number 158 | May 2014

bulletin

→ space for europe

1964–2014
→ SERVING EUROPEAN COOPERATION AND INNOVATION

European Space Agency

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

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

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

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

The ESA headquarters are in Paris.

The major establishments of ESA are:

ESTEC, Noordwijk, Netherlands.

ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

EAC, Cologne, Germany.

ECSAT, Harwell, United Kingdom.

ESA Redu, Belgium.

Chairman of the Council:
Johann-Dietrich Wörner

Vice-Chairs:
Enrico Saggese and David Parker

Director General:
Jean-Jacques Dordain

←

Launched to the International Space Station in May 2014, ESA astronaut Alexander Gerst floats through the Columbus laboratory under night-time illumination (ESA/NASA)

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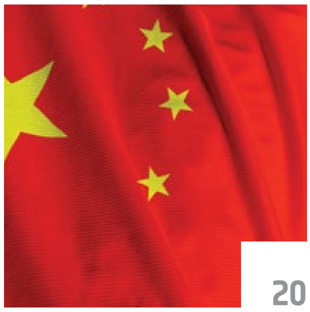

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Spectacular view of Ariane from the top of the launch platform at ESA's Spaceport in Kourou, French Guiana, a few days before launch L01 in December 1979

→ A CHRONOLOGY OF EUROPEAN COOPERATION IN SPACE

Part 2: 1975–94

1975

15 April
The last European Space Conference meeting in Brussels adopts the text of the Convention for the new European Space Agency. Roy Gibson (GB) is nominated Director General

30 May
ESA Convention opened for signature, and the Final Act signed at the Conference of Plenipotentiaries, Paris

24 June
Wolfgang Finke (DE) is elected Chair of Council

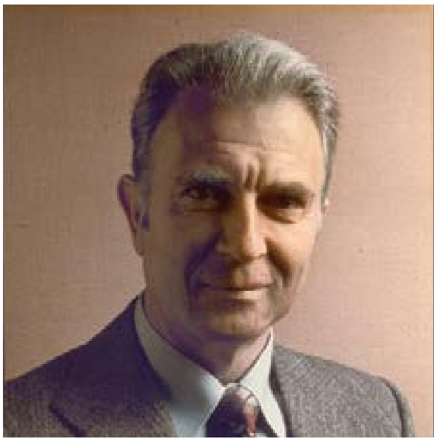
30 August
The Netherlands launches its first satellite, ANS, on US rocket

15 November
Spain launches its first satellite, Intasat, on US rocket

31 December
Ireland signs the ESA Convention and becomes ESA's 11th Member State

The European Space Conference held at the Palais d'Egmont, Brussels, on 15 April 1975, which approved the final draft of the ESA Convention

9 August 1975
Launch of COS-B, ESA's first satellite, to study gamma-ray sources, on US rocket from Vandenberg AFB (ESA/WTR-NASA)



Wolfgang Finke, Chair of ESA Council, 1975–78

1976

May
Refurbishment of the former EUROSTOR building on Rue Mario-Nikis for the new ESA headquarters in Paris

October
ESA headquarters moves from Neuilly-sur-Seine to its new building in Paris

22 November
ESA Council meets for the first time in the agency's new headquarters

→ The new ESA headquarters in Paris during refurbishment, May 1976

1977

14 February
ESA Council meeting at Ministerial Level passes declaration to undertake a communications satellite programme and a resolution creating the Earthnet programme

20 April 1977
Launch of GEOS-1, to study dynamics of Earth atmosphere, on US rocket from Cape Canaveral

30 June
Eutelsat, the intergovernmental European Telecommunications Satellite Organisation, is established by P&T administrations in Europe

↑ The ESA-built International Sun-Earth Explorer 2 (ISEE-2) at ESTEC

13 September
Loss of OTS-1 (Orbital Test Satellite) due to launch failure

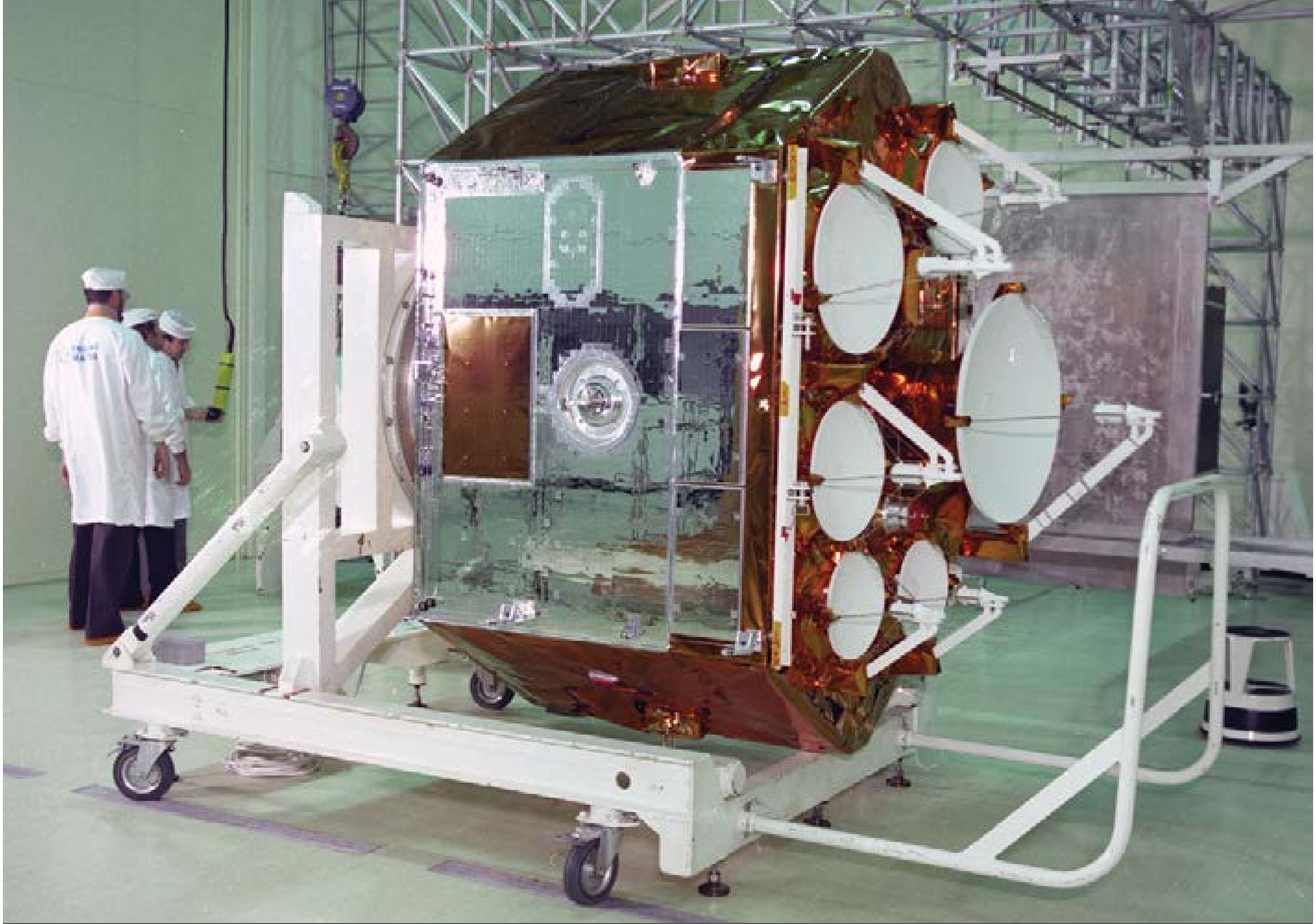
22 October
Launch of ISEE-2 satellite, on US rocket

23 November
Launch of Meteosat-1, the first European meteorological satellite and first European geostationary satellite, on US rocket

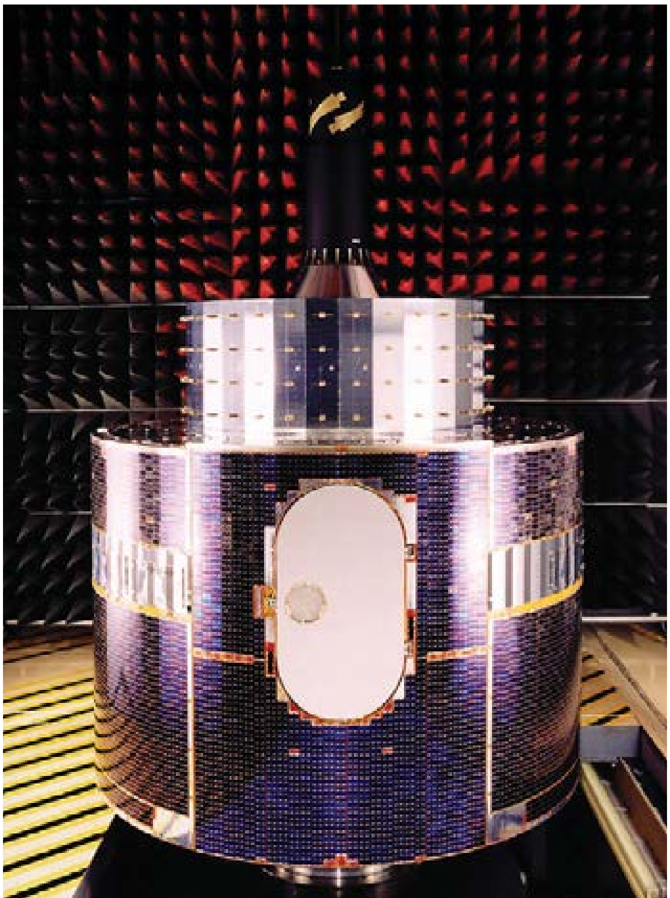
12 December
ESA Council approves launch of GEOS-2

23 December
ESA selects European 'payload specialist' astronauts to train for the Spacelab missions on US Space Shuttle

↑ Claude Nicollier (CH), Ulf Merbold (DE), Wubbo Ockels (NL) and Franco Malerba (IT) are selected as ESA's first astronauts, seen here with Roy Gibson and Michel Bignier



↑ ESA's first telecommunications satellite OTS-2 in the clean room at Matra Toulouse during preparation for testing



↑ Meteosat-1, the first European meteorological satellite

1978

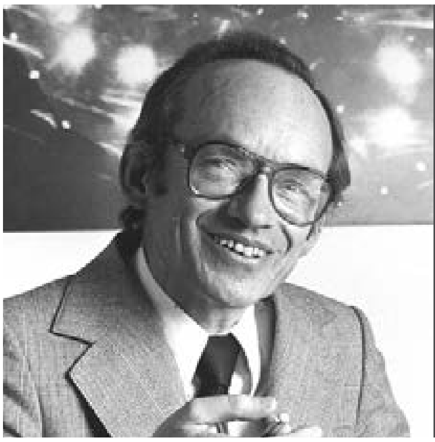
11 May
Launch of Orbital Test Satellite 2 (OTS-2), ESA's first communications satellite, by US rocket from Cape Canaveral

26 January 1978
Launch of IUE, the first astronomical satellite at geostationary altitude, by US rocket from Cape Canaveral

IUE under test in 1975. IUE is the longest-lived and one of the most productive satellites ever built. It worked non-stop from launch in 1978 until it was switched off in September 1996, 14 years later than originally planned

12 May
Inauguration of the Villafranca ground station with HM King Juan Carlos of Spain

22 June
Jan Stiernstedt (SE) replaces Wolfgang Finke as Chair of ESA Council



Jan Stiernstedt, Chair of ESA Council, 1978—81

14 July 1978
Launch of GEOS-2, to study Earth magnetospheric fields, waves and particles, by US rocket from Cape Canaveral

Signature for the ESA Associate Membership of Canada on 9 December 1978 with ESA Director General Roy Gibson and Lady Jeanne Sauvé, Canadian Minister of Communications

1979

1 January
The first five-year Cooperation Agreement between Canada and ESA comes into effect

17 October
Signing of Association Agreement with Austria

19 December
Council appoints Erik Quistgaard (DK) to the post of Director General of ESA. He takes up his duties on 15 May 1980

Erik Quistgaard, second Director General of ESA

1980

26 March
Creation of Arianespace, the world's first commercial space transportation company

15 May
Erik Quistgaard (DK) replaces Roy Gibson as ESA Director General

23 May
Ariane's second test flight (L02) fails, with loss of German Firewheel satellite

3 July
Decision taken to upgrade Ariane to Ariane 3, designed to launch two satellites into geostationary transfer orbit

24 December 1979
The first Ariane is launched from the Guiana Space Centre, Kourou

30 October
Entry into force of the ESA Convention

1981

2 April
Signing of Association Agreement with Norway

19 June
Launch of Meteosat-2 on an Ariane 1 from Kourou

29 June
Hubert Curien (FR) replaces Jan Stiernstedt as Chair of ESA Council

July
Council decision to build a second Ariane launch site (ELA-2) at Kourou

← Hubert Curien, Chair of ESA Council, 1981–84

20 December 1981
Launch of Marecs-A, first European maritime communications satellite, on an Ariane 1 rocket (L04) from Kourou

1982

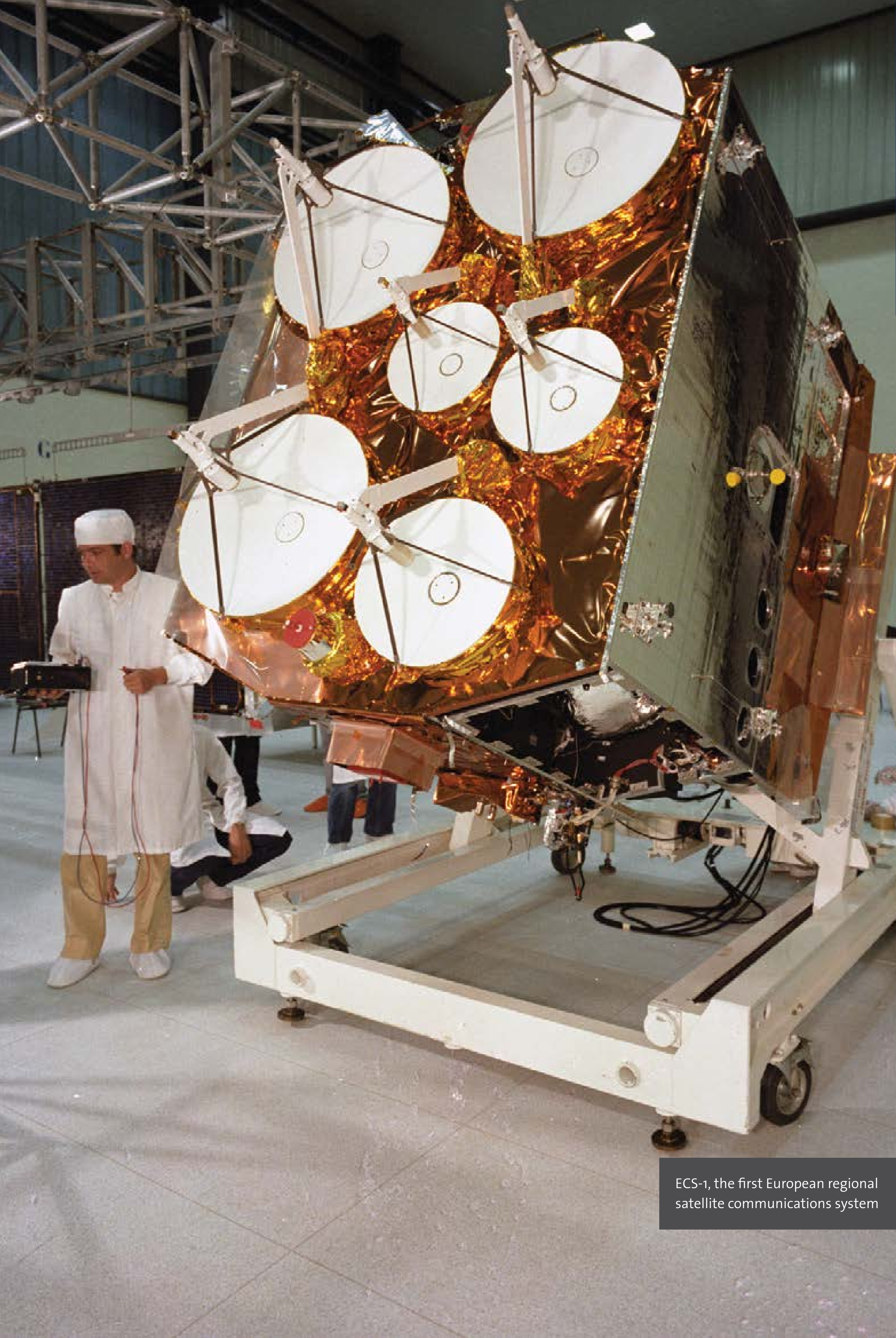
January
Approval of the development of Ariane 4

9 September
Loss of Marecs-B and Sirio-2 satellites in failure of first operational Ariane launch (L05)

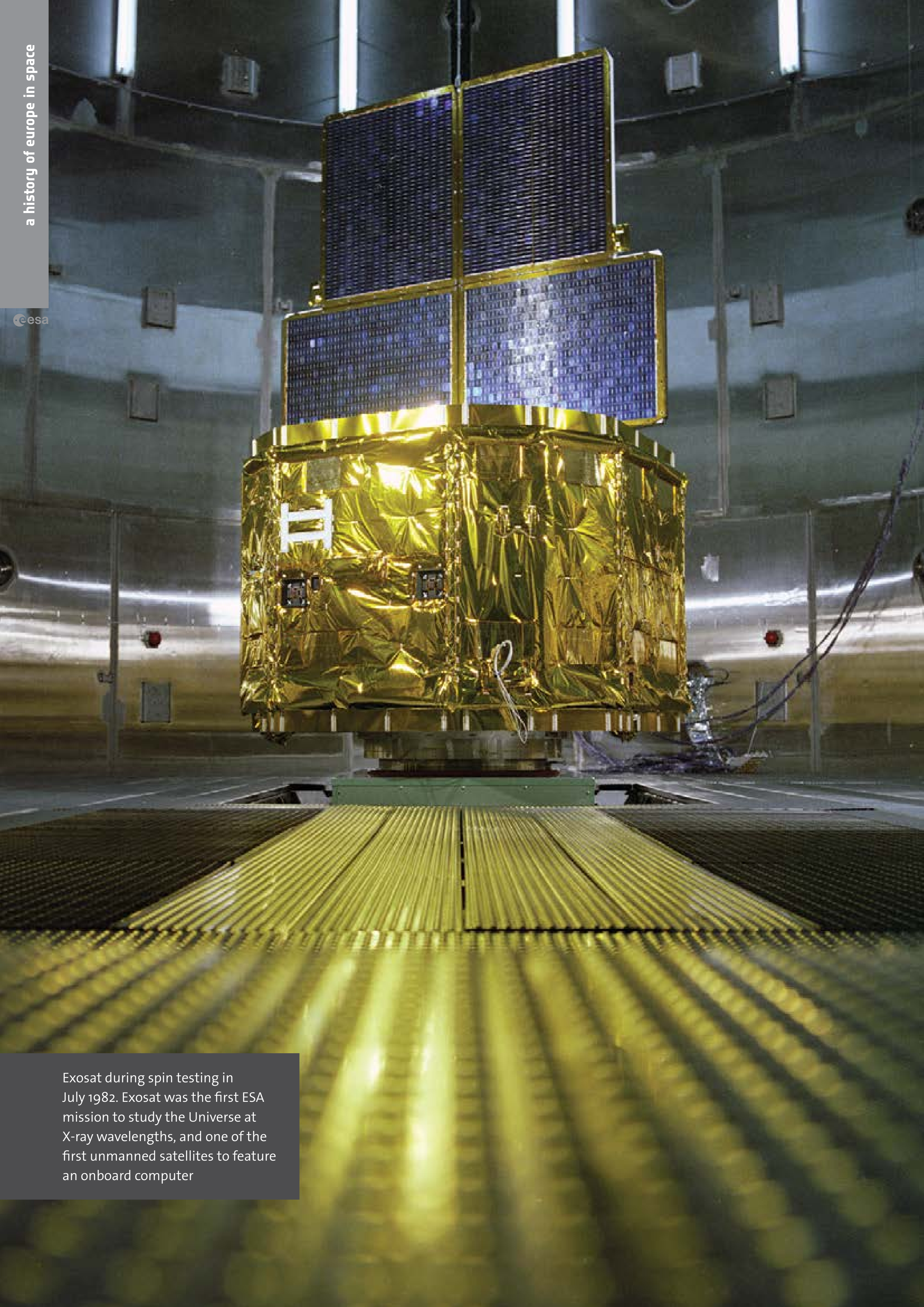
1983

26 May
Launch of Exosat, to make detailed observations of X-ray sources, on US rocket from Vandenberg AFB

16 June 1983
Launch of ECS-1 on an Ariane 1 rocket (L06) from Kourou



ECS-1, the first European regional satellite communications system



Exosat during spin testing in July 1982. Exosat was the first ESA mission to study the Universe at X-ray wavelengths, and one of the first unmanned satellites to feature an onboard computer

28 November 1983
Launch of first Spacelab mission (STS-9 *Columbia*, 10 days). ESA's Ulf Merbold (DE) becomes first non-US astronaut to fly on the US Space Shuttle

1984

27 June
Dr Harry Atkinson (GB) replaces Hubert Curien as Chair of ESA Council

← Harry Atkinson, Chair of ESA Council, 1984—87

4 August
Launch of ECS-2 on the first launch of an Ariane 3 (V10), from Kourou

3 September
Reimar Lüst (DE) replaces Erik Quistgaard as Director General of ESA

← Reimar Lüst, third Director General of ESA

9 November
Launch of Marecs-B2 on an Ariane 3 (V11)

1985

30 January
ESA Council meeting at Ministerial Level in Rome: work on the Ariane 5 launch vehicle is approved and the Horizon 2000 science programme starts, with the science programme granted a 5% increase over a period of five years. Interest in the French decision to undertake the Hermes manned spaceplane programme was noted, with the proposal by France to associate the detailed studies programme with European partners.

12 September
Launch of ECS-3 by Ariane 3 (V15). Suffered geosynchronous orbit injection failure.

2 July 1985
Launch of Giotto, ESA's first deep-space mission aiming to fly by a comet, on an Ariane 1 (V14)

30 October 1985
Launch of Spacelab D1 mission (STS-61A, *Challenger*, 7 days). ESA's Wubbo Ockels (right) becomes first Dutch citizen in space

↓ On 12 December 1985 at ESA headquarters in Paris, Heinz Fischer, the Austrian Federal Minister of Science and Research, and Petter Thomassen, the Norwegian Minister of Industry, signed the accession agreements that would take their countries into full membership of ESA on 1 January 1987. Delegation and ESA officials, including Chair of the ESA Council Harry Atkinson, look on.

1986

21 February
Final launch of Ariane 1 (V16), the first mission to heliosynchronous orbit

19 June
The Eumetsat Convention enters into force as an agreement among 16 European Member States

13/14 March 1986
Historic encounter of the Giotto probe with Halley's Comet

19 September
Signing of an Association Agreement with Finland

1987

1 January
Austria and Norway become the 12th and 13th ESA Member States

22 June
Henrik Grage (DK) replaces Harry Atkinson as Chair of ESA Council

← Henrik Grage, Chair of ESA Council, 1987–90

↑ The first Ariane 2, V20, stands ready for launch in 1987

↑ Early Space Station Freedom concept (NASA)

16 September
Launch of ECS-4 on an Ariane 3 (V19)

9 November
ESA Council meeting at Ministerial Level in The Hague: the Resolution on the European Long-Term Space Plan and Programmes is adopted, and the Ariane 5, Columbus and Hermes development programmes are approved

21 November
First launch of Ariane 2 (V20) from Kourou

1988

14 April
Signing of Cooperation Agreement with India Space Research Organisation

21 July
Launch of ECS-5 by Ariane 3 (V24)

15 June 1988
First launch of an Ariane 4 (V22). Payloads are Meteosat P2, renamed Meteosat 3, and Amsat III

↑ NASA Deputy Administrator Dale Myers and ESA Director General Reimar Lüst sign the Memorandum of Understanding on cooperation for Space Station Freedom in 1988

29 September
Memorandum of Understanding on cooperation in the design and development of Space Station Freedom signed by ESA and NASA in Washington

29 September
(First) Intergovernmental Agreement (IGA) on Space Station signed by European countries, USA and Canada

↑ The Hipparcos satellite in ESA's Large Solar Simulator, ESTEC, February 1988

1989

8 March
Launch of MOP-1 (renamed Meteosat-4) by Ariane 4 (44 LP-03, V29)

2 April
Final launch of Ariane 2 (V30), after five successful missions

19 April
Celebration of 25 years of European cooperation on space in Paris

12 July 1989
Launch of the Olympus telecoms technology demonstration satellite on by Ariane 3 (V32). Final Ariane 3 flight, after 11 missions, all successful)

8 August
Launch of Hipparcos, the first space-based astronomical surveyor, on an Ariane 4 (V33)

1990

24 April 1990
Launch of the Hubble Space Telescope on STS-31 Space Shuttle *Discovery*

25 April
Signing of Cooperation agreement with USSR

10 May
Signing of Host Agreement with the Federal Republic of Germany establishing the European Astronaut Centre

27 June
Francesco Carassa (IT) replaces Henrik Grage as Chair of ESA Council

← Francesco Carassa, Chair of ESA Council, 1990–93

← Jean-Marie Luton, fourth Director General of ESA

1 October
Jean-Marie Luton (FR) succeeds Reimar Lüst as Director General of ESA

6 October 1990
Ulysses probe launched by STS-41 Space Shuttle *Discovery*

1991

2 March
Launch of Meteosat 5 on an Ariane 4 (V42)

17 July
Launch of ERS-1 (European Remote Sensing satellite) on an Ariane 4 (V44)

18 November
ESA Council meeting at Ministerial Level in Munich. Decisions on reorientation of major infrastructure programmes, Columbus and Hermes

←

In-orbit crew portrait of the STS-46 crew with Claude Nicollier and Franco Malerba in 1992 (NASA)

1992

22 January
Launch of Spacelab IML mission (STS-42, Space Shuttle *Discovery*, 8 days) with ESA astronaut Ulf Merbold

24 March
Launch of ATLAS-1 mission (STS-45, Space Shuttle *Atlantis*, 9 days) with Belgian astronaut Dirk Frimout

27 July
Launch of Antares mission (Soyuz TM-15, 14 days) with French cosmonaut Michel Tognini

31 July
Launch of the European Retrievable Carrier and the Tethered Satellite System (STS-46, Space Shuttle *Atlantis*, 8 days) with ESA astronaut Claude Nicollier (CH) and ASI astronaut Franco Malerba (IT)

9 November
ESA Council meeting at Ministerial Level in Granada, Spain: go-ahead to develop Envisat-1 and, in cooperation with Eumetsat, initiate MetOp and startup of Meteosat Second Generation

1993

26 April
Launch of Spacelab D2 mission (STS-55, *Columbia*, 10 days) with ESA astronaut Hans Schlegel (DE)

1 July
Launch of Altaïr mission (Soyuz, TM-17, 21 days) with French cosmonaut Jean-Pierre Haigneré

←

ESA announced the selection of six new astronauts in May 1992: Christer Fuglesang (SE), Thomas Reiter (DE), Pedro Duque (ES), Maurizio Cheli (IT), Marianne Merchez (BE) and Jean-François Clervoy (FR)

↑ French cosmonaut Jean-Pierre Haigneré on Mir during the Altair mission in 1993

← Gaele Winters, Chair of ESA Council, 1993—96

6 July
Signing of Cooperation Agreement with Romania

9 September
Gaele Winters (NL) replaces Francesco Carassa as Chair of ESA Council

20 November
Launch of Meteosat-6 by Ariane 4 (V61)

2 December
Launch of first Hubble Space Telescope servicing and repair mission (STS-61, Space Shuttle *Endeavour*, 10 days) with ESA astronaut Claude Nicollier (CH)

1994

7 June
Signing of Cooperation Agreement with Poland

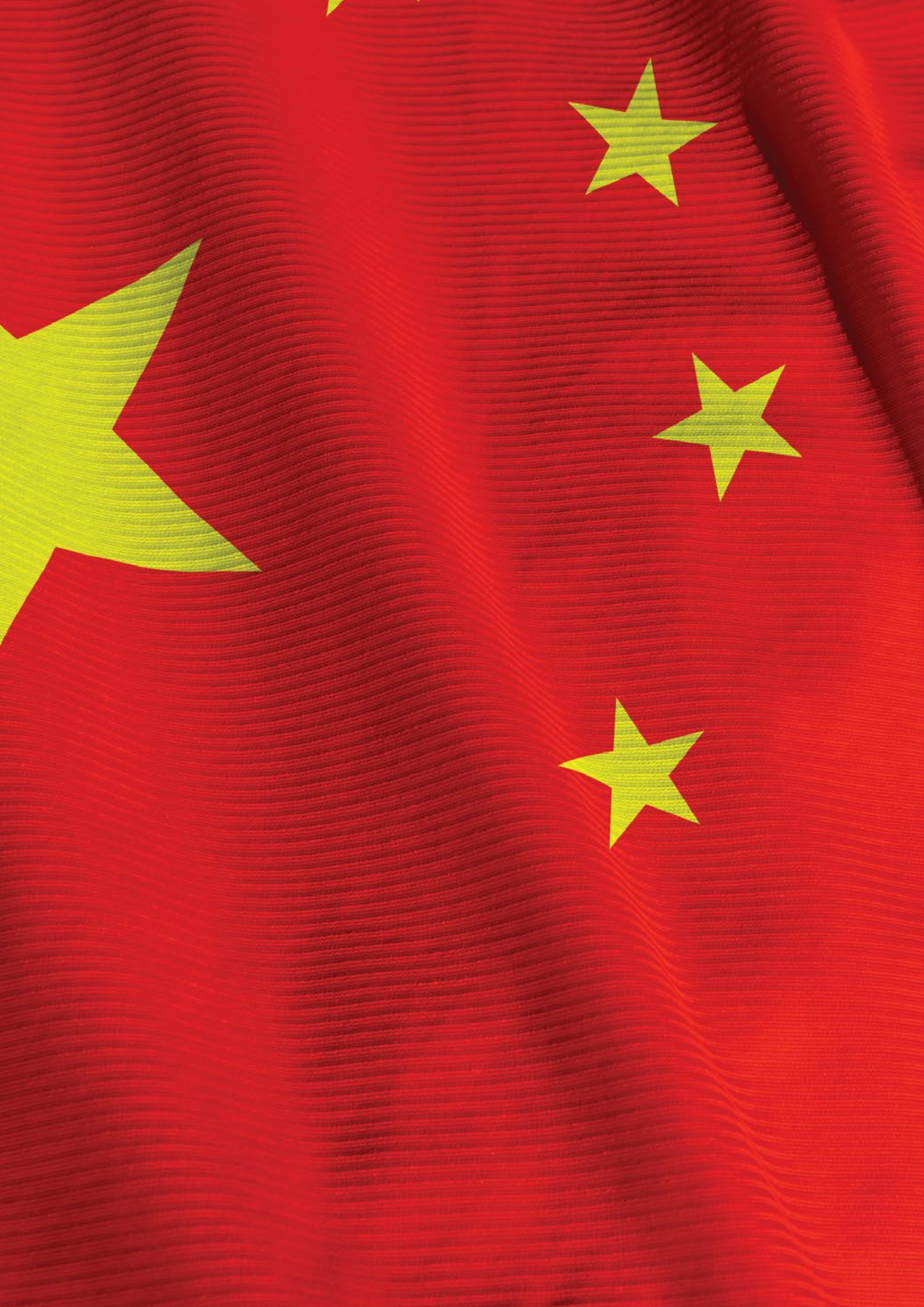
3 November
Launch of ATLAS-3 mission (STS-66, Space Shuttle *Atlantis*, 10 days) with ESA astronaut Jean-François Clervoy (FR). Deployed the CRISTA-SPAS atmospheric research satellite

3 October
Launch of Euromir '94 long-duration mission (Soyuz TM-20, 32 days) with Ulf Merbold, first ESA astronaut to fly to the Russian space station Mir ■

← ESA Euromir astronaut Ulf Merbold (right) with fellow Soyuz TM-20 crew members Alexander Viktorenko and Yelena Kondakova

CHRONOLOGY Part 3: 1995–2014

Continued in next issue ›



→ COOPERATION WITH CHINA IN SPACE SCIENCE

Karl Bergquist
International Relations Department, ESA Headquarters, Paris, France

In 2014, ESA celebrates not only 50 years of European cooperation in space, but also 35 years of relations with China.

The first ESA delegation to visit China in early spring of 1979 was led by ESA Director General Roy Gibson. At the time, the ESA delegation was received by the State Science and Technology Commission and the Centre for Space Science and Applied Research of the Chinese Academy of Sciences. Today, these two entities remain ESA's closest cooperating partners in China.

The State Science and Technology Commission has since been renamed Ministry of Science and Technology and the Centre for Space Science and Applied Research (CSSAR) was renamed recently and is now called the National Space Science Centre (NSSC).

The Chinese space programme is structured around many different organisations. The reasons are mainly historical and specific to the Chinese administrative structure. But, just like in Europe, there is a clear logic behind these different organisations

↑ The first ESA delegation to visit China, 1979, seen at the Academy of Space Technology and Society of Astronautics in Beijing on 14 February 1979. Roy Gibson is third from left, front row, and to his right, the President of the Academy, Dr Jen Hain Min

↑ Mrs Heidi Graf, Head of the ESTEC Communication Office, and the Chinese delegation at ESTEC, Noordwijk, October 1977

↓ Reception of ESA Director General Roy Gibson by Vice Premier Wang Chen in the Great Hall of the People in the National Congress Palace in Beijing during the first visit of an ESA delegation on 18 February 1979. This event was broadcast on Chinese TV on the following Monday evening

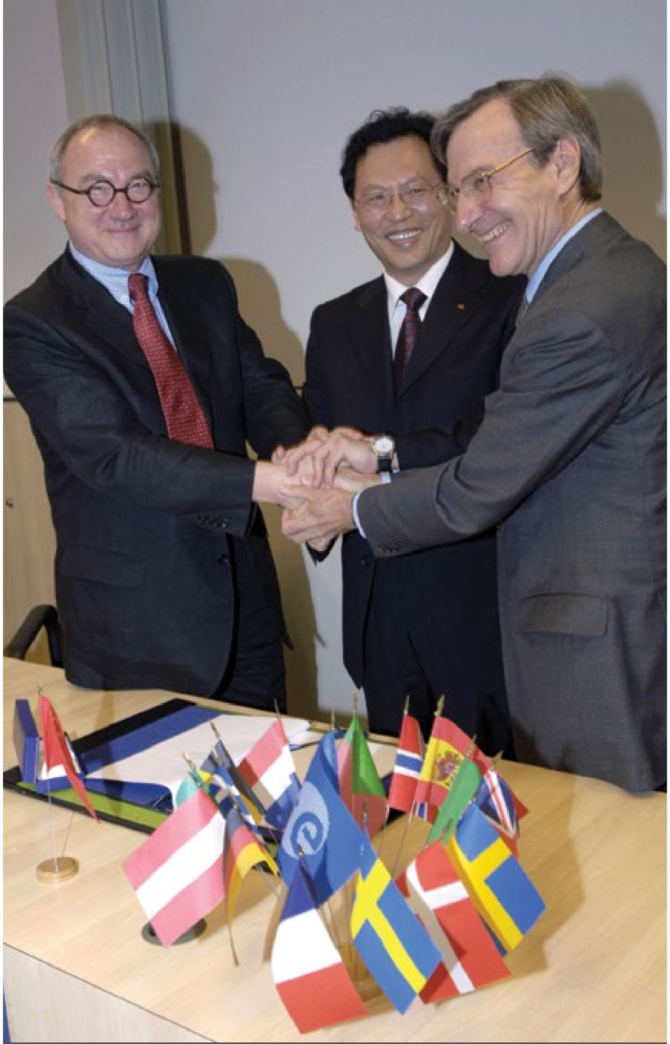
The China National Space Administration (CNSA), under the State Administration for Space, Technology and Industry for National Defence (SASTIND) which itself belongs to the Ministry of Industry and Information Technology, together with SASTIND is mainly responsible for drafting guidelines, policies, laws and regulations.

Typically, the CNSA represents the Chinese government in international forums such as the UN Committee on the Peaceful Uses of Outer Space or meetings of the International Atomic Energy Agency. Another example is the Intergovernmental Agreement between ESA and the Chinese government that is signed for the Chinese side by the CNSA Administrator. CNSA remains ESA's official counterpart in China, even if we have daily interactions with the other space organisations.

The Ministry of Science and Technology is responsible for several of the Chinese large-scale research funds such as the so-called '863' and '973' programmes. These are the programmes that have accompanied the modernisation of China in recent years and have funded many of the national scientific and technological achievements we are witnessing today. There are other large-scale funding mechanisms, but the 863 and 973 are perhaps the best known. Under the Ministry of Science and Technology there is also the National Remote Sensing Centre, the ESA counterpart in the 'Dragon' cooperation.

↓ A symbolic date on the road to cooperation between ESA and China was the first visit in February 1979 of a European delegation to Beijing headed by Roy Gibson. However, the story of ESA/China cooperation really started in 1977, when a Chinese delegation was hosted in Europe. A Chinese delegation, led by Mr Lei Hung, member of the Council of the Chinese Electronics Society, was received at ESA's Headquarters in Paris on 12 September 1977 by André Lebeau, ESA Director of Planning and Future Programmes, and George Van Reeth, Director of Administration. The Chinese delegation then visited ESTEC in the Netherlands on 4/5 October 1977. ESA Director General Roy Gibson and Director of ESTEC Johan Berghuis present to the Chinese delegation led by Mr Lei Hung

↓ The conclusion of an agreement between ESA and China, in Paris, 25 July 1980, during the visit of Mr Li Yeng Yu, Scientific and Technical Councillor of the Embassy of the People's Republic of China, with ESA Director General Erik Quistgaard



↑ On 24 May 2007 the China National Space Administration becomes the newest member of the International Charter 'Space and Major Disasters'. From left, ESA Director General Jean-Jacques Dordain, CNSA Administrator Sun Laiyan and CNES Chairman Yannick d'Escatha

→ The Dragon programme

The Dragon programme's main objective is to establish joint Sino–European teams for the exploitation of data from ESA's ERS and Envisat satellites for science and applications development. The teams, with lead scientific investigators from Europe and China, are focusing on monitoring natural land resources, on supporting natural-disaster management, and on studying the atmosphere and ocean around China.

Following a meeting in Paris in September 2003, Prof. Xu Guanhua, Minister of Science and Technology of China, and Jean Jacques Dordain, ESA Director, agreed that a joint research programme in the field of remote sensing should be initiated. The directors then responsible for the programme, Prof. Shao Liqin, Director General of National Remote Sensing Center of China, and Prof. Jose Achache, Director of ESA Earth Observation Programmes, stressed the importance of the creation of joint Chinese/European teams as a means to stimulate scientific exchange in Earth observation science and technology.

The Dragon programme was created as a formal programme of cooperation, initiated to bring together investigators from Europe and China. The April 2004 Dragon Symposium served as the start of joint exploitation and application development using ERS and Envisat data for China.

Today, after 10 years of cooperation, the Dragon programme has evolved and is using both Chinese and European satellite data.

↓ The 2014 Dragon 3 Mid-Term Results International Symposium, 26–29 May in Chengdu, China. The Dragon Programme is a joint undertaking between ESA and the Ministry of Science and Technology of China that encourages the increased use of ESA, Third Party Missions and Chinese Earth observation satellite data within China

The Chinese Academy of Sciences was established in November 1949, in the same format as the Soviet Academy of Sciences, with many research institutes under its wing. It is now a national research body that reports directly to the State Council as an independent and self-standing entity within the Chinese decision-making system, setting its priorities in coordination with the other ministries.

The stated objective of the Chinese Academy of Sciences is to provide and develop 'high technology and national science for the benefit of China and the world'. In doing so, it acts as a gigantic think-tank for all science and technology issues in China. The financial means are drawn from government programmes like the above-mentioned 863 and 973 programmes, as well as many other science funds.

The Chinese Academy of Sciences has 100 research institutes, 12 branch academies, two universities and 11 supporting organisations in 23 provinces in China. These institutions are home to more than 100 national laboratory and engineering centres, as well as 200 'key' laboratories and engineering centres, in 1000 sites all over the country. There is a ranking distinction between a 'state' laboratory and a 'key' laboratory – the former being judged of national interest.

The Chinese Academy of Sciences is home to over 85% of China's large-scale science facilities with more than 60 000 staff, of which 48 000 are researchers. These figures speak for themselves, but there are other research entities that are also very important. Notably the universities, such as Qinghua University in Beijing or Fudan University in Shanghai, as well as many more that are very important research centres in China.

In the present Chinese Five Year Plan (2011–15) the Chinese Academy of Sciences entrusted the NSSC with preparing and ensuring the development of a Chinese Strategic Pioneer Space Science Programme. The NSSC is to be the focal point for all space science activities in China. Within this Five Year Plan, the NSSC has secured stable five-year financing for the development of five scientific missions:

- Hard X-Ray Modulation Telescope (HXMT), involving some collaboration with ESA on data calibration
- Shi Jian recovery capsule (ESA will participate with the Sore Coefficient in Crude Oil experiment)
- Quantum Experiments at Space Scale
- a 'dark matter' detection mission
- the Kuafu mission (still to be confirmed)

Development of these missions is advancing and they will be launched towards the end of the present Five Year Plan. There are still some uncertainties over Kuafu, given the shelving of the planned cooperation with ESA.

The NSSC is also preparing a range of candidate missions to be implemented in the course of the next Five Year Plan (2016–20). They are studying mission candidates that they will submit to the State Planning Commission for approval. Following an initial pre-selection exercise, these are:

- Magnetosphere-Ionosphere-Thermosphere Coupling Exploration (MIT)
- Solar Polar Orbit Radio Telescope (SPORT)
- X-ray Timing and Polarisation (XTP)
- Space Millimetre Very Long Baseline Interferometry Array

In addition, NSSC is studying the possibility of launching two or three smaller size missions over the 2016–20 period. The pre-selected candidates are:

- Search for Terrestrial Exoplanet (STEP)
- Einstein Probe (EP)
- Advanced Solar Observatory in Space (ASO-S)
- Water Cycle Observatory Mission (WCOM)

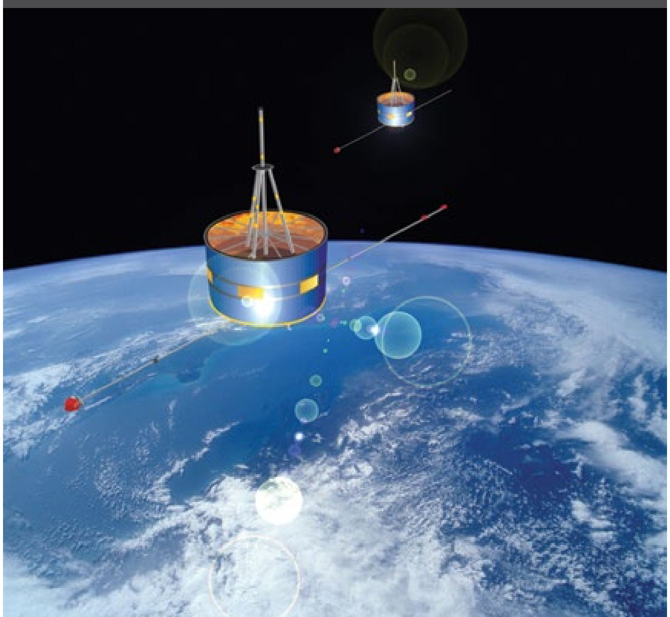
Within the next Five Year Plan, NSSC will also propose having a Key Technology Development Plan covering new concepts for space science missions, key technology development, ground calibration technologies and short-time flight opportunities.

Given NSSC's role as a focal point in China for space science programmes, it is building a new headquarters, located in Huairou, 60 km north-east of Beijing. The new headquarters and technical centre will be inaugurated in 2015.

ESA's programmatic relations with the Chinese Academy of Science go back to the mid-1990s, when ESA received a request to set up a Cluster Data Centre within the premises of the Academy. This small-scale cooperation on Cluster led the Academy and CSSAR (NSSC) to invite ESA to participate in their Double Star Programme, which provided additional data in the same scientific domain as the Cluster mission.

The first of the two spacecraft of the Double Star Programme, TC-1, was launched in December 2003 and the second one, TC-2 in July 2004. The cooperation was very successful from a scientific perspective, but also from a management point of view. It was the first time that a

↓ Double Star



Chinese organisation and ESA cooperated in such a close way and the results, thanks to the efforts of the people involved, were very rewarding. In 2010, the International Academy of Astronautics gave a Team Achievement Award to the Double Star and Cluster Joint team.

Since the Double Star Programme, ESA and Chinese Academy of Science/NSSC hold regular bilateral meetings in which the two sides exchange ideas on possible cooperation perspectives. Following a bilateral meeting in Palermo, Italy, in May 2013, the ESA Director of Science and Robotic Exploration and the Director General of NSSC (supported by the Vice President of the Chinese Academy of Science) agreed to look into the opportunity to develop a small joint mission together, based on scientific proposals to be jointly submitted by European and Chinese researchers.

Accordingly, the two sides agreed to organise a workshop in Chengdu in February for the European and Chinese scientific communities, in order to foster the formation of joint teams and to get European and Chinese scientists working in similar areas to collaborate in view of the possible submissions of common proposals for such a mission. During the workshop, a range of ideas spanning the areas of astronomy, Solar System science and fundamental physics were presented.

A second workshop will take place in Copenhagen in September in order to refine the possible collaborations. A dedicated ESA/NSSC Call will be issued by the end of 2014, and the proposals received will be peer-reviewed by a joint scientific advisory committee. A recommendation on a joint small mission concept will be submitted for approval within the decision-making processes of both sides. This is the first time that two space organisations proceed in this way to define a mission, using a bottom-up approach with an international partner.

Before issuing the announcement for the forthcoming workshops, ESA and NSSC defined together the boundaries of the possible small mission. The mission should be based on a spacecraft with a dry mass limited to approximately 250 kg, which would allow a payload mass limited to approximately 60 kg, with an operational lifetime of two to three years. If approved on respective sides, the mission could be launched in 2020 or 2021.

There has been great interest from the European and Chinese scientific communities in this cooperation opportunity, with more than 100 scientists from Europe and China attending the workshop in Chengdu.

ESA is also taking part in discussions with GESSA, another entity under the Chinese Academy of Sciences, to propose joint projects where Chinese scientists act as co-investigators for experiments that will be flown within the European utilisation plan of the International Space Station and possibly later on the Chinese Space Station. GESSA, which recently changed its name to the Technology and Engineering Centre for Space Utilisation (CSU), is the organisation is responsible for the scientific side of the Chinese manned space programme and, in this capacity, works closely with the China Manned Space Agency (CMSA).

↑ The Bilateral meeting of May 2013 in Palermo: Karl Bergquist with Prof. Wu Ji, Director General of NSSC (third from left), then Jean-Jacques Dordain, Prof. Yin Hejun, Vice President of the Chinese Academy of Sciences, and Alvaro Giménez Cañete, Director of Science and Robotic Exploration

↑ Heads of Agencies meeting 2012: Wang Zhaoyao, Director General of the China Manned Space Agency (CMSA) accompanied by the first female taikonaut, Liu Yang, met ESA Director General Jean-Jacques Dordain in Paris on 8 October 2012. From left: Zong Ye (CMSA), Wang Zhonggui, Chief Designer (CMSA), Karl Bergquist (ESA), Mr Zhaoyao, Director General (CMSA), Mr Dordain, Ms Liu Yang (CMSA), ESA Director of Human Spaceflight and Operations Thomas Reiter, Frédéric Nordlund (ESA) and Hao Chun, Director Planning Bureau (CMSA)

For more information

- http://english.cas.cn/
- http://english.nssc.cas.cn/
(http://iaaweb.org/content/view/143/243/)

→ AUTOMATED TRANSFER VEHICLE

A story of European success and cooperation

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

As ESA's Automated Transfer Vehicle (ATV) reaches orbit for the fifth and last time, a new path beyond low Earth orbit is opening for Europe.

Nearly three decades after the first concept studies, the European ATV spacecraft leaves behind a whole set of flawless missions, a vast industrial knowhow and a team spirit like no other. And it does so with a ticket to ride beyond low Earth orbit by the end of this decade.

When it all started, only about half a dozen people were part of the production team. Nico Dettmann, Head of ESA's ATV Programme, remembers the time when he was trying to recruit experienced engineers. It was not an easy task – being used to do something different every day, those engineers thought that working on recurring missions would be a boring business.

"Today, there isn't a single one of them who would say that ATV production is a tiresome job. None of the different spacecraft production phases has looked like the previous one," says Dettmann.

Building Europe's most reliable and complex spacecraft has been a constant challenge. ESA and European industry

→ The birth of the ATV programme

European industry, under ESA's leadership, had conducted concept and system studies for an automated supply spacecraft from 1987. In the early 1990s, ESA started joint studies with NASA, and then with the Russians, to define supply missions to the International Space Station.

Europe's formal approval for full development of an 'Automated Transfer Vehicle', or ATV, came in 1995. With ATV, ESA gained the right to visit the Space Station with its own space transportation systems. Independent access to the orbital outpost is an important political and operational aspect. This spacecraft is Europe's way of contributing in kind towards its share of the operational costs of the Space Station.

teams have been working together to ensure ATVs were ready for the space endeavour. The programme has built important engineering capabilities for orbital spacecraft, from extremely accurate autonomous docking to free-flight operations.

Since its first voyage in 2008, the Automated Transfer Vehicle has played a vital role in International Space Station logistics: it serves as cargo carrier, 'space tug' and storage facility. The multitasking spacecraft contributes to keeping the Station and its permanent crew of six working at full capacity.

Frequent flyer

The maiden flight of ATV *Jules Verne* in 2008 marked the first rendezvous and docking by a European spacecraft in a resupply mission to the International Space Station. Since then, continuous improvements have been made.

Following that first mission, post-flight analysis came up with 130 technical recommendations and about 30 of them were incorporated into the design of following ATVs. ATV teams repeat this exercise for every mission and agree on corrections and work-around solutions, making every spacecraft slightly different.

The challenge was to upgrade the spacecraft in every mission and yet deal with an ever-changing cargo manifest. Time adds extra pressure, pushing European production and integration chains to work at full capacity.

"None of the ATV missions has been easy. We are launching on a commercial launcher, so we have less flexibility in setting the launch date. That makes it more challenging for us to dock to the Station on time," explains Nico Dettmann.

The second ATV, *Johannes Kepler*, was the first production unit. "The mission was the most difficult of the series. We had to master the transition towards recurrent production, and it was also the first ATV fully loaded with a very challenging manifest," recalls Dettmann.

From a one-of-a-kind spacecraft, the ATV became a frequent flyer with a target launch rate of one per year. There is typically half a year from the end of a mission to the launch of the next ATV, and that leaves very little time to implement upgrades to the spacecraft.

←

Liftoff of the Ariane 5 ES-ATV launcher from French Guiana on 9 March 2008, carrying ATV *Jules Verne*, ESA's first Automated Transfer Vehicle (ESA/CNES/Arianespace/Optique Video CSG)

A major advantage of this tight rhythm is that communication and efficiency within ATV teams increased exponentially. Engineers working on the hardware did not have to wait long to see it being launched into space. The nature of the ATV programme allowed them to check results and look for possible solutions as they happened.

From electrical failures and a stuck communication antenna boom, to detached thermal blankets and fans that refused to work, each ATV had its own number of small flaws, but these did not jeopardise the missions.

Made in Europe

It is no coincidence that ATVs are named after great European scientists and visionaries. The vessels carry their names to highlight Europe's deep roots in science, technology and culture.

Each spacecraft is the happy conclusion to a complex industrial cooperation that goes beyond agencies, companies and borders. A highly skilled workforce of ESA employees and European industry made the development of the advanced space systems and technology for ATV possible.

Airbus DS is the industrial prime contractor for the production of the vehicle. It manages more than 30 subcontractors and about 2000 people, and integrates all the subsystems coming from ten European countries. Arianespace, the world's first commercial space transportation company, specially developed the Ariane 5 ES launcher for ATV with a reignitable upper stage.

But ATV is not only a European endeavour: the project includes the cooperation of Russian companies, which have built the docking mechanism, the refuelling system and the associated electronics. A number of US companies are also involved with the video targets, lights and propulsion components.

Team spirit

There is nothing like a constant challenge to build a strong team culture. People working on this European spacecraft are extremely committed to it, and most of them would not hesitate to declare it as the best part of their careers.

A great sense of cooperation emanates from all the groups involved in the ATV project. Even with short turnarounds, team spirit opened the door to success for ATV missions. "One of the keys to success is that the ATV people are very committed to it, they totally identify themselves with the mission. It is a wonderful team," says Dettmann.

ATV navigates, flies and docks with the Station automatically, but it does require some ground support. Throughout its mission, the spacecraft is monitored and commanded from the ATV Control Centre in Toulouse, which works day and night in coordination with the other control centres in Russia and the USA. Every command is run in agreement with the Space Station partners.

Three space agencies with three different engineering cultures. The trilateral nature of this cooperation kept the teams open-minded. The ATV project allowed common approaches to be developed to design, build and control this complex space vehicle.

Mission Manager Alberto Novelli is working on the lessons learned from the programme. "To me the most important one is that we managed to work together in good cooperation, sharing the same goals and enthusiasm. That is the strength of the ATV team. Without it, none of this would have been possible."

↓ ATV *Johannes Kepler* ready for launch inside its fairing on the Ariane 5 ES launcher V200 on 14 February 2011

ATV *Georges Lemaître*

The European spacecraft is ready to start its fifth – and last – voyage to supply the International Space Station. Named after the Belgian astronomer and cosmologist Georges Lemaître, the spacecraft is scheduled to lift-off at the end of July from Kourou, French Guiana, on top of the Ariane 5 heavy-lift launcher.

Following the path of its predecessors, ATV *Georges Lemaître* is ready to fulfil its duty of resupplying the crew with food, water, oxygen, air and research equipment. It will also adjust the Space Station's orbit during its six months attached to the orbital outpost.

The last ATV in the series will carry nearly 6.6 tonnes of supplies to the Station. ATV *Georges Lemaître* will hold a record amount of 2622 kg of dry cargo and, for the first time, the space freighter's three water tanks are fully loaded with 855 litres, more water and dry cargo than any other ATV mission to date.

The spacecraft is delivering critical equipment for science research. Included in its cargo are several units for the Electromagnetic Levitator, a facility that allows the melting and solidifying of metals as they float in weightlessness.

Experience with ATV *Georges Lemaître* could also help develop tools for a rendezvous with a non-cooperative object, such as space debris or an asteroid. The spacecraft will serve as a testbed for a suite of optical-sensor prototypes to home in on targets, based on a long-range infrared camera and a short-range 3D imaging sensor.

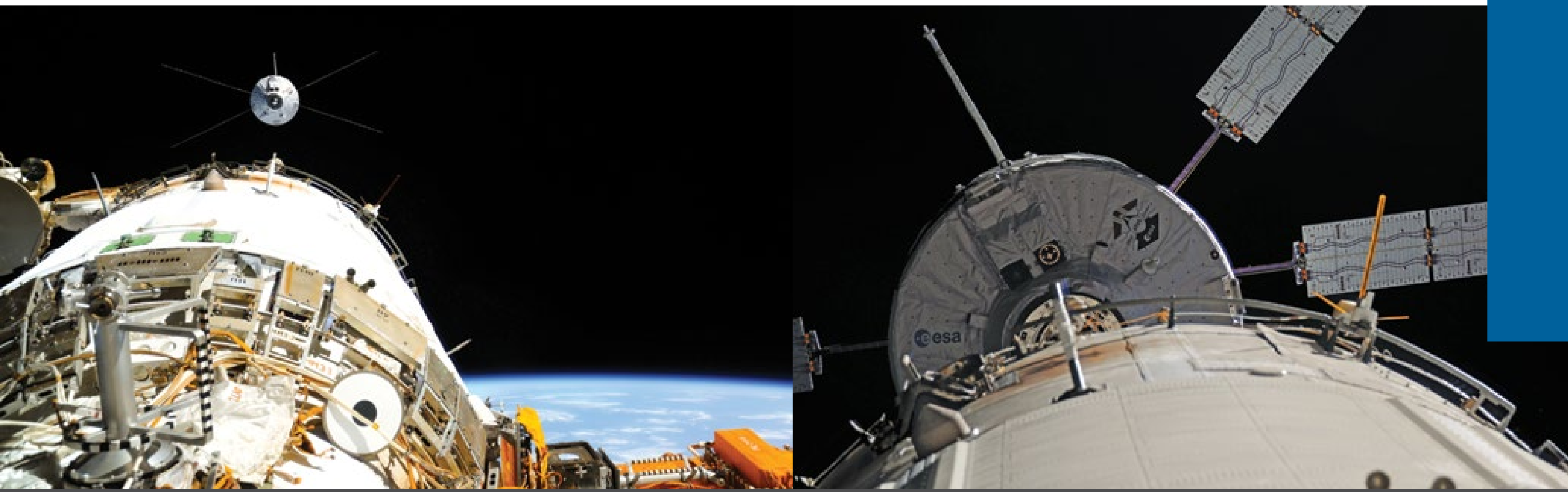
↑ The ATV *Georges Lemaître* mission logo

ESA astronaut Alexander Gerst will be the prime operator monitoring ATV *Georges Lemaître* as it approaches the Station, a role that should not give him too much work: the 20-tonne vehicle will navigate on its own and dock automatically. Once attached, ATV will be used as an extra living module by the astronauts and will remain available to reboost the Station, or push it out of the way of space debris if needed.

Swan song

At the end of its mission, the vehicle will undock from the Space Station filled with a few tonnes of wastewater, materials and equipment. By then, it should be ESA astronaut Samantha Cristoforetti who monitors the undocking, during her Futura mission later in 2014.

→ Technicians wearing cleanroom suits pack cargo on ESA's fifth and last Automated Transfer Vehicle, ATV *Georges Lemaître*, in April (ESA/CNES/Arianespace/Optique Video CSG/P. Baudon)



↑ Views of ATV *Albert Einstein* as it approached the ISS in June 2013 (NASA/ESA)

ATV *Georges Lemaître* will depart with a final gesture before its mission ends. Its 'big dive' will differ from past ATV missions, in that its engines will deorbit the spacecraft on a shallower flight path. This reentry angle will help plan for the Space Station's eventual end of life. While this date is still unknown and some way into the future, engineers are already looking at reentry strategies for the Station.

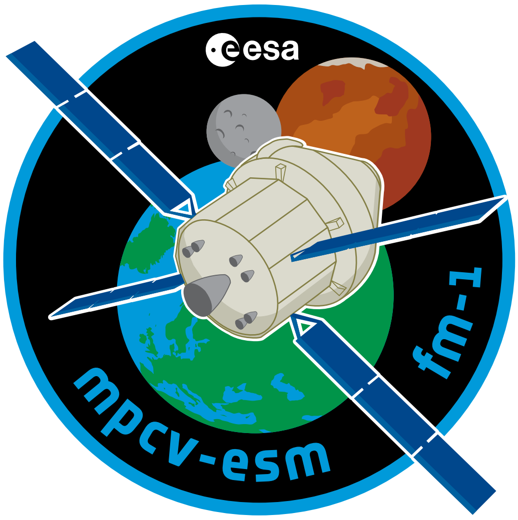
ATV's 'swan song' will be in the spotlight on a moonless night. A camera on the Station will track ATV from above its reentry path. Together with the three onboard experiments and ground-based telescopes also observing ATV's reentry, this will be the most-recorded mission end for a European spacecraft.

The ATV team faces these final moments with mixed feelings. On one hand, there is some sadness to see it coming to an end. "We managed to get each ATV mission done without major hiccups, gaining better precision each year. It feels sad to close the shop now that we are able to manufacture ATVs like the car industry," regrets Daniel Guyomard, Head of ATV Production. On the other hand, there is the pride for the work well done and the memories of 'an exceptional adventure,' as Mission Manager Massimo Cislaghi puts it.

ATV heritage

The duration, assigned resources and technical complexity of the ATV programme have no equal in the history of European spaceflight. Lessons learned from building

← The fiery reentry of ATV *Albert Einstein* in November 2013 (ESA/NASA)



↑ Logo for the European Service Module Flight Model 1, which will fly on NASA's Exploration Mission-1, the first flight of a complete Orion spacecraft

and operating the spacecraft have delivered enormous knowhow. ESA is pursuing the exploitation of this expertise and technology for future spaceflight applications.

"US companies have already benefited from ATV heritage, bringing extra business to European industry" explains Daniel Guyomard. The Cygnus spacecraft, for example, a commercial spacecraft built by the Orbital Sciences Corporation, have used ATV equipment for its missions to the Space Station.

ATV was designed to be flexible, so that it could be the basis for developing a wide variety of new space vehicles. ATV technologies could be used for other automated missions, such as controlling space debris or servicing other spacecraft in orbit. Concepts for ATV evolution had included an unmanned free-flying laboratory, and even a space tug carrying supplies to lunar and martian orbits.

But with the ATV series coming to an end, ESA had to decide between building a sixth spacecraft and developing something new. The decision was the forward-looking choice: ESA started discussing options with NASA about building a new spacecraft together.

European Service Module

ATV will have a second life after completing its resupply role for the International Space Station – a European module will power NASA's Orion spacecraft for Moon missions and beyond. This will be the first collaboration between ESA and NASA on a crew transportation vehicle that will ultimately carry astronauts farther into space than ever before.

"We have shown reliability and excellence with ATV. Our reputation played a vital role in becoming a big partner for a critical part of Orion," says Philippe Deloo, ESA's Phase-B2 Manager of the European Service Module. The Service Module will be heavily based on ATV technology.

The official name of Orion is 'Multi-Purpose Crew Vehicle', because the spacecraft can be used to complete different missions. If everything goes according to plan, the spacecraft will transport up to four astronauts into space and bring them safely back to Earth. Orion will be able to fly to the Moon, and is aimed at visiting an asteroid in the next decade.

The European Service Module will fly on Exploration Mission-1, the first flight of the completed Orion spacecraft. This mission will be an unmanned lunar flyby, returning to Earth's atmosphere at 11 km/s – the fastest reentry ever. The flight is set to take place by the end of this decade.

→

NASA's Orion spacecraft will carry astronauts further into space than ever before using a module based on Europe's ATVs (NASA)

↖

ATV *Albert Einstein*, silhouetted against Earth, departs from the ISS in November 2013 (NASA/ESA)

←

The ATV-derived Service Module, sitting directly below Orion's crew capsule, providing propulsion, power, thermal control, as well as supplying water and gas to the astronauts in the habitable module (NASA)

ATV 2.0

Orion is a delicate spacecraft with demanding functional requirements. The European Service Module will be located directly under its crew module and will feature ATV-derived technologies to provide propulsion and power to the spacecraft as well as oxygen, nitrogen and water for the astronaut crew.

The Service Module will house Orion's main engine, thrusters and fuel needed for orbital transfers, attitude control and high-altitude ascent aborts. All those basic functions and several other components are the same as used on ATV. Extending from the main body of the spacecraft will be ATV's characteristic X-shaped solar wings.

"This is the first time ESA cooperates in such a critical part of a NASA spacecraft. The entire development will take place in Europe after which US engineers will take care of integrating the European Service Module with Orion," says Philippe Deloo.

The main design and the expertise gained throughout a decade of ATV development will be reused for the Orion spacecraft. ESA is implementing new techniques to redefine and qualify the Service Module, and will give support during the missions in case of anomalies.

Providing the Service Module for Orion will be ESA's remaining in-kind contribution to the Space Station partnership. The plan allows European industry to capitalise on ATV technology while significantly cutting research and production costs for NASA. At the same time, the project will create highly skilled jobs for Europeans in an innovative sector ensuring future space endeavours and could see European astronauts flying beyond Earth orbit. ■

> One of the images engraved in my mind of the ATV *Albert Einstein* mission is this one: you can see the spacecraft during free flight against the dark background of space with its thrusters firing, heading towards the International Space Station. It might sound trivial to others, but this picture meant a lot to the team. The last time we saw the spacecraft was during the integration in Kourou, French Guiana. Some ten days later, we saw it there, in space!

Alberto Novelli

ATV *Albert Einstein* Mission Manager

ATV overview

ATV *Jules Verne*

- Launch: 9/03/2008
- Deorbit: 29/09/2008
- Days in Space: 205
- Records: First automated docking of a European vehicle
- Reboosts: 6
- Debris avoidance manoeuvre: 1

ATV *Johannes Kepler*

- Launch: 16/02/2011
- Deorbit: 21/06/2011
- Days in Space: 126
- Records: Largest boost since the Apollo missions to the Moon
  First time a European astronaut welcomed ATV
- Cargo anecdote: Two ESA astronauts in ATV: Paolo Nespoli and Roberto Vittori
- Science payload: GeoFlow II
- Reboosts: 5

Total cargo: 4575 kg

3235	285	20	1150

Total cargo: 7100 kg

5605	0	100	1605	435

Total cargo: 6555 kg

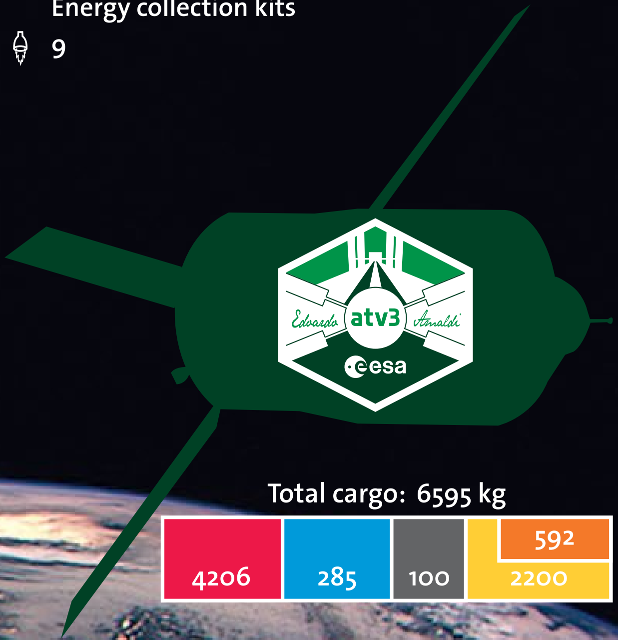
2978	855	100	2622

LEGEND

- Launch
- Deorbit
- Days in Space
- Records
- Cargo anecdote
- Science payload
- Reboosts
- Debris avoidance manoeuvre
- Propellant
- Water
- Gas
- Dry cargo
- Late load cargo

ATV *Edoardo Amaldi*

23/03/2012
04/10/2012
196
Longest attached phase to Space Station: 184 days
Launched just one year after its predecessor
Pump to recycle urine into drinkable water
Tiles for Altea-Shield
Biolab Life Support Module 3
Energy collection kits
9

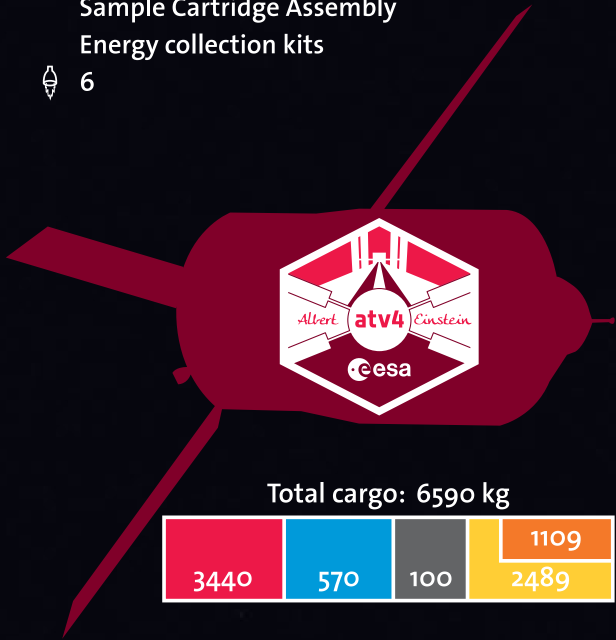


Total cargo: 6595 kg

4206 | 285 | 100 | 592 / 2200

ATV *Albert Einstein*

05/06/2013
02/11/2013
151
Docked to the Space Station with maximum accuracy
Reentry seen from space
3D-printed toolbox
FASES sample container
New microscope for Biolab
Sample Cartridge Assembly
Energy collection kits
6



Total cargo: 6590 kg

3440 | 570 | 100 | 1109 / 2489

ATV *Georges Lemaître*

25/07/2014
Heaviest spacecraft ever launched by Ariane 5: 20 275 kg
Includes piece of meteorite 'Field of the Sky'
Pump to recycle urine into drinkable water
Shallow reentry experiments (REBR-W , I-Ball, BUC)
Electromagnetic levitator
Rendezvous demonstrator

→ LEAVING THE PALE BLUE DOT

The mission of Alexander Gerst

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

At this moment, ESA astronaut Alexander Gerst is looking back at planet Earth from space. From now on, for almost half a year, everyone he loves, everyone he knows, everyone he ever heard of, will be 400 kilometres below him.

"Seen from a distance, our planet is just a blue dot, a fragile spaceship for humankind. We need to understand the Universe we live in to protect our home," says Alexander.

It is not by coincidence that his mission is called 'Blue Dot'. The term was coined by astronomer and science communicator Carl Sagan, who was the first to describe our faintly visible planet as 'a pale blue dot' when he saw the first image of Earth taken from the outer Solar System by NASA's Voyager spacecraft in 1990.

Alexander is on a six-month stay on the Station, serving as flight engineer for Expeditions 40 and 41. The 38-year-old German was launched on a Russian Soyuz spacecraft from Baikonur cosmodrome in Kazakhstan at the end of May, along with Russian cosmonaut Maxim Suraev and NASA astronaut Reid Wiseman. They will return to Earth in November.

Alexander introduces himself as a geophysicist, volcanologist and explorer on his Twitter account @Astro_Alex. "Human spaceflight not only gives us a unique perspective about our planet, but also who we are. We are a species of explorers," he says.

From volcanoes to space

Alexander Gerst was born in 1976 in Künzelsau, a small town in southern Germany. He has always been a keen explorer, eager to understand the environment around him. That interest set his career on the path of science. "I admire scientists like Galileo Galilei and Nicolaus Copernicus – people who made a difference standing out for what they discovered against common beliefs."

While studying geophysics and Earth sciences, Alexander was fascinated by volcanology. The goal of his master's thesis was to determine the mechanics and the energy released during the first seconds of a volcanic eruption. His research led him to visit volcanoes in remote locations, including Antarctica, Ethiopia and Guatemala. Alexander developed new volcano monitoring techniques intended to improve eruption forecasts.

Spaceflight has been always a goal for Alexander. It appeared to him as a logical extension from his job as volcanologist. "Like volcanology, space science is a relatively young science with a great potential for discovery and benefiting people's daily lives," he explains.

←

While studying geophysics and Earth sciences, Alexander was fascinated by volcanology

"Our planet is just a blue dot, a fragile spaceship for humankind. We need to understand the Universe we live in to protect our home."

↑ Alexander's pre-astronaut research led him to visit volcanoes in remote locations, including Antarctica, Ethiopia and Guatemala. Alexander seen here during an Antarctic expedition to Mount Erebus

He sees a lot of parallels between working in space and on volcanoes: common both disciplines involve hostile environments, getting close to the object of study and delivering unique data that cannot be found anywhere else. Even before space, Alexander has had to work under extreme conditions and come up with solutions in a pragmatic and creative way.

Alexander says that he became an astronaut by trying hard to be a good scientist. More than a decade ago, while working as a geophysicist and volcanologist at McMurdo Antarctic station, he found himself talking to NASA astronaut Cady Coleman. She encouraged him to give his dream of becoming an astronaut a chance. "You have to try this every year," she told him. He did try to apply, and for years nothing happened. He kept the possibility open in the back of his mind.

Alexander finally applied in 2009 to ESA's call for candidates to reinforce the European Astronaut Corps.

As it turned out, Alexander passed the demanding year-long selection process, to be chosen from over 8000 people.

Training

The basic training course at ESA's European Astronaut Centre (EAC) in Cologne, Germany, supplied Alexander with the astronaut's toolbox of knowledge. "We must be scientists, janitors, drivers, cleaners, doctors, fire fighters, engineers and guinea pigs. The path to the stars is a bumpy road," says Alexander.

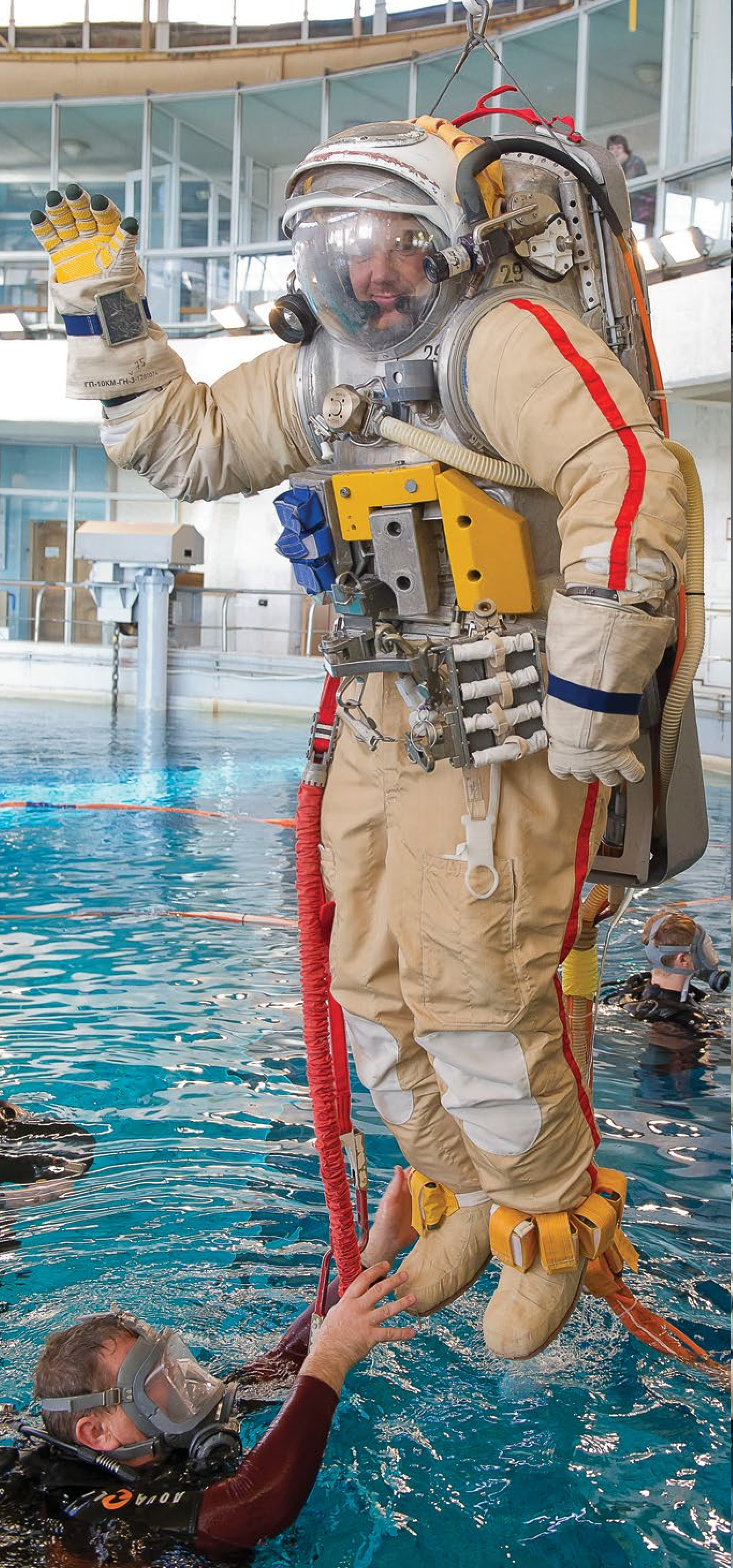
After finishing basic training, Alexander was selected for Expeditions 40 and 41 to the International Space Station. With memories still fresh from his initial course, his training continued at a higher pace almost without a break, travelling between all international partner sites. An intensive schedule, sometimes working 60-hour weeks, took him to Houston, Star City near Moscow, Tsukuba in Japan and Montreal in Canada.

↑ Using a flare during winter survival training near Star City, Russia, in January 2013

→ A spacewalk training session in the Partial Gravity Simulator test area at NASA's Johnson Space Center, Houston, May 2013 (NASA)

↓ Being trained on the Electromagnetic Levitator instrument at the European Astronaut Centre in Cologne (DLR/E. Blink)

↑ Alexander and crewmate Reid Wiseman during emergency procedures training in a life-size mock-up of the ISS in Houston (NASA)



← Training in the Orlan spacesuit at the neutral buoyancy pool of the Gagarin Cosmonaut Training Centre near Moscow in April 2013

↓ During a Soyuz TMA spacecraft training session at the Gagarin Cosmonaut Training Centre, Moscow, August 2013

Norbert Illmer, ESA Increment Training Lead for the Blue Dot mission, explains that ESA's training is tailored to each person's skills and needs for a mission. And that is the most challenging part of the job.

"It is the skill of the instructor team to know what the crew knows and needs at every step of the training. Feedback is very important – it allows us to evaluate the success of our training," adds Norbert.

Over the last four years, Alexander has trained countless times for possible emergencies on the Space Station, he has practiced how to handle blood samples in microgravity and he can make sure that the Automated Transfer Vehicle (ATV) docks safely to the orbital outpost. Looking back, he says this period seems like half a lifetime, but also one of the most exciting periods of his life.

As second flight engineer on the Soyuz spacecraft, he has no major duties during launch and landing. Still, Alexander's role on the crew has given him more time to run scientific experiments and, in particular, getting know every corner of Europe's Columbus laboratory.

"Alexander excels as a very analytically and operationally oriented person," says Norbert Illmer. Robotics operations are some of Alexander's favourite trained skills, and he learnt to operate Canadarm2, a 17 m-long robotic arm on the Space Station. He will use these skills to support the berthing operations of SpaceX's Dragon and Orbital Sciences' Cygnus cargo vehicles as part of NASA's commercial resupply programme.

Astronauts need to be able to handle medical emergencies in space. As a crew medical officer, Alexander has also been trained in basic medical procedures, from stitching wounds to filling teeth. "He even requested some extra training to feel fully confident in case he needed to treat a crewmate in space," says Volker Damann, ESA Crew Medical Officer at EAC.

A specially designed three-day course became part of his training. Alexander observed some real-life medical cases in operating theatres, the emergency department and the intensive care unit of a hospital. He practised through highly realistic simulations and boosted his medical skills for situations he might have to deal with in space.

↑

As a crew medical officer, Alexander has also been trained in basic medical procedures

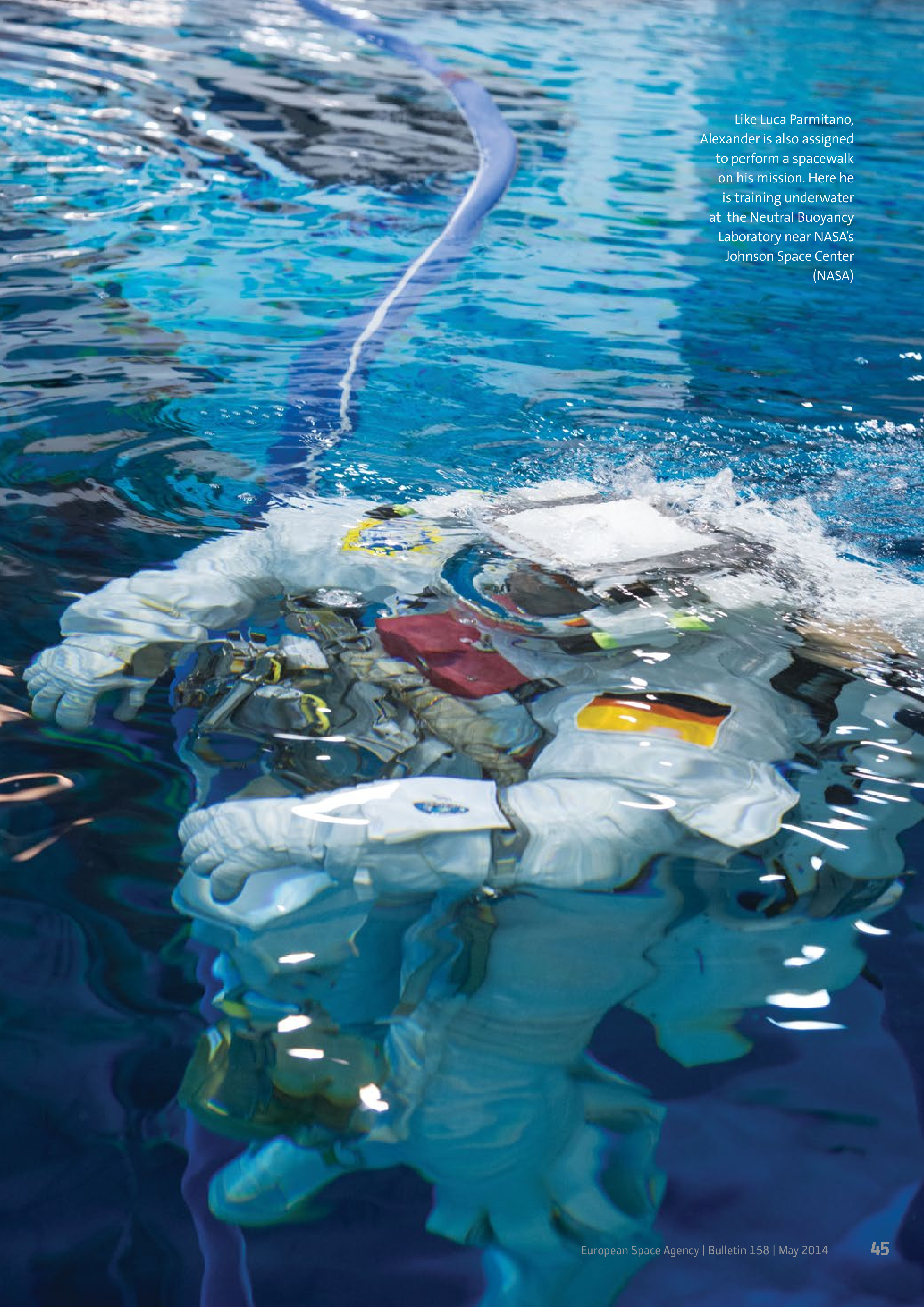
Time to fly

Alexander is the sixth ESA astronaut to carry out a long-duration mission in space, and the second to make a Soyuz fast-track flight to the Space Station, following the path of his fellow ESA astronaut Luca Parmitano. Alexander's Soyuz executed a same-day rendezvous, docking after just four orbits, in less than six hours of flight. Like Luca, Alexander is also assigned to perform a spacewalk, with his NASA crewmate Reid Wiseman, during his mission.

Operators at the Columbus Control Centre in Oberpfaffenhofen, near Munich, Germany, are the direct link to Alexander in orbit. Teams there are constantly adjusting tasks to make sure that Alexander can fulfil his mission. They are there to help him 24 hours a day, seven days a week.

"It is a very demanding job, but it is fantastic to be in the frontline. It is like climbing a mountain – we plan the route but we see new things and changes coming as we progress into the mission," explains Berti Meisinger, mission director for the first part of the Blue Dot mission.

> **We must be scientists, janitors, drivers, cleaners, doctors, fire fighters, engineers and guinea pigs.**



Like Luca Parmitano, Alexander is also assigned to perform a spacewalk on his mission. Here he is training underwater at the Neutral Buoyancy Laboratory near NASA's Johnson Space Center (NASA)

↑ The Expedition 40/41 crew, Soyuz commander Maxim Suraev and flight engineers Alexander Gerst and Reid Wiseman, greet the audience at the launch pad, just before entering the elevator to the top of their Soyuz rocket

The year 2014 is going to be full of space events for the Columbus Control Centre. Two ESA astronauts, Alexander and Samantha Cristoforetti, will be on the Station back to back with only a gap of about two weeks.

"We will have a whole year with permanent European presence on board, a first since the Columbus laboratory was attached to the Station in 2008," highlights Alexander Nitsch, mission director for Expeditions 41 and 42.

A scientist in space

European science will be in full swing during the Blue Dot mission. Alexander will be working n roughly 30 ESA experiments covering human research, biology, physical science and radiation, as well as demonstrating new technology. His genuinely deep interest in science will be of great help during the mission.

"The International Space Station is the best microgravity laboratory we have," says Alexander. "It's a hostile environment and it requires a lot of effort to get there, but we can obtain scientific data that we will not get anywhere else in the world."

Science also requires repetition. Alexander picks up the baton from Luca Parmitano, following up some of the studies performed by the Italian astronaut during his Volare mission in 2013. Alexander will perform high-level science for Europe and take full advantage of the Station scientific facilities, especially those in the European Columbus laboratory. All the experiments are designed to improve life on Earth and prepare for future human spaceflight exploration.

Not counting time spent by other astronauts, Alexander alone will spend at least 70 hours carrying out a set of European experiments selected on the basis of feasibility and potential applications. During his mission, he will also take part in more than 40 other experiments from the US, Canadian and Japanese space agencies.

The arrival of equipment for the Electromagnetic Levitator is one of the highlights of the Blue Dot mission. This facility allows melting and solidifying metallic samples suspended in microgravity with no need for containers. Experiments in this furnace promise to improve industrial casting processes. Alexander is in charge of finishing its installation and processing the first samples.

↓ The Soyuz TMA-13M rocket lifts off from the Baikonur cosmodrome in Kazakhstan carrying Expedition 40/41 on 28 May

Several units of this multi-user facility will arrive at the Space Station on Europe's ATV *Georges Lemaître*. Alexander will be involved in the docking of this ATV, the fifth and last in the series. He will also participate in the transfer of its precious supplies of propellant, food, water and gas for the Station.

"As a little boy, my heartbeat would accelerate by 10 beats per minute whenever I saw exterior shots of a space station with Earth in the background," says Alexander. Now that he has the opportunity to be on the International Space Station himself, Alexander aims to inspire the next generation of engineers and scientists by performing a set of experiments in orbit. Through some of the astronaut's exercises, youngsters will learn about environmental protection, the behaviour of soap bubbles in microgravity and how difficult it will be for ESA's Rosetta spacecraft to land on a comet.

↑ Alexander arrived at the ISS on 29 May after a six-hour flight

Back home

When Alexander returns to Earth he will be the first astronaut to fly directly back to Europe after landing in Kazakhstan. Until now, European astronauts had to spend their first days on Earth in Russia and the United States.

This new development means that all post-flight medical examinations and research activities will be conducted in Cologne, Germany.

By getting early access to Alexander, ESA doctors will be able to monitor his health very closely and to start his fitness and rehabilitation programme quickly. Scientists will also benefit from continuing with their examinations soon after landing.

"These are exciting times. We will be able to apply the expertise we have gained and collect our own medical data from the astronaut," says Volker Damann. Volker's team is working on the details to have the medical control room and all the interfaces complete, ready for Alexander's post-landing phase on European soil. According to him, this new approach establishes EAC as the prime 'centre of gravity' for ESA astronauts.

But, as of a few weeks ago, the waiting ended and all that training is being applied above us. Alexander Gerst's space adventure became real. Even as this story goes to print, Alexander is enthralling the public with his stunning images from space.

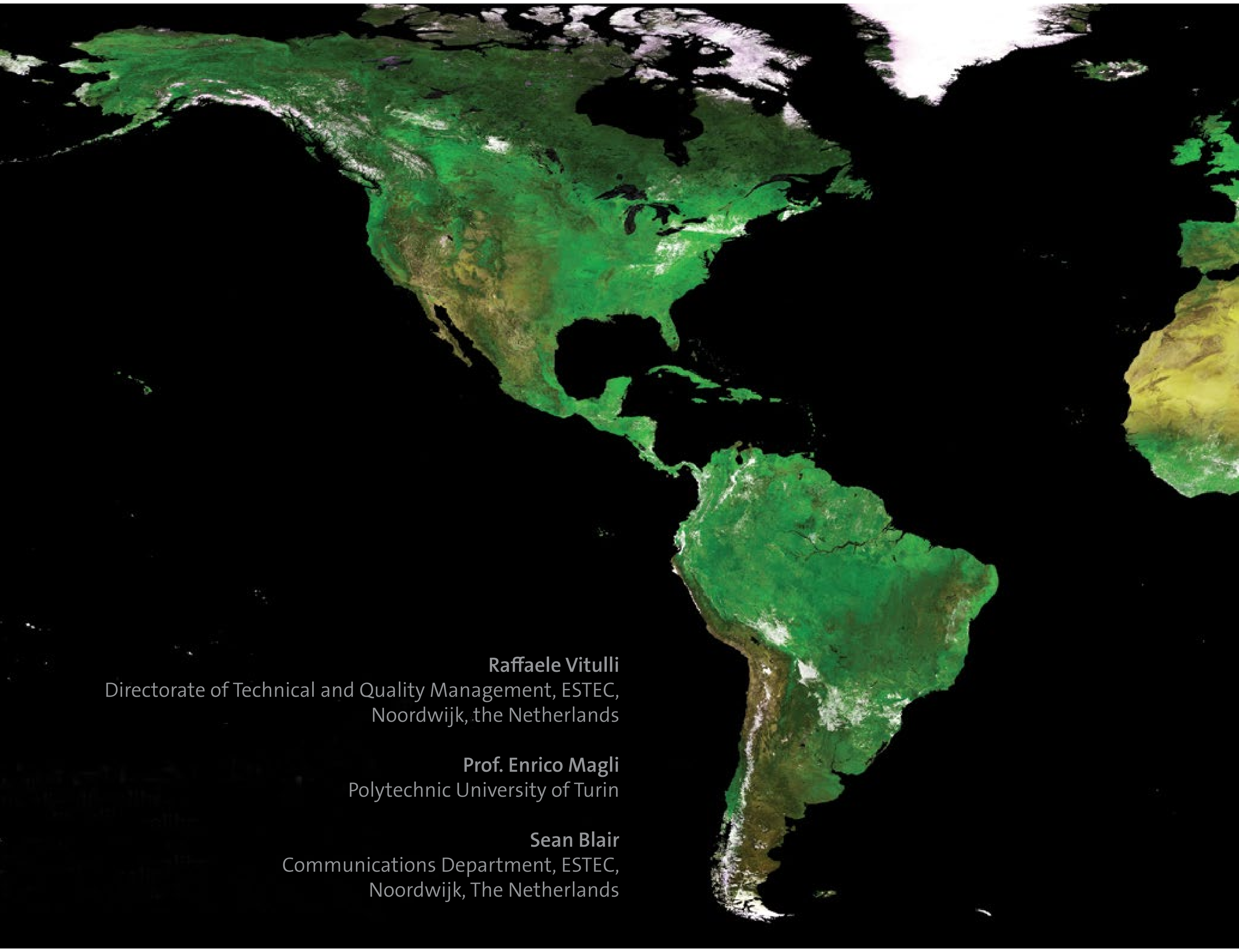
Follow Alexander's Blue Dot mission at:
http://alexandergerst.esa.int/

Nadjejda Vicente is an HE Space writer for ESA

↓ As this edition of the *ESA Bulletin* is printing, Alexander Gerst is sharing his stunning images from space. This view is Banks Peninsula, New Zealand

→ PUTTING THE SQUEEZE ON

How data compression can stop space missions drowning in data



Raffaele Vitulli
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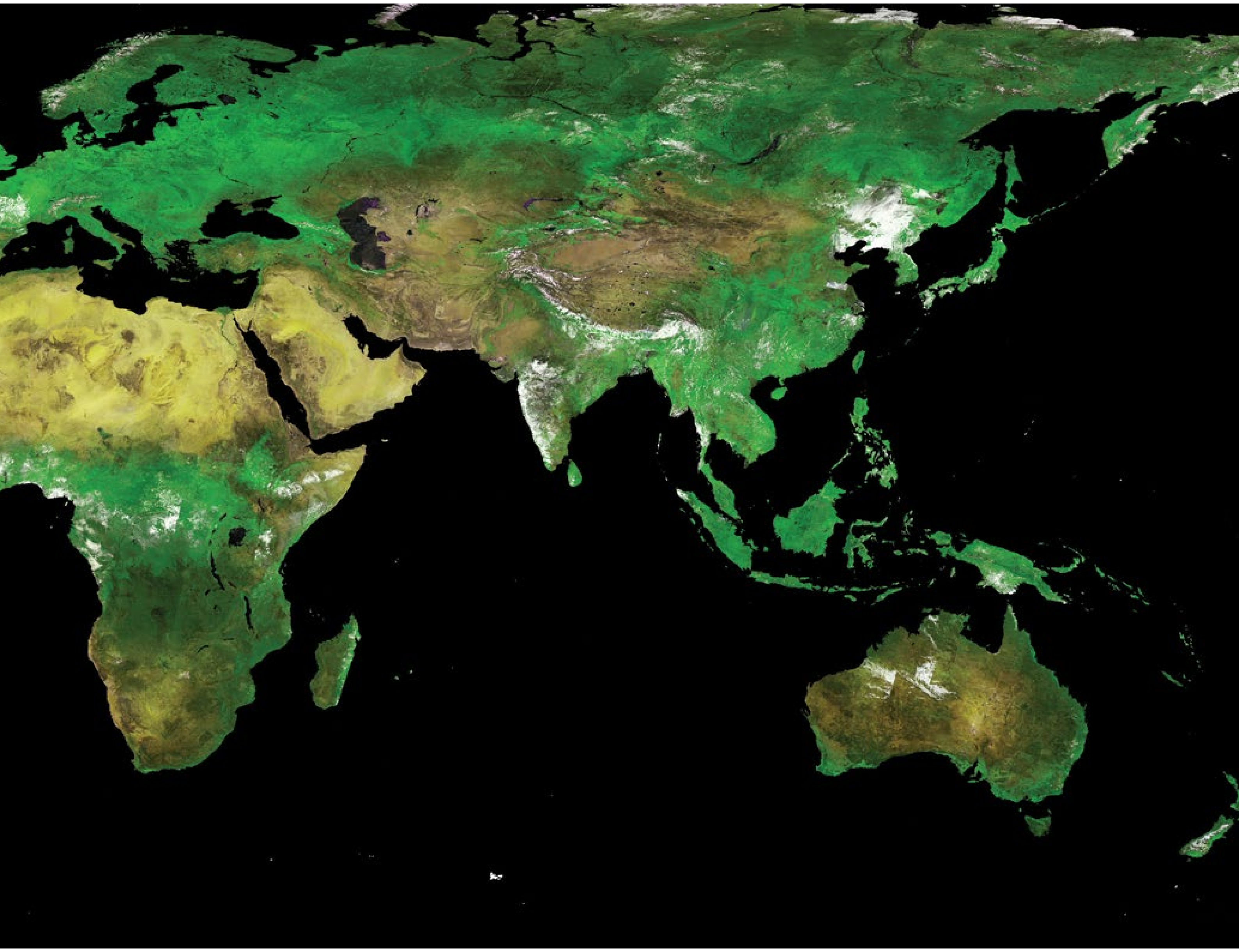
Prof. Enrico Magli
Polytechnic University of Turin

Sean Blair
Communications Department, ESTEC,
Noordwijk, The Netherlands

↑ How does ESA's Proba-V, a minisatellite smaller than a cubic metre, manage to compile a new global portrait of all Earth's vegetation every two days? The answer is data compression, allowing it to transcend its inherent bandwidth limitations



The very first satellite, Sputnik, communicated nothing but a humble 'beep beep' back to Earth. More than five decades on, space missions face the risk of drowning in the vast amounts of data produced by their advanced satellite instruments.

The next generation of multispectral and hyperspectral Earth observation imagers will look back at Earth's surface in a far broader range of colours than the human eye: hundreds of wavelengths per individual pixel, acquired at much greater spectral and spatial resolutions than had instruments of old. Radar instruments are also undergoing a parallel sharpening of radiometric focus.

The trend is for such instruments to observe continuously across the terrestrial land and/or sea surface on an 'always on' basis, such as on ESA's Proba-V, as well as the soon-to-be-launched Sentinel family.

Some space science missions face similar challenges, notably Gaia, launched in December. Gaia has to detect, observe and analyse the brightness, position and motion of hundreds of stars per second in order to achieve its target of mapping in 3D the billion stars in Earth's vicinity during its five-year lifetime.

Mission planners are increasingly coming up against the thorny problem of how to manage such extremely plentiful results – in particular, how to relay them down to the ground. Handling the data aboard the satellite is not so much of a problem: onboard data-processing and storage capabilities can be boosted by leveraging the fruits of the terrestrial computer revolution.

Proba-V, for instance, is able to store multispectral data for half the world thanks to its innovative use of solid-state Flash memory, more typically found in consumer USB sticks, digital cameras and mobile phones.

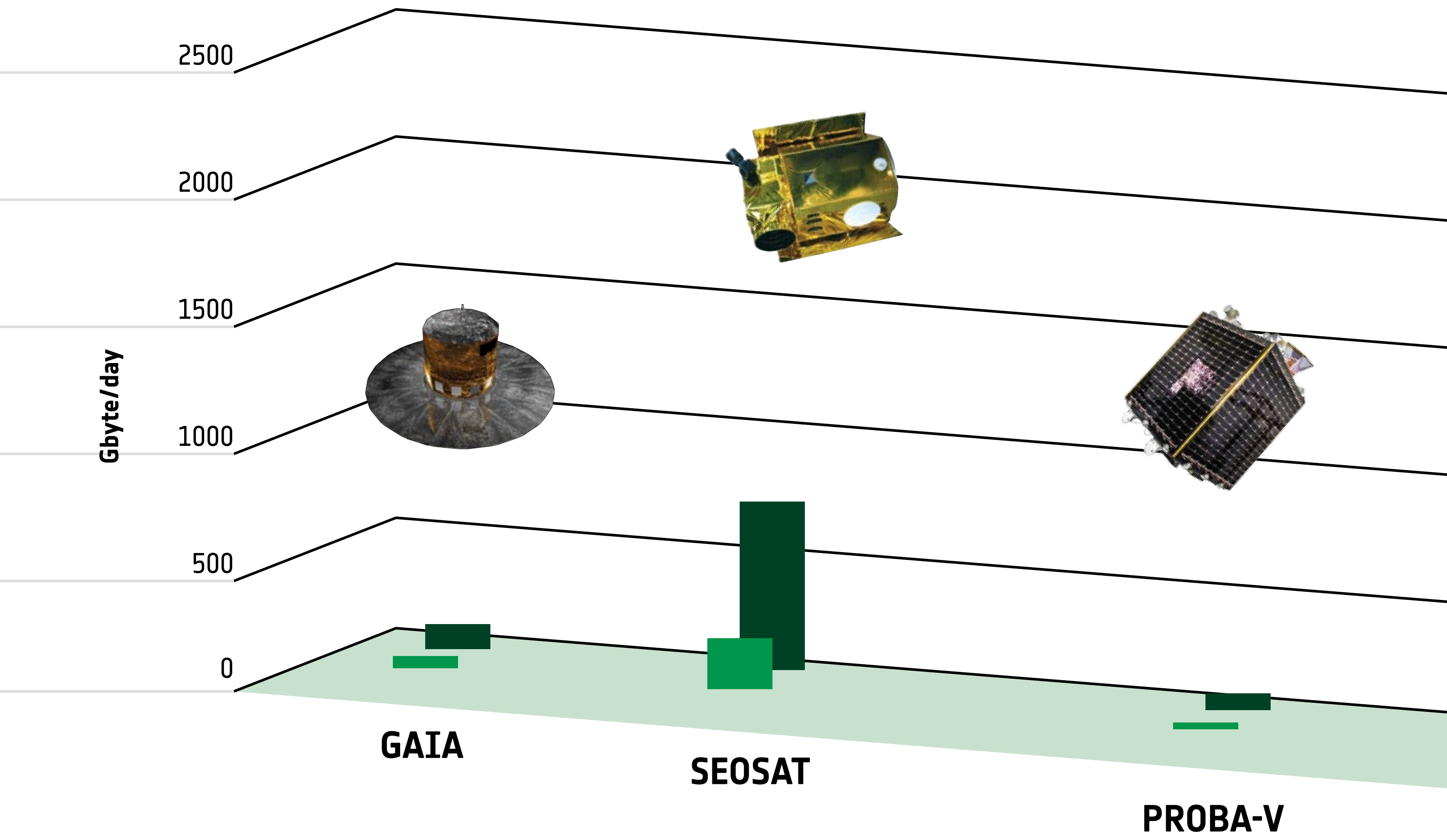
Getting data back to Earth

Data have to be transferred from space to the ground to become useful. And finding a way to fit such torrents of information into the limited communications capabilities available for ground transmission can be likened trying to drink water from a fire-hose.

The limits are set by the laws of physics, not to mention economics. A mission's available bandwidth is bounded by its combination of antenna size, transmitter power and allocated ground stations. An antenna cannot be too much larger than the satellite hosting it, while the strength of its signal is determined by the power delivered to it by its solar arrays (important issues for smaller satellites such as Proba-V, with its one cubic-metre volume).

As space gets busier, bandwidth is becoming a very scarce resource, with traditional bands becoming increasingly crowded. Frequency-sharing and other clever utilisation schemes are at their limits.

In addition, a given mission can only downlink data while its orbit keeps it in sight of its dedicated ground



stations. Increasing the number of ground stations assigned per mission is not an option, because of cost issues: the majority of space missions must make do with one station to serve as their terrestrial link, making a downlink possible only once per orbit (this is only for a few minutes for a typical low-Earth polar-orbiting Earth observation mission).

Relaying communications via higher-orbiting satellites is one promising means of increasing connectivity, set to be carried out by ESA's European Data Relay System by the middle of this decade.

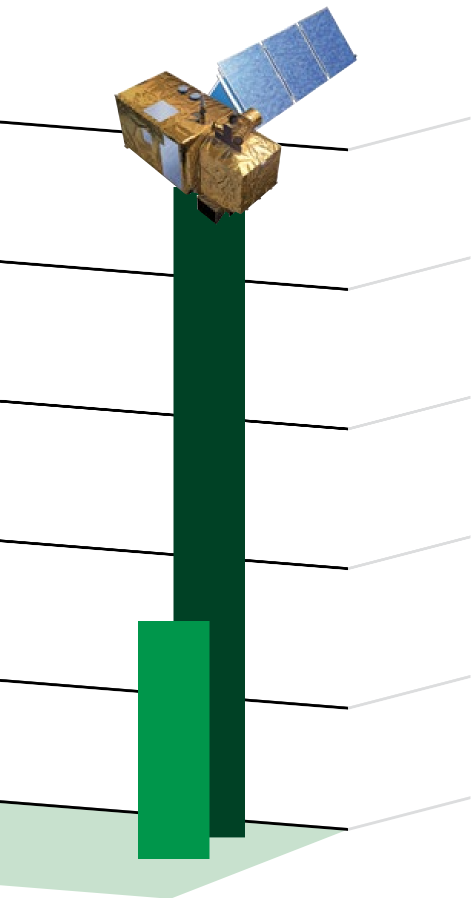
But there is another, more direct, solution to avoid onboard data bottlenecks: shrink a mission's results down to a manageable size before downlinking them to Earth. This is where ESA's On-board Payload Data Processing Section team comes in – ESA's centre of expertise for data compression algorithms, techniques and devices.

Located at ESTEC, ESA's technical heart in the Netherlands, this team provides data compression expertise to missions in need. Powerful compression algorithms are put on offer to match the available channel resources, often possessing sufficiently high data throughput for the resulting imagery to be transmitted to the ground on a real-time basis.

Cooperation for compression

How does the cooperation proceed in practice? Ideally, involvement starts early on in a project's lifetime in order to maximise the science return. Evaluation tools and devices are provided to the team involved. These tools are necessary to quickly assess the performance of the compression algorithms available early in the process, using simulated data to assess their suitability.

In most cases, a standard algorithm meets all the mission requirements, but this will not always be true. In some specific cases – for example, involving outliers in the range of data, or environmental factors influencing the data such as cosmic rays – a dedicated algorithm might need to be developed, or an additional pre-processing stage might prove necessary in front of the standard compression algorithm.



SENTINEL-2

	GAIA	SEOSAT	PROBA-V	SENTINEL-2
AVERAGE COMPRESSION RATIO	2.4	3.5	3.5	2.8
DATA TRANSMITTED TO GROUND (GBYTE/DAY)	42	212	20	850
DATA AFTER DECOMPRESSION	100.8	742	70	2380

Data transmitted to ground (Gbyte/day)

Data after decompression ('unpacking')

← An example of four missions producing massive amounts of data, only made possible by data compression. Their results are shrunk down by carefully tailored algorithms to be downlinked to Earth, then 'decompressed' to full size on the ground

In order to improve efficiency, the algorithm provided is treated as a black box, plugged into the data handling subsystem as simply as possible as just one more step in the processing chain. Such seamless slotting in may then also occur physically as the subsystem is built, often by fitting in Application-Specific Integrated Circuits (ASICs) based on particular data compression standards that the team is also mandated to develop.

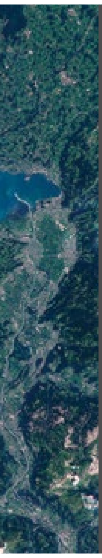
ASICs are computer chips that have been tailored to perform a particular key task, rather than the general-purpose integrated circuits found at the heart of personal computers, for example. For added flexibility, these 'Application Specific Standard Product' ASICs are alternately made available as IP cores, a code-based recipe that can be implemented in programmable chips called Fully Programmable Gate Arrays (FPGAs).

Setting standards for compression

Finally, the Section also works to develop and promote the use of data compression standards both within ESA and across the wider space sector. This includes active participation in the Consultative Committee for Data Systems (CCSDS), a multinational forum founded back in 1982 for the development of communications and data systems standards for spaceflight.

The work of the CCSDS involves leading space communications professionals from 26 nations, collaborating in developing the best-engineered space communications and data handling standards in the world. The goal? To enhance governmental and commercial interoperability and cross-support, while also reducing risk, development rime and project costs. More than 500 space missions have chosen to fly with CCSDS-developed standards, and this number continues to grow.

The CCSDS Standardisation Committee is divided across several areas, with the Multispectral Hyperspectral Data Compression Working Group (SLS-MHDC) focused on meeting the looming challenge of the increased volume of data to be collected and transmitted to the ground.

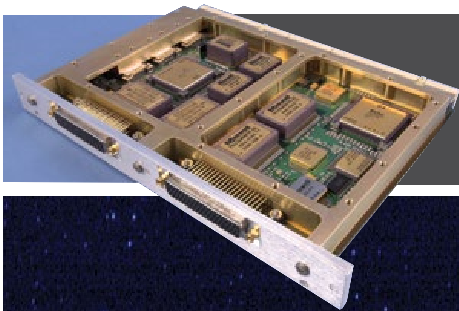


←

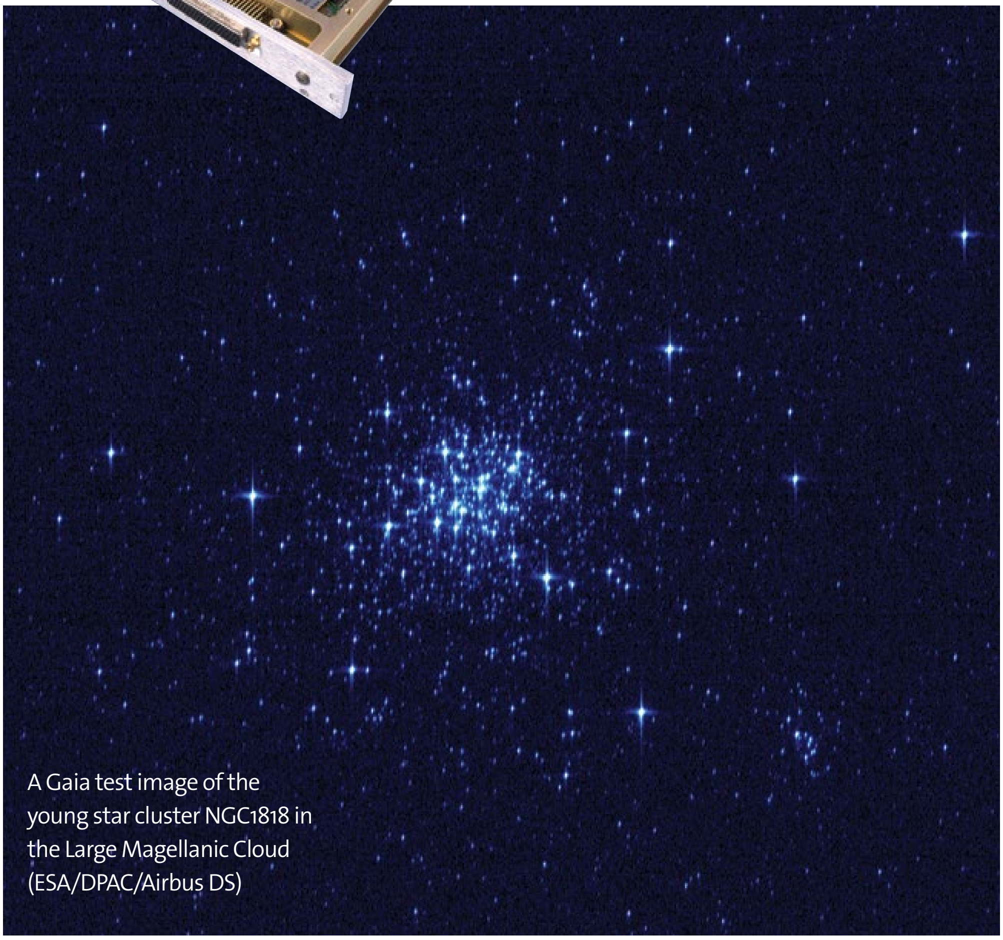
A mockup of the high-resolution hyperspectral images that Sentinel-2 will deliver. It shows the border area of northern Switzerland, southern Germany and eastern France with a swath of 290 km and a resolution of 10 m per pixel

←

Hyperspectral imagery from ESA's pioneering Proba-1 mission, launched in 2001 and still going strong. Left to right: Monument Valley in Utah, USA; the sister cities of Sault Sainte Marie, Ontario in Canada, and Sault Sainte Marie, Michigan, USA; the Solent between Portsmouth and the Isle of Wight in the UK



← One of Gaia's seven parallel video processing units – giving it more number-crunching power than any other ESA mission



A Gaia test image of the young star cluster NGC1818 in the Large Magellanic Cloud (ESA/DPAC/Airbus DS)

Cooperative mission scenarios exist where cross-support is needed to handle this resulting flood of data, but it will only be possible if industry, principal investigators and instrument developers, for instance, all adopt compression standards in common, to combine state-of-the-art data quality with orders of magnitude increases in data volume.

With its expertise in the areas of image compression and computer vision, the Image Processing Lab at the Polytechnic University of Turin has performed several compression activities in the context of ESA projects.

It has been involved in the development of lossless compression algorithms for hyperspectral images. More recently, it has developed a flexible compression approach for lossless, near-lossless and lossy compression, also proposed for standardisation in the CCSDS, which can support very high data rates and combines the simplicity of the prediction paradigm and the ability to fine-tune image quality, compression ratio or both.

Data compression for space – and everyday life

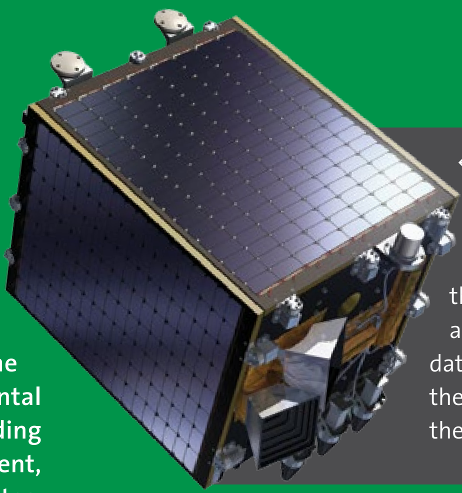
As space instruments generate ever-growing amounts of information, the role of data compression has become increasingly crucial. The underlying principles involved are not so difficult to grasp, and have become an essential part of everyday life. Just about every image or video you see online or on television has been processed by a compression standard, along with the MP3 music files on your media player, even the voices of your friends and family as you talk to them on the phone.

Compression involves the removal of repeated redundant data from a file. This can take place in two ways: 'lossless', when the original file can be exactly reconstructed from the compressed data, or 'lossy', when only an approximation is recovered. Think of ZIP files on the one hand, and JPEG files on the other.

Lossless techniques have always been popular, but lossy methods can achieve much more compression, and have become widespread for Earth observation applications.

→ Case study: Proba-V

Proba-V is a miniaturised ESA satellite tasked with a full-scale mission: to map land cover and vegetation growth across the entire planet every two years.



←

Small satellites such as Proba-V are limited in the size and power of the antennas they can host, so data compression becomes all the more important to convey their results back to Earth

Launched in May 2013, the polar-orbiting Proba-V is the latest addition to the Proba family of small, experimental space missions, but it is doing operational work, extending the 15-year dataset of the full-scale Vegetation instrument, previously hosted aboard France's Spot-4 and -5 satellites. Proba-V is serving hundreds of scientific teams worldwide – feeding for example the *MARS Bulletin* on EU crop production forecasts – as well as food security estimates.

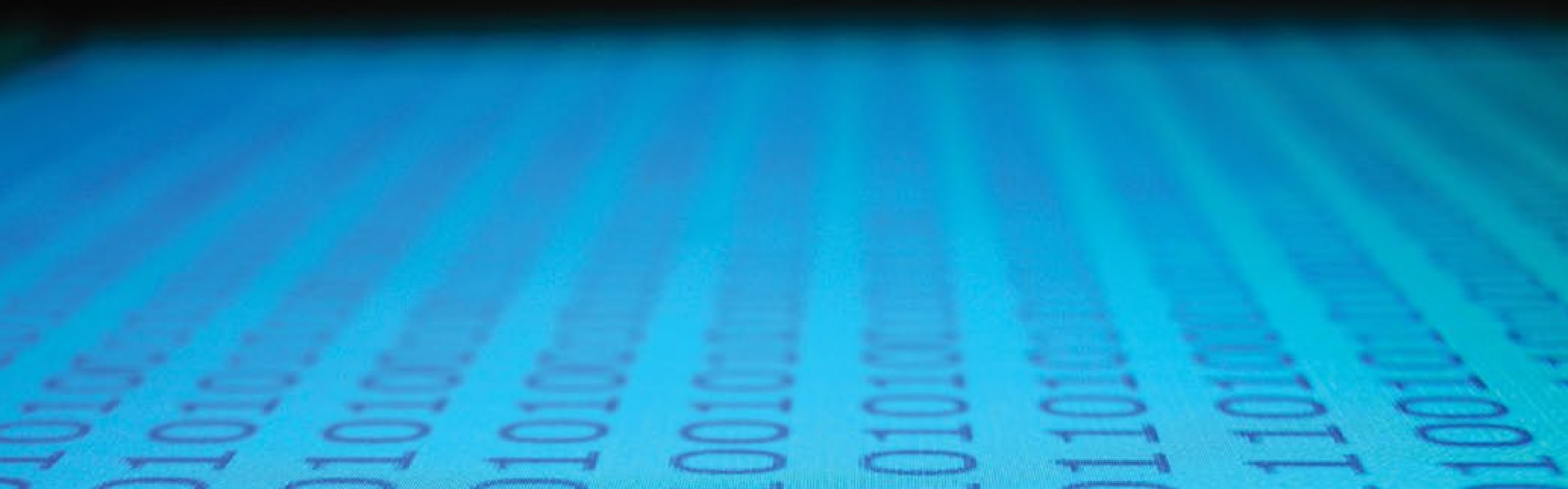
The imager's continent-spanning 2250 km field of view collects light in the blue, red, near-infrared and mid-infrared wavebands, ideal for monitoring plant and forest growth as well as inland water bodies. Proba-V's always-on Vegetation instrument also boasts markedly improved spatial resolution compared to its Spot-based predecessors: 350 m compared to 1 km for Spot Vegetation, down to 100 m within its central field of view.

The massive amount of data produced by the instrument is beyond the capabilities of the bandwidth available on board such a small satellite, less than a cubic metre in volume and 140 kg in mass, so data reduction is essential to enable the satellite's scheduled once-per-orbit data dump to its single northern ground station (ESA's Kiruna site in the Swedish Arctic). This occurs on a near-real time basis via a high-bandwidth X-band antenna, enabling the creation of one-day and ten-day products for distribution to users.

The CCSDS Image Data Compression standard turned out to meet all the requirements in terms of image quality and reachable compression ratio, accordingly reaching the required target data rate. This compression algorithm has been implemented in specific electronics (FGPA) on the satellite. Among many other notable firsts, Proba-V has therefore become the first European mission to fly the CCSDS Image Data Compression standard.

←

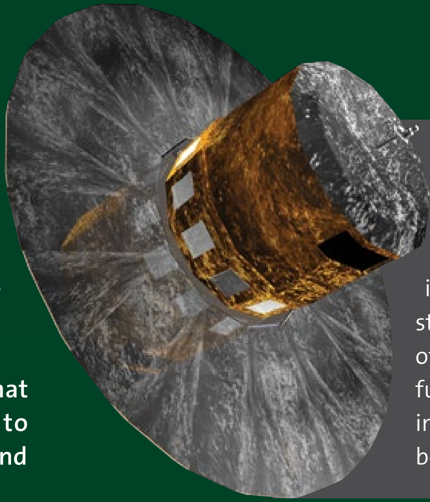
The Kiruna ground station. Its location at a high-latitude position, in northern Sweden, plays a primary role supporting ESA low Earth orbiting satellites as it provides visibility for 10 to 12 out of 14 daily orbits



→ Case study: Gaia

Launched on 19 December 2013, ESA's Gaia astrometry mission is planned to make the largest, most precise three-dimensional map of our galaxy by surveying more than a billion stars.

At its heart, Gaia contains a pair of optical telescopes that work in tandem with a trio of science instruments to precisely determine the location and velocities of stars, and to split their light into a spectrum for analysis.



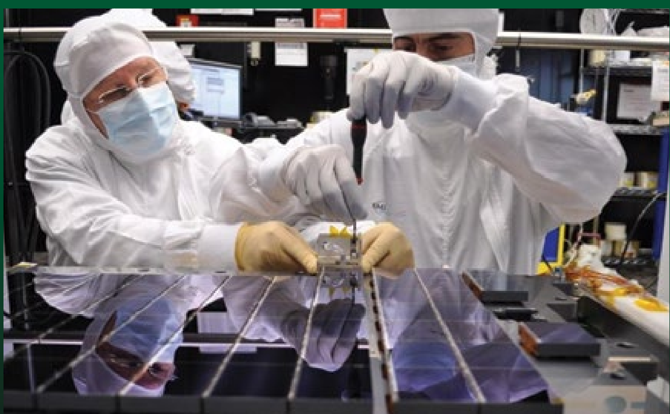
← The latest of ESA's astrometry missions, Gaia is measuring the velocity of stars as well as their position, offering insights into past and future galactic evolution. This increases the size of the data being gathered

By the end of its mission, Gaia's instruments will produce a data archive that is estimated to exceed 1 Petabyte (1 million Gigabytes), equivalent to about 200 000 DVDs worth of data.

Gaia has been placed into orbit around the Sun, at the second Lagrange point L2, some 1.5 million km away from Earth. Considering this enormous distance from the spacecraft to its terrestrial ground stations, the available bandwidth is limited to transmit the huge amount of data the mission will produce.

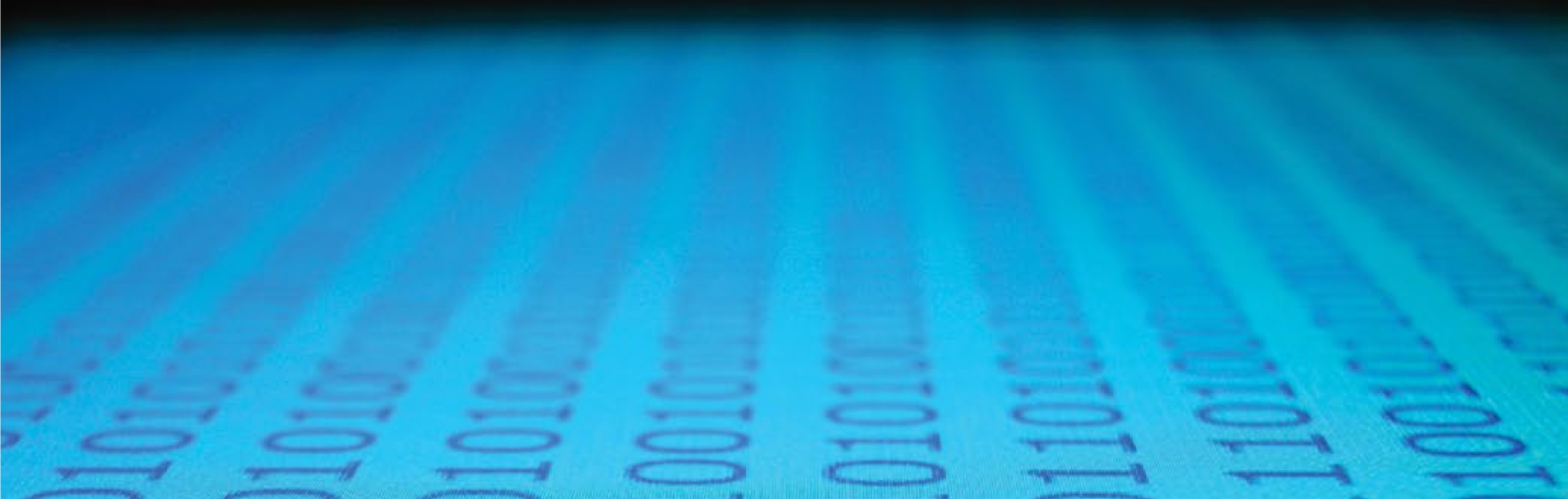
Data compression was considered later in Gaia's development lifetime than was realised to be ideal, but, with payload engineers facing the prospect of having to discard valuable data, On-board Payload Data Processing Section experts lent their expertise.

In order to transmit all the data generated on board, a particularly challenging compression factor averaging 2.8 was necessary. Unfortunately the standard suite of algorithms was not able to reach this target, because of the peculiarities of Gaia imagery, which include 'outliers', such as bright stars and planets, and which are marred by the momentary 'hot pixels' due to cosmic rays in deep space. Instead, with the support of ESA compression experts, industry developed an ad hoc solution, enabling all Gaia mission data to reach their home planet.



↑ Assembling the 106 electronic detectors making up Gaia's billion-pixel camera, produced by e2v Technologies of Chelmsford, UK

↑ Gaia's sunshield is essential for mission success: it keeps the spacecraft telescopes screened from sunglare so it can detect even the faintest of its billion target stars



→ Tools of the trade

WhiteDwarf data compression evaluation tool

WhiteDwarf is an application that supports the evaluation of compression algorithms by their prospective users. It allows users to compress and decompress their own data files, and optimise algorithm choice and compression parameters by testing with representative user-selected datasets.

Experimenting with this tool, users can test how different combinations of algorithm and compression parameters perform when compressing samples of their own data. These combinations may be stored, exported and imported. The generation of test reports is also supported.

CCSDS Image Data Compression ASIC

CWICOM – standing for CCSDS Wavelet Image COMpression ASIC – is a very high-performance image compression ASIC that implements the CCSDS 122.0 wavelet-based image compression standard, to output compressed data according to the CCSDS output source packet protocol standard. This integrated circuit was developed by EADS Astrium through an ESA contract.

→ This CWICOM (CCSDS Wavelet Image COMpression) application-specific integrated circuit (ASIC) is a customised microchip for imaging data compression

CWICOM offers dynamic, large compressed-rate range and high-speed image compression potentially relevant for compression of any 2D image with bi-dimensional data correlation (such as a hyperspectral data cube). Its highly optimised internal architecture allows lossless and lossy image compression at very high data rates (up to 60 Mpixels/second) without any external memory by taking advantage of its on-chip memory – almost 5 Mbits of embedded internal memory).

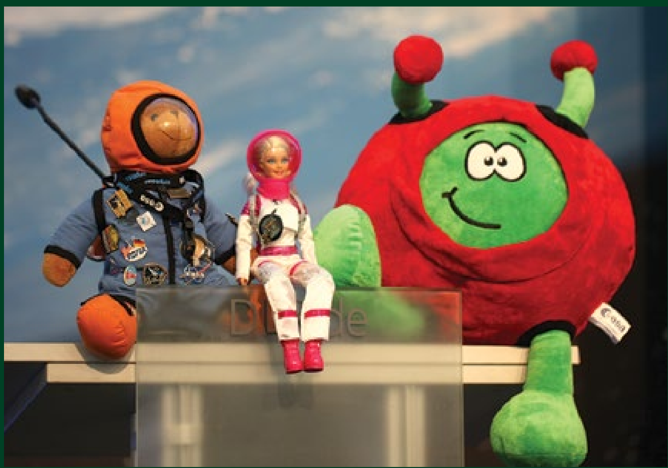
CWICOM is implemented using the largest matrix of the Atmel ATC18RHA ASIC family, and is provided within a standard surface mount package (CQFP 256). CWICOM offers a low-power, cost-effective and highly integrated solution for any image compression application, performing CCSDS image compression treatments without requiring any external memory. The simplicity of such a standalone implementation is achieved thanks to a very efficient internal embedded memory organisation that removes any need for extra memory chip procurement and the potential obsolescence threatened by being bound to a specific external memory interface.

← The multinational Consultative Committee for Data Systems (CCSDS) sets common standards for spacecraft communications and data systems

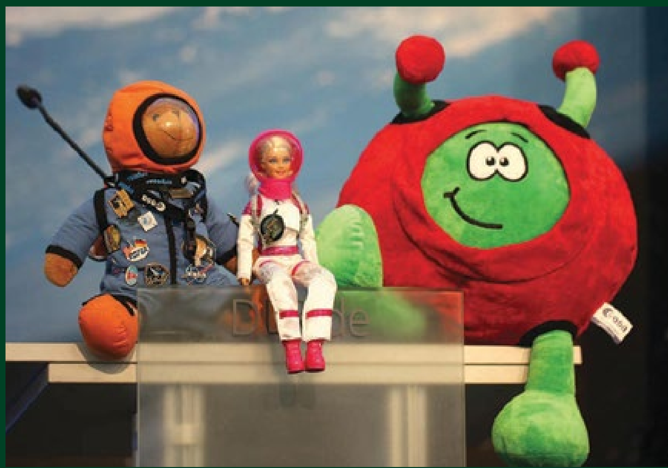
ESA's new 35m deep space station, Malargüe in Argentina, serving missions including Gaia

→ Lossy image compression

The lossy JPEG format allows the level of compression to be adjusted, between 100 to 1.The higher the number, the less compression is obtained and the better the image quality. The images here demonstrate compression qualities of 100, 50, 10 and 1. With greater compression, the image loses its brightness and becomes progressively more blurred. Note the characteristic rectangular regions as an artefact of the JPEG compression process.



Quality 100 334 KB



Quality 50 49.5 KB

Quality 10 16.3 KB

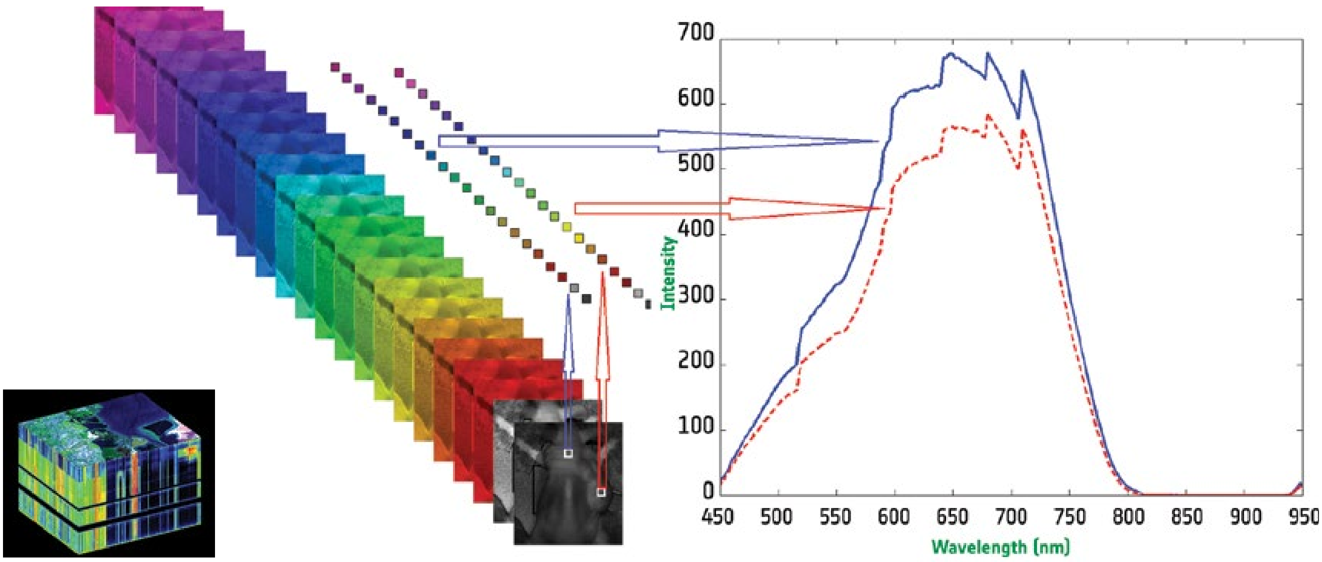
Quality 1 6.3 KB

Interestingly, in the case of imagery it has been observed that high-quality lossy compression actually improves image quality, because it removes part of the inherent noise.

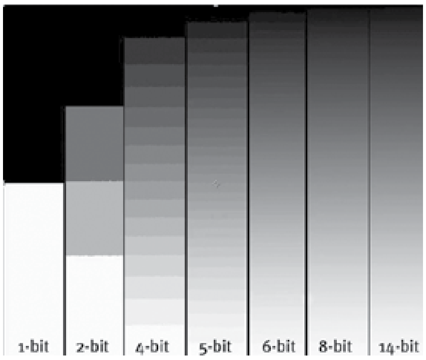
How is it possible to shrink original images to small compressed files without significantly affecting their quality? The answer lies in the fact that most signals generated by a natural source, including images, exhibit a large amount of correlation. That is to say, the values of neighbouring pixels in an image do not change in an unpredictable way but follow a smooth transition.

Take for example, any hyperspectral data cube image, composed of stacked images of the same scene seen at adjacent wavelengths. Considering a single pixel at a given spatial position and wavelength, it is evident that knowledge of the value of this pixel can be used to infer – at least approximately – the value of the spatially and spectrally adjacent pixels.

In other words, the rate of variation of pixel values is limited. So when a mathematical tool such as the famous 'Fourier transform' is applied – a means of breaking down a signal or image into its underlying waves, like the way music is rendered into 'dancing' LED bars on a sound system – then the results would typically exhibit rather strong low frequencies and weak or negligible high frequencies.



↑ A multispectral cube acquired by the CHRIS instrument on the Proba-1 mission. Images at different wavelengths are very similar. This allows to employ mathematical models to exploit this correlation, achieving a large amount of compression of each single band



↑

Any electronic image is formed out of pixels. The more pixels the sharper and richer the image. The range of colours and brightness that the pixels are permitted to express – known as its 'bit-depth' – influences its sharpness, but also increases the overall file size

8 bit
256 possible values

4 bit
16 possible values

2 bit
4 possible values

1 bit
2 possible values

The ability to devise mathematical models to describe such behaviour is at the root of image compression. Two such mathematical models are prevalent, namely transforms and prediction, and can be applied to both lossless and lossy compression.

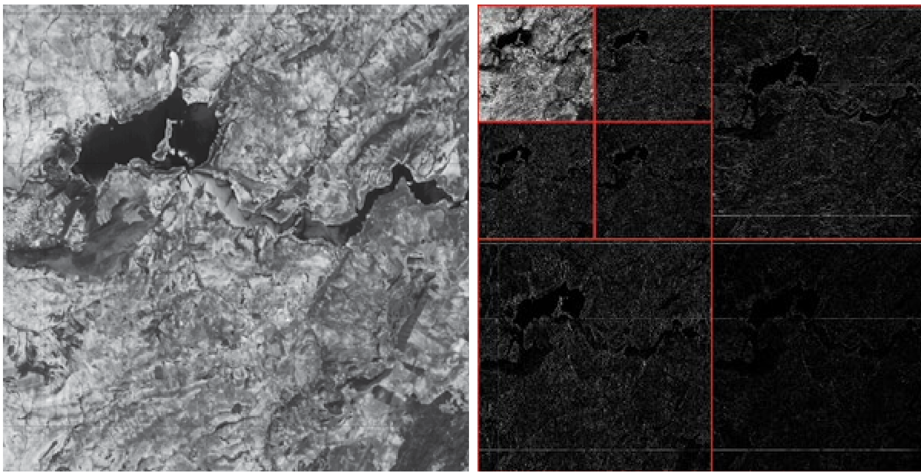
Transforms and prediction: the technical bit

The 'transform model' represents the image in a different domain – such as that of frequency – in which only a few coefficients are significantly different from zero. Approximating most of the image content with a small number of transform coefficients readily leads to effective compression algorithms. These simply pick the desired number of coefficients among the largest ones: the number retained determines the trade-off between quality and amount of compression – the compression ratio.

The JPEG standard for example (named after the Joint Photographic Expert Group that devised it), is based on the 'discrete cosine transform' (DCT), converting spatial data to frequency components on a typically lossy basis.

The low-frequency components (derived from uniform areas such as sky or a wall) are then encoded with a larger number of bits, while the high-frequency components (derived from zones where rapid changes are seen, such as vegetation) are encoded with a lower number of bits.

This helps remove surplus high-frequency information that is not important to human perception of the image – the human eye being less sensitive to very high frequency changes in the colour domain in particular.



← The wavelet transform of the Proba CHRIS image at one specific wavelength. The wavelet transform applies a bank of bandpass filters to the image on the left, creating a transform as depicted on the right. Only few coefficients of the wavelet transform are significantly larger than zero, allowing the exploitation of the spatial correlation of each single band

The resulting compressed image has slight blurring of high-frequency areas, but this is scarcely perceptible to human vision. Low-frequency compression, by contrast, is more easily discerned, as in the characteristic 'blocky' artifact layers in the sky of a too-severely-compressed image. (The follow-on JPEG2000 standard – as well as the CCSDS-122 space standard – swaps the DCT for a wavelet transform instead. Simply put, if the DCT resembles a prism – splitting a signal into component waves – then a wavelet is closer to a tuning fork, triggering mathematical resonances for frequency transformation).

The 'prediction paradigm', by contrast, employs a mathematical model to predict the value of each pixel from the values of a few neighbouring pixels that have already been processed. In this way, the model removes all predictable correlations, so that only the 'prediction residual' – meaning what the mathematical model could not predict – has to be written in the compressed file (the near lossless JPEG-LS and the CCSDS-123 recommendation have adopted this approach).

Compression can also be applied to general-purpose non-image data. In such cases transforms and prediction are not employed, but the data volume can still be reduced with applicable compression techniques such as 'Huffman-' or 'Golomb-coding', exploiting the fact that some symbols appear more often than others in the data stream. ■

Sean Blair is an EJR-Quartz writer for ESA

→ Data compression of image leads to an increasing level of distortion, as groups of pixels are represented by fewer number of bits

Recommended CCSDS-published standards on data compression

- CCSDS 121.0-B-1
  Lossless Data Compression. Blue Book. Issue 1. May 1997.
  Defines a source-coding data-compression algorithm and specifies how data compressed using the algorithm are inserted into source packets for retrieval and decoding.

- CCSDS 122.0-B-1
  Image Data Compression. Blue Book. Issue 1. November 2005.
  Defines an image-data compression algorithm applicable to digital data from payload instruments and specifies means to control compression rate and how these compressed data shall be inserted into source packets for retrieval and decoding.

- CCSDS 123.0-B-1
  Lossless Multispectral & Hyperspectral Image Compression. Blue Book. Issue 1. May 2012.
  Specifies a method for lossless compression of multispectral and hyperspectral image data and a format for storing the compressed data.

→ THE CHASE IS ON

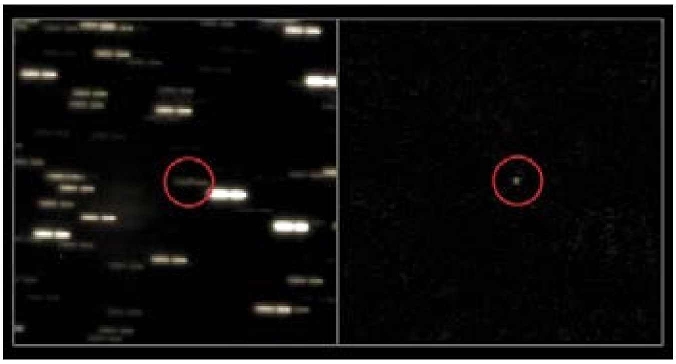
Rosetta's arrival at Comet 67P/Churyumov-Gerasimenko

Emily Baldwin
Communications Department, ESTEC, Noordwijk, the Netherlands

Almost six months have passed since ESA's Rosetta spacecraft woke up from deep-space hibernation, ready to complete the final leg of its 10-year comet chase. Now, with a gap of less than 200 000 km to close, the comet is firmly in Rosetta's sights.

Earlier in the spring, the 11 science instruments on board the Rosetta orbiter were reactivated and checked out, as was the Philae lander. One highlight was the much-anticipated first glimpse of Rosetta's target by the OSIRIS imaging system. The spacecraft's two navigation cameras were also in full working order and both cameras are being used to home in Comet 67P/ Churyumov-Gerasimenko.

At the end of February, the comet was observed from the ground by the European Southern Observatory (ESO) Very Large Telescope in Chile. ESA and ESO are collaborating to monitor the position and brightness of the 4 km-wide comet to help refine Rosetta's navigation and to make assessments of the comet's activity before the spacecraft's arrival in August.



↑

Comet 67P/Churyumov-Gerasimenko seen on 28 February by ESO's Very Large Telescope in Chile (ESO/C. Snodgrass (MPI)/O. Hainaut)

↑

This image was taken on 30 April by the OSIRIS Narrow Angle Camera and the comet is already displaying a coma, which extends over 1300 km from the nucleus (ESA/MPS for OSIRIS Team)

In May, Rosetta began a critical series of manoeuvres that will steadily bring the spacecraft in line for its rendezvous with the comet. If these manoeuvres were not carried out, Rosetta would sail by the comet at a distance of around 50 000 km and at a relative velocity of 800 m/s. The aim of the manoeuvres is to reduce Rosetta's relative velocity to 1 m/s and bring it to within 100 km distance of the comet by 6 August.

The first manoeuvre was carried out on 7 May to decrease Rosetta's velocity relative to the comet by just 20 m/s. The biggest reduction in relative velocity of 290 m/s will take place on 21 May. Ten manoeuvres in total will ensure the spacecraft's arrival at the comet.

Along the way, the comet will appear to grow in Rosetta's field of view, from appearing to have a diameter of less than 1 camera pixel in May to well over 1000 pixels – equivalent to a resolution of better than a few metres per pixel – by August. During this chase phase, Rosetta's instruments will be able to make a preliminary assessment of the comet's activity, its size, shape and rotation.

Rosetta's arrival on the 6 August will secure its place in history, as the first mission to make a slow-speed rendezvous with a comet. Then the spacecraft will follow a two-step triangular path in front of the comet to bring it from an altitude of 100 km to 50 km, manoeuvres that will take about a month to complete.

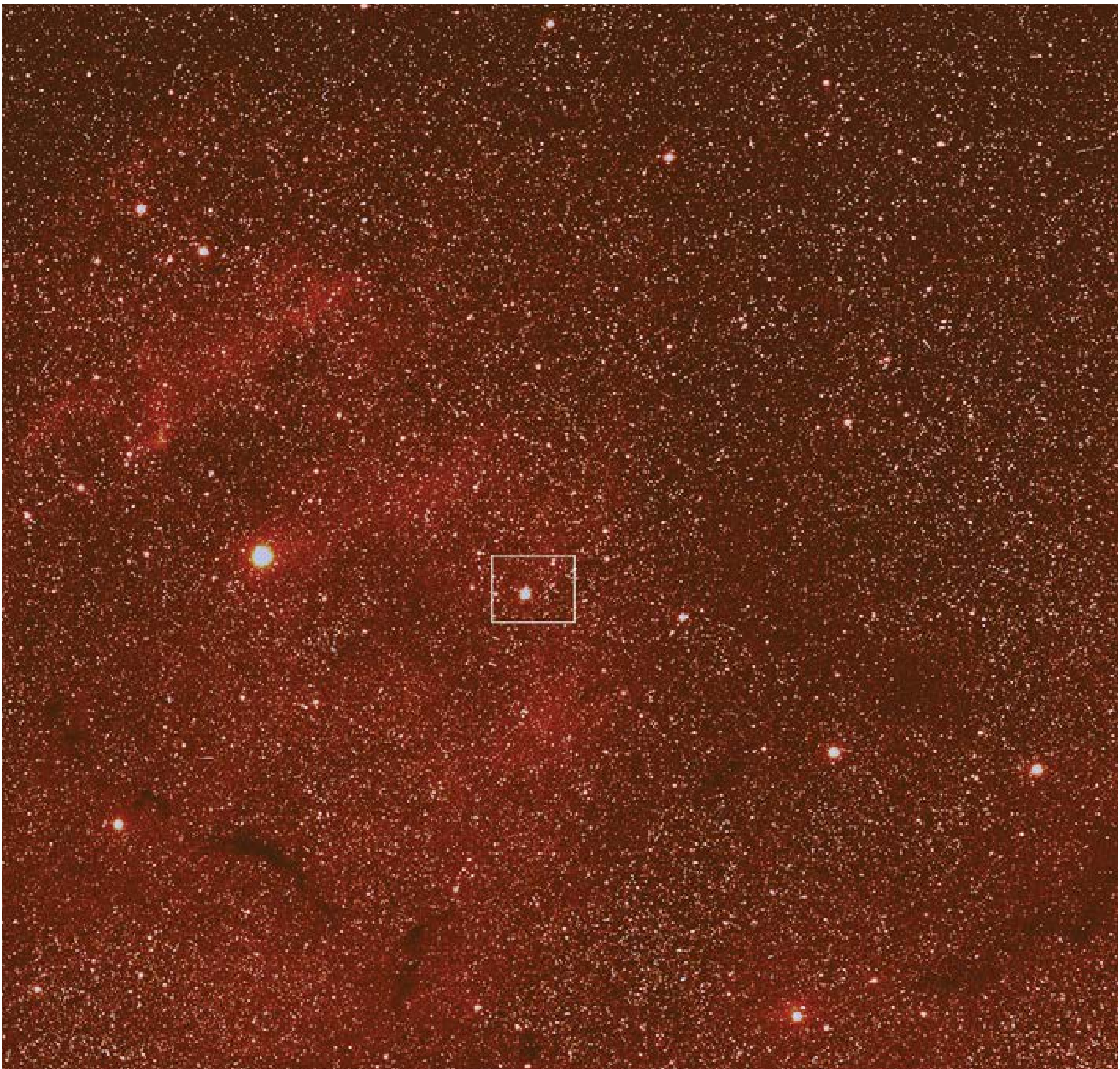
During this time, five locations of particular interest will be identified as possible landing sites for the mission's 100 kg Philae probe, which is to be deployed in November 2014. Right now, we know next to nothing about the geology and activity of the comet, both of which will play key roles in deciding where Philae can land safely.

The selection of the final landing site will likely be made at the end of September, by which time Rosetta will be orbiting at an altitude of about 30 kilometres above the surface – depending on the comet's activity – allowing detailed mapping of its nucleus at a resolution on the order of half a metre.

At the time of landing, Rosetta and the comet will still be on their approach towards the Sun, at a distance of

“No one has ever attempted this before. In the history of spaceflight. We're very excited about the challenge!”

– Matt Taylor, Rosetta project scientist



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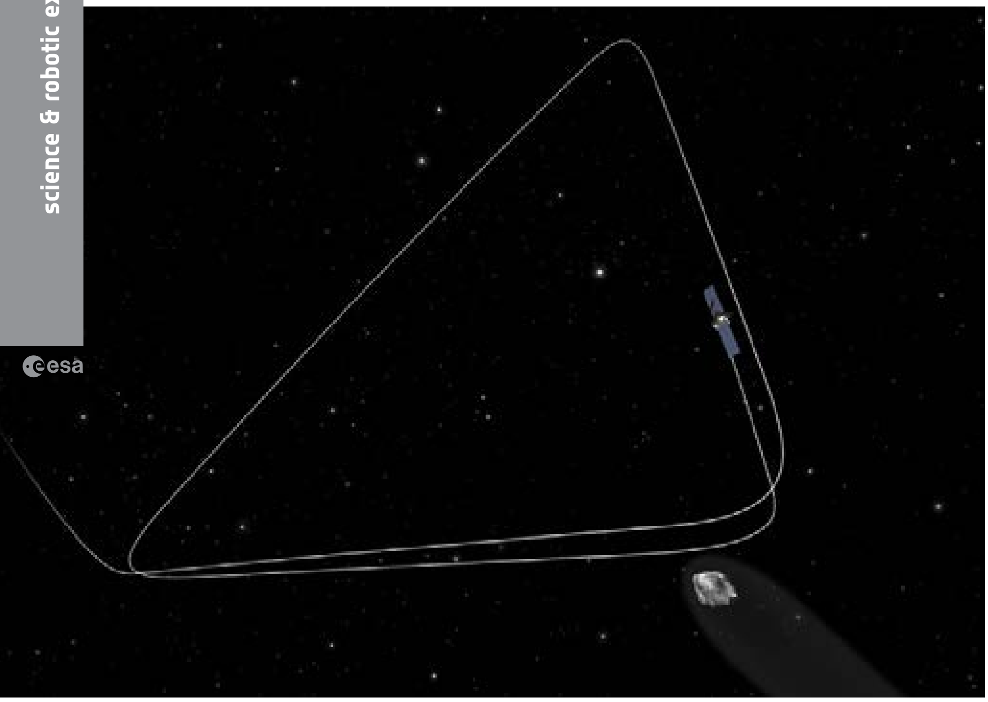
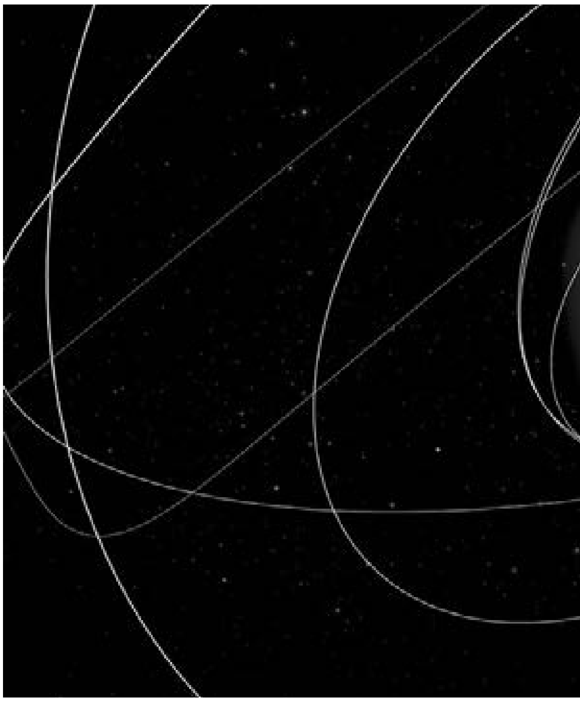
This is Rosetta's first sighting of its target, Comet 67P/Churyumov-Gerasimenko, in 2014. It was taken with the OSIRIS Wide Angle Camera on 20 March (ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA)

roughly 450 million km, between the orbits of Mars and Jupiter. The orbiter will come to within a few kilometres of the comet's surface to deploy the Philae lander, which will take several hours to drop slowly towards the comet's surface.

Once anchored to the nucleus, the lander will begin its primary science mission, based on an initial 64-hour initial battery lifetime. It will send back high-resolution pictures of Comet 67P/Churyumov-Gerasimenko's surface and perform on-the-spot analysis of the composition of its ices and organic material.

A drilling system will also take samples from a depth of 23 cm below the surface and will feed these to the onboard laboratory for analysis. The data will be relayed back to Earth via Rosetta during the next ground station contact period.





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After catching up with the comet, Rosetta will slightly overtake and enter orbit from the 'front' of the comet, first following a two-step triangular path in front of the comet to bring it from an altitude of 100 km to 50 km

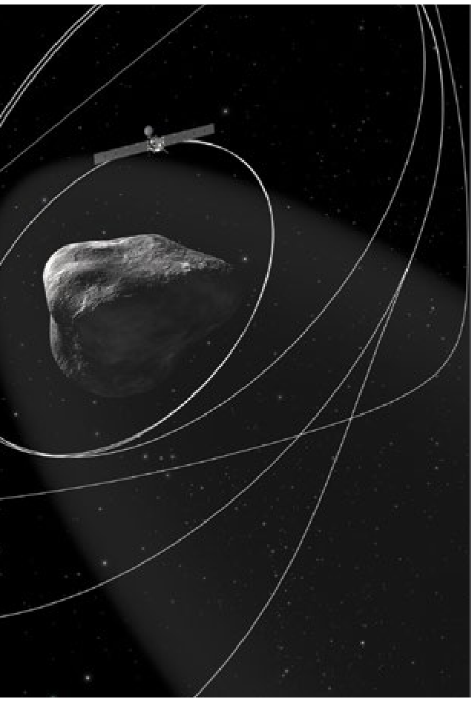
Philae also has solar panels that can be used to recharge the batteries, hopefully allowing for extended operations on the comet. But this will depend on the specific landing conditions and the accumulation of cometary dust on the cells, so this is not guaranteed.

The data collected on the surface will complement the extensive measurements made by the orbiter, which will continue following the comet on its orbit around the Sun through 2015. The closest approach to the Sun takes place at a distance of 185 million km – between the orbits of Earth and Mars – on 13 August 2015, and Rosetta will continue to return unique observations of the comet's ever-changing behaviour as it moves back towards the outer Solar System again. ■

Emily Baldwin is an EJR-Quartz writer for ESA

→ Rosetta mission milestones 2014–15

> **"Rosetta's arrival on the 6 August will secure its place in history."**



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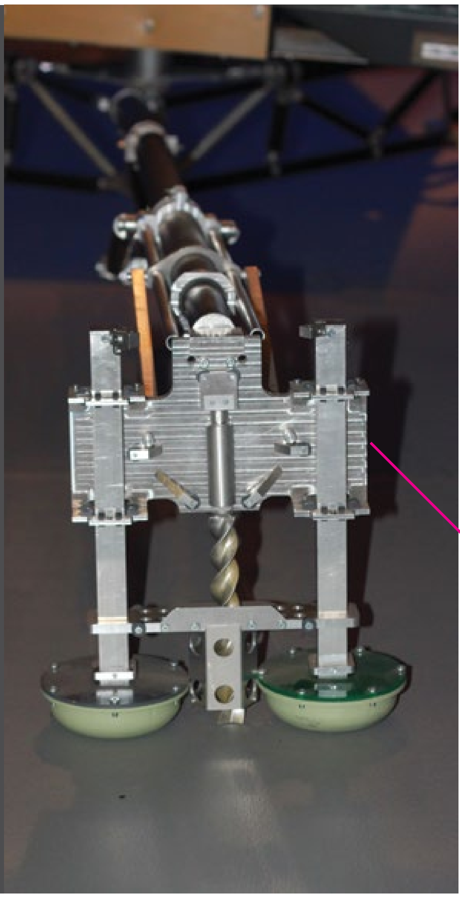
After more complex manoeuvres, the separation between the spacecraft and comet will be reduced to around 25–30 km

→

Landing pads and ice screws in on of Philae's three feet that will lock the probe to the comet surface (Neozoon)



Follow Rosetta and Philae

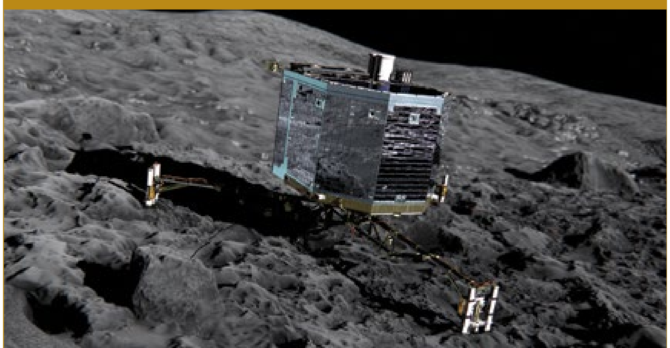
https://www.facebook.com/RosettaMission

@ESA_Rosetta @Philae2014

http://blogs.esa.int/rosetta/

→ Philae's landing

Because of the comet's extremely low gravity, Philae has a sophisticated set of systems on board to prevent it from rebounding back into space. A landing gear will absorb the forces experienced during touchdown, while a harpoon system together with ice screws in the probe's three feet will lock the probe to the surface. At the same time, a thruster on top of the lander may be used to push it down in order to counteract the impulse of the harpoons fired in the opposite direction (images ATG/medialab)



→ NEWS IN BRIEF

Wubbo Ockels, 1946–2014

Wubbo Ockels

Former ESA astronaut Wubbo Ockels passed away on 18 May in the Netherlands. Wubbo was the second ESA astronaut and the first Dutch citizen to go into space in 1985.

→ Wubbo Ockels in Spacelab-D1, 1985 (NASA)

Born 28 March 1946, in Almelo, the Netherlands, Wubbo gained a degree in physics and mathematics from the University of Groningen in 1973, and completed his PhD in nuclear physics in 1978. In the same year, Wubbo was selected by ESA as one of three science astronauts to train for the Spacelab missions, together with Ulf Merbold and Claude Nicollier.

During the first Spacelab mission, he served as ground-communicator and liaison-scientist for the crew on STS-9. During the STS-61A Spacelab-D1 mission, he orbited Earth 110 times in the Space Shuttle *Challenger.*

After his flight, he was based at ESA's ESTEC technology centre in Noordwijk, the Netherlands, where he supported human spaceflight activities and later became Head of ESA's Education and Outreach Office. During this time, he also held a part-time professorship in aerospace at the Delft University of Technology.

In 2003, he became full-time professor of Aerospace for Sustainable Engineering and Technology at TU Delft, dealing with the exploitation of alternative sources of energy. Wubbo's team won the World Solar Challenge in 2001, 2003, 2005, 2007 and 2013 with their Nuna solar-powered car, racing over 3000 km across Australia. Wubbo continued to champion sustainable projects such as the Ecolution ship.

Wubbo saw the fame he received as an astronaut as a responsibility to use for good. He championed sustainability, innovation and youth throughout his life. ESA has lost a fantastic ambassador and a dear friend.

First commercial launch for Vega

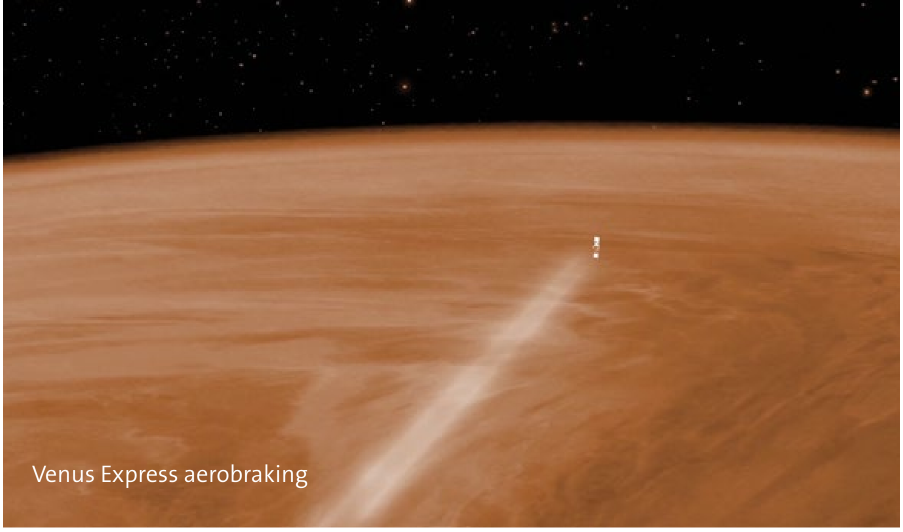
The third launch by Europe's Vega small launcher in April delivered Kazakhstan's first satellite for high-resolution Earth observation into space.

Liftoff of flight VV03 from Europe's Spaceport in Kourou, French Guiana, took place 30 April. The KazEOSat-1 satellite, built by Airbus Defence and Space, was released into its planned Sun-synchronous circular orbit at an altitude of 750 km and is expected to operate for more than seven years.

← Vega flight VV-03 liftoff on 30 April

Through this launch, Vega has entered into commercial exploitation and is being operated in conjunction with the heavy-lift Ariane 5 and medium-lift Soyuz rockets at Europe's Spaceport to provide a full range of services meeting the varied demands of the launchers market.

Swansong at Venus



Venus Express aerobraking

After eight years in orbit, ESA's Venus Express has completed routine science observations and is preparing for a daring plunge into the planet's hostile atmosphere.

Venus Express was launched on a Soyuz–Fregat from the Baikonur Cosmodrome in Kazakhstan on 9 November 2005, and arrived at Venus on 11 April 2006. It has been orbiting Venus in an elliptical 24-hour loop that takes it from a distant 66 000 km over the south pole – affording incredible global views – to an altitude of around 250 km above the surface at the north pole, close to the top of the planet's atmosphere.

Now, after eight years in orbit, the fuel supplies necessary to maintain this orbit are running low and will soon be exhausted. Thus, routine science operations concluded in May, and the spacecraft is being prepared for one final mission: to make a controlled plunge deeper into the atmosphere than ever before attempted.

An experimental aerobraking phase is planned for 18 June – 11 July ('aerobraking' can be used as a way of getting into orbit around planets without having to carry so much fuel, thus reducing the launch mass). This phase will provide the opportunity to develop and practise critical operations and techniques that will be valuable for future planetary missions.

It is possible that the remaining fuel in Venus Express will be exhausted during this phase or that the spacecraft does not survive these risky operations. But if the spacecraft is still healthy afterwards, its orbit will be raised again and limited operations will continue for several more months, fuel permitting.

However, by the end of the year, it is likely that Venus Express will have made its final descent into the atmosphere of the planet, bringing a fantastic scientific endeavour to an end. With a suite of seven instruments, the spacecraft has provided a comprehensive study of the ionosphere, atmosphere and surface of Venus.

Swarm's challenging task

↑ The Swarm constellation (ESA/ATG medialab)

Although they were launched only five months ago, ESA's trio of Swarm satellites are already delivering results with a precision that took earlier missions 10 years to achieve.

Engineers have spent the last five months commissioning the identical satellites and carefully guiding them into their orbits to provide the crucial measurements that will unravel the mysteries of Earth's magnetic field.

Two satellites are now orbiting almost side by side and have started their operational life at 462 km altitude. The third is higher, at 510 km. The readings made at different locations will be used to distinguish between the changes in the magnetic field caused by the Sun's activity and those signals that originate from inside Earth.

Swarm is now in its fine-tuning phase but it has already produced enough information to build models of the magnetic field for comparison with existing models. This proves that only a few months of Swarm data agree very well with a decade or more of predecessor missions.

Over the coming years, this innovative mission will provide new insight into many natural processes, from those occurring deep inside the planet to weather in space caused by solar activity. In turn, this information will yield a better understanding of why Earth's magnetic field is weakening.

Andreas's mission name

The name of ESA astronaut Andreas Mogensen's 10-day mission to the International Space Station in 2015 was announced at the Science Forum in Copenhagen in April.

The winning proposal for Andreas's mission, 'iriss', was submitted by Filippo Magni, a 20-year-old student from Italy, and chosen from over 700 suggestions received from across Europe. The name combines Iris and ISS: Iris was a Greek goddess, the messenger of the gods of Olympus and the personification of the rainbow. As messenger, she represents the link between humanity and the cosmos, and between the heavens and Earth.

The name also invokes the image of a rainbow – a symbol of peace – linking this with Andreas's scientific and technology demonstration mission to the Space Station.

Andreas said, "Science has been a bridge between East and West, helping to foster peace and understanding. The name iriss perfectly captures this aspect of the ISS."

↗ Andreas Mogensen

Fifty years since first ELDO launch

5 June 1964: a launch took place signalling the start of Europe's cooperative venture into space – the first test flight of a Europa-1 first stage (F1), a repurposed British Blue Streak missile – from Woomera, Australia.

The Europa rocket was an early launch system of the European Launcher Development Organisation (ELDO), which was one of the precursors to ESA and its family of Ariane launchers.

Europa was built to develop Europe's access to space and put European scientific satellites into orbit. This task was expanded later to include telecommunications and meteorological satellites. It was composed of three stages (the UK's Blue Streak, the French Coralie and German Astris stages). The first Europa firing using all three stages took place on 30 November 1968.

F1 was the first test flight in Phase 1 of the ELDO launcher development programme, launching a Europa first stage. The F1 vehicle had arrived in Adelaide, Australia, on 18 January 1964 and was transported to Woomera for launch preparations. It was installed on its launch pad in March and underwent static firing tests in April. Launch was planned for 25 May, but unsettled weather at Woomera caused some delays. After several launch attempts, another firing was set for 5 June.

At dawn on 5 June, the weather was excellent and after an extremely smooth and efficient final countdown, the vehicle lifted off successfully at 9.11 a.m. It followed its programmed course downrange, with its flight path and projected impact point being as planned.

At about 130 seconds into the flight, however, telemetry records indicated that the vehicle was becoming unstable. This became marked at 140 seconds, developing into an uncontrolled corkscrew at 145 seconds. At 147.5 seconds the engine ceased thrusting, only six seconds before the planned time for engine cut-off.

The termination of powered flight was diagnosed as caused by fuel starvation owing to the manoeuvres of the vehicle during its final period of instability. The instability was caused by fuel sloshing in its propellant tanks.

Although the vehicle broke up near the end of the flight, the launch was classed as a success. Telemetry records and radar tracking were excellent. The good visibility enabled observers to obtain data on the flight up to its highest point, at about 4 minutes, when break-up was observed.

Except for some loss of camera coverage around the period of engine cut-off because of the long ranges involved, the data obtained from range instrumentation were excellent, and the performance of the vehicle was well up to theoretical expectations.

→ Europa-1 F1, 5 June 1964

Galileo taking shape

Europe's latest Galileo navigation satellite arrived in the Netherlands in May for testing, the same time as the previous two satellites arrived in French Guiana for launch this summer.

The new satellite travelled safely enclosed in an environmentally controlled container from manufacturer OHB in Bremen, Germany, to ESTEC, ESA's technical centre in Noordwijk and Europe's largest site for spacecraft testing.

Meanwhile, the previous two Galileo satellites had completed their long test campaign and were shipped to Europe's Spaceport in French Guiana, for launch together on a Soyuz rocket.

Europe's first four Galileo satellites are already in orbit, the minimum number needed for achieving a position fix. This initial quartet has demonstrated the overall system works as planned, while also serving as the operational nucleus of the coming full constellation. Next come the 22 full-capability satellites being built by OHB, incorporating navigation payloads produced by Surrey Satellite Technology Ltd in the UK.

These three latest satellites are the first of these 22 to be tested for launch – all of them will pass through the site's gates within the next few years on their way to space. A fourth satellite is scheduled to arrive at ESTEC in June – the test facilities can accommodate two satellites at a time.

Tests to be carried out on this latest arrival, 'acceptance testing', will check the workmanship is up to standard. Acoustic tests reproduce the violent forces of launch, and a session in a thermal-vacuum chamber will subject the satellite to the atmospheric and temperature extremes it will endure over the course of its 12-year working life.

Such a changeover, between satellites arriving as others are being readied to leave for launch, will become commonplace in the next few years, as Europe builds up its constellation. In future two-satellite Soyuz launches will be supplemented by four-satellite Ariane 5 launches, employing a specially customised version of the launcher.

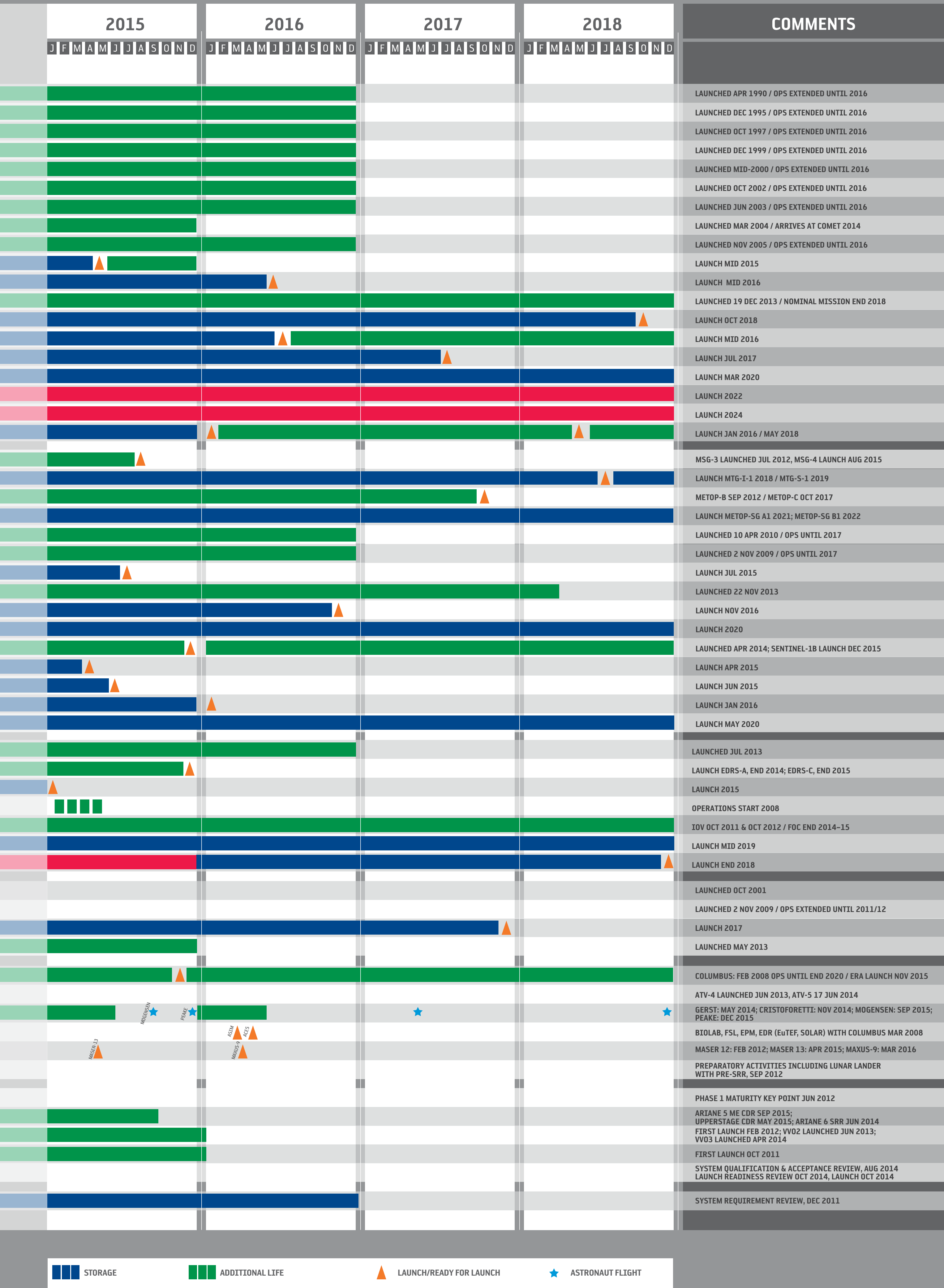
↑ The third Galileo Full Operational Capability satellite being unboxed at the ESTEC Test Centre in the Netherlands in April

→ PROGRAMMES IN PROGRESS

Status at end of April 2014

Sentinel-1A launch on 3 April


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
VENUS EXPRESS
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
SOLAR ORBITER (M1)
EUCLID (M2)
JUICE (L1)
COSMIC VISION M3
EXOMARS
EARTH OBSERVATION PROGRAMME
MSG
MTG
METOP
METEOP-SG
CRYOSAT
SMOS
AEOLUS
SWARM
EARTHCARE
BIOMASS
SENTINEL-1
SENTINEL-2
SENTINEL-3
SENTINEL-5 PRECURSOR
JASON-CS
TELECOMMS/NAVIGATION PROGRAMMES
ALPHASAT
EDRS
SMALLGEO
GNSS-1/EGNOS
GALILEO
ELECTRA
NEOSAT
TECHNOLOGY PROGRAMME
PROBA-1
PROBA-2
PROBA-3
PROBA-V
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS / NODE-2 / NODE-3 / CUPOLA / ERA
ATV
ASTRONAUT FLIGHTS
ELIPS ISS UTILISATION
ELIPS NON-ISS PAYLOADS
TRANSPORTATION & HUMAN EXPLORATION
VITTORI
KUIPERS
PARMITANO
GERST
CRISTOFORETTI
FASES
FASTER
EML
TRIPLELUX-B
PK-4
TRIPLELUX-A
CYTOSKEL
MASER-12
LAUNCHER PROGRAMME
ARIANE 5 POST-ECA
ARIANE 5 ME & ARIANE 6
VEGA
SOYUZ AT CSG
IXV
SSA
PERIOD 2
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS


2015
2016
2017
2018
J F M A M J J A S O N D
COMMENTS
LAUNCHED APR 1990 / OPS EXTENDED UNTIL 2016
LAUNCHED DEC 1995 / OPS EXTENDED UNTIL 2016
LAUNCHED OCT 1997 / OPS EXTENDED UNTIL 2016
LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 2016
LAUNCHED MID-2000 / OPS EXTENDED UNTIL 2016
LAUNCHED OCT 2002 / OPS EXTENDED UNTIL 2016
LAUNCHED JUN 2003 / OPS EXTENDED UNTIL 2016
LAUNCHED MAR 2004 / ARRIVES AT COMET 2014
LAUNCHED NOV 2005 / OPS EXTENDED UNTIL 2016
LAUNCH MID 2015
LAUNCH MID 2016
LAUNCHED 19 DEC 2013 / NOMINAL MISSION END 2018
LAUNCH OCT 2018
LAUNCH MID 2016
LAUNCH JUL 2017
LAUNCH MAR 2020
LAUNCH 2022
LAUNCH 2024
LAUNCH JAN 2016 / MAY 2018
MSG-3 LAUNCHED JUL 2012, MSG-4 LAUNCH AUG 2015
LAUNCH MTG-I-1 2018 / MTG-S-1 2019
METOP-B SEP 2012 / METOP-C OCT 2017
LAUNCH METOP-SG A1 2021; METOP-SG B1 2022
LAUNCHED 10 APR 2010 / OPS UNTIL 2017
LAUNCHED 2 NOV 2009 / OPS UNTIL 2017
LAUNCH JUL 2015
LAUNCHED 22 NOV 2013
LAUNCH NOV 2016
LAUNCH 2020
LAUNCHED APR 2014; SENTINEL-1B LAUNCH DEC 2015
LAUNCH APR 2015
LAUNCH JUN 2015
LAUNCH JAN 2016
LAUNCH MAY 2020
LAUNCHED JUL 2013
LAUNCH EDRS-A, END 2014; EDRS-C, END 2015
LAUNCH 2015
OPERATIONS START 2008
IOV OCT 2011 & OCT 2012 / FOC END 2014–15
LAUNCH MID 2019
LAUNCH END 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 NOV 2015
ATV-4 LAUNCHED JUN 2013, ATV-5 17 JUN 2014
MOGENSEN
PEAKE
GERST: MAY 2014; CRISTOFORETTI: NOV 2014; MOGENSEN: SEP 2015; PEAKE: DEC 2015
ASIM
ACES
BIOLAB, FSL, EPM, EDR (EuTEF, SOLAR) WITH COLUMBUS MAR 2008
MASER 13
MAXUS-9
MASER 12: FEB 2012; MASER 13: APR 2015; MAXUS-9: MAR 2016
PREPARATORY ACTIVITIES INCLUDING LUNAR LANDER WITH PRE-SRR, SEP 2012
PHASE 1 MATURITY KEY POINT JUN 2012
ARIANE 5 ME CDR SEP 2015; UPPERSTAGE CDR MAY 2015; ARIANE 6 SRR JUN 2014
FIRST LAUNCH FEB 2012; VV02 LAUNCHED JUN 2013; VV03 LAUNCHED APR 2014
FIRST LAUNCH OCT 2011
SYSTEM QUALIFICATION & ACCEPTANCE REVIEW, AUG 2014 LAUNCH READINESS REVIEW OCT 2014, LAUNCH OCT 2014
SYSTEM REQUIREMENT REVIEW, DEC 2011
STORAGE
ADDITIONAL LIFE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

KEY TO ACRONYMS

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

→ HUBBLE SPACE TELESCOPE

Hubble has captured images of the break-up of an asteroid, the first such observation in the asteroid belt. The crumbling asteroid, designated P/2013 R3, was noticed in September 2013 and follow-up observations in October revealed three bodies moving together embedded in a dusty envelope about the diameter of Earth. The most recent Hubble observations showed that there are 10 distinct objects, each with comet-like dust tails. The four largest rocky fragments are up to 200 m in radius. The Hubble data showed that the fragments are drifting away from each other at approximately 1.5 km/h. The asteroid began disintegrating early last year, but the latest images show that pieces continue to emerge.

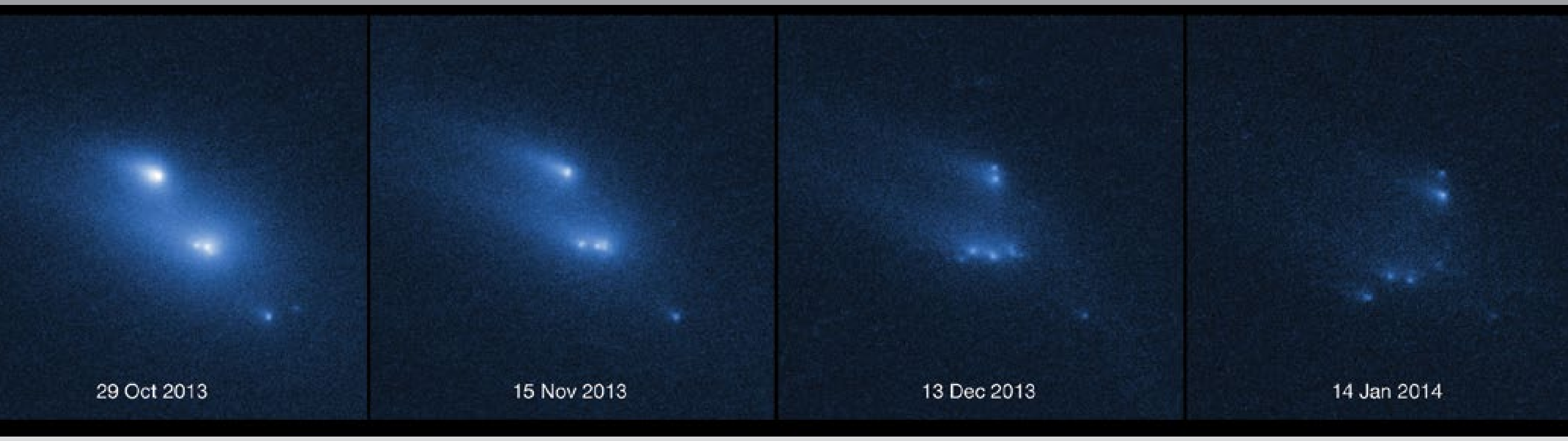
The evidence indicates it is unlikely that the asteroid is breaking up due to a collision with another asteroid or due to the pressure of interior ices warming and vapourising. It is thought the asteroid is disintegrating because of a phenomenon known as the 'YORP' effect, a subtle effect of sunlight that causes the rotation rate to increase slowly over time, which has been discussed by scientists for several years but not previously observed. For break-up to occur, P/2013 R3 is thought to have a weak, fractured interior, probably the result of numerous ancient and non-destructive collisions with other asteroids. P/2013 R3 itself is probably the product of collisional shattering of a bigger body sometime in the last billion years.

→ XMM-NEWTON

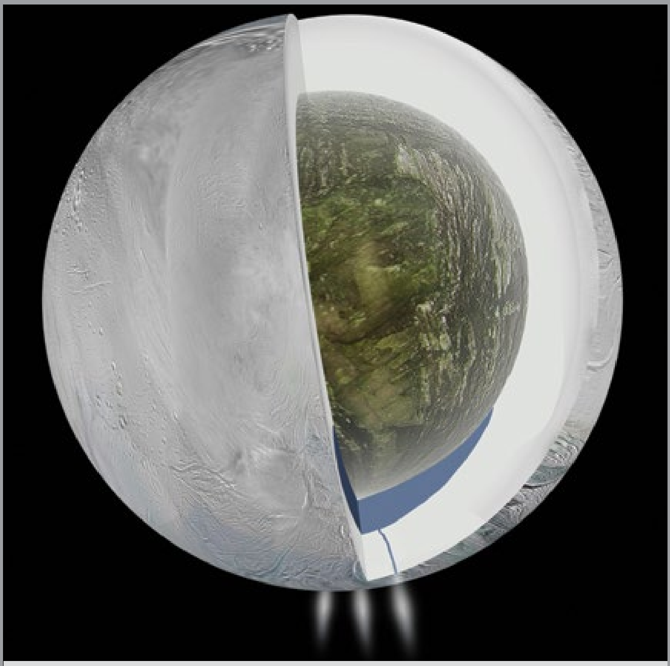
The XMM-Newton Science Operations Centre is organising a major astrophysical symposium, 'The X-ray Universe 2014', 16–19 June, in Dublin, Ireland.

→ CASSINI

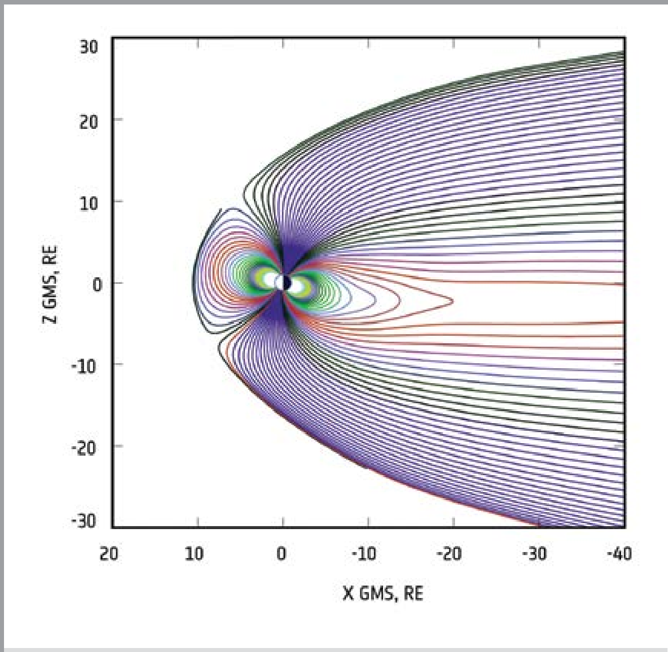
The Radio Science experiment has detected an extended sea deep below the icy crust of Enceladus. The detection was made possible by tracking small anomalies in the mass distribution inside the moon, resulting in tiny changes in the spacecraft velocity as it flew close to the moon. Taking into account the bulk composition of Enceladus, the sea is most likely made of liquid water. Furthermore, it is located beneath the south pole, where cryo-volcanic activity has been recorded and monitored since 2005. Plumes made of ice and water, mixed with organic material, have been observed to originate from a set of narrow fractures in the ice of the south pole of Enceladus, called the 'Tiger Stripes'. Attempts to understand the plume activity relied on the existence of liquid water below the surface, now identified in the radio science data.



Asteroid P/2013 R3 breaking apart, as viewed by the NASA/ESA Hubble Space Telescope. Images run from left to right showing how the clumps of debris material moved over time (NASA/ESA/D. Jewitt, UCLA)



The possible interior of Enceladus based on Cassini's gravity investigation. Data suggest an ice outer shell and a low-density, rocky core with a regional water ocean at high southern latitudes. Cassini images were used to depict the surface geology in this artwork (NASA/JPL)



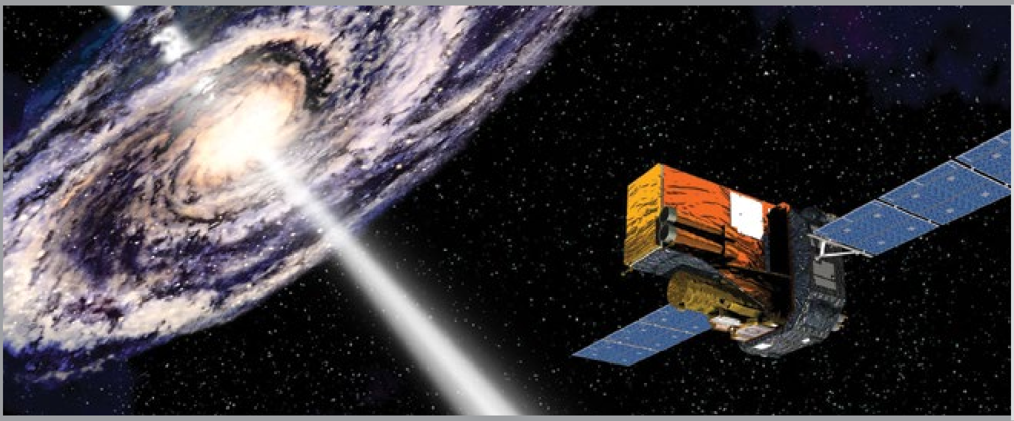
Model of Earth's magnetic field using Cluster data, magnetic field lines are plotted in XZgsm plane. Field lines are coloured according to the magnetic latitude of their footpoints. Earth is the small sphere at the centre (N. Tsyganenko)

→ CLUSTER

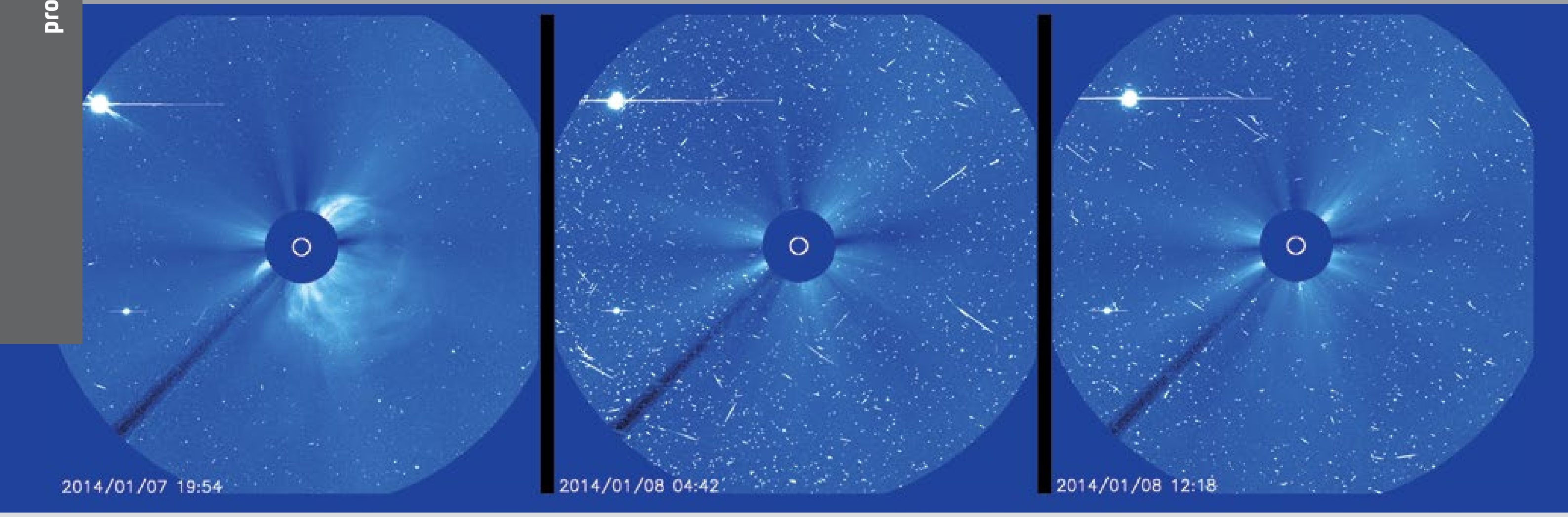
Data from the Cluster Science Data System and Cluster Active Archive are a key input to a new model of Earth's external magnetic field published by N. Tsyganenko. The new model includes the interplanetary magnetic field effect on the magnetopause, geomagnetic storms, realistic ring current and the extension in size up to 50 Earth radii. Cluster data are a key input to derive such models, since they have collected data for more than 13 years and they are now the only satellites covering the high-altitude polar regions. These essential models can be produced to support magnetospheric physicists worldwide.

→ INTEGRAL

Powerful extragalactic radio sources are galaxies hosting active galactic nuclei (AGN), which produce jets and extended radio-emitting regions of plasma. Some of them are characterised by giant structures and are known as Giant Radio Galaxies (GRGs). GRGs are very useful for studying many astrophysical issues, such as understanding the evolution of radio sources, probing the intergalactic medium at different redshifts and investigating the nature of their central AGN. One such source is IGR J17488–2338, recently discovered by Integral.



Integral observing a spiral galaxy with an active nucleus emitting powerful jets

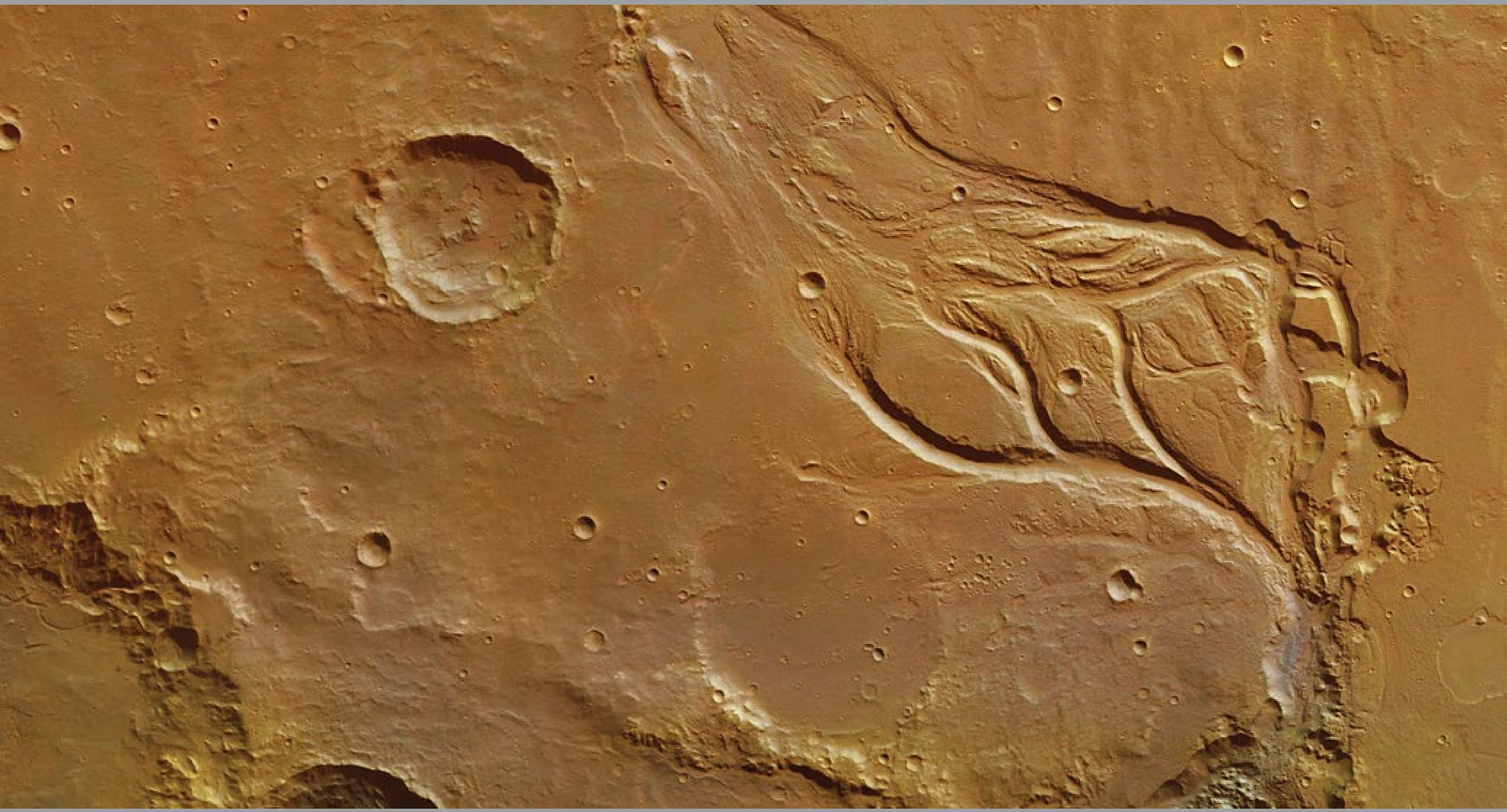


Venus, upper left, just enters the field of view of the SOHO/LASCO C3 instrument, while Mercury, lower left, is just about to leave the field of view (ESA/NASA)

Of 25 radio galaxies detected so far by Integral, this is the brightest object in the sample and also one of the most efficient accretors. IGR J17488–2338 contains a black hole of around a billion solar masses, suggesting that it may be capable of producing a highly powerful jet or of maintaining the activity over a long period of time. Either possibility provides the conditions to form a large-scale radio structure.

→ SOHO

Active region AR1944, containing one of the largest sunspot groups of the last 10 years, unleashed a powerful X-ray flare on 7 January when it was facing towards Earth. The flare was associated with a bright coronal mass ejection (CME).



A fast-moving cloud of high-energy particles accelerated in the flare and the CME front began striking the SOHO detectors soon after, creating the 'snow shower' effect that can be seen in the middle and right figure. The coronal mass ejection hit Earth on 9 January. The impact was weaker than expected. While it failed to produce widespread geomagnetic storms, some beautiful auroras appeared around the Arctic circle. SOHO is 1.5 million km sunwards of Earth, and outside Earth's protective magnetosphere. In these coronagraph images, the Sun is represented by the white circle and is blocked by an occulting disc, so we can observe fainter structures in the Sun's corona.

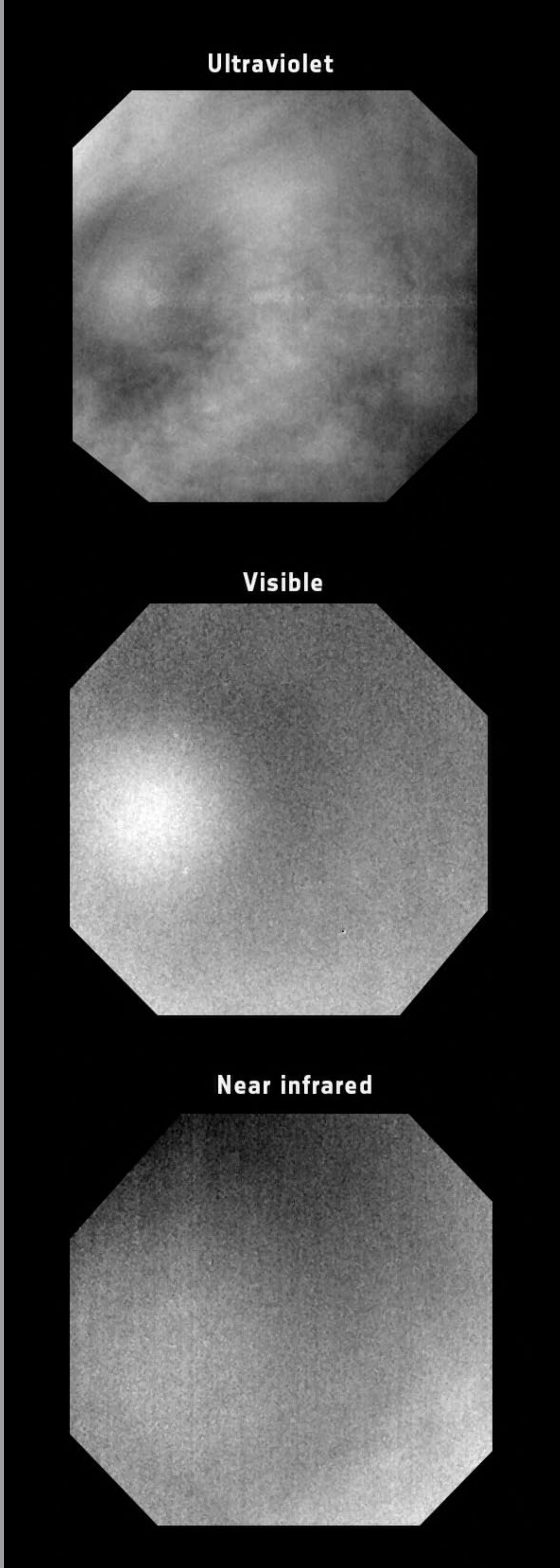
→ VENUS EXPRESS

A rainbow-like feature known as a 'glory' was seen by Venus Express in the atmosphere of our nearest neighbour – the first time one has been fully imaged on another planet. The feature was observed on 24 July 2011 and measures 1200 km across, as seen from the spacecraft, 6000 km away.

→ ROSETTA

The spacecraft came out of hibernation on 20 January. Since then the platform has been thoroughly checked and instrument recommissioning began. In May, instrument

This image was created using data the High Resolution Stereo Camera on ESA's Mars Express on 7 December 2013. The image resolution is about 17 m per pixel and shows the central portion of Osuga Valles on Mars, which has a total length of 164 km. In some places, it is 20 km wide and plunges to a depth of 900 m. This area is at the edge of the far eastern portion of the vast Valles Marineris canyon system. Catastrophic flooding is thought to have created the heavily eroded Osuga Valles, which displays streamlined islands and a grooved floor carved by fast-flowing water. The water flowed in a northeasterly direction (towards the bottom right in this image) and eventually drained into another region of chaotic terrain, just seen at the bottom of the image. Several large impact craters are also seen in this scene, including the ghostly outline of an ancient, partially buried crater in the bottom centre of the image (ESA/DLR/FU Berlin)



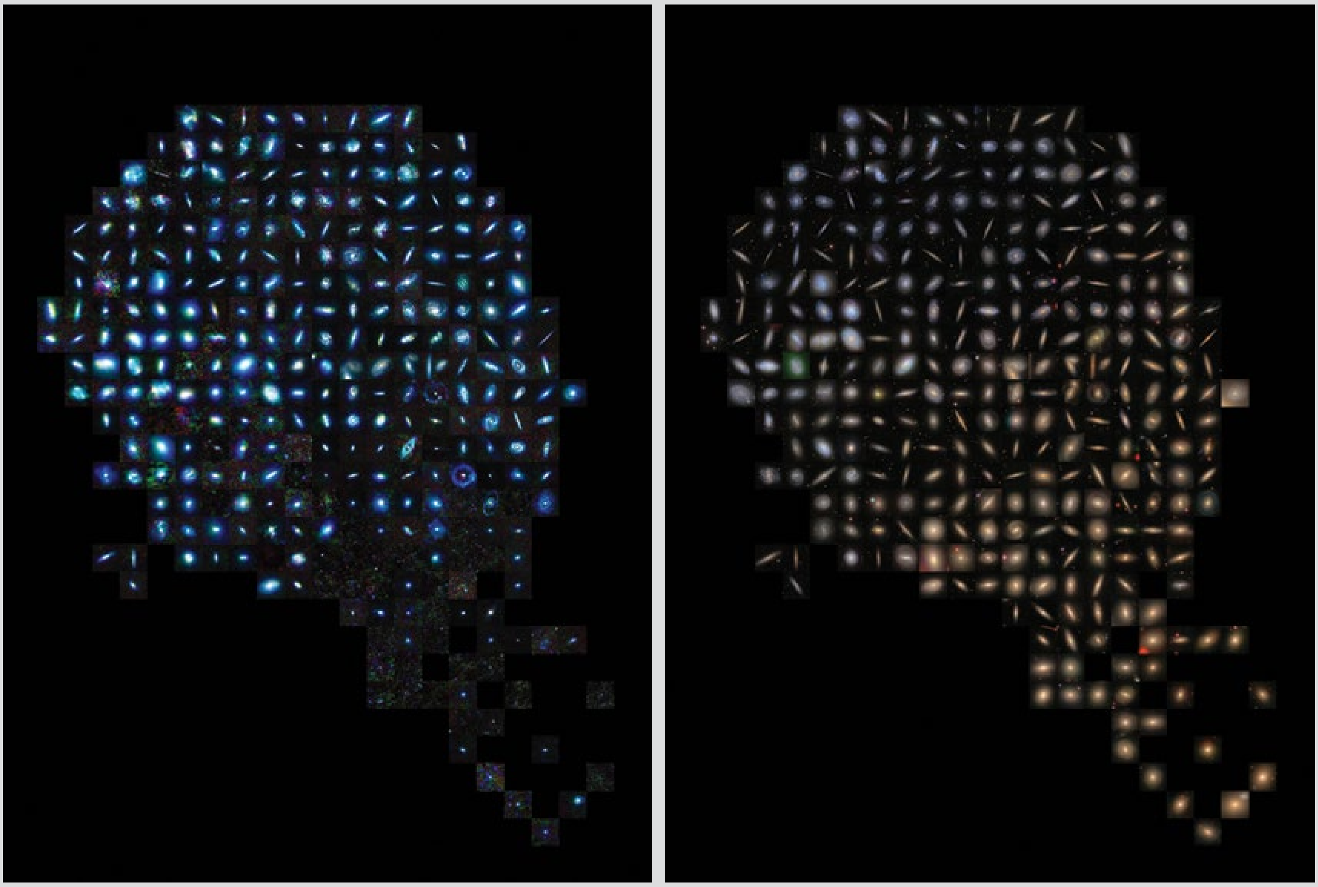
Three images showing the glory phenomena in the atmosphere of Venus in 2011 in ultraviolet (left) visible (centre) and near-infrared (right) wavelengths as taken by the Venus Monitoring Camera on Venus Express (ESA/MPS/DLR/IDA) operations will begin to characterise the comet operationally and identify a landing site for Philae and to provide science measurements from which subsequent observations can be compared as the comet becomes more active.

→ PLANCK

Now in post-operations phase. All data that have been acquired by Planck during its routine operations will be delivered to the public at the end of October. This will include maps based on five all-sky surveys for the high-frequency instrument and eight all-sky surveys for the low-frequency instrument. For the first time, calibrated timelines will also be released, which will allow expert users to produce their own maps. A conference to highlight the scientific results based on these products will take place in Ferrara, Italy, 1–5 December.

→ HERSCHEL

Now in the post-operations phase until the end of 2017. The Herschel Reference Survey is investigating how dust varies with different types of galaxies and how it might affect our understanding of how galaxies evolve. Herschel has observed a representative sample of 323 local galaxies in order to investigate how dust emission in the range 100–500 µm correlates with other galactic properties. The study has looked at galaxies spanning four orders of magnitude in stellar mass, with a wide range of morphologies, cold gas contents, metallicities and star formation activities. The observations show that there is a smooth transition in the nature of dust emission when moving from giant to dwarf galaxies. This variation is related more to the metallicity of the interstellar medium in an individual galaxy than to the mass or morphology of the galaxy.



Comparison of a sample of the Herschel Reference Survey galaxies. Left, Herschel survey galaxies observed in infrared (galaxies are presented in false-colour to highlight different dust temperatures, with blue and red representing colder and warmer regions respectively. The collage is presented with dust-rich, spiral and irregular galaxies in the top left, and giant, dust-poor elliptical galaxies in the bottom right). Right: galaxies observed in visible light obtained by the Sloan Digital Sky Survey (the colour distribution highlights different stellar ages, with red and blue indicating older and younger stars, respectively (ESA/Herschel/HRS-SAG2 and HeViCS Key Programmes/L. Cortese, Swinburne Univ.)

→ GAIA

The commissioning phase has started, due to finish in July. Commissioning activities are progressing after some extra time was needed to eliminate water ice inside the Payload Module. The commissioning is now focused on the final tuning of the instrument (telescopes and focal plane) and on the verification of the scientific performances. Gaia is in normal mode, spinning at four revolutions per day, controlled by the micropropulsion system that uses the focal plane itself as attitude and rate detector. The ground segment is working on producing Gaia's first images.

→ LISA PATHFINDER

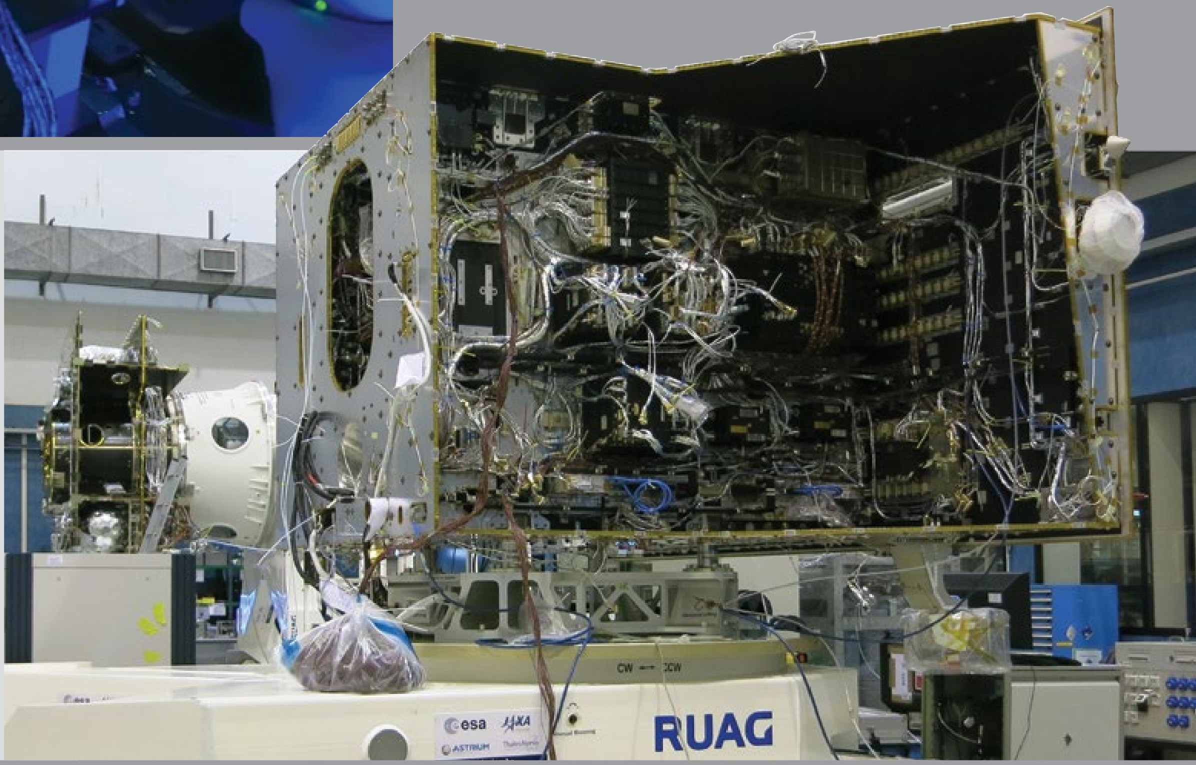
Cold-gas micropropulsion engineering and procurement activities on the LISA Pathfinder Science Module are complete with one unit still under testing. The microthruster drive electronics EM has been integrated in the realtime testbed. Integration of the two Inertial Sensor Head (ISH) FM units is proceeding in parallel. The ISH FMs will be integrated on the LTP Core Assembly (LCA). The LCA includes an optical interferometry ultrastable bench on its support frame, the two ISH units, diagnostics equipment and support equipment. Activities by the launcher authority, ESAC and ESOC are proceeding for a Verta launch on Vega.

The LISA Pathfinder Core Assembly is very sensitive to particulate contamination, seen here during ultraviolet light inspection (Airbus Defence & Space)

→ BEPICOLOMBO

Mechanical and electrical integration of the payload equipment on the PFM Mercury Planetary Orbiter (MPO) is largely complete. The remaining payload equipment to support the MPO spacecraft thermal vacuum test was delivered and integrated. In parallel, spacecraft equipment integration continued and the integrated system tests for the power and communication systems were completed. The integrated communications system test with the MORE experiment is continuing. Work on the Mercury Transfer Module (MTM) proceeded with the completion of the spacecraft harness integration. The four electric-propulsion thruster pointing assemblies were integrated on the thruster floor.

The refurbished EQM solid-state mass memory unit was returned and integrated on the Engineering Test Bench. Testing continued with integrated system tests for a number



BepiColombo Mercury Planetary Orbiter and Mercury Transfer Module Flight Models under integration of scientific instruments alongside preparation for coupling tests with the electric-propulsion system and spacecraft power distribution system.

An independent peer review of the solar panel manufacturing was completed. The findings and recommendations are being followed up. The MPO panel manufacturing is going ahead, but the MTM production capability remains to be demonstrated. Measures to improve the manufacturing process were introduced for the production of new substrate samples and have produced good results.

Most spacecraft equipment has now been delivered and integrated. Launch readiness remains for July 2016.

→ MICROSCOPE

The testing of the first hardware of the ESA cold-gas micropropulsion system is progressing. The delivery to CNES of the electronic controller EQM together with two QM microthrusters is planned for May.

→ EXOMARS

The ESA/Roscosmos cooperation continued with the definition and start of the 2018 mission Descent Module Design Review. The system CDR for the 2016 mission is complete and the collocation of industry and ESA personnel, including the Russian partners began on 31 March.

Schiaparelli Flight Model landing platform with integrated propulsion elements (Thales Alenia Space Italy)

Significant progress continues on the assembly of the Trace Gas Orbiter (TGO) FM and the Schiaparelli Mars entry and landing vehicle. The TGO Mechanical, Thermal and Propulsion (MTP) module was shipped for system integration activities in February. Assembly of the Schiaparelli FM hardware completed its first stage with the integration of the propulsion elements into the landing platform. Software versioning activities for the TGO and EDM are now proceeding and the avionics test benches are receiving various models of electronic units from manufacturers.

The Rover Analytical Design Laboratory and the Rover Vehicle passed their reviews. The related QMs will now be built. An intensive period of procurement activities is underway for the many subcontractor contributions needed for the Rover Module but also for the Descent Module and Carrier Module.

The 2016 mission ground segment has performed a first connectivity test with the TGO avionics test bench and has proven the basic communications protocols for the subsequent system verification testing planned this year.

→ SOLAR ORBITER

The spacecraft primary structure STM completed the static load test. It will now be populated with STMs of various spacecraft and payload units. The spacecraft-level engineering test bench integration and testing activities are continuing. The first version of the central software was delivered.

A serious electromagnetic compatibility problem was identified during characterisation tests of the reaction wheels. Several solutions and mitigations are being pursued in parallel, including using other wheels and adding shielding.

Significant progress has been made in the analysis of the mission downlink availability for data return and spacecraft attitude for satisfaction of *in situ* instrument requirements. The schedule of the solar generator continues to be a concern. Capacity increases and additional suppliers for various subelements are being put in place.

The second METIS PDR is running. Various instrument STM items have been delivered to the prime contractor facilities, others are going through their Delivery Review Boards. Progress of both the science ground segment and the operational ground segment is on schedule.

NASA has awarded the contract for the launch vehicle to a subsidiary of United Launch Alliance for an Atlas V 411. The launch date is July 2017 with a back-up launch date of October 2018.

→ JAMES WEBB SPACE TELESCOPE (JWST)

The NIRCam and NIRSpec instruments were integrated on the Integrated Science Instrument Module (ISIM) FM. The next step is system functional testing followed by the second ISIM cryo-performance test. The spacecraft CDR was completed.

NASA completed the manufacturing of three new microshutter arrays for NIRSpec. Four are required for the planned rebuild of the microshutter assembly FM. NASA has also completed the NIRSpec detector rebuild and the acceptance test campaign is under way.

After lengthy problems, a compliant heat lift performance was measured on the MIRI verification model coolers and work is now taking place to finish the flight coolers.

→ EUCLID

Contracts have been awarded for PLM units, including the secondary mirror mechanism, the mirror polishing, the external baffle and the optical ground support equipment. The PLM is undergoing a PDR. SVM activities are proceeding with the prime contractor submitting a data package to the SRR that was completed in February. The subcontractor for the fine guidance sensor has been selected and preparation for the subsystem layer procurement is proceeding.

The detector system is composed of three units: a HgCdTe hybrid detector, a flex cable and a proximity electronic unit packaged into an Application Specific Integrated Circuit. Teledyne Imaging Sensors (USA) has manufactured all the necessary detectors for the Evaluation and Qualification phase, which show very good performance. The proximity electronic unit had some mechanical problems and a redesign was necessary. This has caused a delay in the qualification test phase, which is now due for completion in the autumn. The flight production phase, under NASA/JPL responsibility, will start in parallel in order to limit the schedule delay.

The procurement of the CCD detectors for the Visible Imager Instrument (VIS) is also proceeding. Many of the STM devices have been delivered and the QM/FM

Integration of NIRSpec onto the Webb ISIM Flight Model (NASA)

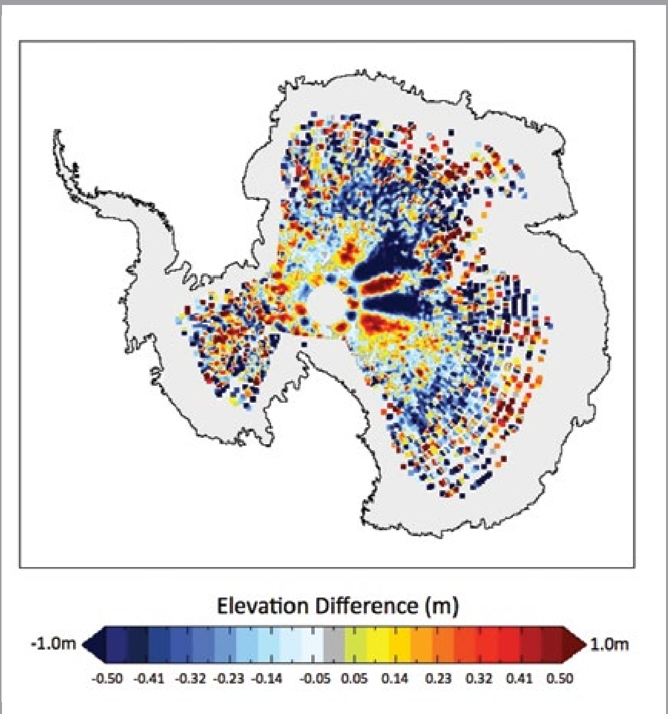
production of the various parts is proceeding on to schedule. The team leading the VIS development at Mullard Space Science Laboratory prepared a PDR data package, reviewed by ESA in March. The NISP PDR has also started. The science ground segment team is now working on the preparation of the SRR for the end of the year.

→ SMOS

The satellite continues to operate beyond its planned lifetime. A second reprocessing of the entire SMOS dataset is planned later in the year.

→ CRYOSAT

In January, the scientific community published important results about an unusual pattern in the Antarctic ice sheet's elevation. Scientists found that the wind-driven features of the ice sheet can modify altimetry radar measurements in such a way as to produce a pattern. The behaviour had been theoretically proposed previously in literature but CryoSat provided the first observed evidence of the relationship.



Elevation differences over Antarctica as measured by CryoSat in November 2013. There is a distinct pattern of alternating high and low elevations (red and blue), which inverts closer to the South Pole. After careful analysis, it was discovered that this is an artefact caused by the interaction of the polarisation of CryoSat's antenna with the structure of the ice (ESA/MSSL)

→ SWARM

In-orbit commissioning activities have been completed. All three satellites are working normally and the ground segment is functioning as planned. Swarm data have been routinely processed and distributed to 'special users' including project, prime contractor, instrument providers and the three lead proposers. Swarm A and B are already at their final orbit altitudes and Swarm C will reach its final position in early April. The flight operations segment and the payload data ground segment are ready to enter routine operations.

→ ADM-AEOLUS

Airbus Defence & Space Toulouse completed the electrical and functional testing of the first laser transmitter FM in its nominal configuration. In parallel, preparations are in progress for the second optical bench assembly high fluence test, designed to verify the flightworthiness of the transmit path optics. In Selex ES, the integration of the second laser FM was completed and the acceptance test campaign began with the initial functional and performance tests. The platform remains in storage and periodic maintenance of the reaction wheels is conducted in order to verify their performance.

→ EARTHCARE

The spacecraft Base Platform is being set up into a 'flat-sat' configuration to prepare for the electrical and avionics hardware PFM integration. Most of the ATLID instrument subsystem CDRs have been conducted. Following the environmental tests of the transmitter master oscillator QM, the CDR of the transmitter has also been initiated. In parallel, SELEX is preparing for the integration of the first laser head FM.

The Broadband Radiometer (BBR) optical head PFM assembly is proceeding and the test campaign of the redesigned BBR mechanism life-test model has been initiated. The multispectral instrument PFM manufacturing release has taken place for both thermal camera and VNS camera. A local redesign of the filter and dichroic holder assembly took place to improve shock robustness.

In Japan, JAXA and its main contractor NTS are finalising the cloud profiling radar (CPR) interface CDR documentation and are proceeding with the CPR PFM production. The ground segment PDR, encompassing the Japanese element, was concluded.

→ BIOMASS

Biomass is the seventh and latest addition to the family of Earth Explorer missions. It will measure the amount of biomass stored in the world's forests and determine the annual changes over the mission lifetime, with the main scientific objective to reduce uncertainties in the understanding of the carbon cycle for climate modelling and to monitor land use change and deforestation. Forests contain about 80% of the terrestrial above-ground biomass and roughly 50% of biomass is carbon.

Biomass is a single-instrument mission and carries a low-frequency, fully polarimetric and interferometric P-band SAR into a Sun-synchronous low Earth orbit.

The mission was approved in May 2013 and is currently in its mission definition phase, with two parallel and competitive industrial studies. These studies will end in autumn, after which the two consortia will compete for the mission implementation contract.

→ METEOSAT

Meteosat-8/MSG-1

Located at 3.9°E longitude, the operational back up for Meteosat-9 and -10.

Meteosat-9/MSG-2

Located at 9.5°E longitude, providing the Rapid Scan Service complementing the full-disc mission of Meteosat-10.

Meteosat-10/MSG-3

Located at 0° longitude, performing the full-disc mission, data collection, data distribution and search and rescue missions.

MSG-4

Following the repair of the Scan Drive Unit and of the Calibration Motor, the SEVIRI instrument has been reintegrated on MSG-4. Integration and testing activities, in particular, the acoustic vibration test and the thermal vacuum test, are taking place in preparation for launch. Based on the current planning, MSG-4 will be ready for launch in July 2015, although a launch date is yet to be agreed between Eumetsat and Arianespace.

→ MTG

Stable baselines have been established at satellite level for MTG-I and MTG-S. Development is now focused on subsystem and unit design. Key performance-related system activities are being continued, such as the in-orbit calibration methodology for the scan assembly, which is necessary to achieve the geometrical performance of the Flexible Combined Imager (FCI) and Infrared Sounder (IRS) instruments.

An industry-led working group was established at the end of 2013 with the aim of recovering compliance with the agreed customer instrument mass targets of 3600 kg and 3800 kg for MTG-I and MTG-S, respectively. This mass optimisation process should conclude by late May.

For the platform PDR, progress continues towards the final consolidation of the major subsystem reviews. For both FCI and IRS, the design consolidation continues with the implementation of mitigation measures for predicted performance non-compliance and mass optimisation.

→ METOP

MetOp-A

The satellite will operate in parallel with MetOp-B until the commissioning of MetOp-C.

MetOp-B

Eumetsat's prime operational satellite.

MetOp-C

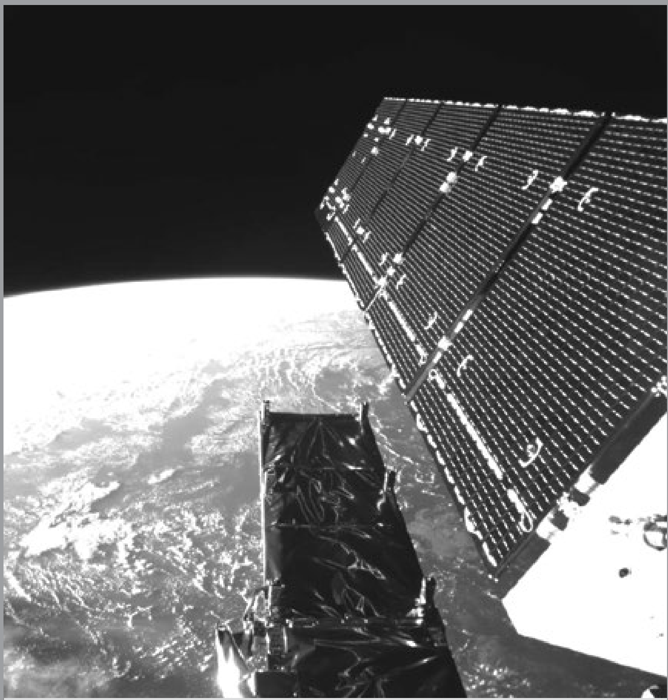
The satellite is in storage, with a nominal launch slot planned for October 2017 on Soyuz from French Guiana.

→ METOP-SG

The second generation of MetOp satellites (MetOp-SG) is planned to continue and enhance the observations provided by the current first-generation satellites. MetOp-SG will consist of two series of satellites and will provide the operational meteorological observations from polar orbit for 2021–45. A competitive ITT was released in September 2013 and the resulting industrial offers are under evaluation.

→ SENTINEL-1

Sentinel-1A was launched on a Soyuz rocket from French Guiana on 3 April. ESOC received the first telemetry 26 minutes after liftoff and took control of the satellite. The first command was the deployment of the Synthetic Aperture Radar antenna and the solar array wings. Four hours later, the solar array was charging the satellite's batteries and six hours later all appendages were fully deployed and locked.



Sentinel-1A deployed in orbit: the satellite's own view of its solar wing and radar antenna

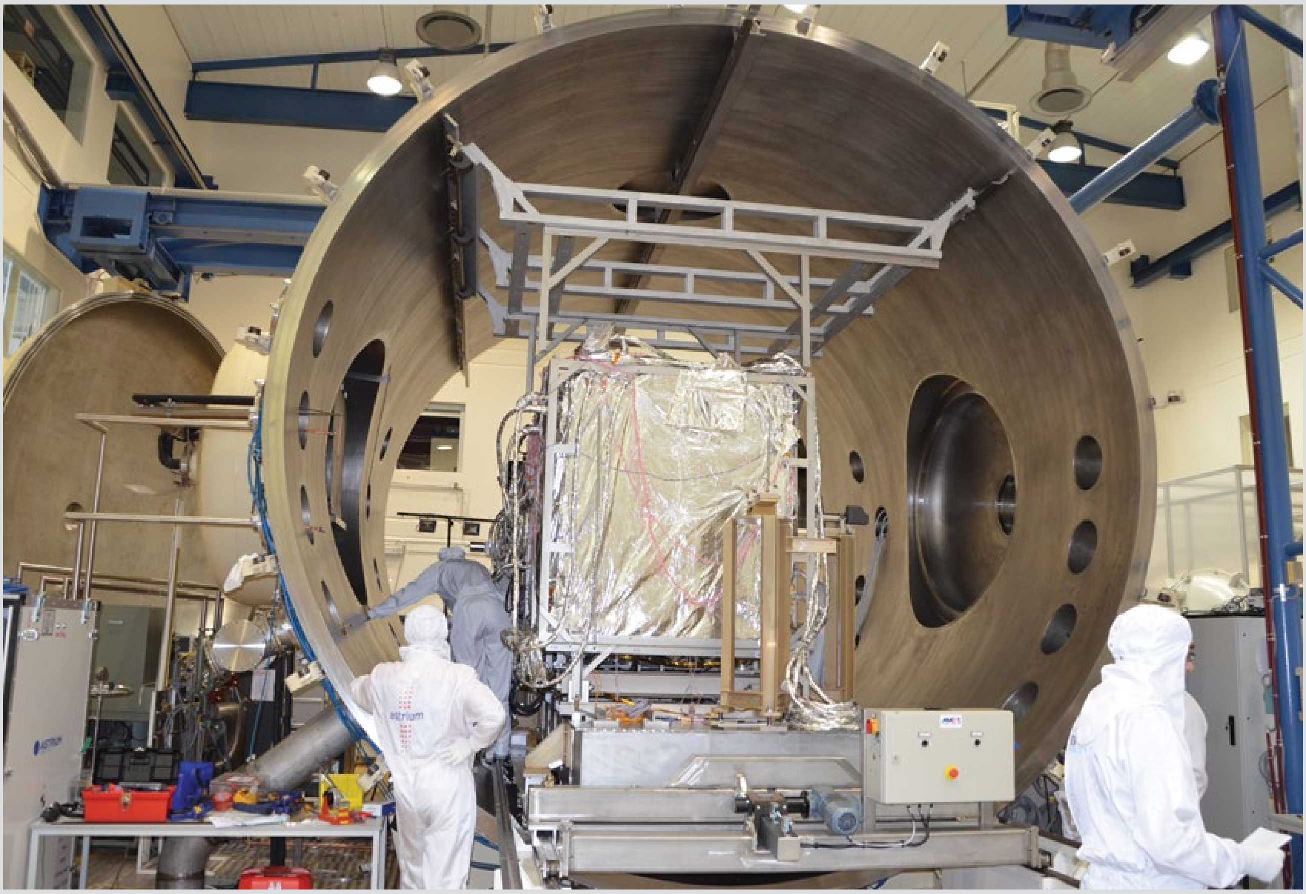
All subsystems were switched on and their good health confirmed. On 6 April, the Synthetic Aperture Radar instrument was switched on. LEOP was completed three days after liftoff for commissioning activities to begin. The industrial team are continuing the assembly, integration and tests of Sentinel-1B.

→ SENTINEL-2

The Sentinel-2A Multispectral Instrument PFM underwent its EMC and mechanical qualification tests. The instrument is currently undergoing the final thermal vacuum qualification test prior to delivery for integration at satellite level in May.

The two focal planes of the second instrument FM are being integrated and tested, with an instrument delivery forecast for July 2015, in line with a predicted April 2016 launch for Sentinel-2B.

The Optical Communication Payload (OCP) STM is expected for integration from TESAT-D and DLR in April. The OCP FM should be delivered in October. The Reaction



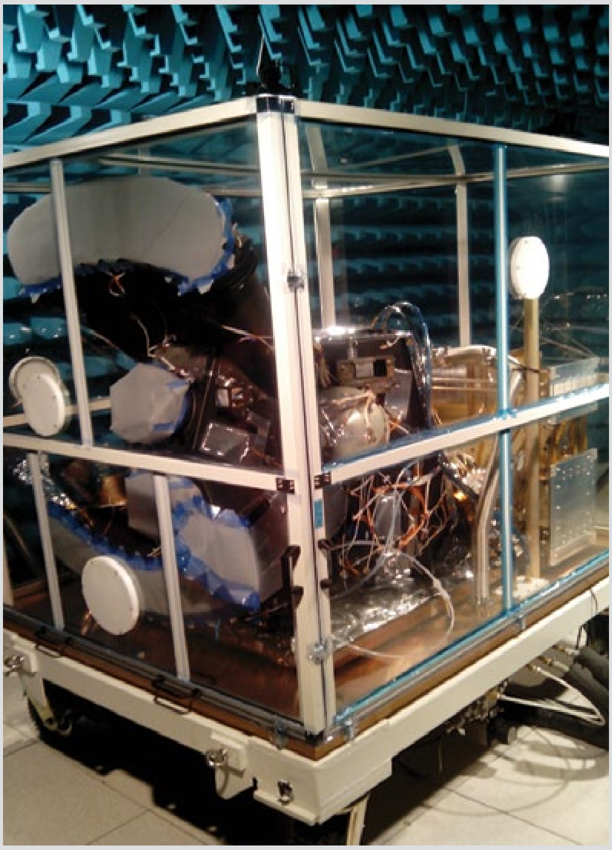
Sentinel-2 Multispectral Instrument ready for thermal vacuum qualification testing at CSL, Belgium (Airbus Defence & Space)

Wheel Assemblies are expected in April. The PFM spacecraft should start the satellite environmental test campaign in July.

Satellite in-orbit commissioning preparations are conducted with the close involvement of the ESOC and ESRIN ground segment teams, and CNES is supporting the project in the area of instrument calibration, validation and image quality. The second 'Sentinel-2 for science' workshop at ESRIN, in May, will gather the user communities, one year prior to the Sentinel-2A launch, to present plans for the exploitation of the Sentinel-2 operational mission.

→ SENTINEL-3

The environmental test campaign for the Sentinel-3A satellite is planned for summer 2015. The avionics and topography payload integrated system test has been completed. The integration of the Ocean and Land Colour Instrument (OLCI) and the Sea and Land Surface Temperature Radiometer (SLSTR) instruments are planned later this year. The SLSTR PFM is completing predelivery testing. All tests so far have confirmed proper operation of the instrument, which will be submitted to vibration testing. OLCI PFM integration and testing is proceeding following delays due to modifications to the OLCI Electronic Unit.



The Sentinel-3 SLSTR Protoflight Model being prepared for EMC testing at Selex in Florence (SES)

In parallel to the Sentinel-3A activities, the Sentinel-3B platform activities have been completed. Formal release of the updated version of the ground prototype processors and the system performance simulators for both the optical and topography missions has taken place.

→ SENTINEL-4

The S4-UVN instrument prime contractor plans are due for submission. Several subsystems PDRs have been held. The majority of the remaining subsystems PDRs are due to be completed shortly. The Mission Advisory Group, which met in March, focused on instrument geo-coverage and occurrence of potential saturation of the instrument.

→ SENTINEL-5

The mission objective is to monitor the composition of the atmosphere and is part of the Copernicus Space Component Programme. The Sentinel-5 instrument will be carried on the MetOp-SG satellite A series. The service it will provide is focused on air quality monitoring and composition/climate interaction with the main data products being O_3, NO_2, SO_2, HCHO, CO and CH_4 concentrations and aerosol optical depth with daily global coverage. To achieve this goal, the instrument will consist of a wide-field imaging spectrometer covering ultraviolet, visible, near-infrared and shortwave infrared bands.

Following an ITT, a consortium led by Airbus Defence & Space was selected as prime contractor. Work is now focused on finalising configuration trades and the establishment of the complete industrial team. The first set of best-practice procurements, related to the shortwave infrared and CCD detectors have been issued. Coordination with Eumetsat for the ground segment activities has started. In order to complete the funding of the programme, the Phase-2 of the Copernicus Space Component Segment-3 has been opened for subscription.

→ SENTINEL-5 PRECURSOR

Platform AIT programme is progressing. A fully mechanically integrated and electrically tested platform, including all flight software, is expected in April. System validation testing (SVT-0) of the platform in conjunction with the Flight Operations Segment is scheduled for May.


Integrated Flight Model Platform in Stevenage, UK (Airbus Defence & Space)

For the ground segment, preparations are under way for a CDR in May or June. Following installation of updated versions of the Level-1b and Level-2 processors in the payload data ground segment, integration tests have started and first results on the runtime performance of critical CPU demanding processors have been obtained.

Following negotiation for the Rockot launcher procurement, the contract began in January. The SRR was held in March, with the preliminary mission analysis review scheduled for July.

→ SENTINEL-6/JASON-CS

Mission funding progressed with funds coming from ESA and the EU. The remaining parts, from Eumetsat and NOAA, are in the approval process. Eumetsat held the first part of the Jason-CS SRR.

Detailed design of the satellite is in progress with two subcontractors selected to study different aspects of the monopropellant propulsion subsystem. This is a major design driver for the satellite, because it has to be able to perform a major orbit change at its end-of-life to comply with space debris mitigation requirements. This is more difficult than normal because of the high operating orbit of Jason-CS/Sentinel-6, at 1336 km altitude. A study has started using the SCARAB tool to perform a detailed modelling of the reentry and break-up process.

→ ALPHASAT

The spacecraft and the main Inmarsat L-band payload are performing well. The ESA Technology Demonstration Payloads (TDPs) on Alphasat are providing experimental results to industry and science groups across Europe. Critical tests of the Laser Communications Terminal were conducted in March with the ESA optical ground station in Tenerife, confirming that all parameters are correctly tuned and aligned. Testing has also started for the Aldo Paraboni Q/V-band payload and implementation of the network of receivers for the propagation beacons. The ESA/Inmarsat In-Orbit Acceptance Review Board was held in April, confirming that the operations phase for TDPs and for Alphabus platform monitoring will run up to end-2016.

The Alphabus programme extension phase is continuing with work on the Deployable Panel Radiator, the CDR process began in March.


An Alphabus-based telecommunications satellite, with deployable panel radiator to increase thermal rejection capability (Airbus Defence & Space)

The Hispasat-AG1 repeater module arrives at OHB in Bremen, Germany

→ SMALLGEO

After integration and test activities at TESAT, the Hispasat-AG1 repeater module arrived at OHB in Bremen, Germany. Tests confirmed the performance of the Ku- and Ka-band repeaters. The Ku-band repeater features new-generation regenerative processor units. The repeater was also tested with the Direct Radiating Array ELSA antenna allowing the generation and control of four receiving spot beams at Ku-band.

The AG1 repeater includes a number of new technologies, including a flexible digitally controlled microwave power module, an innovative payload interface unit, dielectric IMUX and aluminium temperature-compensated OMUXs for both Ku- and Ka-band and new low-noise amplifiers and down converters in Ku- and Ka-bands.

The repeater module will now be prepared for mating with the SmallGEO platform, currently under integration and test at OHB. The Hispasat-AG1 satellite will then go through its environmental test campaign before launch.

→ EDRS

EDRS-A payload integration activities at Airbus Portsmouth are complete. Mating of the integrated communication module with the SVM was completed in March and the first switch-on of the integrated EB9B satellite followed. The baseline payload performance tests are under way and will be followed by the satellite's environmental test campaign. The Laser Communications Terminal is due for delivery to Airbus Toulouse in May for integration on the satellite.

EDRS-C satellite CDR began in April. This marks the formal start of the Phase-C/D for EDRS-C. The mission CDR is planned for the end of 2014. The first structural elements of EDRS-C are being manufactured and the structure's central tube is the first element to have completed manufacturing.

Development of the ground segment hardware is in progress. Several system validation tests ensuring operability of the EDRS-A mission through the ground segment are to be carried out this year as part of the EB9B satellite AIT campaign. All ground segment hardware is being manufactured and the stations in Weilheim, Redu and Harwell are being built.

The EDRS-C structure central tube

Bertrand Maureau, Vice-President, Business Line Telecom of Thales Alenia Space, Magali Vaissiere, ESA's Director of Telecommunications and Integrated Applications, and Eric Béranger, Head of Space Systems/Programmes (Airbus Defence & Space), signed the Neosat Phase-B contract in Paris in February

→ NEOSAT

The objective of ARTES 14 element, Neosat, is to develop and qualify Next Generation Platform product lines allowing the two European satellite prime integrators, Airbus Space & Defence (FR) and Thales Alenia Space (FR) to deliver competitive satellites (in the 3–6 tonne launch mass range) to the commercial satellite market to address future satellite operators' needs. The programme, implemented in cooperation between ESA and CNES, includes the in-orbit validation of the new platform product lines, with PFM delivery in orbit by end of 2018 or early 2019. Phase-A activities concluded with the architectural design review in March. The ARTES 14 Phase-B contract was signed on 20 February with Airbus Defence & Space and Thales Alenia Space.

→ ELECTRA

Electra is the first Public Private Partnership developed under ARTES 33. It aims at developing, launching and validating in orbit a telecommunications satellite system below three tonnes launch mass, based on an innovative platform using full electric propulsion for transfer to geostationary orbit as well as for stationkeeping. The contract for Phase-B1 was signed in October 2013. The SRR is now complete and the satellite prime contractor, OHB-System GmbH, is issuing request for proposals for the different platform equipment.

→ ADAPTED ARIANE 5 ME AND ARIANE 6 ACTIVITIES

Adapted Ariane 5 ME

Launcher system, software and electrical systems, avionics and upper part composite activities are proceeding according to schedule. A first meeting with Arianespace on ground–board interfaces took place in February. The Key Point report is being finalised, with a steering committee scheduled in April.

Upper Stage and Commonalities

The Vinci M5 test campaign achieved an important milestone with its 11th test sequence. The motor underwent four consecutive ignitions, which is a major achievement. The last sequence was stopped due to unexpected dynamic behaviour of the engine. The cause is being analysed and tests are planned to restart in mid-May. The oxygen turbopump tests have started. The PDR for upper stage Hot Gas Reaction System (HGRS) activities was completed on 7 April. The project will proceed with the implementation of the HGRS into the Ariane 5 ME baseline definition.

Ariane 6

The Rider 1 to cover the full Phase-B1 up to the launch SRR was signed in February. During the First Design Analysis Cycle (DAC-1), held in December, some options on the launcher architecture were confirmed, including separated tanks for the upper stage, delayed ignition of the central Solid Rocket Motor (SRM) of the lower stage, and introduction of lateral SRM loads by the aft skirt. The DAC-1 Key Point and DAC-2 began in March. A project Key Point will review and decide on possible conservative measures to ease a later evolution of the Ariane 6 concept to adapt to the market.

→ VEGA

Work continued on the generic qualification review, closure of the flight anomalies identified during the VV02 flight exploitation, preparation of the VV03 flight, implementation of improvements on the launch system aiming at reducing costs and preparation of next Vega exploitation and Verta flights.

The flight programme software generic qualification tests are completed and the generic qualification review steering board took place on 11 February. The VV03 launch campaign started in February and the flight readiness review took place on 28 February. Launch is scheduled for 28 April.

Vega C Phase-A activities are completed, and a review of the suitability and compliance of technical requirements is planned. In parallel, the negotiation of the VECEP proposal has started. The contract proposal will be presented to the Industrial Policy Committee in May for signature in June.

→ IXV & PRIDE

The development, qualification, integration and acceptance activities for the IXV flight and ground segments are progressing well, including preparation of the IXV flight and ground segments deployment worldwide and the launch campaign for the mission. The vehicle will be shipped to Kourou by August for a launch at the end of October. The Pride programme objectives are being reassessed to maximise the return on the technology investments in view of potential future scenarios.

→ FUTURE LAUNCHERS PREPARATORY PROGRAMME

System, demonstrators, technologies

The deployment of the integrated requirements downflow is in place for integrated demonstrators including Cryotank, Expander Cycle technology, POD-X, SRM composite casing, Engine Thrust Frame and Opto Pyro systems.

Propulsion

The POD-X test took place in March. Manufacturing and testing is progressing as planned for hybrid propulsion and the first full-scale hot fire testing is planned for later this year. Expander Cycle technology activities are in progress. The thrust chamber assembly concept review, incorporating the combustion chamber, nozzle extension and igniter, has been performed.

Technologies

The Cryotank demonstrator contract is in place and the PDR was passed in February. The SRR for the SRM composite casing demonstrator was passed in January.

→ HUMAN SPACEFLIGHT

The launch, rendezvous, docking and undocking of Orbital Sciences' first Cygnus Commercial Resupply Service mission CRS-1 (Orbital-1 *C. Gordon Fullerton*) took place in January. The period also saw the undocking of Progress 52P and the launch and docking of Progress 54P. The scheduled launch of the SpaceX CRS-3 Dragon spacecraft was delayed to 18 April because of an issue at the Kennedy Space Center range radar site.

The transition from ISS Expedition 38 to Expedition 39 took place in March. On departure of Expedition 38, Koichi Wakata (JAXA) took over from Oleg Kotov as ISS Commander (Expedition 39), as the first Japanese Commander of the ISS. The Expedition 39/40 crew, Steve Swanson (NASA), Alexander Skvortsov (Roscosmos) and Oleg Artemyev (Roscosmos), was launched on Soyuz TMA-12M on 26 March. The four-orbits-to-docking manoeuvre was unsuccessful when the Soyuz spacecraft was unable to complete its third engine burn once in orbit. Soyuz reverted to the two-day (34 orbits) manoeuvre, which was the standard rendezvous profile until last year.

→ ASTRONAUTS

Alexander Gerst (DE) completed his ATV Part 2 training in January. In February, he undertook payload training and underwent preflight medical examinations in preparation for the first direct return to EAC after landing (and therefore collection of important initial postflight baseline data in Europe). Alex is scheduled for launch to the ISS in May as part of Expedition 40/41, on the European 'Blue Dot' mission.

Alex Gerst during training on the plant gravity- sensing experiment, at JAXA's Tsukuba Space Center, Japan, in March

Thomas Pesquet, on the announcement in March of his assignment to Expedition 50/51, a long-duration mission to the ISS in December 2016

Tim Peake and Samantha Cristoforetti training in medical procedures at the Uniklinik Hospital, Cologne, Germany (Uniklinik Köln/MFK)

Samantha Cristoforetti (IT) and Tim Peake (GB) both had Field Medical Training in January. Samantha's training continued at EAC in February and March with payload training, medical activities and baseline data collection. Tim trained at the Johnson Space Center, Houston, in February. Samantha is scheduled for launch later this year as a member of Expedition 42/43. Tim is assigned to fly to the ISS on a long-duration mission at the end of 2015 as a member of Expedition 46/47.

Andreas Mogensen (DK), set to fly on a Soyuz mission to the ISS in 2015, trained with Thomas Pesquet (FR) at the Gagarin Cosmonaut Training Centre in Star City, Moscow, in February. Thomas Pesquet's assignment to Expedition 50/51, a long-duration mission to the ISS in December 2016, was announced on 17 March.

ATV *Georges Lemaître*

The ATV-5 launch date has been set for 25 July for a docking on 12 August. ATV-5 will perform the LIRIS sensor demonstration experiment before docking.

Packing late cargo on ATV *Georges Lemaître* in January at Europe's Spaceport in Kourou, French Guiana (ESA/CNES/Arianespace/Optique Video du CSG)

In April, around 1500 kg of cargo was loaded into ATV *Georges Lemaître*. Here, cargo waits for loading, as another 1130 kg is expected to be loaded as late cargo in June or early July (ESA/CNES/Arianespace/Optique Video du CSG)

European Robotic Arm (ERA)

Roscosmos confirmed in March the delay of the Multipurpose Laboratory Module (MLM)/ERA launch to not earlier than the end of 2016. The Roscosmos schedule on the MLM repair is overdue, and is expected by the end of April. In the meantime, a new critical non-conformance was found in the Integrated Service Tool, the screwdriver at the end of the ERA arm.

→ RESEARCH

The International Life Science Research Announcement in coordination with ASI, CNES, DLR, NASA, CSA and JAXA was released on 28 February.

Technology on ISS

ESA's Ham Video hardware was installed in Columbus and commissioned in March. The ARISS (Amateur Radio on the International Space Station) ground station at Matera (IT) tested video and audio signals with different frequencies via different ISS antennas. ISS Ham Video will also produce valuable imagery for use in education and promotion activities.

Biology on ISS

No research activities took place between January and March, following extensive maintenance and commissioning activities for the Biolab facility at the end of 2013. Final preparations are now under way for the start of the Gravi-2 experiment in the European Modular Cultivation System. Gravi-2 is still awaiting the launch on the SpaceX CRS-3 Dragon spacecraft. The Gravi-2 experiment continues the research undertaken within the Gravi-1 experiment in determining the threshold of perception of gravity by lentil roots.

The DCMIX-2 experiment completed sample runs using the Selectable Optical Diagnostic Instrument (SODI) in the Microgravity Science Glovebox in the US Laboratory. The experiment data were returned to the ground in March. SODI-DCMIX 2 is supporting research to determine diffusion coefficients in different petroleum field samples and refine petroleum reservoir models to help lead to more efficient extraction of oil resources.

Radiation research on ISS

The Dose Distribution inside the ISS 3D experiment (DOSIS-3D) continued using both active radiation detectors in the European Physiology Modules facility. In January, the active detectors of DOSIS were set to a higher acquisition mode because of increased solar activity. The set of DOSIS-3D passive detectors was returned to Earth for analysis. A new set of passive detectors arrived on Soyuz TMA-12, which were deployed at various locations in the Columbus laboratory on 28 March. The active detectors make timedependent cosmic radiation measurements, while the passive detectors are used for 'area dosimetry' – measuring spatial radiation gradients inside Columbus.

Non-ISS research in ELIPS

The latest Concordia winter-over season including nine ESA experiments and 13 crewmembers started in February.

The new contract was signed for the use of the Drop Tower in Bremen (DE) until the end of 2016. By the end of March, four campaigns had been completed on the new contract, with 50 drops/catapult shots in total. A further five campaigns are scheduled this year with a total of 54 drops.

With the recent completion of the Casting of Large Ti Structures (COLTS) project, the other advanced materials research projects with the European Commission (ThermoMag, Accelerated Metallurgy, ExoMet, AMAZE) are progressing. In Accelerated Metallurgy, patents are being actively used in the project and metallurgy trials have been conducted at ESA, Airbus and Birmingham University (GB). Close links with ELIPS projects are exploited in terms of science team members and flight experiments.

→ EXPLORATION

Multi-Purpose Crew Vehicle European Service Module (MPCV-ESM)

Recovery measures were implemented to get back on track for FM1 shipment date of March 2017. The mass non-compliance has been improved, and the remaining over mass is considered manageable. Savings have been identified with a new concept of a bellow water tank. Deletion of a Command (and) Monitoring Unit should allow a further saving. Clarification on Thermal Control System mass increase and assessment of an alternative radiator layout is under way. The MPCV mission data for the ESM design and verification were baselined. The Crew Module Adapter SM mechanical interface design was agreed. The MPCV PDR is scheduled for 15 May with all intermediate milestones achieved.

International Berthing Docking Mechanism (IBDM)

The work plan for the coming year was discussed with prime contractor, QinetiQ (BE). It will be based on the development of the new version of the docking mechanism, which is compliant with the most recent version of the International Standard, and also with its application to the US Dream Chaser crew vehicle.

International Docking Standard System (IDSS)

NASA has adopted mechanical latches for their system, which is the baseline for the IDSS Revision C. NASA will provide available information and the preliminary design of the mechanical latches at the CDR of their mechanism in May.

Operation Avionics Subsystem (OAS)

The third phase of activity is advancing with the development of a crew vehicle mock-up. The Sierra Nevada Corporation has expressed interest for the use of elements of the OAS for their Dream Chaser vehicle. Initial tasks have been defined and will be implemented once a Technical Assistance Agreement is completed. Discussions are under way with Russia for integration of OAS Integrated Crew Aids in their new crew vehicle.

→ METERON

During the Roscosmos/ESA bilateral meeting at director level in March, Roscosmos stated readiness to support the ESA short-duration mission of astronaut Andreas Mogensen in 2015 with the use of the Kontur system for one of ESA's telerobotic experiments.

A body-mounted joystick for the Haptics-1 experiment, developed by ESA as part of the multi-agency Meteron initiative, investigating telerobotics for space. The Haptics-1 experiment will be flown to the Space Station on ATV-5 this summer

European Experimental Reentry Testbed (Expert)

Makeyev confirmed that the export authorisation for the recovery parachute was granted by the Russian government. Delivery and integration of the parachute on Expert in Turin (IT) is being planned, together with an extension of the storage until end-2015. The search for an alternative launch system for this suborbital mission continues, in particular in the USA.

Lunar exploration

The 'Science and Challenges of Lunar Sample Return' Workshop took place at ESTEC in February. This was an opportunity for the worldwide lunar science community to come together and present current work in this field. The workshop was attended by more than 150 scientists from institutions from 16 countries.

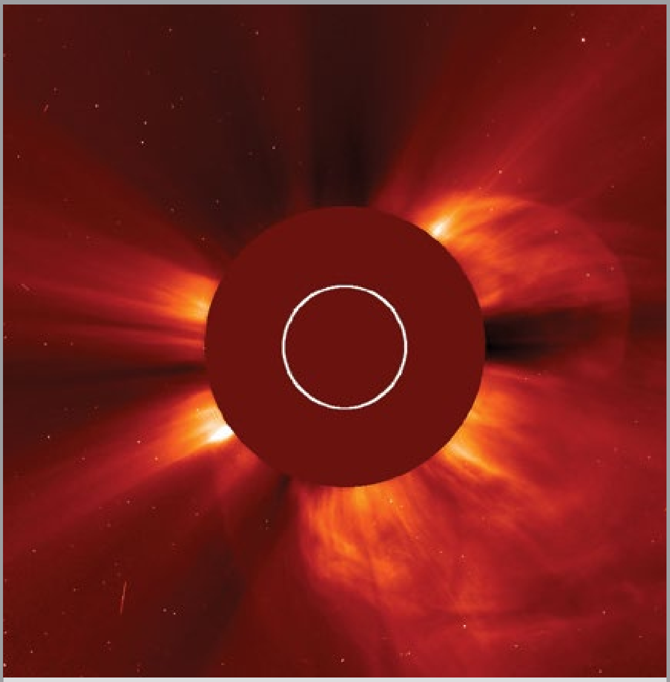
A Concurrent Design Facility study for a Lunar Polar Sample Return mission was conducted, concentrating on the potential elements that Europe could provide and assessing the requirements space.

Strategic planning on space exploration

The International Space Exploration Coordination Group (ISECG) finalised and adopted its workplan. It will focus on the mission scenario of the Global Exploration Roadmap and assessing opportunities for science. Following the meeting of the International Space Exploration Forum held in January in Washington, China has become a participant in the ISECG work and is hosting an ISECG meeting in the spring.

→ SPACE SITUATIONAL AWARENESS

Parallel studies are being carried out to define the architecture for the future European Space Situational Awareness (SSA) system. The Final Review of two of the architectural design contracts, one led by Airbus Defence & Space (DE) and the other by Indra (ES), was initiated in 2013 and is approaching completion. The review will mark the end of these activities and contracts.



A coronal mass ejection explodes off the Sun on 7 January as seen in the light halo in the lower right of this image captured by SOHO (ESA/NASA)

Space Weather (SWE)

The strongest X-class solar flare in the present solar cycle with an associated Solar Proton Event was detected on 7 January by the NOAA GOES-15 satellite X-ray flux monitor and the Proba-2 Lyman Alpha Radiometer. The SSA SWE Coordination Centre raised the alert for increasing proton flux to the Gaia Flight Control Team. This forecast proved to be accurate, as the proton flux threshold set by the Gaia mission was exceeded within an hour of the bulletin.

Preparations are under way for the SSA Programme's first hosted payload mission, with the Next Generation Radiation Monitor (NGRM) to be placed on the EDRS-C satellite. The changes to contracts with RUAG Space for adapting NGRM to meet EDRS-C mission requirements have been made. The embarcation fee and the flight cost will be covered by the SSA programme under an ESA Inter-Directorate Agreement.

Near-Earth Objects (NEOs)

The NEO Segment discovered its first comet, now named TOTAS, during a regular survey observation using the Tenerife telescope in the Canary Islands. ESA hosted the first meeting of the Space Missions Planning Advisory Group (SMPAG) in February. ESA was elected as the interim chair of the group. A total of 14 space agencies have since become members.

Space Surveillance and Tracking (SST)

The Reentry Prediction and Conjunction Warning Systems have been updated to take into account feedback received from the SST team during extensive test and validation. The system can now handle an increased number of objects. The full reports, which are prepared in cooperation with the ESA Space Debris Office, help in the evaluation of risk regarding potentially hazardous reentries or orbital conjunctions.

The programme continues to receive observation data from three European observation sites: La Sagra (ES), TFRM (ES) and Zimmerwald (CH). The data are used to test and validate all elements of the systems being developed.

Radars and telescopes

The monostatic breadboard radar at Santorcaz (ES) has undergone its first test and validation campaign, demonstrating the capability to detect space objects. The development of the second breadboard, which uses bistatic technology, with a consortium of industries led by Onera (FR), is continuing.

→ ESA PUBLICATIONS

Brochures

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BR-315 // 92 pp
E-book online

Earth Explorers: New Views of Dynamic Earth (December 2013)
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Gaia: ESA's Galactic Census (DE August 2013; FR & ES May 2013)
BR-296 DE/FR/ES // 12 pp
E-book online

Special Publications

ERS Missions: 20 Years of Observing Earth (July 2013)
SP-1326 // 303 pp
Price: €40

How Columbus Learnt to Fly (October 2013)
SP-1321 // 304 pp
Price: €50

Conference Proceedings

Proc. 13th European Conference on Spacecraft Structures, Materials and Environmental Testing, 1–4 April 2014, Braunschweig, Germany (June 2014)
SP-727 // CD
Price: €60

Proc. 6th European Conference on Space Debris, 22–25 April 2013, Darmstadt, Germany (August 2013)
SP-723 // CD
Price: €60

Proc. ESA Living Planet Symposium, 9–13 September 2013, Edinburgh, UK (December 2013)
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Proc. 21st European Rocket and Balloon Programmes and Related Research, 9–13 June 2013, Thun, Switzerland (October 2013)
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Proc. DASIA (Data Systems in Aerospace) 2013 Conference, 14–16 May 2013, Porto, Portugal (August 2013)
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Proc. CryoSat Third User Workshop, 12–14 March 2013, Dresden, Germany (March 2014)
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Proc. 6th IAASS Conference 'Safety is Not an Option', 21–23 May 2013, Montreal, Canada (September 2013)
SP-715 // CD
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ESA Technology Tree, Version 3.0 (January 2014)
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