator cavity more stable, for example, improving the measurement accuracy and stability.

The next major leaps for science could be achieved with the development of cold atom optical clocks and atom interferometers and their use in space. While caesium clocks use a microwave frequency reference, this type of clock relies on an optical frequency reference. This implies that the clock will have on the order of  $1 \times 10^{14}$  pulses per second (100 trillion pulses per second) or over 10 000 times more pulses per second than the caesium clock.

Extensive research and development is already ongoing to develop optical atomic clock and atom interferometer systems for operation on the ground. Technology breakthroughs, such as the frequency comb and cold atom traps, have allowed for major progress in the development of these devices. Effort has already been initiated to develop these systems for operation in space.

An example of a project under study in this context is SOC (Space Optical Clock), an optical clock with  $10^{-17}$  stability



An atomic clock in space will allow a new kind of Earth research: relativistic geodesy. These measurements require a timekeeper of almost unimaginable accuracy. ACES, a facility that will be flown to the ISS in 2015–16, which includes PHARAO, a caesium-based 'space' clock

and accuracy based on the orbiting platform of the ISS. Its scientific objectives include testing general relativity (one order of magnitude beyond ACES) and establishing a global network for the ground clock comparison at the  $10^{-18}$  level after a few days of integration time.

Like for PHARAO (the caesium-based 'space' clock), it will be a challenge to design, develop and produce an optical clock that satisfies the mass, size and power criteria for spaceflight. The associated challenges are linked to the improvement and the adaptation of the system's sophisticated building blocks for space and the systems design effort needed to meet the performance needs.

### Large ultrastable structures

A wide range of scientific missions (for example, for Earth and space sciences) is being proposed that require large structures (beyond 5 m in length, typically in the 10–20 m range), with a very demanding dimensional stability (the ability to achieve a specific dimension or shape and maintain it with a tolerance of less than a sub-millimetre).

While missions requiring ultrastable structures would bring significant benefits to science, they are often not selected because of the technology challenge and the associated risk. Larger structures in space are constrained by the available volume on top of a launcher. Therefore, a structure must be stowed to be able to fit in launcher fairings, to be deployed reliably and be stable during operations.

One approach is to develop ultrastable deployable structures. Various solutions, at different technology maturity levels, have been or are being explored in Europe and around the world. They include:

- Articulated rigid booms (hinged)
- Deployable truss structures
- Telescopic booms
- Deployable coiled booms
- Deployable tape springs
- Inflatable booms
- Shape memory composite

Typically, missions that can benefit from ultrastable deployable structures are ones that need longer focal lengths, instrumentation deployed at a large distance from the spacecraft and aperture synthesis in terms of radar and optical domains.

The requirements for structures for proposed missions have some commonalities in term of length (10–20 m), mast diameter (30–100 cm), mechanical stiffness requirements and deployment accuracy. Nevertheless, the requirements can deviate with respect to specific needs and constraints of the missions (such as final structural configuration, pointing requirements, thermal environment, and so on).

## Large monolithic telescopes and mirrors

The current state of the art for the ‘large monolithic telescope’ is the 3.5 m infrared telescope of ESA’s Herschel mission. To take further benefit of this capability, there are two key considerations: is it possible to use launchers in the future with larger fairing diameters, and is it feasible to



↑ ESA/DLR Solar Sail full-scale deployment test, 20 x 20 m, in 1999 (ESA/DLR)

extend existing mirror/telescope production capabilities to make larger structures?

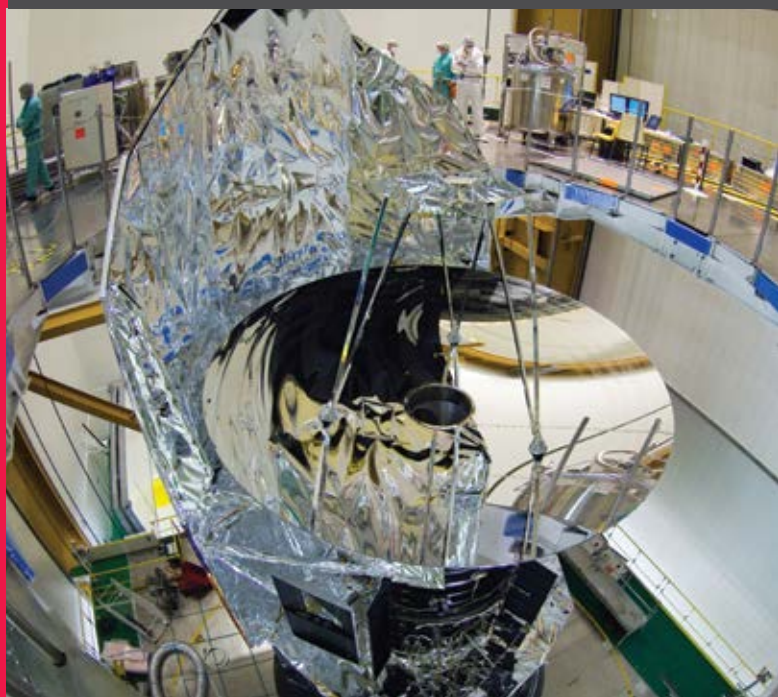
While the degraded aerodynamics of a larger fairing could be a difficult issue for the launcher system, this issue could be addressed; it is important to note that the US Space Launch System (SLS) is designed to accommodate an 8 m diameter fairing.

Extending existing capabilities (such as those used for Herschel) to make a mirror of 6 m, 7 m or possibly 8 m diameter seems to be possible (with reasonable weight) but needs further study. This approach could have been used for the James Webb Space Telescope and has other future space science applications (for example, imaging of exoplanets, monitoring from Lagrange points) and Earth observation/science applications.

- ↓ An engineer looks on as the first six flight-ready primary mirror segments for the NASA/ESA/CSA James Webb Space Telescope are prepared for cryogenic testing at the Marshall Space Flight Center (NASA/D. Higginbotham)



- ↓ One of the last views of ESA’s Herschel mirror as the satellite was prepared for integration with the launcher fairing in 2009 (ESA/CNES/Arianespace/Optique Vidéo du CSG)





Fairing separation from the Intermediate eXperimental Vehicle (IXV) and its Vega upper stage after launch





## → FLYING HOME

### IXV and ISV: a way to affordable and routine access to space

Giorgio Tumino

ESA Directorate of Launchers, ESA Headquarters, Paris, France

**A miniature robotic spaceplane, capable of orbital operations and returning to Earth on a conventional runway, opens scenarios where access to space can be routine and competitive compared to today's expendable solutions.**

Looking to ten, fifty or hundred years from today, with the ever-increasing number of satellites, the natural progression of space activities will lead to a growing need for access to orbit. This will be for servicing these satellites, extending their lives, limiting their replacement and controlling their disposal.

The availability of a reusable system, with a multi-purpose cargo bay, able to carry modular payloads and perform robotic in-orbit operations, will be an important asset for the future exploitation of space.

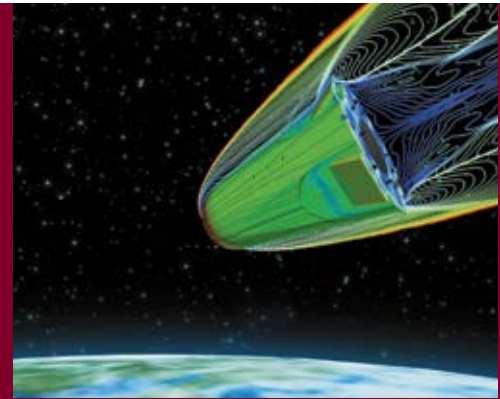
Considering the extensive efforts in this direction already taking place in several spacefaring nations, including the latest developments of classified spaceplanes, such as the X-37 in the United States and the Shenlong in China, the consolidation of an affordable roadmap to prepare similar vehicles is of strategic importance for Europe.



Hermes was a spaceplane concept proposed by the French space agency CNES in 1975 and developed by ESA through the 1980s. The project was cancelled in 1992



ESA's Atmospheric Reentry Demonstrator (ARD) was launched in 1998 on an Ariane 5 from Europe's Spaceport and made a pinpoint splashdown in the Pacific Ocean



ESA's European Experimental Reentry Testbed (Expert), a wingless reentry vehicle designed as a testbed for gathering aerothermodynamic flight data

In the 1990s, the development of atmospheric reentry enabling technologies started with the Hermes programme and continued within the Manned Space Transportation Programme, the Atmospheric Reentry Demonstrator (ARD), the X38/Crew Return Vehicle, the Expert and the several basic ESA research and technology preparatory programmes (the Technology Research Programme and General Support Technology Programme). In the early 2000s, several European studies were initiated to define experimental vehicle concepts for the inflight verification of enabling atmospheric reentry systems and technologies.

In 2002, a comprehensive assessment was made of all existing proposals for experimental vehicles in Europe, to harmonise ESA and national efforts (such as France, Germany and Italy). This assessment was made against technical and programmatic requirements provided by ESA's Directorates of Launchers and Human Spaceflight. Driven by ESA with the involvement of national agencies, it identified commonalities and synergies among vehicles, determined critical areas, provided recommendations for planning European inflight experimentation activities.

The result was a large European consensus on a preferable progressive inflight demonstration plan to limit the risks,

to allow progressive investment efforts and to ensure that more sophisticated developments built on previous achievements. This provided the ground for setting up such a programmatic 'roadmap' within ESA's short-term activities.

The first step of the roadmap in this direction dates back to 2005, with the start of the Intermediate eXperimental Vehicle (IXV) mission definition in ESA's Future Launchers Preparatory Programme (FLPP). The design of the IXV system was conceived as an advance from the ARD flown in 1998, increasing the system performance and verifying the critical atmospheric reentry technology in a reentry corridor that was wider than that for classical quasi-ballistic capsules.

Therefore, the IXV mission and system are being developed as the 'intermediate' step of a technology-effective and cost-efficient European development of a future operational system with limited risks for Europe.

IXV is currently in manufacturing, integration and testing, heading for a launch campaign in mid-2014. Because of the progress of these IXV activities, early reflections on the next step have already started in Europe. In particular, ESA has performed a preliminary parametric assessment of potential

“

**The roadmap: progressive in-flight demonstration steps to limit risks and cost.**

”





The Boeing X-37 began as a NASA project in 1999, before being transferred to the US Department of Defense in 2004 (USAF)



The drop-test mock-up of the NASA/ESA/DLR X38/Crew Return Vehicle, a prototype lifting body vehicle for returning crews from the ISS (NASA)



The Chinese Shenlong 'Divine Dragon' Test Platform, a delta-winged spaceplane, which reportedly made a first suborbital flight in January 2011 (CJDBY.net)

IXV mission evolutions using the ESTEC Concurrent Design Facility, while the Italian space agency (ASI) and Italian aerospace research centre (CIRA) jointly with Japan's space agency have performed concepts studies based on the CIRA Unmanned Space Vehicle heritage.

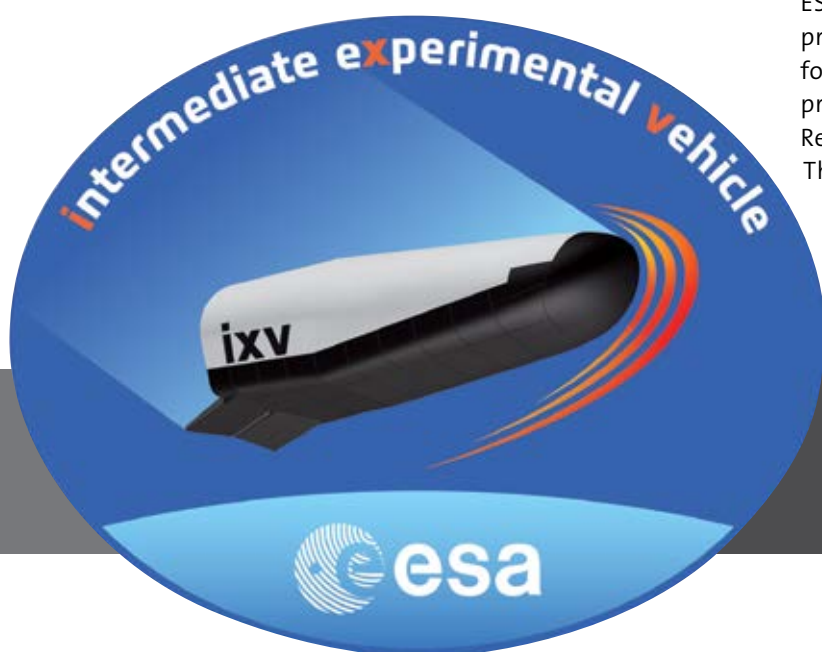
With the birth of ESA's Programme for a Reusable In-orbit Demonstrator for Europe (PRIDE) at the Ministerial Council in 2012, the consolidation of the programmatic roadmap will continue to be pursued with the start of the Innovative Space Vehicle (ISV) mission definition. ISV builds on IXV, by increasing the system performance and demonstrating a reusable operational system capable of multiple robotic in-orbit operations.

The ISV mission and system will be implementing development philosophies similar to the IXV that have proven to be effective and efficient, securing industrial technological results while containing the programme cost-at-completion.

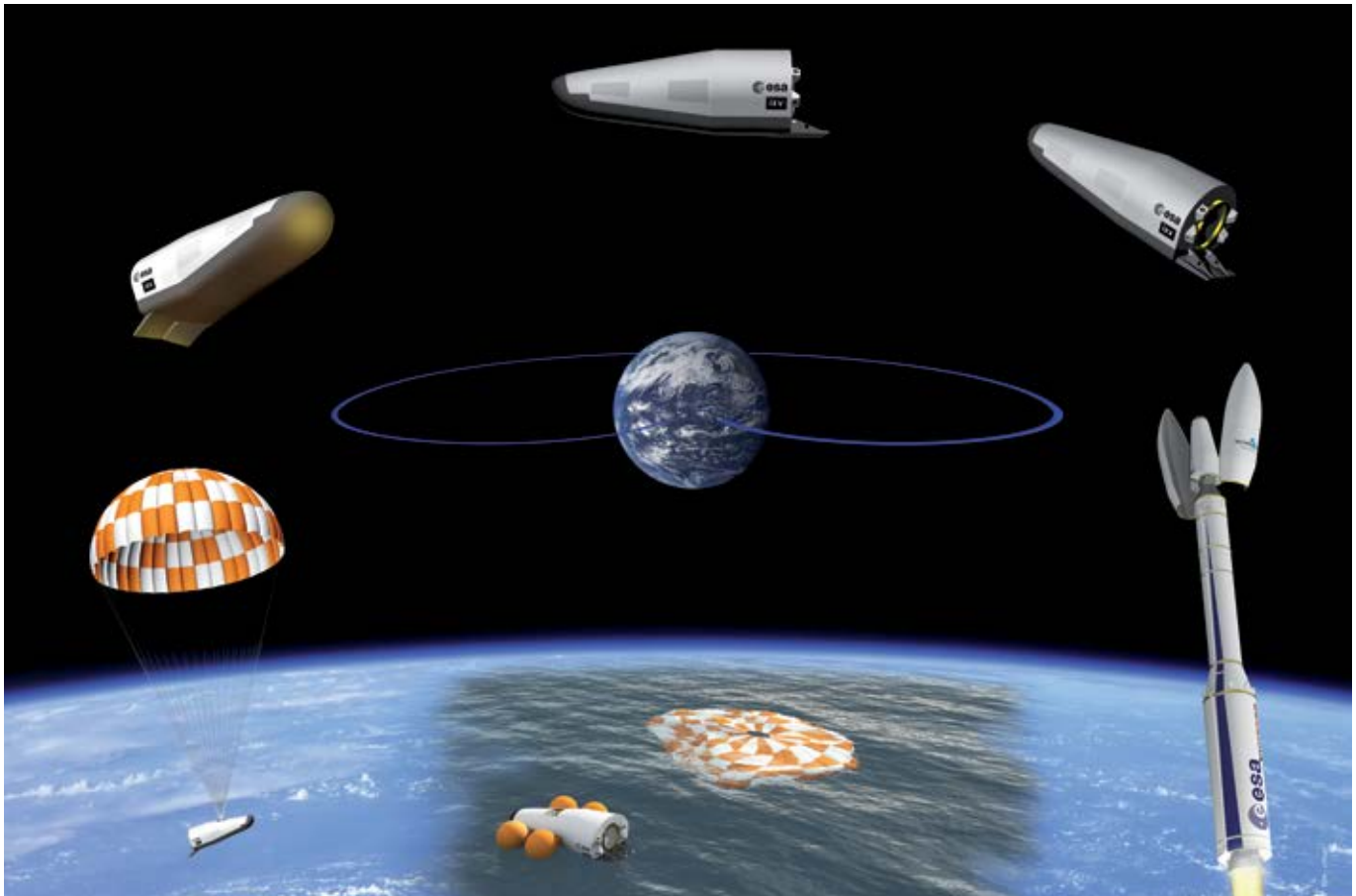
With the objective to ensure the affordability of such a roadmap for Europe, the global planning of the IXV/ISV activities sets its financial resources to around €25–30 million per year, equivalent to less than 1% of ESA's annual budget.

## Steps to enable controlled return from orbit

The activities on the IXV started with the detailed industrial trade-off performed among all existing proposals for experimental vehicles in Europe, including ESA and national concepts, against ESA technical and programmatic requirements. The concept down-selected for the IXV was a lifting body, derived from the data provided by previous studies on the ESA Atmospheric Reentry Experimental Vehicle (AREV) and the CNES PRE-X. This coordinated the available European technical and financial resources, and ensured a single harmonised product for Europe.



Intermediate eXperimental Vehicle (IXV) project logo: IXV's mission definition began in ESA's Future Launchers Preparatory Programme in 2005



↑ The main phases of IXV flight

## IXV high-level requirements

The IXV was designed to fulfil a set of inflight demonstration and experiment requirements, iteratively discussed and jointly defined by ESA with industry and research institutes. The IXV mission was defined as:

- performing for the first time for Europe a flight representing a return from low Earth orbit, with a lifting system capable of travelling large downrange and crossrange distances, controlled with a combination of rockets and aerodynamic surfaces;
- performing for the first time for Europe the inflight verification of reentry and reusable technologies integrated at system level and inflight conditions fully representative of a return from low Earth orbit;
- carrying out the experimental part of the mission over unpopulated areas, to ensure safety on the ground, and to recover the vehicle intact for post-flight inspection and analysis;
- launching on an ESA Vega rocket to ensure an end-to-end European mission at limited cost.

## IXV mission description

The IXV mission trajectory will be equatorial to comply with the minimisation of the experimental flight over inhabited regions, and the maximisation of the Vega launcher performance and the safety of its stages as they are jettisoned.

The impact points of Vega's first and second stages are positioned in the Atlantic Ocean, while those of the third and fourth stages in the Indian Ocean.

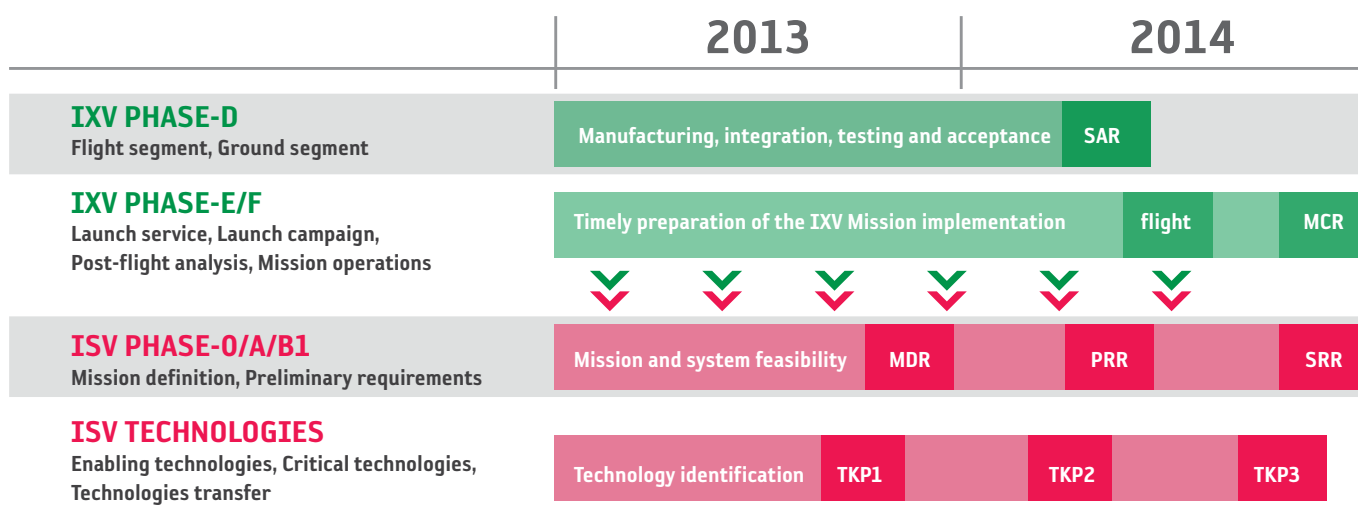
The IXV's maximum altitude is set above 400 km, to provide an entry velocity on impact with the atmosphere of 7.5 km/s and a flight path angle of  $-1.2^\circ$ , fully representative of atmospheric reentry missions from low Earth orbit.

The IXV will fly through the atmosphere from hypersonic to supersonic flight regimes, controlled by propulsive rockets and aerodynamic flaps, acquiring a large set of experimental data, transmitting the data to a dedicated network of ground stations, until deployment of the parachute for a soft landing and recovery in the Pacific Ocean.

The nominal trajectory is complemented with the uncertainties and dispersions of the different parameters



## → IXV/ISV INTEGRATED PLANNING



obtained through Monte Carlo mathematical simulations. There are no islands present inside the footprint of the maximum reachable area in a case of failure, fulfilling the major mission safety requirement.

### IXV technological objectives

Technological objectives are met by flying a large number of experiments chosen from a wide range of European proposals. The main areas of investigation are in thermal protection systems, aerodynamics and aerothermodynamics, guidance navigation and control, and flight dynamics.

Since each experiment required a specific set of measurements, several synergies and commonalities were exploited to identify a global set of sensors covering all experimental requirements. Sensors were split into conventional (37 pressure ports, 194 thermocouples, 12 displacement sensors, 48 strain gauges) and advanced (infrared cameras).

Extensive post-flight analysis is planned, fulfilling the IXV inflight demonstration and experiment requirements, with the objective of a measurable reduction of current uncertainties for future system designs. The analysis

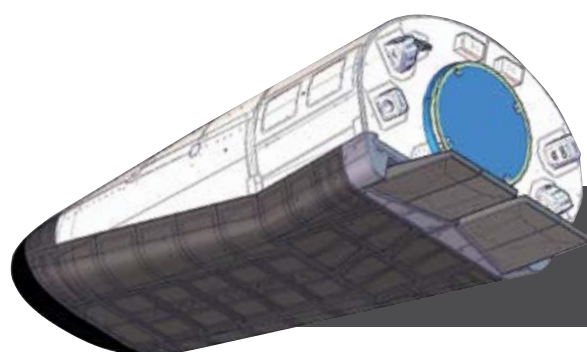
will look at three different levels: Level-0 and Level-1 will focus on the reconstruction and verification of the system and subsystem performances, with a first assessment of experiment results; Level-2 will focus on the full exploitation of the flight data, for the disciplines and technologies under demonstration and experimentation, by a dedicated Data Exploitation Working Group.

### IXV flight segment

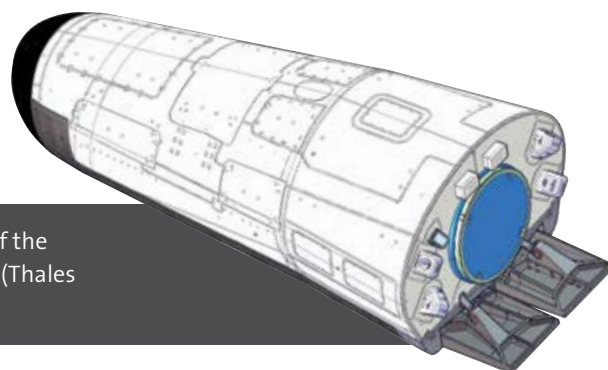
The IXV flight segment includes the vehicle and its ground support equipment (for example, mechanical, electrical, fluid systems). The vehicle configuration is based on a 'lifting body' shape with a length of about 5 m, 2.2 m wide and 1.5 m high. This shape has a lift-to-drag (L/D) ratio of approximately 0.7 in the hypersonic flight regime.

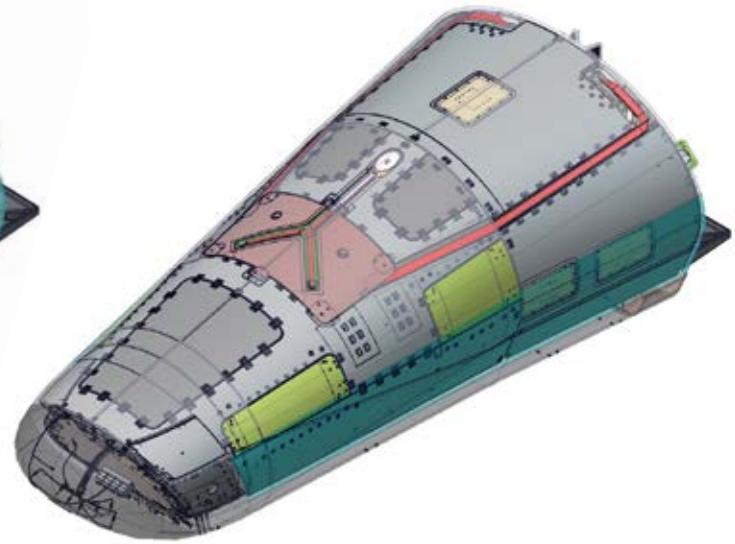
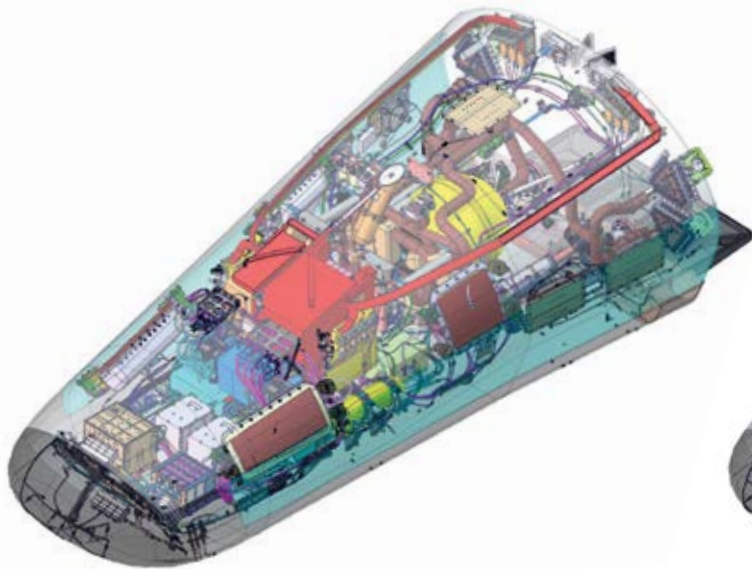
The thermal protection and hot structures architecture is based on ceramic materials for the nose, windward, hinge and body flaps, and ablative material for the lateral, leeward and base areas.

In particular, the nose and windward areas are protected by carbon/silicon carbide ceramic matrix composite skins



Top and bottom views of the IXV 'lifting body' design (Thales Alenia Space)





↑ Layered views of IXV inner subsystems configuration, internal structure and outer thermal protection (Thales Alenia Space)

with lightweight ceramic insulation (alumina/silica). Specific attachments made of superalloy bolts, flexible stand-offs, ceramic thermal barrier washers and ceramic fibres seals.

The hinge and body flaps are based on a different carbon/silicon carbide ceramic matrix composite (Keraman®), providing highly integral components complying with combined thermal, mechanical and vibration loads, interfaces and mass constraints.

The lateral, leeward and base areas are protected by ablative thermal protection system, with an external coating providing antistatic properties and proper thermo-optical characteristics. The ablative tiles are bonded on the cold structure with an epoxy-based structural adhesive.

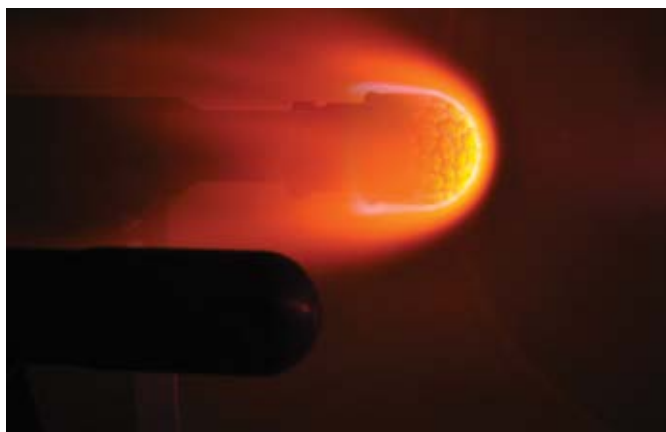
The cold structure of the vehicle is built with carbon-fibre reinforced plastics (CFRP). The matrix of the composite is a

high-temperature resin, selected to be able to withstand the high temperature reached by the structure during the reentry.

The design is compliant with the challenging Vega launcher requirements on stiffness, and mission requirements on strength induced by the sea-landing impact loads.

The avionics are composed of three subsystems: power, data handling and radio telemetry, connected by dedicated sets of harnesses. The power subsystem is based on a 28 V main bus, making best use of off-the-shelf units, with protected outputs, performing DC/DC conversion to 55 V for the Inertial Measurement Unit, with a dedicated pyrotechnic section.

The data-handling subsystem provides vital layer and experimental data acquisition, storage, recording and real-time and delayed transmission. The radio telemetry

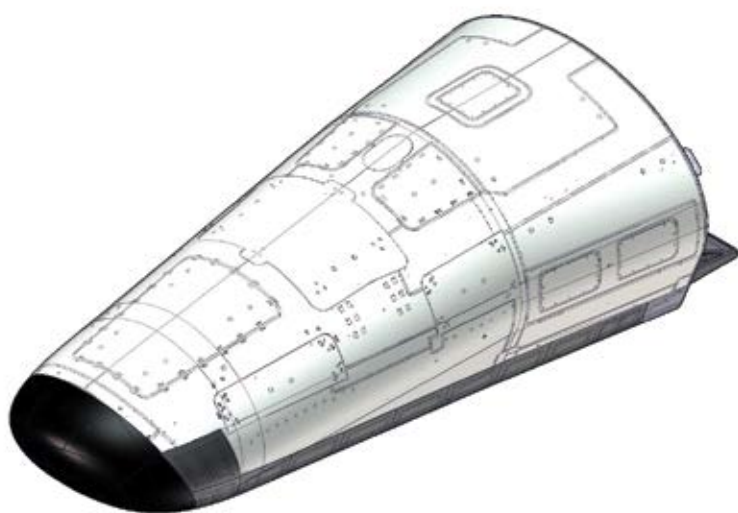


↑ IXV ablative materials testing (Avio)



↑ IXV nose thermal protection (Herakles)





subsystem uses two independent chains, one for layer telemetry and one for experiments. It implements frequency and polarisation diversity techniques for maximum coverage and data download capability, and relies on optimised positions of the antennas.

Flight is controlled by four 400 N reaction thrusters and two aerodynamic body flaps. The thrusters, inherited from the Ariane 5 SCA attitude control system, are at the base of the vehicle to control the attitude around three axes during the orbital phase, and yaw during atmospheric reentry.

The flaps are also located at the base of the vehicle for trim during the reentry phase, on the longitudinal axes through symmetrical deflections, and on the lateral axes through unsymmetrical deflections. The flaps are moved by two electromechanical actuators, whose technology is derived from the Vega Zefiro thrust vector control system.

The descent and recovery phase calls on two dedicated subsystems: parachutes for descent and flotation devices for recovery. The descent subsystem is based on a four-stage parachute with consolidated technology, including one supersonic pilot chute, one supersonic ribbon drogue, one subsonic ribbon drogue and one ringsail main parachute.

The recovery subsystem is also based on consolidated technology, and includes inflation devices (gas bottles, valves and hoses) and flotation devices (balloons).

The success of the IXV descent and landing phases is of utmost importance for the recovery of the vehicle and the experimental data. Data are also recorded on board as a back-up in case of telemetry failure during the mission.



↑ IXV parachute test in Arizona (Pioneer)

Since multiple failures have occurred within these phases in past national and international experiment programmes, robustness in the design and verification methods should secure the successful recovery of the vehicle and the data.

In particular, a series of specific tests at systems and subsystems level are being performed in addition to the standard qualification approach.

Water splashdown attitude verification tests are being made at the INSEAN marine engineering institute in Rome. Parachute subsystem qualification tests have been made at the Yuma Proving Ground in Arizona, USA, and descent and landing system tests have taken place at Poligono Interforze Salto di Quirra, Sardinia.

## IXV ground segment

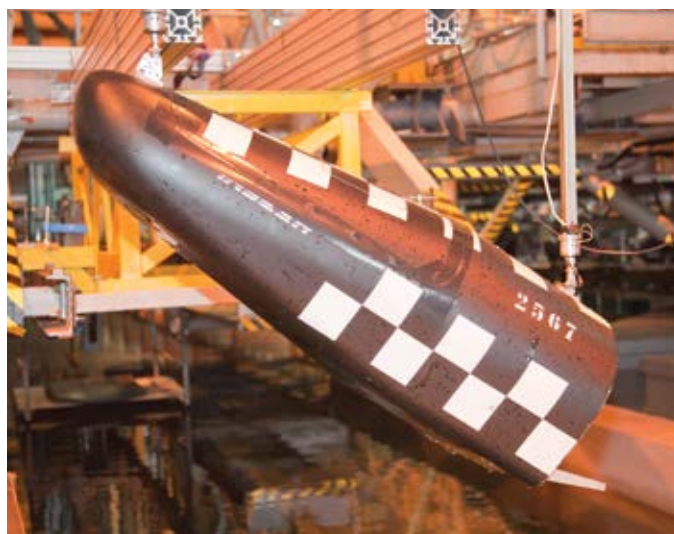
The IXV ground segment includes the Mission Control Centre in Turin, ground stations in Libreville, Malindi, Tarawa and on the recovery ship, the Launch Control Centre in Kourou and the communications network. The Mission Control Centre will provide the infrastructure, systems, tools and applications for telemetry monitoring, data storage, data processing, data displaying, trajectory prediction and ground segment operations coordination. Ground stations will enable the flight-to-ground communications, vehicle tracking, telemetry reception, recording and transmission in real time and offline mode to the Mission Control Centre.

The communications network will provide the infrastructure to allow communication between the Mission Control Centre, the ground Stations, and the Vega launch site in Kourou. The ground segment network connections will provide telemetry data, trajectory data, voice and video (the latter for the recovery ship only), for Malindi via the Network Control Centre at Fucino in Italy, and for Libreville, Tarawa and the recovery ship via Inmarsat.

## Upcoming challenges

Since the completion of the Critical Design Review in 2011, the IXV Phase-D industrial activities are progressing with the manufacturing, assembly, integration and tests of all flight segment and ground segment elements. These will lead to the launch of a mission into space in the middle of 2014.

To make a timely start on the launch campaign, the procurement of the IXV Phase-E/F activities will start by the second quarter of 2013 at the latest. These activities



↑ IXV splashdown test prototype in Rome (INSEAN)



↑ IXV Mission Control Centre in Turin (ALTEC)

relate to launch services, logistics and transportation, launch and mission operations, for example, and include:

- Vega launcher procurement with associated services benefiting from the VERTA launch opportunity;
- IXV flight segment, ground support equipment and ground-segment elements shipping worldwide (from Europe to Kourou, Libreville, Tarawa, Pacific Ocean);
- implementing the launch campaign up to countdown, setting up a joint ESA/industry team, to include Vega/IXV mating and integrated testing, ground segment installation, verification and operations;
- mission operations for the launch, flight telemetry acquisition, IXV tracking and recovery operations and transportation of IXV to the post-flight processing facilities;
- post-flight analysis, with level-0 for the preliminary assessment of the mission accomplishment, and level-1 for the detailed assessment of flight and ground segment performance and anomalies, if any;
- an elaboration of 'Lessons Learned', with synthesis of the findings related to system, technologies, operation, safety and standards aspects, for direct implementation into the ISV design phases.

## Innovative Space Vehicle (ISV)

In line with the process followed for the IXV concept down-selection, a detailed industrial trade-off exercise will be performed among all available concepts to choose the most suitable for the ISV design baseline, ensuring once again a single harmonised product for Europe.





↑ Overview of the IXV mission, showing ground track and location of main mission elements

## The step to multiple in-orbit applications

ISV will be designed to provide a multipurpose payload bay and to be capable of deorbiting and gliding back to Earth with high manoeuvrability and controllability through all flight regimes from hypersonic down to subsonic. It will be able to make a safe and precise landing on a conventional runway.

Taking into account inputs from payload end-users, the multipurpose payload bay will be able to integrate a number of modular payloads to fulfil multiple mission objectives. Early proposals for payload capabilities include deploying future-generation cooperative satellites, servicing and controlled disposal, Earth observation, microgravity experiments and high-altitude atmospheric research.



↑ The ESA IXV team with IXV descent and landing test prototype (Thales Alenia Space/CIRA/APCO)

## Mission description

The ISV operational mission will include the full spectrum of orbital altitudes and inclinations in low Earth orbit, compatible with the performance of the Vega launcher and its potential evolutions.

The ISV demonstration mission will use a Vega launcher for injection into a circular orbit, at an inclination and an orbital lifetime to be defined according to the mission objectives and payloads.

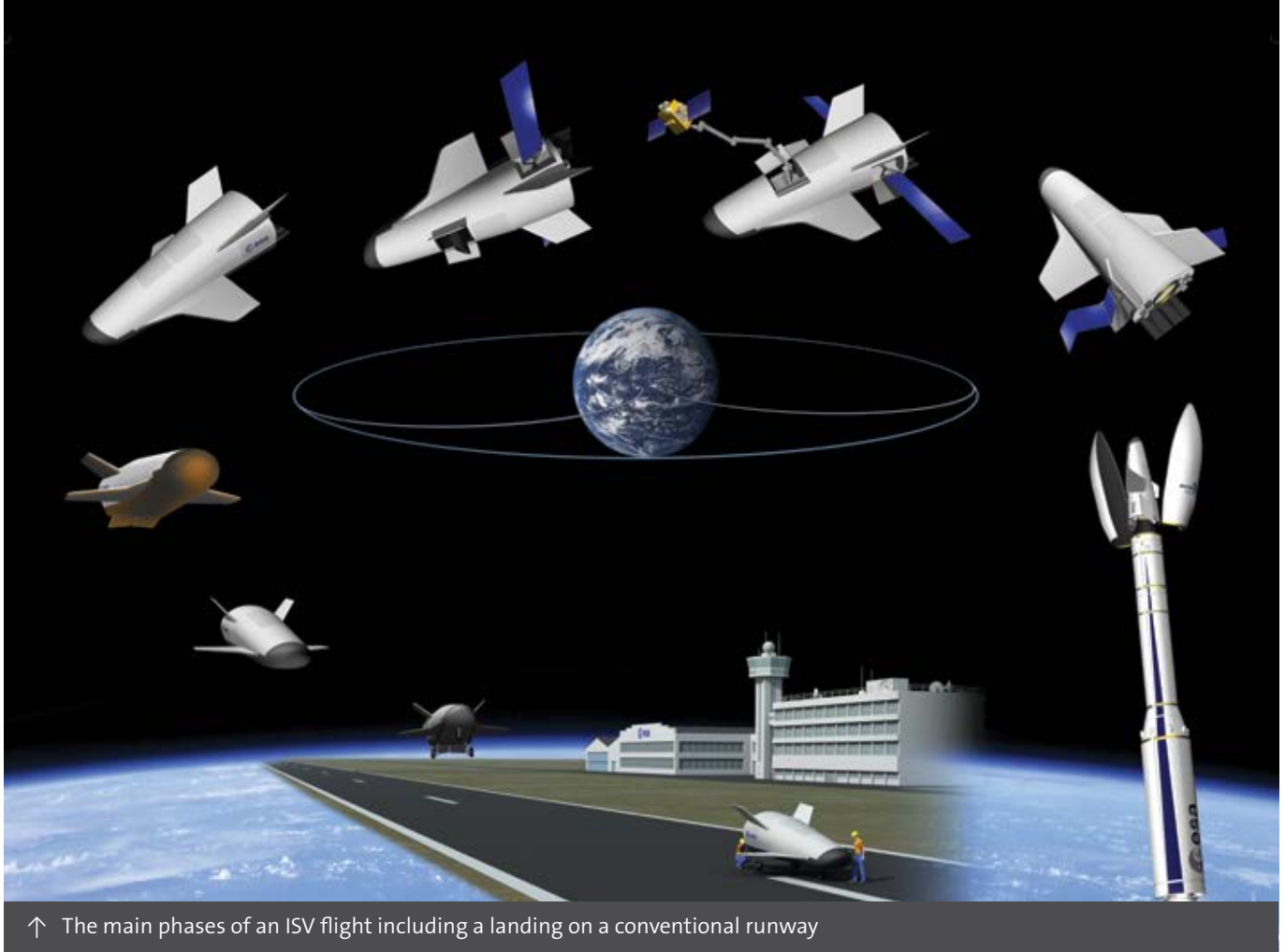
## Main ISV challenge

To ensure affordability and foster competitiveness with alternative expendable solutions, ISV will be based on a small orbital system, either fully or partially reusable to allow reuse of expensive components, whose limited dimensions will minimise refurbishment cost. This will also limit programme risks by building on a consolidated technological basis.

The limited development, production and operational costs of ISV will be achieved by building on the system and technological knowhow acquired through the IXV experience, implementing all the necessary design innovations (for example, accommodating a multipurpose cargo bay, safe and precise ground landing capabilities, introducing effective end-to-end guidance and control techniques), maximising the use of Commercial Off The Shelf items and the technology transfers from other space and non-space applications (such as avionics and aeronautical mechanisms, micro-electronics, optical-link electronics), challenging hardware miniaturisation and reusability.

The hardware miniaturisation will drive the system dimensions, mass and consequently launch service costs,





↑ The main phases of an ISV flight including a landing on a conventional runway



↑ Two potential ISV mission scenarios: Earth observation and satellite servicing/controlled disposal

while the hardware reusability, associated with the reduced dimensions to avoid complex refurbishment scenarios and infrastructures, will provide a system with limited life-cycle turnaround costs.

The ability to combine the minimum launch service cost and the minimum vehicle refurbishment cost for multiple in-orbit applications will be the main challenge for ISV, to remain competitive with alternative expendable solutions.

### National and international cooperation

Although PRIDE is conceived as a self-standing ESA programme, the cooperation with European partners will be fostered to the maximum possible extent, optimising the use of the available technical and financial resources in Europe. In particular, ESA looks with interest at ASI/CIRA studies already performed on the subject, therefore, a joint ESA/ASI Strategic Committee is being planned, which will federate potential national in-kind contributions from Italy.

Cooperation with international partners will also be fostered, in particular with Japan, on the basis of the shared programme objectives, identification of mission and system requirements, and distribution of industrial work, for implementation in the development phase. ■



## → 2012 IN PICTURES

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



**8 January**

One of a series of photos of the Moon and Earth's atmosphere as seen from the ISS taken by the new Expedition 30 crew which included ESA's André Kuipers (ESA/NASA)



**28 March**

ATV *Edoardo Amaldi* approaches the ISS for docking in this photo taken by NASA astronaut Don Pettit. It shows the ATV thrusters firing and, in the background, the airglow phenomena and cities illuminated at night (ESA/NASA)



**March**

Engineers complete the dish of ESA's new deep space antenna in Malargüe, Argentina (ESA/CONAE)







**13 February**

ESA new small launcher Vega lifts off on its maiden flight from Europe's Spaceport in French Guiana (ESA/CNES/Arianespace/Optique Video CSG)

1 July

ESA astronaut  
André Kuipers  
returns to Earth  
after 193 days in  
space



2 July

The main antenna  
of the Gaia billion-  
star surveyor is put  
through its paces in  
the test facility at  
EADS CASA, Madrid,  
ahead of launch this  
year (Astrium)

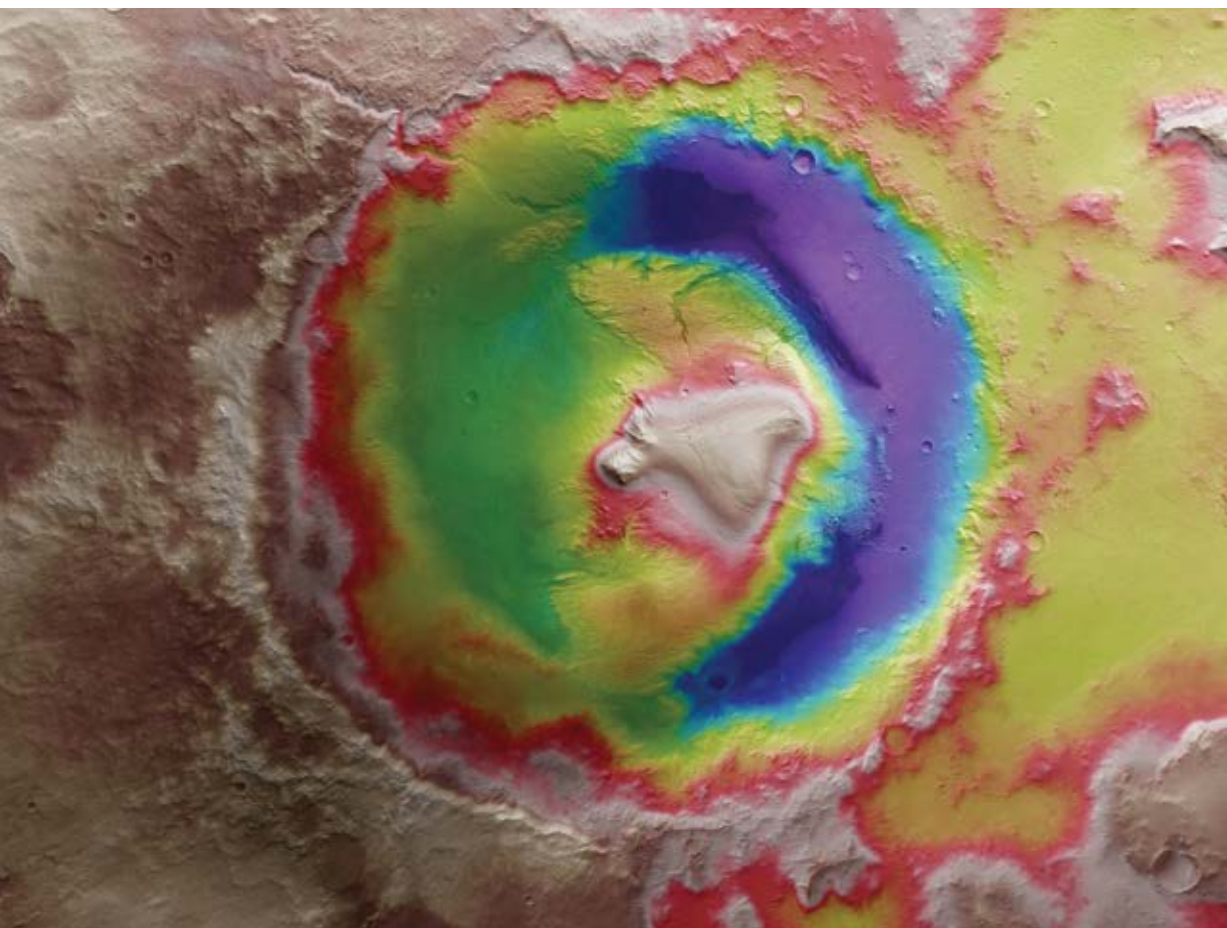






**5 July**

MSG-3, the latest satellite in Europe's Meteosat Second Generation series, lifts off on an Ariane 5 from Europe's Spaceport in French Guiana. The satellite will ensure that Europe and Africa continue to receive up-to-date weather coverage (ESA/CNES/Arianespace/Optique Video CSG)



**6 August**

Mars Express had an important role in monitoring the spectacular delivery of Curiosity to the martian surface, but the ESA spacecraft had already provided crucial information that led to refinements of the rover's landing – elevation data, seen here in this colour-coded view of Gale Crater (ESA/DLR/FU Berlin)

**17 September**

The second Meteorological Operational satellite (MetOp-B) is launched from the Baikonur Cosmodrome, Kazakhstan. MetOp-B will ensure the continuity of the weather and atmospheric monitoring service provided by its predecessor MetOp-A (Eumetsat)



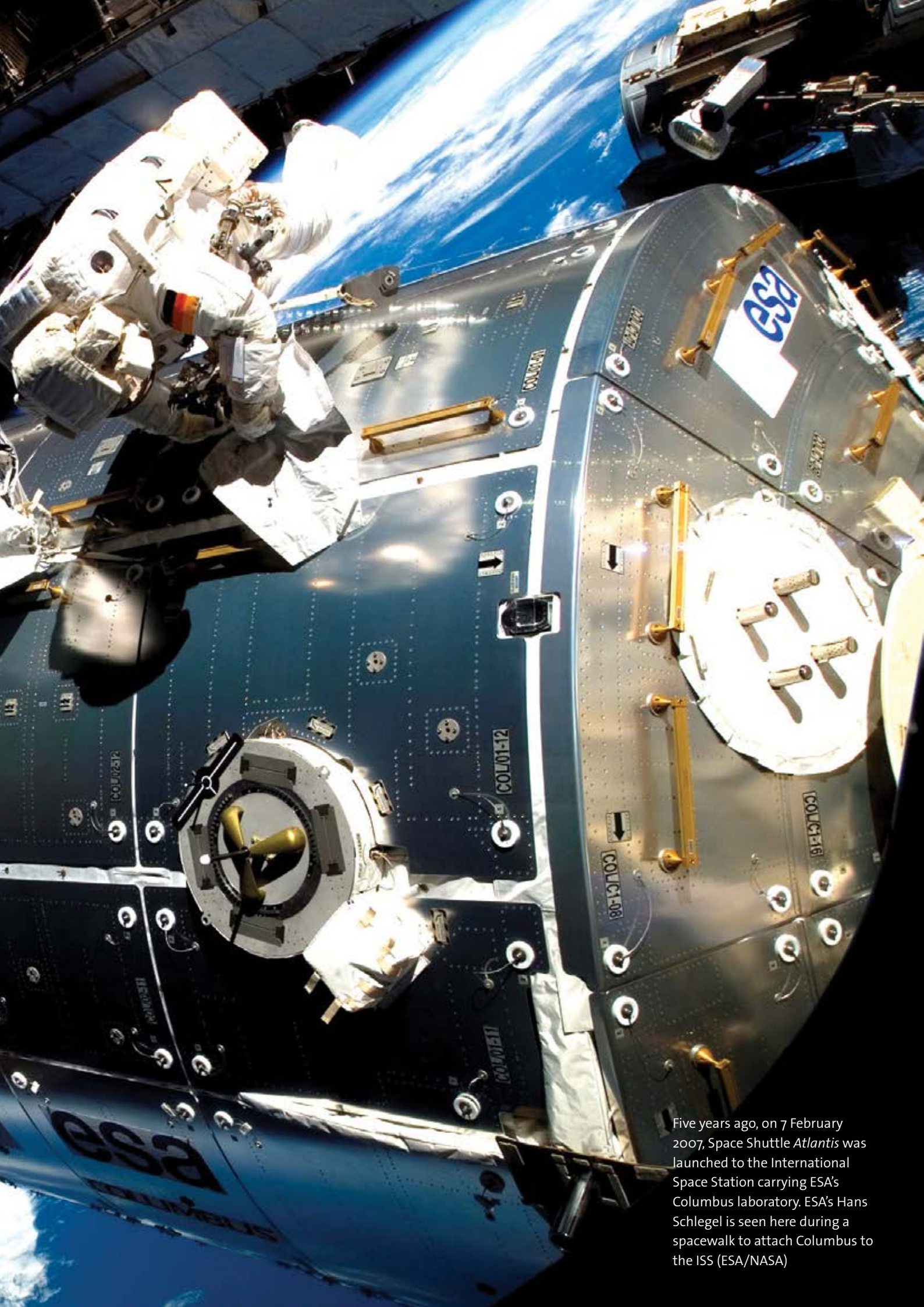




A photograph of the Space Shuttle Columbia in orbit above Earth. The shuttle is oriented vertically, with its nose pointing towards the top of the frame. The orbiter is attached to the external tank and solid rocket boosters. The Earth's blue and white clouds are visible at the bottom of the frame. A yellow banner with the text "→ NEWS IN BRIEF" is overlaid on the lower left portion of the image.

**→ NEWS IN BRIEF**





Five years ago, on 7 February 2007, Space Shuttle *Atlantis* was launched to the International Space Station carrying ESA's Columbus laboratory. ESA's Hans Schlegel is seen here during a spacewalk to attach Columbus to the ISS (ESA/NASA)



# New tracking station



↑ The inauguration ceremony at Malargüe (ESA/CONAE/D. Dubrowsky)

ESA's new deep-space tracking station at Malargüe, in Argentina, was inaugurated on 19 December by Julio de Vido, Argentina's Minister of Federal Planning, Services and Public Investment.

ESA's Director of Human Spaceflight and Operations Thomas Reiter and Director of Science and Robotic Exploration Alvaro Giménez Cañete attended the event.

Once in regular service early this year, Malargüe station will support ESA

science missions such as Mars Express, Venus Express, Rosetta and, in the future, Gaia, BepiColombo, ExoMars, Solar Orbiter, Euclid and JUICE.

The agreement to build and exploit the station was signed with Argentina in 2009. ESA will make 10% of the antenna time available to Argentina for their national scientific projects.

Argentina's Comisión Nacional de Actividades Espaciales (CONAE) is responsible for coordinating Argentinian use of the station.

# NASA joins Euclid mission

**NASA has officially joined ESA's Euclid mission, a space telescope designed to investigate the mysterious natures of dark matter and dark energy.**

To be launched in 2020, Euclid's 1.2 m-diameter telescope and two scientific instruments will map the shape, brightness and 3D distribution of two billion galaxies covering more than a third of the whole sky and looking back over three-quarters of the history of the Universe.

Scientists hope to solve key problems in our understanding of the evolution and fate of our expanding cosmos: the roles played by 'dark matter' and 'dark energy'. Dark matter is invisible, but has gravity and acts to slow the expansion. Dark energy, however, seems to be accelerating the expansion seen around us today.

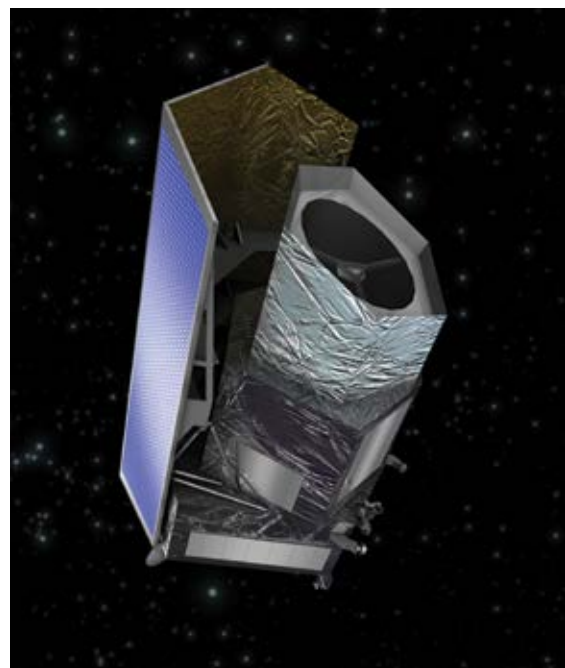
Together, these two components are thought to comprise more than 95% of the mass and energy of the Universe, with 'normal' matter and energy making up the remaining

small fraction. But what they are remains a profound mystery.

NASA recently signed a Memorandum of Understanding with ESA outlining its contribution to the mission. The US agency will provide 20 detectors for the near-infrared instrument, which will operate alongside a visible-wavelength camera. The instruments, telescope and spacecraft will be built and operated in Europe.

NASA has also nominated 40 US scientists to become members of the Euclid Consortium, who will build the instruments and analyse the science data returned from the mission. The consortium already includes almost 1000 scientists from 13 European countries and the US.

"ESA's Euclid mission is designed to probe one of the most fundamental questions in modern cosmology, and we welcome NASA's contribution to this important endeavour, the most recent in a long history of cooperation in space science between our two



↑ Euclid

agencies," said Alvaro Giménez Cañete, ESA's Director of Science and Robotic Exploration.

"NASA is very proud to contribute to ESA's mission to understand perhaps the greatest science mystery of our time," said John Grunsfeld, associate administrator for NASA's Science Mission Directorate.



# Space network to go ahead

The design of Europe's data relay satellite system – EDRS – has been completed and approved. This marks the moment when it moves ahead with a green light from its first customer, the Global Monitoring for Environment and Security initiative from the European Union (GMES).

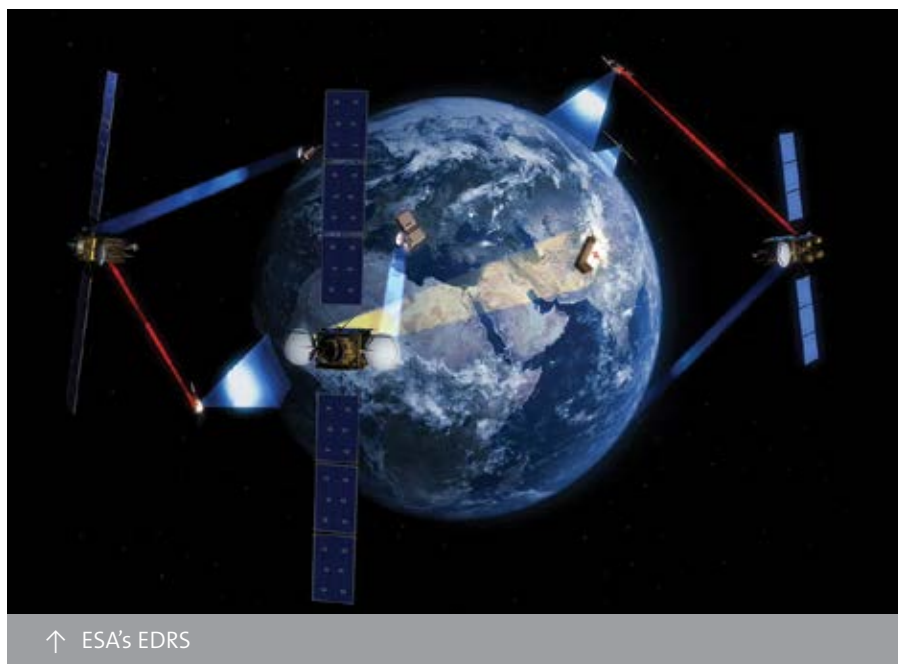
EDRS will provide a telecommunications network that is fast, reliable and seamless, making real-time information from satellites available on demand. EDRS will be the first commercially operated data relay system to deliver services to the Earth observation community.

It is being built through a Public–Private Partnership (PPP) between ESA and Astrium Services, using payloads carried by two satellites in geostationary orbit, hovering 36 000 km above the Equator, where their speed matches Earth's rotation.

Data transmitted from satellites in lower orbits to either of these EDRS payloads can then be relayed to the ground. The payload includes a laser terminal developed by TESAT of Germany to transmit up to 1.8 gigabits per second over distances in excess of 40 000 km, between the lower satellites and EDRS in geostationary orbit.

The first of the two EDRS payloads will be carried on the Eutelsat-EB9B satellite, starting operation in 2014, built by Astrium and positioned at 9°E over the Equator.

The second satellite, planned for launch in 2016, will carry the second EDRS payload as well as the Hylas-3 payload from the UK's Avanti Communications. This satellite will be built by Germany's OHB using the Small GEO platform, currently under development by OHB under ESA contract.



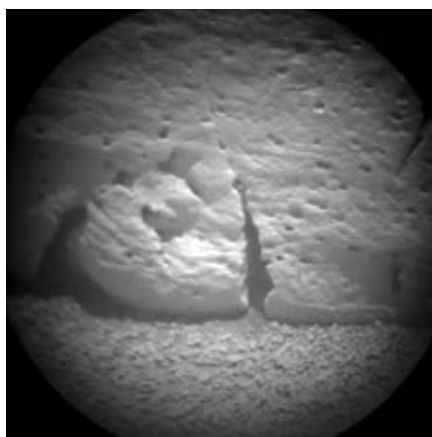
## Expressing curiosity

**For the first time, ESA's Mars Express orbiter has relayed scientific data from NASA's Curiosity rover on the Red Planet's surface, in a small but significant step in interplanetary cooperation between space agencies.**

Early on the morning of 6 October, Mars Express looked down as it orbited the planet, lining up its lander communication antenna to point at Curiosity far below on the surface. For 15 minutes, the NASA rover transmitted scientific data up to the ESA satellite.

A few hours later, Mars Express slewed to point its high-gain antenna toward Earth and began downlinking the precious information, including detailed images, to the European Space Operations Centre in Darmstadt, Germany, via ESA's 35 m-diameter antenna in New Norcia, Australia.

The data were immediately made available to NASA's Jet Propulsion Laboratory in California for processing and analysis, proving again that Europe's veteran Mars orbiter can still work with NASA's new rover.



The information relayed by Mars Express included interesting images acquired on 4 October by Curiosity's ChemCam Remote Micro-Imager camera of 'Rocknest', an area where Curiosity stopped for a month to perform its first mobile laboratory analyses on soil scooped from a small sand dune (NASA/JPL-Caltech/LANL/CNES/IRAP)



ATV-4 team photo  
after connecting the  
Integrated Cargo  
Carrier and the Service  
Module in January





# Filled up for space

One of the most reliable and complex spacecraft ever built in Europe is set for another trip to the International Space Station. Named after the famous physicist, *ATV Albert Einstein* is the fourth Automated Transfer vehicle and it is being made ready to lift off from Europe's Spaceport in French Guiana this summer.

Europe's space freighter plays a vital role in Station logistics: it serves as cargo carrier, storage facility and 'space tug'. Launched on an Ariane 5, the objectives of this mission are to deliver 6.6 tonnes of cargo and maintain the Station's orbit for six months.

*ATV Albert Einstein* will carry more dry cargo than any ATV to date. The spacecraft is being well loaded to keep the Station and its permanent crew of six working at full capacity. Its pressurised module is now completely full with bags, reaching its own volume limits for the first time. Also for the first time, its two water tanks are filled with more than 500 litres of drinking water for the astronauts.

The 20-tonne vehicle will navigate on its own in low-Earth orbit and dock automatically with the Space Station a week or so later. Once attached, more than three tonnes of propellant delivered by *ATV Albert Einstein* will refuel the Russian module of the Station.



Mating of ATV-4 Cargo Carrier and Service Module in progress

Teams in Kourou and in Europe are busy with several tasks in parallel, working up to three shifts per day – weekends included – to ready *ATV-4* for flight. "Each ATV is really its own single adventure, nothing is routine in it," says *ATV-4* Mission Manager Alberto Novelli.

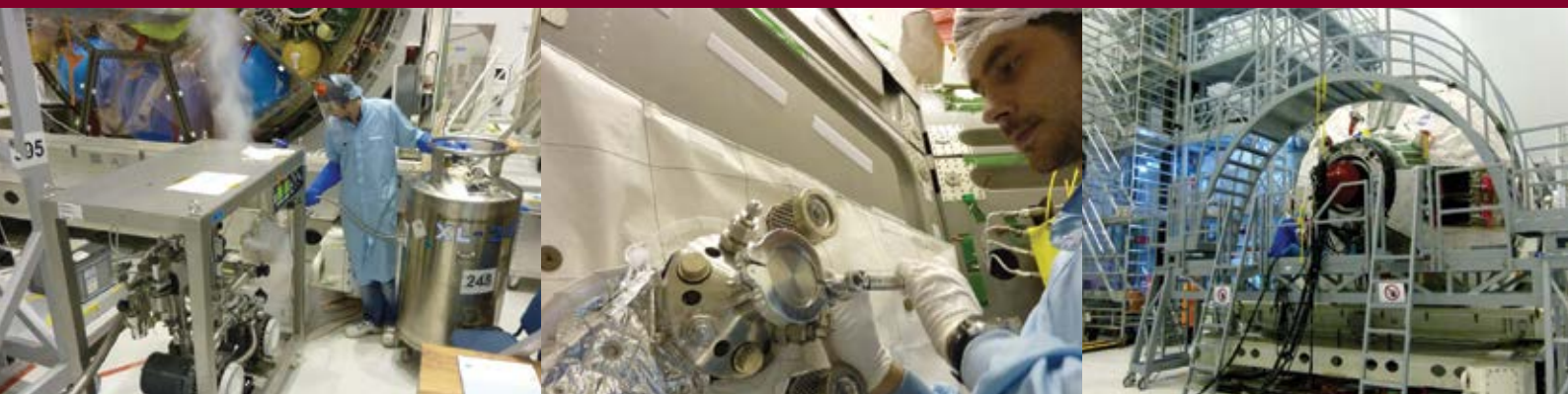
*ATV* is becoming more flexible. A few weeks before launch, a new 'Late Cargo Access Means' lift will be used to load larger and heavier bags through the spacecraft's front hatch with the



Fyodor Yurchikhin and Luca Parmitano training for ATV operations at EAC, Cologne

Station's last-minute needs. "We are much more reactive in bringing up every kind of cargo and exploiting in full *ATV*'s capabilities," says Novelli.

ESA's *ATV* has become a unique resource for the orbital outpost. Not only does it have the largest cargo capability of all currently visiting vehicles, but also it is the only one that is truly operated trilaterally. Europe, USA and Russia are cooperating closely to make this mission the fourth success for *ATV*.



Left, checking for leakages in the refuelling system; centre, installing a test adaptor on the Cargo Carrier; right, the Cargo Carrier ready for mating (Astrium)



The background image shows the BepiColombo spacecraft in the Large Space Simulator at ESTEC. The spacecraft is a complex structure with various instruments and antennas, suspended by cables in a large, dark, cylindrical chamber. The lighting is dramatic, highlighting the metallic surfaces and the intricate details of the spacecraft. The text is overlaid on the left side of the image.

# → PROGRAMMES IN PROGRESS

**Status at February 2013**

BepiColombo in the Large Space  
Simulator at ESTEC in February

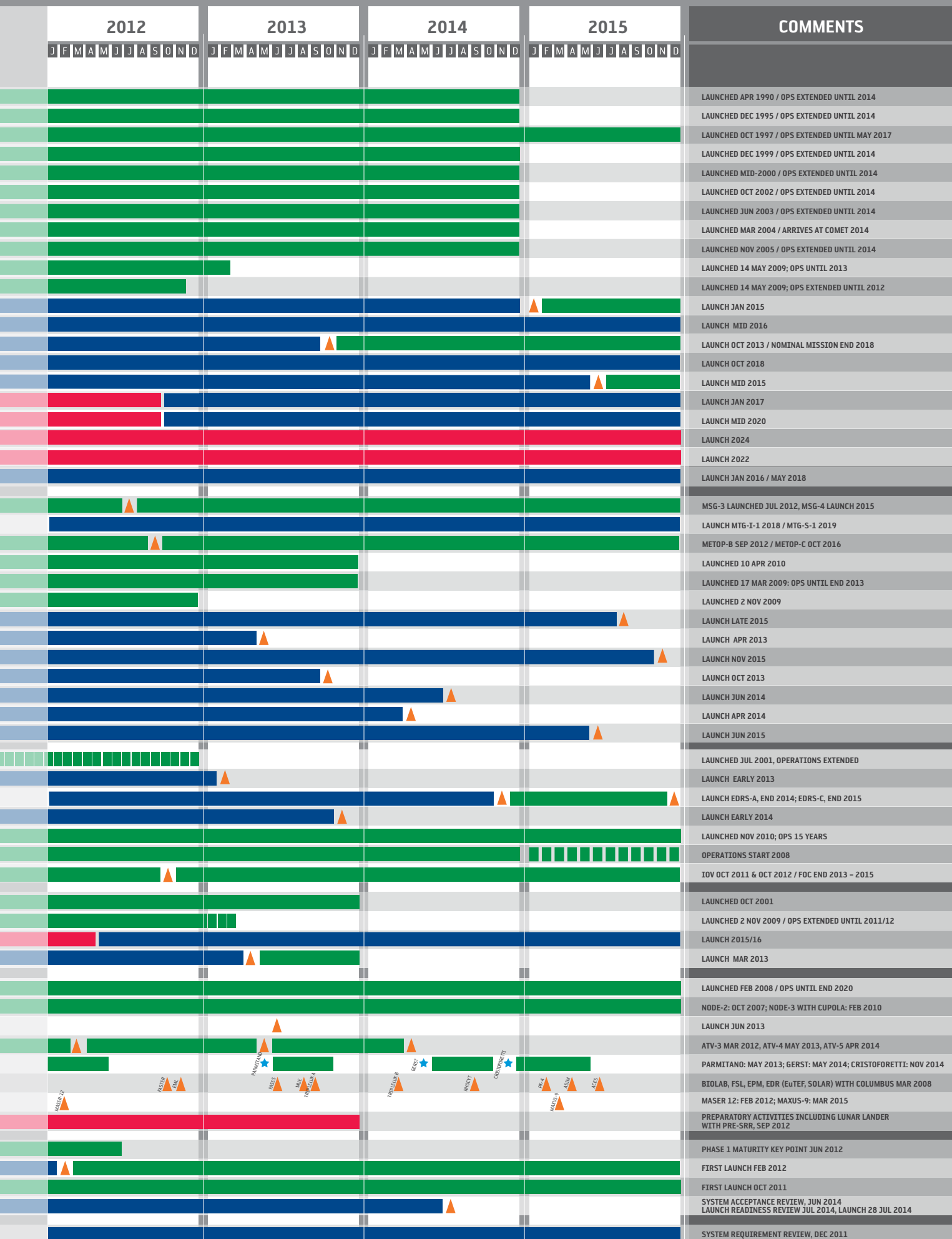












## KEY TO ACRONYMS

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

## → HUBBLE SPACE TELESCOPE

Using Hubble, the Spitzer Space Telescope and one of nature's 'zoom' lenses, astronomers have found what is probably the most distant galaxy yet seen in the Universe. The object offers a peek back into a time of 13.3 billion years when the Universe had only reached 3% of its present age.

We see the newly discovered galaxy, named MACS0647-JD, as it was 420 million years after the Big Bang. Its light has travelled for 13.3 billion years to reach Earth. Along

the way, eight billion years into its journey, the massive galaxy cluster MACS J0647.7+701 has bent the galaxy's light along multiple paths. Because of this 'gravitational lensing' effect, the astronomers could observe three magnified images of MACS0647-JD with Hubble.

The cluster's gravity boosted the light from the faraway galaxy, making the images appear far brighter than they otherwise would, although they still appear as tiny dots in Hubble's portrait. The object is so small it may be in the first stages of formation, with analysis showing the galaxy is less than 600 light-years across. Our Milky Way is 150 000 light-years across.

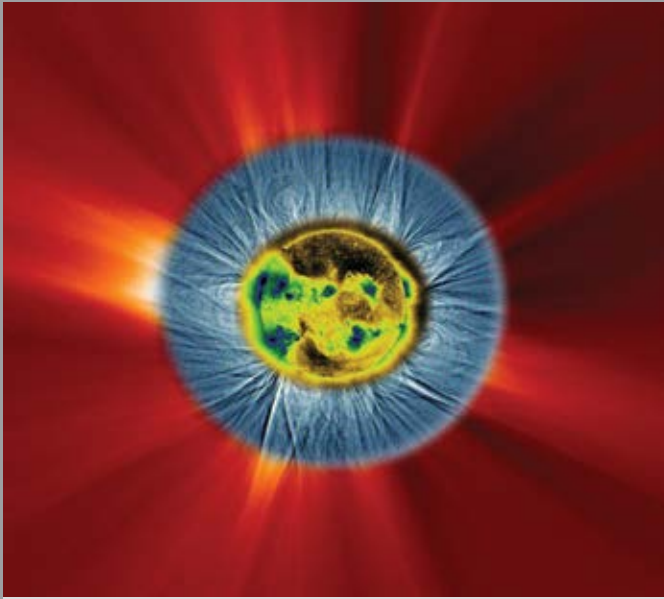
The team spent months systematically ruling out all other alternative explanations for the object's identity before concluding that it is the distance record holder. This was important, because nearby objects (such as red stars, brown dwarfs and old or dusty galaxies) can mimic the appearance of an extremely distant galaxy. MACS0647-JD may be too far away for any current telescope to confirm the distance with spectroscopy.

The galaxy will be a prime target for the James Webb Space Telescope, scheduled for launch in 2018, which will be able to make a definitive measurement of its distance and study its properties in more detail.



This Hubble composite image shows the newly discovered galaxy MACS0647-JD. The inset shows a close-up of the young dwarf galaxy. Astronomers used the massive galaxy cluster MACS J0647.7+7015 as a giant cosmic telescope. The bright yellow galaxies near the centre of the image are cluster members (NASA/ESA/STSI/CLASH)





The false-colour Sun image in the centre was taken by SOHO's EIT instrument. It shows emission produced by the two-million-degree hot plasma in the Sun's inner corona. The bluish reconstructed white-light image was taken by J.M. Lecomte, Queensland. Here it is inserted inside SOHO's red LASCO instrument data (J.M. Lecomte & S. Koutchmy/ Institut d'Astrophysique de Paris/CNRS/CNES/ESA/NASA)

## → SOHO

Total solar eclipses offer unique opportunities to study the solar corona, the Sun's outermost atmosphere, in detail from the ground. A composite image shows the latest eclipse, was visible from northern Queensland, Australia, in the early morning of 14 November 2012. It combines an image from the ground with data from SOHO and shows the magnetic field connection between the solar disk and the coronal structure, including the more outer parts stretched out by the action of the solar wind.

## → CASSINI-HUYGENS

Saturn's moon Titan appears to have a miniature version of Earth's River Nile. The extraterrestrial twin river was spotted on a radar image from Cassini. The river valley stretches more than 400 km from its 'headwaters' to a large sea, and likely contains hydrocarbons, most likely a mixture of methane and ethane in a liquid phase, as suggested by the very smooth surface. This is the first time images have revealed a river system this big and in such high resolution

Titan's own 'River Nile' (NASA/JPL-Caltech/ASI)



anywhere beyond Earth. The image was acquired in September 2012, on Cassini's 87th close flyby of Titan.

The river valley crosses Titan's north polar region and runs into the sea called Ligeia Mare, one of the hydrocarbon seas in the high northern latitudes of the moon.

## → XMM-NEWTON

Astronomers have discovered a new bright X-ray source in the Andromeda galaxy, our nearest spiral galaxy neighbour. Using ESA's XMM-Newton X-ray space observatory the source was identified as a black hole. It contains a few times the Sun's mass and accretes matter at a very high rate. Astronomers were able to study the emission from the black hole's accretion disc, at X-ray wavelengths, and from its jets, in radio waves. For the first time for an extragalactic stellar-mass black hole, the link between the black hole's X-ray brightening and the ejection of radio-bright material from the vicinity of the black hole into the jets was revealed. It seems to have a big appetite as its accretion rate is very close to the maximum allowed by accretion physics.

## → INTEGRAL

Astronomers using Integral detected the first direct signature of titanium-44 in the remnant of supernova SN 1987A in the Large Magellanic Cloud, 25 years after its explosion. Before now, titanium-44 had only been seen in one other supernova remnant, Cassiopeia A. Supernovae and their remnants are unique laboratories to study how the heavier elements are formed once the bigger stars have burned all their hydrogen and reach temperatures high enough to start nuclear fusion of heavier elements before finally collapsing and exploding. The amount of titanium-44 found in the famous SN 1987A shows that it is the titanium-44 decay that has been powering the supernova for the last 22 years.

PSR B0540-69



SNR 1987A

LMC X-1

The sky surrounding the remnant of supernova 1987A seen in hard X-ray energies by Integral. The image is based on data collected in the 65–82 keV band, which includes two of the emission lines produced during the radioactive decay of the isotope titanium-44 at 67.9 and 78.4 keV. Also seen are two other bright sources of high-energy emission, the black hole binary LMC X-1 and the pulsar PSR B0540-69 (ESA/Integral/IBIS-ISGRI/S. Grebenev)

## → MARS EXPRESS

Last October, science data acquired by the NASA Curiosity rover were for the first time relayed by Mars Express. The data consisted of a set of two close-up images of a target nicknamed 'Rocknest3', taken by the Remote Micro-Imager on Curiosity on 4 October 2012.

On 18 December, ESA's new tracking station in Malargüe, Argentina, received and relayed a Mars Express Visual Monitoring Camera (VMC) image to mark the station's formal inauguration and the symbolic transmission of 'first data'.

The Mars Express radio-science experiment uses a technique called radio occultation, which can be applied when the spacecraft disappears behind the planet, as seen from Earth. As the radio signals that are transmitted between the spacecraft



Images from XMM-Newton in 2012 show the discovery of a new source, XMMU J004243.6+412519. On 7 January, the new source is not yet visible. The source was first detected on

15 January and can be seen in the upper part of the frame. Ten days after its discovery, XMMU J004243.6+412519 underwent a dramatic brightness boost, as seen on 31 January (MPE/ESA)



and Earth pass through the martian ionosphere, they reveal information about how the concentration of electrons varies with altitude. A recent paper in *Geophysical Research Letters* shows that the vertical structure of the day-side ionosphere of Mars is more variable and more complex than previously thought. A second paper reports on new results about the structure and variability of the night-side ionosphere, which is less well known.

## → VENUS EXPRESS

The solar wind, the stream of charged particles from the Sun that expand outwards through all of the Solar System, influences the near environment of all the planets. The effect is markedly different on planets with an internal magnetic field, like Earth or Jupiter, compared to those without such a field, like Venus or Mars. The intensity of the solar wind varies with the sunspot cycle with a period of about 11 years.

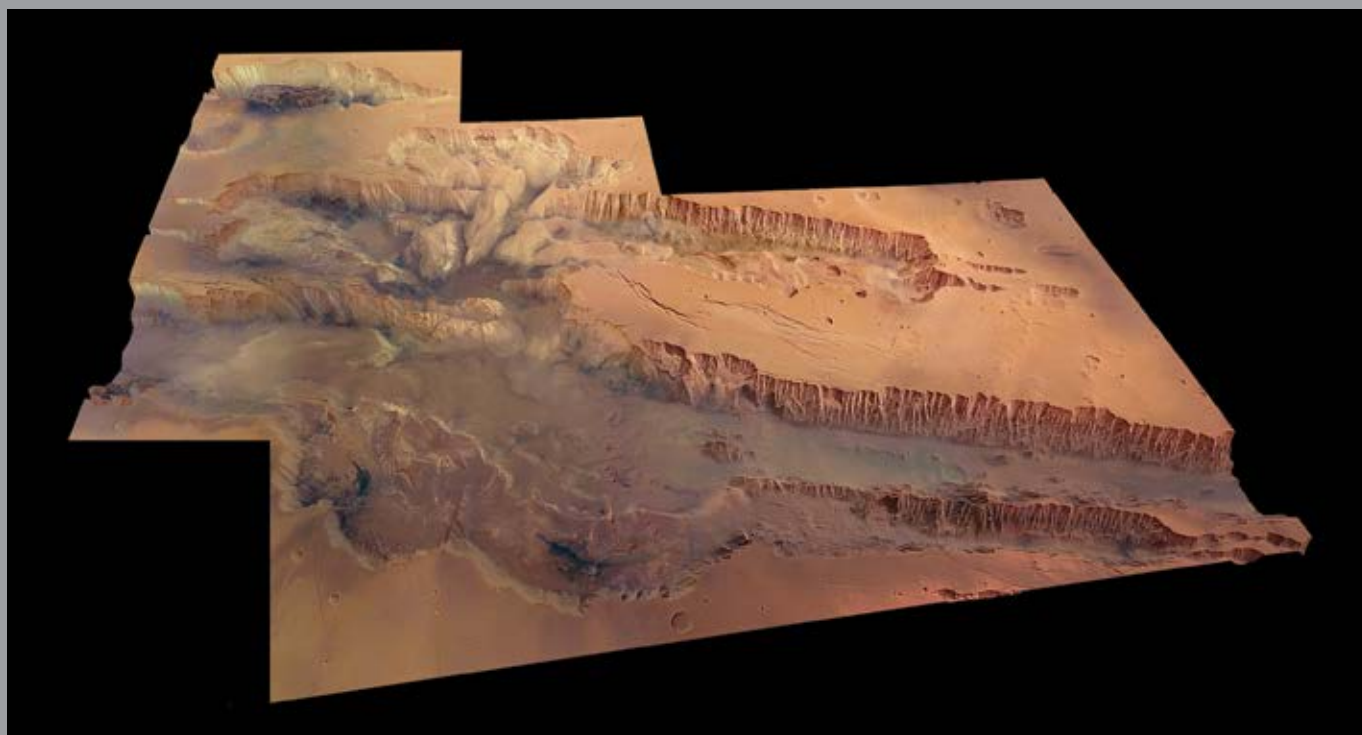
A strong intrinsic magnetic field causes a large 'bubble' to appear around the planet and the interaction between the solar wind and the planetary ionosphere (the uppermost part of the atmosphere where the air molecules and atoms are largely ionised by the solar ultraviolet radiation) takes place high above the surface of the planet.

For planets without a magnetic field, an artificial induced field is formed by a complex interplay of the solar wind, the heliospheric magnetic field and the planetary atmosphere. This creates a small 'bubble' and allows the solar wind to come much closer to the planet. For Venus, the ionosphere is confined within this bubble at a distance of some hundreds of kilometres above the surface on the day side and somewhat more on the night side.

New measurements from Venus Express show that at specific periods when the solar wind has been unusually weak, this has resulted in a very inflated induced magnetosphere, and ionospheric ions have been detected at much larger distances from the planet than normal.

On the night side, in the 'tail' region, the ionosphere extends up to at least a full Venus radius (6050 km) above the surface of the planet. This shows how important the solar wind and its variability are to the near environment of the planets.

These findings give new clues to how and how much atmospheric gases can escape from the planet into the interplanetary space. Atmospheric escape is a major factor in the evolution of the life of planets and is an important field studied by planetary scientists.



This bird's-eye view of the Solar System's grandest canyon Valles Marineris was created from data captured over 20 orbits of ESA's Mars Express. In near-true colour and with four times vertical exaggeration, a variety of geological features can be seen, reflecting the complex geological history of the region. Over 4000 km long, 200 km wide and with a dizzying

depth of 10 km, it is ten times longer and five times deeper than Earth's Grand Canyon. The canyon's formation is likely to be intimately linked with the formation of the neighbouring Tharsis bulge, out of shot to the left of this image and home to the largest volcano in the Solar System, Olympus Mons (ESA/DLR/FU Berlin)

## → COROT

The mission appears to be over. On 2 November 2012, after almost six years in orbit, the second data processing unit stopped working. With the first unit failing in 2009, this second failure means the detector can no longer send data obtained by the telescope to the spacecraft computer for transmission to the ground. The fault was probably caused by particle hits sustained when the satellite passed through the South Atlantic Anomaly, a part of Earth's radiation belts with an unusually high density of high-energy particles. It has not been possible to reset or repair the unit.

Designed for around two years of operation and launched on 27 December 2006, the mission has racked up a long series of scientific successes. These include the discovery of the first terrestrial exoplanet outside our Solar System, CoRoT-7b. Another important discovery was the first detection of acoustic oscillations in red giant stars, allowing high-precision characterisation of the physical parameters of such stars.

COROT's scientific teams have so far found around 35 previously unknown exoplanets that, because of the high precision obtained with this spacecraft, are among the best characterised. These include two Neptune-sized planets, CoRoT-24b and 24c orbiting the same solar-type star.

Because of its unique precision and many discoveries, the mission had just been extended for a second time for three years. COROT is leaving an important legacy and future missions, such as Cheops or PLATO now being studied by ESA, will all benefit from its pioneering results.

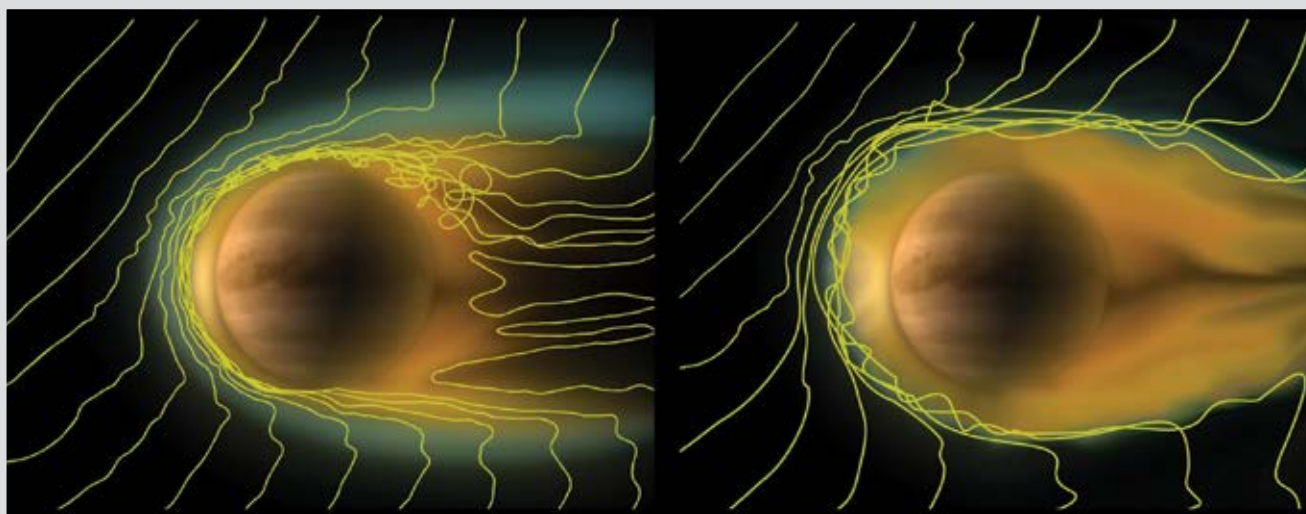
## → HERSCHEL

Scientific observations will continue until Herschel runs out of its superfluid helium coolant, which is predicted to occur sometime in March 2013. Following tests of various spacecraft systems, Herschel will be injected into a heliocentric orbit where it will remain indefinitely.

Herschel science data will continue to be a vital scientific asset generating new knowledge for decades to come. Re-use of archival Herschel data is already taking place. A recent example addresses one of Herschel's main scientific questions: what is the history of star formation over the entire history of the Universe?

Herschel has been performing photometric surveys for galaxies in various 'fields' on the sky. Galaxies that are seen at Herschel's far-infrared wavelengths produce copious amounts of stars, hundreds and even thousands more than our own galaxy does today. But Herschel photometry alone does not provide accurate information about when in the history of the Universe the stars in these 'infrared-bright' galaxies formed.

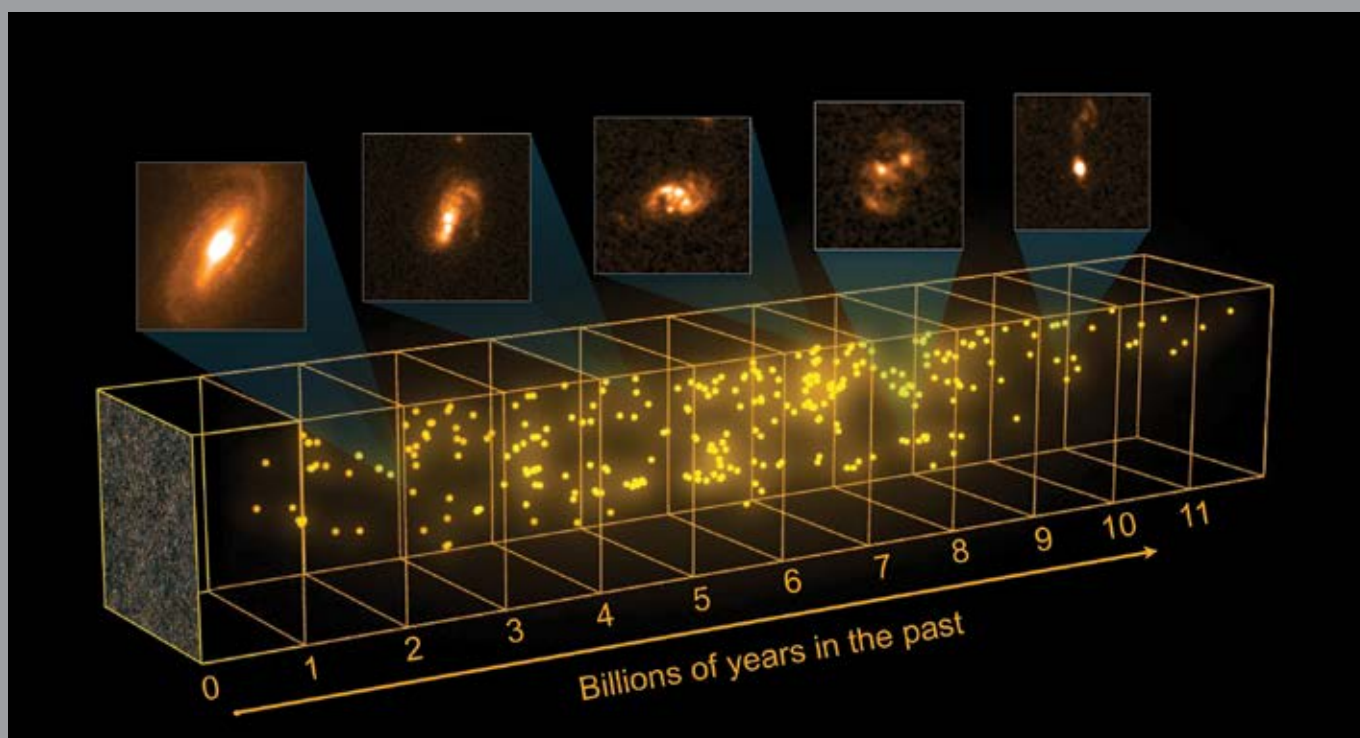
In a recent observing campaign astronomers have used the two 10 m Keck telescopes on Mauna Kea, Hawaii, to measure spectroscopic 'redshifts' of galaxies detected by Herschel that produce stars at a rate more than one hundred times that of our own. Almost 800 accurate redshifts have been obtained, allowing the observers to determine the duration that the light has been travelling since its emission in the source galaxies until observed by Herschel and Keck. This is called the 'lookback time', which tells us when in the history of the Universe these galaxies looked the way we see them today.



Left, the shape and size of the ionosphere and the magnetic bubble of Venus during normal solar wind conditions. The yellow lines indicate magnetic field lines of the heliocentric magnetic field and show how it is wrapping around the planet

to form the induced magnetosphere. Right, when the solar wind intensity, the size of the induced magnetosphere and ionosphere grows significantly, the ionosphere can extend well into the tail region above the night side of the planet (ESA/MPS)





A new census of infrared-bright galaxies detected by Herschel, with redshifts provided by the Keck telescopes; insets, galaxies as seen Hubble (ESA/Univ. Hawaii/SPIRE/HerMES/NASA)

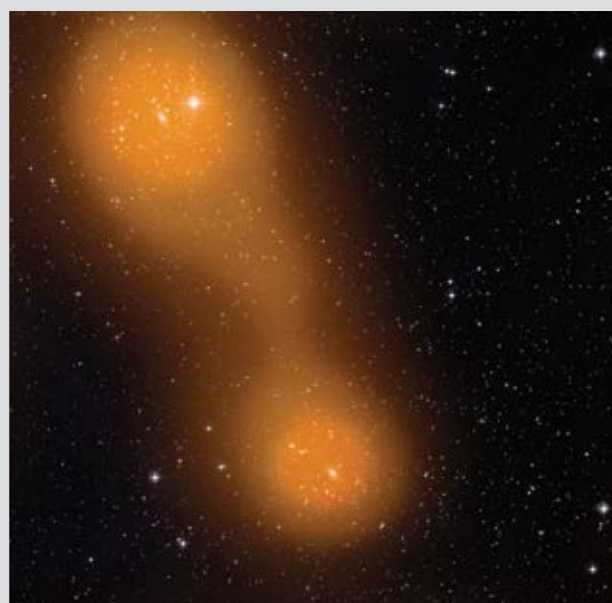
A subset of nearly 300 galaxies from a field on the sky called COSMOS has been plotted in the figure below, showing their 'lookback times', ranging from 2.6 to over 10 thousand million years, at which time the Universe had only a fourth of its present age. For the entire sample it was found that about 5% of them are seen as they were when the Universe was even younger. This work has demonstrated that infrared-bright galaxies form an integral part of the galaxy formation process across a wide range of epochs, particularly for the most recent 10 thousand million years.

## → PLANCK

The Low Frequency Instrument continues to gather observations and is currently completing its seventh survey. ESA agreed to extend the operations to August, which will allow it to complete its eighth (and last) survey of the sky. The currently operating sorption cooler (required to run the LFI detectors at a low temperature) is performing well, and it is now planned to regenerate it (an operation which permits to extend its lifetime) around mid-April 2013. At the end of the mission, Planck will be deorbited from its station around L2 in a manoeuvre that guarantees no return of the spacecraft to the Earth–Moon system for at least 200 years.

ESA and the Planck Collaboration are preparing for the first release of Planck maps and scientific results. Data and papers will be released to the public in March via an

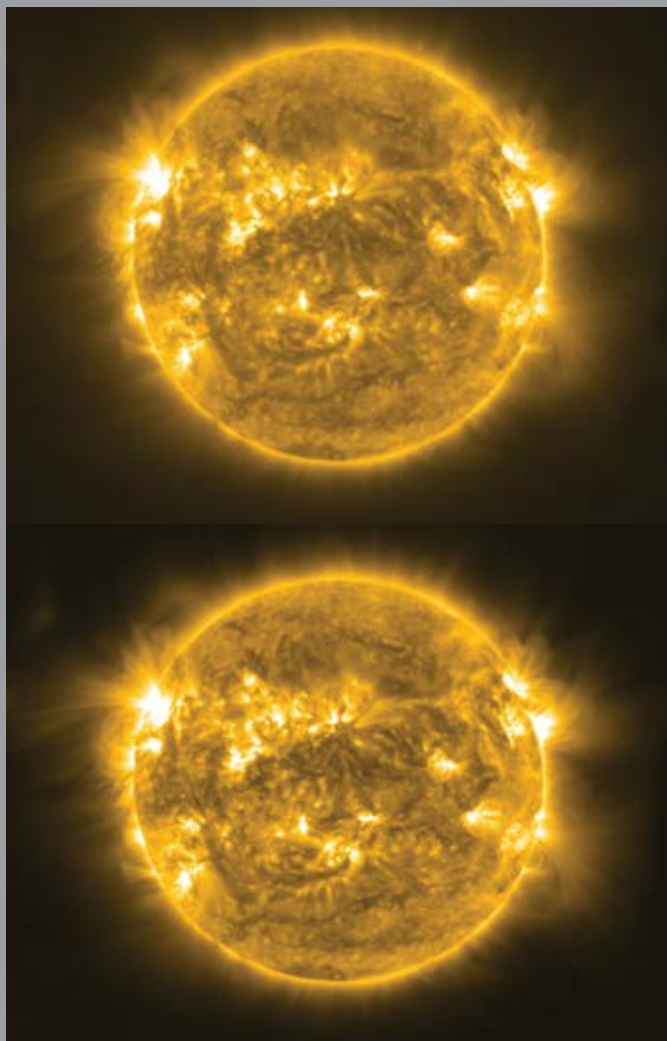
archive developed at ESAC. In April, a conference at ESTEC will showcase the scientific results related to the Cosmic Microwave Background and astrophysical foregrounds. See <http://www.congrexprojects.com/13a11>



Planck has made the first conclusive detection of a bridge of hot gas connecting a pair of galaxy clusters across 10 million light-years of intergalactic space (ESA/Planck Collaboration/STScI)

## → PROBA-2

Proba-2 celebrated its third birthday on 2 November. Since launch, the scientific instruments have acquired a continuous stream of data from our Sun: more than 700 000 solar disk images have been made available to the scientific community in raw and calibrated format, as still images or as movie files; over 1000 files of daily solar irradiance values in the extreme ultraviolet are available, also raw and calibrated. The solar eclipse of 14 November was observed four times as a geometric consequence of the spacecraft orbit. Besides direct scientific data analysis, the shape of the Moon on the solar disk can be used to analyse the in-field stray light of the SWAP imager. The in-field stray light is caused by photons that do not travel directly from the entrance onto a pixel on the detector, but instead are scattered randomly by tiny imperfections in the telescope optics. Once in orbit, it is very difficult to analyse this effect – except with the help of solar eclipses.



Top, a calibrated image from the Proba-2 SWAP camera; bottom, the same image processed by the stray light correction algorithm by D. Seaton (Royal Obs. Belgium) and P. Shearer (Univ. Michigan) showing improved quality

The knowledge of the in-field stray light is used to improve the image quality – which was also the case for SWAP.

## → ROSETTA

The spacecraft reached its most distant point from Earth (6.26 AU) in early December and is now heading toward its rendezvous with Comet 67P/Churyumov-Gerasimenko.

The ground segment was updated to support the approach/rendezvous with the comet and the landing final phase. Operational analyses of the comet phases were refined and a consolidated plan for spacecraft activities established to maintain the planned reference trajectory up to Philae lander delivery in October 2014, for which a viable scenario has been designed. The definition of detailed observation strategies for this mission phase is now under way, together with the definition of the trajectories to be flown during the escort phase after deployment of the lander and the completion of its first science sequence.

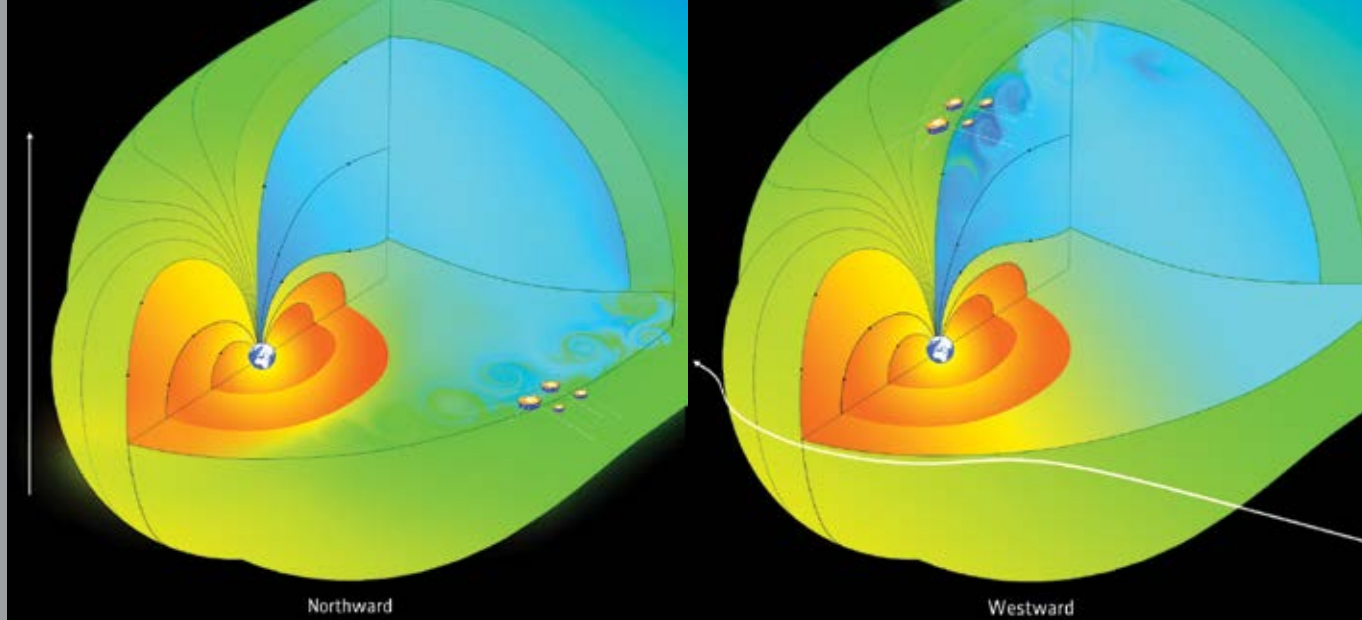
## → CLUSTER

Depending on how the solar wind's interplanetary magnetic field (IMF) is aligned with Earth's magnetic field, different phenomena can arise in Earth's immediate environment. One well-known process is magnetic reconnection, where magnetic field lines pointing in opposite directions spontaneously break and reconnect with other nearby field lines. This redirects their plasma load into the magnetosphere, opening the door to the solar wind and allowing it to reach Earth. Under certain circumstances this can drive 'space weather', generating spectacular aurorae, perturbing GPS signals and affecting terrestrial power systems.

In 2006, Cluster made the surprising discovery that huge, 40 000 km swirls of plasma along the magnetopause could allow the solar wind to enter, even when Earth's magnetic field and the IMF are aligned, in other words when magnetic reconnection should not occur at the nose of the magnetosphere. These swirls were found at low equatorial latitudes, where the magnetic fields were most closely aligned. These giant vortices are driven by a process called the Kelvin–Helmholtz (KH) instability, which can occur anywhere in nature when two adjacent flows slip past each other at different speeds. Examples include waves whipped up by wind sliding across the surface of the ocean or in atmospheric clouds.

Analysis of Cluster data has found that KH waves can also occur at a wider range of magnetopause locations and when the IMF is arranged in other configurations, providing a mechanism for the continuous transport of the solar wind into Earth's magnetosphere. The findings confirm theoretical predictions and are reproduced by simulations. The KH effect





Driving Kelvin–Helmholtz (KH) waves at the magnetopause; left, when Earth’s magnetic field and the interplanetary magnetic field are aligned, KH waves are generated at low latitudes, where the magnetic fields are most

closely aligned; right, when the interplanetary magnetic field is oriented westward or east, magnetopause boundary layers at higher latitude become most subject to KH instabilities

is also seen in the magnetospheres of Mercury and Saturn, and the new results suggest that it may provide a possible continuous entry mechanism of solar wind into those planetary magnetospheres too.

Last autumn, the Cluster spacecraft were separated into the largest configuration so far in the mission, over 20 000 km at the magnetopause, following a Guest Investigator (GI) proposal to investigate large-scale wave generation, such as the KH instability. Inner magnetosphere observations were also made during this period to support the recently launched NASA Van Allen mission. This spring, Cluster will be configured to investigate the nose of the magnetopause for another set of GI observations, along with observations of the auroral regions and high-latitude current systems, leading up to the launch of ESA’s Swarm mission.



Gaia Payload Module Flight Model in final configuration (Astrium SAS)

## → GAIA

The PLM FM Thermal Balance/Thermal Vacuum test was completed at the Centre Spatial de Liège in December. The PLM is now ready for integration on the SM.

The planned retrofits of units on the SM FM were carried out with the completion of the Integrated Subsystem Test programme. The last system tests at SM level are running. The module will be ready for mating with the PLM by the end of January.

The work with the Operation and Science Ground segments is progressing well. The System Validation Test on the AM was completed in November (a total test time of 21 days). The second operation rehearsal (end-to-end test of the Science Ground Segment) took place including the rehearsal of the Gaia optical observation (consisting of an observation

of the Planck spacecraft using a telescope at La Palma and data processing at ESAC/ESOC).

Activities with Arianespace are focused on the preparation of the Final Mission Analysis Review for the spring. Gaia is planned for launch in October

## → LISA PATHFINDER

The cold-gas micropropulsion engineering and procurement activities are proceeding. The qualification status review for the cold-gas thrusters was held in December. Launch lock mechanism development is proceeding and qualification tests at the mechanism supplier level were performed. The complete inertial sensor head QM was integrated with including, among others, the Vacuum Enclosure, the launch lock mechanism and a gold-platinum Test Mass flight spare.

A failure one of the components of the Inertial Sensor Head during mechanical testing of the Electrode Housing was addressed. The baseline launch vehicle is Vega, on the third VERTA launch.

## → BEPICOLOMBO

The mass properties test of the Mercury Transfer Module (MTM) STMs was completed, and only the MTM thermal balance test at 10 Solar Constants remains to complete the STM test programme. The assembly of the MPO FM mechanical and propulsion bus thermal and propulsion hardware was completed at Astrium Ltd, Stevenage, and the spacecraft was packed for delivery. The MTM FM mechanical and propulsion bus is being integrated in Stevenage. System tests on the spacecraft Engineering Test Bench proceeded with the delivery and integration of the MMO EM.

The Principal Investigator teams continue the development of the instrument FMs. Based on STM vibration test results, the sine vibration acceptance test levels have been significantly relaxed for various payload units, and in some cases the qualification test levels were reduced as well. The MMO flight units' acceptance tests are ongoing at JAXA. Installation of the harness and integration of flight units onto the structure are ongoing.

In the ground segment, the spacecraft simulator was delivered. Compatibility tests with the FM transponder and the spacecraft Engineering Test Bench are ongoing.

## → MICROSCOPE

Most of the Myriade standard equipment has been delivered to CNES (Myriade is a microsatellite product line developed jointly by Astrium and CNES). Procurement of the satellite's equipment started. The Equipment Suitability Review of the thrusters took place in October. FM manufacturing began and the PDR of the electronics unit was completed.

## → EXOMARS

For the 2016 mission, the AIT campaign for the Entry, Descent and Landing Demonstrator Module (EDM) SM began and deliveries of the elements of the aeroshell arrived at Thales Alenia Space Italy for planetary protection treatment and mechanical testing. The Trace Gas Orbiter (TGO) is also moving quickly into the hardware phase with the completion of the central tube and principal structural panels. On both modules, models of units for testing in avionics benches are arriving. The first software versions for the TGO and the EDM have been coded and testing started.

For the 2018 mission, industry delivered its Phase-B proposal establishing the planning for this complex study phase where the Russian partners must play an integral part. The Russian contribution of the Descent Module for the 2018 mission places them in the centre of the spacecraft development. The 2018 mission Phase-B study began on 12 December.



The Mercury Planetary Orbiter Flight Model at ESTEC with Structural Thermal Model of the Mercury Transfer Module in the background



Developments continue on the Rover 2 m Drill and Sample Preparation and Distribution System. These are critical developments that have been supported continuously in order to be ready in time for the full development approval. The Pasteur Payload complement within the Analytical Laboratory Drawer (ALD) has been accommodated after a rescoping exercise.

A Ground Segment Requirements Review was completed for the 2016 mission and is proceeding to detailed design activities and procurements for the system. A large part of the 2016 mission ground segment will also be used for the 2018 mission (reviewed in the 2018 mission Phase-B study).

## → SOLAR ORBITER

Lengthening of the Instrument Boom and supplementary testing at EQM level with payload sensors have been defined in detail. This will improve the electromagnetic compatibility performance. Tests of surface-treated materials at ESTEC are continuing. A production facility for titanium sheets using this technology has been commissioned.

All ten Instrument PDRs were carried out. Following design changes, one for the METIS coronagraph will be rerun. The On-Board Computer Development Model was delivered (a milestone marking the delivery of the first actual spacecraft hardware item, although not a FM yet). The Ground Segment Requirements Review was conducted. One of the main issues discussed addresses the overall data return.

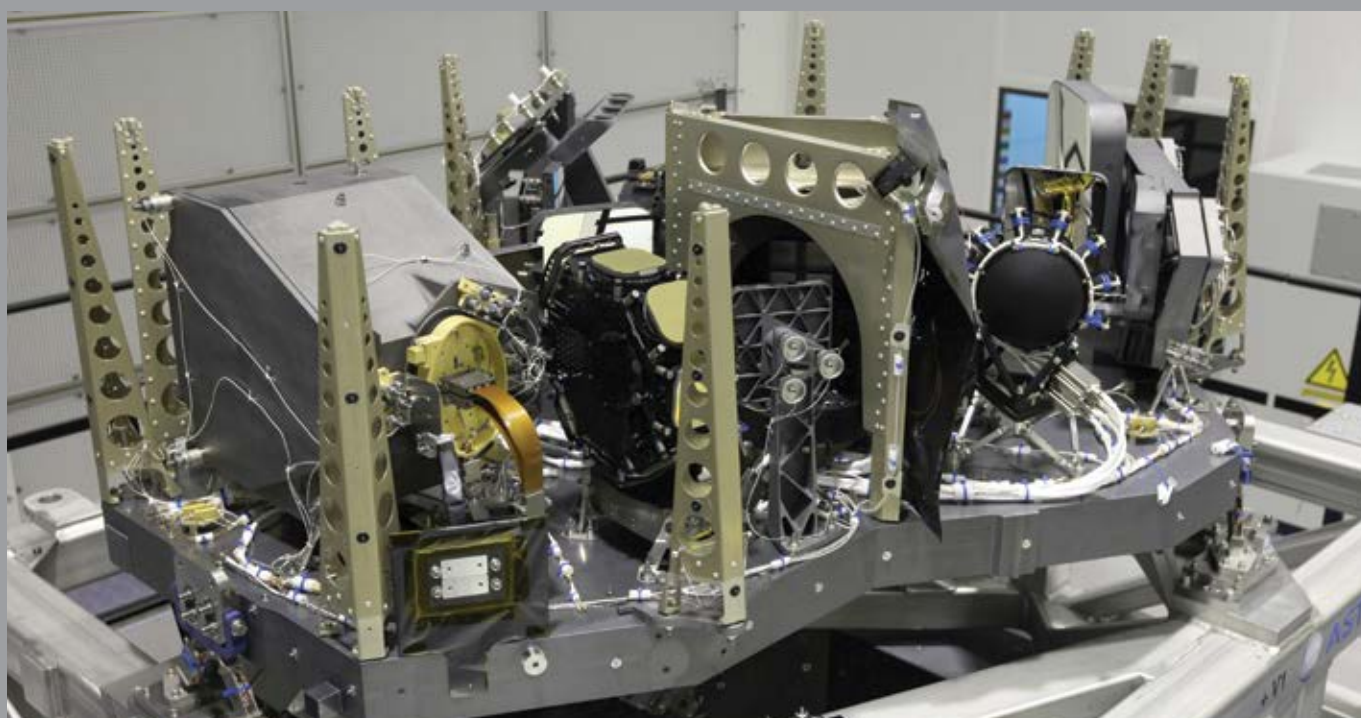
Two extra launch opportunities (in July 2017 and October 2018) are being studied, using an Atlas V-411 launch vehicle, in addition to the baseline opportunities in January and March 2017 and the backup opportunity in August 2018. NASA confirmed their readiness to procure the Atlas V-411 and the formal go-ahead decision to be made on 1 February.

## → JAMES WEBB SPACE TELESCOPE

Integration of NIRSpec FM-2 was followed by an ambient functional test. The cryogenic functional test at IABG was completed including the operation of the Microshutter Assembly (MSA) for the first time in the instrument.

The problem with 'failed closed' microshutters seen on the MSA FM after the instrument's FM-1 acoustic test has been reproduced at the MSA-level acoustic test, and the failure mode identified. Minor adjustment of the shutter design should mitigate the problem. The manufacturing of new microshutter arrays started. The overall recovery plan anticipates the exchange of the MSA in mid-2014 when the detectors will also be exchanged.

The NIRSpec Engineering Test Unit (ETU) has been shipped to Goddard Space Flight Center. It will first be used as a test platform for the MSA to support the resolution of the 'failed closed' shutter problem and afterwards replace the NIRSpec FM-2 units for the first Integrated Science Instrument Module cryo-test.



NIRSpec Flight Module-2 in final configuration before installation of the cover

An Acceptance Review in December for the MIRI instrument demonstrated full compliance to the sensitivity requirement. The proposed solution to the Data Frame Corruption issue was also endorsed.

## → EUCLID

The PLM prime contractor, Astrium SAS, was selected and the contract for Phase-C/D/E1 began in December. Meetings have taken place with the instrument representatives to define the interfaces and work on the accommodation. The prime contractor ITT was issued.

Procurement of the Near Infrared Spectrometer-Photometer (NISP) detectors and the CCDs for the Visible Imager (VIS), both managed by ESA, is proceeding. The VIS and NISP instruments are provided by the Euclid Consortium.

Progress meetings have taken place for the Euclid Science Ground Segment. This controls the processing of the Euclid data and is split into parts under ESA responsibility (the Science Operations Centre at ESAC) and a part developed by the Euclid Consortium. Mission operations activities, under ESOC, have also begun. Launch is planned for early 2020 on a Soyuz-Fregat from Europe's Spaceport in Kourou. Euclid will be put in a large halo orbit around the second Sun/Earth Lagrange point L2. The mission will last six years.

## → GOCE

Release 4 of GOCE-based gravity field models is expected in early 2013. The mission team is executing a plan for lowering the satellite orbit to significantly improve the spatial resolution of the gravity field data, in a way no other mission (flying or planned) is able to do. Strongly supported by the Earth science communities, the mission is now aiming for mesoscale observations of ocean circulation and geophysical processes. This is achieved by lowering the flight altitude by 20 km. Note that GOCE was already by far the lowest orbiting research satellite worldwide. By the end of February, the third (and for now last) phase of the orbit lowering was completed.

Having analysed all data on the xenon gas consumption by the drag-free control system, as well as the available neutral air density predictions for 2013, it is now predicted that the GOCE mission will come to a natural end in late 2013.

## → ADM-AEOLUS

The platform is in storage and work is concentrated on the Aladin laser. The new ultraviolet laser optics procurement is progressing with the first batch available and undergoing tests. Optical integration of the infrared sections of both flight units is continuing in parallel with the frequency conversion stage of the first flight laser nearing completion.

ADM-Aeolus optical bench assembly ready for environmental testing (Thales Alenia Space)





The environmental qualification of the Aladin optical bench assembly is ongoing with thermal cycling completed and acoustic vibration tests due to start. The delay of the development of the special purpose pressure transducers for the Aladin in situ cleaning system will result in completion of the subsystem later than planned (but in time for the required date at satellite level).

## → SMOS

The mission of three years was completed in November but, thanks to the excellent technical and scientific status of the mission, SMOS will continue to operate beyond this lifetime.

All data, brightness temperatures (level 1) and soil moisture and ocean salinity data (level 2), have been released to the science community. In general, the RFI situation keeps improving with some 200 sources being switched off.

However, very strong sources in Central Europe have recently rendered the SMOS data unusable over most parts of Europe. ESA, together with national frequency authorities, continues to work on improving the situation.

## → CRYOSAT

The reprocessing of the first 18 months of data is ongoing and will be completed this summer. The development of marine products is on going; their release is also planned for the summer.

New results on sea-ice thickness and volume for the two winters of 2010/11 and 2011/12 were presented at the '20 Years of Progress in Radar Altimetry' symposium in Venice. With the winter freeze-up in progress, CryoSat resumed measurements of winter sea-ice in the Arctic. Over the coming months, CryoSat data will reveal the effect of this summer's record minimum on sea-ice thickness and volume.

## → SWARM

The three satellites are ready for launch and are in storage. Launch has been delayed until the end of April after a failure of a Proton rocket upper stage, and a delay of the Rockot launch, which was initially planned for November. Roscosmos still have to confirm an official launch date for Swarm.

## → EARTHCARE

In Europe, the satellite sub-system sub-contractor selection performed under the Best Practices Procurement scheme is complete and the industrial consortium is proceeding with the detailed design of all spacecraft elements. The Base

Platform development, led by Astrium Ltd, is progressing and the CDRs of major sub-systems took place.

The spacecraft EM was tested at Astrium GmbH and this test bench is now ready for integration and the test of the four instrument ICUs.

The ATLID instrument transmitter STM manufacturing is complete and the testing initiated to establish pressurisation and thermo-mechanical sensitivity parameters. Long-term Laser Induced Contamination (LIC) tests were performed in a representative model of pressurised laser head without significant transmission loss. The Multi-Spectral Instrument Engineering Confidence Model (ECM) was assembled and tested at SSTL (UK). The ECM test results will be incorporated in the Data Package of the MSI CDR in early 2013.

In Japan, JAXA and its industrial partners completed testing of the Cloud Profiling Radar EM. The mechanical qualification is ongoing at the Tsukuba test centre.

## → METEOSAT

### MSG

#### Meteosat-8/MSG-1

In October, as a result of the loss of thermal frames, thermal instabilities in the fuel tanks induced a wobble of the

SEVIRI Flight Model-4 removed from MSG-4 in Cannes (Thales/ESA)



satellite spin axis that affected the SEVIRI image quality. From late November, satellite performance is back to normal after thermal control of fuel tanks was regained.

#### Meteosat-10/MSG-3

Commissioning of the satellite and associated ground segment was concluded on 12 December. The satellite and ground segment were declared operational. Now renamed Meteosat-10, MSG-3 will relocate to 0° longitude and take over the nominal full-disc mission from Meteosat-9. Meteosat-9 takes over the Rapid Scan Service from Meteosat-8 (now back-up).

#### MSG-4

To exchange the failed Mirror Scan Drive Unit (SDU), the SEVIRI instrument was removed from the spacecraft and shipped to Astrium SAS, Toulouse. The Scan Assembly unit (including mirror and actuator) was removed from the instrument and shipped to Astrium GmbH, Friedrichshafen, where the SDU replacement will take place. The new SDU is being tested at Thales Alenia Space Cannes and should be delivered to Friedrichshafen in February.

#### MTG

The Infrared Sounder PDR was held in October/November. All PDRs relating to MTG satellites and associated platforms and

instruments were completed. At subsystem and equipment level, preparation and implementation of PDRs is under way.

The MTG Best Practice Procurement activities are approaching completion with selection of preferred suppliers for approximately 90% of the procurements completed. Of note was the kick-off for the technically challenging Scan Assembly supplier at the end of 2012.

## → METOP

#### MetOp-A

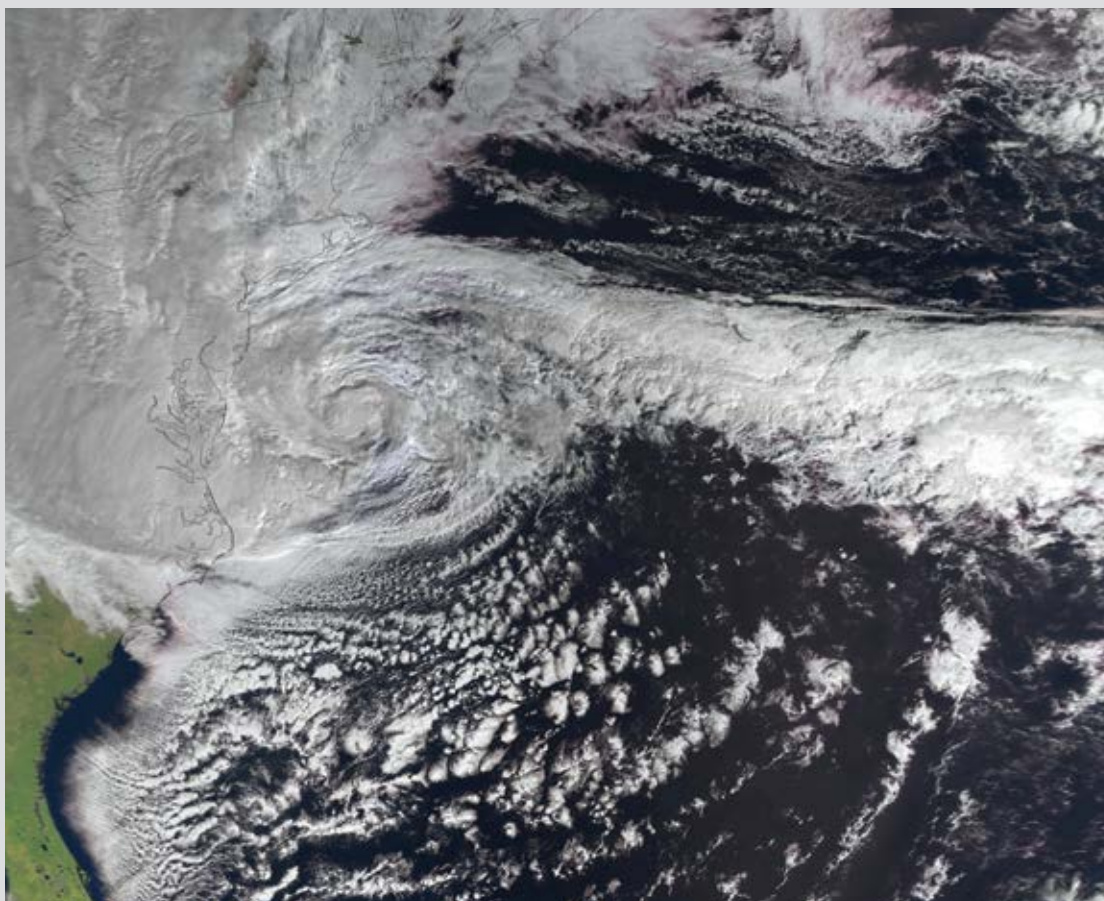
The Microwave Humidity Sounder shows a degradation trend not cured by the swap of the local oscillator of H3/4; extrapolation shows that limit of specification would be reached by third quarter of 2013.

#### MetOp-B

The Calibration and Validation phase is nominal. Most of the Level 1 and 2 products should be operational by the end of January.

#### MetOp-C

The satellite is stored as three separate modules (platform, payload, solar array). Some equipment and instruments have been dismantled for repair or calibration.



Hurricane Sandy captured by MetOp-A as the huge storm hit the east coast of the USA on 29 October 2012 (Eumetsat)



## → SENTINEL-1

The Synthetic Aperture Radar (SAR) instrument is under test at Astrium GmbH, Friedrichshafen. The Optical Communication Payload (OCP) has passed the critical environmental tests. Batteries, avionics, propulsion subsystem, power subsystem, and payload data handling and transmission subsystem are integrated on the spacecraft at Thales Alenia Space Italy, Rome. The SAR Antenna test campaign has shown excellent performance, consistent with the radiometric requirements specified for the mission.

The definition of the commissioning phase is progressing with the preparation of the tools and ground equipment to be used (including the Calibration and Performance Analysis Facility, the Calibration Transponder, and Prototype SAR Processor). The Final Mission Analysis Review began for the Sentinel-1A launch vehicle, a Soyuz from Kourou.

## → SENTINEL-2

The telescope PFM was integrated and ready to host the two focal planes prior to the payload instrument full acceptance test campaign at Centre Spatial de Liège.

Equipment for the second instrument FM was delivered for integration. The Visible and Near Infrared (VNIR) and the Short Wave Infrared (SWIR) focal planes are undergoing characterisation.

Satellite AIT activities progressed with a successful first AOCs system test and a second System Verification Test involving ESOC. Most platform PFM equipment was delivered and integrated in the flight structure, ready for the PFM satellite acceptance test programme in 2013.

The launch service contract with Eurockot (Sentinel-2A) had its Preliminary Mission Analysis Review at the end of 2012. Image quality activities progressed with the qualification review of the Ground Prototype Processor.

The OCP development for data recovery through EDRS encountered several design issues that require correction.

ESA and NASA conducted their first technical activity of the Sentinel-2/LDCM cooperation agreement. This test campaign was completed, with the joint characterisation of the OLI and MSI payload instrument optical sources used on the ground for instrument performance characterisation.

These data sets should permit more accurate radiometric corrections during the in-orbit commissioning phase, with the goal to produce interoperable data sets between the LDCM and Sentinel-2 operational missions, bringing the revisit down to three days.

## → SENTINEL-3

The Sentinel-3A platform Integrated System Testing (IST) was completed. Activities related to the Sentinel-3B platform started. At system level, software verification is proceeding.

In October, the second meeting of the Sentinel-3 Mission Advisory Group took place, attended by technical experts and representatives from GMES Services, EC, ESA and Eumetsat. Several recommendations were issued which are now being assessed within the GMES community for possible implementation.

Several Sea and Land Surface Temperature Radiometer (SLSTR) PFM elements were already delivered and activities are concentrating on the integration and alignment of optics and the spectral calibration of the Focal Plane Assembly. The SLSTR EM test campaign was completed.

FMs of the Focal Plane Assembly and the Video Acquisition Module of the OLCI (Ocean and Land Colour Instrument) were delivered while the PFM Camera is under test. The OLCI EM test activities were also completed. The SRAL PFM is on its way to become the first Sentinel-3 instrument to complete its test campaign ready for satellite integration. MWR activities have been on hold pending investigation of some anomalies.

The Rockot Preliminary Mission Analysis Review concluded at the end of 2012, confirming the full compatibility between the Sentinel-3A satellite and the launcher.

## → SENTINEL-4

The PDR process started later than originally planned but benefited from the rigorous evaluation of the technical status of the design maturity, design consolidation at various levels and the consideration of the new instrument accommodation on the MTG-S platform. The PDR concluded on 23 October.

The Best Practice Procurement process continues with more than 85% (by value) of anticipated ITTs/RFOs being released in December. For more than 70% of these procurements, the preferred suppliers have been selected. Ground segment implementation is being coordinated with Eumetsat.

## → SENTINEL-5 PRECURSOR

Platform FM equipment (Coarse Sun Sensor, OBC, GPS and Magnetotorquers) was delivered at Astrium Ltd. Manufacturing Readiness Reviews began for the remaining satellite sub-systems and equipment.

Dutch Space has concluded Tropospheric Monitoring Instrument (TROPOMI) design activities on sub-systems with subcontractors, with CDRs for the SWIR in October and the

Instrument Control Unit and Radiant Cooler in December. The TROPOMI-level CDR is scheduled for February. Recent flight hardware deliveries include both the Front-end Electronics by SRON and the SOFRADIR detector for SWIR.

Level-0/1b processors are developed by KNMI under a frame contract funded by the Netherlands Space Office, which includes also TROPOMI Calibration Requirements definition and Operations support. A Level-0/1b processor CDR took place at KNMI in December. Level-2 Processors SRR/PDR is scheduled for January. The Rockot launcher study began on 28 November, and the Vega study is planned for early January.

## → SMALLGEO

The STM completed its mechanical and thermal test campaign at ESTEC in November, and was then moved to ESTEC's Large Space Simulator for thermal testing. The STM was assembled by RUAG (CH), with elements provided by OHB System (DE) and its consortium of European contractors. The Repeater Module is being integrated with PFM payload units at TESAT (DE) while the Core Platform Module is being integrated at OHB premises.

## → ALPHASAT

The spacecraft is now in the thermal vacuum chamber in Toulouse. Tests of the Inmarsat commercial payload, the

four ESA Technology Demonstration Payloads and Alphasat platform should be completed in January. Launch is planned for mid 2013. In the ESA/Inmarsat ground segment initiative, a new activity has started to develop enhanced maritime safety services using Alphasat and Inmarsat 4 satellites.

## → ALPHABUS PRODUCT LINE

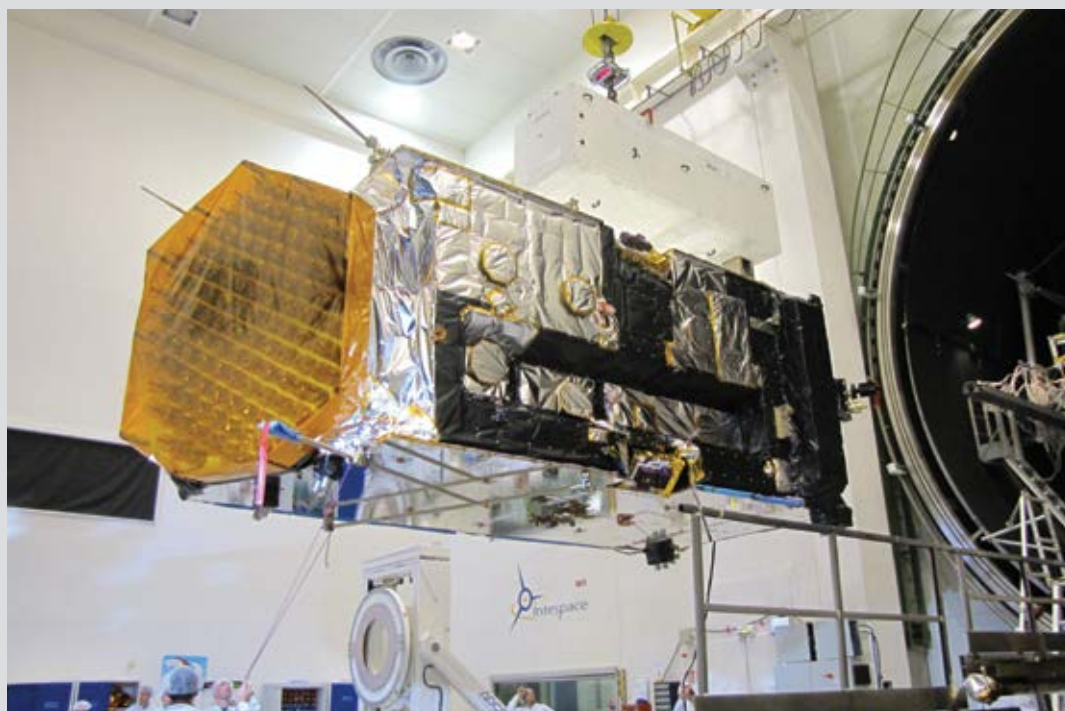
The CDR is now planned for September after the Alphasat launch. Progress has been made on the development of a number of technologies, including the Deployable Radiator and the Antenna Module.

## → ARIANE 5 POST-ECA

The M4R Vinci Post-test Review took place at Lampoldshausen. A nominal Vinci specific impulse of 464 seconds was confirmed. A key-point took place on 19 December to assess the engine idle and 130 kN operating modes.

## → VEGA

The VVo2 Flight Qualification Review was held and the Launch Vehicle Updated Qualification Certificate was delivered. The Qualification Review for the ground segment took place. The transfer of property to ESA and hand-over to Arianespace are scheduled for February.



The Alphasat spacecraft entering the thermal vacuum chamber in Toulouse (Intespace)





The first stage of the second Vega on its launch pad at Europe's Spaceport in French Guiana, marking the start of the Vega VVo2 launch campaign (Europropulsion)

The planning of the VERTA flight programme software (FPSA) remains a criticality for flight VVo2 due to the change of mission configuration and delays during the development activities. However, the FPSA CDR was completed and the Qualification Review is planned for February.

Following the Delivery Review Boards for A2 and A3 stages, the first three VVo2 stages were delivered. The qualification tests of the Vega Secondary Payload Adaptor were completed. The VVo2 (VERTA-1) launch campaign started with the P80 transfer to the Mobile Gantry. The deliveries of the fourth stage, the Vega Secondary Payload Adaptor and payloads are due in February.

Following the recommendations to improve the Radio Frequency visibility during the first part of the mission, a complementary portable telecommand station was procured.

## → FLPP

### Intermediate Experimental Vehicle (IXV)

The IXV Phases-D/E1A/B are progressing, including the manufacturing and qualification of the flight and ground segment deliveries, and preliminary mission analysis activities. ESA has frozen the scenario for implementation of Phase-E/F and the statement of work for the industrial activities.

To cope with the level of under-subscription, it is proposed to start the procurement process according to the nominal



Ariane 5 flight VA212 was the first Ariane launch of 2013, on 7 February, delivering the Amazonas-3 and Azerspace/Africasat-1a communication satellites into geostationary transfer orbit (ESA/CNES/Arianespace/Optique Video du CSG)

timeline, solicit the subscription of the missing contributions from the Participating States until the actual signature of the industrial contracts, to compute the updated percentage of overcost, if any, for FLPP-2.1 and FLPP-2.2/IXV in June.

#### Next Generation Launcher preparation

Final approval of updated documents from the third system loop activities, addressing the HH Boosted configurations (both in Staged Combustion and Gas Generator variants) as well as on the PPH concepts, is in progress. Impacts of variations of the Mission Statement, in particular targeting an earlier qualification flight (in line with the evolution of the European family of launchers) have been studied.

These results show interest in some other concepts (HH type in NGL alpha approach based on the use of Vulcain-2, a twin-engine first stage or quadri engine first stage). Such concepts allow an earlier qualification flight while presenting also interesting recurrent costs.

Phase-B of SCORE-D (Stage Combustion Rocket Engine Demonstrator) was completed with the engine PDR in December. The SCORE-D Review outcomes, based on an extensive assessment of the data package, do not show any blocking issue for Phase-C.

In Cryogenic Upper Stage Technologies, industrial activities are progressing with, in particular, the detailed design, mechanical and functional analysis of the GPPS. Several other technology developments are progressing, such as the Jettisonable Fluid Ground Connector for which the PDR was performed in November.

## → HUMAN SPACEFLIGHT

Following the first demonstration flight of the commercial SpaceX Dragon in May, the first operational flight of Dragon spacecraft (SpaceX-1) to the ISS was launched from Florida on 8 October. SpaceX-1 remained at the ISS until 28 October when it returned to Earth bringing back research samples, excess equipment and waste from the ISS, including some samples from ESA experiments and facilities.

## → ISS TRANSPORTATION

#### ATV *Albert Einstein*

ATV-4 vehicle integration activities have taken place in Kourou, French Guiana. The Integrated Cargo Carrier (ICC) underwent leak testing in November and solar panels were installed. The

Taken in January by ESA's Alberto Novelli, ATV-4 Mission Manager, this photo shows the Integrated Cargo Carrier portion of ATV *Albert Einstein* being weighed in Kourou with nominal cargo loaded





ICC tanks were loaded with water, and dry cargo processing and loading started. Launch is expected no earlier than 7 May.

#### ATV *Georges Lemaître*

The Avionics Bay was completed and accepted for further processing. ICC integration activities in Turin were completed and the ICC shipped to Bremen. The Propulsion Bay is on schedule for completion in early 2013.

## → ISS DEVELOPMENT/EXPLOITATION

The Implementing Arrangement Negotiation with NASA for the 'Orion' Multipurpose Crew Vehicle Service Module (MPCV SM) was completed. ESA and NASA approved the Arrangement in December 2012. A press event related to this significant achievement was planned for 16 January.

The European Robotic Arm (ERA) launch and integration campaign, which started in Russia last summer, is proceeding. Roscosmos confirmed the launch date of 11 December. ESA astronaut Alexander Gerst (DE) is training for the first ERA operations at the Gagarin Cosmonaut Training Centre (Star City, Russia).

## → ISS UTILISATION

#### European research on the ISS

The European ISS science programme has been continuing with the assistance of the Expedition 33/34 crews in orbit.

#### Human research

NASA's Sunita Williams and JAXA's Akihiko Hoshide completed their final sessions of ESA's Vessel Imaging experiment in conjunction with NASA's Integrated Cardiovascular

experiment, consisting of an echography scan together with ECG and heart rate measurements in November. These joint experiments help to quantify the cardiovascular response to fluid shifts in the body during long-term exposure to weightlessness, with the aim to optimise countermeasures to the adverse effects of spaceflight.

Additional experiments were undertaken using the Portable Pulmonary Function System (PFS) to record a variety of pulmonary measurements during varying degrees of exercise on the CEVIS Cycle Ergometer. This formed part of ESA's Thermolab and EKE experiments in conjunction with NASA's Maximum Volume Oxygen (VO<sub>2</sub> Max) experiment. Williams completed her fourth and final session of the experiments in October. If the post-flight baseline data collection sessions prove successful, this will bring the experiment to a successful conclusion.

Thermolab sensors were also used in ESA's new Circadian Rhythms experiment, which started in July with Hoshide as the first subject. Hoshide undertook his final two sessions of the experiment in October and November. NASA's Tom Marshburn started as the second test subject on 27 December. The main objective of the experiment is to get a better understanding of alterations in circadian rhythms in humans during long spaceflights.

Another experiment using the PFS was Energy, which aims to determine the energy requirements of astronauts on long spaceflights. Hoshide continued the experiment as the second test subject in October. Hoshide used PFS to make Oxygen Uptake Measurements. A Double Labelled Water isotope consumed by Hoshide will be tracked through samples from the ISS Water Recovery System (which reclaims water from urine) to determine levels of the isotope he excretes. This was combined with Hoshide consuming



JAXA astronaut Aki Hoshide, Expedition 33 Flight Engineer, conducts an Oxygen Uptake Measurement for the ESA Energy in the Columbus laboratory (NASA/ESA)

dedicated food and drinks, measuring activity using special armbands and providing of urine samples for analysis.

Water and urine samples from ESA astronaut André Kuipers (the first test subject in May 2012) and for NASA astronaut Don Pettit (the control subject) were returned to Earth on SpaceX-1 in October.

Sunita Williams completed her fourth and final session of ESA's new Reversible Figures experiment (as first subject) on 29 October. This neuroscience experiment is investigating the adaptive nature of the human neurovestibular system in the processing of gravitational information related to 3D visual perception. NASA astronauts Kevin Ford and Tom Marshburn and CSA astronaut Chris Hadfield have also become subjects of the experiment.

Hadfield is also the final test subject for the Neurospat experiment, which was the first experiment to make full use of the European Physiology Modules facility and its Multi-Electrode Electroencephalogram Measurement Module in 2009. NeuroSpat is investigating the ways in which crew members' three-dimensional perception is affected by long-duration stays in space.

Kevin Ford started the 'Space Headaches' experiment, filling in daily questionnaires as the third subject for this experiment following his arrival on 23 October. Hadfield and

Marshburn also started as test subjects. The questionnaires are being analysed on ground to help determine the incidence and characteristics of headaches occurring within astronauts in orbit.

Samples from ESA's Immuno experiment were returned to Earth on 19 December. The samples covered four different test subjects from the Russian crews in Expeditions 29/30 and 31/32. Performed under a bilateral cooperation agreement with Roscosmos, Immuno determines changes in stress and immune responses, during and after a stay on the ISS. The results will help develop pharmacological tools to counter unwanted immunological side-effects during long-duration spaceflights.

### Fluids research

Additional tests were made on the Fluids Science Laboratory (FSL) in Columbus in advance of the FASES experiment, which is due to arrive on ATV Albert Einstein in April/May. This included a long-duration 'stress' test for the Video Management Unit, software upgrades of the FSL's Optical Diagnostic Module and Central Experiment Module, and tests with the facility's Microgravity Measurement Apparatus.

Science runs for the additional Geoflow-2b experiment inside the FSL started on 17 December. Three no-rotation runs were completed by 20 December and related data was downlinked. Geoflow-2 and -2b (following on from the initial Geoflow experiment with new objectives and a different configuration)



NASA astronaut Sunita Williams, Expedition 32 Flight Engineer, works on the Reversible Figures experiment in the Columbus laboratory (NASA/ESA)





The new ESA-sponsored medical research doctor for Concordia base, Evangelos Kaimakamis, arrived in Antarctica on 22 January (ESA/IPEV/PNRA/E. Kaimakamis)

are investigating the flow of an incompressible viscous fluid held between two concentric spheres rotating about a common axis as a representation of a planet.

#### Materials research

Kevin Ford cleaned the Solidification and Quenching Furnace of ESA's Materials Science Laboratory (MSL) on 21 November. The cleaning procedure removed some remaining graphite foil that had detached from a Sample Cartridge Assembly during experiment processing in 2011 (when a failure of a primary payload computer in the US laboratory caused a loss of cooling to the MSL). With cleaning completed, software will be upgraded to avoid the possibility of future cooling loss. Batch 2a experiments (MICAST-2, CETSOL-2, SETA-2) will resume the science programme, studying different aspects of the solidification process in metal alloys which will help to optimise industrial casting processes.

#### Radiation research

The Dose Distribution inside the ISS 3D (DOSIS 3D) experiment continued using the active radiation detectors

located in the European Physiology Modules facility. A second set of passive detectors, delivered on Soyuz TMA-o6M, were installed in different locations around Columbus by Sunita Williams on 26 October (the first set of passive detectors in Columbus from May to September were returned to Earth for analysis).

Data acquisition has been completed for the ALTEA-Shield experiment in the 'shielding' configuration in EXPRESS Rack 3 in Columbus. On 13 November, the hardware was deactivated and stowed, at which point 94 cumulative days of successful science acquisition had been taken, testing Kevlar radiation shielding tiles.

The active cosmic radiation detector hardware for the new Tri-Axis Telescope (TriTel) experiment was installed and activated in Columbus on 6 November by Akihiko Hoshide. This active detector, which includes three different detector types, is able to provide a three-dimensional mapping of radiation entering Columbus. An accompanying set of passive radiation detectors was launched to the ISS on Soyuz TMA-o7M.

## Solar research

ESA's SOLAR facility carried out two additional data acquisition periods during Sun visibility windows between October and December. Sun visibility windows open when the ISS is in the correct orbital profile with relation to the Sun. The first was a standard period lasting about 10–11 days.

The second period was very significant from a research perspective, because it lasted from 18 November until 23 December, making it possible to undertake solar measurements during a full Sun rotation cycle lasting around 27 days. This was made possible by joining together two scheduled Sun visibility windows by rotating the ISS slightly out of its standard flight profile from 30 November to 12 December, allowing SOLAR to continue working between the visibility windows. This is the first time that the attitude of the ISS has been changed for science reasons.

## Non-ISS research

The 57th ESA Parabolic Flight Campaign took place in October. This joint ESA/CNES/DLR campaign was a reflight of 11 of the initial set of 13 experiments from the first partial-g campaign with a new set of experimental parameters.

The most recent Concordia winter-over season ended in October and 2013's crew flew to the Antarctic station in November to begin the next winter-over period from February.

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

A new medium-duration bed-rest campaign started at the MEDES Space Clinic in Toulouse, in November. This incorporated a 21-day bed-rest period completed in December with 12 male subjects. Two additional 21-day bed-rest periods will be undertaken in 2013 as part of the campaign with the same 12 subjects in each period.

Two droptower campaigns were completed at the ZARM Drop Tower. The first was Chondrule 2b (a study on particle rotation and photophoresis), and the second a student campaign from Magdeburg University, part of Drop Your Thesis 2012.

New advanced materials research projects with the EC are continuing on track. Accelerated Metallurgy is continuing with more patent opportunities emerging. ThermoMag had a successful mid-term review in November. ExoMet and COLTS are progressing, and ESA and the EC have signed the contract for the AMAZE project, to start in January.

## → ASTRONAUTS

Luca Parmitano (IT) completed duties as back-up Flight Engineer for CSA astronaut Chris Hadfield following Hadfield's launch to the ISS in December. Parmitano continued training in payloads and mission support at EAC in October.

Alexander Gerst (DE), scheduled to launch in May 2014 on Exp. 40/41, and Samantha Cristoforetti (IT), scheduled to launch in November 2014 on Exp. 42/43, completed training in Russia and are now training at Johnson Space Center, Houston. Timothy Peake (UK) completed Extravehicular Mobility Unit EVA training in Houston. Thomas Pesquet (FR) took part in weightlessness training during three parabolic flights at Novespace, Bordeaux.

Since October, a number of international astronauts were trained at EAC. Cosmonauts Pavel Vinogradov and Alexander Misurkin (Exp. 35/36) received the first part of ATV training; NASA astronaut Karen Nyberg (Exp. 36/37) received payload and ATV training; Cosmonauts Oleg Kotov, Sergei Ryazansky (Exp. 37/38) and Mikhail Tyurin (Exp. 38/39) received Columbus user training (with Kotov receiving additional ATV training); NASA astronauts Michael Hopkins (Exp. 37/38) and Richard Mastracchio (Exp. 38/39) received Columbus specialist training; and NASA astronaut Steve Swanson (Exp. 39/40) received Columbus and payload training.

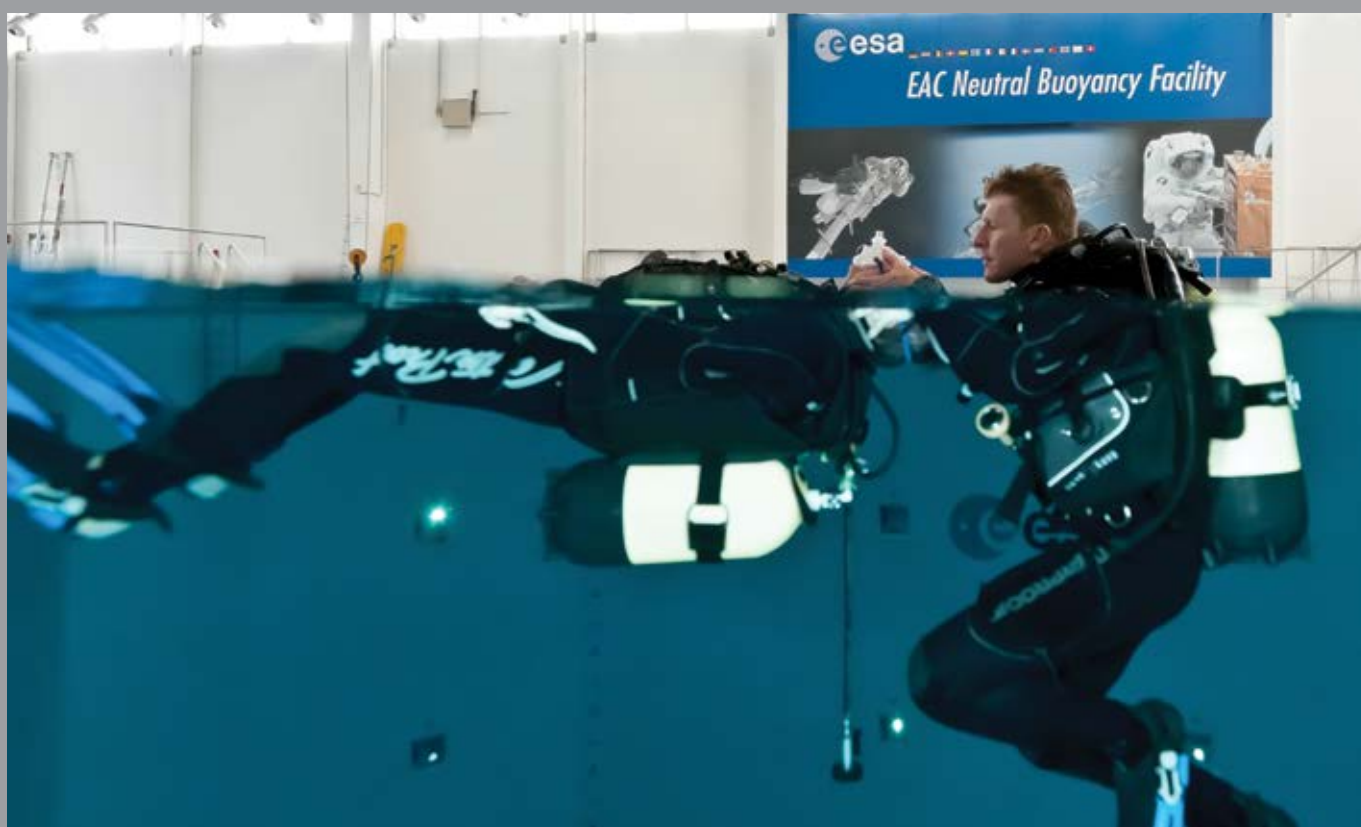
At the cosmonaut crew quarters in Baikonur, Kazakhstan, Expedition 34 back-up Luca Parmitano chats with CSA astronaut Chris Hadfield while using exercise equipment (NASA/V. Zelentsov)







Samantha Cristoforetti and Alexander Gerst during training in Russian EVA suits at Star City, near Moscow



Astronaut Tim Peake rehearsing diver rescue skills in EAC's Neutral Buoyancy Facility in Cologne

## → TRANSPORTATION/EXPLORATION

International Berthing and Docking Mechanism (IBDM) and International Docking System Standard (IDSS) Results of the Assessment of Feasibility and Predesign on 'Narrow Ring' Soft Docking System were presented to the International Docking Standard Working Group in October. All parties agreed that the narrow ring option was both feasible and desirable, since it provides an 800 mm diameter free passage for the astronauts without requiring the removal of the contact guide petals. It is geometrically compatible with the Russian Androgynous Peripheral Attach System used previously by the ISS for the Space Shuttle. NASA reviewed the its equivalent docking system in November and decided to evolve also towards a narrow ring configuration.

### Expert

Investigation into launcher alternatives continued after a Technical Assistance Agreement with Orbital Sciences on Pegasus and Minotaur vehicles. Talks were held with NASA and the US Army for the possible use of a new rapid response system, SWORDS, under development with NASA and the US Army. The updated Athena small launcher family from Lockheed Martin and ATK are also being studied. The most promising options appear to be those with a launch from the southern Alaska towards the north, but associated range safety issues need to be clarified.

### Lunar Lander

Results of mission and system activities for Lunar Lander Phase-B1 were presented in October. Analyses of envisaged landing areas in terms of illumination, communication

and potential hazards were updated based on the latest topographic data from the Lunar Reconnaissance Orbiter (LRO), resulting in a number of confirmed candidate landing sites. All Phase-B1 activities were reviewed at a mid-term checkpoint to assess progress towards SRR at the end of 2013.

A number of breadboarding activities (both hardware and software) progressed in parallel to the Phase-B1 mission and system study. Test readiness reviews were conducted. Avionics breadboarding activities began.

High-resolution digital elevation maps of the planned landing areas at the lunar south pole were generated based on stereo-images acquired by LRO and are under evaluation. These maps will give further confidence in the landing site candidates already identified based on earlier topographic data. A Science Definition Team was created to analyse the responses to the Call for Declarations of Interest for a payload on the lander.

### Exploration

The first Operations & Communications Test for the Multi-Purpose End-To-End Robotic Operation Network (METERON) was performed on the ISS on 23 October 2012. Astronaut Sunita Williams commanded a small rover at ESOC in near-realtime from the ISS. Data and photo feedback were received.

ESA presented its Concept for Human Space Exploration at the JAXA Space Exploration Symposium in October in Tokyo. Final presentations of the Scenario Studies, aimed at developing inputs for the European strategic planning in the area of human spaceflight and exploration and implemented by a consortium led by Thales Alenia Space and Astrium GmbH, took place in December.

## → SPACE SITUATIONAL AWARENESS (SSA)

### SSA Architectural Design

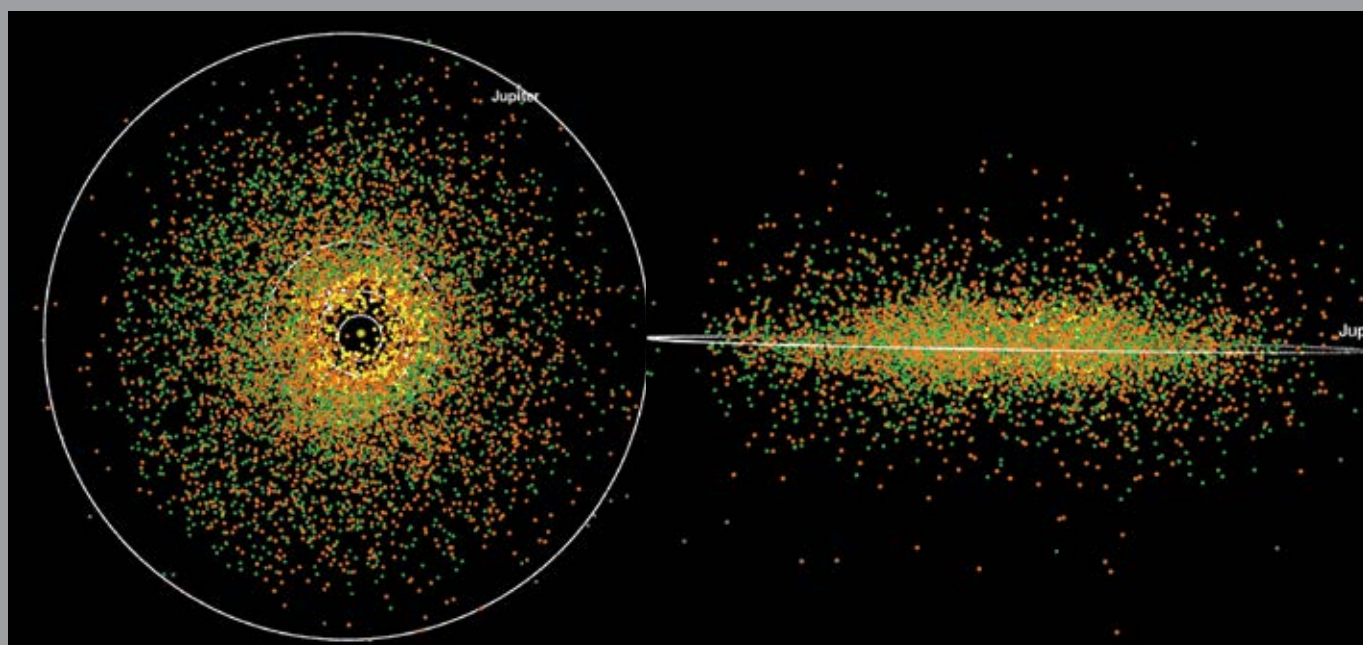
The work led by Astrium GmbH under the first SSA Architectural Design contract passed the Mid-Term Review. ESA selected the architectural design baseline for each of the SSA segments that will be further detailed during the second phase of the contract scheduled to start in February.

The second SSA Architectural Design contract with Indra (ES) progressed towards the Space Surveillance and Tracking (SST) and Near Earth Objects (NEO) segments Requirements Review in January. A proposal for a second SSA/Space Weather (SWE) Architectural Design contract for the SWE segment was submitted by industry for evaluation.



NASA astronaut Sunita Williams controls a small rover at ESOC from her laptop on the ISS during the METERON test (NASA/S. Williams)





Near Earth Object (NEO) positions on 1 July 2012, as recorded by ESA's Small Bodies Data Centre (Apohele asteroids, or Interior-Earth Objects, IEOs, in white,

Atens-type asteroids in yellow, Apollo-type in orange and Amor-type in green. Views from above and from the side of our Solar System orbital plane (Albin/ESA)

### SSA/SST

The new Conjunction Prediction System (CPS) passed its On-Site Acceptance Test and will replace the previous system in January. The novel Re-Entry Prediction System (RPS) is still undergoing acceptance testing, however this should be complete by the end of January. The Data Processing Chain (DPC) is also being developed to process observations of orbiting objects so that they can be incorporated into a dedicated catalogue.

Contractual agreements have been made, or are being finalised, for ten existing space surveillance sensors to start providing data to the Space Surveillance and Tracking Centre (SSTC) for 2013 and beyond. This will ensure that the live data required to adequately test and verify both the SST Data Processing Chain, as well as the services arising from a catalogue of man-made objects, is available. A coordinated surveillance campaign began at the end of January to operate diverse independent sensors as a federated system and attempt to maintain a catalogue of geostationary objects over an extended period.

### SSA/SWE

The space weather precursor services are available for the end users at <http://swe.ssa.esa.int/>

Testing and validation of the services continued with user support through the SWE Service Coordination Centre (SSCC) in the Space Pole in Brussels. The implementation design studies for space weather hosted payload flight opportunities on European satellite missions were

completed and the study reports for each mission delivered by the prime contractor, Astrium GmbH, for final review. The satellite missions analysed in the framework of this activity include, for example, MetOp-C, Galileo FOC, Eurostar, Euclid, MTG, MetOp-SG and commercial geostationary telecommunication missions.

### SSA/NEO

Architectural studies for the SSA/NEO segment continue. The European Small Bodies Data Centre in ESRI is in place and the initial web services at <http://neo.ssa.esa.int/> are being used regularly. The ESA 1-m OGS telescope on Tenerife received a new camera, now in regular use for NEO observations. The SSA/NEO segment liaises closely with the General Support Technology Programme (GSTP), which is supporting studies on asteroid deflection mission scenarios. An international decision process on NEO impact threat mitigation is being set up in coordination with the Action Team 14 of the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS).

### SSA Ground Segment Engineering

The monostatic breadboard radar (developed by Indra and the Fraunhofer Institute for High Frequency Physics and Radar Techniques) is being integrated at Santorcaz, near Madrid. Phase-2 of the contract for developing the bistatic breadboard radar with Onera (FR) progressed. Both the PDR and the Final Design Review were completed. A new project named 'Demonstration Test-Bed for the Remote Control of an Automated Follow-Up Telescope' was started under the GSTP to study and prototype the full automation of the Space Surveillance and NEO telescopes.

# → ESA PUBLICATIONS

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