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bulletin

→ space for europe

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European Space Agency

European Space Agency

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

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

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

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

The ESA headquarters are in Paris.

The major establishments of ESA are:

ESTEC, Noordwijk, Netherlands.

ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

EAC, Cologne, Germany.

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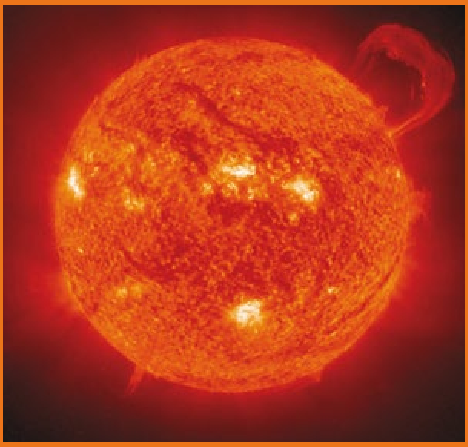

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On cover:
The Sun seen by ESA/NASA SOHO on 14 September 1999.
Launched on 2 December 1995, the space-based observatory marked 20 years of studying the Sun
(NASA/ESA)

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Thomas Reiter performed the first spacewalk by an ESA astronaut during the ESA/Russian Euromir '95 mission to the Mir space station

→ EVA!

A chronology of Europeans walking in space

Carl Walker
Communications Department, ESTEC, Noordwijk, the Netherlands

Fifty years ago, Russian cosmonaut Alexei Leonov became the first person leave the relative safety of his spacecraft and 'walk' in space - paving the way for generations of explorers to venture out into open space.

The term 'extravehicular activity' (EVA), now used to describe any activity outside a spacecraft, was originally coined by NASA planners in the early 1960s for the Apollo programme, because the astronauts would leave their vehicle on the lunar surface to collect samples and deploy scientific experiments.

The spacewalking astronauts of the US Gemini programme, who pioneered the techniques for working outside an orbiting spacecraft and eventually walking on the Moon, would also use the term EVA. Several Apollo astronauts performed 'Stand-up' EVAs (SEVA), where they did not fully leave their spacecraft, but were completely reliant on the spacesuit for life support.

Brief history of spacewalking

Although Leonov's pioneering spacewalk from Voskhod 2 on the 18 March 1965 lasted only 12 minutes, it was not without drama. Leonov's spacesuit expanded in the vacuum of space so much that he was unable to squeeze back into the spacecraft. Taking extreme measures, Leonov opened a valve on his suit to let enough air escape for him to enter the airlock. It would be almost four years before the Russians tried another spacewalk.

Less than three months later, NASA astronaut Ed White made the first American spacewalk as part of the Gemini 4 mission; it lasted 23 minutes. White was the first to use an oxygen 'gun', a hand-held unit designed to help control his motion in space.

White had found the experience so exhilarating that he was reluctant to end his spacewalk at the planned time, and he had to be ordered to get back inside the spacecraft.

On 16 January 1969, the Soviet Union achieved another first, a crew transfer EVA from one spacecraft to another. Alexei Yeliseyev and Yevgeny Khrunov transferred from Soyuz 5 to Soyuz 4, which were docked together. This was the second Russian EVA, and it would be almost another nine years before Russia performed a third.

In March 1969, only two months after Soyuz 4/5, the US Apollo 9 mission achieved the second docking of two manned spacecraft. US astronauts Dave Scott and Rusty Schweickart performed an EVA: Schweickart tested the new Apollo spacesuit, the first to have its own life-support system rather than being connected by an umbilical line to the spacecraft, while Scott filmed from the open hatch of the Command Module.

On 5 August 1971, US astronaut Al Worden became the first person to make an EVA in deep space during Apollo 15's return trip from the Moon. The first repair work done during EVA was by the crew of Skylab 2 in 1973. The Skylab astronauts rescued their launch-damaged space station by freeing a stuck solar panel and deploying a sunshield. After Skylab, no more EVAs were made by US astronauts until the Space Shuttle flights of the early 1980s.

Spending six hours outside Mir on 9 December 1988, Jean-Loup Chrétien of France was the first non-US/non-Russian space traveller to make a spacewalk

Thomas Reiter was the first German and ESA astronaut to make a spacewalk from Mir, on 20 October 1995, with Sergei Avdeyev. This is his second EVA of the EuroMir '95 mission, with Yuri Gidzenko, on 8 February 1996 (spacefacts.de)

→ European walking in space

9 Dec 1988

Jean-Loup Chrétien (FR)

Soyuz TM-7/Aragatz

1995-1996

Thomas Reiter (DE)

Soyuz TM-22/Euromir '95

In this period, the Russians resumed their spacewalk activities, making four from the Salyut 6 and Salyut 7 space stations between December 1977 and July 1982.

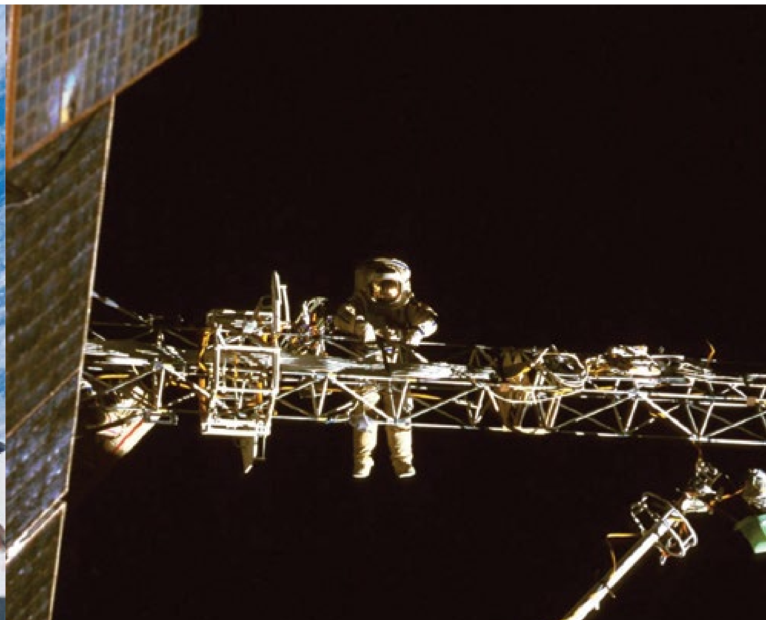
Europeans walking in space

The first European to make a spacewalk was France's CNES cosmonaut Jean-Loup Chrétien, who spent 26 days in space on the Russian Mir space station in 1988. Preparations for the first EVA involving a non-Russian/non-US space traveller had meant cutting short a TV linkup with diplomats from 47 countries on 8 December. The next day, Chrétien and Alexander Volkov finally depressurised the Mir multiport docking adapter and climbed outside.

Chrétien was first out. The cosmonauts installed handrails and equipment, including the French Échantillons package that carried five technological experiments with applications to the Hermes shuttle programme. Spending six hours outside Mir on 9 December 1988, Chrétien's was the longest spacewalk at the time.

The next spacewalk by a European was also the first by an ESA astronaut. Thomas Reiter of Germany was flight engineer for the record-breaking 179-day EuroMir '95 mission from September 1995 to February 1996.

Wearing a Russian Orlan suit, Reiter made two spacewalks, first with Sergei Avdeyev and then with Yuri Gidzenko (eleven years later Thomas would fly to the International Space Station and perform another spacewalk, that time in NASA's Extravehicular Mobility Unit, making him one of a handful of astronauts to use both Russian and US spacesuits).



↑ During the Mir-27 expedition in 1999, Soyuz TM-29's Jean-Pierre Haigneré worked outside Mir with fellow cosmonaut Viktor Afanasyev (capcomespace.net))

1999

Jean-Pierre Haigneré (FR)

Soyuz TM-29/Perseus Mir-27

1999

Claude Nicollier (CH)

STS-103

Another French cosmonaut, Jean-Pierre Haigneré of CNES, would be the next European to walk in space. During the Mir-27 expedition in 1999, Haigneré worked outside Mir with fellow cosmonaut Viktor Afanasyev to retrieve scientific equipment, install new experiments and deploy the Sputnik 99 subsatellite.

In December 1999, Swiss ESA astronaut Claude Nicollier became the first European to perform an EVA during a Shuttle flight, this one being the STS-103 Hubble Space Telescope servicing mission.

In 2002, another CNES astronaut Philippe Perrin was assigned as a Mission Specialist on the STS-111 Shuttle mission. He logged over 19 hours of EVA over three spacewalks, a new record for a European astronaut. STS-111 was the last flight of a CNES astronaut, by then French space agency had transferred its astronauts to ESA's European Astronaut Corps.

In 2006, Thomas Reiter was in space again on ISS Expedition 13. Together with Space Station crewmember Jeff Williams, Reiter wrapped up a successful five-hour, 54-minute spacewalk, installing and replacing equipment and setting up scientific experiments outside the orbiting laboratory. This would put Reiter in top position for total time spent in EVA for an ESA astronaut, but only for a short time.

↑ ESA's Claude Nicollier became the first European to perform an EVA during a Shuttle flight (NASA)

↘ CNES astronaut Philippe Perrin seen during the second of three scheduled EVAs on STS-111 by spacewalking colleague Franklin Chang-Diaz (NASA)

2002

Philippe Perrin (FR)

STS-111

2006

Thomas Reiter (DE)

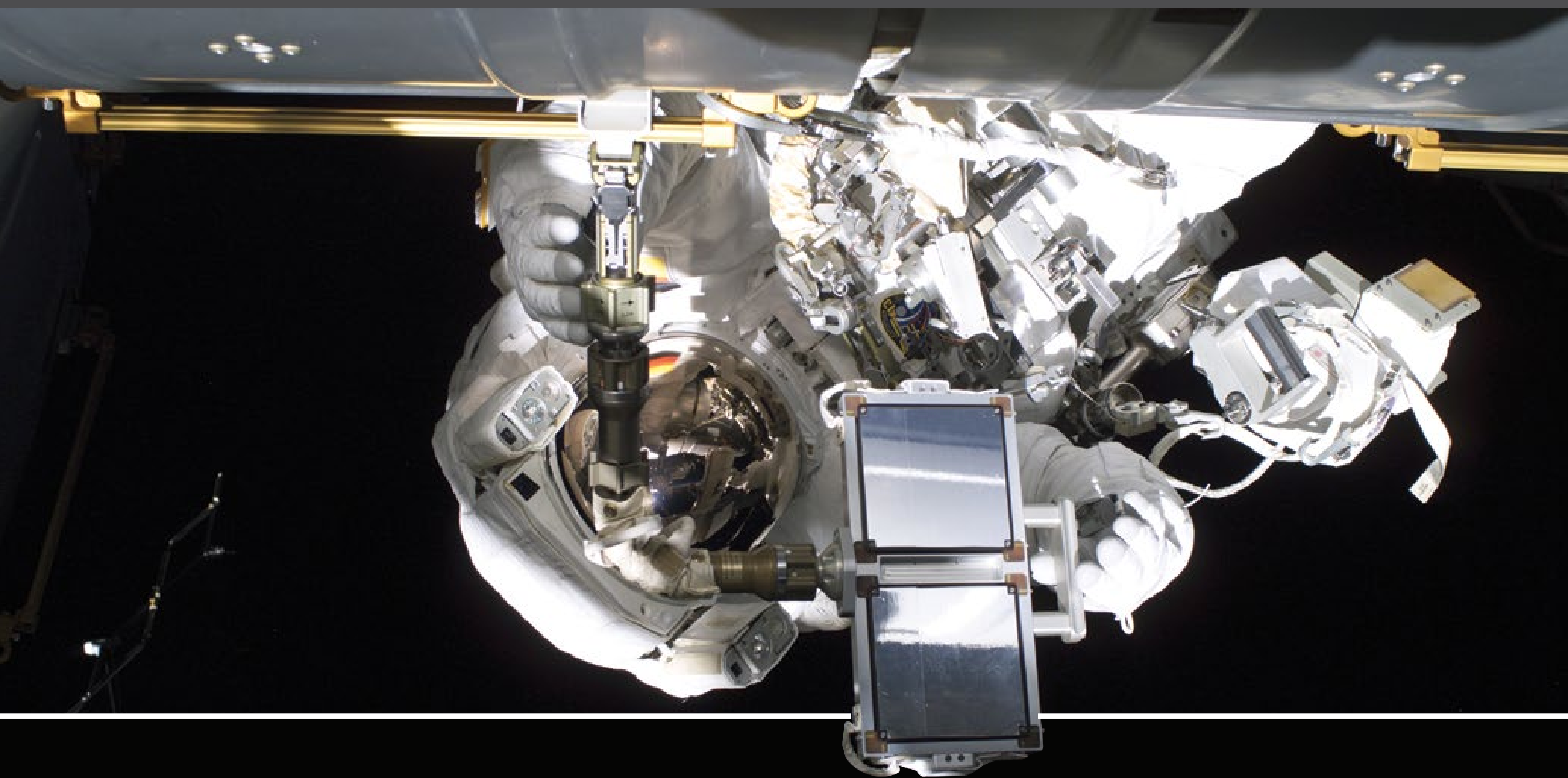
STS-121/Astrolab

In late 2006, on the mission that would bring Reiter home, fellow ESA astronaut Christer Fuglesang of Sweden was making his first spaceflight. As a Mission Specialist on STS-116, Fuglesang notched up three spacewalks with total EVA time of 18 hours and 15 minutes; enough to beat Reiter's record, but not enough to topple Philippe Perrin.

Next up for a spacewalk was German ESA astronaut Hans Schlegel, Mission Specialist on the STS-122 Space Shuttle mission, charged with the responsibility of putting the Columbus laboratory in orbit and its connection to the International Space Station. Schlegel performed the second EVA of the mission in February 2008.

↑ As a Mission Specialist on STS-116, ESA's Christer Fuglesang notched up three spacewalks (NASA/ESA)

↓ ESA astronaut Thomas Reiter, Expedition 13 Flight Engineer 2, works on a cooling line on the S1 truss of the International Space Station during a 5 hour 54 minute spacewalk on 3 August 2006 (NASA/ESA)



2006

Christer Fuglesang (SE)

STS-116/Celsius

2008

Hans Schlegel (DE)

STS-122

→ Spacewalk expertise at the European Astronaut Centre

Spacewalks are among the most demanding tasks of an astronaut's career. Working outside the International Space Station is the ultimate challenge.

Astronauts prepare for spacewalks in huge water tanks, operating equipment and tools in 'neutral buoyancy', meaning they neither float nor sink. Although it is not exactly the same as being weightless in space, it is the closest you can get on Earth.

There are lots of things to take into consideration to carry out a successful spacewalk. It is not only about the tasks you have to perform, but also about the way you handle yourself in space. This requires strong psychomotor, cognitive and behavioural skills.

It is vital for the spacewalker to be aware at all times of where their colleague and equipment are. Together with a high level of situational awareness, astronauts must have a good understanding of the spacewalk as a whole.

Working outside the Station, they get the big picture relying on frequent communications with ground control. Spacewalkers must show decision-making, problem-solving and communication skills.

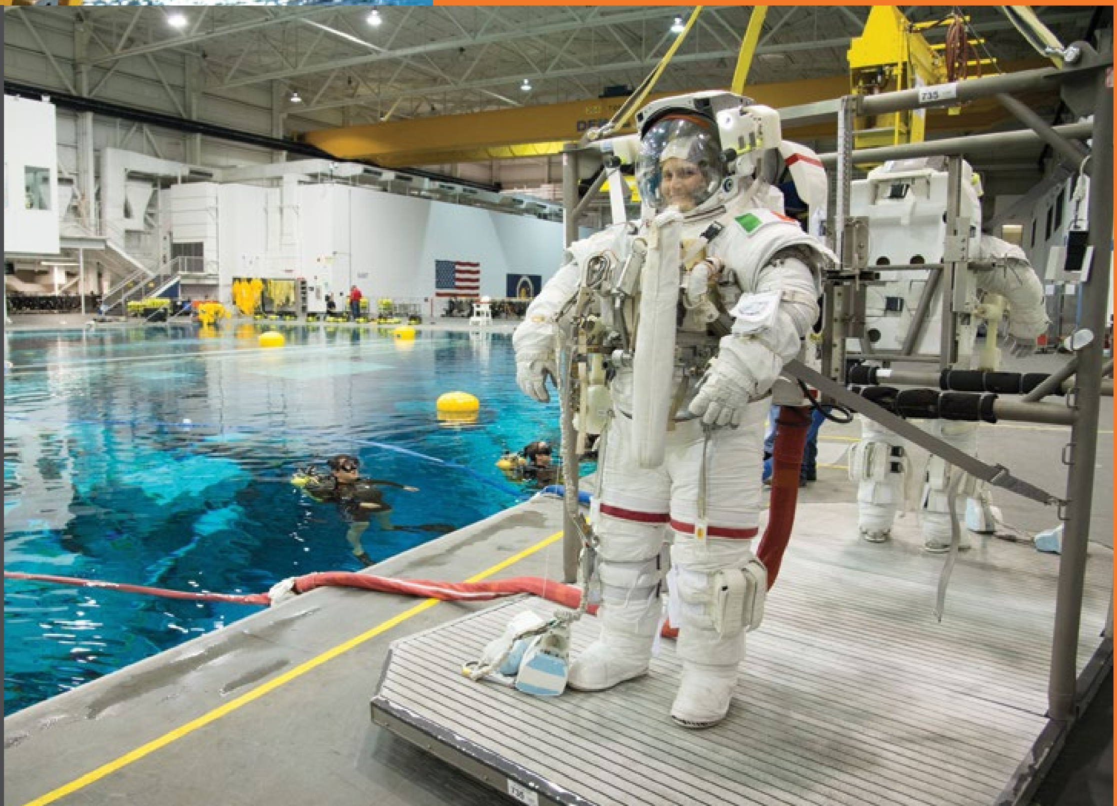
The average duration of an EVA is about six hours. Being tired or overworked can easily lead to fatal mistakes in the high-risk environment of space. The bulky spacesuit does not make things easier. With limited visibility and mobility inside it, astronauts learn to work 'slowly fast' for the sake of safety and efficiency.

Working with life-size mockups of the Space Station underwater, they practise moving between modules and exchanging equipment. The crew must be able to manoeuvre in the suit and guide themselves around the Station using handrails and tethers.

European fast track

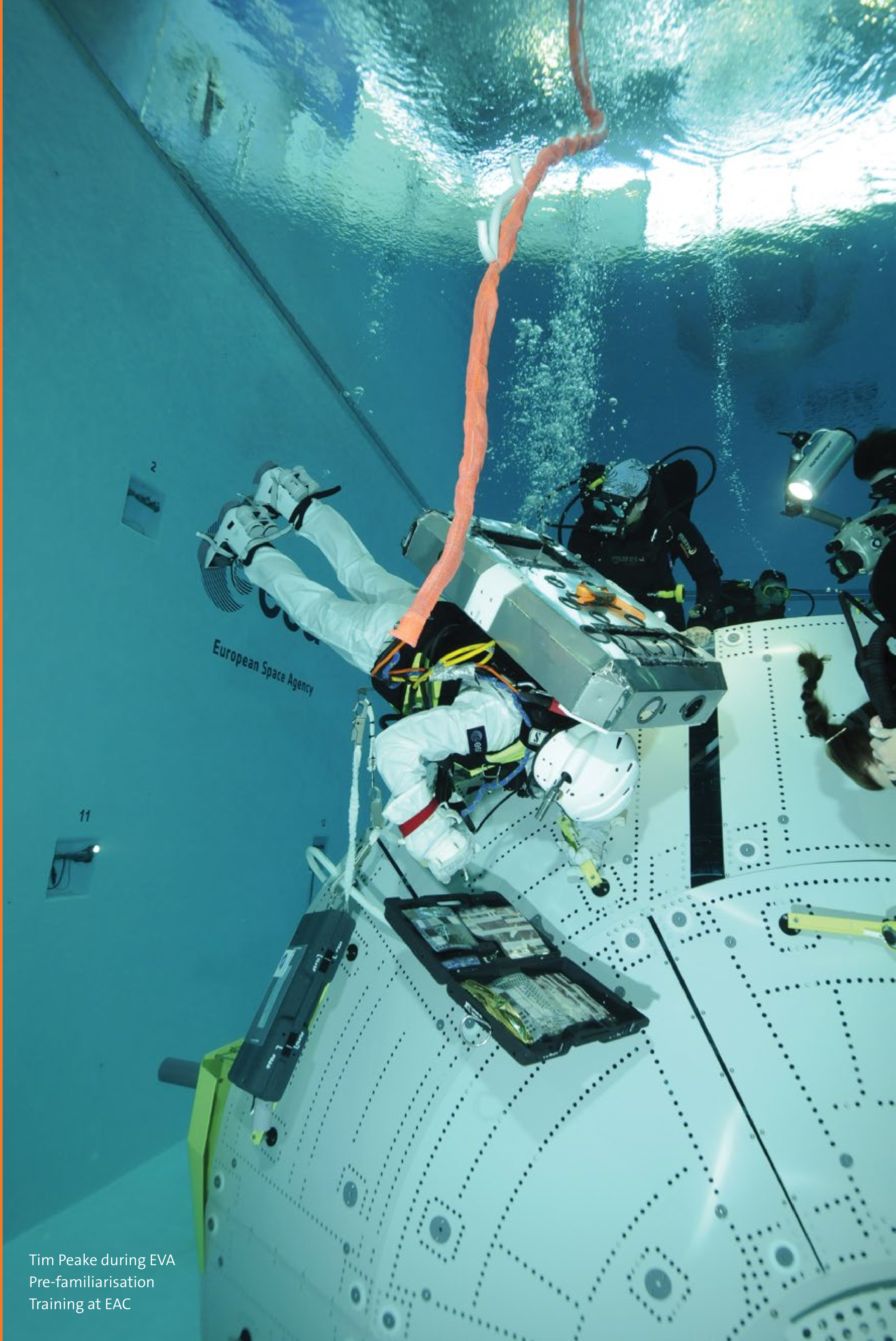
ESA has developed a unique EVA training to help European astronauts bridging the gap between their scuba diving certification and NASA's spacesuit qualification. The programme immerses them into the Neutral Buoyancy Facility, in Cologne, equipped with replicas of the spacesuit and tools.

These underwater lessons boost their skills before getting into real spacesuits at the American and Russian facilities. Known as 'EVA Pre-familiarisation, Proficiency Rebuilt and Recurrent Training', this programme gives them a head start on the core training on EVA and ISS operations.



↑ →

As well as EAC, astronauts train at both US and Russian neutral buoyancy facilities. ESA's Samantha Cristoforetti is seen at NASA's Neutral Buoyancy Laboratory in Houston (right), and in a Russian Orlan suit at Star City, Moscow (above)



Tim Peake during EVA Pre-familiarisation Training at EAC

ESA's Hans Schlegel during installation of the Columbus laboratory on the ISS in 2008 (NASA/ESA)

In August 2009, Christer Fuglesang was flying again, this time on STS-128. During this mission, Fuglesang became the first non-US/non-Russian astronaut to have participated in four or more spacewalks. With the completion of two more EVAs, his total EVA time added up to 31 hours 54 minutes, making him the most experienced European spacewalker so far.

In July 2013, Luca Parmitano became the first Italian ESA astronaut to take part in a spacewalk. With NASA astronaut Chris Cassidy, he made his first EVA, retrieving material research samples and accomplishing a number of maintenance tasks. He even got to ride on the Station's Mobile Servicing System robot arm to install some equipment.

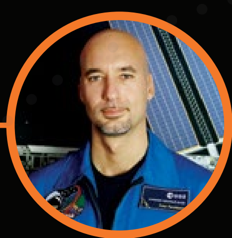
A little more than one hour into Parmitano's second EVA, he reported water floating behind his head inside his helmet and Mission Control decided to end the spacewalk early.

↑ On STS-128, Christer Fuglesang became the first non-US/non-Russian astronaut to have participated in four or more spacewalks (NASA/ESA)

2009

Christer Fuglesang (SE)

STS-128/Alissé



2013

Luca Parmitano (IT)

Soyuz TMA-09M/Volare

After the second shortest spacewalk in Space Station history, Parmitano was in good spirits and suffered no injury: his training and calmness under pressure possibly prevented a more serious outcome.

The most recent spacewalk for an ESA astronaut was by Germany's Alexander Gerst during his Blue Dot mission in 2014. British ESA astronaut Tim Peake is scheduled to make his first spacewalk on 15 January 2016 during ESA's Principia mission. In the 50 years since Alexei Leonov's first spacewalk, more than 200 astronauts from 10 countries have left their different spacecraft to work outside, and no doubt there will be many more.

While this article was in production, British ESA astronaut Tim Peake completed his first spacewalk on 15 January 2016 (see over page)

ASTRONAUT	MISSION	EVAS	TOTALS
Peake	Exp. 46/47	1	4h 43m
Chrétien	Soyuz TM-7	1	5h 57m
Gerst	Exp. 40/41	1	6h 13m
Haigneré	Soyuz TM-29	1	6h 19m
Schlegel	STS-122	1	6h 45m
Parmitano	Exp. 36/37	2	7h 39m
Nicollier	STS-103	1	8h 10m
Reiter	EuroMir '95/Exp. 13	3	14h 6m
Perrin	STS-111	3	19h 31m
Fuglesang	STS-116/128	5	31h 54m

↑ In July 2013, Luca Parmitano became the first Italian ESA astronaut to make a spacewalk (NASA/ESA)

↑ ESA's Alexander Gerst during his Blue Dot mission in 2014 (NASA/ESA)

2014

Alexander Gerst (DE)

Soyuz TMA-13M/Blue Dot

2016

Tim Peake (GB)

Soyuz TMA-19M/Principia

On 15 January, ESA's Tim Peake and NASA astronaut Tim Kopra completed a 4-hour 43-minute spacewalk to replace a failed power regulator and install cabling outside the International Space Station.

This was the first spacewalk for a British astronaut, but also the first sortie for the suit used by Tim Peake, which arrived on the Station in December.

The astronauts left the confines of the Space Station at 12:48 GMT after their five-hour preparation, which included donning their spacesuits and purging their bodies of nitrogen to avoid decompression sickness.

First, Tim Kopra worked his way to the far end of the Station's starboard truss, with Tim Peake following with the replacement Sequential Shunt Unit.

Swapping the suitcase-sized box was a relatively simple task, but one that needed to be done under some time pressure.

To avoid high-voltage sparks, the unit could only be replaced as the Station flew in Earth's shadow, giving spacewalkers only half an hour to unbolt the failed power regulator and then insert and bolt down its replacement.

Tim Peake gives quick wave to NASA astronaut Scott Kelly in the Cupola as he starts to tie down cables and complete electrical connections (ESA/NASA)

→ EXTRAORDINARY DAY

Next, with this main task complete, the Tims separated for individual jobs for the remainder of their time outside.

Tim Kopra reinstalled a valve that was removed as part of the relocation of the Leonardo module last year. Tim Peake was installing new cables for a new docking system when suddenly Tim Kopra reported a small amount of water building up in his helmet.

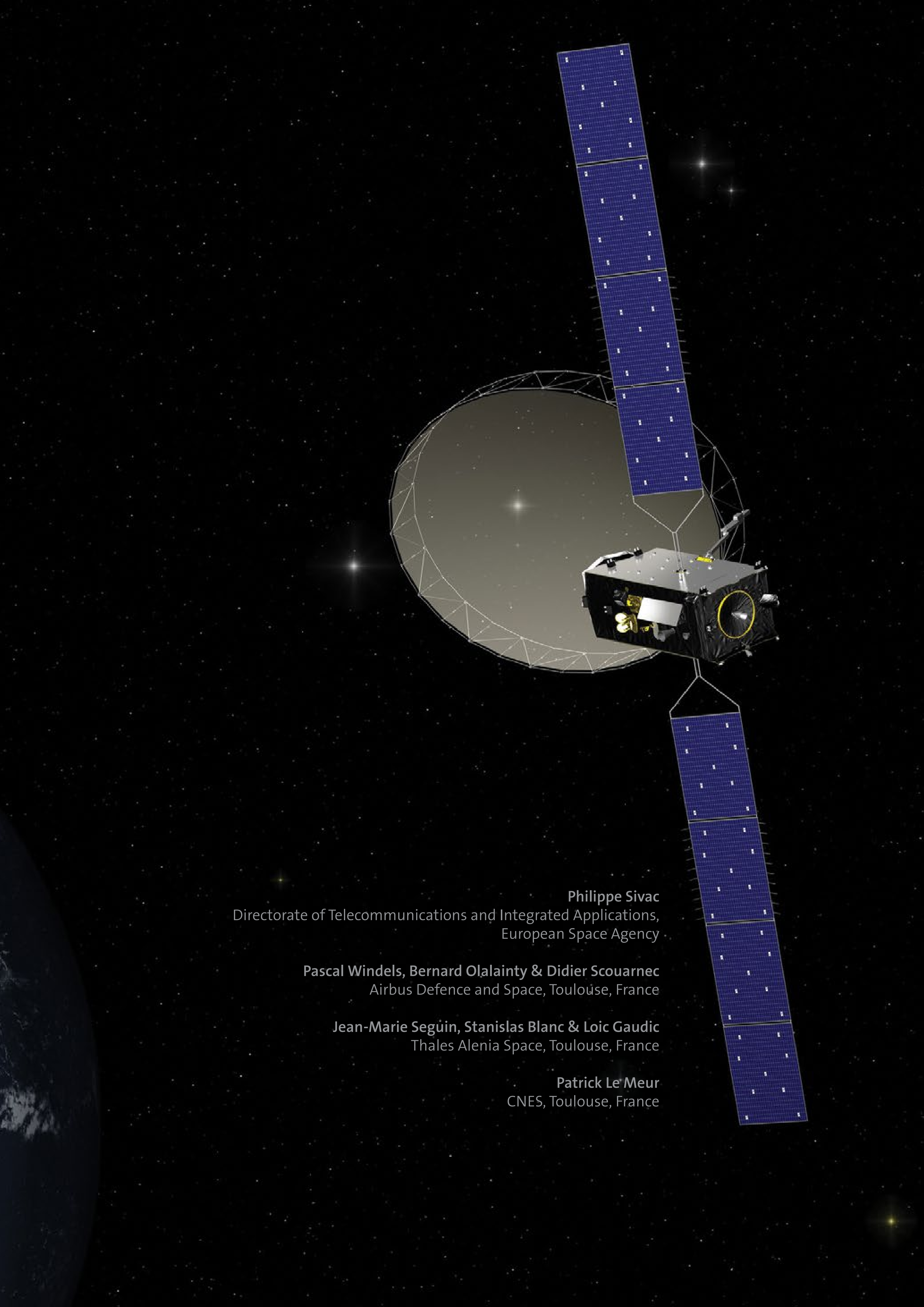
To be safe, Mission Control decided to end the spacewalk early and Kopra was told to return to the airlock before he could start his next task. The duo calmly cleaned up their work and the meticulously planned and executed sortie was stopped two hours ahead of schedule.

The two Tims helped each other in returning to the Space Station's airlock with NASA commander Scott Kelly and cosmonaut Sergei Volkov waiting inside, ready to help them out of their suits. The spacewalk officially ended at 17:31 GMT when the Tims began the repressurisation of the Quest airlock.

With the spacewalk completed, Tim had a few days of rest before continuing work on his extensive scientific programme that is part of his six-month Principia mission.

→ BENEFITS OF ALPHABUS

Europe's first large telecoms platform



Philippe Sivac
Directorate of Telecommunications and Integrated Applications,
European Space Agency

Pascal Windels, Bernard Olalainty & Didier Scouarnec
Airbus Defence and Space, Toulouse, France

Jean-Marie Seguin, Stanislas Blanc & Loic Gaudic
Thales Alenia Space, Toulouse, France

Patrick Le Meur
CNES, Toulouse, France

The high-power, high-capacity geostationary satellite market segment is critical for European industry – it now generates most of its activity in terms of business and employment.

European industry has developed and maintains a worldwide leading role in this fast growing market, largely due to the experience and benefits from the new high-power Alphabus platform. These are being applied to the Airbus Defence & Space's Eurostar and Thales Alenia Space's SpaceBus platform product lines and to their next generations, developed under ESA's Neosat programme.

Alphabus is a joint development by Airbus Defence & Space and Thales Alenia Space as co-prime contractors under a combined ESA and CNES contract. Both prime contractors jointly lead a European-wide industrial consortium to build Alphabus and solidify Europe's position in the worldwide high-power satellite market.

Alphabus has been acquiring in-flight validation since its first launch with Inmarsat's Alphasat in 2013. Most of the On Board Software components and avionics equipment developed for the Alphabus and Alphasat programme have been reused and up to now, have been a critical success factor in Airbus and Thales Alenia Space securing 20 satellite contracts that represent a value of €4 billion (including €2.5 billion for missions above 12 kW) and some 5000 jobs in Europe.

Alphabus: a powerful market enabler

The Alphabus development was Europe's response in the early 2000s to the market demand for larger telecommunication payloads aimed at direct-to-home TV broadcasting, digital audio broadcasting, broadband access and mobile services. At that time, only a couple of US firms were offering satellite power capability above 12 kW.

Yet there were clear market indicators (for example, return of investment of the satellite launch cost/channel) showing strong growth potential in the demand for high power capacity satellites in the years to come.

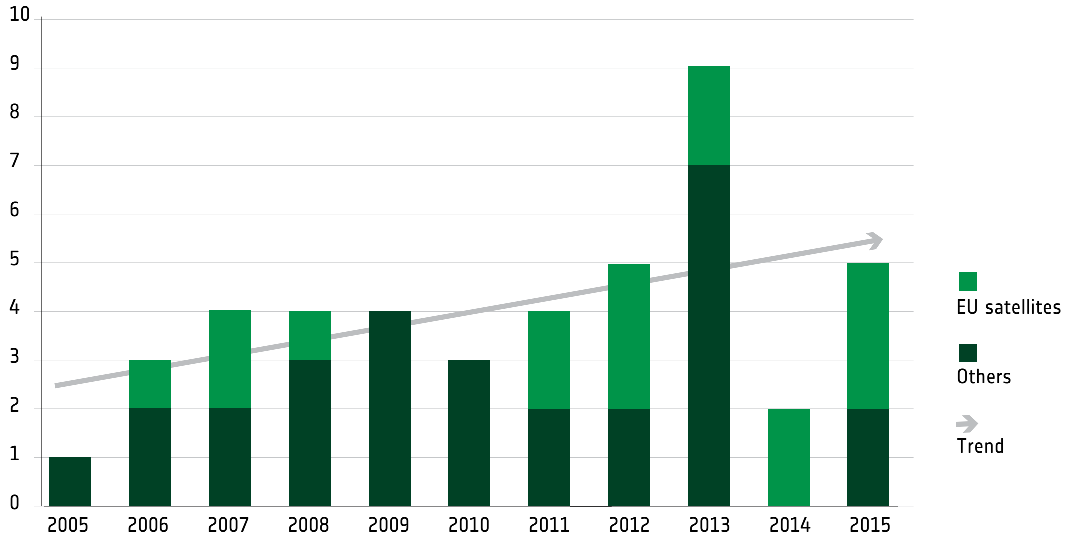
An analysis of the contracted satellites show that the satellites ordered with capacity above 12 kW has steadily increased from a single satellite in 2005 to five or six satellites per year (on average) in recent years.

The market share, in value, of telecommunications satellites with a power capacity above 12 kW represents more than 60% of the satellites contracted in the last three years versus an average value of less than 25% averaged in the past ten years confirming the estimated trend predictions of the early 2000s.

Today, thanks to the Alphabus research, development and qualification activities supported by ESA and CNES and the impact on the current and future product lines, Europe is firmly present on this segment with more than 45% market share with a total value exceeding €2.5 billion.

The currently running Neosat platform development integrates many of the Alphabus technical developments with the scope to further improve the integration and the industrial competitiveness. Throughout the Alphabus programme, synergies with existing platforms were fully exploited and where feasible, Alphabus developments were incorporated within these existing platforms, making the greater than 12 kW segment attainable.

Not only does this respond to a significant market need today, but it also paves the way for the forthcoming Very High Throughput Satellites (VHTS) such as the 1 TBit/s Viasat-3 satellites, rated at more than 20 kW, which will stretch the power and mass envelope even further.



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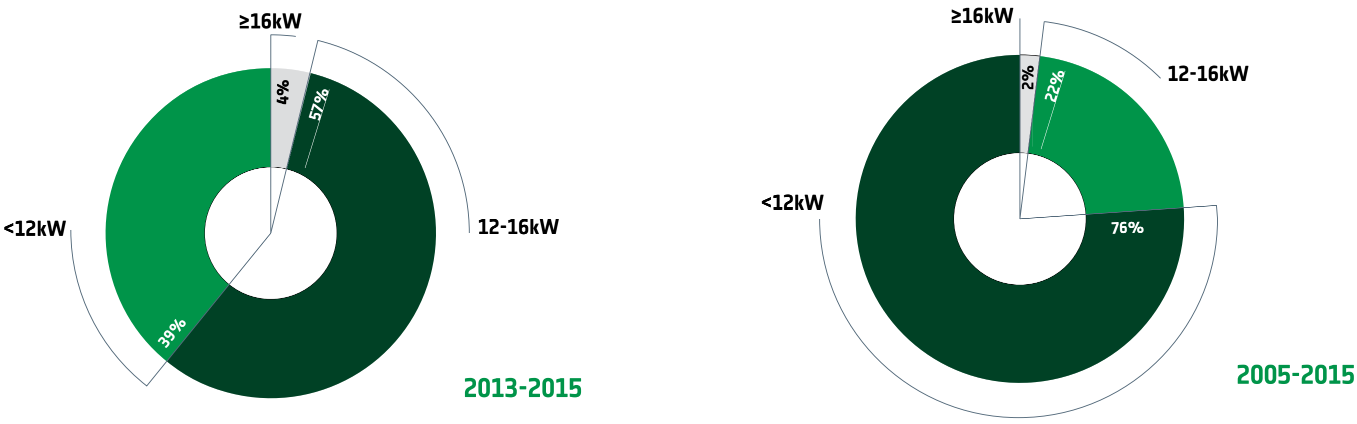
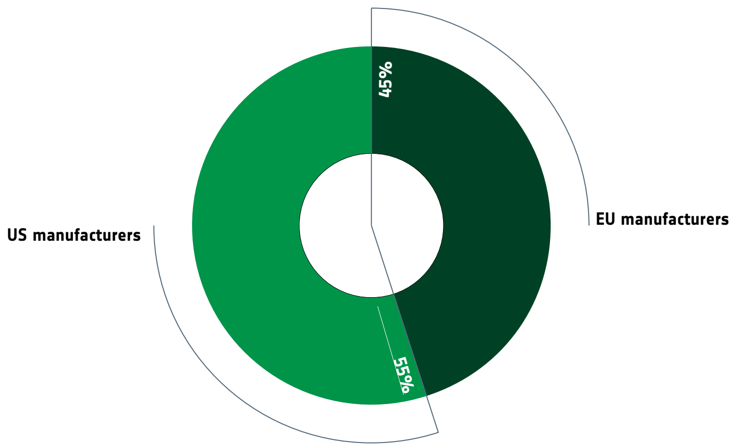
A decade of contracted high power capacity satellites, 2005–15

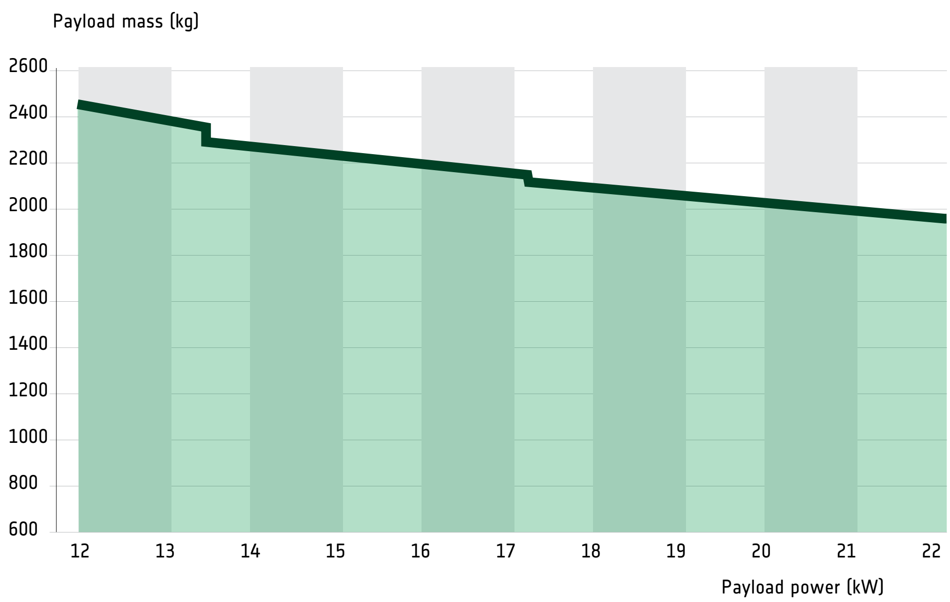


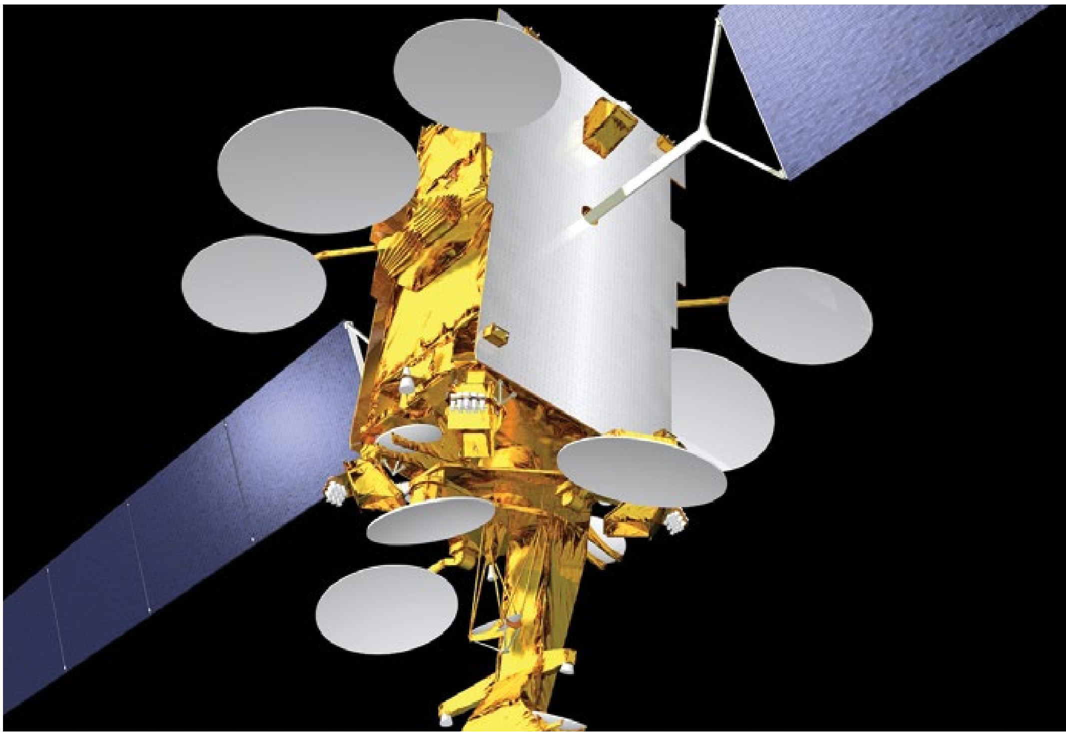
↑ Market share (in value) per payload capacity in the last two years and the last ten years



← Large power capacity satellites market share (in value), 2013–15

→ Alphabus payload domain





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Example of payload accommodation on the Alphabus platform

The Alphabus product

The Alphabus platform's main applications, given today's market trends are:

- HD TV large missions
- Multimedia applications with high numbers of spot beams
- Large geo-mobile missions

The payload domain covers up to 22 kW payload DC power; and up to 2 tonnes payload mass.

The Alphabus structure is a successful development of a complex structure compatible with a wide range of payloads and options. It is based on a modular concept, partially inherited from existing SpaceBus and Eurostar product lines but largely improved in order to achieve extension of the payload power range.

Structure development and qualification has been performed in both Thales Alenia Space French and Italian subsidiaries leading Thales Alenia Space Italy to be qualified and fully autonomous for the platform panels. The same approach of a modular structure is chosen for Neosat with reuse of parts of Alphabus structure for Thales Alenia Space SpaceBus Neo product line.

Major milestones

The Alphabus Phase-C/D programme has been running for nearly ten years. The initial contract was initiated in April 2006 to develop the Alphabus platform up to 18 kW and completed in October 2010, with a successful Qualification Review.

The Alphabus Extension programme was initiated in January 2011 to increase payload domain in terms of payload power, mass, thermal rejection, improve the compatibility with 4 m fairing launchers and improve equipment competitiveness.

The final Qualification Review for this extended range was passed in May 2015 for most of the domain up to 22 kW. For some applications, in which extra thermal rejection is required, the development and qualification of a Deployable Panel Radiator (DPR) is still running and expected to be completed by end of 2016.

Apart from this DPR development, the product line is presently in the maintenance phase and Alphabus-based solutions are being recommended for various Requests for Proposals of major telecommunications operators in the upper power range (17–22 kW).

Paving the way

The Alphabus programme has allowed both prime contractors to increase their system exposure to high-power platforms. The extensive work performed under Alphabus has generated tools in market analysis, competitiveness analysis, platform sizing and engineering skills in the various disciplines from design to operations.

These have been constantly updated to remain relevant with the high-power capacity market. Those competences

→ Deployable Panel Radiator

The Deployable Panel Radiator (DPR) is an innovative product providing additional radiating capability for highly dissipative payloads installed on the platform. Up to four DPRs can be accommodated on the spacecraft, with up to 1.3 kW dissipation on each unit. The DPR is made of a large aluminium panel (4 m x 1 m) fitted with Loop Heat Pipes. A single-axis deployment mechanism, including flexible hoses circulating ammonia between evaporators and condensers, allows the deployment of the assembly from launch configuration, stowed behind the solar array wings, to in-orbit configuration. EHP (BE) is responsible for the thermal and structural elements, while Sener (ES) provides the rotary actuator. The DPR Qualification Model will be ready by November 2016.

↑ DPR accommodation on the Alphabus platform

and tools directly contributed to the award of various programmes, open to worldwide competition, such as the Ekspress AM series, SES 12/14 and Inmarsat-6. They will also benefit future high-power SpaceBus, Eurostar and Neosat programmes.

The development of the Alphabus Data Handling System included improving the Platform Distribution Interface Unit and Satellite Management Unit. The SMU V1 has been used on each SpaceBus spacecraft since 2010. The same system architecture and many of these equipments have been chosen for the Thales Alenia Space Neosat product line, keeping competitiveness improvement as a major design driver.

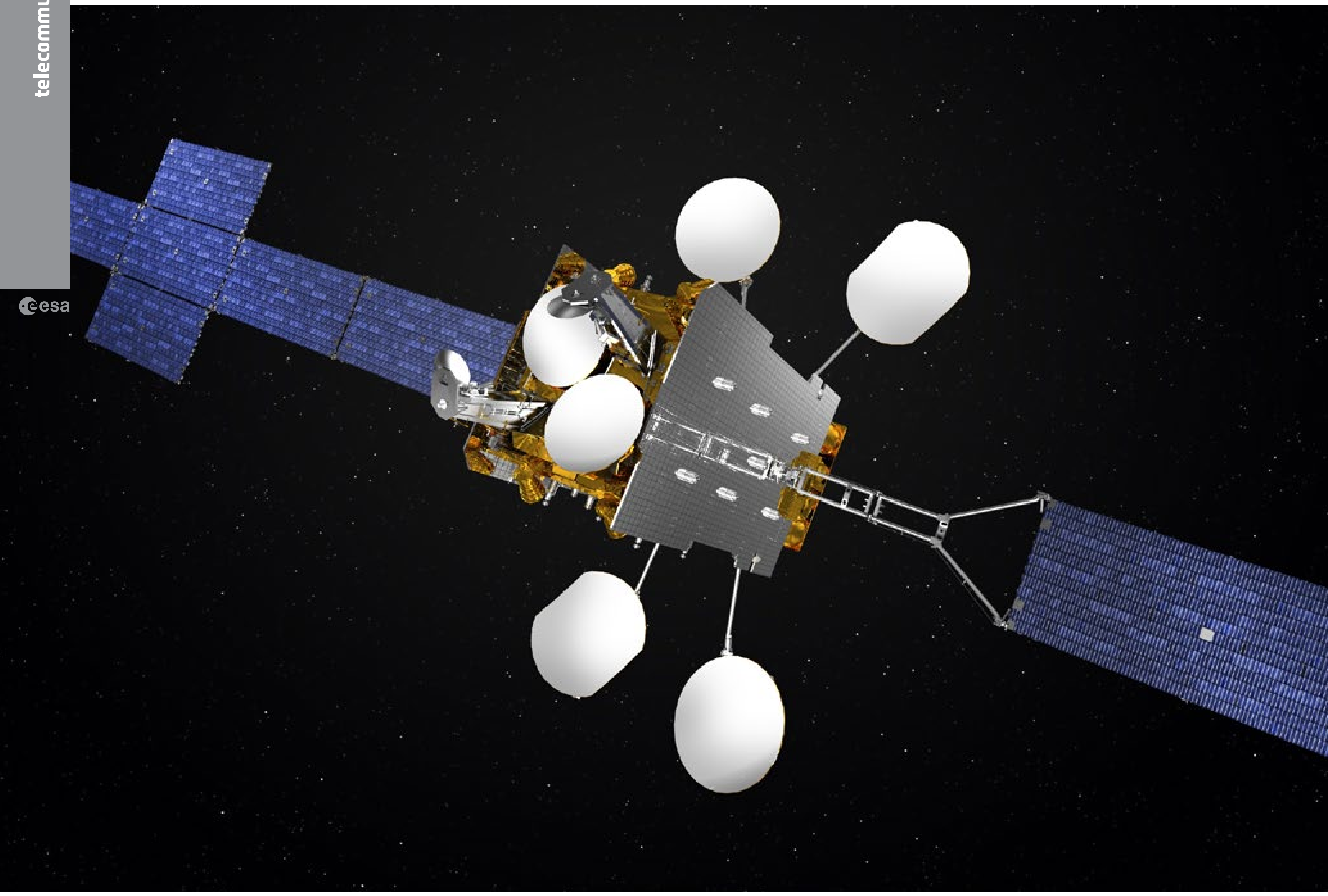
A numerical simulator has been developed and qualified to validate not only the operational procedures but also the Onboard Software (OBSW), and the Assembly, Integration and Test (AIT) procedures at system and avionics level.

The model is reused for other programmes such as Iridium and the Thales Alenia Space Neosat product line. This thermal model is accurate enough to be used as a support for the system-level thermal vacuum test sequence preparation, improving the test preparation time and reducing system-level risks during the test.

The Alphabus Attitude and Orbit Control System architecture and algorithms have been developed to improve platform pointing and provide a competitive solution without export control restrictions. The Alphabus Failure Detection Isolation and Recovery architecture and strategy are also extensively reused on Thales Alenia Space's SpaceBus 4000 and SpaceBus Neo product lines.

A very important synergy was obtained between Alphabus and Airbus Defence & Space Eurostar E3000 product lines, allowing Eurostar to be proposed in a 100 V version, with increased power capability. For example, the new generation (G5) battery cell modules were an

A PPS1350G electric propulsion thruster: since August 2013, four of these units have been operated on Alphasat. The two nominal units have each now accumulated more than 800 hours of operation, demonstrating Thales Alenia Space's flight experience and expertise in electric propulsion



impressive commercial success: they now constitute the baseline for all telecom bids, with either 50 V or 100 V power supplies. This synergy allowed common bulk procurement, and therefore greatly improved competitiveness on both product lines.

The Alphabus Plasma Propulsion activities have enabled both prime contractors to continue mastering electric propulsion at system and functional levels and successfully and rapidly introduce full electric versions of their products on the market. In addition it allowed Snecma and Thales Alenia Space to prepare their future generations of Hall effect thrusters and Power Processing Units.

The development of the Alphabus product line was a major contributor towards the maturity of several thermal engineering domains. For example, the Active Thermal Control Architecture with Thermal Hardware Unit on Alphabus demonstrated the benefits of full software temperature control as opposed to hardware-embedded regulation. It is a baseline feature on Neosat and provides high design flexibility with respect to equipment and system constraints.

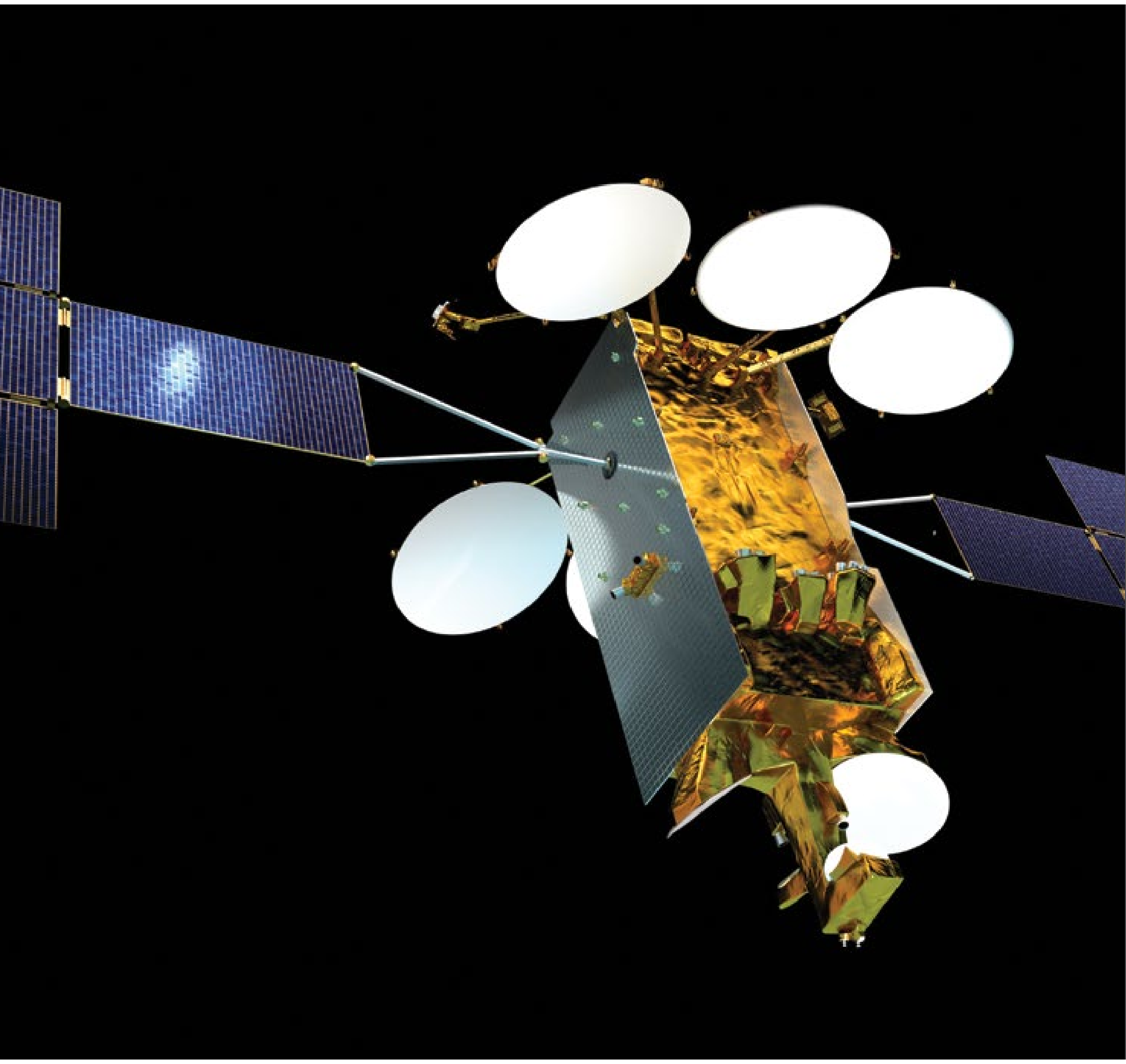
Production and AIT

The Alphabus programme is a major enabler towards the AIT of large telecommunication platforms, directly usable by the high end of Eurostar E3000 and SpaceBus, and available for future programmes. High-capability Mechanical Ground Support Equipment was developed, such as spacecraft lifting beams and heavy horizontal trollies. A large transport container was produced and used for transportation to launch site. 100 V Electrical Ground Support Equipment was developed and now used for in-house product lines.

Teams and processes were qualified for 100 V applications. Test facilities devices were upgraded: a weighing device for up to 6 tonnes, high-capacity travelling cranes and L-shape lifting systems. Additionally, possible improvements of RF measurement systems are identified for large telecommunication antenna configurations.

Operations

Within the framework of the Alphabus project, the operational preparations, development and implementation



←

ESA's Neosat programme, started in February 2014, is supporting prime contractors Airbus Defence & Space and Thales Alenia Space for development and qualification of their next-generation satellite platform product lines: Thales Alenia Space SpaceBus Neo (left) and Eurostar Neo from Airbus Defence & Space. The first prototype platforms are planned for launch in 2019 for in-orbit demonstration under a public–private partnership with satellite operators

were shared between Thales Alenia Space France and Airbus Defence & Space.

The Alphabus Extension programme was the main point of the operational roadmap to migrate the operations procedures editor from PGE (Procedures Generation Editor) to SCOPE (Satellite Control Operations Preparation Environment).

This migration produced operational procedures written with an editor function that follows the European Standard (ECSS) in terms of structure and instructions. This editor also upgraded the SpaceBus 4000 procedures with new functionalities, securing the first use of these functions in flight on SpaceBus 4000 satellites.

In addition, a translator tool was developed and validated to translate the Airbus Defence & Space procedures format written with OPSAT (PIL procedures) into Thales procedures format (SCOPE format). Alphanumeric displays, plots and database are also translated from one format to another. This translator eases the exchange between both companies, and Thales Alenia Space intend to use it in the Comsat-NG project (based on Neosat) to provide the customer with identical operational procedures for both Comsat-NG satellites.

Significant impact

Alphabus has made a significant impact on European industry, allowing it to consolidate its share of the high-power/high-capacity geostationary telecommunications satellite market.

A number of functional chains developed within the Alphabus programme have enabled upgrades and improvements of the Eurostar and the SpaceBus product lines. Also, Alphabus equipment and technologies have been very successful in sales by suppliers on the world market.

Today, the development of the Neosat platforms of each prime contractor is moving ahead very quickly, in large part due to Alphabus contributions and the prime contractors' experiences with this strategic market segment.

ESA's Asteroid Impact Mission concept, currently under study, would be humanity's first mission to a binary asteroid

→ AIMING FOR ASTEROIDS

A mission for testing deep-space technologies

ESA's Asteroid Impact Mission team
Directorate of Technical and Quality Management, HQ, Paris, France & ESTEC, Noordwijk, the Netherlands

Directorate of Science, ESAC, Villanueva de la Cañada, Madrid, Spain & ESTEC, Noordwijk, the Netherlands

Directorate of Operations, ESOC, Darmstadt, Germany

Sean Blair
Communication Department, ESTEC, Noordwijk, the Netherlands

Europe's proposed Asteroid Impact Mission is set to become humanity's first mission to a binary asteroid system, and ESA's first mission to a small body since Rosetta put down its lander on Comet 67P/Churyumov-Gerasimenko.

ESA's Asteroid Impact Mission (AIM) will have a ringside seat for the collision of a separate NASA spacecraft with the asteroid's tiny moon, gathering data that could help save Earth from impacts in the future. In addition, with its own microlander plus accompanying CubeSats, AIM will serve as a deep-space technology demonstrator gathering cutting-edge science data.

AIM is a mission in a hurry. It must be built and ready to fly for a firm October/November 2020 launch window in order to reach the Didymos binary asteroid system by June 2022. April saw the formal start of the AIM's design Phase-A/B1. Benefiting from a wealth of studies started in 2002 addressing the potential role of space missions to mitigate asteroid hazards, up to the latest Marco-Polo-R and Phobos sample return mission assessments and technology developments, AIM has taken full benefit of these results to run on a fast-track focused design effort.

As a result, the current AIM mission scenario is in fact the simplest and most cost-effective solution. It will enable the spacecraft to gather all the data necessary to validate the asteroid deflection technique known as 'kinetic impact' and its underlying physical models, demonstrate technologies for future exploration missions and retrieve scientific information that will finally constrain models describing the formation and evolution of our Solar System as well as planetary rings.

Two separate industrial consortia began working on design concepts for the mission's satellite platform, payload accommodation and operations in proximity to the asteroid. Running dual industrial contracts in parallel is a tried and tested way of encouraging as much innovation as possible, where a decision will be made between the two sets of results in summer 2016 following the intermediate system requirements review. The finalised design will enable ESA Member States to take a decision for the full mission implementation. After that, things should get really busy.

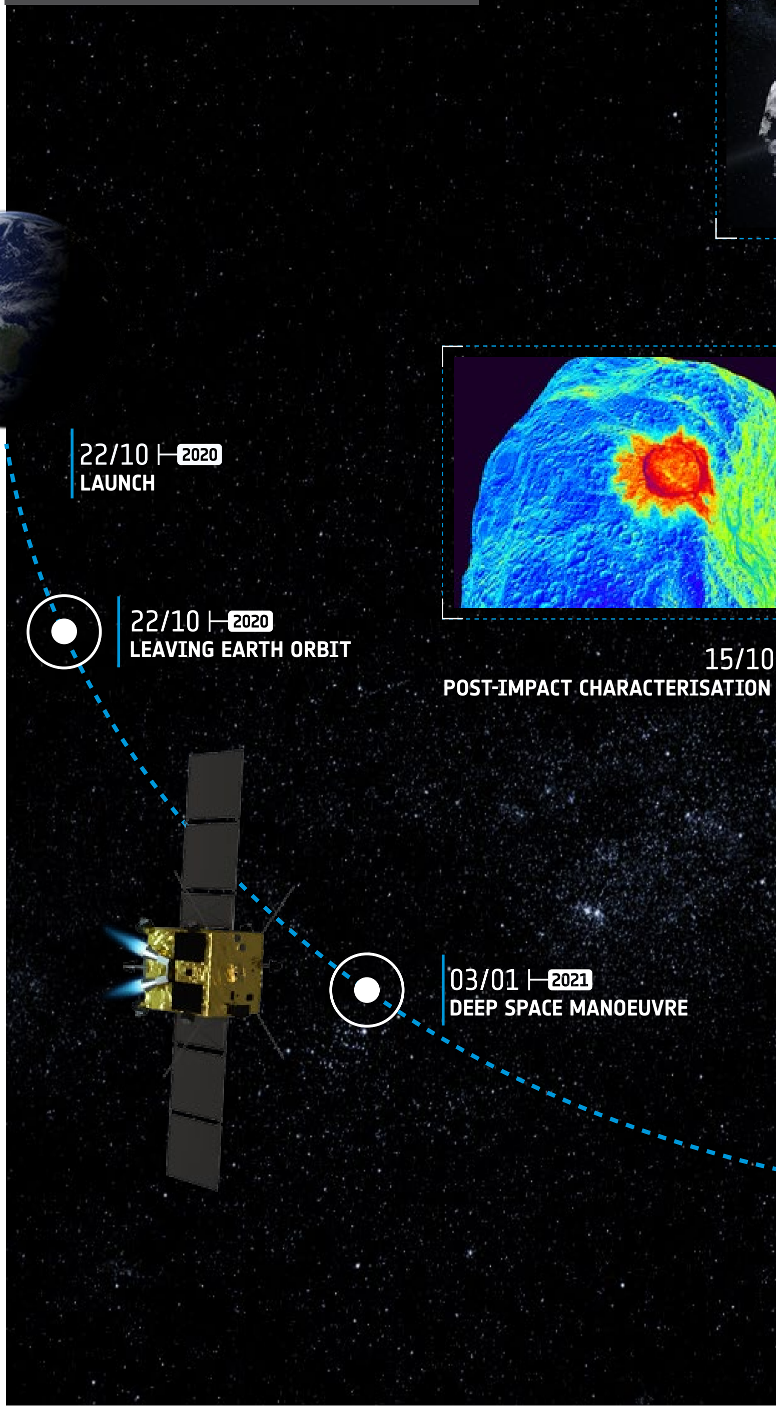
Low in cost, high in innovation

The objective of AIM is to be a new type of deep-space mission – low in cost, high in innovation and developed as fast as possible while accepting a higher level of risk. Past missions beyond Earth orbit proceeded at a statelier pace. Rosetta, by way of example, took a decade to construct, with key technologies such as its 'low intensity, low temperature' solar cells in development for much longer still. Rosetta then needed another ten years of planetary flybys before it reached its goal. AIM has to come together more rapidly – its launch window will allow it to reach its binary asteroid target within merely a year and a half thanks to a one of a kind celestial encounter with binary asteroid 65803 Didymos (1996 GT).

To stay affordable, AIM is first of all applying an aggressive development strategy, including testing and validation. It will also be a much shorter-lived mission than the decade-spanning Rosetta. AIM, with a maximum mass of 800 kg at launch and about the size of a large office desk, will also be much more compact than the lorry-sized Rosetta. The rest of the savings are coming from a simple design avoiding any costly mechanisms, exploiting technology developments from other ESA programmes – where AIM will provide flight validation – and reusing as much proven technology as possible. As a result, AIM will be a cheaper, though riskier, mission compared to the past.

AIM's target system comprises an 775 m diameter main asteroid orbited in turn by a 163 m moon, informally known as 'Didymoon'. In mid 2022, the path of these two asteroids will take them a relatively close 15 million km to Earth (less than 0.1 AU), enabling a battery of ground-based telescope and radar observations to complement the measurements performed from space. The smaller moon will be AIM's main focus, although data will also be gathered from the larger asteroid on an opportunistic basis.

↓ Stages of the Asteroid Impact Mission (ESA/ScienceOffice.org)



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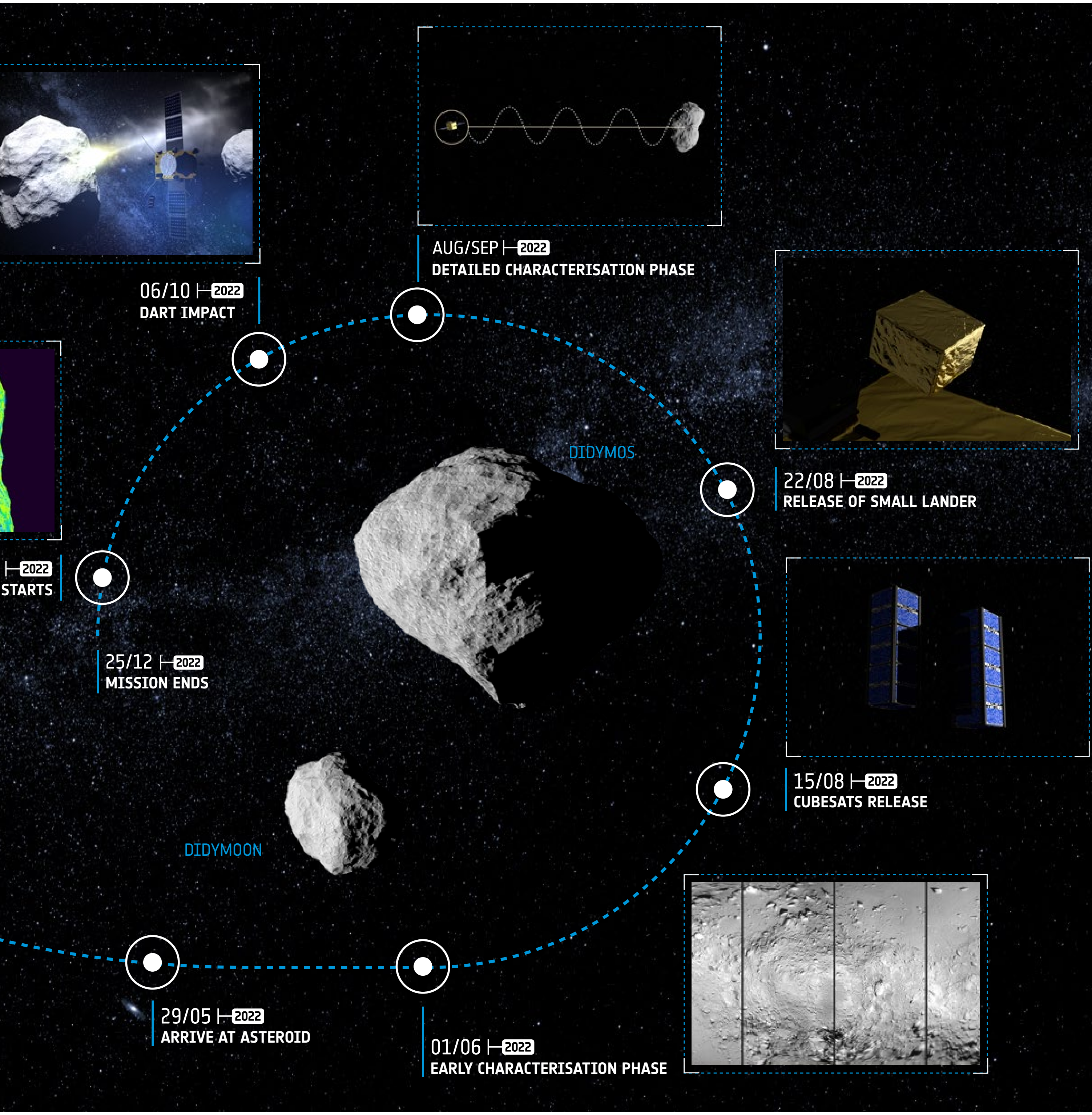


aim

ASTEROID IMPACT MISSION

+

dart

DOUBLE ASTEROID REDIRECTION TEST

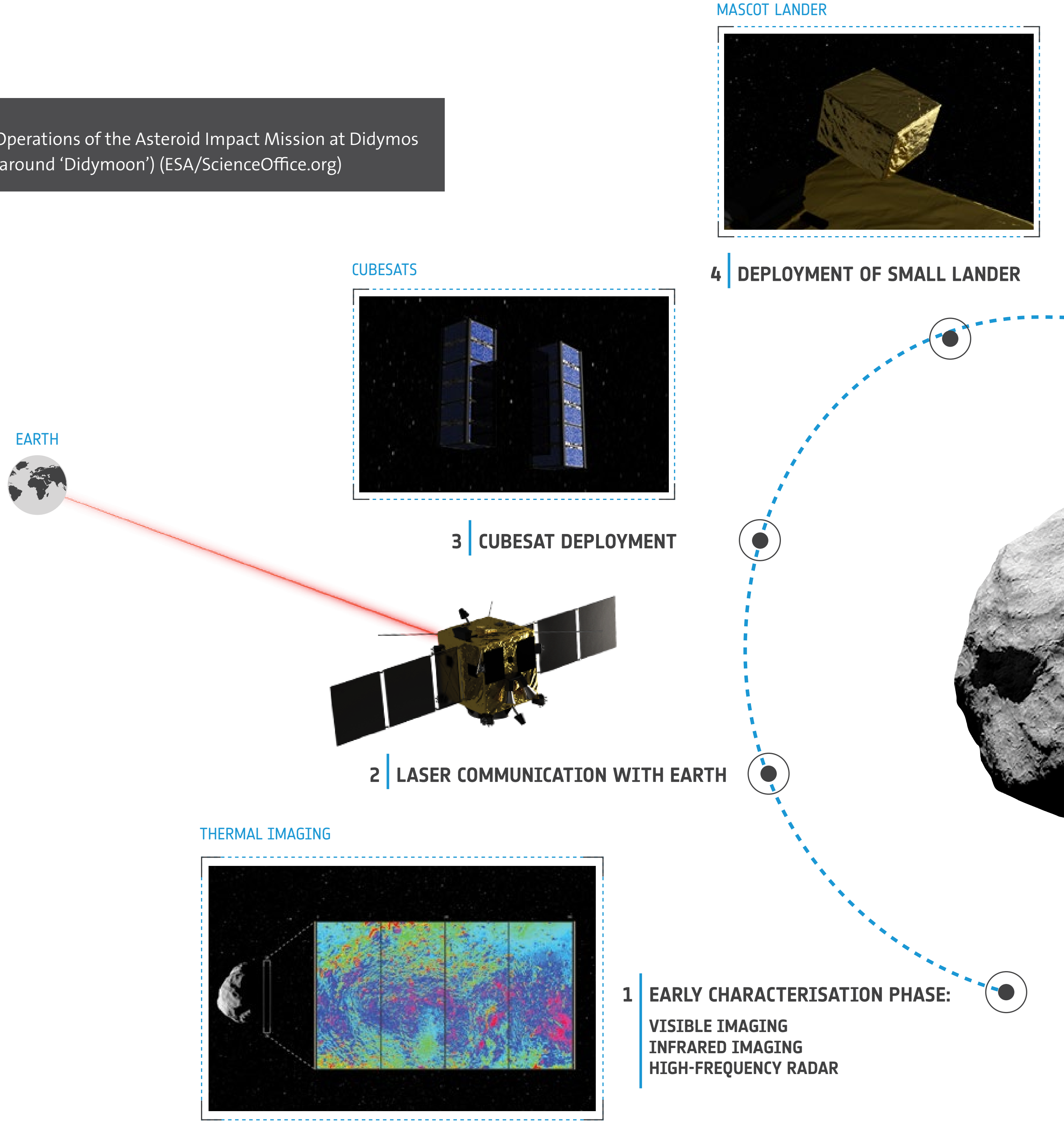
=

aida

ASTEROID IMPACT & DEFLECTION ASSESSMENT

AIDA is the combination of ESA's Asteroid Impact Mission with two triple-unit CubeSats to observe the impact of the NASA-led Demonstration of Autonomous Rendezvous Technology (DART) probe with the secondary Didymos asteroid, planned for late 2022

↓ Operations of the Asteroid Impact Mission at Didymos (around ‘Didymoon’) (ESA/ScienceOffice.org)



Making history

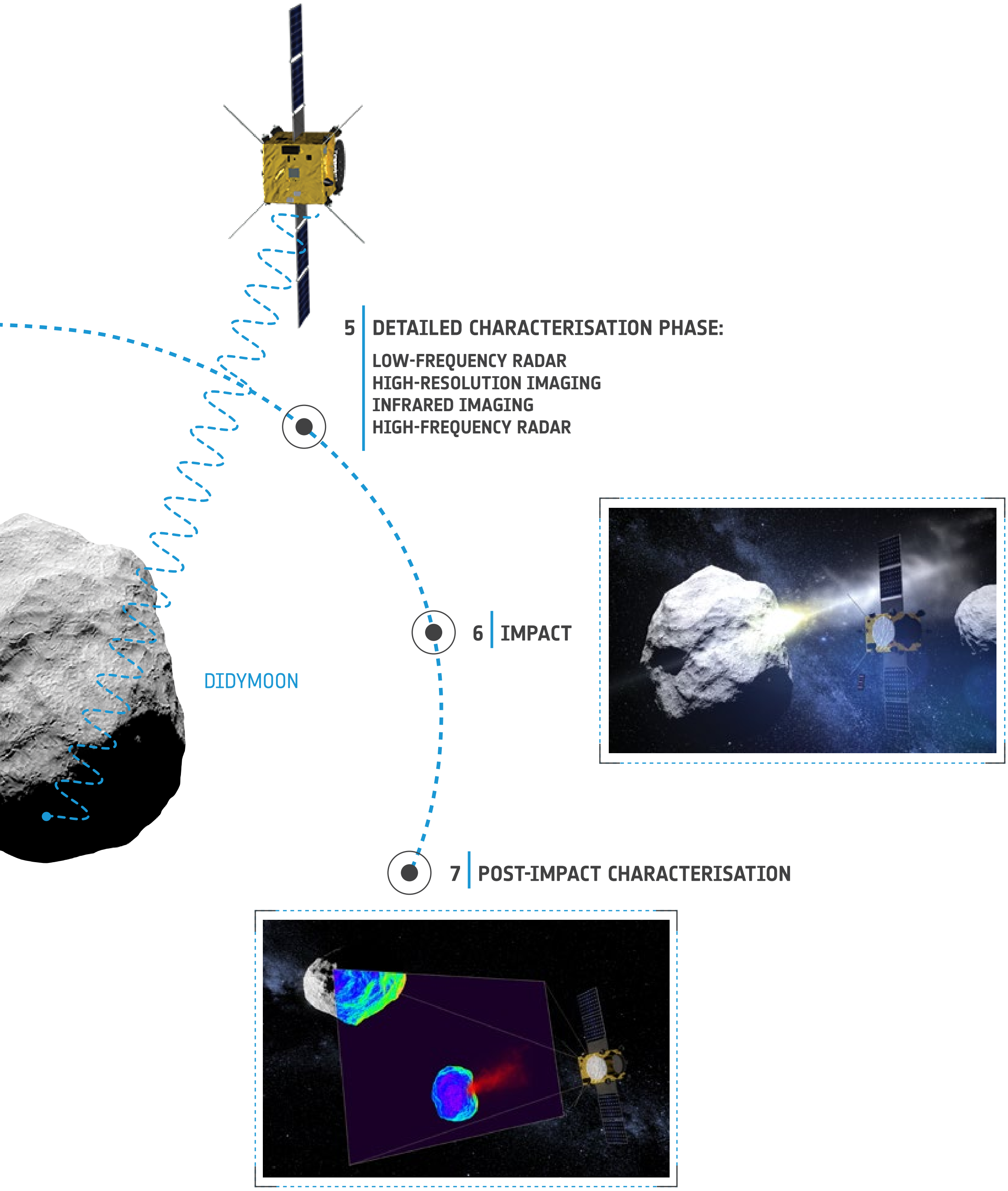
After about four months of detailed observations at Didymos, the next stage of the mission will be reached, when AIM is joined briefly by a terrestrial companion. Another spacecraft, the NASA-led Double Asteroid Redirection Test (DART) probe will home in on Didymoon, then crash into it at about 6 km/s.

DART, developed by the Johns Hopkins University’s Applied Physics Laboratory, intends to test the feasibility of diverting the path of an asteroid. This historic first attempt to shift the orbit of a Solar System body in a measurable way represents a ground-breaking test of planetary defence methods.

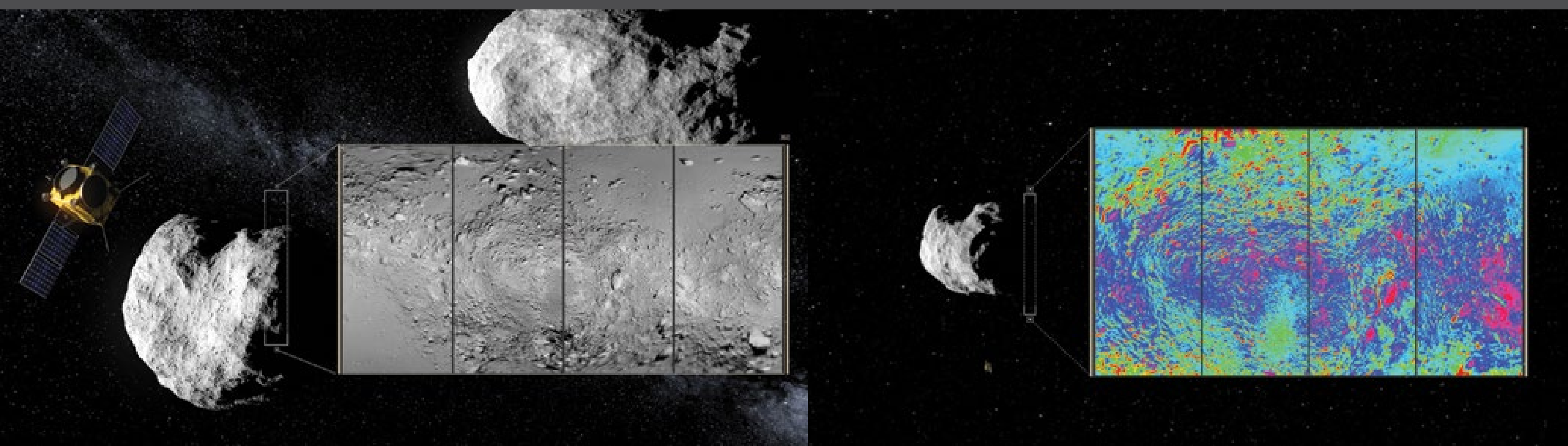
Meanwhile, AIM itself will be on hand to carry out detailed before-and-after observations of the asteroid’s deep-interior structure as well as its orbit, fully documenting the consequences of DART’s kinetic impact.

The closest precedent to this collision would be the 2005 impact of NASA’s Deep Impact probe with Comet Tempel 1, but that comet was a mountain-size 6 km across, whereas Didymoon is only the size of the Great Pyramid of Giza.

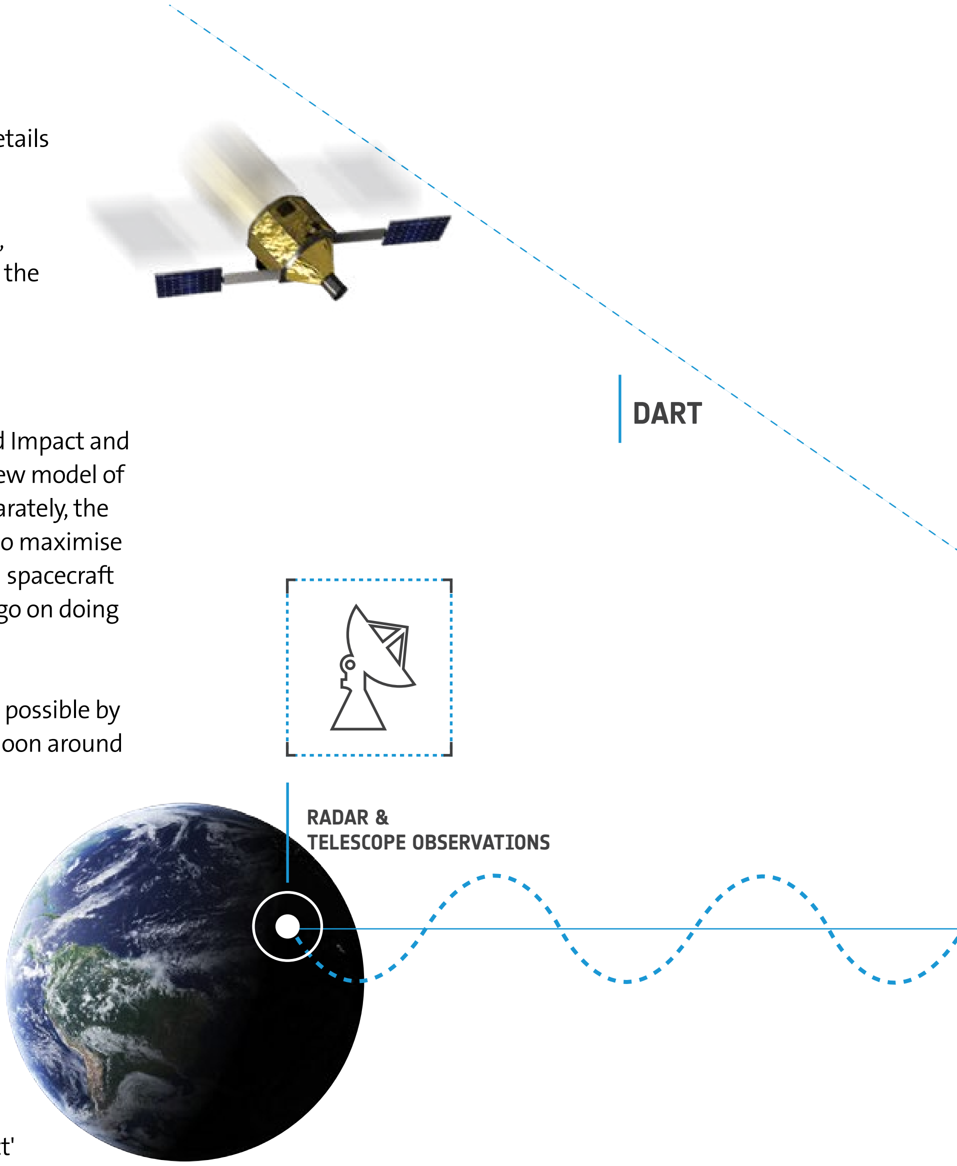
There was no prospect of deflecting Tempel 1’s orbit – the mission was actually tasked with revealing the cometary subsurface. Deep Impact’s accompanying observer spacecraft



↓ A combination of visual (left) and thermal (right) imagers will be trained on the asteroid's surface



was on a fast-moving flyby trajectory, and many details of the cratering event and its aftermath were not captured. This time the watching AIM will remain in a safe but close distance to the Didymos system, imaging in high resolution the cratering event and the ejecta plume dynamics.



↑ The Asteroid Impact and Deflection Assessment (AIDA) mission (ESA/ScienceOffice.org)

A new model of cooperation

The two missions combined are called the Asteroid Impact and Deflection Assessment (AIDA) mission. AIDA is a new model of international cooperation: while built and run separately, the two spacecraft are being planned in coordination to maximise their overall mission return. At the same time both spacecraft can pursue their own independent goals, and can go on doing so even if one of the two never reaches Didymos.

The fundamental measurement that will be made possible by AIDA is the variation of the orbital period of Didymoon around its parent 'Didymain' after the impact. AIM's own post-impact observations will be supplemented by monitoring from the ground. Cooperating astronomers will apply the light curve technique to estimate the shifted asteroid's rotation – measuring shifts in its light intensity over time. Ground-based radars will complement such measurements providing a second independent set of data.

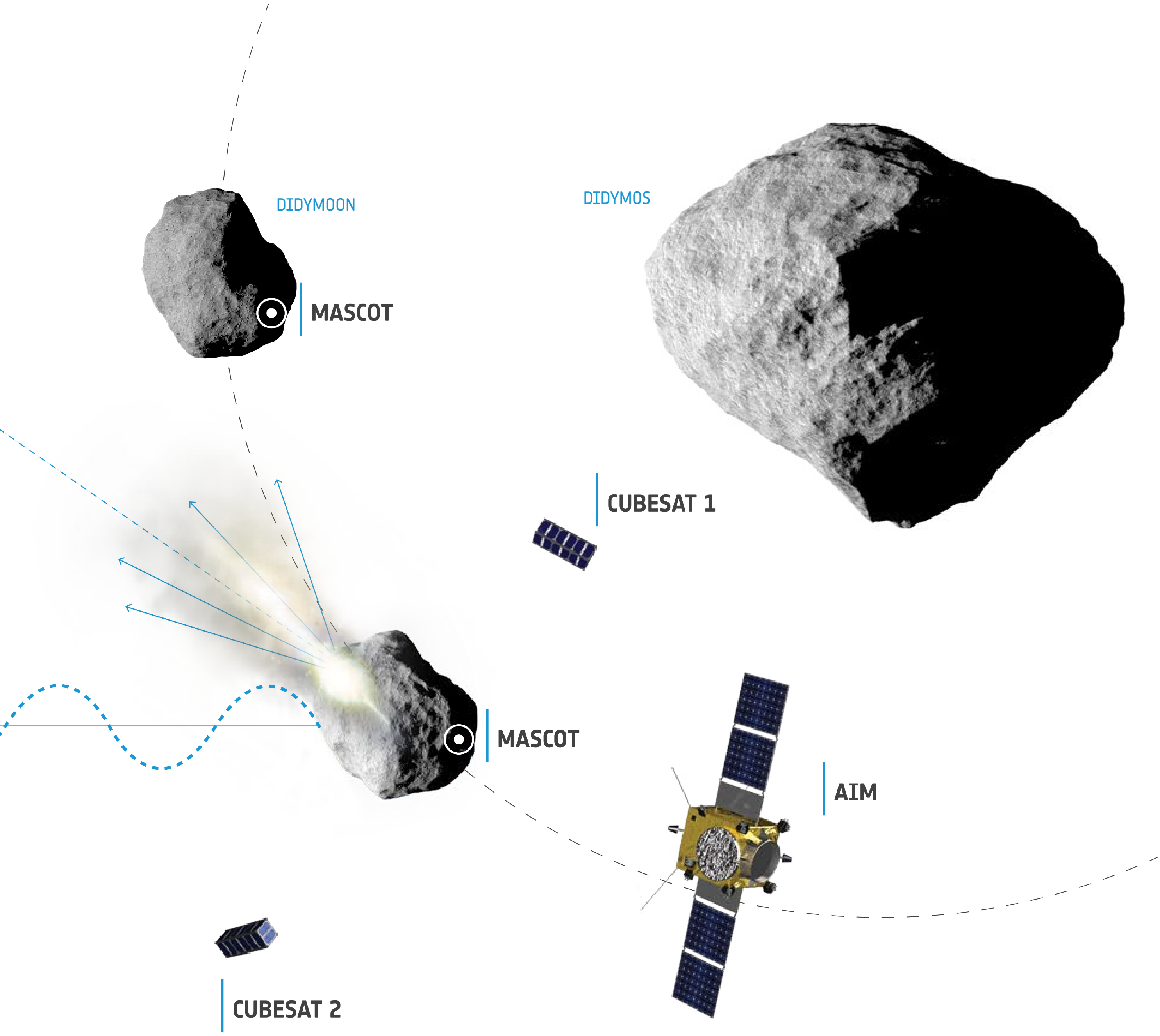
In the aftermath, once the collision's effects have been fully documented and studied, 'kinetic impact' will become a proven technique that could feasibly be applied to other targets, should the need ever arise to protect our home planet. In this context, AIM will also enable the ground-truthing of a number of parameters for future asteroid observations relevant to the Near Earth Object segment of ESA's Space Situational Awareness programme.

Intended to be launched on an Ariane 6.2 rocket from Europe's Spaceport in French Guiana, the spacecraft design will be a simple one. Measuring 1.8 x 2.0 x 2.1 m^3 (with solar arrays stowed), it will have a simple integration-optimised structure, a fixed high-gain antenna and a bipropellant thruster system with 24 10-Newton thrusters.

Among its other purposes, AIM will serve as an important technology demonstration mission. It will prepare the way for future interplanetary missions to come by using deep-space optical communication techniques, intersatellite communication with its CubeSats and microlander, and novel autonomous proximity operations in low gravity. In addition, AIM will perform science – indeed, meaningful scientific results are seen as the best possible proof of its various technologies – but to do this within the available budget, mass and time envelope requires an extremely tight focus in terms of mission design.

AIM is therefore undergoing streamlined design work, with many trade-off options already closed through numerous past ESA studies of asteroid missions. For instance, during its 18 month-long cruise phase – the bulk of AIM's time in space – the spacecraft will remain largely inactive. However, once at Didymos, there will be six months of extremely busy days. With a payload suite selected early on, teams are devising detailed plans to operate every instrument in an optimal way while coping with a simple, resource-limited platform.

AIM's hardware, therefore, will operate in an interdisciplinary, multi-tasking fashion. Take the visual imaging system used to perform guidance and navigation on the way to Didymos: this will also work to achieve the main mission objectives, measuring the Didymos orbital period change and mapping the asteroid surface in high resolution. The laser, too, which

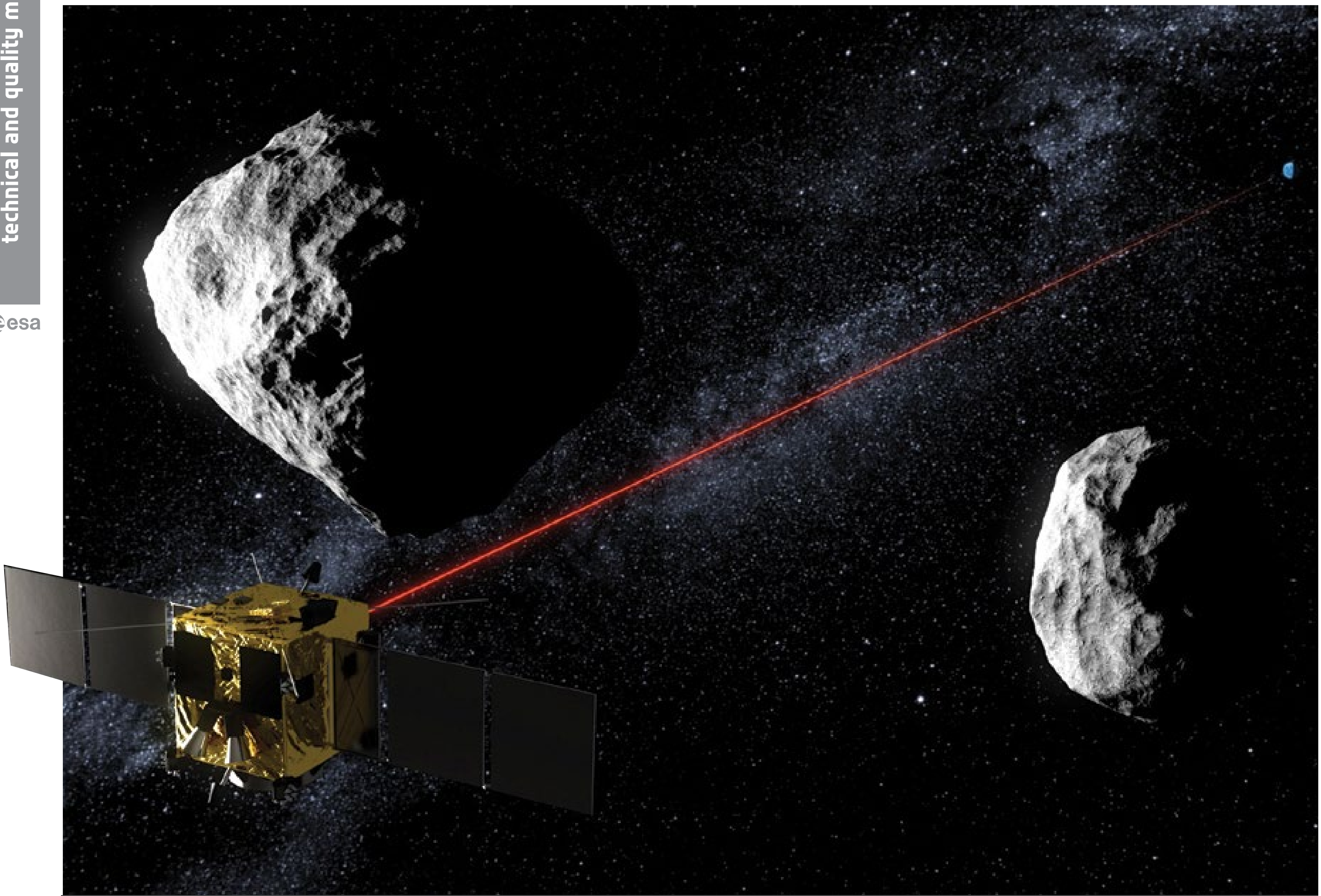


will be demonstrating potentially high-bandwidth return of science data high-bandwidth return of science data to Earth, will also perform laser ranging with the asteroid for both close proximity operations in closed loop with AIM's guidance system and altimetry measurements.

A combination of visual and thermal imagers will be trained on the asteroid's surface. The thermal imager – also being considered to do double duty as the potential receiving end of the optical communications terminal – will work to discriminate between the various properties of the Didymoon surface, from solid rock to loose stones to layers of dust. Such thermal measurements will help characterise the structure and cohesion of the soil, as well as other effects believed to influence asteroid motion (photon pressure on an irregular asteroid body can induce force and torque – known as the 'Yarkovsky/YORP effect').

These imagers will be complemented by high-frequency radar (HFR) to sound the outermost surface and sub-surface layers, down to a depth of a few metres. A unique bistatic low-frequency radar will also characterise, for the first time in history, the deep interior structure of the asteroid, shedding light over decades of debate on the formation processes of these tiny celestial bodies.

The HFR is a stepped frequency radar which, with very modest power consumption, can operate over a wide bandwidth to provide a free-space resolution distance between spacecraft and asteroid of less than 10 cm. As the AIM spacecraft passes relatively slowly across the surface, HFR will build up a detailed 3D surface map. Pulses at the lower end of the spectrum will penetrate down to 6–10 m depth.



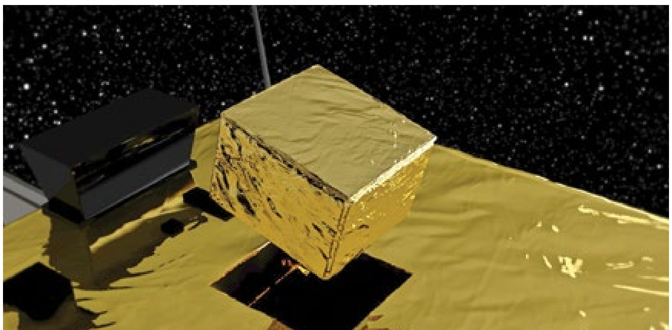
↑ AIM would send science results back to Earth via a high-bandwidth laser link

Getting the data back

The large amounts of data generated by the AIM payload will be returned to Earth via a novel holographic high-gain antenna plus its laser communication system, maintaining a high-bandwidth link back to ESA's Optical Ground Station in Tenerife. To keep mission costs down, AIM's laser terminal is not optimised to be the main communication system. Instead, an existing terminal designed for low-Earth orbiting satellites is being adapted for deep space and demonstrate key new features (such as using Earth's own infrared emission as a beacon for coarse pointing). Optical communication in general is not yet a well-established technology for space and ESA's European Data Relay System (EDRS) will be the first commercial application.

EDRS satellites in high orbits will use laser links to return environmental data from Europe's low-orbiting Sentinel satellites on a real-time basis, a technique previously demonstrated using ESA's Alphasat and Artemis telecoms missions. Such technology in the future will be key to enabling deep-space human exploration missions where high bandwidth will be required.

In principle, optical communication works something like Morse code, with encoded rapid flashes on and off. The much higher frequency of laser light delivers higher directivity and as a result increased bandwidth.
The scale of optical communications continues to increase: in 2013 ESA's Optical Ground Station in Tenerife participated in a two-way contact with NASA's LADEE lunar orbiter, across 400 000 km. However, AIM will need to operate over much



↑ AIM's MASCOT-2 lander deployment

→ Choosing CubeSats

Five CubeSat concepts to potentially accompany AIM into deep space are being studied following a call for mission proposals. Other options may be addressed in the near future following ESA Member States' capabilities and advancing technologies.

The ideas currently being looked at include taking a close-up look at the composition of the asteroid surface, measuring the gravity field, assessing the dust and ejecta plumes created during a collision and landing a CubeSat for seismic monitoring.

The proposals selected for further study are:

- AGEX (Royal Observatory of Belgium, ISAE-SUPAERO, Antwerp Space, EMXYS, Asteroid Initiatives Ltd). A CubeSat touches down to assess the surface material, surface gravity, subsurface structure and DART impact effects. Another CubeSat in orbit deploys smaller 'chipsats' dispersed over the asteroid.

- ASPECT (VTT Technical Research Centre of Finland, University of Helsinki, Aalto University Foundation). A CubeSat equipped with a near-infrared spectrometer to assess the asteroid composition and effects of space weathering and metamorphic shock, as well as post-impact plume observations.

- DustCube (University of Vigo, Micos Engineering GmbH, University of Bologna). A CubeSat to measure the size, shape and concentration of fine dust ejected in the aftermath of the collision and its evolution over time.

- CUBATA (GMV, Sapienza University of Rome, INTA). Two CubeSats measure the asteroid system's gravity field before and after impact through Doppler tracking of CubeSats, as well as performing close-range imaging of the impact event.

- PALS (Swedish Institute of Space Physics, Institute for Space Sciences IEEC, Royal Institute of Technology KTH, AAC Microtec, DLR). Two CubeSats characterise the magnetisation, bulk chemical composition of, and presence of volatiles in, the impact ejecta, as well as performing very high resolution imaging of the ejecta components.

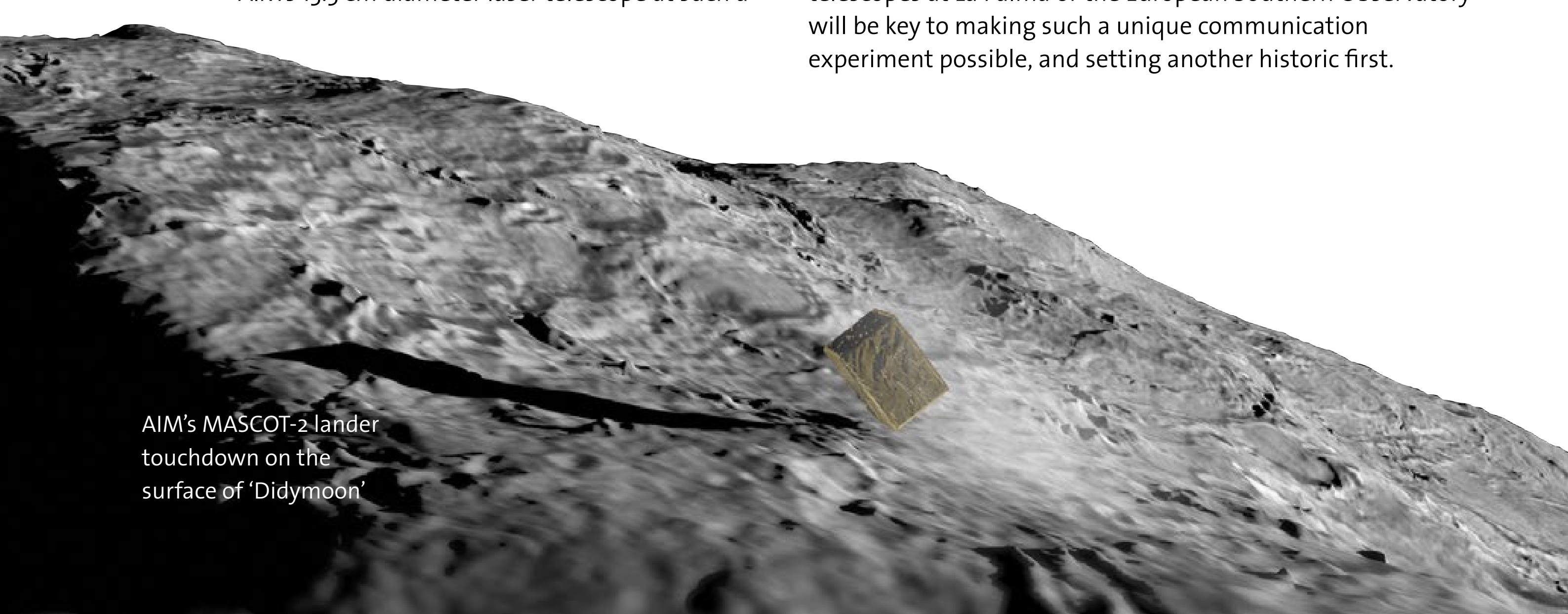
With these opportunity payloads, ESA is applying current European technology miniaturisation efforts to explore our wider Solar System in unprecedented ways, lowering the cost and risk of interplanetary missions. The selected proposals will complete their detailed study phase in June 2016, helping the AIM team define all necessary interfaces, ahead of a final selection to fill the two berths.

→ A pair of triple-unit CubeSats. ESA's Asteroid Impact Mission spacecraft will have room to carry six CubeSat units – potentially single-unit miniature spacecraft but more probably a pair of larger CubeSats

farther distances: the team is benchmarking a maximum span of 75 million km, or half the distance between Earth and the Sun. That might sound like a lot, but operating around Mars one day will involve much greater distances still.

That is why the industrial team is working hard to devise a low-power mode to demonstrate the terminal's operability when the transfer orbit will take AIM at distances very close to the ones of Mars. A laser beam shone back from AIM's 13.5 cm diameter laser telescope at such a distance would have a ground footprint of about 1100 km – farther than from London to Berlin. That may seem large, but an equivalent radio beam radiating out across space would end up wider than our whole planet. Even so, many photons will get lost on the way, so the 1 m diameter scale receiver telescope will need sophisticated photon-counting methods to detect the signal reliably.

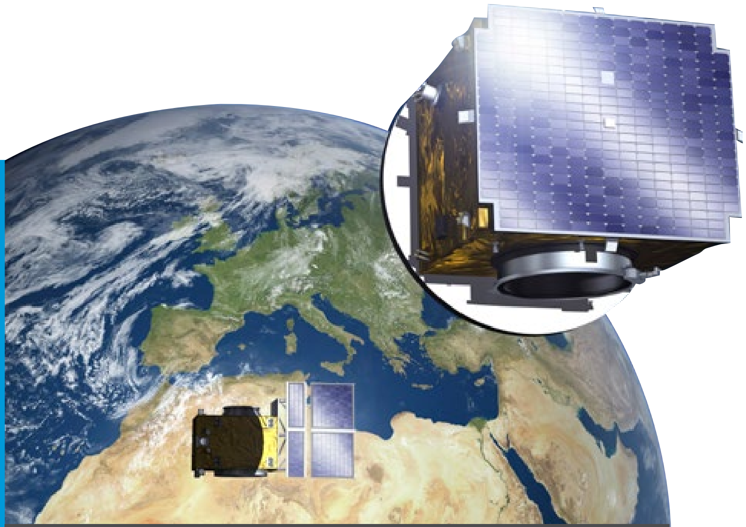
When AIM is furthest away, the support of larger ground telescopes at La Palma or the European Southern Observatory will be key to making such a unique communication experiment possible, and setting another historic first.



AIM's MASCOT-2 lander touchdown on the surface of 'Didymoon'

→ Technology testers

ESA has a noble history of technology demonstration missions, which go on to double as innovative science missions. Demanding science payloads serve as the best possible demonstration of experimental technologies. If the results are good enough, then the scientific end users will come – challenging Europe's space engineers to do their very best to make it happen.



↑ Proba-3

The Project for On-Board Autonomy (Proba) family of mini-satellites exemplifies this approach. Proba-1, launched in 2001 and still going strong, was an experimental hyperspectral satellite turned operational Earth observation mission. Onboard innovations included what were then novel gallium arsenide solar cells, one of the first lithium-ion batteries – now the longest operating such item in low-Earth orbit – and attitude and orbit determination using only star trackers and GPS sensors, doing without the then-standard Earth or Sun sensors or gyros (GPS timing being used to synchronise operations).

Navigation and attitude control software was generated through 'autocoding' to cut costs – essentially applying code to write code – with Proba-1's onboard computer running on one of the first ERC32 microprocessors.

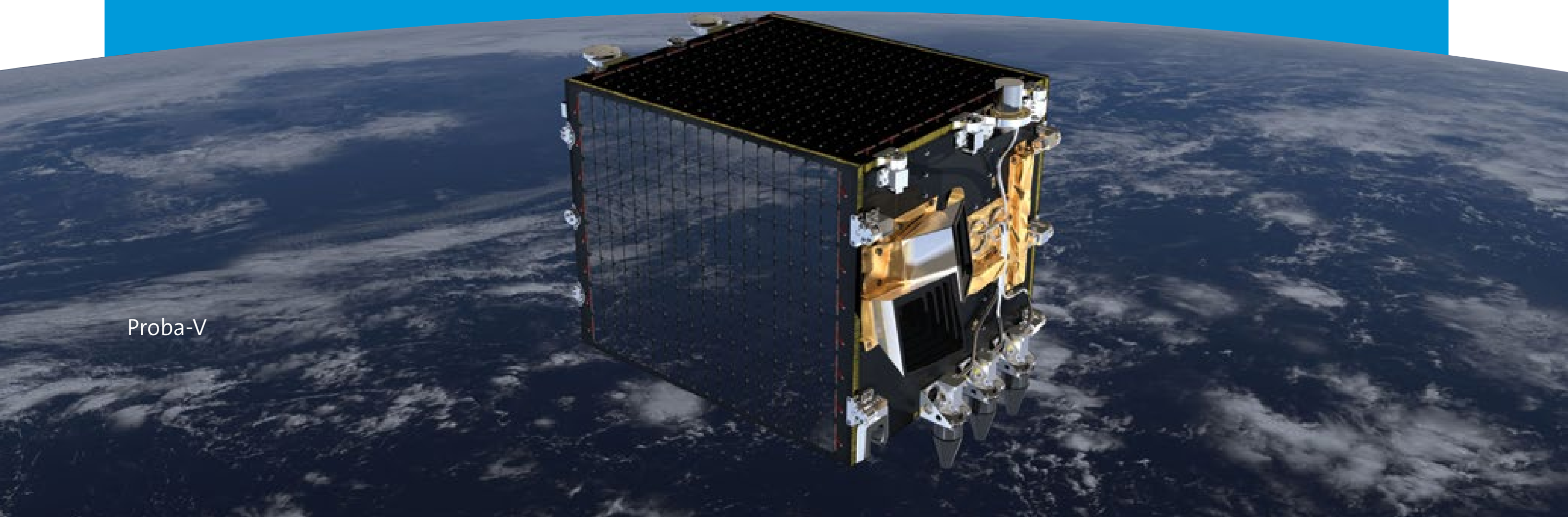
Next, ESA's SMART-1 took technology testing beyond Earth orbit, demonstrating an innovative electric engine on a slow flight to the Moon following its launch on 27 September 2003. It went on to survey the lunar surface and investigate the prospect of ice at the lunar poles, finally ending its mission in September 2006 with a planned impact on the lunar surface.

Proba-2, launched in 2009, focused on solar observations and space weather monitoring. The satellite's main computer ran on the first LEON2-FT microprocessor operated in space, while the mission also hosted 16 other new technologies including a new type of lithium-ion battery, an advanced data and power management system, combined carbon-fibre and aluminium structural panels, the first Active Pixel Sensor startracker (subsequently used on BepiColombo) and new models of reaction wheels.

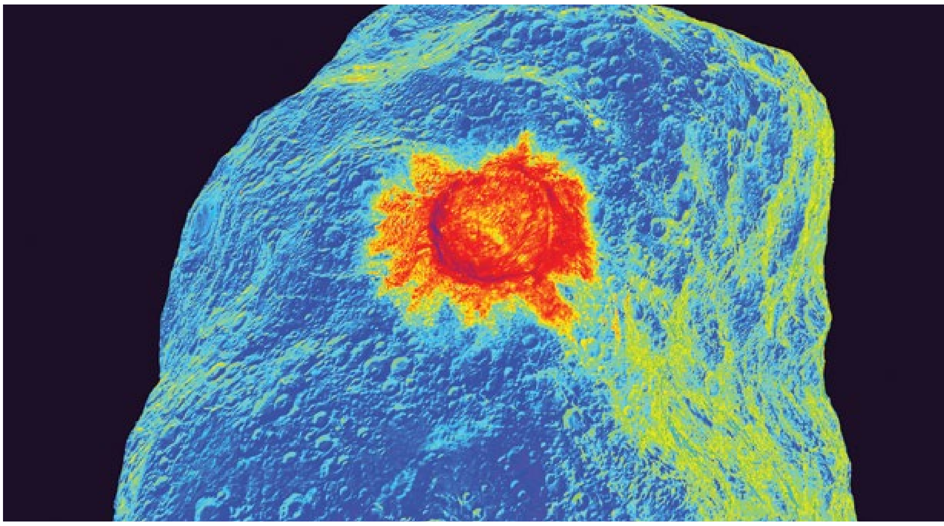
Proba-V, launched in 2013, was tasked with a full-scale operational mission, previously handled by the Vegetation instrument on France's full-sized Spot satellites: to map land cover and vegetation growth across the entire planet every two days. Key technology developments underpinning its improved, miniaturised version of the instrument included a novel short-wave infrared detector and a compact three-mirror-anastigmat telescope. Proba-V also performed the first detection of aircraft ADS-B signals from orbit and demonstrated the first transmitter based on gallium nitride.

Proba-3, planned for launch in 2018, will be ESA's – and the world's – first precision formation-flying mission. A pair of satellites will fly together, maintaining a fixed configuration as a 'large rigid structure' in space, to prove formation-flying technologies down to millimetre precision. The mission will demonstrate formation flying in the context of a large-scale science experiment. The paired satellites will form a 150 m long solar coronagraph to study the Sun's faint corona closer to the solar rim than has ever before been achieved.

A follow-on Proba NEXT mission is currently under study, involving either stratospheric limb sounding or microwave-based Earth observation.



Proba-V



← AIM's thermal imaging of the crater left by the NASA-led DART probe impacting the Didymoon asteroid in 2022 (ESA/ ScienceOffice.org)

Four spacecraft in one

AIM's onboard payload will be supplemented by more mobile elements, effectively rendering the AIM mission four spacecraft in one. The main 'mothership' will be the carrier of the Mobile Asteroid Surface Scout-2 (MASCOT-2) microlander, supplied by the German Aerospace Centre DLR – a direct descendant of the MASCOT-1 lander currently in transit aboard JAXA's Hayabusa-2 mission, heading to near-Earth asteroid 1999 JU3 for a planned 2018 landing.

MASCOT-2 will have two main differences compared to its predecessor: it will carry low-frequency radar systems to perform soundings right through the body of the asteroid, and a solar panel to allow it to go on working for several weeks on the surface of Didymoon.

This shoebox-sized lander will carry the surface transmitter of the low-frequency radar measuring the propagation of waves between MASCOT-2 and the AIM orbiter. This allows the deep internal dielectric properties of Didymos to be sounded, while benefiting from the heritage of Rosetta's CONSERT instrument, which leads to an instrument architecture with separated orbiter and lander parts.

In addition, its sophisticated payload suite consists of a compact wide-angle CMOS camera (CAM) designed to cover a large part of the surface in front of MASCOT, an accelerometer (DACC) assessing the unknown surface mechanical properties (the effective soil-lander E-module, the strength of regolith material, the friction coefficients between soil and lander), and a radiometer (MARA) measuring the surface temperature brightness temperature for a full day/night cycle at least one location completes the highly sophisticated yet compact payload suite. Rosetta's Philae lander bounced right back off the surface of Comet 67P during its first attempt at landing; MASCOT-2 will be a chance to gain extra experience of operating in low-gravity environments for future sample-return missions (for example, to Phobos).

Devising a safe collision-free strategy for MASCOT-2's landing with a high probability of success is no easy task. This will be the most critical phase for AIM – as the spacecraft will come to just 140 m from the asteroid. Onboard autonomy can be used but careful analysis is also being performed with the support of laboratory analysis.

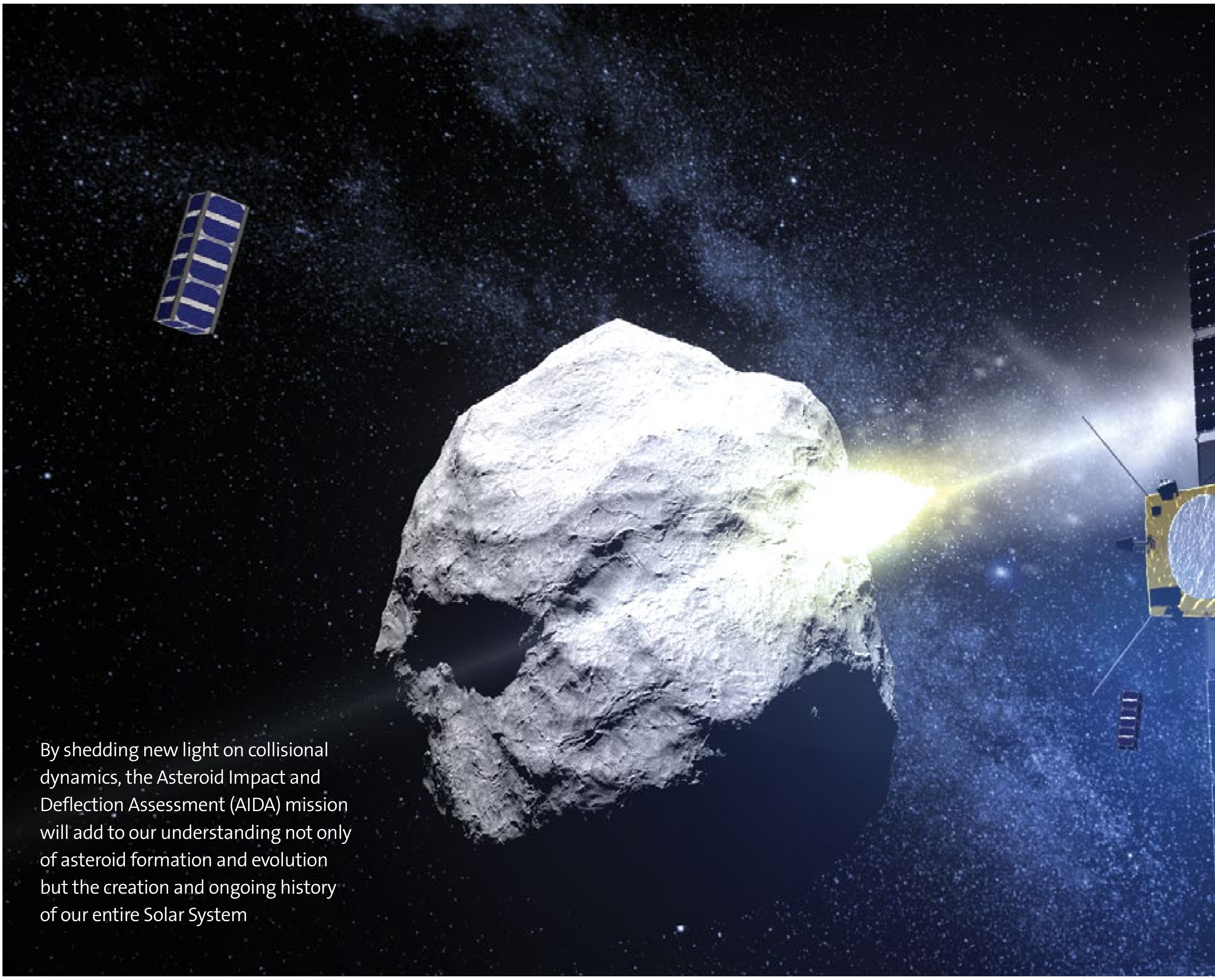
AIM will also be carrying two CubeSats. This early demonstration of standardised nanosatellites in deep space will enable valuable intersatellite communication and data relay experiments between spacecraft, opening up the prospect of such miniaturised satellites accomplishing exploratory tasks that might be judged too risky for a standard full-sized model. Achieving the maintenance of communications and rendezvous operations between separate spacecraft will be essential in accomplishing future sample-return missions to Mars or other targets.

The mission team put out an announcement of opportunity for what are referred to as CubeSat Opportunity Payloads Intersatellite Network Systems (COPINS), seeking innovative hosted sensors to complement and boost AIM's own scientific return. AIM's two three-unit CubeSats currently under study will possess the necessary capability to produce meaningful scientific results fully complementing AIM's main objectives.

The stuff of science fiction

AIM as a whole is likely to revolutionise asteroid science. Each new close encounter with an asteroid body has led to a fresh transformation of our understanding, but there is still much to learn. Spacecraft flybys combined with ground-based observations, meteorite analysis and software modelling have highlighted the striking variety of asteroids in terms of size, shape, surface characteristics and constituent materials.

Similarly, asteroids rotate in various ways, from simple rotation to slow precession or rapid tumbling. It is possible



By shedding new light on collisional dynamics, the Asteroid Impact and Deflection Assessment (AIDA) mission will add to our understanding not only of asteroid formation and evolution but the creation and ongoing history of our entire Solar System

that asteroid rotation is constrained by fundamental ‘spin limits’, beyond which centrifugal acceleration would cause material to escape from the surface of rubble-pile bodies. Indeed, such escaping might explain the origins of many binary asteroid systems, which are estimated to make up 15% of the known total.

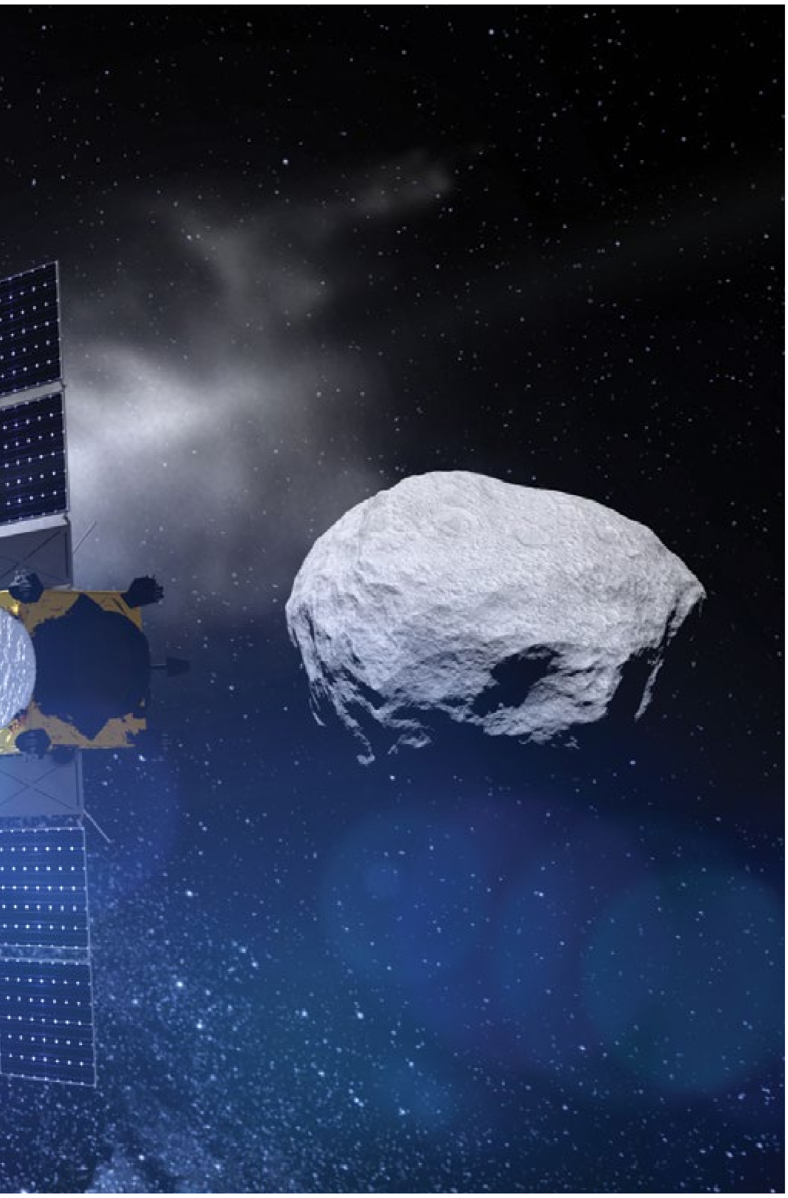
The internal structure of asteroids remains a blank spot in scientific understanding. Are there large voids within the deep interior of asteroids, or are they composed of loose dust or rubble, or conglomerates of monolithic rock? In particular, there is no way of knowing how an actual asteroid would respond to the specific external stimulus of an impact – short of trying it for real.

The sheer scale of the DART impact dwarfs anything that could be replicated in terrestrial laboratories, and software models rely on assumptions and extrapolations that cannot be verified – yet.

By shedding new light on collisional dynamics, the AIDA mission will add to our understanding not only of asteroid formation and evolution but the creation and ongoing history of our entire Solar System, and even the arising of preconditions for life on Earth.

Down at a smaller scale, AIM’s surface observations will reveal the range of physical phenomena apart from gravity that govern the surface character of asteroids, influence their material properties and keep them bound together. What are the relative roles of electrostatic and Van der Waals forces, for example?

One suggestion is that some fine-grained asteroids might resemble ‘fairy castles’, crumbling to the touch. Such findings would be relevant to asteroid mining as well as planetary defence, while also offering insight into the very earliest microscopic-scale processes of accretion, right back at the dawn of this and other planetary systems.



AIDA, if it goes ahead as envisaged, will represent humanity's very first attempt to address an extremely important question: what could humanity do if an asteroid were on a collision course with Earth? A mission that would previously have been the stuff of science fiction movies, is likely to prove a massive hit with the global public. ■

Sean Blair is an EJR-Quartz writer for ESA

→ Intersatellite links

AIM's release of nanosatellites and a small lander across the Didymos system presents a problem: how to keep them linked with Earth? They are simply too small to house the amount of electrical power and host an antenna of the necessary scale. Instead they will employ radio-based intersatellite links to their AIM mothership, already equipped for direct communication with our planet.

However, all these smaller spacecraft will end up in constant motion relative to AIM, so that maintaining high-speed transmission of data will have to cope with ongoing changes in distance, visibility or available power. The optimal solution would be an auto-adjusting network that seeks to maintain transmission speed at the maximum achievable at that moment – rather than pre-programmed to operate on a worst-case basis. This technique will be demonstrated for the first time in deep space by AIM.

Another important goal will be to determine the distance between transmitters and receivers within this intersatellite link system on a continual basis. This will become vital to understanding the position of the CubeSats in relation to the asteroid and eventually that of the lander. Such knowledge would provide a big boost to the quality of science data as well as assisting mission planning. AIM's intersatellite link system will build up to a complete three-dimensional localisation of each element, and this autonomous positioning determination system would be another AIM first.

Enabling such an intersatellite link system for all elements of the AIM mission will have to be achieved within an extremely tight design space, taking account of the extremely tight mass and volume constraints on such tiny spacecraft. Nevertheless, the rewards would be significant: opening up the prospect of future missions that are more and more based on multiple satellites cooperating in common goals, both in Earth orbit and deeper into space.

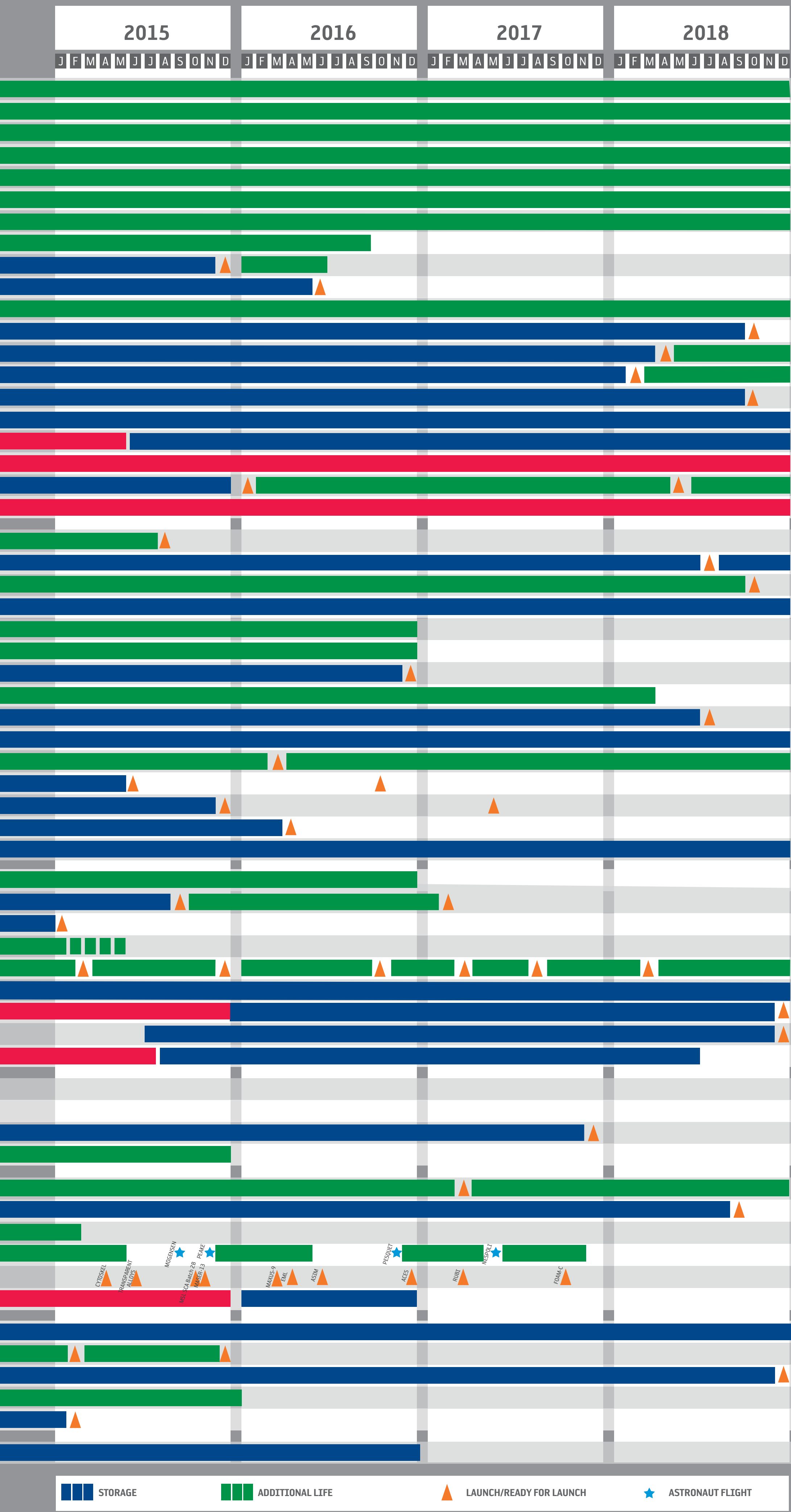
→ AIM's two CubeSats will demonstrate the use standardised nanosatellites in deep-space intersatellite communication

→ PROGRAMMES IN PROGRESS

Status at October 2015

Andreas Mogensen in the recovery helicopter shortly after landing on 12 September, with ESA Flight Surgeon Ulrich Straube of EAC

2011
2012
2013
2014
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
SOHO
CASSINI-HUYGENS
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
ROSETTA
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
CHEOPS
SOLAR ORBITER (M1)
EUCLID (M2)
JUICE (L1)
PLATO (M3)
EXOMARS
ATHENA (L2)
EARTH OBSERVATION PROGRAMME
MSG
MTG
METOP
METOP-SG
CRYOSAT
SMOS
AEOLUS
SWARM
EARTHCARE
BIOMASS
SENTINEL-1
SENTINEL-2
SENTINEL-3
SENTINEL-5 PRECURSOR
SENTINEL-6
TELECOMMS/NAVIGATION PROGRAMMES
ALPHASAT
EDRS
SMALLGEO
GNSS-1/EGNOS
GALILEO
ELECTRA
NEOSAT
QUANTUM
SAT-AIS
TECHNOLOGY PROGRAMME
PROBA-1
PROBA-2
PROBA-3
PROBA-V
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS & ERA
MPCV-ESM
ATV
ASTRONAUT FLIGHTS
ELIPS PAYLOADS
TRANSPORTATION & HUMAN EXPLORATION
VITTORI
KUIPERS
PARMITANO
GERST
CRISTOFORETTI
MASER-12
FASES
FASTER
EML
PK-4
TRIPLELUX A
TRIPLELUX B
LAUNCHER PROGRAMME
ARIANE 6
VEGA DEV. AND EXPL.
VEGA C
SOYUZ AT CSG
IXV
SSA
PERIOD 2
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS



COMMENTS

LAUNCHED APR 1990 / OPS EXTENDED UNTIL 2018
LAUNCHED DEC 1995 / OPS EXTENDED UNTIL 2018
LAUNCHED OCT 1997 / OPS EXTENDED UNTIL 2018
LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 2018
LAUNCHED MID-2000 / OPS EXTENDED UNTIL 2018
LAUNCHED OCT 2002 / OPS EXTENDED UNTIL 2018
LAUNCHED JUN 2003 / OPS EXTENDED UNTIL 2018
LAUNCHED MAR 2004 / LANDED ON COMET NOV 2014
LAUNCHED 2 DEC 2015
LAUNCH MID 2016
LAUNCHED 19 DEC 2013 / NOMINAL MISSION END 2019
LAUNCH OCT 2018
LAUNCH APR 2018
LAUNCH FEB 2018 / OPERATIONS TO JUN 2021
LAUNCH OCT 2018
LAUNCH DEC 2020
LAUNCH JUN 2022
LAUNCH 2024
LAUNCH MAR 2016 / MAY 2018
LAUNCH 2028

MSG-3 LAUNCHED JUL 2012, MSG-4 LAUNCHED / 15 JUL 2015
LAUNCH MTG-I-1 2019 / MTG-S-1 2021
METOP-B SEP 2012 / METOP-C OCT 2018
LAUNCH METOP-SG A1 2021 / METOP-SG B1 2022
LAUNCHED 10 APR 2010 / OPS UNTIL 2017
LAUNCHED 2 NOV 2009 / OPS UNTIL 2017
LAUNCH DEC 2016
LAUNCHED 22 NOV 2013
LAUNCH AUG 2018
LAUNCH 2020
LAUNCHED APR 2014 / SENTINEL-1B LAUNCH APR 2016
LAUNCHED 23 JUN 2015 / SENTINEL-2B FAR OCT 2016
LAUNCH SENTINEL-3A DEC 2015 / SENTINEL-3B FAR MAY 2017
LAUNCH APR 2016
LAUNCH MAY 2020

LAUNCHED JUL 2013
LAUNCH EDRS-A AUG 2015 / EDRS-C EARLY 2017
LAUNCH 2015
OPERATIONS START 2008
IOV OCT 2011 & OCT 2012 / FOC 2014–15
LAUNCH MID 2019
LAUNCH END 2018
LAUNCH END 2018
LAUNCH READINESS SATELLITE-A, MID 2018

LAUNCHED OCT 2001
LAUNCHED 2 NOV 2009 / OPS EXTENDED UNTIL 2011/12
LAUNCH 2017
LAUNCHED MAY 2013

COLUMBUS: FEB 2008 OPS UNTIL END 2020 / ERA LAUNCH MAR 2017
LAUNCH SEP 2018 / OPERATIONS FROM OCT 2018
ATV-5 LAUNCHED 29 JUL 2014
CRISTOFORETTI: NOV 2014; MOGENSEN: SEP 2015; PEAKE: NOV 2015; PESQUET: NOV 2016; NESPOLI: MAY 2017
LAUNCHES MASER 13: OCT 2015 / MAXUS-9: MAR 2016
PREPARATORY ACTIVITIES INCLUDING LUNAR EXPLORATION

QUALIFICATION FLIGHT JUN 2020
LAUNCH DEC 2018
FIRST LAUNCH FEB 2012 / VV02 LAUNCHED JUN 2013; VV03 LAUNCHED APR 2014 / VV04 LAUNCHED NOV 2014
FIRST LAUNCH OCT 2011
SYSTEM QUALIFICATION & ACCEPTANCE REVIEW, AUG 2014 LAUNCH READINESS REVIEW OCT 2014, LAUNCHED FEB 2015

SYSTEM REQUIREMENT REVIEW, DEC 2011

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	SVT – System Validation Testing
IPC – Industrial Policy Committee	TM – Thermal Model
ITT – Invitation to Tender	

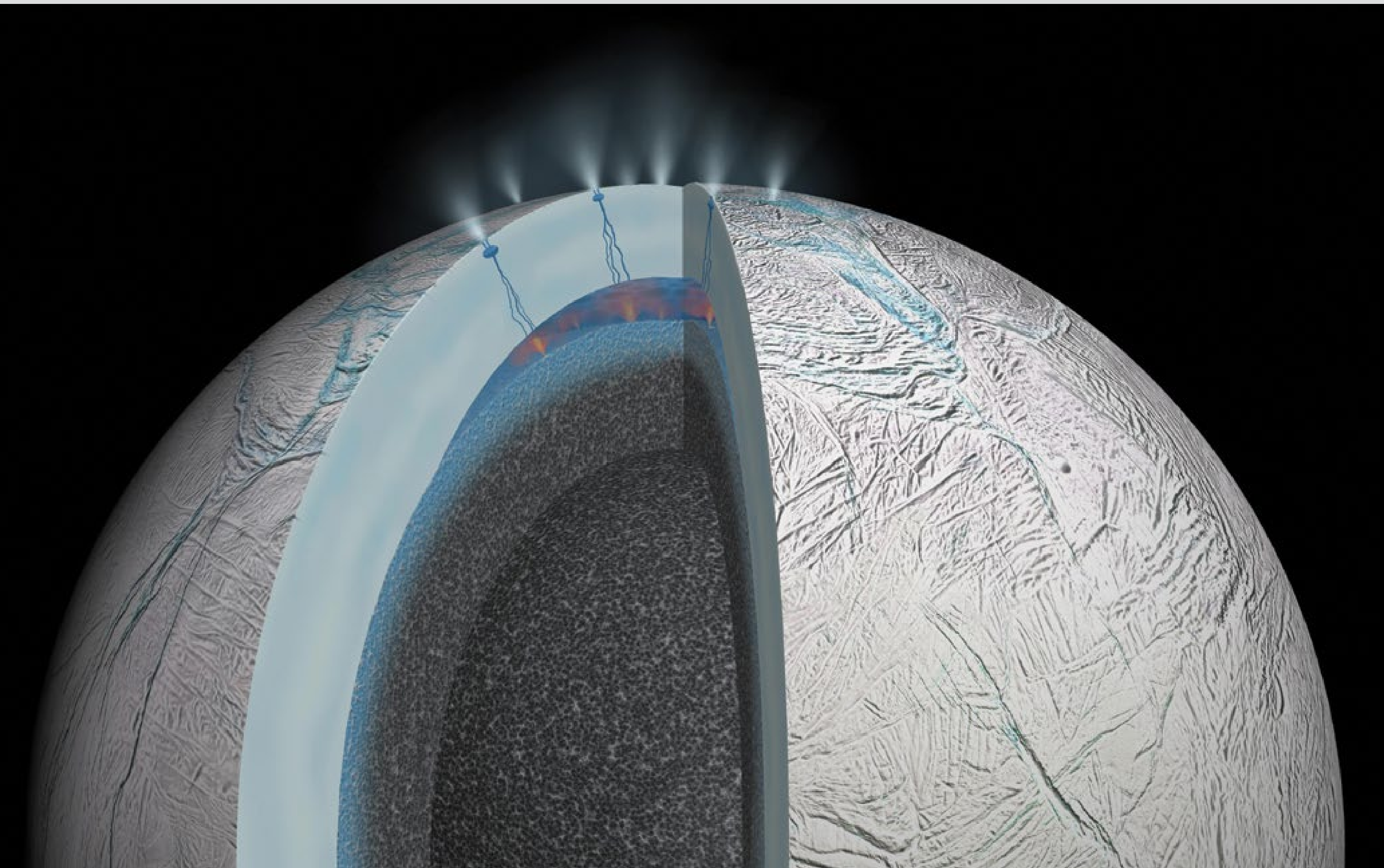
→ CASSINI-HUYGENS

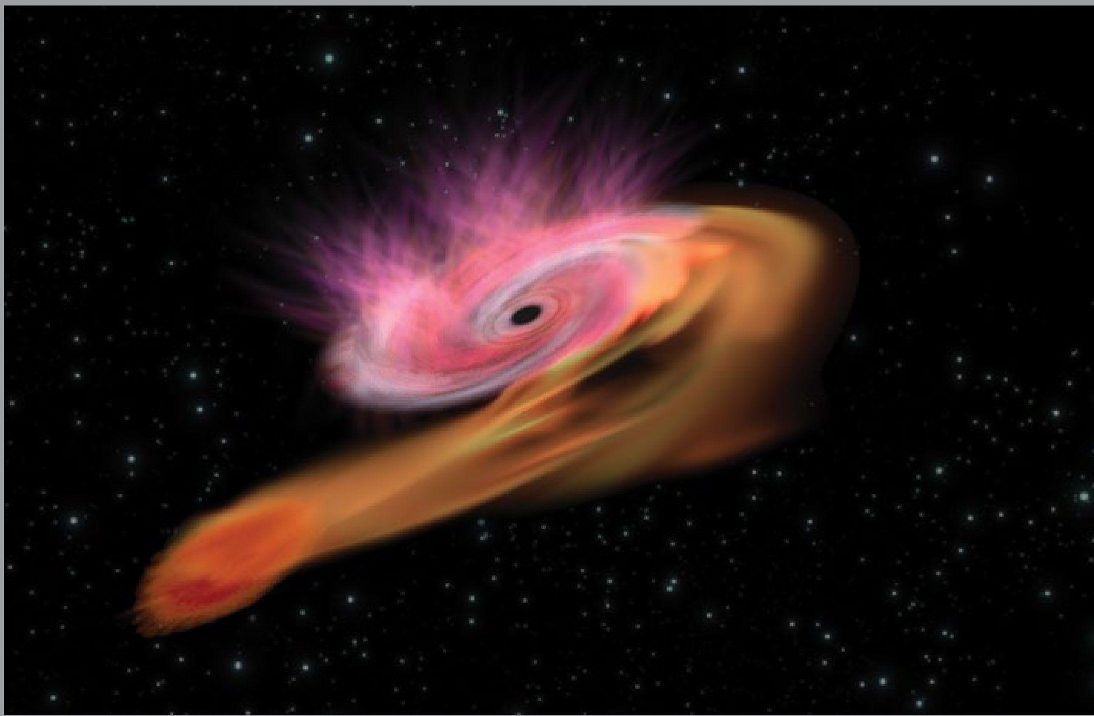
The ongoing hydrothermal activity in the Enceladus sub-surface ocean is still being investigated. Nanosilicate inclusions were discovered in the icy grains within the plumes of Enceladus by Cassini's Cosmic Dust Analyser (a European-led instrument for micrometeoroid detection). The formation of silicate grains of sub-micrometre size requires the presence of alkaline, salty water, super-saturated with silica and a strong temperature drop to allow the condensation of the grains from the liquid phase. The presence of a large reservoir of liquid water, below the icy crust of Enceladus, has been confirmed recently by radio-science gravity measurements, as well as by a detailed study of the libration of the moon's rotation axis. The fact that the icy grains analysed previously had shown a significant enrichment in salt also suggests that the liquid water is in contact with Enceladus's rocky core, inferred to be most likely porous from gravity measurements, hence providing a large surface area for water/rock interaction, enriching the water in silica. The small size of the silica grains also suggests a rapid transport from the hot rock/water interface up toward the cold surface, not allowing larger grains to form. Those conditions taken together strongly suggest that hydrothermal activity is at play at the ocean floor of Enceladus, boosting (by analogy with similar processes in Earth's oceans) the astrobiological potential of this fascinating moon.

→ XMM-NEWTON

Astronomers have detected the last 'cry' from a star that passed too close to the central black hole of its host galaxy and was being destroyed and 'swallowed' – a phenomenon known as a tidal disruption event. The study, based on the observations of X-rays emitted by leftover material

Geysers erupting from the south pole of Saturn's icy moon Enceladus. It is suggested that Enceladus's geysers are powered by hydrothermal activity (NASA/JPL-Caltech)





The supermassive black hole at the centre of a galaxy accreting mass from a star that dared to venture too close to the galaxy's centre (ESA/C. Carreau)

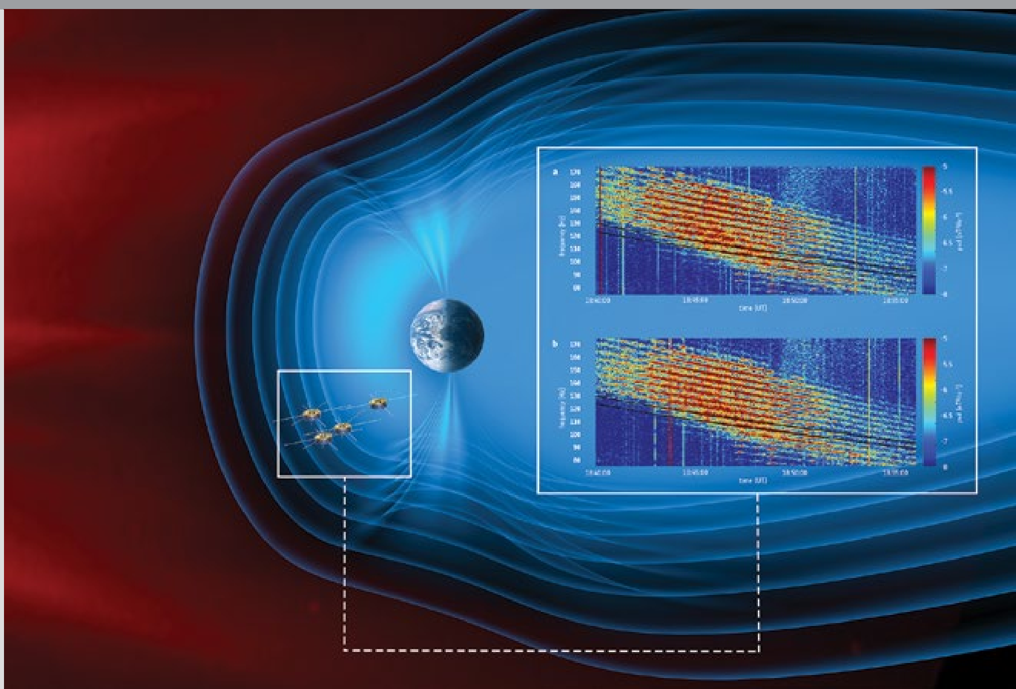
from the star in the vicinity of the black hole, allowed the astronomers to measure, for the first time, the physical properties of a newly formed accretion disc, enabling them to investigate the initial phases of such a powerful event.

→ CLUSTER

This mission has solved a mystery that has puzzled scientists for almost half a century. Data sent back by two of the spacecraft have revealed for the first time the physical mechanism behind the generation of 'noisy' waves in near-Earth space. In an effort to solve the mystery of the generation and propagation of the equatorial noise, an international team of scientists decided to take advantage of the multipoint observations provided by Cluster. A specially planned Inner Magnetosphere Campaign was introduced, to study the structure of these waves in their source region.

The most significant observations were made between 18:40 and 18:55 GMT on 6 July 2013, when all four Cluster spacecraft were flying through the outer radiation belt, close to the

The four Cluster spacecraft flying through Earth's outer radiation belt, close to the geomagnetic equator, where in July 2013, Cluster observed the type of plasma waves known as 'equatorial noise'. The inset (right) shows the observations by the instruments on Cluster 3 (upper) and Cluster 4 (lower). These observations revealed that the waves had a highly structured and periodic pattern, providing clear observational evidence about how they were generated (Balikhin, Shprits *et al*)

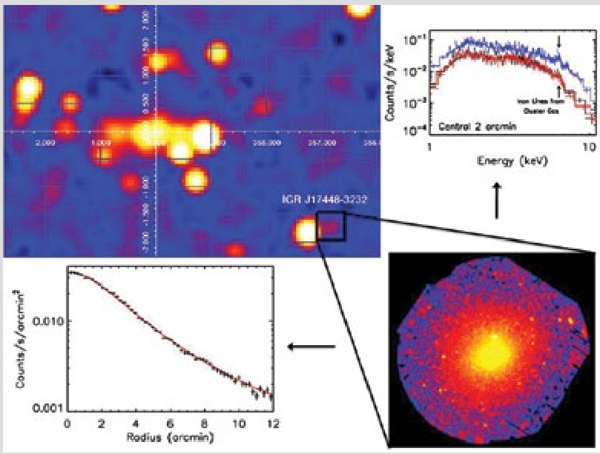


geomagnetic equator. Clusters 3 and 4 were very close (within 60 km) to each other, while Cluster 1 was approximately 800 km from the pair, and Cluster 2 was around 4400 km away in the earthward direction from the other three.

Observations by the Spatio-Temporal Analysis of Field Fluctuations (STAFF) instruments on Cluster 3 and 4 revealed that the waves had a highly structured and periodic pattern, providing clear observational evidence about how they were generated. The data also revealed in detail their banded structure, the most remarkable example of these structures ever observed in space.

The Cluster measurements enabled not only the observation of the fine structure of the wave spectrum but also provided multi-satellite measurements of this emission at very short separation distances. The periodic pattern of emissions observed on Cluster 4 was almost an exact replication of that observed by Cluster 3, showing that the highly organised, periodic wave structure measured at least 60 km across.

The spectral observations, together with observations of particle distributions, allowed the researchers to calculate the growth rates of the waves. The Cluster spacecraft measurements also enabled them to determine the polarisation properties of the waves, further confirming that the observed emissions were the same type as those usually observed in equatorial noise waves. This study clearly showed that these waves were produced by so-called ion ring distributions. This arrangement refers to the ring-like velocity distributions of the charged particles close to the geomagnetic equator, where more particles are observed at high velocity than low velocity. The Cluster spacecraft were able to measure these distributions, and models used by the



IGR J17448-3232 is a relatively faint Intergral source (top left) first reported in the third IBIS/ISGRI catalogue. A follow-up Chandra observation showed it to be an extended object (bottom, right)

scientists definitively showed that they are responsible for the excitation of the waves.

This result is an outstanding example of how Cluster is deepening our understanding of wave–particle interaction. This mechanism is believed to be responsible for the generation of other types of waves in the equatorial plane that directly impact the content of the radiation belts.

→ INTEGRAL

IGR J17448-3232 is a relatively faint Integral source that was first reported in the third IBIS/ISGRI catalogue. A follow-up Chandra observation showed it to be an extended object. Given that the source is 3.6 degrees from the galactic centre, it was suggested that it might possibly be a supernova remnant, but this identification was uncertain. The mystery was solved when XMM-Newton observed it and found an emission line from iron with an energy indicating that the object is outside our galaxy at a redshift of $z = 0.055$. Also, the radial surface brightness profile is consistent with a shape that is characteristic of galaxy clusters; the source has been named the Scorpius galaxy cluster. Because of the high interstellar absorption for a source so close to the galactic centre, the source was invisible to earlier soft X-ray all-sky surveys; Integral's hard X-ray bandpass was needed to find this interesting object.

If our galaxy was not in the way, the Scorpius cluster would be the 36th brightest in the sky. It is also one of the hotter known clusters: of the brightest 50, only 10 have virial or emission-weighted temperatures above 8 keV (the Scorpius cluster's temperature is 8.8 keV). Even more interesting is the fact that it exhibits signatures of having recently undergone a merger event. The Scorpius cluster is a very rare system in our local volume, giving us a detailed look at the type of clusters typically observed in high redshift surveys (see NM Barrière, *et al* 2015, *Astrophysical Journal* 799, 24)

→ ROSETTA

Rosetta passed through perihelion in August, with the comet providing some wonderful fireworks, including an outburst event that lasted over an hour and ejected material with such force that it pushed the solar wind (the extended outer atmosphere of the Sun which permeates the entire Solar System) away from the comet nucleus by at least 187 km. During this event, a large change in the composition of the gases in the coma (the comet's outer atmosphere), suggesting the outburst may have revealed some 'fresh' subsurface material.

The latest scientific results were presented at the EPSC conference in Nantes in September/October, including a press conference highlighting *Nature* papers on the

A short-lived outburst from Comet 67P/Churyumov-Gerasimenko seen by Rosetta's OSIRIS narrow-angle camera on 29 July (ESA/Rosetta/MPS for OSIRIS Team)

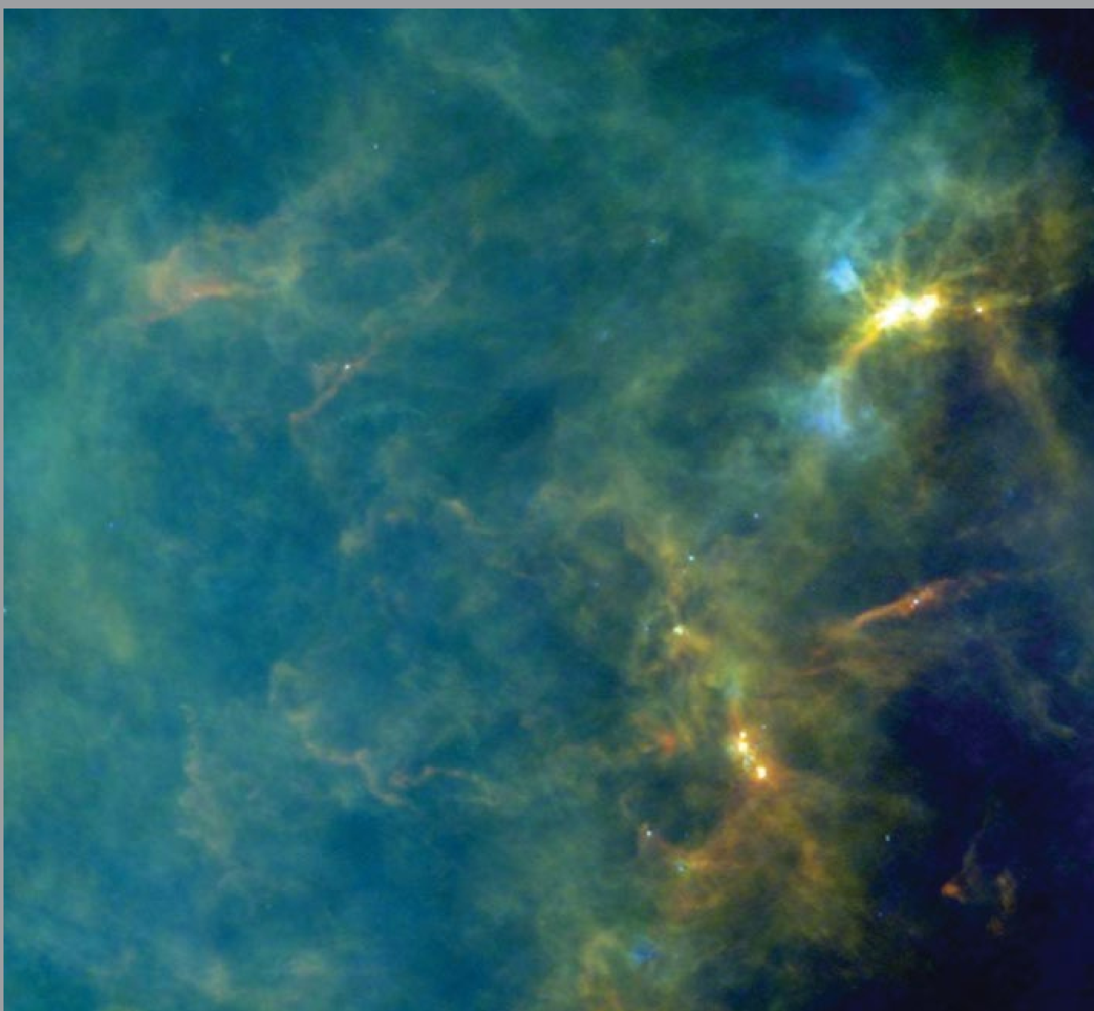
cycle of ice just below the surface of the comet and also a paper that explained the origin of the unusual 'duck' shape of the nucleus.

Although the Philae lander reestablished contact with the orbiter in June and July, we were not able to maintain the link with the lander and hence were not able to command operation of the science instruments. Contact was only possible with the orbiter in northern latitudes. Because of increasing activity, the orbiter had to retreat to higher altitudes and move to southern latitudes to observe that part of the comet (which had only recently, since May, been illuminated by the Sun). As a result, we have not had anymore contact with the lander and wait until later this year when activity is reduced and we can reduce altitude again.

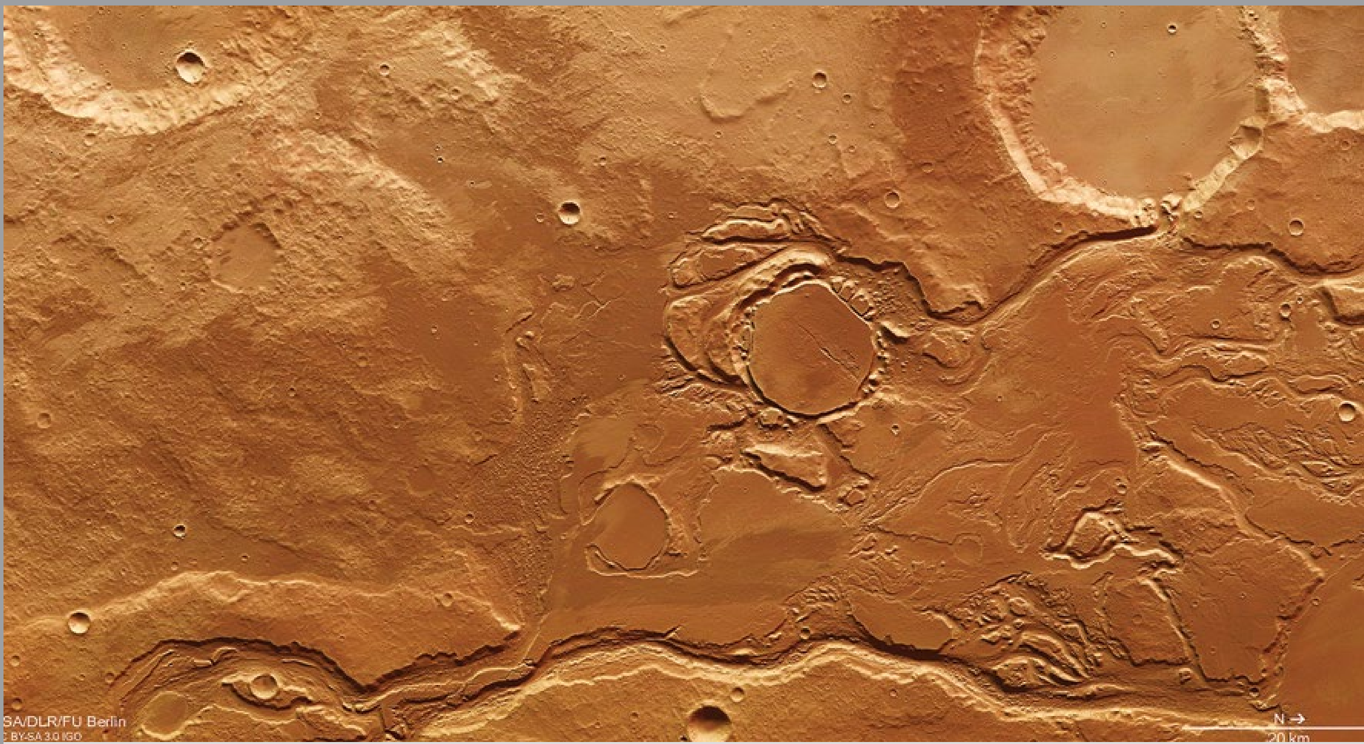
→ HERSCHEL

This mission is its post-operations phase. All Herschel science data are freely available, and the Herschel Science Centre supports the astronomical community exploiting the Herschel data to do science.

Star formation is one of the core areas of the scientific endeavour of Herschel. The Serpens molecular cloud is a relatively near (around 415 parsecs) star-forming region. It was observed as part of the Herschel Gould Belt survey, where a number of nearby star-forming clouds were under study. The total amount of gas and dust in the region shown is approximately 3000 solar masses, and the average temperature is about 24K. The brightest region



A composite Herschel image of the Serpens molecular cloud in three wavelengths (ESA/Herschel/PACS/SPIRE/Roccatagliata *et al* 2015)



Mars Express view taken on 12 July of the mouth of Minio Vallis region, part of the Mangala Valles outflow channel system, in the southwestern portion of the Tharsis bulge, home to several volcanoes, including the Solar System's largest: Olympus Mons. The region's proximity to these volcanic giants likely played an important role in creating the channels seen in these images, which were carved by large volumes of flowing water. The source of the water is believed to be related to the formation of the Mangala Fossae, an east–west fault system spanning several hundreds of kilometres to the south of the region seen here (ESA/DLR/FU Berlin)

is called the 'Serpens Core' and has a mass of about 500 times that of the Sun. Networks of 'filaments' are clearly discernible, and ongoing star formation can be inferred. By comparing the star formation in Serpens with that in other clouds, astronomers are learning why some clouds produce stars while others do not, and what the mechanisms and necessary conditions for forming stars are.

→ MARS EXPRESS

Spacecraft and payload remain in excellent state. The mission is slowly coming out of the eclipse season that imposed significant restrictions on science operations. Tests of the OMEGA infrared channel have cleared the way for resuming its science operations. A fruitful collaboration has been established with the NASA MAVEN mission, focused on the study of the upper atmosphere, ionosphere and magnetosphere of Mars and involving the ASPERA-3, MARSIS, SPICAM and MaRS experiments on Mars Express.

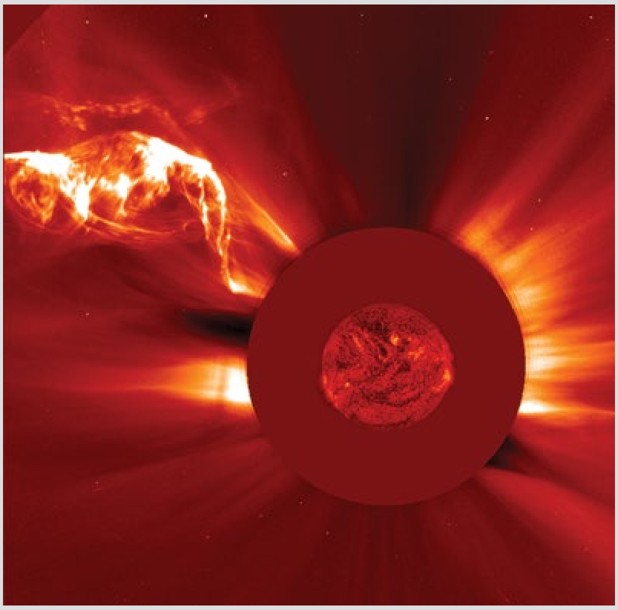
Several papers contributed to the science highlights of the mission. ASPERA-3 measurements over more than seven years revealed dependence of the ion flux in the energy range 10 eV to 5 keV on upstream solar wind conditions and solar extreme ultraviolet intensity. The ion escape rate was found to significantly decrease, up to a factor of three, with the solar wind density. This (at first glance) unexpected result was explained by contraction of the martian magnetosphere, thus decreasing of its effective cross-section at high solar wind density.

PFS continued investigations of minor species and their behaviour in the atmosphere of Mars. A seasonal increase of the HDO/H_2O ratio, by more than a factor of two, during the northern spring/summer period in the northern polar regions was found in observations by PFS/MEX and IRSC spectrograph on Subaru telescope. This suggests that the HDO/H_2O distribution is mainly controlled by condensation-induced fractionation between the subliming polar cap and the atmosphere. A PFS sensitive search for minor species also led to the first spaceborne detection of hydrogen peroxide H_2O_2 – the gas playing a key role in the oxidising capacity of the Mars atmosphere.

A martian year ago (June 2013 – January 2014) about an order of magnitude increase in the methane background level was detected by the NASA Tunable Laser Spectrometer (TLS-SAM) on the Curiosity rover. In July/October, when Mars returned to the northern winter/spring season, PFS carried out a campaign of Gale crater observations in support for repeated TLS-SAM *in situ* measurements. A Phobos flyby with the closest approach of about 58 km on the dayside was performed on 26 August. Teams are analysing the collected data and preparing for observations during the next close flyby (about 53 km) on 14 January 2016.

→ SOHO

On 13 September, SOHO discovered its 3000th comet. It was first spotted by Worachate Boonplod from Samut Songkhram, Thailand. Well over 50% of all comets for which orbital elements have been determined were discovered by SOHO, 95% of which were discovered by citizen scientists, among them teachers, writers and even two 13-year-olds. The winner of SOHO's 3000th comet contest is Michal Biesiada from Poland. The runners up are Dominique Nicolas from France and Giampaolo Salvato from Italy.



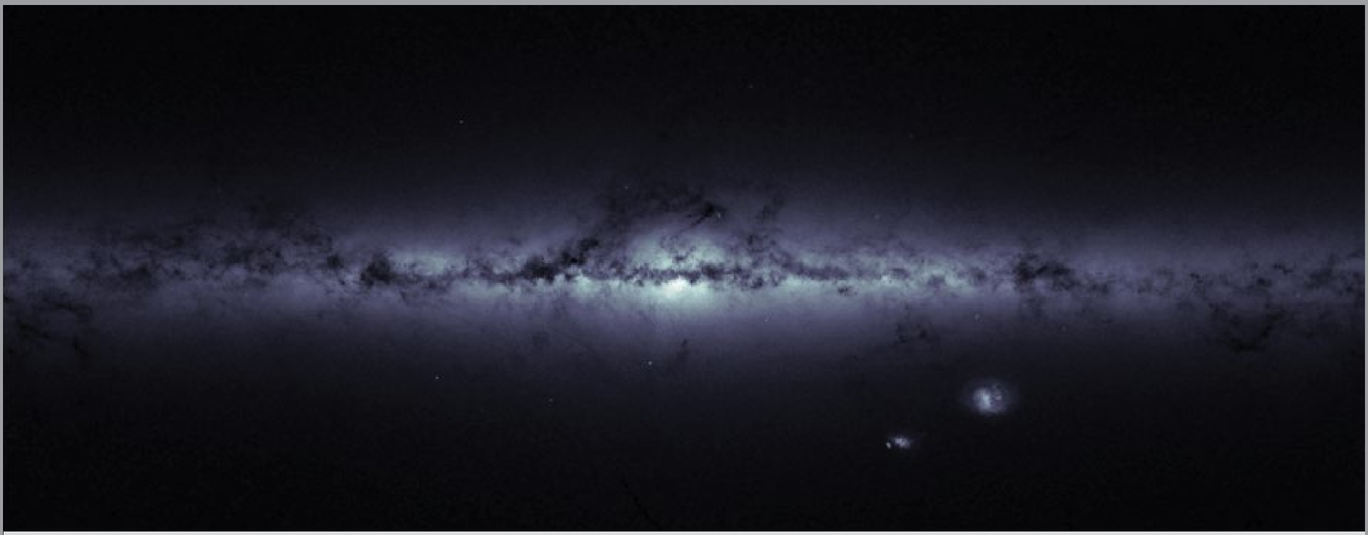
SOHO's 3000th comet (SOHO/ESA/NASA/NRL)

→ GAIA

A decontamination operation was conducted 3 June to clean all optical surfaces of collected water ice. Full transmission was recovered and monitoring has not yet revealed any return of transmission loss. Because the decontamination operation also disturbed the thermal balance of the satellite, it was necessary to make a small focus adjustment on 3 August.

In October, Gaia had its third Galactic Plane Scanning period. These are the periods when Gaia constantly encounters a high density of stars while the field of view is all the time close to the Galactic Plane. During these periods, Gaia is collecting more observations than it can transmit to Earth. This is the moment when the priority procedures on board get activated so that highest priority data are preserved and transmitted to ground stations.

Data processing activities are proceeding toward the first intermediate Gaia data release, planned for Summer 2016. The cyclic processing for the release has already started using more than a year's worth of data from the routine phase. The remaining processing time lasts until early 2016 and then a validation period follows until summer. The final release contents are decided only after the validation exercise.



As Gaia scans the sky to measure positions and velocities of billions of stars, for some stars it also determines their speed across the camera's sensor. This information is used in real time by the attitude and orbit control system and is routinely sent to Earth, along with the science data, in the form of housekeeping data. These data were used to produce this uncommon visualisation of the celestial sphere. Brighter regions indicate higher concentrations of stars, while darker regions correspond to patches of the sky where fewer stars are observed

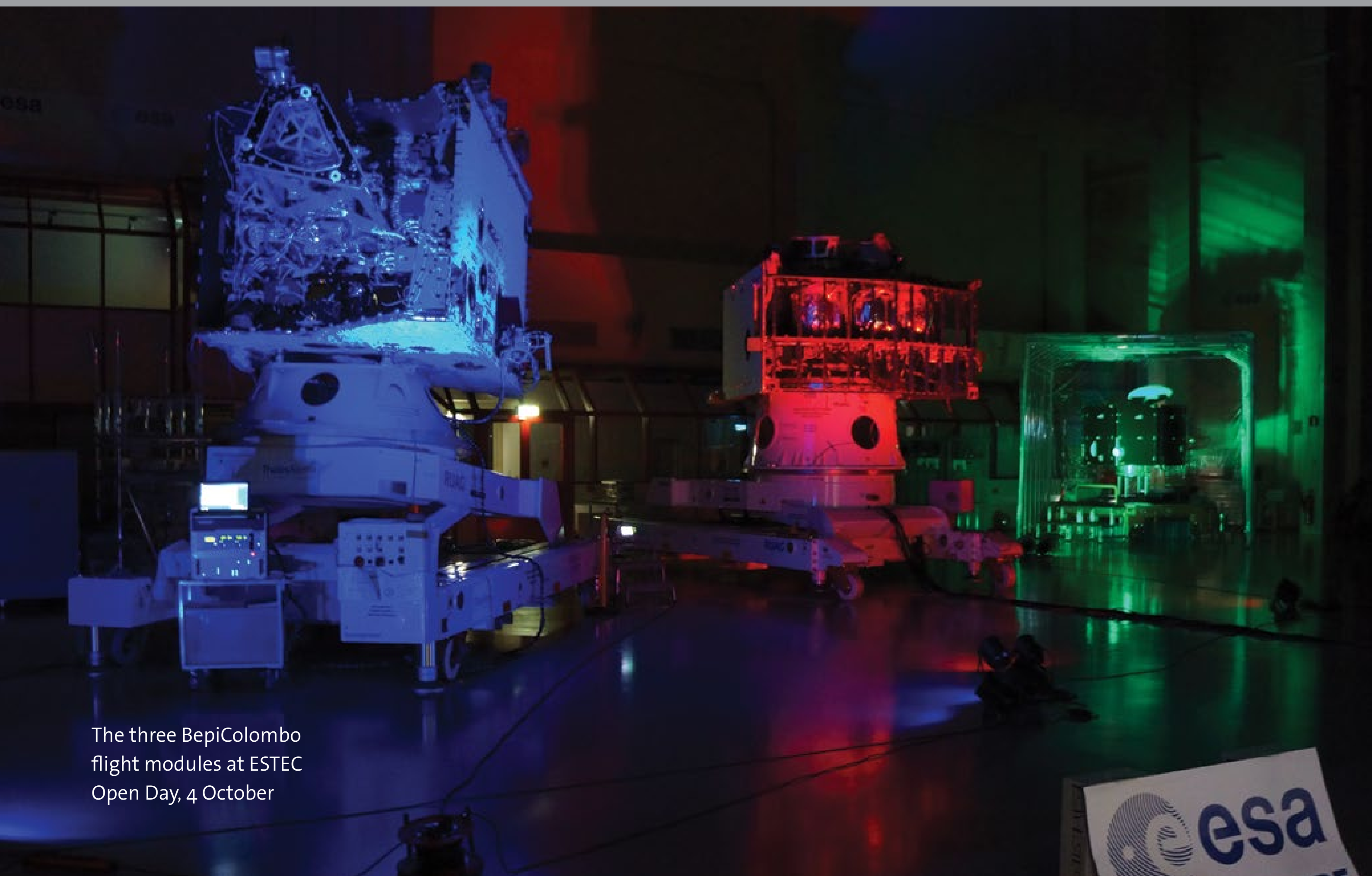
The LISA Pathfinder spacecraft taken out of its transport container after arriving at Europe's Spaceport in French Guiana on 8 October (ESA/CNES/Arianespace)

The launch campaign started on 8 October with the arrival of the spacecraft in French Guiana. All spacecraft checks and activities before filling the propulsion tanks with propellant were completed. In particular, the functional tests of the spacecraft and the LTP instrument were repeated after shipment to confirm that all systems were ready to go. The Vega VV06 launcher was readied on the launch pad. Combined operations, when LISA Pathfinder was encapsulated under the fairing and then integrated onto Vega, began on 13 November.

The simulation campaign of in-flight operations, which started in June, approached its completion. These highly realistic simulations are carried out at ESOC, where the mission operations will be conducted. In late October, an operation readiness review confirmed, that ground segment development and testing at ESOC and ESAC were complete. Launch was planned for December.

→ BEPICOLOMBO

Integration and test activities on the Mercury Planetary Orbiter (MPO) are progressing and the conducted EMC test was completed after final delivery and integration of the wheel drive electronics. The EMC test, one of the most significant electrical tests on module level, is running without major problems. With the exception of two instruments, the solar array and the Antennas Pointing mechanism (APM) of the High Gain Antenna Mechanism Assembly the module has reached



The three BepiColombo flight modules at ESTEC Open Day, 4 October flight configuration. Additional tests and procurement of new motors for the APM have been initiated to recover from a mechanism failure during the life test earlier in the year.

Integration of the Flow Control Units on the Mercury Transfer Module (MTM) was completed. The module is now awaiting the delivery of the Power Processing Units (PPU) of the Solar Electric Propulsion System (SEPS). Intensive rework is carried out on these units after an earlier failure during unit level vacuum testing.

On the remaining equipment developments the EQM of the High Gain Antenna Mechanism has completed the thermal test in the LSS test chamber of ESTEC at high intensity illumination (up to 10 Solar Constants). The cell lay-down for all FM MPO Solar Array panels is now completed. For the MTM Solar Array FM, nine out of ten panels were manufactured and cell lay-down is progressing. A full deployment of both SM wings has been achieved.

The remaining work on the JAXA-provided Mercury Magnetospheric Orbiter (MMO) is progressing and will be completed well in advance of the anticipated need date.

The critical path for the overall schedule is defined by the Power Processing Units of the SEPS in the MTM and the High Gain Antenna Mechanism Assembly of the MPO. Launch readiness will be reached in January 2018, leading to a launch window opening in April 2018.

→ MICROSCOPE

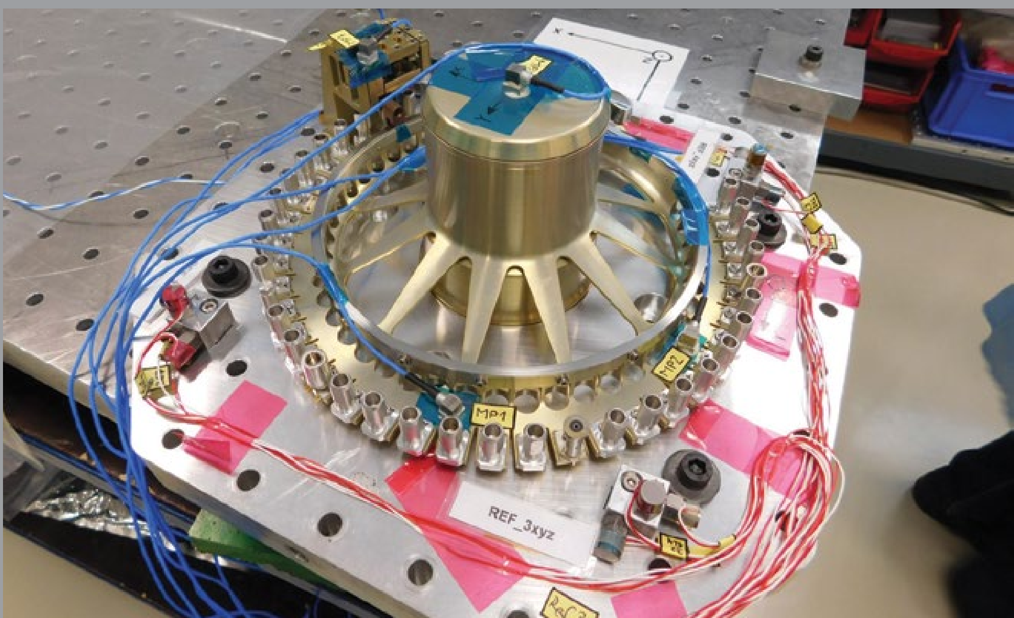
Key elements of the ESA-provided cold-gas micropropulsion system were delivered by Selex-ES to CNES for integration on the spacecraft: the microthrusters batches 1 and 2 (eight thrusters in total) and the electronic units. Work is now focusing on the assembly and test of the remaining eight microthrusters (batches 3 and 4). The delivered hardware was integrated and tested on the spacecraft. The environmental test campaign started and the thermal balance/vacuum test in Intespace Toulouse was ongoing.

→ EXOMARS

The ESA/Roscosmos ExoMars Programme is proceeding in line with the planned milestones of the 2016 and 2018 missions respectively. The system-level integration and environmental test activities for the 2016 mission are now completed. Negotiations for the implementation phase contract of the 2018 mission have started with a target of completion by end of the year.

On the 2016 mission, after completion of the thermal balance/vacuum tests at module level, the main environmental tests to complete acceptance of the spacecraft were carried out. The Schiaparelli propulsion system needed a repair, but the addition of this unplanned work eroded the January 2016 launch window considerably and a decision to move to the back-up March launch window was taken to minimise mission risk. The Qualification and Flight Acceptance Review (QAR) began on 26 August as planned and review teams are poring through the data package provided by industry. The CaSSIS instrument completed its instrument-level assembly and went into environmental testing. The instrument will be integrated late in the verification flow because of its late start in the programme.

The 2018 mission Phase-C/D/E1 proposal was submitted and negotiations started. Rover development is proceeding with elements of the STM ready for integration. Several



The ExoMars 2018 Rover Analytical Laboratory Drawer Sample Carousel Mechanism Qualification Model

PDRs are ongoing at equipment suppliers and in some cases the CDR has been accomplished. The Analytical Laboratory Drawer (ALD) EQM integration facility is now functioning in Thales Alenia Space Italy in preparation for building the EQM in an ultraclean environment. The facility will be used for the integration of the Sample Preparation and Distribution System (SPDS) QMs and the Pasteur Payload analytical instrument EQMs to prove the concept for the FM build. The SPDS QMs are partially complete and some of the instrument QMs are ready to be shipped to Thales Alenia Space Italy.

→ SOLAR ORBITER

The CDR is continuing, with delta-CDR beginning in February. After completion of mechanical testing and post-mechanical checks, the spacecraft STM was shipped back to IABG test facilities in October for thermal tests. Tests on the Onboard Computer Test Bench (OTB) are close to completion. On the spacecraft Engineering Test Bench, most of the integration tests have been completed and the focus is moving to functional verification.

Manufacturing of a number of spacecraft FM units continues. On the solar array, progress was made in production of QM panels and the FM panel substrate. At the back-up substrate manufacturer CASA, acceptance of a qualification panel is planned in mid-December. The work on the new reaction wheels has started. Confirmation of actual reaction wheel characteristics and qualification status are necessary steps to complete the spacecraft design. Most units have been EMC-characterised. Some mitigation may be necessary for EMC noise identified from the FM Onboard Computer. Further EMC tests are planned for the new reaction wheels and several instruments. Cleanliness and contamination control analyses are continuing to confirm results and further analyse possible mitigations, under guidance of the Solar Orbiter Cleanliness Working Group. Implementation of the reconfigured and simplified payload radiator (SORA) continues.

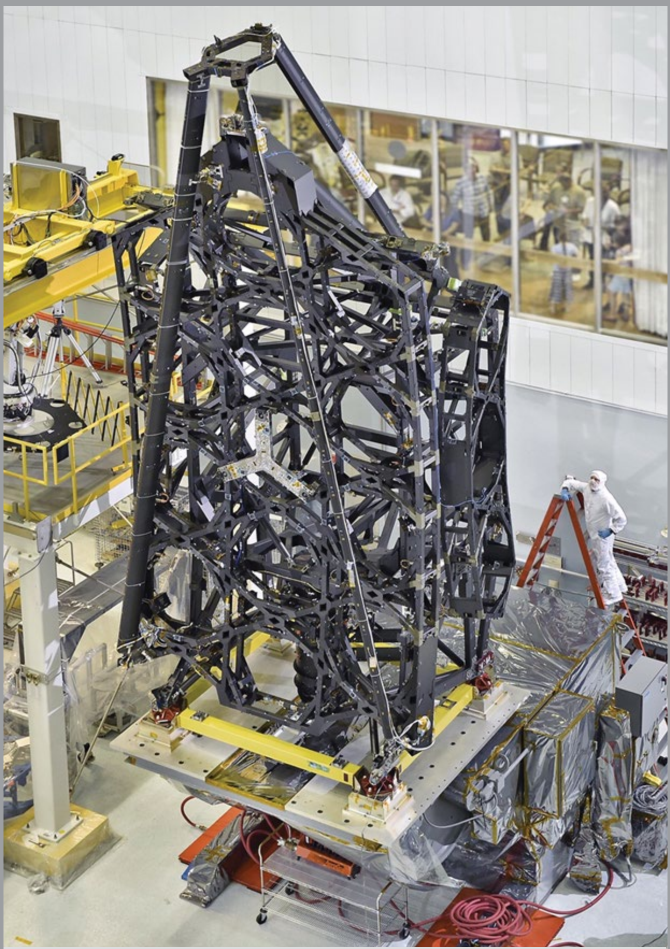
Among the launch trajectories proposed by ESOC to improve the science data return, an option has been found that provides a large improvement of data return. The launch window of this option opens on 22 September 2018.

Work with NASA Goddard and Kennedy Space Centers and United Launch Alliance for the baseline Atlas V-411 launch vehicle is progressing. An increase of Not-To-be-Exceeded launch mass from 1800 kg to 1900 kg was approved by NASA, which improves the project mass margins.

Following the CDR, an updated schedule was established that includes the delivery of the payload instruments in November 2016 and a launch in October 2018.

→ JAMES WEBB SPACE TELESCOPE (JWST)

The overall programme continues according to the plan established in 2011 with a launch date in October 2018. The telescope back-plane structure was completed and shipped to Goddard Spaceflight Center. It is now being prepared for the final integration of all the mirror segments. The final cryo-verification test of the Integrated Science Instrument Module (ISIM) has started. This test will provide the final verification for all instrument upgrades to flight configuration performed early this year. This test was preceded by the sine vibration, acoustic and EMC tests of the ISIM, which were all passed. The telescope pathfinder is undergoing cryo and thermal confidence tests at the Johnson Space Center. This is a risk mitigation activity for the final cryo end-to-end verification tests of the combined telescope/ISIM FM. The MIRI flight Cryo Cooler Assembly (CCA) was delivered to JPL and a reference performance test with the flight electronics indicated a heat lift fully in line with requirements. The environmental test programme of the CCA has been initiated.



JWST telescope back-plane structure being prepared for mirror segment installation at NASA Goddard Spaceflight Center (NASA/C. Gunn)

→ EUCLID

The industrial team is working in Phase-C/D. The prime contractor Thales Alenia Space Italy and its subsystem subcontractors (among which notably Airbus Defence & Space France for the Payload Module) have completed the definition of the subsystem requirements and have advanced in system and subsystem design. Many second-layer contracts under the PLM and several of the SVM units have also been selected. For the Visible Imager (VIS) instrument, the detailed design of the subsystems is ongoing and the first subsystem CDRs have started.

Several subsystem STM tests have been already performed and the first EM units are also under test. The contract with e2v for the development, QM and FM production of the VIS CCD detectors is on schedule. Phase 1, dedicated to the qualification of the CCDs and the production of the required STM and EM devices has been completed. Phase 2, devoted to flight production, has started and the manufacturing of the wafer dies for all the FM devices has already been completed.

The Near Infrared Spectro-Photometer (NISP) instrument PDR and the lower-level PDRs have been completed. The STM manufacturing of the instrument, mainly made of SiC, is also nearly finished and the assembly of the STM will start shortly. The CDR of the first subsystem has started and will continue until the spring 2016, when the instrument CDR will be held. The NISP schedule has been reviewed by the funding agencies under the leadership of CNES and a delay of 8 to 15 months has been reported.

The overall schedule has been reshuffled to minimise the impact on the launch date. Procurement of the NISP detector systems is ongoing. Teledyne Imaging Sensors of Camarillo (US) has completed all the activities of the Evaluation and Qualification phase. The flight production phase, under NASA/JPL responsibility, has started with the manufacturing of the first detector elements and procurement of the proximity electronics long lead items.

Ground Segment development is progressing; Science Operations were scrutinised as part of the mission PDR in October. This review confirmed that the design meets the scientific and mission requirements. Launch is now planned for the end of 2020 on a Soyuz-Fregat from Kourou.

→ JUICE

Airbus Defence & Space SAS has been selected as prime contractor. Phases-B2, -C/D and -E1 began on 28 July. Procurement of subsystems/equipment is running. There are 87 procurements to be performed (including the six subsystems). An industry day took place in October.

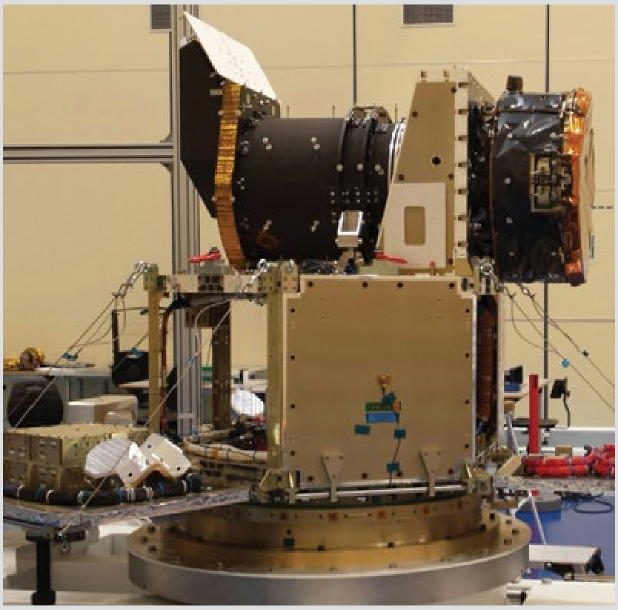
The Ariane 5 ECA performance analysis was completed in July. Launcher performance is slightly better than anticipated, which improves the mass margin. A review of the end-to-end mission analysis, including the jovian tour, was performed by ESOC. The fuel consumption and the feasibility of the mission with the current spacecraft design are confirmed.

→ CHEOPS

At the end of August, the prime contractor, Airbus Defence & Space Spain, completed the assembly and alignment of the platform structural QM. During September, the platform structure was integrated with equipment mass dummies and with the instrument STM, enabling the start of the spacecraft STM testing. Proof lift checks and measurements of the mass and centre-of-mass were performed, after which the spacecraft QM was transported to RUAG Space Switzerland, in Zurich, for sine vibration testing.

In parallel, following the delivery of a preliminary version of the onboard software, the first part of the EFM test campaign started. Equipment procurement continues and the first flight units (magnetorquers and star trackers) were delivered to the prime contractor.

The Instrument Consortium, led by the University of Bern, completed the test campaign of the instrument STM, which was delivered to the prime contractor at the end of August. Critical thermal stability tests on a dedicated instrument model were completed at TNO-Delft in the Netherlands.



The CHEOPS spacecraft Structural Model under test

→ SMOS

SMOS has been in orbit for six years, continuing to operate beyond its planned lifetime. Following a joint extension review with CNES, the mission has been extended to 2017. All brightness, temperature, soil moisture and ocean salinity data are available to the science community since 2010. New data, such as sea-ice thickness and soil moisture provided in near-real time, are now included in the SMOS data catalogue. The entire SMOS data set is being reprocessed a second time. Reprocessed brightness temperature data are available since May, reprocessed soil moisture and ocean salinity were made available in the autumn. The results of the 2nd SMOS science conference in May, are available on **www.smos2015.info**

→ CRYOSAT

The production of near real-time maps of Arctic sea ice thickness resumed after the summer melting, providing an operational dataset that aids maritime activities in ice infested-waters and improves scientific understanding of the polar regions.

Arctic sea-ice volume during the first two weeks of October was about 6200 km3, slightly higher than for the same period in 2010, but 1500 km3 below the 2013 high point, establishing 2015 as the third lowest in six years of operations. The mission continues also to provide valuable data to a handful of non-cryospheric domains, in particular, oceanography, marine gravity and hydrology.

→ AEOLUS

The Aladin instrument is fully integrated and both laser transmitters are aligned for optimal performance. The In-situ Cleaning Subsystem was tested together with the latest satellite flight software. The satellite platform was finalised and checked out in preparation for mating with the Aladin PLM. The Payload Data Ground Segment facilities are being prepared and undergoing tests. The Flight Operations Segment facilities are also being readied.

→ EARTHCARE

The ATLID Instrument CDR took place. The lidar transmitter PFM integration has been completed at SELEX-IT, and, following testing, the unit was subjected to a bake-out test as part of the contamination control plan. The unit was being prepared for pressurisation and closure to allow the start of burn-in test and environmental tests. The second FM transmitter integration continued with the mounting and alignment of master oscillator and optical amplifier.

The integration of the PFM Broadband Radiometer Optical Unit was completed at the Rutherford Appleton Laboratory, UK and the unit is being prepared for closure. The Multi-Spectral Imager Thermal Infrared Camera assembly was finalised and the unit test campaign being prepared. In Japan, Cloud Profiling Radar PFM integration was completed.

Aladin instrument operators under the telescope and UV laser illumination (Airbus Defence & Space)

→ BIOMASS

Proposals from European industries to build the Biomass satellite have been received and are being evaluated. The industrial prime contractor will be announced shortly.

→ METEOSAT SECOND GENERATION

MSG-4

Launch took place on 15 July. It was followed by LEOP that concluded with the handover of the control of the spacecraft from ESOC to Eumetsat on 26 July. The spacecraft is now in a storage position at 3.4° W. The commissioning of MSG-4 by Eumetsat took place ready to begin full operation in December.

First image from MSG-4, taken on 4 August 2015 (Eumetsat)

→ METEOSAT THIRD GENERATION

The manufacturing focus is now on the implementation of the MTG development models (STM and EMs). For the platform, the STM Central Tube has been delivered and populated with harness tie bases and single layer insulation. Preparation for structural panels integration is well advanced with all associated procedures established and processes qualified. Initial panel delivery is expected in early October, with integration activities now scheduled to start in early November.

MSG-4 launch campaign team: ESA, Thales Alenia Space France and Eumetsat (CNES)

MSG-4 launch on Ariane 5 flight VA224 on 15 July 2015 (ESA/CNES/Arianespace-Optique Videpo du CSG)

MTG Central Tube STM delivered by RUAG to OHB (OHB)

For the platform EM, the definition of the build standard and the test objectives was completed in late September. Much of the platform EM equipment has already been delivered, and is being utilised for the AM for early validation of interfaces and software functionality.

For the Lightning Imager, the PDR has brought together the instrument hardware design and associated electrical/data-handling architecture. Focus now moves to optimising the onboard and ground algorithms required for identification of actual 'lightning events' and filtering of 'false transients' that are an inevitable by-product of such a sensitive detection system.

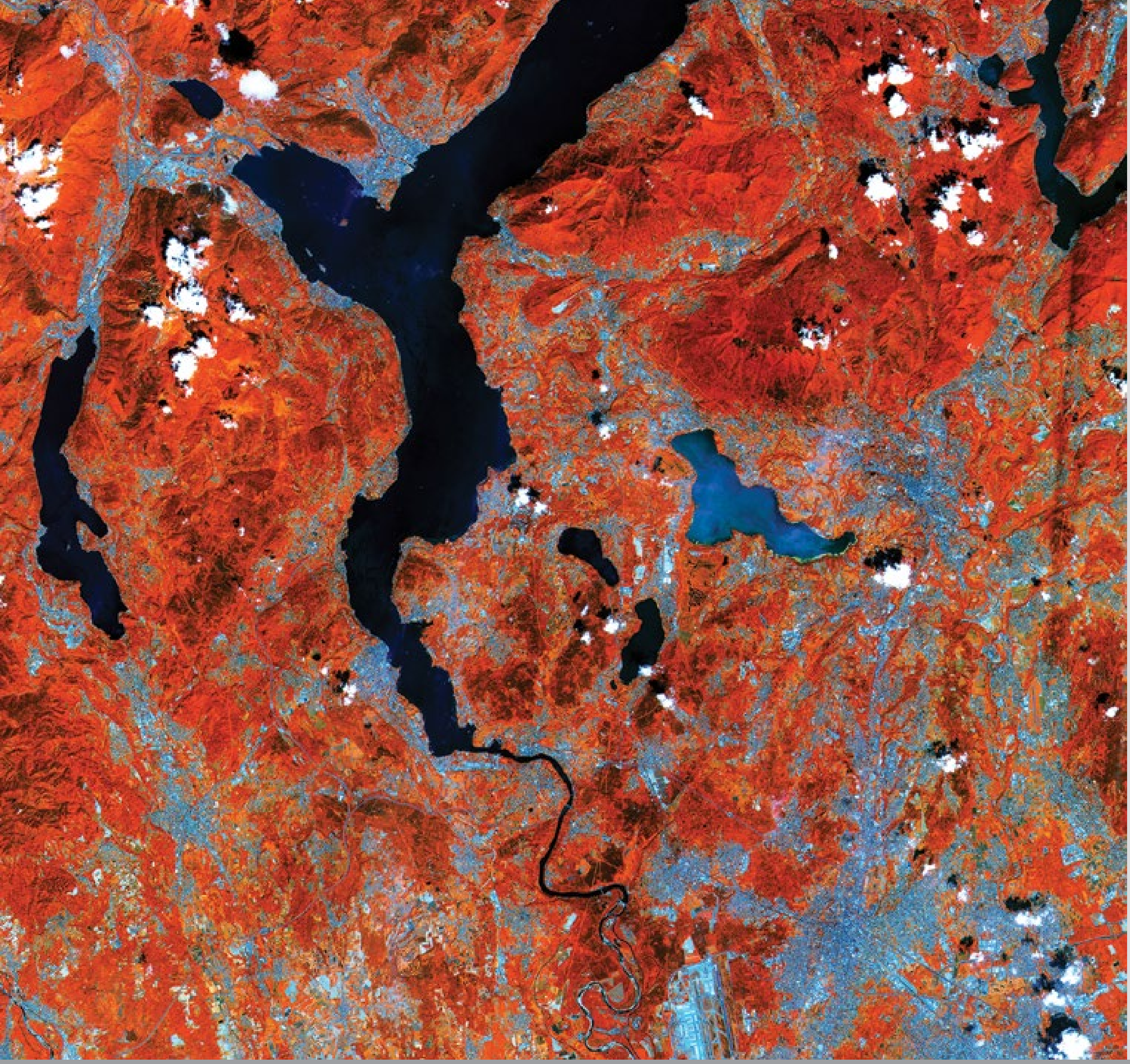
→ METOP

MetOp-C

The satellite is in storage and following the latest annual reactivation is confirmed to be in good health. The nominal launch, on a Soyuz from French Guiana, is planned for October 2018.

→ METOP SECOND GENERATION

MetOp-SG consists of two series of satellites (A and B) embarking a total of ten different instruments, which will



Sentinel-2 image of northern Italy in September (Copernicus Sentinel data/ESA)

Sentinel-1B after the SAR Antenna integration (Thales Alenia Space)

provide the operational meteorological observations from polar orbit from 2021 to the mid-2040s.

The PDR began in September and concluded in November. This PDR covers both Satellites A and B, as well as the six instruments procured under the MetOp-SG contracts (MWS, 3MI, RO, SCA, MWI and ICI). In parallel, the creating of an industrial consortium continues, with ITTs for more than 100 items released to date.

→ COPERNICUS

Sentinel-1

More than 10 000 users have already been registered in the Sentinel Scientific Data hub (scihub.esa.int), and more than two petabytes of Sentinel-1A data have been downloaded by users in the last ten months. Sentinel-1A remains stable using all of its prime units, running in pre-programmed operational mode that ensures the continuous production of data.

Sentinel-1B, its identical sister, is going through the final stages of its AIT campaign in the facilities of Thales Alenia Space Italy in Rome. The spacecraft is fully integrated, including the 12 m SAR Antenna, the Laser Communication Terminal, and the Solar Array wings. Sentinel-1B will be launched early next year on board a Soyuz rocket from Kourou. The procurement process for Sentinel-1C and Sentinel-1D is in progress, with the goal of starting the new development contract by the end of the year. It will guarantee the continuation of the Sentinel-1 mission through the next decade.

Sentinel-2

Sentinel-2A was launched from Kourou on the 22 June on Vega rocket. The commissioning phase took nearly four months and now complete. Following the tuning of the spacecraft and ground system for maximum mission performance, a commissioning review board will authorise transition to operations. The In Orbit Commissioning phase should also demonstrate the health of the optical communication payload that is expected to relay its first Sentinel-2 image through Alphasat in the first week of October. The delivery of the second payload instrument FM by Airbus Defence & Space France is expected.

Sentinel-3

The AIT campaign was completed. At instrument level, the SLSTR FM2 was integrated on the satellite in June replacing the SLSTR uncalibrated model used during the first part of the environmental test campaign. The OLCI PFM instrument was also reintegrated on the satellite in August, after having undergone a preventive replacement of the five optical cameras following an investigation that identified some manufacturing process deficiency on another camera model. The satellite was shipped to Plesetsk for a December launch on Rockot.

On Sentinel-3B, the SLSTR is being refurbished for later integration on the satellite. The Sentinel-3B AIT remains on hold until after the launch of Sentinel-3A.

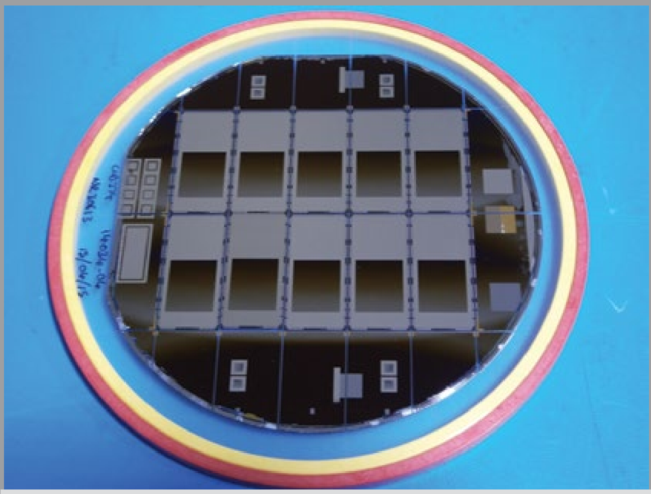
Sentinel-4

The initial characterisation of all twelve silicon wafers for the CCD detectors showed good preliminary results. The polishing for all the silicon oxide lenses of all the three protoflight optical assemblies were completed; their optical coating is progressing well. The manufacturing of the carbon-fibre reinforced plastic (CFRP) baseplate for the Optical Instrument Module STM began. Manufacturing of several EQM subsystems has begun. All but one subsystem PDR have been completed. The subsystem CDRs continue.

Sentinel-5

Major progress has been achieved in the creation of the industrial consortium. Suppliers for spectrometers, electronics and the calibration unit have been contracted.

Sentinel-3A in CATR facilities in Cannes during EMC tests (Thales Alenia Space)



Ultraviolet and visible light CCD detector wafer #374 with ten CCDs for flight and spare detectors selection (E2V UK)

Sentinel-5 Precursor set up for sine vibration test in Intespace (Airbus Defence & Space)

Procurement of the various ground support equipment's and test facilities is now progressing. The system PDR took place on 8 July. Performance measurements on a new diffusor material, intended for use in the calibration assembly, confirm the lower spectral features compared to previous designs. The material is now undergoing environmental tests. In particular the degradation due to ultraviolet radiation needs to be verified. In preparation of the PDR, the instrument's optical assembly structure was optimised. In view of tackling some remaining technology risks, a Design Validation Sample was fabricated. Tests on this unit, which is about half the size of the instrument structure's baseplate, are almost complete.

Sentinel-5 Precursor

Satellite thermal vacuum/thermal balance (TV/TB) testing took place at Intespace in Toulouse in August. Sine vibration and acoustic testing were carried out in September. For the overall ground segment, system validation tests are planned for October/December. For the Rockot launcher, a satellite/launcher fit-check and separation/shock test is scheduled for October. A launch window from mid-April 2016 to mid-July 2016 was confirmed by the launcher authority. A strategy for in-flight tandem operation of Sentinel-5 Precursor and Suomi-NPP has been agreed with NOAA/NASA. A safe in-orbit separation of both satellites of 3.5 minutes has been confirmed.

Instrument Control Unit (ICU) Engineering Qualification Model (RUAG Sweden)

Jason CS/Sentinel-6

The Jason-CS Eumetsat programme was initiated in September. An ESA/Eumetsat arrangement defines the respective roles and responsibilities of the partners and its approval by both ESA and Eumetsat respective Member State Councils means funding will be released for the industrial Phase-C/D. Phase-Co was completed and the project continues under a contractual 'Preliminary Authorisation To Proceed', covering the Airbus Defence & Space Germany industrial consortium activities until the end of the year for both satellite A and B models. Procurement of the system elements according to ESA Best Practices is ongoing and the 80% target value should be reached by the end of the year.

As partner in the mission, NASA will contribute the radiometer, the laser reflector and a radio occultation package as well as the launch services for both satellites.

→ ALPHASAT

The Technology Demonstration Payloads on board Alphasat, provided by ESA and national agencies, are now in operation. The Laser Communications Terminal (DLR) was used for in-orbit testing of a laser terminal on board the Sentinel-2A spacecraft.

The Alphabus Extension Qualification Review, qualifying the Alphabus product line up to 22 kW payload power, as well as several other performance improvements, is complete, except for the Deployable Panel Radiator (DPR). The manufacturing of the deployment mechanism, the radiator panel, the loop heat pipes, with their evaporators and condensers, and the mechanical ground support equipment, started.

Testing of a large (4 m) sample, in preparation for the Deployable Panel Radiator Qualification testing at EHP, Belgium)

→ SMALLGEO/AG1

The industrial team led by OHB System is preparing the spacecraft for its environmental testing. All technical issues affecting the Solar Array Drive Mechanisms and the Low Shock Release Mechanisms have been cleared up and new units were assembled onto the spacecraft. The Integrated System Tests that provide the performance reference for the environmental test campaign have been completed. The finalisation of the spacecraft configuration for the sine and acoustic test started with the integration and alignment of the two 2 m deployable reflectors.

→ EDRS

The launch of Eutelsat 9B with the EDRS-A payload was scheduled for early 2016.

The EDRS-C satellite CDR cycle was completed. AIT activities on the FM started. While procurement of satellite equipment was progressing, the flight hardware AIT was progressing at several sites: integration of the Core Platform Module at OHB in Bremen; assembly of the Propulsion Module at Avio; EDRS-C payload integration on its dedicated repeater panel at the prime contractor TESAT's site, and the hosted HYLAS-3 payload from Avanti assembled on its dedicated repeater panel at its supplier MDA, Canada.

All ground segment hardware is being manufactured, and the stations in Weilheim, Redu and Harwell are deployed and have completed their partial acceptance test campaigns. The Mission Operations Center (MOC) is the heart of the EDRS, were the overall data relay link and data flow planning will take place. It provides the link between the EDRS Space Segment & Ground Segment on one side and the EDRS users on the other. The utilisation of the system capacity and the type of services provided will be planned from here, based on the requests received from users.

The MOC, in Ottobrunn (DE), is being integrated and its functionality and interfaces to the EDRS Ground Segment as well as to the anchor customer Copernicus Sentinel are being tested as part of the ongoing Ground Segment Validation Test (GSVT) campaign. The next GSVT will verify readiness of the EDRS Ground Segment to commence services for the Sentinel satellites.

→ NEOSAT

Separate Phase-C/D activities were prepared with Thales Alenia Space and Airbus Defence & Space, based on system PDRs and results from the various predevelopments on critical technologies. The Thales Alenia Space Phase-C/D contract was signed on 15 September. The Airbus Defence & Space contract proposal was approved by the Industrial Policy Committee. Contract signature was planned for 17 November.

→ ARIANE 6

Industrial activities are ongoing with the implementation of the Industrial Procurement Plan; in particular with the evaluation of the proposals for the Inertial Measurement Unit and the preparation of several ITTs, such as pyrotechnic-cords, the multiple Channel Acquisition Unit, and the pyrotechnic Firing Unit. The third Design Analysis Cycle kick-off meeting took place on 28 September.

P120C and synergy with Vega

The P120C Solid Rocket Motor PDR was completed. Following the conclusion of the P120C Igniter PDR, the ITT for the procurement of the P120C Igniter detailed design and manufacturing was finalised. The first progress meeting on the initial activities for development of the P120C Insulated Motor Case second production line was held on 16 October. The BEAP Adaptations PDR, dealing with the infrastructure and mechanical aspects, took place in November.

Launch base

Excavation works continued as well as preparation of the PDR in line with the horizontal integration process. A concurrent engineering process was set up on the Ariane 6 Control Benches. The Control Bench PDR was scheduled for December with a Steering Committee expected in January 2016.

System architect activities

The operational concept baseline design reverted to a horizontal integration of assemblies produced in Europe (LLPM and ULPM) in the Batiment Assemblage Lanceur building to produce the launcher's central core. The latter is then transferred to the launch zone (ZL) where ESRs and payload and fairing are integrated. The launch table is fixed in the launch zone. In conformance with the Ariane 6 Master Development Plan, the launch system specifications have been updated accordingly and the Launch System Architect activities are now looking at the Launch System SRR. The DLR proposal for the P5.2 test bench was received in October and clarifications were requested. Final evaluation was planned for December.

→ VEGA EVOLUTION AND VEGA C

Since the approval of the programme in 2012, the launch vehicle configuration is being defined and then the launch base modified. Activities at launch vehicle system level are progressing to plan with the start of the Vega C Launch System implementation, after completion of the Launch System Requirements Key Point. Having frozen the Launch System Requirements and the internal and external interfaces among the launch vehicle and launch base components, it is now possible to proceed with the launch vehicle PDR for the configuration constituted by the P120C/ Z40/ Z9/AVUM+ /Standard Payload Fairing, planned for early 2016, and with the placement of the industrial contracts for the start of the launch base industrial activities.

Considering that a significant number of ground facilities will be need to be changed for Vega C while still in operation for Vega, a joint plan will be implemented to avoid either introduction of delays in Vega C development because of Vega exploitation or vice versa. The elaboration of the plan will start with completion the Launch System Requirements Key Point in December. Activities for AVUM+ BERTA configuration are going according to plan. An important BERTA Key Point was held in October, which showed no technical issues at system level.

→ LAUNCHERS EVOLUTION PREPARATION PROGRAMMES

Ongoing contributions are being made to the Launcher Evolution Element Working Group meetings, programme proposals, draft declarations and Tender Evaluation Boards. Microlauncher internal studies started, with the Future Launchers Preparatory Programme (FLPP) industrial prime contractor now identified. FLPP CRONUS aluminium/lithium tank technology has been selected for the Ariane 6 upper stage.

The FLPP Storable Demonstrator team took part on the Vega C Key Point. The Demonstrator stability test campaign is ongoing with excellent results. The contract for Rider 1 of the Expander Technology Integrated Demonstrator 1 was finalised. POD-X closure activities were negotiated, without second hot-firing tests. Equipment is now available for future development of solid rocket motors.

On 7 October, an in-flight demonstration of an aluminium main structure, forming part of the upper stage of a research rocket, was performed on a suborbital sounding rocket mission from NASA's Wallops Island facility. The composite booster-casing demonstrator CDR was held on 8 October. Negotiations on the Kick-Stage Demonstrator were finalised.

The Semi Active Damping System PDR was performed. Following the Composite Cryotank test campaign, the post-test review was performed.

→ IXV AND PRIDE

In line with the logistics plan, most of the IXV flight and ground segment elements were shipped to ESTEC's storage facility, with the exception of the IXV vehicle, which is planned to remain at Thales Alenia Space Italy in Turin for Level-1b/2 post-flight activities.

Following the finalisation of the mission and system requirement document and of the statement of work, the issue of the Request for Quotations for PRIDE Phase A/B was authorised.

→ HUMAN SPACEFLIGHT

ISS

ESA astronaut Andreas Mogensen (DK) flew a 10-day mission to the ISS, launched on 2 September on Soyuz TMA-18M with Roscosmos cosmonaut Sergei Volkov and Kazakh cosmonaut Aidyn Aimbetov. The mission ended on 12 September with undocking and landing of Mogensen in Soyuz TMA-16M together with Aimbetov and Gennady Padalka. Mogensen became the first Danish astronaut in space and the fourth of ESA's class of 2009 to complete a mission to the ISS. Even though a last-minute change of launch-to-docking profile occurred (two days rather than six hours), Andreas did a great job in catching up lost time and a full spectrum of ESA experiments was performed in the life and physical sciences, and technology, including Mogensen being the subject of human research experiments and performing various education activities.

The mission provided a newer return craft for the one-year crew members on the ISS, Scott Kelly (NASA) and Mikhail Kornienko (Roscosmos), since Soyuz spacecraft are only certified for a six-month stay at the Station.

The period from July to September saw the fifth Japanese H-II Transfer Vehicle (Kounotori 5) mission and the launch of Progress 60P, which will remain docked at the ISS until November. These logistics spacecraft both brought supplies to support the crew in undertaking research on the Station.

Astronauts

Samantha Cristoforetti (IT) is on the post-flight tour for her Futura mission. Post-flight data collection and debriefings of Andreas Mogensen are continuing in parallel with preparations for his iriss mission post-flight tour. Tim Peake (GB) finished training in the US, Japan and Europe. He is now in Russia for the final stages of preparation for launch of his Principia mission in December. Training continues for Thomas Pesquet (FR), with a focus on US system and

operations. Paolo Nespoli (IT) started preparing for his next mission with training in the US and Russia.

Multi-Purpose Crew Vehicle/European Service Module

The technical baseline design was frozen in July for a system CDR beginning in December. The equipment-level CDR process started in July and is in progress. However, a number of new external changes were requested and are under preparation, which may impact the CDR planning.

Exploitation

Contract negotiations with DLR and ALTEC for the implementation of the ISS exploitation programme are under finalisation, and contract proposals were approved by the IPC in September.

Andreas Mogensen just after landing on 12 September in Kazakhstan, marking the end of his iriss mission to the International Space Station

→ RESEARCH

European research on the ISS

In addition to the iriss mission, the European ISS utilisation programme continued with the assistance of the Expedition 44/45 crew members in orbit. Highlights of the period 1 July-date are as follows:

Human research

Sessions of two ESA experiments (with Russian cooperation), Immuno-2 and EDOS-2, were performed by Roscosmos cosmonaut Mikhail Korniyenko. Fellow cosmonaut Gennady Padalka was also a test subject for EDOS-2. EDOS-2 continues the research from the Early Detection of Osteoporosis in Space (EDOS) experiment, though with in-flight sampling, in determining post reentry bone loss and long-term recovery from spaceflight-induced bone loss. Immuno-2 is an integrative study protocol to provide a more holistic approach to increase the knowledge of the complex physiological adaptation of humans during long-term space missions. The research follows up the positive research from the first Immuno experiment.

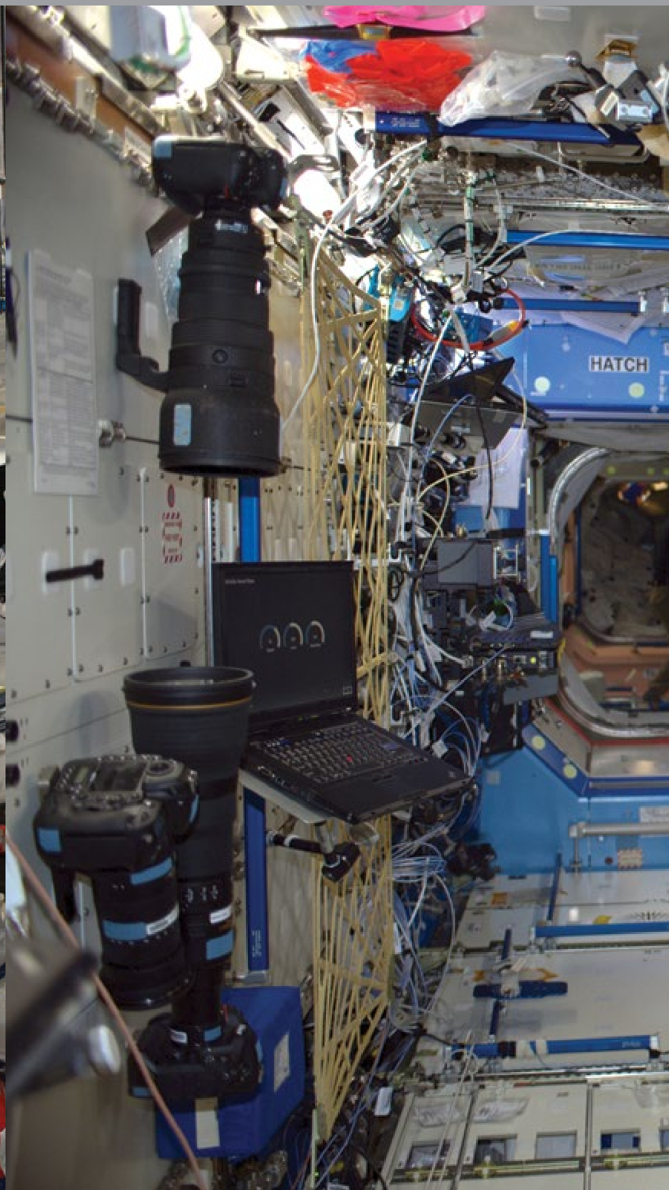
The second part of commissioning for the Muscle Atrophy Research and Exercise System (MARES) was performed including mechanical setup, gathering ultrasound measurements, and performing the checkout of the Percutaneous Electrical Muscle Stimulator (PEMS) instrument. These are the final checkout activities to perform an integrated 'man-in-the-loop' protocol that characterises all MARES subsystems and associated auxiliary measurement devices.

Biology research

ESA's fourth major cell biology experiment of the year, Endothelial Cells, was undertaken in a Kubik incubator during the iriss mission. Endothelial cells play important roles in transportation of blood around the body, blood filtration and wound healing. Their dysfunction is central to many serious cardiovascular diseases on Earth as well as the cause of some adverse physiological conditions in space. The Endothelial Cells experiment is evaluating the cause of this dysfunction. Results could lead to improved treatments and countermeasures for associated medical conditions both in space and on Earth. Samples were returned in September.

Earth observation

The THOR experiment, concerning thunderstorm convection related to transport of water vapour, took place during the iriss mission. The project is studying the relationship between these processes and electrical activity of thunderstorms by using optical cameras on the ISS, ground observations of lightning, and meteorological satellite observations of cloud properties. The experiment also studies one of the main topics of investigation for ESA's future Atmospheric Space Interactions Monitoring Instrument (ASIM), and generation



of electric discharges in the stratosphere and mesosphere over thunderstorms.

The THOR experiment will improve our understanding of how lightning activity powers cloud turrets, gravity waves, and the structure of Transient Luminous Events above thunderstorms. This could in turn improve atmospheric models and our understanding of Earth's climate and weather.

The DEMES experiment (short for DEmonstration of MELiSSA Snacks) on the iriss mission tested cereal bars made with spirulina bacteria

Radiation monitoring/research

An initial test of the first active radiation dose measurement technology to be worn directly on an astronaut's body was made during the iriss mission in September. Two mobile units of the European Crew Personal Active Dosimeter were placed in Columbus for continuous active environmental measurements.

This will be followed up in the future with the launch and test of the full hardware which includes five astronaut-worn mobile units as well as a rack-installed unit in which the astronaut-worn sensors can be charged and data transferred. The two mobile units were returned to Earth to undergo analysis after the flight. The time-resolved

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Andreas Mogensen purifying some of the Station's waste water for a test of 'biomimetic' membrane in the Aquamembrane experiment

←

Andreas Mogensen works on two experiments during his iriss mission on the Space Station, SkinSuit and MobileHR

radiation dose data during the iriss mission were resolved over 14 orders of magnitude in energy for entire mission, so that this technology could become a novel part of ESA's radiation protection strategy for astronauts.

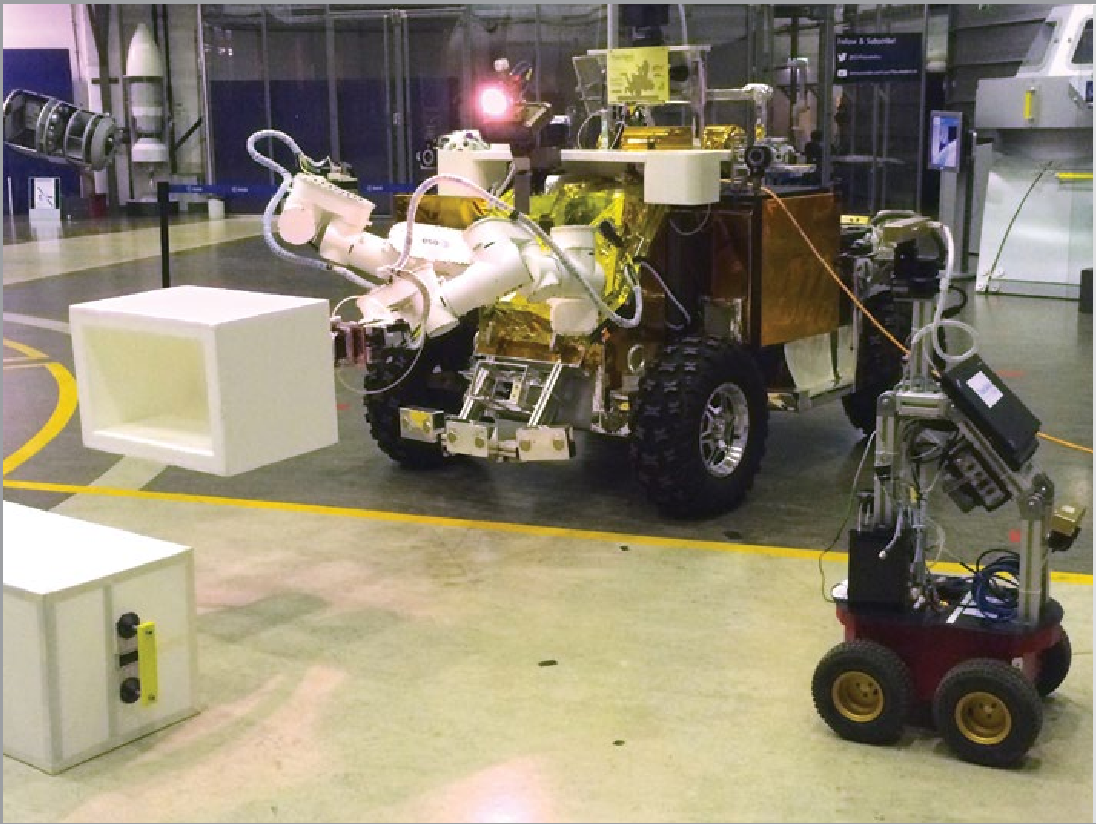
Technology research

Two technology experiments undertaken during the iriss mission have strong links to future exploration, and more specifically life support on such missions. The Aquamembrane experiment could revolutionise water reclamation on Earth and in space with a new membrane (Aquaporin-Inside Membrane), which simulates nature in water filtration using aquaporins that are water channel proteins that only allow H_2O to pass through them.

This could lead to improved efficiency in ISS systems for reclaiming water for use as drinking water, etc., which will help reduce upload mass of expendable media used in water processing.

The MELONDAU experiment was validating the recovery of full biological processes of different bacteria from the Micro-Ecological Life Support System Alternative (MELiSSA), after storage and travel into, and return from, space; and testing food products derived from MELiSSA-produced nutrients. MELONDAU is a significant precursor flight experiment for MELiSSA and a first step to enable the deployment of the MELiSSA system in space in the future.

Other technology tests undertaken during the iriss mission include a test of a bluetooth heart rate monitor (MobileHR) which should improve on the current magnetic pulse technology on the ISS, provide improvements to future payload developments and provide a greater stability in the data for human research investigations; an improved mobile procedure viewer aimed at increasing efficiency of astronauts in undertaking on-orbit procedures; and a test of a new countermeasure garment (SkinSuit) to counter the adverse effects of weightlessness on physiology.



The Eurobot rover (left) with the surveyor rover during the Supvis-E experiment at ESTEC in the Netherlands. On 11 September, Andreas Mogensen controlled Eurobot from space in a simulated troubleshooting Moon scenario, while the second rover was controlled from ESOC in Germany

Robotics

Two experiments were conducted: Haptics-2 and SupvisE. Haptics-2 is the first space-to-ground control experiment with force-feedback. A force-feedback joystick in Columbus on the ISS was connected in real time to a similar joystick at ESTEC. The Earth-based joystick directly copied any motion/force exerted on the ISS-based joystick (and vice versa). The SupvisE experiment was executed with ESTEC, ESOC, BUSOC, Huntsville and White Sands in the loop and five video streams active between ground and the ISS, two rovers were conducting a realistic lunar robotic operations scenario (offloading a lunar lander). One rover was controlled from the ISS by Andreas and the other from ESOC. All data were transferred using the new data protocol Disruption Tolerant Networking (DTN), also nicknamed 'space internet'.

Non-ISS research in ELIPS

A 60-day bed rest study started at DLR on 25 August with 12 volunteers. The bed study is evaluating the efficacy of a reactive jump countermeasure to protect from the negative effects of muscle disuse which not only astronauts experience, but also bed-ridden patients. The two latest winter-over seasons (Concordia and the British Antarctic Survey, BAS) are proceeding, Concordia with five ESA experiments and 13 crewmembers and the BAS with two ESA experiments and 16 crewmembers. A drop tower campaign was undertaken in July, testing hardware for the PERWAVES module, planned for launch on the MAXUS-9 sounding rocket in 2016.

→ EXPLORATION

International Berthing Docking Mechanism (IBDM)

Meetings with the interested participating states (BE, IT, PL, ES, CH) took place and the agreement between ESA and Sierra Nevada Corporation (SNC) will be approved by the Programme Board for Human Spaceflight, Microgravity and Exploration and the Industrial Policy Committee in September.

Lunar exploration

A letter was signed between ESA and Roscosmos on 26 August, formalising the initial phase of cooperation on lunar exploration. The activities of the follow-on phase will be subject to further decisions at the next Council meeting at ministerial level end of 2016.

Two ITTs for the PROSPECT (lunar drill and sample analysis instrument) Phase B+ and for the PILOT (visual navigation and hazard avoidance for landing) Phase B+ were released in August. The PROSPECT User Group was selected. It will represent the users of PROSPECT from various fields (in situ resource utilisation, exploration technologies, fundamental science, etc.).

International cooperation

The International Space Exploration Coordination Group (ISECG), chaired by ESA, met in Cologne in October. The United Arab Emirates became full member of ISECG.

A volunteer has a blood-pressure check during the 60-day bedrest study that began in August 2015 (DLR)

Space Exploration Strategy

The expert panel for the evaluation of the ideas received for the Call For Ideas on 'Space Exploration as a Driver for Economic Growth' selected 19 ideas to be examined together with the proposing team in consultation process, and seven will be followed by ESA as observer. The Announcement and Call for Abstracts for ESA 'Moon 2020–30' symposium was published on a dedicated web site: **http://spaceflight.esa.int/humanrobotics/**

→ SPACE SITUATIONAL AWARENESS (SSA)

Space Weather (SWE)

The SSA SWE Coordination Centre (SSCC) has continued providing helpdesk support to the end users and monitoring the SWE system. The number of registered users of the SSA SWE system is approaching 250 and the SWE Service Portal has 1000–2000 hits weekly. The SSCC also continued to provide tailored space weather information to the operators of Gaia and Rosetta missions. Preparations for providing space weather services for the LISA Pathfinder launch and LEOP were made.

Preparation of two hosted payload missions for space weather instruments has continued. The Next Generation Radiation Monitor (NGRM), which will fly on the European Data Relay System (EDRS-C) mission, reached the integration and qualification/test phase, while the development of the SOSMAG magnetometer for the Korean Space Environment Monitor (KSEM) instrument package to fly on the GEO-KOMPSAT-2A mission progressed on the EQM.

Near Earth Objects (NEO)

On the NEO Coordination Centre's initiative, the 8.2 m Very Large Telescope observed the NEO 2014 WU200. At a magnitude of about 27 this was the faintest asteroid ever observed. The measurements allowed a refining of its orbit. The total number of known NEOs now exceeds 13000.

Space Surveillance & Tracking (SST)

The segment is preparing for the integration and testing of the SST data processing components and applications. Based on requirement analyses, procurement of a follow-on activity to establish an expert centre for federated laser and optical systems is ongoing.

Radars and telescopes

Indra Espacio (ES) still has to complete the test and validation campaigns on the monostatic breadboard radar, which have been delayed because of a radar malfunction. To date, no data have been exported outside the radar secure zone because of security restrictions. The bistatic breadboard radar's test and validation campaigns started. The first cycle was completed and confirmed the radar's performance. The detailed design of the NEO Survey Telescope is on schedule. Following the completion of the PDR, industry is completing the Final Design documentation.

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