number 157 | February 2014

bulletin

→ space for europe

esa

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

←

On cover:
ESA's Gaia star-mapper satellite was launched on 19 December 2013. Here, Gaia is lowered into position on its Soyuz launcher earlier in December (ESA/CNES/Arianespace/Optique Vidéo du CSG)

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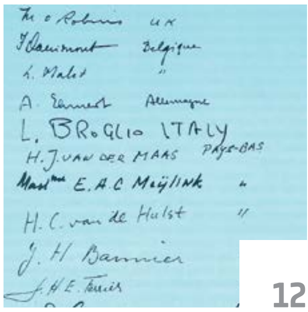
→ contents

1964-2014

→ SERVING EUROPEAN COOPERATION AND INNOVATION

02

06



12

30

38

45

WHY 1964?
An introduction by Jean-Jacques Dordain, ESA Director General
Jean-Jacques Dordain → 02

FIFTY YEARS OF COOPERATION
A history of Europe in space
Dr John Krige → 06

A CHRONOLOGY OF EUROPEAN COOPERATION IN SPACE
Part 1: 1959–74 → 12

COPERNICUS
Moving from development to operations
Josef Aschbacher et al → 30

GETTING 'SPACE' EXPERIENCE ON EARTH
Education activities for university students
Natacha Callens & Piero Galeone → 38

2013 IN PICTURES
Some of the most memorable moments and inspirational images taken last year → 45

NEWS IN BRIEF → 56

PROGRAMMES IN PROGRESS → 68

PUBLICATIONS → 92

The notification by ESRO that the French government had ratified the original text of the ESRO Convention (deposited with the French Ministère des Affaires étrangères as an intergovernmental agreement signed in Paris)

COPERS/303
Paris, January 31 1964
(Translated from the French)

EUROPEAN PREPARATORY COMMISSION FOR SPACE RESEARCH.

Note by the Secretariat

RATIFICATION OF THE CONVENTION

The Secretariat has the honour to advise National delegations that it has been informed by the French Government that this Government has, on January 17 1964, deposited its instrument of ratification of the Convention for the establishment of the European Space Research Organisation.

P.T.O.

R/2266

→ WHY 1964?

An introduction by Jean-Jacques Dordain, ESA Director General

A new year opens, but 2014 is special: this year the space community is celebrating the anniversary of the construction of Europe as a space power and 50 years of unique achievements in space.

The collaborative European space effort was officially born 50 years ago. In 1964, the Conventions of the European Launcher Development Organisation (ELDO) and the European Space Research Organisation (ESRO) entered into force. A little more than a decade later, ESA was established, taking over from these two organisations.

This year, 2014, will be dedicated to addressing the future in the light of these 50 years of unique achievements in space, which have put ESA among the leading space agencies of the world.

In the late 1940s and 1950s, European integration in advanced scientific and technological developments was then very much in the air – until two leading scientific statesmen, Pierre Auger of France and Edoardo Amaldi of Italy, made the first steps towards establishing a significant European presence in space.

Amaldi's informal paper on the 'Introduction to the discussion on space research in Europe', written in 1959, suggested the creation of a 'European Space Research Organisation' that would need five years to get itself off the ground. A young French scientist, Jacques Blamont, also pleaded for the 'creation of a European centre for rocket research, which could be managed by scientists', on the model of CERN.

The momentum was established, leading to a meeting of those interested with the Committee on Space Research, held in Nice, France, in January 1960. The UK's Sir Harrie Massey came armed with a blueprint for a possible programme for a European space organisation. Scientists met again shortly afterwards in Paris, in February 1960. A major step forward was taken at this gathering towards formalising the European space programme, based on Massey's proposal.

A European Space Research Study Group produced a draft document that was then submitted to a high-level meeting of scientific and government officials that met in the main auditorium at CERN (Meyrin, 28 November 1960). The delegates sanctioned the formation of a Preparatory Commission to Study the Possibilities for European Collaboration in the Field of Space (COPERS).

It was widely accepted that European space science should be organisationally distinct from launcher development. Thus were the seeds sown for Europe to enter space with two organisations. One was ESRO that emerged from COPERS. The other was ELDO, whose structure was defined in parallel negotiations between a smaller group of governments and which included a non-European country, Australia, among its Member States.

COPERS laid its draft convention before an intergovernmental conference in Paris on 14 June 1962. It entered into force on 20 March 1964, the official birth date of ESRO. The 10 founding states were Belgium, Denmark, France, the Federal Republic of Germany, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Austria and Norway, originally engaged in the deliberations over the formation of ESRO, retained observer status.

The first ESRO Council meeting took place on 23 March 1964. Open for signature on 29 March 1962, the ELDO convention entered into force two years later, on 29 February 1964. Its Council met for the first time on 5 May of that year.

→

Europe's celebration of 50 years in space was launched on 5 December 2013, at the European Centre for Space Applications and Telecommunications (ECSAT) naming ceremony at Harwell, UK. ECSAT's new building will be named after ESA's first Director General, Roy Gibson. Here current ESA Director General Jean-Jacques Dordain, Roy Gibson and UK Minister for Universities and Science David Willetts laid the stones of a sculpture that will be placed in the future building's courtyard (UKSA/M. Alexander)

The European space effort was almost overwhelmed by a crisis in the late 1960s and early 1970s. Out of the technological setbacks and political uncertainties that marked the period, the template for a viable collaborative European effort in space science and applications, along with launcher development, was defined. This template provided the framework for the successful European space programme that ensued.

A single European Space Agency was established in 1975. A Silver Jubilee Celebration took place in 1989, in the presence of French President Mitterrand and German Chancellor Kohl, to mark 25 years of successful European cooperation.

In those years, ESA has become Europe's gateway to space, with the mission to shape the development of Europe's space capability and ensure that investment in space delivers benefits to the citizens of Europe and the world. Space utilisation provided more and more services to citizens, from weather forecasts to telecommunications and navigation. Space exploration provides greater knowledge of our Solar System, and planet Earth, delivering unique data to help understand global changes.

This is only possible because we have the launchers, systems and technologies capable of placing satellites accurately into space. The benefits of space utilisation and exploration have expanded in ways that could not have been envisaged 50 years ago. Space applications are now a fact of daily life for all European citizens, and have become one of the most efficient vectors of growth. The future is therefore much more important for space than its past.

Now a suite of events and activities are planned during 2014 to mark the 50 years of European cooperation in space – anniversary for the whole space sector in Europe, which can be proud of its results and achievements.

With the motto 'serving European cooperation and innovation', we underline how much ESA, together with its Member States, space industry, the scientific community and more recently the EU, has made a difference for Europe and its citizens.

It is a testimony that when Member States share the same challenging objectives and join forces, Europe can be at the leading edge of scientific progress, strengthening economic growth and competitiveness for the benefit of all citizens. ■

"This is a good opportunity to recall impressive past achievements, but even more so to reflect on future evolution and growth."

Jean-Jacques Dordain


Pierre Auger and Edoardo Amaldi

→ FIFTY YEARS OF COOPERATION

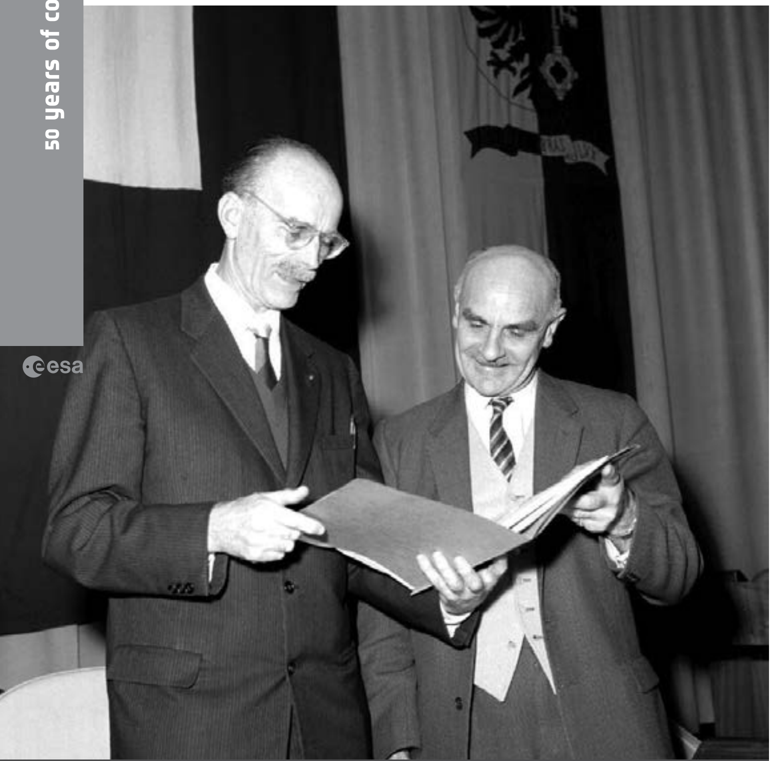
A history of Europe in space

Dr John Krige
School of History, Technology and Society, Georgia Institute of Technology, Atlanta, USA

The collaborative European space effort was officially born fifty years ago. To commemorate this event, ESA has supported the writing and publication of a scholarly history that describes the history of ESA from its origins in the two intergovernmental organisations, ESRO and ELDO, that preceded it in the 1960s, through its establishment in 1975 and on up to the present.

The narrative summarises the findings of previous historical work done under the impetus of Professor Reimar Lüst when he was ESA's Director General, extended to bring the story up to date as regards the major programmes. It is based on the extensive archive that ESA has established at the European University Institute in Florence, Italy, along with interviews conducted by the author and various other space enthusiasts. ESA's Nathalie Tinjod has steered the project to completion with great skill.

What image do we get of ESA from this study? What are the lessons of this sometimes quite detailed history? Two factors stand out. The first is the political will of the Member States, notwithstanding sometimes sharp political differences, to construct a durable, scientific and technologically



↑ Pioneers and founding fathers: Pierre Auger (FR) and Harrie Massey (UK)

↑ Edoardo Amaldi (IT)

advanced European presence in space. This was done in parallel to – and sometimes in competition with – national space programmes, be they funded by the US, Russia (and previously the Soviet Union) or by some of those same European governments themselves.

The second striking feature has been the capacity of the European space organisations to adjust to changing circumstances. These adjustments were often painful, but always necessary. Indeed these two key findings are linked: it is because governments were determined not to walk away from building a European presence in space that they had to make painful choices in order to maintain that presence.

In sum, looking at the history of the collaborative European space effort, and its institutionalisation in ESA today, the Agency can be seen as an evolving organism that has successfully adapted to repeatedly changing environments in order to survive.

This adaptation has not been arbitrary. The evolving organism that is ESA has a backbone made up of the national ministries that fund it, of the firms that build its hardware, and of the scientists, engineers, project managers and administrators who integrate its parts into a whole, and who define its primary goals. They set the terms on which it shapes, and is shaped by the changing environments it has to contend with.

It is often forgotten that it was scientific statesmen who promoted a collaborative European space effort in the early 1960s: European governments did not rush into space nor compete for kudos in the conquest of space as did the two superpowers. In fact, ESRO benefited from the vision of a young group of space science enthusiasts, along with good timing.

CERN was already establishing itself as a leading high-energy physics laboratory. The second wave of intergovernmental organisations was taking shape, propelled by the period of sustained economic growth referred to as *les trente glorieuses* in France, but which was more generally applicable. When ESRO and ELDO were formed for space science and launcher development, so too were ESO, for ground-based astronomy, and EMBO, for molecular biology.

Governments invested in collaborative science and technology projects to pool economic and industrial resources as well as brainpower. They were convinced that only by doing so could they hope to close the gap that had opened up between them and the United States two decades after the devastating effects of the war.

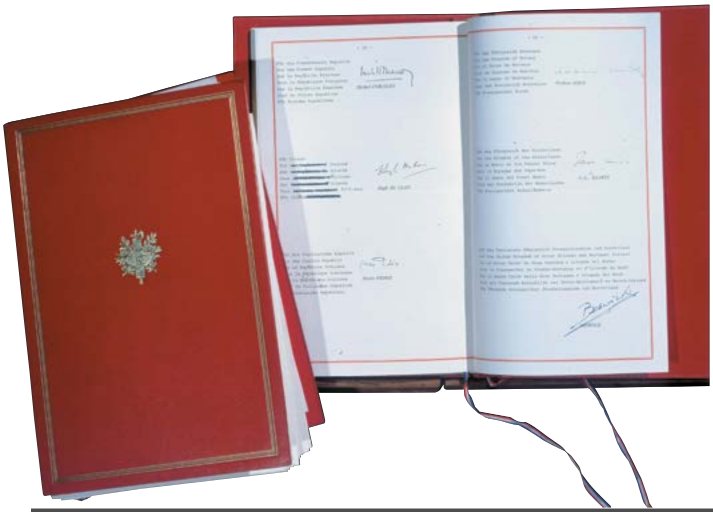
The founding fathers of ESRO soon had to come to terms with the reorientation of the mission of their organisation to include space applications, above all telecommunications. This new technology, understood at once to have enormous political, economic and ideological benefits for those who could exploit it, also injected new energy into the floundering ELDO rocket programme.

For many governments, the freedom to exploit space for non-military purposes became the dominant rationale for investing in the domain and for securing their own launch capability. It kept ELDO alive through many a precarious moment in the late 1960s and until early 1971, when the organisation's fate was sealed with a major launch failure from the new launch base in Kourou, French Guiana.

The early 1970s were years of crisis for the European space programme, resolved by the brokering of two major package deals. This involved adopting the principle of *à la carte* participation in programmes, which increased flexibility by allowing governments to selectively join in activities that were of interest to them. It was complemented by a tightening of the fair return principle. This principle, not widely welcomed by the major European space powers, was particularly prized by Member States with smaller or weaker space industries.

These arrangements accepted that European governments had different, even conflicting interests, and were seen by some as diluting the ideal of a genuinely collaborative programme. They were, however, indicative of that pragmatic approach that I mentioned earlier, and of the willingness of national space actors to find creative solutions to the challenges that faced them so as to maintain the European space effort.

↑ A test flight of an ELDO Europa 2 rocket from Kourou, French Guiana, ends when the vehicle breaks up about 150 seconds after launch, 5 November 1971



↑ The ESA Convention opened for signature, and the Final Act signed at the Conference of Plenipotentiaries, Paris, 30 May 1975

A new single organisation was formed in 1975, today's European Space Agency. Space applications were expanded to include telecommunications, meteorology and navigation. Space science was made mandatory and subject to strict budget control: the community could work with ESA, with the US NASA or with national programmes to launch their experiments. Germany took the lead in developing Spacelab with the USA and France took the lead in developing Ariane.

None of this was easy. France and Germany were ahead of others in developing and testing a new telecommunications satellite (Symphonie) and were accused of trying to steal a march on their partners in the European programme by preferentially securing industrial contracts for themselves. The USA backed away from a joint air navigation satellite. European R&D ministers were willing to fund a Europeanised French meteorological satellite, but expected the national meteorological services to take over the operational costs once the principle was proven — to little avail. Traditional meteorological service budgets were not used to the high costs, notably of data handling, and it took the formation of a new European organisation to put the meteorological satellite programme on a secure footing. The costs of Spacelab soared. The existing ESA space science community saw little interest in its shirt-sleeve, zero-g experimental environment and here again it proved immensely difficult to build a viable user-community.

Ariane had somewhat fraught beginnings as well: some believed that reusable spacecraft such as the US Space Shuttle defined the new technological horizon for the low-cost exploitation of space and could not see how Europe's new European Launch Vehicle would ever be economically viable. Again it was political will, industrial strength and the pragmatic approach of strong engineering teams, above esa

↑ First Ariane 1 launch in 1979

all in France's space agency CNES, that prevailed and that were celebrated in Ariane's maiden launch from Kourou on Christmas Eve, 1979. (The second launch failed!)

Relations with NASA, Europe's preferred international partner, did not go smoothly in the 1970s. The US space agency had been extremely supportive of ESRO, ELDO and of young national programmes, particularly in France in the 1960s. However, as these fledgling programmes grew to maturity, officials in the White House were alarmed that important US technology could flow to Western Europe. Along with kindred spirits in NASA and other arms of the US administration, they limited European participation in the Post-Apollo Program – which had been extensive until President Nixon authorised the Shuttle in 1972 – to ensure the preservation of clean technological and managerial interfaces (Spacelab footed that bill).

They also played a major role in killing the joint aeronautical navigation satellite. The US State Department placed conditions on the operational activities of Symphonie if it was orbited with a US launcher, so playing into the hands of those in France who were persuaded that freedom of access to space was essential, and stimulating the birth of Ariane.

Later in the decade NASA withdrew its contribution to the dual-satellite International Solar Polar Mission without prior consultation. Europeans resented the US attitude and were determined never to be treated as junior partners again. When the US invited them to participate in the International Space Station, the European negotiators in the 1980s went out of their way to ensure that their interests were protected, increasing their demands even more when Russia joined the ISS project in the mid-1990s.

Friction with the US continued to co-exist with cooperation in the new millennium. Transatlantic relations that might otherwise have been far smoother with the stabilised Horizon space science programmes were perturbed by the reclassification of all US satellites as 'defense articles' by the US Congress in 1999. This placed any satellite, including one solely dedicated to science, under the sway of the International Traffic in Arms Regulations (ITAR).

Technology sharing with European partners was now defined as a 'defense service' and subject to export controls. In the domain of applications, too, there is a simmering conflict over Europe's Galileo navigation satellite system that threatens to take markets away from US firms and to give European governments considerable autonomy in various emergency and military-related ground activities.

The European space agencies owe much to NASA. But they have learnt that to collaborate fruitfully one has to be able to compete successfully. Reciprocity is a sine qua non for successful international scientific and technological collaboration.

In the late 1990s, a new actor entered the space domain: the European Commission. Satellite navigation and Earth observation were activities that affected multiple areas of daily life on the European continent, and so fell within the Commission's newly extended range of competence.

Once again ESA has shown its ability to adjust and to take advantage of new opportunities while securing its core mission. Galileo overcame a severe financial crisis thanks to a major injection of EU funds. At the same time, to enhance the rationale for public funding, ESA has redefined the meaning of its commitment to the peaceful use of outer space in line with US practice to allow Galileo to be used for certain types of armed intervention on Earth.

↑ President Nixon authorising the US Shuttle programme in 1972

←

View of the new Vega launch complex at Europe's Spaceport in French Guiana

Here, as in the domain of launchers, the European space effort is seriously disadvantaged vis-à-vis the US by the lack of strong government demand at home. In the US, by contrast, there are large institutional, especially military, markets for both GPS and launcher services that are (obviously) not easily penetrated by European firms.

Indeed, the global upheaval caused by the collapse of communism, and the emergence of multiple new private launch system providers that could capitalise on 50 years of government support for rocketry, posed a serious threat to the viability of Europe's Ariane launcher in the early 2000s. The solution, essential to securing sovereignty and freedom of access to space, was to develop a family of launchers that includes Ariane but also the Italian-led Vega and Russia's Soyuz, all at the Centre Spatial Guyanais in French Guiana.

Looking back over the history of this evolving organism that is ESA, one is struck by the frequency with which the same themes re-emerge. Of course, they take on different forms, and they demand different responses. Yet the very fact that they reappear means that we should not be surprised when they do, and that we are better able to handle them as a result.

Therein lies the interest of this new scholarly history. It is a tribute to ESA's capacity for survival by adaptation. It is also a guide to the past that points the way to what might happen in the future. Forewarned is forearmed. ■

Dr John Krige

Dr John Krige has a PhD in physical chemistry from the University of Pretoria (South Africa) and a PhD in the history and philosophy of science from the University of Sussex (UK). He joined the Georgia Institute of Technology in 2000 as Kranzberg Professor in the School of History, Technology, and Society.

Prior to that, he directed a research group in the history of science and technology at the Cité des Sciences et de l'Industrie in Paris, and was the project leader of a team that wrote the history of the ESA (see in particular ESA SP-1172, ESA SP-1235).

Dr Krige's research focuses on the intersection between support for science and technology and the foreign policies of governments. He has lately expanded his interest beyond the study of intergovernmental organisations in Western Europe to include an analysis of US/European relations during the Cold War.

His most recent monograph is *American Hegemony and the Postwar Reconstruction of Science in Europe* (MIT Press, 2006). Other publications include *NASA in the World: Fifty Years of International Collaboration in Space* (Palgrave Macmillan, 2013), co-authored with Angelina Long Callahan and Ashok Maharaj.

Fifty Years of Cooperation in Space – Building on the past, shaping the future (Beauchesne) will be published in April 2014, as the tenth monograph dedicated to the European space endeavour and issued in the *Explorations collection – Studies in Modern Science and Technology* from the International Academy of the History of Science (see *The ESA History project*, ESA BR-294).

Fri a.m
24/6/60.

H S W Massey UK

M O Robins UK

J Daurimont Belgique

L. Malet "

A. Ehmert Allemagne

L. BROGLIO ITALY

H. J. VAN DER MAAS PAYS-BAS

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Lamek Hulthén "

ROBERT MAJOR, NORWAY

Svein Rosseland — " —

J. PIERRAT FRANCE

Mme Labeyrie Winahem France.

Alune UK

Signatures of participants from European states in the meeting held on 24 June 1960 to establish the Groupe des Experts Européens des recherches Spatiales (GEERS)

→ A CHRONOLOGY OF EUROPEAN COOPERATION IN SPACE

Part 1: 1959–74

1959

April
Edoardo Amaldi (IT) and Pierre Auger (FR) discuss the possibility of a joint European space effort

December
Edoardo Amaldi's article, *'Créons une organisation européenne pour la recherche spatiale'*, is published in the French magazine *L'Expansion de la recherche scientifique*

1960

11 January
First General Assembly of COSPAR in Nice. Amaldi's proposal discussed by European space scientists

13 April
The UK government announces its decision to cancel its Blue Streak rocket as a missile for military use

29 April
Meeting of space scientists from ten Western European countries at the Royal Society in London chaired by Sir William Hodge (GB): plea for 'European co-operation in space research'

24 June
At a meeting in Paris, the Groupe des Experts Européens des Recherches Spatiales (GEERS) is established

September
UK Minister of Aviation, Lord Peter Thorneycroft, tours several European capitals to invite governments to

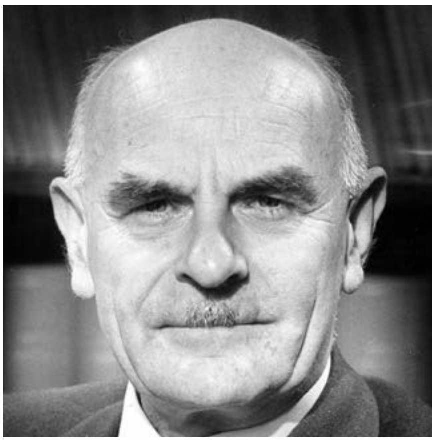
← Edoardo Amaldi (INFN)

← Pierre Auger

participate in the development of an all-European satellite launcher with Britain's Blue Streak as the first stage

3 October
Scientific experts, convened at the Royal Society by GEERS, outline the principles of a possible space organisation. Sir Harrie Massey (GB) is chair of GEERS

28 November
Delegates from 11 Western European governments meet at CERN in Geneva and adopt an agreement setting up COPERS (Meyrin Agreement)



← Sir Harrie Massey, chair of GEERS (UCL)

↑ Delegates of the Intergovernmental Conference of Space Research at Meyrin, Geneva, November 1960 (ESA/CIRS)

1961

30 January
Intergovernmental meeting, chaired by Lord Thorneycroft in Strasbourg, agrees to go ahead with European launcher development

27 February
Agreement establishing COPERS comes into force

24 October
The third plenary session of COPERS approves the initial eight-year programme of ESRO (Blue Book)

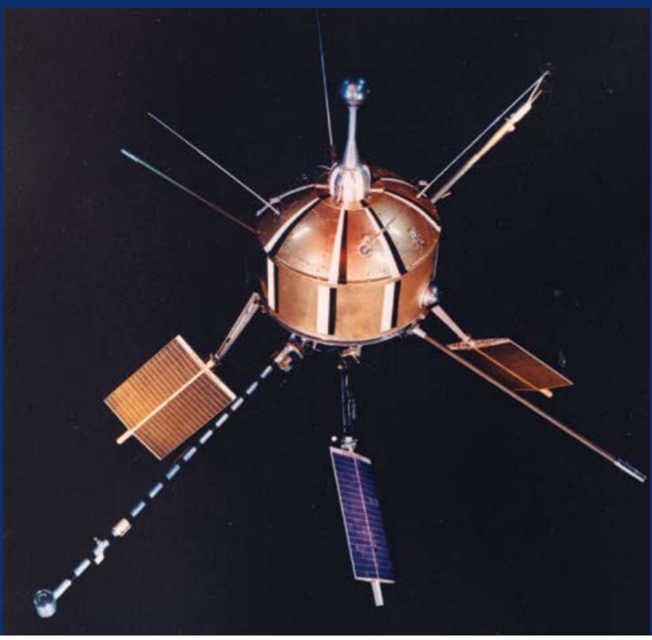
30 October
Delegates from six Western European governments plus Australia, meet at Lancaster House in London chaired by Lord Thorneycroft, to agree on the ELDO programme and establish a Preparatory Group to start its implementation

3 November
Woomera, Australia, selected for ELDO launches. European delegates plan to launch a satellite in mid-1965, using Europa launcher (UK Blue Streak first stage, a French Veronique second stage, and a West German third stage)

1962

29 March
ELDO Convention opens for signature (Belgium, France, Germany, Italy, the Netherlands and the United Kingdom, with Australia as Associate Member)

26 April 1962
Ariel-1, the first UK satellite, launched on a US rocket



→ Sir Harrie Massey with UK Ariel satellite engineers at Cape Canaveral in 1962 (UCL)

14 June
ESRO Convention opens for signature (Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom)

1 November
Alfred W. Lines (GB) nominated as Technical Director to head the European space technology centre. Under his authority, Mr A. Kesselring (CH) is named first Director of ESTEC in 1964

1963

1 January
Under Dr Sidney Shapcott (UK), later Director of Projects at ESTEC, planning of the ESTEC facility begins at the Technical University of Delft, Netherlands

Autumn
European Space Data Analysis Centre (ESDAC, later renamed ESOC) established in Darmstadt, Germany, headed by Stig Comet (SE)

↑ Meeting of the Scientific and Technical Working Group of COPERS, Switzerland, in January 1963. From left: Pierre Blassel, Michel Bignier, Professor Boyd, Dr Reimar Lüst, Edgar Page, Alexander Hocker (ESA/ESRO)

1964

29 February
ELDO Convention enters into force

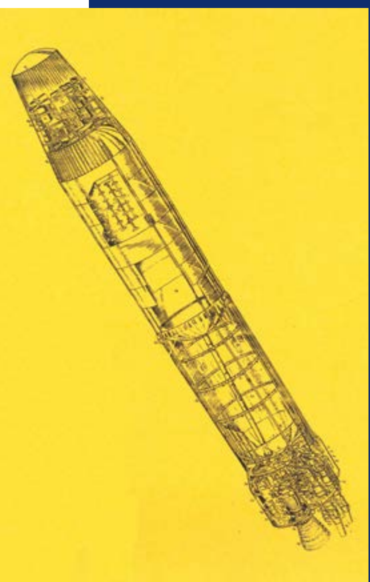
20 March
ESRO Convention enters into force

23 March
First meeting of the ESRO Council: Pierre Auger appointed Director General and Sir Harrie Massey as Chair of Council

5 May
First meeting of the ELDO Council: Renzo Carrobio di Carrobio (IT) appointed Secretary General and Günther Bock (DE) as Chair of ELDO Council

29 July
First Director of ESRIN, Hermann Jordan (DE) appointed

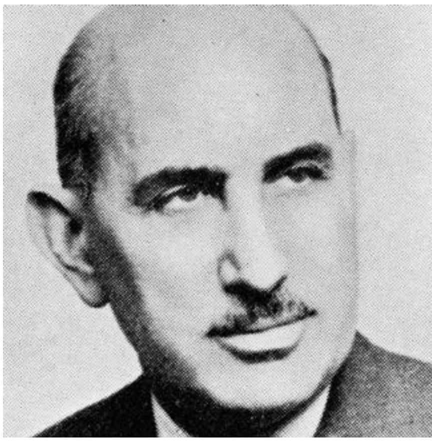
5 June 1964
First test launch of the Europa-1 (F1) first stage (Blue Streak)



15 December 1964
Italy's first satellite, San Marco 1, is launched on a US rocket

↑ ESRO logo

↑ ELDO logo



← Renzo Carrobio di Carrobio, first ELDO Secretary General

1965

1 March
First foundation pile laid for ESTEC at Noordwijk

24 March
Alexander Hocker (DE) replaces Sir Harrie Massey as Chairman of ESRO Council

September
First major vacuum test facility installed at ESTEC

↑ ESRO heads inspect the foundations of ESTEC near Noordwijk, 1965

26 November 1965
France (CNES) launches its first satellite, Astérix, on a Diamant A rocket from the Hammaguir launch site, Algeria (ECPA/EADS)

↑ ESTEC's first Large Space Chamber, 1966

1966

1 January
ESRIN begins operating from the old Park Hotel in Frascati, Italy

12 January
Inauguration of the first Large Space Chamber at ESTEC

23 May
Fourth test flight of the Europa first stage (Blue Streak) with dummy upper stages, Europa-1 (F4)

7 July
ELDO Ministerial Conference approves the ELDO-PAS (Europa 2) programme

24 September
Inauguration of Esrange, Kiruna, Sweden

14 October
Fire destroys part of ESLAB and ESTEC buildings

30 November
ESRO Council fails to agree unanimously on a three-year level of resources. The organisation loses legality and all future budget decisions require unanimity. The Council, however, agrees that ESRO should undertake a study on a European communications satellite programme

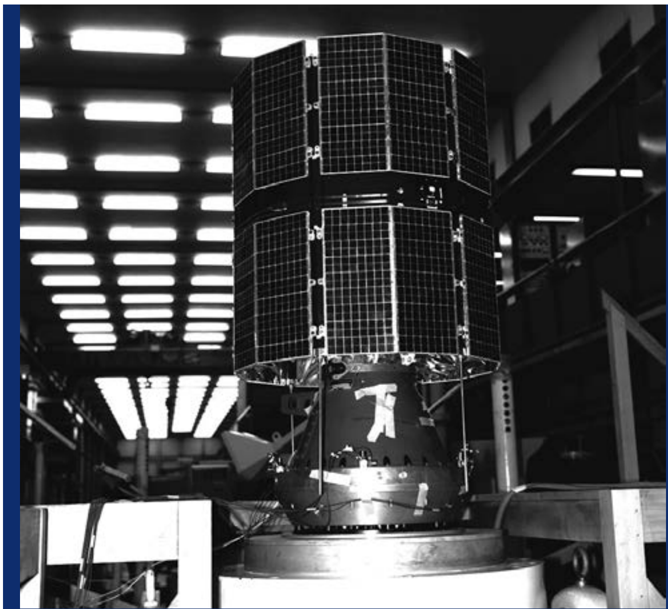
13 December
First meeting of the European Space Conference (ESC), Paris, chaired by Alain Peyrefitte (FR)

↓ The construction of ESTEC, Noordwijk, looking south from the dune side, 1966

1967

16 February
Alexandre Paternotte de la Vaillée (BE) replaces Günther Bock as Chair of ELDO Council

26 April
First successful launch from the San Marco offshore platform of Italian satellite San Marco 2



29 May 1967
ESRO's first satellite, ESRO-2A, lost after launch failure

June
Franco–German agreement for joint development of experimental communications satellite Symphonie

11 July
Second ESC, Rome. Creation of the Causse Committee to work out a coherent European space programme. ESRO requested to design a television-relay satellite meeting the needs of the European Broadcasting Union

← Delegates joining the second European Space Conference, in Rome, 11 July 1967

↓ ESOC, 1967

September
Inauguration of ESDAC in Darmstadt, Germany. Signature of the host agreement between ESRO and Germany by Pierre Auger and Dr Gerhard Stoltenberg, German Minister of Research

1 November
Hermann Bondi (GB) replaces Pierre Auger as ESRO's Director General

← Herman Bondi, ESRO's second Director General

December
Publication of the Causse report, presenting a long-term comprehensive European Space programme, including science, applications and launchers

1968

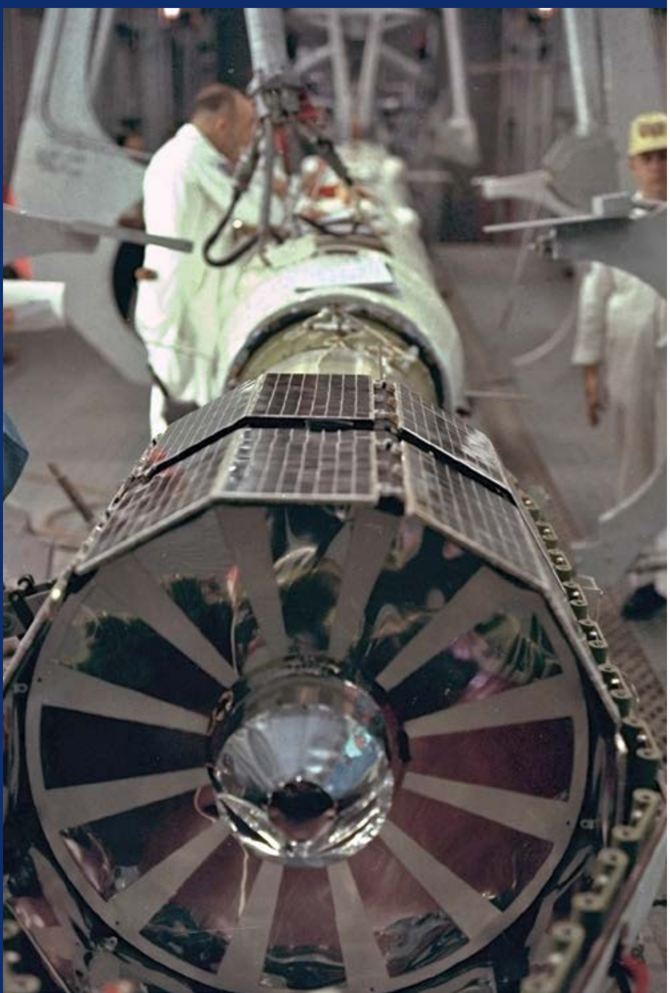
28 March
Prof. Hendrik C. van de Hulst (NL) replaces Alexander Hocker as Chairman of ESRO Council

3 April
Inauguration of ESTEC by HRH Princess Beatrix of the Netherlands

16 April
The UK government rejects the Causse report and announces that the UK will not increase its financial commitment to the existing ELDO programmes or take part in any additional projects

25 April
Preliminary industrial contract for the ESRO TD-1/TD-2 satellites cancelled because of cost escalation

17 May 1968
First ESRO satellite in orbit, ESRO-2B (Iris)



July 1968
ESRO-1 in solar simulation testing at ESTEC

1 September
ESLAB integrated into ESTEC, and renamed Space Science Department (SSD)

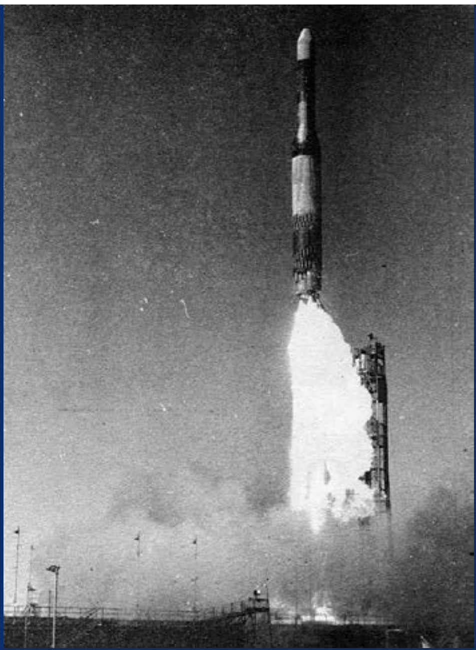
27 September
ESRIN foundation stone laid in Frascati, Italy

8 October
ESRO Council agrees to fund the TD-1 satellite as a special project, excluding Italy

11 November
ELDO Ministerial Conference, in Bonn, decides to drop apogee motor and test satellite from ELDO-PAS in order to stay within financial ceiling

12 November
Third ESC, in Bad Godesberg, agreement on creating a single European space organisation out of ESRO and ELDO, with a minimum mandatory programme and a number of optional programmes. Also agreed that European launchers can be used at no more than 125% of the cost of a US launcher. Level of resources agreed for ESRO in the period 1969–71

3 October 1968
ESRO-1A (Aurorae) launched on US rocket



30 November 1968
First orbit attempt, Europa-1 (F7) with three-stage Europa launcher, ends in failure

5 December 1968
HEOS-A (HEOS-1) launched on US rocket

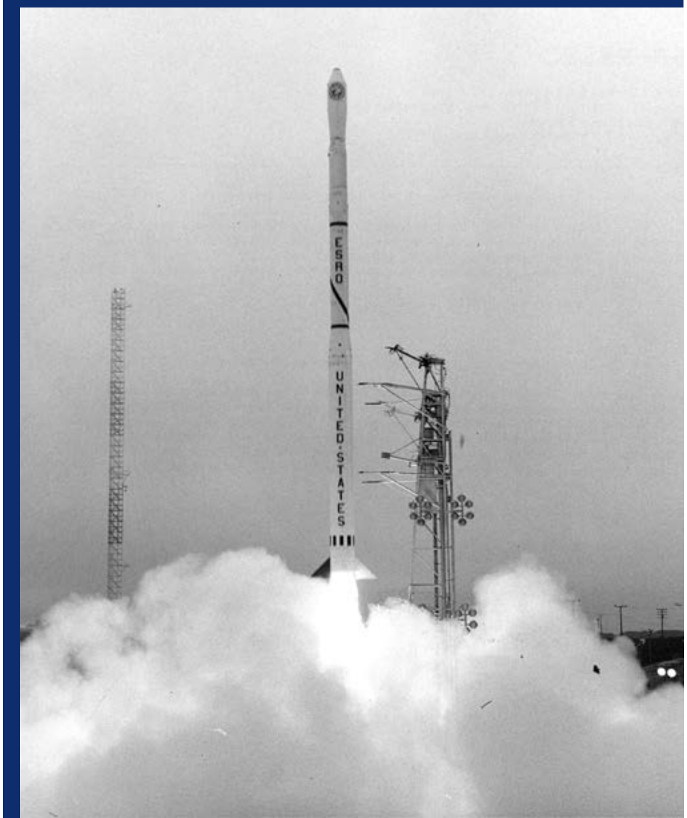
19 December
ELDO Council session ends with strong disagreement between Member States: budget for 1969 not approved

1969

27 March
The ESC Committee of Senior Officials set up at Bad Godesberg meets for the first time and nominates Giampietro Puppi (IT) as Chairman

15 April
ELDO Ministerial Conference adopts 1969 budget, but Italy and the UK withdraw from the Europa 2 programme. Belgium, France, Germany and the Netherlands agree to continue this programme and to start studying a new rocket project (Europa 3)

1 July
ESRO Council approves next ESRO satellite programme: the gamma-ray astronomy satellite COS-B and the geostationary GEOS for magnetospheric studies



1 October 1969
ESRO-IB (Boreas) launched. Because of injection into a lower orbit than planned, its lifetime was only 52 days

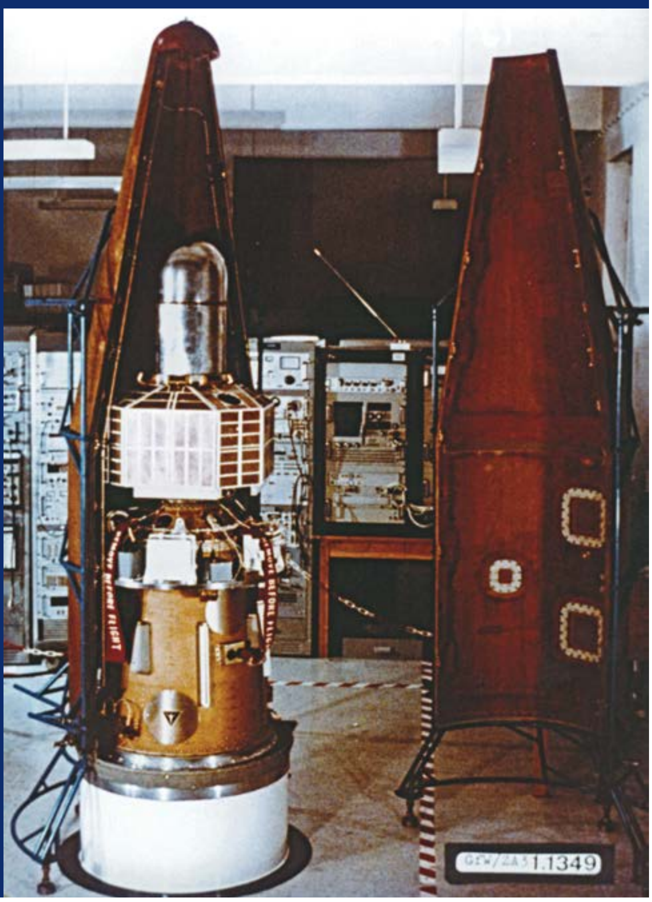
14 October
NASA Administrator Thomas O. Paine meets the ESC Committee of Senior Officials, offering opportunities for cooperation in post-Apollo programmes (space shuttle, a space station and a manned expedition to Mars)

8 November 1969
West Germany's first scientific satellite, Azur, is launched on US rocket

1970

April
The Working Group on telecommunications presents its programme for a European communications satellite (ECS) system to be operational by 1980. The European PTT ministers endorse the programme

10 March 1970
The first spacecraft launched from the Guiana Space Centre at Kourou is the French DIAL satellite on a Diamant-B rocket



27 April
ELDO Council decides to go ahead with study and pre-development work on Europa 3. It also decides on a study on a tug for transporting payloads between the space shuttle orbit and a geostationary orbit, in the NASA post-Apollo programme

22 July
First session of the fourth ESC meeting in Brussels. Negotiations to begin with NASA over post-Apollo cooperation, and in particular over availability of US launchers for European commercial satellites.

4 November
Second session of the fourth ESC meeting, with ambiguous US position on launchers, a disagreement on an independent European launcher is of such a magnitude that the meeting ends on the first day

22 December
Trying to recover from the ESC crisis, the ESRO Council instructs its new Chairman, Giampietro Puppi, to negotiate a new institutional framework for the development of application satellite programmes

1971

27 January
Wolfgang J. Schmidt-Kuster (DE) replaces Alexandre C. Paternotte de la Vaillée as ELDO Chairman of Council

1 March
Alexander Hocker replaces Hermann Bondi as ESRO's Director General

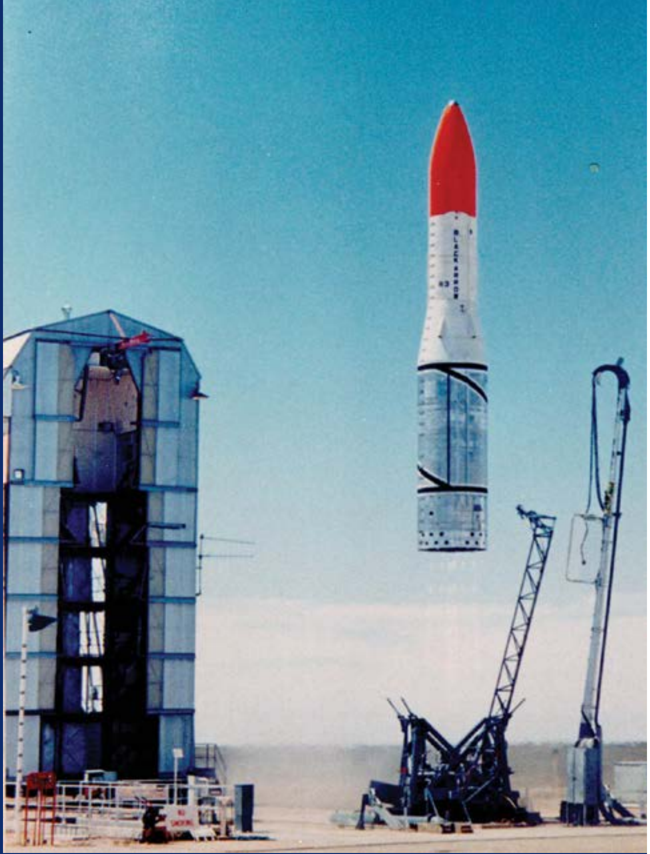
←

Alexander Hocker, third ESRO Director General

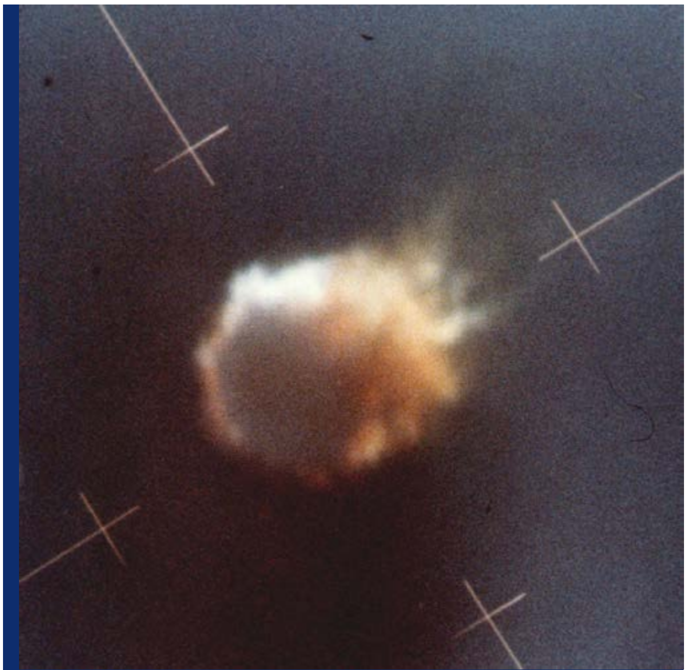
13 July
The ESRO Council agrees to contribute to the joint NASA/UK SAS-D satellite for ultraviolet astronomy (eventually renamed International Ultraviolet Explorer, IUE)

29 July
European firms present results of 12-month study of Space Tug to representatives of ELDO, ESC and NASA

12 June 1970
A planned tenth test of Europa 1 from Woomera (F10) never took place, ELDO launch operations were then moved to Kourou in French Guiana



28 October 1971
First UK satellite, Prospero, launched on UK Black Arrow (R3) rocket from Woomera, Australia



5 November 1971
Launch of Europa-2 (F11) ends in explosion after 3 minutes of flight

5 November 1971
First launch of four-stage Europa-2 (F11), first Europa launch from French Guiana

20 December
ESRO Council agrees on the first 'package deal'. Only the science programme is made mandatory. All application satellite programmes (aeronautical, communications and meteorological) are optional, but the four major countries commit contributions from 1974. The use of a European launcher is foreseen at a cost not higher than 125% of the cost of an equivalent non-European vehicle. The sounding-rocket programme and scientific work at ESRIN are terminated

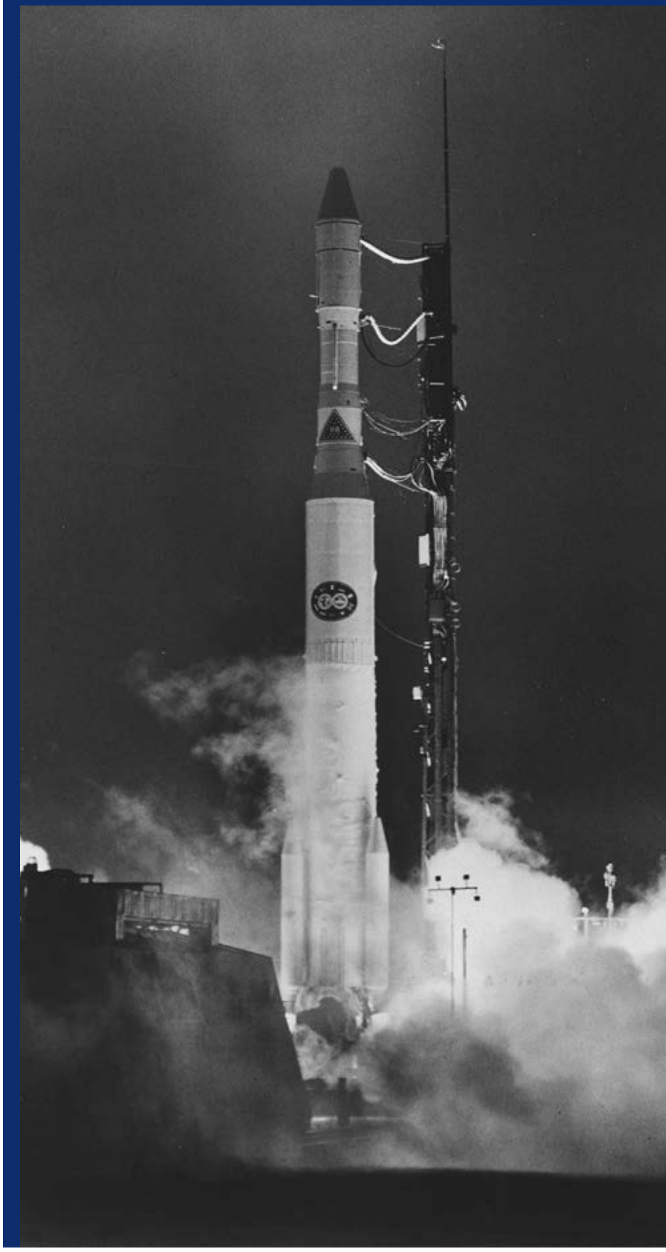
↑ ESRO Council, December 1971, agrees on the first 'package deal'

1972

1 January
Robert Aubinière (FR) replaces Renzo Carrobio di Carrobio as ELDO Secretary General

← Robert Aubinière

12 March 1972
TD-1 launched on a US rocket from Vandenberg AFB, USA



31 January 1972
HEOS-A2 (HEOS-2) launched on a US rocket from Vandenberg AFB, USA

14 April
E.A. Plate (NL) replaces Wolfgang J. Schmidt-Kuster (DE) as Chairman of ELDO Council

June
Crisis in US/European negotiations on the post-Apollo programme. The US withdraws offer to collaborate on Space Tug and drastically restricts possibilities of subcontracting on the Shuttle in Europe. Only 'sortie module' (Spacelab) is left for collaboration

1 July
Swedish authorities take over Esrange from ESRO

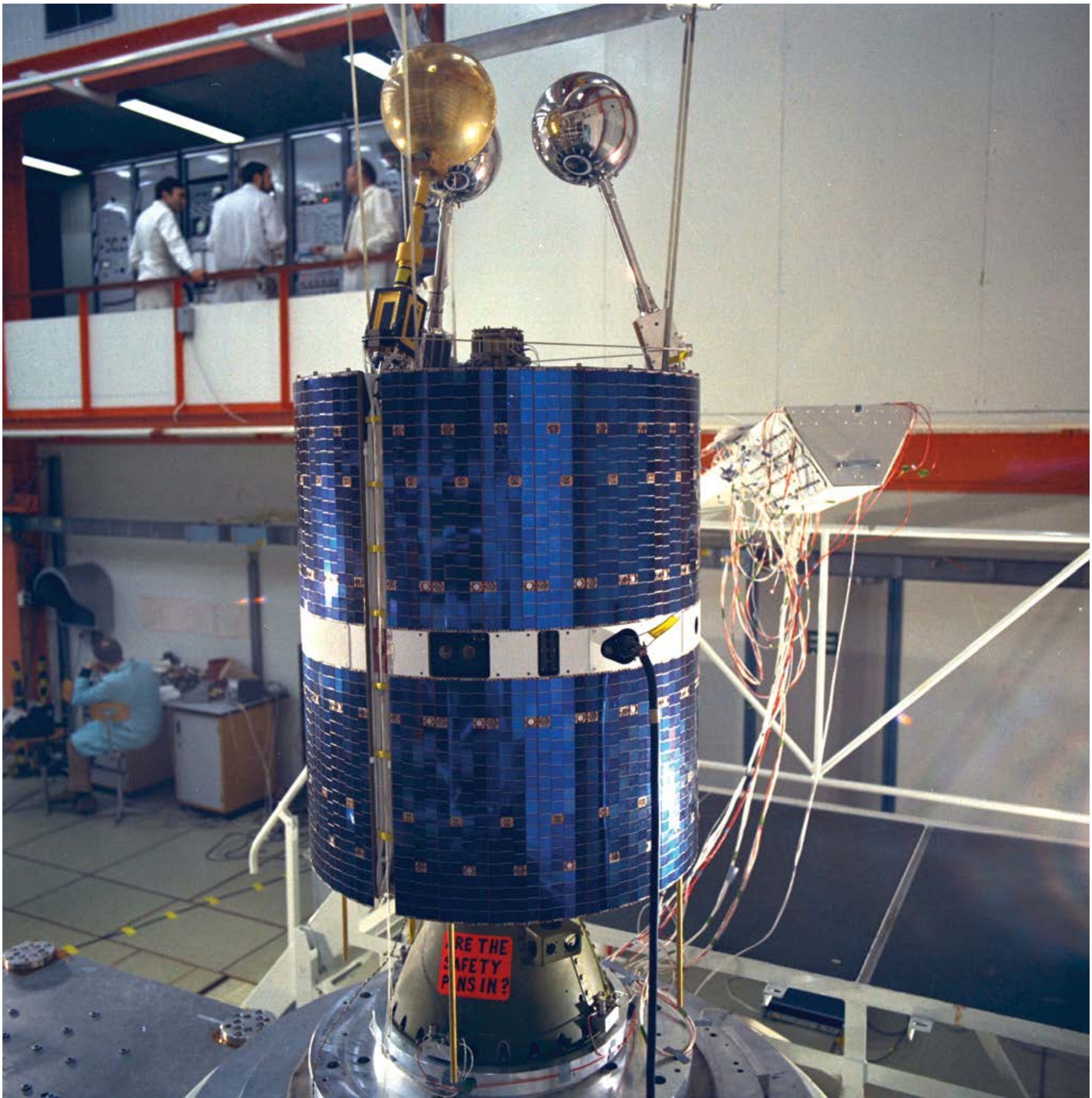
12 July
ESRO Council authorises the Director General to sign an agreement with CNES concerning the development of Meteosat

20 December
Fifth ESC meeting, in Brussels, agrees on Spacelab and carrying out the French LIIIS launcher project (eventually renamed Ariane) in a European framework. Europa 3 is cancelled

1973

18 January
Maurice Lévy (FR) replaces Giampietro Puppi as Chairman of ESRO Council

11 April
ESRO Council approves the new scientific satellite programme: the X-ray astronomy satellite HELOS (Exosat) and the magnetospheric satellite IMP-D (ISEE-2), the latter being coupled with a NASA satellite (ISEE-1)



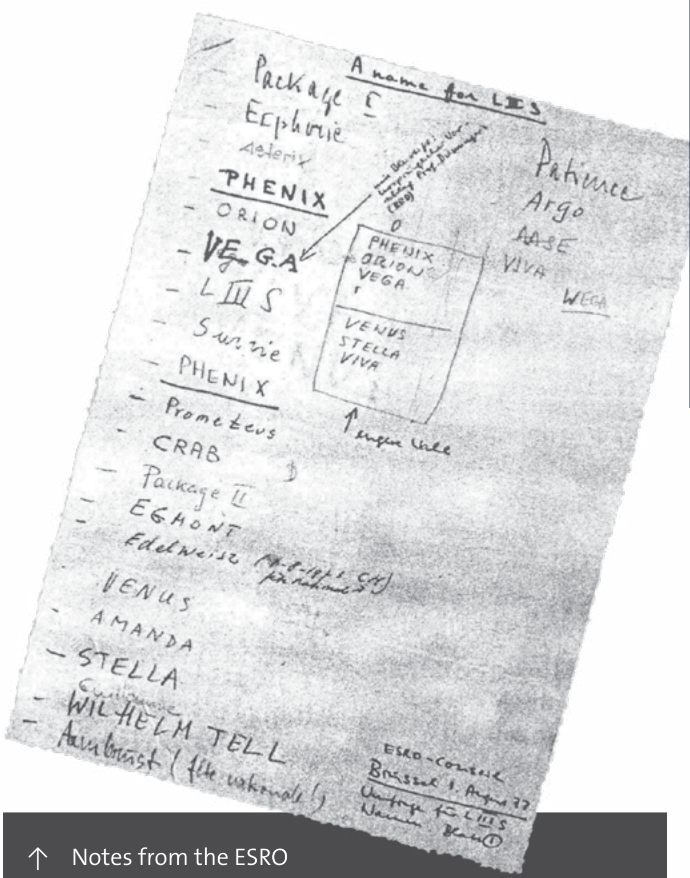
↑ ESRO-4 structural model undergoing vibration testing at ESTEC in March 1972

22 November 1972
Successful launch of ESRO-4

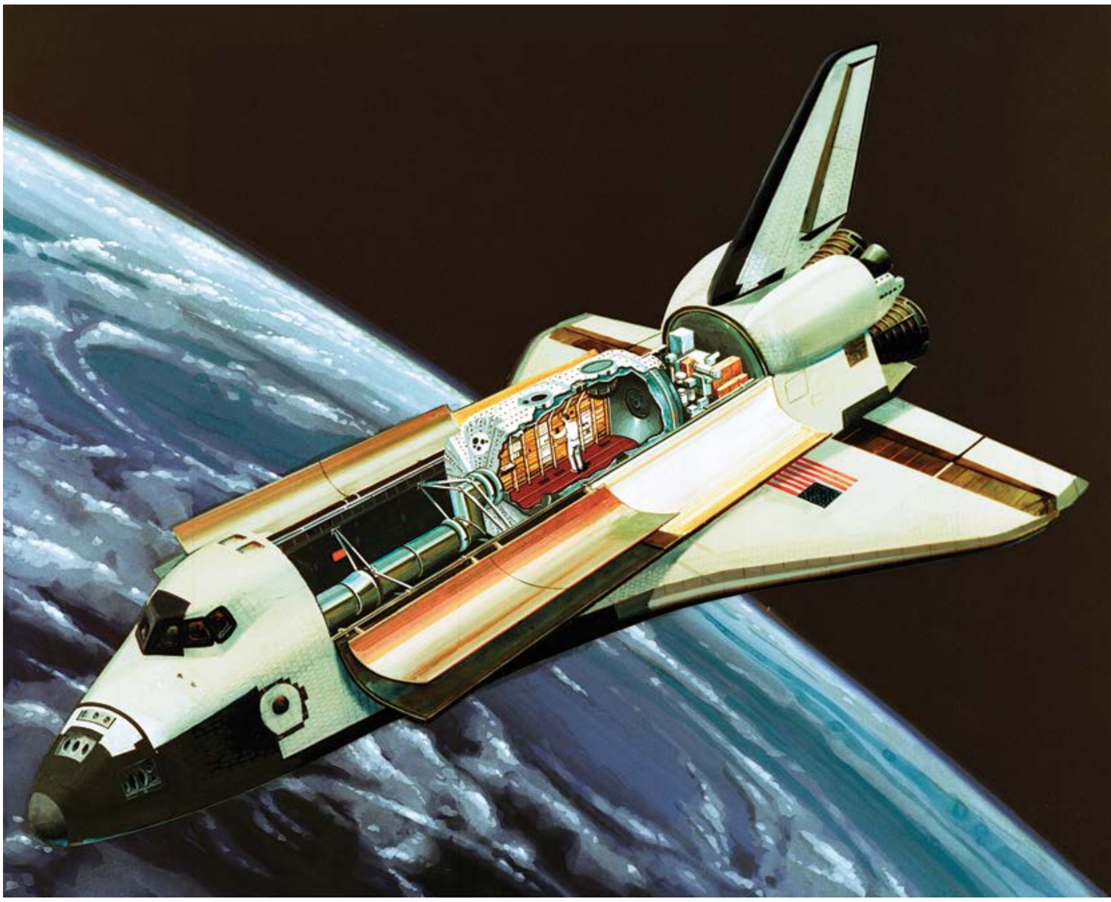
27 April
ELDO Council decides to liquidate the Europa 2 programme and to wind down ELDO. George van Reeth (BE) becomes Acting Secretary General

← George van Reeth

31 July
Sixth ESC meeting, in Brussels, agrees on the second 'package deal', thus paving the way for the creation of the European Space Agency, potentially by 1 April 1974. The new agency will be based on the 'programme à la carte' concept. France, Germany and the UK take major responsibility for funding the Ariane, Spacelab and MAROTS (maritime communications satellite) respectively



↑ Notes from the ESRO Council meeting in Brussels in 1973 showing the potential names for the proposed LIIIS, launcher (eventually named Ariane)



← Concept for the European 'sortie' module, or Spacelab, as a part of the US Space Shuttle programme (NASA)

↑ Concept for the Orbital Test Satellite as agreed in September 1973

↑ The sixth ESC meeting, in July 1973, agrees on the second 'package deal', paving the way for the creation of the European Space Agency

↑ Celebrating ten years in space, at an event in Paris, 18 March 1974, Prof. H.C. van de Hulst (NL) and Prof. Pierre Auger

September
Arrangement between ESRO and participating states in the first phase of the telecommunications programme enters into force. It foresees the development of the experimental satellite Orbital Test Satellite (OTS)

21 September
ESRO Council approves the draft arrangement between ESRO and European governments for the execution of the Ariane programme, open for signature from 15 October

24 September
Signature of the Memorandum of Understanding governing NASA/ESRO cooperation on Spacelab

1974

1 July
Roy Gibson (GB), ESRO's Director of Administration, takes over as Acting Director General

2 August
Signature of the Memorandum of Understanding governing the Aerosat programme between ESRO, the US Federal Aviation Administration and Canada ■

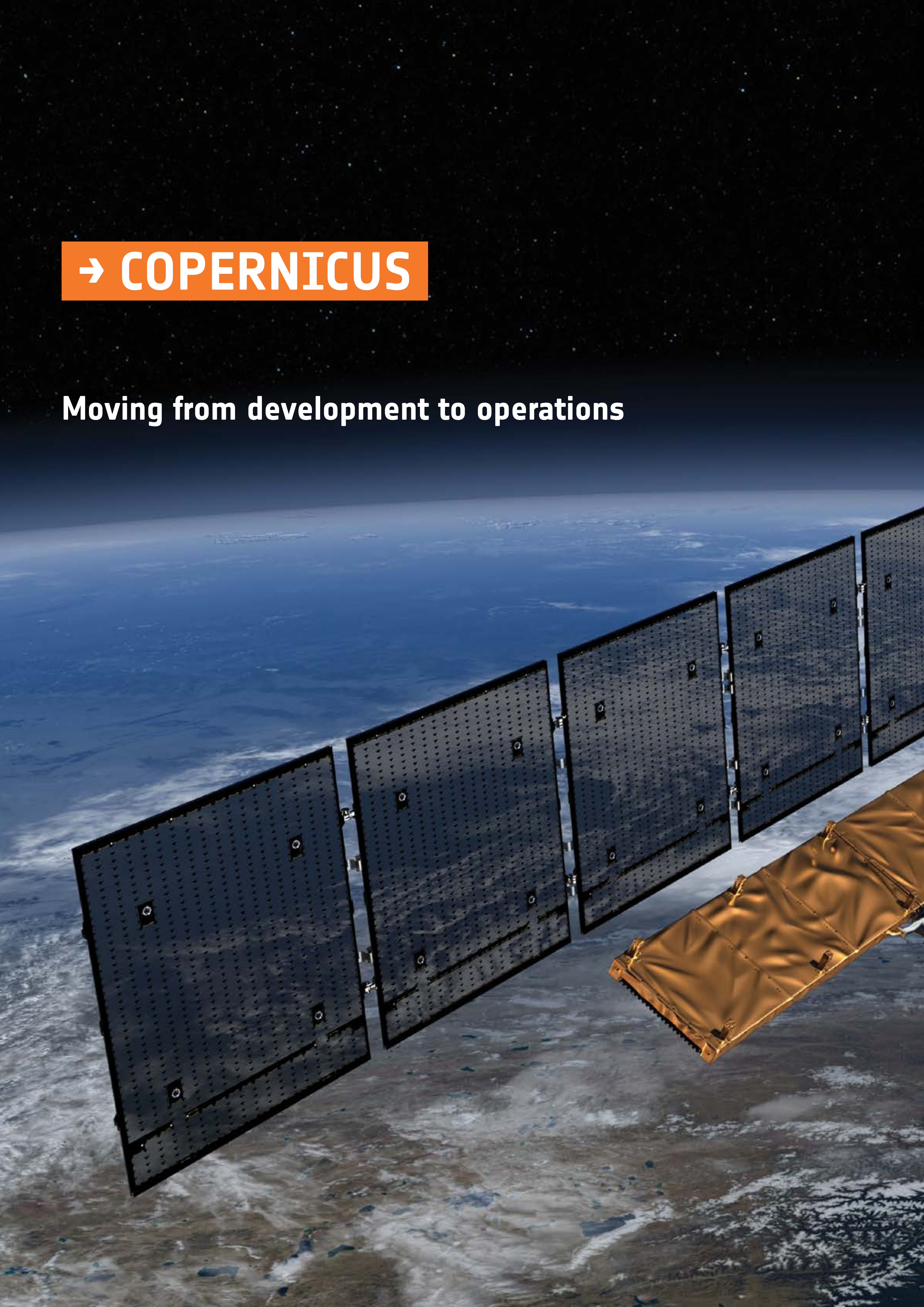
← Roy Gibson

↓ Signature of the Spacelab Memorandum of Understanding between ESRO and NASA, 1973

CHRONOLOGY Part 2: 1975–1994 Continued in next issue

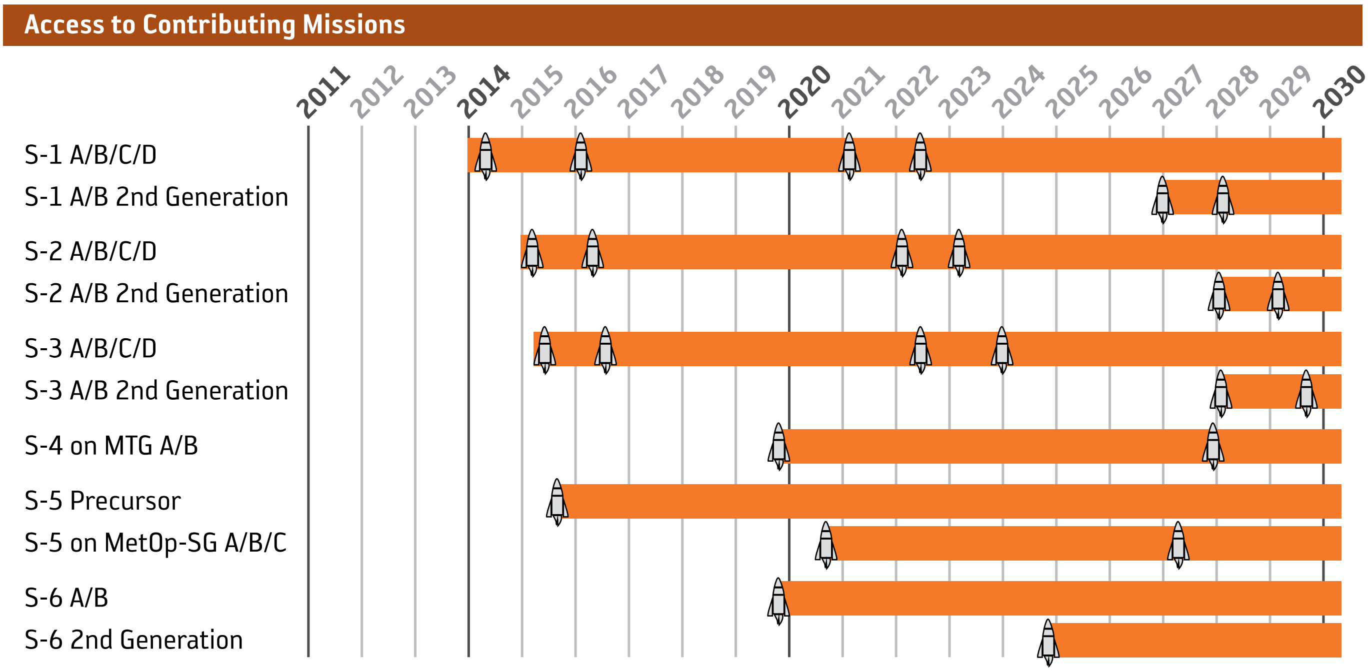
→ COPERNICUS

Moving from development to operations



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

Sentinel-1A, the first satellite in the Copernicus programme (ESA/ATG medialab)



↑ Schedule of Sentinel launches

Sentinel-1A, the first Copernicus satellite mission, is being prepared for launch, about the same time as the launch of the EU Copernicus programme. These events mark the beginning of the Copernicus operational phase and a major milestone for Earth observation in Europe.

The Copernicus programme is already partly operational (mainly through data acquired from existing satellite missions and sensors on the ground, at sea and in the air) and is already providing the world with great benefits.

The first dedicated Copernicus satellite mission, Sentinel-1A, will ensure the continuation and improvement of SAR operational services allowing imaging of global landmasses, coastal zones, sea ice, polar areas and shipping routes at high resolution. Sentinel-1 data products will be made available systematically and free of charge to all data users including the general public, scientific and commercial users.

The Copernicus programme

Copernicus, formerly known as Global Monitoring for Environment and Security (GMES), is a EU-led programme carried out in partnership with the Member States and ESA. This initiative aims to provide accurate and reliable information in the fields of the environment and security, tailored to the needs of users but also supporting other EU policies. It uses multiple source data from Earth observation satellites, as well as ground-based, air- and sea-borne sensors, to provide timely, accurate and global information services.

Copernicus has three components, focusing on the space, *in situ* and services aspects. The Copernicus Space Component, coordinated by ESA, is composed of two types of satellites:

- The Sentinel families, dedicated satellites that are specifically developed by ESA to satisfy users' needs in a wide range of applications; and
- The Contributing Missions, satellite missions from ESA, ESA or EU Member States, Eumetsat and other third party mission operators that make some of their data available for Copernicus.

By definition, the Sentinels have been designed to be complementary to Contributing Missions in terms of instrument type, instrument wavelengths/frequencies and resolutions or repeat cycles. The ground segment, facilitating access to Sentinel and Contributing Missions data, completes the Copernicus Space Component.

The Copernicus In situ Component, coordinated by the European Environment Agency (EEA), focuses on data acquired by a multitude of sensors on the ground, at sea or in the air. These data come from national European and non-European organisations.

Data from the space and the *in situ* infrastructure, once processed or modelled, are used to feed the Copernicus services, coordinated by the European Commission, which address six thematic areas: atmosphere monitoring, climate change monitoring, emergency management, land monitoring, marine monitoring and security.

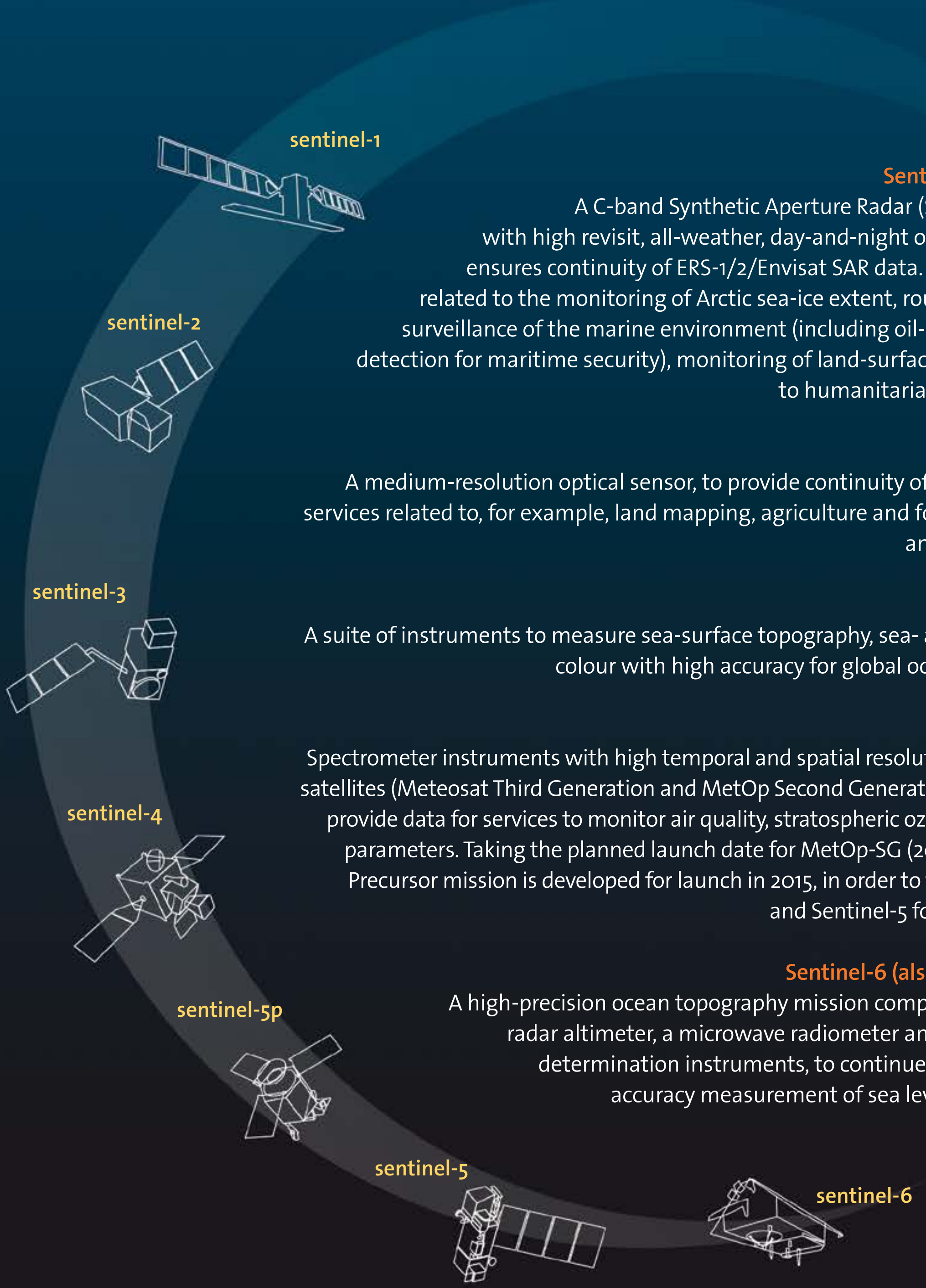
The Copernicus Space Component

ESA is responsible for coordinating the Space Component, i.e. the Sentinel missions and the access to data from Contributing Missions, relying on Eumetsat where necessary.

The Sentinels are six families of missions, each carrying different instruments so that together they offer a wealth of information for services that will help improve daily life and address the environmental consequences of climate change.

The first three Sentinel missions are based on a constellation of two satellites each, in the same orbital plane. This configuration fulfils the revisit and coverage requirements, and provides a robust and affordable operational service. The nominal lifetime of the individual satellites is specified as seven years, with consumables on board each satellite allowing a mission extension up to 12 years.

The following Sentinel satellites and instruments are being developed:



Sentinel-1

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

Sentinel-2

A medium-resolution optical sensor, to provide continuity of SPOT and Landsat-type data for services related to, for example, land mapping, agriculture and forestry, as well as disaster control and humanitarian relief operations.

Sentinel-3

A suite of instruments to measure sea-surface topography, sea- and land-surface temperature and colour with high accuracy for global ocean, land and climate monitoring.

Sentinel-4/-5

Spectrometer instruments with high temporal and spatial resolution to be embarked on Eumetsat satellites (Meteosat Third Generation and MetOp Second Generation (SG), respectively), which will provide data for services to monitor air quality, stratospheric ozone, solar radiation and climate parameters. Taking the planned launch date for MetOp-SG (2020) into account, a Sentinel-5 Precursor mission is developed for launch in 2015, in order to fill the gaps between Envisat and Sentinel-5 for atmospheric monitoring.

Sentinel-6 (also known as Jason-CS)

A high-precision ocean topography mission comprising a dual-band radar altimeter, a microwave radiometer and precise orbit determination instruments, to continue the high-accuracy measurement of sea level.

The Copernicus Contributing Missions have been mostly developed for purposes other than Copernicus but still provide valuable data, ensuring that European space infrastructure is fully used for the programme. They complement the capacities of the dedicated Sentinel missions. Their data policy, established by the mission owners, is fully respected for the purpose of providing data to Copernicus users. ESA, on behalf of the EU, procures data through contractual agreements with the different missions owners.

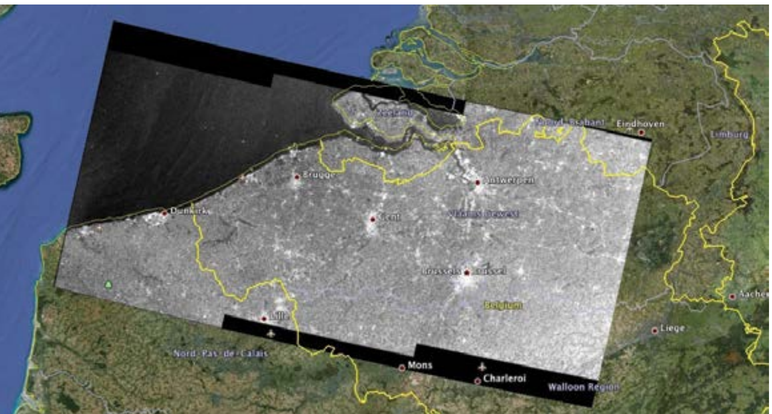
An integrated ground segment, developed by ESA, operates and provides access to Sentinel data and interfaces with Contributing Missions in order to obtain a coordinated data stream to satisfy observation requirements of Copernicus services.

A trade-off analysis is performed between the services requirements (specified in the Data Warehouse document), the capabilities of the portfolio of over 30 Contributing Missions and the available funding, the result of which is the actual satellite data offer for a certain period (the so called Data Access Portfolio). This document evolves in time in response to new services, for example, or new or updated requirements, or because new Contributing Missions become available.

Copernicus services

The Copernicus services support a wide range of applications, including environmental protection, management of urban areas, regional and local planning, agriculture, forestry, fisheries, health, transport, climate change, sustainable development, civil protection and tourism.

1. The Atmosphere Monitoring service will ensure the monitoring of air quality on a European scale and of the chemical composition of the atmosphere on a global scale. In particular, it will provide information for air quality monitoring systems at the local to national scales, and should contribute to the monitoring of atmospheric chemistry climate variables.



↑ Simulated Sentinel-1 interferometric wide-swath mode image over the Netherlands using archive Envisat radar data. The simulated data are overlaid on Google Earth

2. The Marine Monitoring service will provide information on the state of physical ocean and marine ecosystems for the global ocean and the European regional areas. The marine service will support activities in maritime safety, marine environment and coastal regions, marine resources as well as seasonal meteorological forecasting.

3. The Land Monitoring service will ensure that Earth observation data and derived information products are made available for the benefit of European, national, regional and international authorities responsible for the global-to-local environmental monitoring of biodiversity, soil, water, forests and national resources, as well as in general implementation of environment, agriculture, development, energy, urban planning, infrastructure and transport policies.

4. The Climate Change monitoring service will increase the knowledge base to support adaptation and mitigation policies. In particular, it will contribute to the provision of Essential Climate Variables, climate analyses and projections at temporal and spatial scales relevant to adaptation and mitigation strategies for the various EU sectorial and societal benefit areas.

5. The Emergency Management service will ensure that Earth observation data and derived information products are made available for the benefit of emergency response players at international, European, national and regional levels in relation to different types of disasters, including meteorological hazards (including storms, fires and floods), geophysical hazards (including earthquakes, tsunamis, volcanic eruptions and landslides), deliberate and accidental man-made disasters and other humanitarian disasters.

6. The Security service will provide useful information in support of the challenges that face Europe in the security field, notably border control, maritime surveillance and support for the EU's External Action.

Two of the six Copernicus services, the Emergency Management service and the Land Monitoring service are already operational. The Atmosphere and Marine monitoring services will become operational in the first quarter of 2015. The Climate Change and Security services will follow.

The European Commission ensures that service specifications match user needs throughout appropriate mechanisms, as well as coordination with public sector users in Member States, third countries and international organisations.

Flood monitoring with Sentinel-1-like data: January 2011 floods in Elbe, Germany (Radarsat-2/DLR/SAFER)

Sentinel data policy

Data currently delivered to Copernicus users comes from the Contributing Missions, which follow different data policies according to each operator/owner's business plans.

For the Sentinel missions, a free and open data policy has already been approved by ESA Member States in September 2013, complemented by a Delegated EU Regulation on the Copernicus data and information policy that entered into force in December.

Under this data policy, Sentinel data will be provided to users on a full, free and open basis worldwide. Access restrictions are only foreseen in case of technical limitations (for example, data bandwidths) or if security interests and external relations of the EU or its Member States are impacted. This free and open data policy will maximise the beneficial use of Sentinel data for the vital task of monitoring the environment, will stimulate the uptake of information based on Earth observation data for end users and will also help Europe's enterprises creating new jobs and business opportunities.

Quantum leap

Based on over 30 years of experience in developing and implementing Earth observation satellites, ESA is developing the six series of Sentinel missions specifically for the operational needs of the Copernicus programme.

Sentinel-1 operations, unlike other SAR missions for which the observation scenarios are based on data tasking and ordering from users, have been conceived as a preprogrammed, routine and conflict-free scenario. The main Sentinel-1 mode (Interferometric Wide Swath with 250 km swath width and 5 m x 20 m range/azimuth resolution) will allow complete coverage of Earth in six days in the operational configuration when the two Sentinel-1 satellites are in orbit simultaneously. High-priority areas, such as Europe, Canada and some shipping routes, will be covered daily. This high global observation frequency is unprecedented and cannot be reached with any other current radar mission. Envisat, for example, which was the 'workhorse' in this domain up to April 2012, reached global coverage every 35 days.

Sentinel-2 covers systematically and globally all land surfaces between 56° S and 84° N latitude with a 290 km swath width. The global coverage is obtained after five days with the two-satellite constellation. Knowing that the revisit time of Landsat-8 is 16 days, this means that Sentinel-2 will acquire three times as many views of any given target.

In addition, Sentinel-2 has a total of 13 spectral bands, six of which in the Near Infrared (NIR) region (central wavelengths 700, 740, 783, 842, 865 and 945 microns), the so-called 'red edge' part of the spectrum, while there is only one (850–880 microns) on Landsat-8. This guarantees full-fledged Sentinel-2 land applications using NIR reflected energy (for example, vegetation discrimination, crop stress, weed/pest infestation) with unprecedented accuracy of desired land-cover maps and vegetation products.

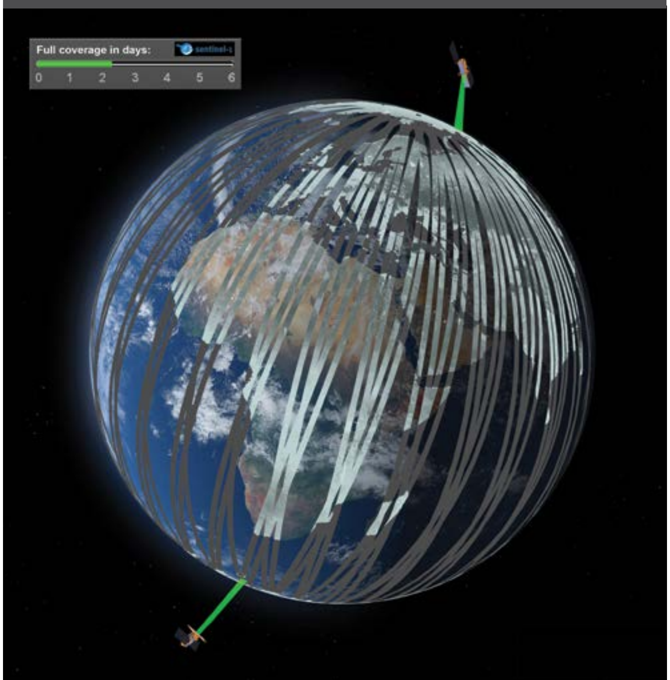
The different Sentinel-3 instruments bring remarkable improvements with respect to the similar instruments on board Envisat: the Ocean Land Colour Instrument (OLCI), the Sea and Land Surface Temperature Radiometer (SLSTR) and the Radar Altimeter (SRAL).

The OLCI on board Sentinel-3 contains 21 spectral bands (Envisat MERIS instruments had only 15), with a reduced sun glint obtained by the tilt of the camera in the west direction, an improved coverage of three to four days over land and ocean (MERIS coverage time was 15 days) and three hours (from sensing) for products delivery.

The Sentinel-3 SLSTR contains two additional bands (with respect to Envisat AATSR) plus two Fire channels, allowing the sea/land temperature retrieval with a better accuracy. It also contains one channel in the visible part of the spectrum for coregistration with the other optical instrument on board the satellite and a new detector technology that allows higher resolution images. With both instruments combined, coverage of continental Europe is obtained approximately every two days.

The topography package on Sentinel-3 is composed of a dual-band radar altimeter, a microwave radiometer and precise orbit determination instruments. The Sentinel-3 radar altimeter has the possibility of working in SAR mode, which highly improves the performance over rough surfaces with respect to the radar altimeter on Envisat.

↑ The main Sentinel-1 mode will allow complete coverage of Earth in six days when operational with the two Sentinel-1 satellites are in orbit simultaneously (ESA/ATG medialab)



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The launch of Sentinel-1 in April marks the beginning of the Copernicus operational phase and a major milestone for Earth observation in Europe (ESA/ATG medialab)

Socioeconomic impact of Copernicus

Some recent studies have demonstrated that Copernicus can stimulate growth and employment and could lead to an increase in the total market for Earth Observation services. The ESPI Report 39 (*The Socio-Economic Benefits of GMES*) published in November 2011 compares a study by PricewaterhouseCoopers (PwC) and another one by Booz and Company. An important result is that both studies, although employing different approaches, reach similar conclusions regarding the order of magnitude of potential socio-economic benefits of Copernicus.

The PwC study establishes three categories of potential Copernicus benefits: Efficiency benefits, European policy formulation benefits and global action benefits and assesses them separately. The Booz and Company study, based on a literature review, looks at different funding levels and performs an impact analysis in the areas of climate change, environment and security and industrial development. Moreover, it differentiates between static and dynamic scenarios. The dynamic scenario, unlike the static one, allows for interaction between relevant ecosystems in the realm of Copernicus. From both studies, a benefit/cost ratio of about 10:1 can be derived for the dynamic model. This means that for every Euro spent by the European taxpayer on Copernicus, a public return of 10 Euros can be expected.

Finally, the report from Spacetec partners (Assessing the Economic Value of GMES: 'European Earth Observation and GMES Downstream Services Market Study', Specific Contract under the Framework Service Contract 89/PP/ENT/2011 – LOT 3, 10 December 2012) shows that Copernicus is not only an environmental monitoring tool, but also can stimulate economic growth in a wide range of industrial sectors, leading to the creation or maintenance of approximately 20 000 direct jobs in Europe by 2030, if enabling factors are put in place.

With highly skilled jobs in this sector typically impacting employment in other sectors, the economic stimulus by Copernicus could also result in a wider economic effect, with an additional 63 000 indirect jobs secured or created by 2030. Overall, the impact on employment from Copernicus, according to this study, is estimated at approximately 83 000 jobs in Europe by 2030.

In addition to these economic benefits, Copernicus is expected to give much larger strategic benefits by providing Europe with better information globally and therefore allowing Europe to assume a stronger role on the political stage and the global marketplace.

Long-term partnership in the making

From a budgetary point of view, ESA Member States and the EU have already financed approximately €3.4 billion of the Copernicus programme during its development phase. Of this, about €2.4 billion have been invested in the Copernicus Space Component (€1.6 billion by ESA and €0.8 billion by the EU).

The transition of the programme from development to operations will take place at about the same time as the first Sentinel satellite is launched. During the operational phase, funding of the programme will come from the EU Multiannual Financial Framework for the years 2014–20. In this context, €4.3 billion (c.e.c.) have been allocated for Copernicus, of which around €3.4 billion are allocated to the Space Component.

The EU Copernicus Regulation, laying down the legal basis for the EU operational Copernicus programme, is being finalised by the European Parliament, Council and the Commission.

Based on this, the future EU/ESA Copernicus Agreement will define the modalities for the cooperation between ESA and the EU for the period 2014–20 and will regulate the budget implementation tasks entrusted to ESA by the EU for the accomplishment of the space segment and the programme operations phase. The agreement, once signed, will pave the way for important procurements over the next seven years in the Earth observation domain.

The successful uptake of the operational phase of the Copernicus Space Component and the full economic benefits of the Copernicus programme will materialise only when the wealth of data from the whole series of Sentinel satellites will be accurately delivered on time to users.


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ESA's Spin Your Thesis! programmes allow students to conduct their experiments on the Large Diameter Centrifuge at ESTEC, Noordwijk

→ GETTING 'SPACE' EXPERIENCE ON EARTH

Education activities for university students

Natacha Callens and Piero Galeone
Education and Knowledge Management Office, ESTEC, Noordwijk, The Netherlands

Drop-tower tests, hypergravity centrifuge tests, sounding rockets and stratospheric balloons campaigns: all included in the portfolio offered by ESA's Education and Knowledge Management Office to university students.

Responsible for the ESA's corporate education programme, the ESA Education Office is bringing together young people from Member and Cooperating States, aged from 6 to 32, helping them to gain and maintain an interest in science and technology. The long-term objectives are to contribute to sustaining Europe as a knowledge-based society and to ensure a qualified workforce for ESA and the European space industry, needed to implement a European space programme.

In particular, in the past five years, the Education Office has offered, in addition to satellite projects through four different programmes, unique hands-on opportunities to around 500 university students from Member and Cooperating States. Theses programmes are targeted towards science and engineering students who have good concepts for experiments to be performed in microgravity, hypergravity or in other space-like conditions.

'Fly Your Thesis!', now on hold since 2013, enabled 11 student teams from eight countries to participate in three Airbus A300 Zero-G flights of 30 parabolas each, with every parabola providing about 20 seconds of microgravity. 'Drop Your Thesis!' gave five student teams from four countries the opportunity to carry out up to five 'launches' at the ZARM drop tower in Bremen, Germany, with each 'launch' offering up to 9.3 seconds of microgravity.

Fifteen student teams from 11 Member States and one Cooperating State performed hypergravity experiments, with accelerations of up to 20 times Earth's gravity, during up to three days of 'Spin Your Thesis!' at ESA's Large Diameter Centrifuge at ESTEC in the Netherlands.

The fourth opportunity is through ESA's collaboration in the DLR/Swedish National Space Board (SNSB) REXUS/BEXUS programme. REXUS sounding rockets are capable of taking 40 kg of experiment modules to altitudes between 75 and 90 km and can offer up to two minutes of milligravity environment.

The BEXUS stratospheric balloon brings student experiments to altitudes of 25–30 km with flight durations typically between two and five hours. Sponsored by the SNSB and ESA, 46 university student teams, from 14 Member States and one Cooperating State, were able to fly their experiments in these two vehicles. In addition, DLR sponsored 29 student teams from German universities.

The opportunity to take part in this wide range of activities gives students a unique chance to participate in the complete life cycle of a space project, starting from the scientific or technical idea, through the design, development and testing phases, up to the launch campaign and the data analysis.

Students have to provide scientific and technical documentation and undergo several design and experiment reviews. They have the opportunity to travel and make contact with other European student teams, as well as with professional space organisations. All participating teams provide a final report and most of the students include their results in their Bachelors, Masters or PhD theses.

Several teams have already presented their projects at international conferences and published papers in refereed journals. Some of these students have also gone on to become our colleagues in the space business, working at ESA, or in other organisations or in industry.

At the end of each programme cycle, the students are requested to provide their feedback. It is important for ESA's Education Office to review and examine what can be improved from one cycle to the next, and see what are the benefits of these hands-on programmes.

These benefits are not only limited to the value of the educational experience for the students (which is extremely important, by the way) but also, in several cases, the

↓ Drop Your Thesis! 2013 campaign, Fall of Fame students preparing their experiment for a catapult launch in the ZARM drop tower, Germany

↓ Spin Your Thesis! 2010 campaign, ETH Space biology team checking their experiment before a run in the Large Diameter Centrifuge, ESTEC, the Netherlands

results achieved by the student-built experiments have an interesting intrinsic value for the professional scientific community and the space sector in general.

Students results

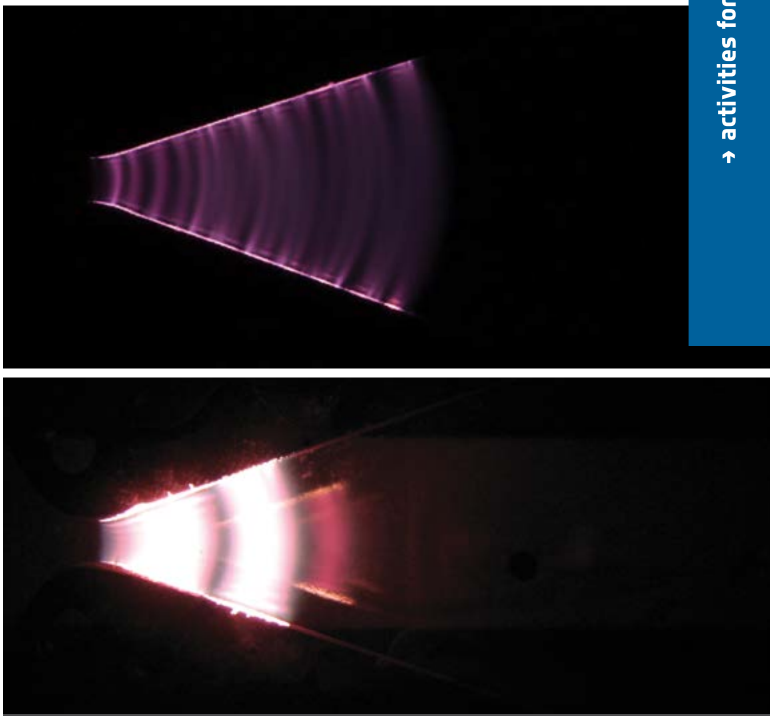
The GRAVARC team was two students from Masaryk University in Czech Republic. During the Spin Your Thesis! 2012 campaign, they investigated the behaviour of gliding arc discharge in a helium and helium/methane atmosphere in hypergravity conditions and the properties of the solid products of the involved plasma/chemical reactions.

A gliding arc is an electrical discharge that is formed between two divergent electrodes when a suitable electric voltage is applied on them. The electrical discharge is formed in the gas at the smallest gap between the electrodes. The discharge then elongates as it glides along the electrode edges with an increasingly large gap until it extinguishes at certain length.

The students studied the effects of gravity on the shape, intensity, colour and emission spectra of the discharge. They confirmed that gravity has a visible effect on the plasma itself and also on morphology of the carbon deposit and showed that gravity-driven convection changes the gliding frequency of the discharge, influencing the rate of plasma/chemical reactions.

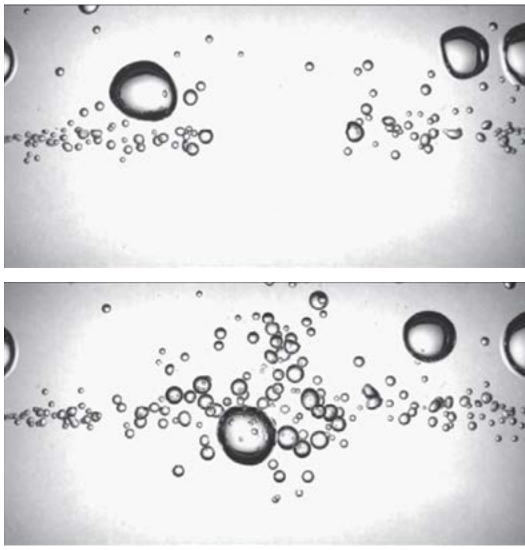
The three students on the BudJet team from the Polytechnic University of Catalonia, Spain, developed an experimental setup to investigate the collision of bubble jets in microgravity conditions. The experiment was carried out during the Drop Your Thesis! 2010 campaign at the ZARM drop tower. The objective was to understand better the behaviour of two-phase flows in a low-gravity environment.

In particular, the students investigated the effects of gas/liquid flow rates and separation between jets on the bubble coalescence probability. Results on the global structure of the impinging jets and the individual behaviour of bubbles were obtained, including on the velocity field, bubble size distribution and the spatial distribution of coalescence events.



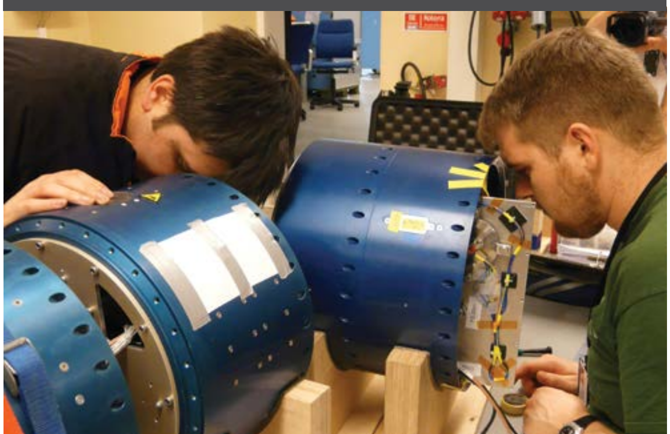
↑ From the GRAVARC team, a glide arc in helium atmosphere at 1g level (top) and at 18g level (bottom)

→ Snapshots taken by the BudJet team showing two impinging bubble jets in microgravity at different times after capsule release



↓ BEXUS 16 and 17 campaign, ARCADE-R2 students integrating their experiment in the gondola of the stratospheric balloon

↓ REXUS 11 and 12 campaign, CaRu and Telescobe 2 students during payload assembly of sounding rocket



↑ AstEx students in microgravity alongside their experiment

The AstEx team, two students from the Open University in the United Kingdom and one affiliated with both the Open University and the University of Nice-Sophia Antipolis, France, wanted to study the behaviour of granular material in microgravity. This could have possible applications in the design of future asteroid sample return missions and in the interpretation of asteroid geology. Their experiment was carried out during the Fly Your Thesis! 2009 campaign, in the A300 Zero-G aircraft, operated and maintained by Novespace in Bordeaux, France.

When analysing the results afterwards, the students observed no difference in the main flow of the grains under different gravity conditions in response to a shear, but found that secondary, convective-like flows in a sheared granular material are close to zero in microgravity and enhanced under high-gravity conditions. The results of a further experiment, in which the team investigated transient weakening of granular material after shear reversal in microgravity, indicate that asteroid surfaces may be even more unstable than previously imagined.

↑ A panorama taken from the REXUS 11 rocket at deployment of the two RAIN team aerosol collection probes

The RAIN team from Sweden was composed of 19 students from the Royal Institute of Technology (KTH) in Stockholm. Their experiment was launched on board REXUS 11 from the SSC Esrange Space Centre and demonstrated a technique for collecting aerosol particles in the middle atmosphere using two probes ejected from a sounding rocket. Collection samples on each probe were exposed over varying height ranges between 80 and 20 km giving an altitude distribution profile of aerosol particles. Initial results indicate that aerosols have been successfully collected, however further analysis seeks to determine size and composition of the particles.

↓ The TECHDOSE Team during the BEXUS-14 and 15 launch campaign

The TECHDOSE teams consisted of nine students from different universities all over Hungary and supported by several research institutes governed by the Centre for Energy Research at the Hungarian Academy of Sciences. The goal of the experiment was to measure the cosmic radiation field in the stratosphere for dosimetry purposes. It combined active and passive radiation monitoring measurement methods. The experiment was launched on the BEXUS 14 balloon from Esrange Space Centre and included an onboard camera for outreach purposes. ■

→ Picture taken by the TECHDOSE onboard camera

→ WHAT THE STUDENTS SAY

"From all points of view, Fly Your Thesis! has been a great programme. All of us have profited and learned from many different things: project management, technical build-up of the experimental set up, the scientific objectives of the experiment and, last but not least, the great human experience."

QNEM and 'Nano's on board!' team, Fly Your Thesis! 2011

↑ Fly Your Thesis 2012 campaign, Hydronauts2Fly experiment

↑ Drop Your Thesis 2009 campaign participants

"The Drop Your Thesis! programme was a really great time. We had to invest a lot of work in our set-up but finally it was worth it. Every problem we had led to a learning effect, and we obtained knowledge we wouldn't have received in our studies. The experiences of success helped us going on even in difficult moments and in the end, seeing our set up functioning as we expected was a great feeling. We had a lot of fun, the possibility to see many interesting things and the results of our experiment in microgravity exceeded all our expectations."

Fall of Fame team, Drop Your Thesis! 2013

"Thanks to my participation in the Spin Your Thesis! programme, I have gained experience and knowledge in many areas, from researching the topic that we wanted to study, to analysing the really interesting data we recorded."

Bubble Movers team, Spin Your Thesis! 2012

→ Spin Your Thesis! 2010 second campaign week participants

↑ BEXUS 14 and 15 campaign participants

"We found the entire experience of BEXUS a great chance to apply our knowledge to a practical project. It was an amazing opportunity to send our experiment into the stratosphere. Hard work but fun at the same time."

iSEDE team, BEXUS 16 and 17

"It's an amazing feeling that something you designed got launched into space – of course, it was a valuable experience, but more importantly it was exciting."

PoleCATS team, REXUS 13 and 14

← REXUS 13 and 14 campaign participants

→ REXUS/BEXUS programme survey

In 2013, after five cycles of the REXUS/BEXUS programme, a survey was made to examine the profile of former REXUS/BEXUS participants and the benefits of these hands-on opportunities on their studies and careers.

Over 160 respondents answered with at least one student from each of the 20 flown vehicles. The following results are detailed as percentages of those respondents who chose to answer the question (i.e. not necessarily the percentage of all respondents). The majority of respondents were male, average age 27 years.

The results were skewed towards the more recent campaigns, with 58% of respondents having flown experiments on the most recent launches in 2012 and 2013. Twenty nationalities were represented identified in total: 94% of respondents identified themselves as nationals of ESA Member or Cooperating States. Two thirds identified themselves as German, Italian, Swedish, British or Polish. The top five countries represented were Germany, Italy, Sweden, United Kingdom and Hungary.

Most respondents were students at Masters level when they joined their educational programme, (with 19.7% at PhD level and 16.9% at Bachelors level). Half of the courses followed included the subjects 'Engineering', 'Physics' or 'Science'.

Around half of the respondents stated their involvement was part of their degree programme. Overall, 34.2% stated they had gained credits from REXUS/BEXUS towards their courses, and 42.7% of respondents stated they accepted to delay their course to participate in REXUS/BEXUS, with an average delay of approximately six months.

Asked about the main tasks of their involvement in the hands-on projects, the respondents mainly listed electronics (23.5%), mechanics (19.6%) and project management (16.3%). The respondents averaged a self-estimated workload of 728 hours on their projects.

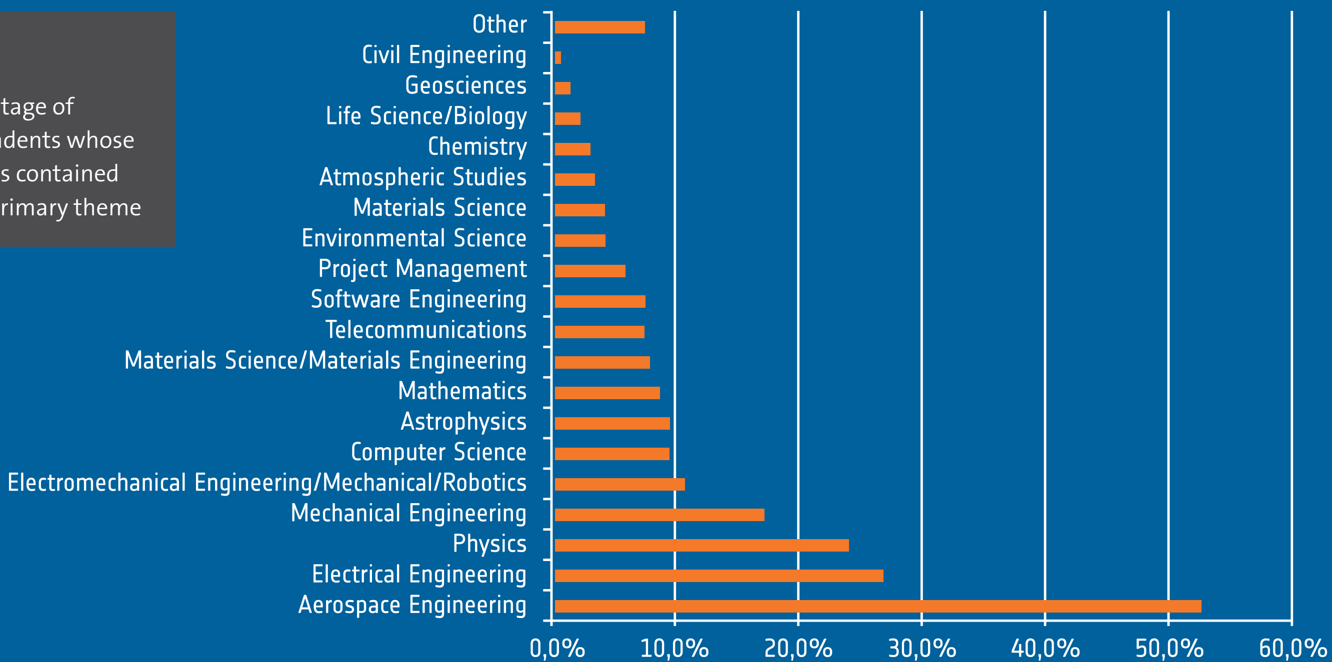
Around 40% of respondents had the chance to present personally their project at conferences, with an average of two conferences each. The amount of respondents who personally contributed to conference papers was 56.8%, with 17.2 % having also published in scientific and/or technical journals with a further 37.2 % planning to do so.

About a third of respondents are currently employed (most in a space-related job), with 52.7% still engaged in their studies. The majority of respondents stated that REXUS/BEXUS was relevant for their career, saying it was a springboard for their career.

Nearly all were satisfied or highly satisfied with the result of their sounding rocket or stratospheric balloon project. Over 95% of the respondents (including those that had to delay their studies) were convinced of the value of their participation in the programme, which offered an important chance to increase their understanding of space projects, their design and practical skills, teamwork abilities and other soft skills.

→

Percentage of respondents whose courses contained each primary theme



→ 2013 IN PICTURES

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

(Preceding page)
5 June

Ariane 5 flight VA213 lifts off from Europe's Spaceport in French Guiana carrying ESA's fourth Automated Transfer Vehicle, *Albert Einstein*, to the International Space Station (ESA/S. Corvaja)

13 September

ESA astronaut Andreas Mogensen (DK) is seen 20 m under the sea on a simulated spacewalk, as part of the Seatest mission off the coast of Florida, USA (ESA/T. Pesquet)

1 December

Like a scene from a sci-fi movie, scientists working in Antarctica during the polar night and in a storm, studying the properties of snow for later validation of CryoSat satellite data. The icebreaker vessel Polarstern is in the background (A. Wegner Inst./ S. Hendricks)

22 March

ESA-sponsored medical doctor Evangelos Kaimakamis during research at Concordia station (ESA/IPEV/PNRA/ E. Kaimakamis)

19 June

Safety divers recover ESA's Intermediate eXperimental Vehicle after the Descent and Landing System Test was performed off the east coast of Sardinia, Italy (ESA)

25 July

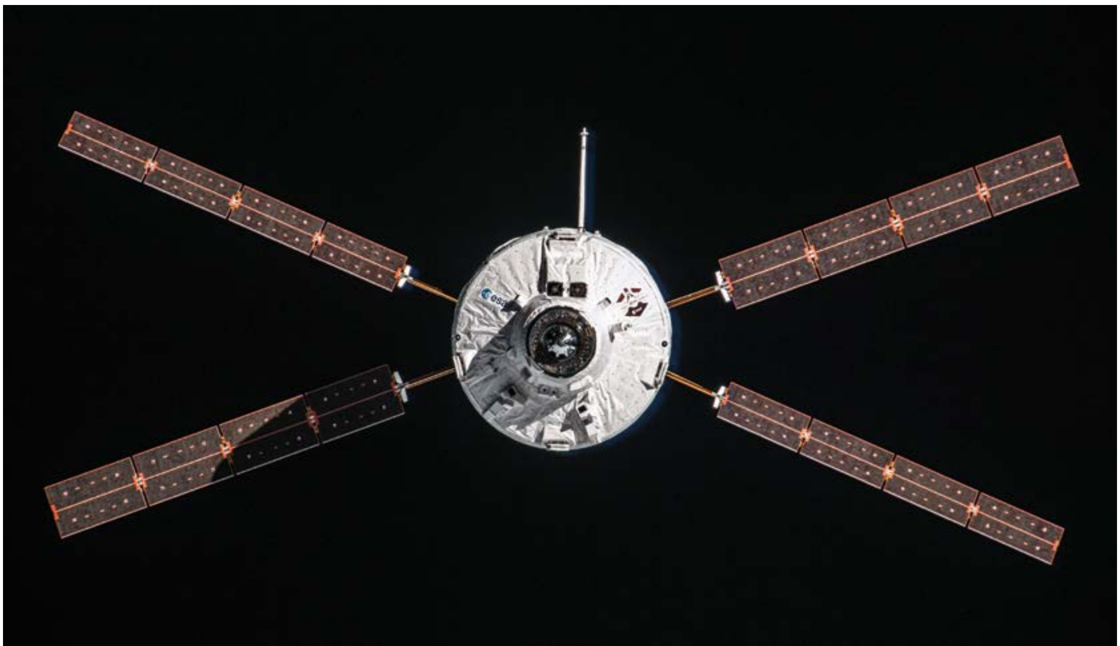
Ariane 5 flight VA214 lifts off from Europe's Spaceport in French Guiana carrying Europe's largest telecom satellite Alphasat (ESA/CNES/Arianespace-Optique Photo Video du CSG/L. Boyer)

10 October

This technician is not having a quick snooze, but is checking the deployment of the sunshield of Gaia, ESA's billion star surveyor, during testing at Europe's Spaceport in French Guiana (ESA/M. Pedoussaut)

9 July

ESA astronaut Luca Parmitano during a spacewalk with NASA astronaut Chris Cassidy (ESA/NASA)



15 June

ATV *Albert Einstein*, Europe's fourth supply and support ferry, seen just before docking with the International Space Station (ESA/NASA)

1 November

ESA astronaut Luca Parmitano tweeted this photo of himself dressed as Superman on the International Space Station, poking fun at himself for Halloween (ESA/NASA)

30 October

All three Swarm satellites in the vertical position, ready to be joined to the launch adapter at Plesetsk, Russia, for a launch in November (ESA/M. Shafiq)

6 October

ESA astronauts past and present attending the ESTEC Open Day: Reinhold Ewald, André Kuipers and Ulf Merbold (ESA/G. Schoonewille)

19 December

Silhouetting the launch gantry at Europe's Spaceport, French Guiana, Soyuz VS06 lifts off carrying ESA's Gaia space observatory (ESA/S. Corvaja)

→ SEE INSIDE ESA'S EARTH OBSERVATION CENTRE

ESRIN Open Days, 18–21 March 2014


ESRIN from the air

↑ Institute 'Sacro Cuore' Rome: Primary school students wanting to grab a 3D image of the GOCE satellite at ESRIN Open Day, 18 March 2013 (ESA/V. Stefanelli)

↑ Students learning how the body reacts to weightlessness: it's like being in upside down, says Paolo as he demonstrates with young volunteers (ESA/V. Stefanelli)

Every spring, ESA's ESRIN centre opens its doors to primary and secondary students, aged 8–13 years, together with their teachers. This event, which has taken place for the last 14 years, attracts children and teachers from over 30 schools in the Rome area.

Last year, over 1500 young people had the opportunity to 'touch' European space research projects and activities, and hopefully spark their interest in studies for a scientific career.

ESRIN presents a rich programme, showing students 3D satellite animations and images of our planet, all for a better understanding of Earth and its environment. Students and teachers learn how satellites provide clear views of Earth's various systems – volcanoes, ice, atmosphere, biosphere and oceans – and how these processes interact and influence each other.

There will be hands-on laboratory activities, demonstrating remote sensing using real instruments, showing how launchers work by building water rockets, and experiencing human spaceflight by eating like an astronaut.

Last year, children were asked to make drawings of the Copernicus Sentinel-1 satellite and write a slogan that captured the essence of the mission. Many of the children attending took part in the competition and, judging by the quality of drawings, the Sentinel-1 mission certainly captured their imaginations.

An animated interactive session showed students a launch of Vega from Europe's Spaceport in French Guiana. Vega offers a safe, reliable and competitive capacity to carry smaller payloads into orbit for science,

← ESA astronaut Paolo Nespoli during his outreach presentation in 2013

→ The Envisat building at ESRIN

technology demonstration and Earth observation missions.

One of the stars of the open days was ESA astronaut Paolo Nespoli, who has flown twice into space. The audience was keen to learn about the life of astronauts on the International Space Station, flying 400 km above Earth, and Paolo encouraged participation when he asked, "Can you imagine living and working in a floating laboratory in space in weightless conditions?"

"On Earth, everything we do is strongly influenced by gravity. We are so accustomed to gravity that we take it for granted: it is perfectly natural for something to fall when you drop it, after all."

Paolo took the young audience on a guided tour through the ISS, his home in 2011 for six months during his MagISStra mission, showing impressive scenes and 3D images, such as his living and sleeping room, his experiments and his crewmates, the breathtaking pictures of Earth taken from the European-built 'Cupola'.

For more information

www.esa.int/ita/ESA_in_your_country/Italy

↑ The bravest volunteers being briefed by Paolo on how it feels to be crushed into your seat in a Soyuz capsule during reentry (ESA/V. Stefanelli)

→ NEWS IN BRIEF

ESOC mission controllers, ESA staff and press cheer as the first signal is received from the Rosetta spacecraft on 20 January 2014 (ESA/J. Mai)

↑ ESA Director General Jean-Jacques Dordain and Director of Human Spaceflight & Operations Thomas Reiter react after the signal from Rosetta is received at ESOC (R. Orlowski/Reuters)

Rosetta is alive and well

It was a fairy-tale ending to a tense chapter in the story of the Rosetta mission as ESA heard from its distant spacecraft on 20 January for the first time in 31 months.

Rosetta is chasing Comet 67P/Churyumov-Gerasimenko, where it will become the first space mission to rendezvous with a comet, the first ever to attempt a landing on a comet's surface and the first to follow a comet as it swings around the Sun.

Operating on solar energy alone, Rosetta was placed into a deep-space hibernation in June 2011 as it cruised out to a distance of nearly 800 million km from the warmth of the Sun, beyond the orbit of Jupiter.

Now, as Rosetta's orbit has brought it back to within 'only' 673 million km from the Sun, there is enough solar energy to power the spacecraft fully again. On time, while still about 9 million km from the comet, Rosetta's pre-programmed internal 'alarm clock' woke up the spacecraft.

After warming up its key navigation instruments, coming out of a stabilising spin, and aiming its main radio antenna at Earth, Rosetta sent a signal to let mission operators know it had survived the most distant part of its journey.

The signal was received by both NASA's Goldstone and Canberra ground stations at 18:18 GMT, during the first window of opportunity the spacecraft had to communicate with Earth.

"We have our comet-chaser back. With Rosetta, we will take comet exploration to a new level. This incredible mission continues our history of 'firsts' at comets, building on the technological and scientific achievements of our first deep space mission Giotto, which returned the first close-up images of a comet nucleus as it flew past Halley in 1986," said Alvaro Giménez, ESA's Director of Science and Robotic Exploration.

Rosetta's first images of Comet 67P/Churyumov-Gerasimenko are expected in May, when the spacecraft is still two million km from its target. Towards the end of May, the spacecraft will execute a major manoeuvre to line up for its critical rendezvous with the comet in August.

After rendezvous, Rosetta will start with two months of extensive mapping of the comet's surface, and will also make important measurements of the comet's gravity, mass and shape, and assess its gaseous, dust-laden atmosphere, or coma. The orbiter will also probe the plasma environment and analyse how it interacts with the Sun's outer atmosphere, the solar wind.

Using these data, scientists will choose a landing site for the mission's 100 kg Philae probe. The landing is currently scheduled for 11 November and will be the first time that a landing on a comet has ever been attempted.

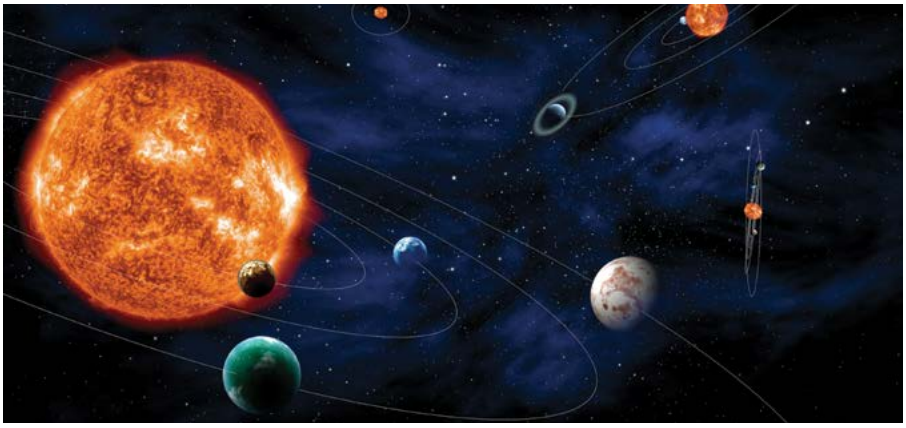
Given the almost negligible gravity of the comet's 4 km-wide nucleus, Philae will have to use ice screws and harpoons to stop it from rebounding back into space after touchdown. Philae will send back a panorama of its surroundings, as well as very high-resolution pictures of the surface.

It will also perform an on-the-spot analysis of the composition of the ices and organic material, including drilling down to 23 cm below the surface and feeding samples to Philae's onboard laboratory.

The comet will reach its closest distance to the Sun on 13 August 2015 at about 185 million km, roughly between the orbits of Earth and Mars. Rosetta will follow the comet throughout the remainder of 2015, as it heads away from the Sun and activity begins to subside.

ESA selects planet-hunting Plato mission

A space-based observatory to search for planets orbiting alien stars has been selected as ESA's third medium-class science mission, planned for launch by 2024.



The 'Plato' mission, standing for 'Planetary Transits and Oscillations of stars', was selected by ESA's Science Programme Committee for implementation as part of its Cosmic Vision 2015–25 programme. The mission will address two key themes of Cosmic Vision: what are the conditions for planet formation and the emergence of life, and how does the Solar System work?

Plato will monitor relatively nearby stars, searching for tiny, regular dips in brightness as their planets transit in front of them, temporarily blocking out a small fraction of the starlight. By using 34 separate small telescopes and cameras, Plato will search for planets around up to a million stars spread over half of the sky.

It will also investigate seismic activity in the stars, enabling a precise characterisation of the host sun of each planet discovered, including its mass, radius and age. When coupled with ground-based radial velocity observations, Plato's measurements will allow a planet's mass and radius to be calculated, and therefore its density, providing an indication of its composition.

The mission will identify and study thousands of exoplanetary systems, with an emphasis on discovering and characterising Earth-sized planets and super-Earths in the habitable zone of their parent star – the distance from the star where liquid surface water could exist. These systems will provide natural targets for detailed follow-up observations by future large ground- and space-based observatories.

The four other mission concepts competing for the M3 launch opportunity were: ECHO (the Exoplanet Characterisation Observatory), LOFT (the Large Observatory For X-ray Timing), MarcoPolo-R (to collect and return a sample from a near-Earth asteroid) and STE-Quest (Space-Time Explorer and Quantum Equivalence Principle Space Test).

Plato joins Solar Orbiter and Euclid, which were chosen in 2011 as ESA's first M-class missions. Solar Orbiter will be launched in 2017 to study the Sun and solar wind from a distance of less than 50 million km, while Euclid, to be launched in 2020, will focus on dark energy, dark matter and the structure of the Universe.

Plato will be launched on a Soyuz rocket from Europe's Spaceport in Kourou by 2024 for an initial six-year mission. It will operate from L2, a point in space 1.5 million km beyond Earth as seen from the Sun.

←

Ceres is the largest object in the asteroid belt, which lies between the orbits of Mars and Jupiter

Water vapour around Ceres

ESA's Herschel space observatory has discovered water vapour around Ceres, the first unambiguous detection of water vapour around an object in the asteroid belt.

With a diameter of 950 km, Ceres is the largest object in the asteroid belt, which lies between the orbits of Mars and Jupiter. But unlike most asteroids, Ceres is almost spherical and belongs to the category of 'dwarf planets', which also includes Pluto.

It is thought that Ceres is layered, perhaps with a rocky core and an icy outer mantle. This is important, because the water-ice content of the asteroid belt has significant implications for our understanding of the evolution of the Solar System.

When the Solar System formed 4.6 billion years ago, it was too hot in its central regions for water to have condensed at the locations of the innermost planets, Mercury, Venus, Earth and Mars. Instead, it is thought that water was delivered to these planets later during a prolonged period of intense asteroid and comet impacts around 3.9 billion years ago.

While comets are well known to contain water ice, it is not certain about asteroids. Water in the asteroid belt has been hinted at through the observation of comet-like activity around some asteroids – the so-called Main Belt Comet family – but no definitive detection of water vapour has ever been made.

Now, using the HIFI instrument on Herschel to study Ceres, scientists have collected data that point to water vapour being emitted from the icy world's surface.

"This is the first time that water has been detected in the asteroid belt, and provides proof that Ceres has an icy surface and an atmosphere," said Michael Küppers of ESA's European Space Astronomy Centre in Spain.

Although Herschel was not able to make a resolved image of Ceres, the astronomers were able to derive the distribution of water sources on the surface by observing variations in the water signal during the dwarf planet's nine-hour rotation period. Almost all of the water vapour was seen to be coming from just two spots on the surface.

The most straightforward explanation of the water vapour production is through sublimation, whereby ice is warmed and transforms directly into gas, dragging the surface dust with it, and thus exposing fresh ice underneath to sustain the process (similar to comets).

The two emitting regions are about 5% darker than the average on Ceres. Able to absorb more sunlight, they are then likely the warmest regions, resulting in a more efficient sublimation of small reservoirs of water ice. An alternative possibility is that geysers or icy volcanoes – cryovolcanism – play a role in the dwarf planet's activity.

"Herschel's discovery of water vapour outgassing from Ceres gives us new information on how water is distributed in the Solar System. Since Ceres constitutes about one fifth of the total mass of asteroid belt, this finding is important not only for the study of small Solar System bodies in general, but also for learning more about the origin of water on Earth," said Göran Pilbratt, ESA's Herschel project scientist.

Prehistoric cave paint to shield Solar Orbiter

Pigment once daubed onto prehistoric cave walls is set to protect the ESA/NASA Solar Orbiter mission from the Sun's close-up glare. Burnt bone charcoal will be applied to the spacecraft's titanium heatshield using a novel technique.

Solar Orbiter, due for launch in 2017, will carry a portfolio of instruments to perform high-resolution imaging of our parent star from as close as 42 million km – a little more than a quarter of the distance to Earth.

Operating in direct view of the Sun, the mission must endure 13 times the intensity of terrestrial sunlight and temperatures rising as high as 520°C. Back in 2010, during the Phase-A planning stage, ESA's materials specialists began checking that the mission was indeed achievable with current manufacturing methods and materials.

"We soon identified a problem with the heatshield requirements," said Andrew Norman, an ESA materials technology specialist. "To go on absorbing sunlight, then convert it into infrared to radiate back out to space, its surface material needs to maintain constant 'thermo-optical properties' – keeping the same colour despite years of exposure to extreme ultraviolet radiation.

"At the same time, the shield cannot shed material or outgas vapour, because of the risk of contaminating Solar Orbiter's highly sensitive instruments. And it has to avoid any build-up of static charge in the solar wind because that might threaten a disruptive or even destructive discharge."

The initial choice – carbon-fibre fabric – was ruled out. Instead the team began looking for the answer outside the space business. They found it in the shape of Irish company Enbio and its 'CoBlast' technique, originally developed to coat titanium medical implants.

"The process works for reactive metals like titanium, aluminium and stainless steel, which have a surface oxide layer," said John O'Donoghue of Enbio. "We spray the metal surface with abrasive material to grit-blast this layer off, but we also include a second 'dopant' material possessing whatever characteristics are needed. This simultaneously takes the place of the oxide layer being stripped out.

"The big advantage is that the new layer ends up bonded, rather than only painted or stuck on. It effectively becomes part of the metal – when you handle metal you never worry about its surface coming off in your hands."

The material that will be applied to the outermost titanium sheet of Solar Orbiter's multi-layered heatshield is called 'Solar Black' – a type of black calcium phosphate processed from burnt bone charcoal. This burnt 'char bone' is widely used in everyday life, employed for everything from fertiliser and metal alloy production to purifying white sugar and filtering heavy metals out of water.

Its robustness is demonstrated by the endurance of prehistoric cave paintings over many thousands of years – burnt bone, along with wooden charcoal, serving as an early black pigment.

The CoBlasted Solar Black titanium passed a series of tests in ESA's Materials and Electrical Components Laboratories at ESTEC, Noordwijk. The treated titanium is now being used for the Solar Orbiter heatshield, being developed by Thales Alenia Space in Italy. A prototype structural and thermal model is due to be tested inside ESTEC's Large Space Simulator.

Another Enbio product, 'Solar White' is also being tested for other elements of Solar Orbiter exposed to the Sun, including its main antenna, instrument booms and solar array attachments.

ESA is also studying wider uses for the coating process, including boosting the long-term surface robustness of telecom satellites, which typically operate for 15 years or more.

↑ Nigel Cobbe, John O'Donoghue and Dr James Carton of Enbio demonstrate the heat absorption of Solar Black CoBlast-treated titanium (Enbio/NovaUCD)

Global agencies join in asteroid defence

With a mandate from the UN, ESA and other space agencies have established a high-level group to help coordinate global response should a threatening asteroid ever be found heading towards Earth.

For the first time, national space agencies from North and South America, Europe, Asia and Africa have an expert group aimed at getting the world's space-faring nations on the 'same page' when it comes to reacting to asteroid threats.

Its task is to coordinate expertise and capabilities for missions aimed at countering asteroids that might one day strike Earth. Of the more than 600 000 known asteroids in our Solar System, more than 10 000 are classified as near-

→ Asteroids passing Earth

Global warming hiding underwater

Satellite observations of global sea-surface temperature show that a 30-year upward trend has slowed down within the last 15 years. Climate scientists say this is not the end of global warming, but the result of a rearrangement in the energy flow of the climate system and, in particular, how the ocean stores heat.

Like flying thermometers, some satellites carry instruments that provide a global view of the surface temperature of oceans and seas. Measuring the sea-surface temperature is important for improving weather and ocean forecasting and climate change research.

Satellite and local readings show that sea-surface temperature has been rising rapidly since the 1970s, in line with the overall warming of our planet. But this increase has significantly slowed in the last 15 years.

In contrast, other variables such as increasing atmospheric carbon dioxide, rising sea levels and declining Arctic sea ice have not experienced the same reduction in trend and therefore demonstrate that Earth's climate continues to change.

Scientists have speculated that one of the causes of this 'plateau' in sea-surface temperature could be a change in the exchange of ocean water between warm, surface waters and cold, deep waters below 700 m – as if the warming is 'hiding' underwater. Temperature measurements at this depth cover a relatively short period.

But the warm water will not hide below the surface forever: scientists believe that it may re-emerge later or affect other climate indicators, such as sea level or ocean circulation.

ESA's Climate Change Initiative (CCI) responds to the need for continuous data on the energy budget in our climate system to understand better the slowing increase in sea-surface temperature. Satellite readings enable the detection of real trends in climate.

"We can observe changes in sea-surface temperature from the 19th century onwards using millions of

Earth objects (NEOs), because their orbits bring them relatively close to our path.

Dramatic proof that any of these can strike Earth came on 15 February 2013, when an unknown object thought to be 17–20 m in diameter arrived at 66 000 km/h and exploded high above Chelyabinsk, Russia, with 20–30 times the energy of an atomic bomb.

The resulting shock wave caused widespread damage and injuries, making it the largest known natural object to have entered the atmosphere since the 1908 Tunguska event, which destroyed a remote forest area of Siberia.

The Space Mission Planning and Advisory Group (SMPAG – pronounced 'same page') was established by Action Team 14, a technical forum with a mandate from the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) to develop a strategy on how to react on a possible asteroid impact threat.

The first meeting was held at ESOC in Darmstadt on 6–7 February. Representatives of the following agencies and governments attended with ESA: AEM (Mexico), ASI (Italy), CNES (France), CSA (Canada), Chile, DLR (Germany), Ghana, JAXA (Japan), Roscosmos (Russia), UK Space Agency, SSAU (Ukraine) and NASA. Representatives of the AT-14 and the UN Office for Outer Space Affairs (UNOOSA) were also present.

SMPAG will coordinate the technological knowhow of agencies to recommend specific efforts related to asteroid threats, including basic research and development, impact mitigation measures and deflection missions.

"SMPAG will also develop and refine a set of reference missions that could be individually or cooperatively flown to intercept an asteroid. These include precursor missions or test and evaluation missions, which we need to fly to prove technology before a real threat arises," said Detlef Koschny, Head of the NEO Segment in ESA's Space Situational Awareness programme office.

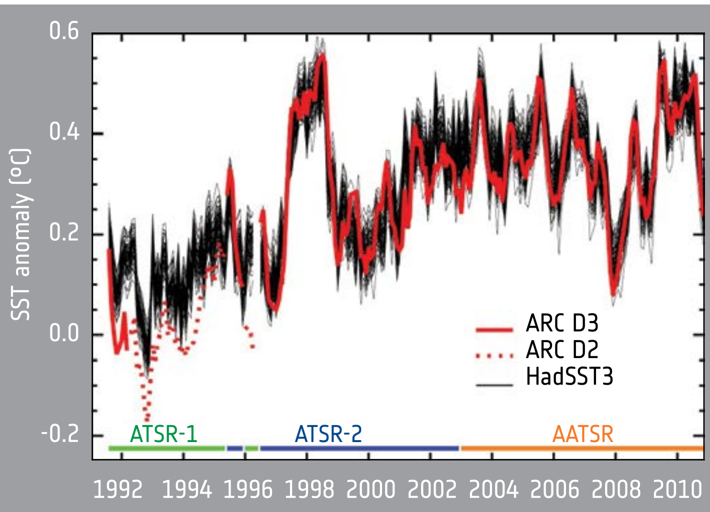
The group will work in close cooperation with another Action Team 14-mandated committee: the International Asteroid Warning Network (IAWN). Each will study and recommend specific actions to deal with different aspects of the asteroid threat – IAWN to coordinate the global search for threatening NEOs, understand their effects in case of a collision, and interface with disaster preparation and civil response agencies; and SMPAG for the technology and space mission aspects.

The critical first step is to spot potential threats in the sky with as much advance warning as possible. ESA is now developing the capability to integrate Europe's current NEO tracking assets – as well as new technology such as automated, wide-field-of-view telescopes – into a coordinated and more efficient NEO system that can provide nightly sky surveys and advanced warnings.

Among other recent developments, ESA will make use of observing time at the European Southern Observatory in Chile to conduct quick and accurate confirmations of the most hazardous NEOs.

measurements gathered by voluntary observers at sea and by buoys that drift around the oceans. ESA's CCI is developing sea-surface temperature information from satellites that provides an independent assessment of these changes over the last few decades," said Nick Rayner from the UK Met Office's Hadley Centre.

"When comparing changes in global average sea-surface temperature from these two sources, we see they provide a consistent picture since 1996, when the most reliable satellite measurements began. We are now working on applying our methods to earlier satellites, in order to extend reliable satellite-based information back into the 1980s," said Chris



→ Sea-surface temperature measurements

Merchant of the University of Reading, the science leader for this project.

ESA began monitoring sea-surface temperature in 1991 with the first Along-Track Scanning Radiometer on the ERS-1 satellite, followed by instruments on ERS-2 and Envisat. ESA will continue observations of sea-surface temperature with the upcoming Sentinel-3 mission, being developed for Europe's Copernicus programme.

Neosat contract signed

ESA is forging ahead with the Neosat next-generation satcom platform, planning the first flights within five years. The goal is for European satellite builders to capture at least half of the world's satcom market in 2018–30 through innovation and efficiency, generating €25 billion in sales.

Magali Vaissiere, ESA's Director of Telecommunications and Integrated Applications, Eric Béranger of Airbus Defence and Space and Bertrand Maureau of Thales Alenia Space signed the contract for Phase-B of Neosat in February.

Neosat is part of ESA's Advanced Research in Telecommunications Systems programme (ARTES), and aims at developing, qualifying and validating in orbit next-generation satellite platforms for the core satcom market. Neosat is based on cooperation between ESA and France's CNES space agency, and managed by a joint ESA/CNES team

A crucial objective for Neosat is to reduce the cost of a satellite in orbit by 30% compared with today's designs by the end of the decade. Existing and new technologies will be used in innovative ways and to achieve economies of scale by creating a common supply chain for both satellite prime contractors.

Neosat will be optimised for electric propulsion – both for raising the satellite into its final orbit after separation from its launcher, and for maintaining its operating position.

↑ Bertrand Maureau of Thales Alenia Space, Magali Vaissiere, ESA's Director of Telecommunications and Integrated Applications, and Eric Béranger of Airbus Defence and Space sign the Neosat Phase-B contract on 20 February

Electric thrusters use significantly less propellant than traditional thrusters to reach the same destination.

The Neosat product lines will offer the option of all-electric, hybrid electric/chemical and all-chemical propulsion versions. In the hybrid and all-chemical versions, the telecommunications operator will have the flexibility to speed-up orbit-raising using chemical propellants – a manoeuvre that could take a few months by electric propulsion alone.

The contract signed covers selection of the equipment suppliers for the Neosat product lines. The two co-prime contractors will run competitions between equipment suppliers for platform building blocks, based on an agreed single set of requirements. The winners of these competitions will become part of the industrial consortium for developing the two platform lines, one led by Airbus Defence and Space, the other by Thales Alenia Space.

The upcoming phase will include concurrent engineering activities to define the technical baseline of the new platforms and involve subcontractors in the UK, Sweden, Switzerland and Luxembourg. The Neosat prime contractors have activities in France and in the UK, both countries being major contributors to Neosat.

Technologies to be investigated for the future platforms include orbit-raising by electric propulsion, new thermal control concepts and next-generation battery cells.

The contract for Phase-B is expected to last around 13 months. The subsequent Phase-C/D will start in 2015 for the development and manufacture of the first two prototype flight platforms, launch in 2018–19 and in-orbit demonstration under a public–private partnership to be established with satellite operators.

↑ The Sierra Nevada Corporation Dream Chaser (SNC)

Helping Dream Chaser become reality

ESA and US company Sierra Nevada Corporation (SNC) have signed an understanding to identify areas of collaboration with European industry for developing hardware and mission concepts for the Dream Chaser orbital transportation system.

Dream Chaser is part of NASA's Commercial Crew Program to transport crew to the International Space Station and back to Earth by 2017. With the aim of developing an economical successor to the Space Shuttle, the Dream Chaser is the only lifting-body vehicle proposed in the programme. It will transport astronauts and cargo to low Earth orbit and land like an aircraft on a runway.

The spacecraft can also serve as a platform for technology demonstrations, construction and repair in space, as well as a platform for crewed and uncrewed scientific missions.

ESA will work with SNC to identify how European hardware, software and expertise can be used to further the capabilities of the Dream Chaser orbital crew vehicle. ESA and SNC will also study the possibilities for creating an industrial consortium including European partners to use Dream Chaser for European missions.

A major area to be explored is ESA's International Berthing Docking Mechanism, an advanced docking system designed for use on the Space Station that would actively capture and seal the vehicle to the orbiting station. A number of other current and developing technologies and processes will also be evaluated including, the use of ESA's human factors expertise, simulators and cockpit displays and several other key European offerings which are of interest to SNC.

This arrangement allows ESA to prove its hardware and technology in space on a crewed spacecraft. In exchange, SNC will have its development costs and production time potentially lessened as well as benefit from the extensive experience of ESA and its industrial partners.

At the end of an initial evaluation and planning phase, which will continue through 2014, the organisations expect to continue the partnership through a long-term agreement leading to flight operations. Both foresee further arrangements leading to the potential use of Dream Chaser for European missions.

UK centre launches European space celebrations

↑ David Willetts MP, Jean-Jacques Dordain and Roy Gibson

The first stones of ESA's new establishment in the UK were laid in a ceremony in December, with ESA Director General Jean-Jacques Dordain, UK Minister of Universities and Science David Willetts and ESA's first Director General Roy Gibson.

While placing one of the stones in a sculpture that will later grace the establishment's courtyard, Mr Dordain revealed that the first building of ESA's European Centre for Space Applications and Telecommunications, or ECSAT, scheduled for completion in 2015, will be named after Mr Gibson.

Here it was also announced that 2014 will see celebrations of 50 years of European cooperation in space, with major events in all ESA establishments, including HQ and ECSAT, as well as in the capitals of some Member States.

↑ Samantha Cristoforetti

Samantha's mission logo

The logo for ESA astronaut Samantha Cristoforetti's Futura long-duration mission to the International Space Station was revealed in January.

The logo was chosen in a competition where entrants were asked for a design that captured the elements of Samantha's mission: research, discovery, science, technology, exploration, wonder, adventure, travel, excellence, teamwork, humanity, enthusiasm, dreams and nutrition.

Samantha explains: "I derive a strong sense of purpose from being part of the space community, as we build a future in space for we human beings. The name Futura for me is about our collective journey towards that future."

From the many entries, the winning design was from 31-year-old Valerio Papeti of Turin, Italy. Valerio has a degree in Fine Arts at the Albertina Academy of Fine Arts in Turin, and is interested in astronomy, science and art. Valerio's logo shows a stylised orbit of the International Space Station circling Earth – he added a sunrise, saying it is the most beautiful image he has seen of space.

"I stand here next to the man who drove ESA at the very beginning of its history, and with the symbolic representation of ESA's future building. The UK space sector has been around for as long as ESA, and it is fitting that our first ever Director General hailed from this country, and ECSAT is marking the renewed ambitions of the UK in using space for competitiveness and growth, in particular within the ESA framework," said Mr Dordain.

"Fifty years of Europe's cooperation in space and the 50th anniversary of the birth of the two predecessors that led to ESA is an important milestone, and I am happy to mark it in such a way."

The Roy Gibson Building is set to be one-of-a-kind in the UK, with almost zero carbon emissions and a dedicated area open to the public, emphasising its cooperative nature on the campus. This also makes it unique as an ESA centre.

Marking 50 years of European space

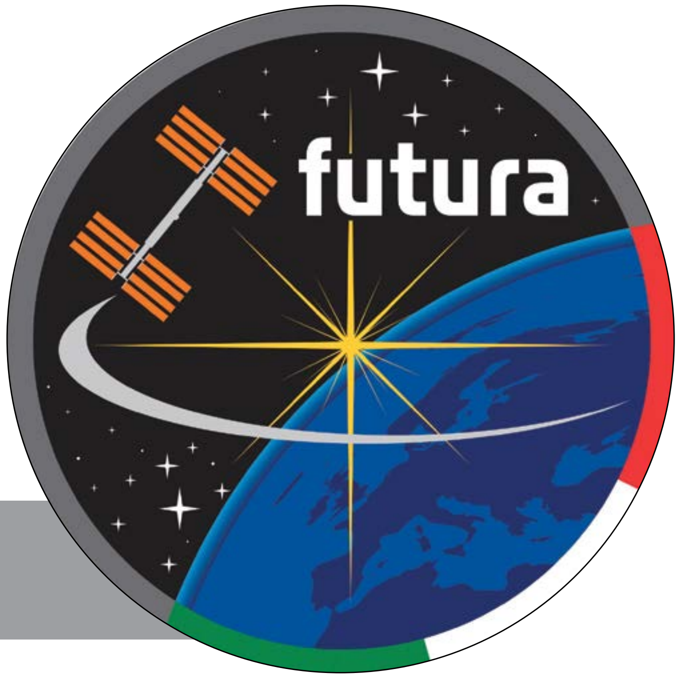
Looking back with pride on 50 years of space cooperation, the Monnaie de Paris, France's national mint, is issuing a set of collectors' coins in gold and silver to celebrate Europe's exploits in space.

The collection, dubbed '50 Years of European Space Cooperation', forms part of the Europa series, which every year since 2002 has featured on the reverse side of these coins individuals or events that have made contributions to European cooperation and construction.

Wishing this year to pay tribute to Europe's successes in space, the Monnaie de Paris naturally turned to ESA, which in its several decades of existence has achieved success upon success. The two organisations have been working together since September 2013 on this project now seeing the light of day, which is certain to delight collectors and space enthusiasts alike.

As the best-known and most popular symbol of this historic cooperation, the Ariane launcher was chosen to appear on the coin. The collection is available from February 2014 and will include the following coins: gold €5, gold €50, gold €200, gold €500 and silver €10. These coins are available from the Monnaie de Paris or directly through the resellers in different countries.

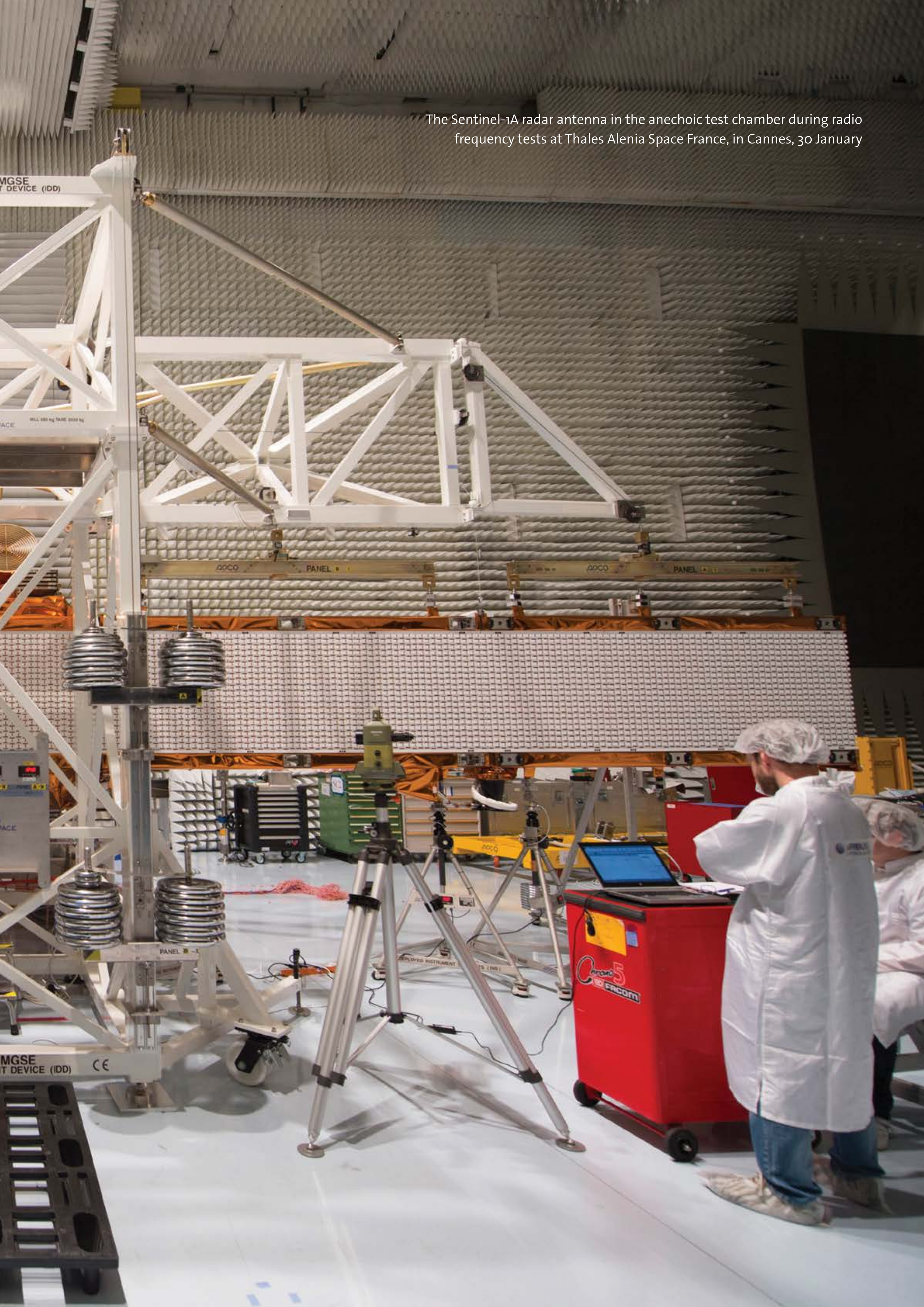
"The logo beautifully represents that momentum, that voyage of discovery. As a European of Italian nationality, I am especially proud of Europe's and Italy's contributions to this endeavour and I am happy to see Europe's outline and the Italian colours in the design," said Samantha.



→ The Futura mission logo (ESA/ASI/V. Papeti)

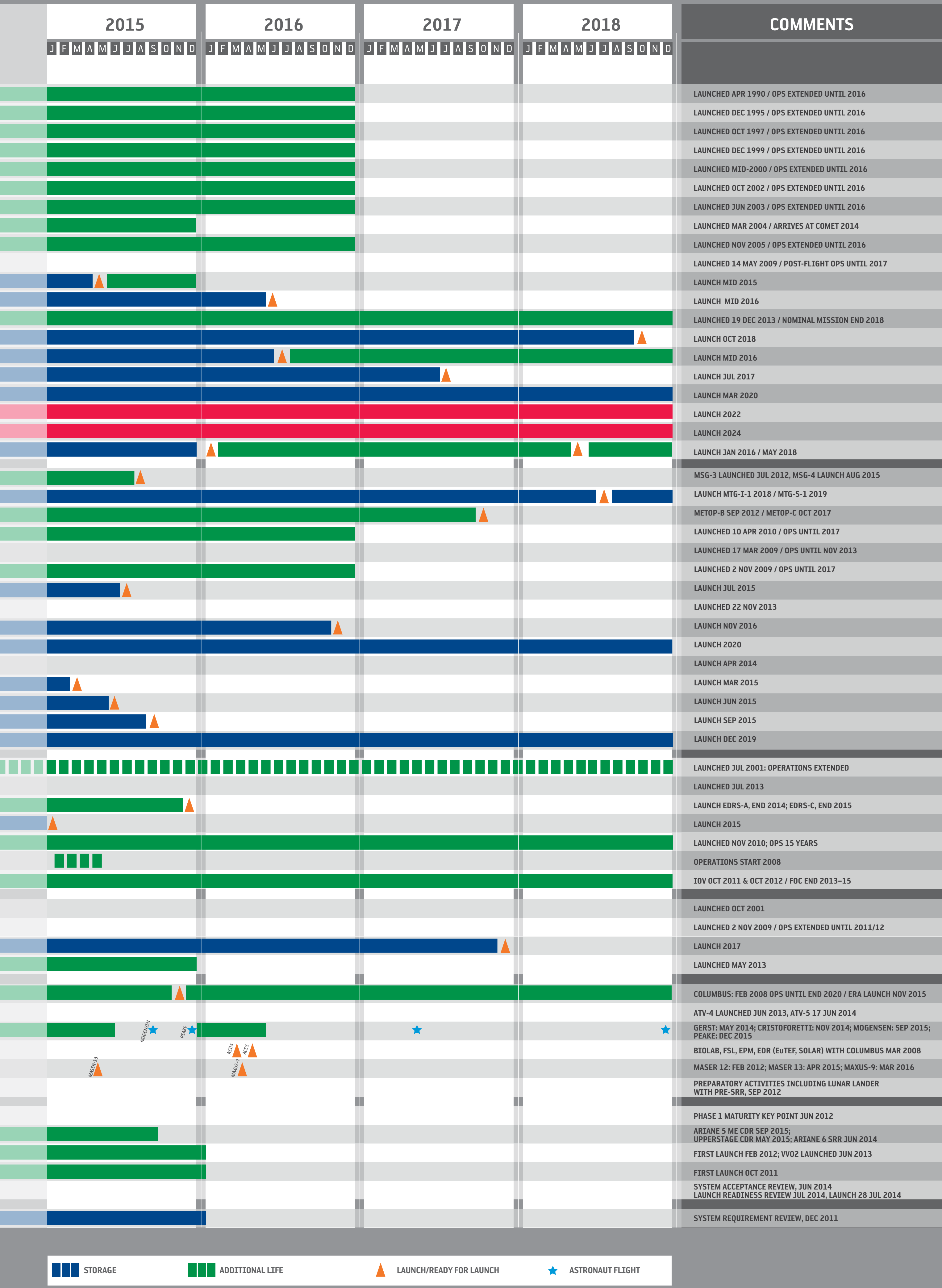
→ PROGRAMMES IN PROGRESS

Status at end January 2014



The Sentinel-1A radar antenna in the anechoic test chamber during radio frequency tests at Thales Alenia Space France, in Cannes, 30 January

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
HERSCHEL
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
SOLAR ORBITER (M1)
EUCLID (M2)
JUICE (L1)
COSMIC VISION M3
EXOMARS
EARTH OBSERVATION PROGRAMME
MSG
MTG
METOP
CRYOSAT
GOCE
SMOS
AEOLUS
SWARM
EARTHCARE
BIOMASS
SENTINEL-1
SENTINEL-2
SENTINEL-3
SENTINEL-5 PRECURSOR
JASON-CS
TELECOMMS/NAVIGATION PROGRAMMES
ARTEMIS
ALPHASAT
EDRS
SMALLGEO
HYLAS
GNSS-1/EGNOS
GALILEO
TECHNOLOGY PROGRAMME
PROBA-1
PROBA-2
PROBA-3
PROBA-V
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS / NODE-2 / NODE-3 / CUPOLA / ERA
ATV
ASTRONAUT FLIGHTS
ELIPS ISS UTILISATION
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
PREPARATORY PROGRAMME
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS


2015
2016
2017
2018
COMMENTS
J F M A M J J A S O N D
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
LAUNCHED 14 MAY 2009 / POST-FLIGHT OPS UNTIL 2017
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
LAUNCHED 10 APR 2010 / OPS UNTIL 2017
LAUNCHED 17 MAR 2009 / OPS UNTIL NOV 2013
LAUNCHED 2 NOV 2009 / OPS UNTIL 2017
LAUNCH JUL 2015
LAUNCHED 22 NOV 2013
LAUNCH NOV 2016
LAUNCH 2020
LAUNCH APR 2014
LAUNCH MAR 2015
LAUNCH JUN 2015
LAUNCH SEP 2015
LAUNCH DEC 2019
LAUNCHED JUL 2001: OPERATIONS EXTENDED
LAUNCHED JUL 2013
LAUNCH EDRS-A, END 2014; EDRS-C, END 2015
LAUNCH 2015
LAUNCHED NOV 2010; OPS 15 YEARS
OPERATIONS START 2008
IOV OCT 2011 & OCT 2012 / FOC END 2013–15
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
GERST: MAY 2014; CRISTOFORETTI: NOV 2014; MOGENSEN: SEP 2015; PEAKE: DEC 2015
BIOLAB, FSL, EPM, EDR (EuTEF, SOLAR) WITH COLUMBUS MAR 2008
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
FIRST LAUNCH OCT 2011
SYSTEM ACCEPTANCE REVIEW, JUN 2014 LAUNCH READINESS REVIEW JUL 2014, LAUNCH 28 JUL 2014
SYSTEM REQUIREMENT REVIEW, DEC 2011
MOGENSEN
PEAKE
ASIM
ACES
MASER-13
MAXUS-9
STORAGE
ADDITIONAL LIFE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

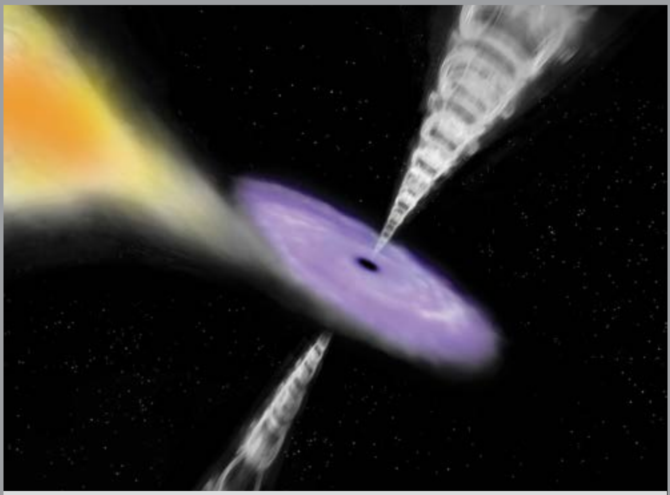
KEY TO ACRONYMS

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- Proto-flight 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

The first images have been released from the Frontier Fields observing programme, which uses the magnifying power of massive galaxy clusters to peer deeper into the distant Universe. The first target was Abell 2744, nicknamed Pandora's Cluster. Astronomers previously observed Abell 2744 with Hubble in 2011, to study the cluster's history. They found that at least four galaxy clusters had merged to form Abell 2744. Abell 2744 is the first of six targets to be observed as part of the Frontier Fields. This three-year, 840-orbit programme will yield our deepest views of the Universe to date, by observing gravitational lensing effects around six different galaxy clusters.

Hubble optical/near-infrared composite image of Abell 2744. A mix of elliptical galaxies and spirals can be seen clumping together in the centre. The effects of the cluster's gravity can be seen in the blue arcs and distorted shapes that are scattered across the frame, including galaxies that seem to be bleeding into the surrounding space. The arcs are actually the distorted images of galaxies far in the distance (NASA/ESA/STScI)

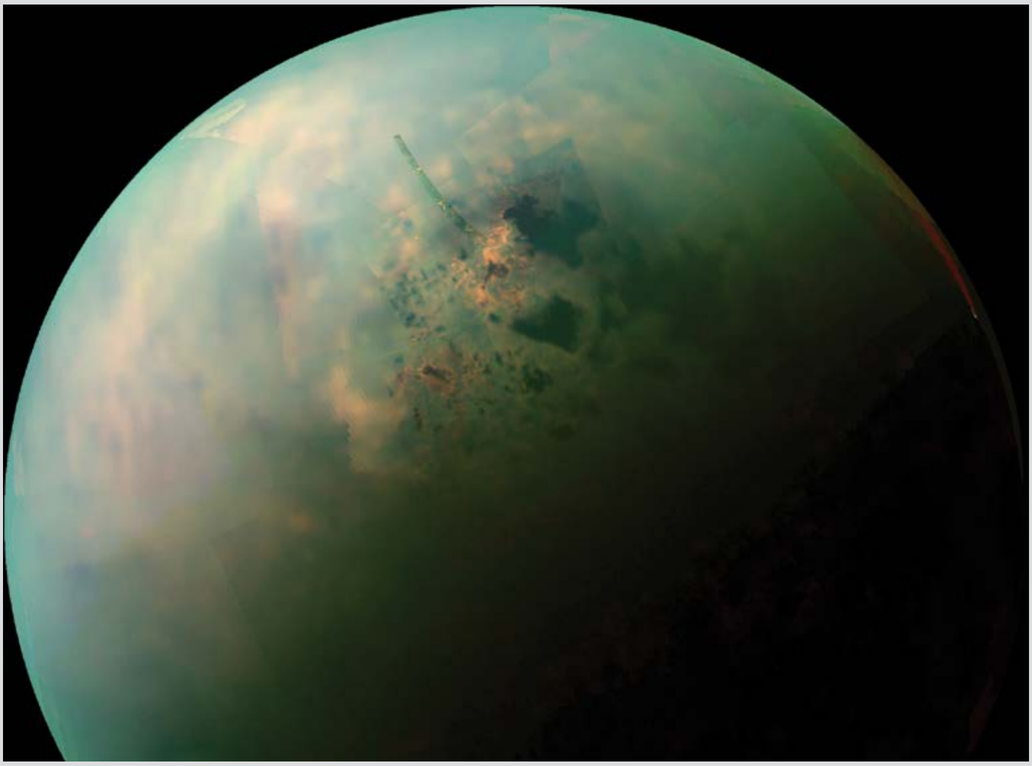


A black hole accreting matter from its companion and emitting two jets. XMM-Newton observations have demonstrated that the jets of black hole binary system 4U1630-47 consist of atomic nuclei as well as electrons (ESA/ATG medialab)

→ XMM-NEWTON

Stellar-mass black holes are often accreting material from a companion star. Matter flows from the star towards the black hole, circling in a disc around it with a temperature so high that it emits X-rays. Sometimes not all the material is accreted and some is emitted in the form of two powerful jets of particles. Observations at radio wavelengths have already found that black hole jets contain electrons moving at close to the speed of light. But, until now, it was not clear whether the negative charge of the electrons is complemented by their anti-particles, positrons, or rather by heavy positively charged atomic nuclei.

XMM-Newton observed a black hole binary system called 4U1630-47, which in the past showed outbursts of X-rays over intervals of months and years. The XMM-Newton spectra taken during one of these outbursts revealed the presence of highly ionised nuclei of two heavy elements, iron and nickel. Simultaneous radio observations with the Australia Telescope Compact Array showed that these spectral features only occurred when the jets were present.



Cassini acquired near-infrared images of the liquid methane and ethane lakes at Titan's north pole in October. The Sun is now shining on Titan's north pole and the favourable weather reduced the cloud coverage over this region, allowing Cassini's VIMS instrument to perform observations of the lakes. Compositional variations around the lakes suggest evaporation processes ongoing since the onset of spring at northern latitudes (NASA/JPL/Caltech/Univ. Ariz./Univ. Idaho)

→ CASSINI

A recent study has revealed an interesting correlation between morphological and geological structures of Saturn's moon Dione and their spectral properties in the near infrared wavelengths (VIMS observations). These regions show variations in water ice bands depths, in average ice grain size and in the concentration of contaminants, such as CO_2 and hydrocarbons. Darker terrains appear to have suppressed water bands and a finer ice granularity and higher amount of CO_2. Interestingly, the spectral characteristics of one of the freshest morphological units of Dione match well the infrared spectra of Helene, one of Dione's 'trojan moons'.

→ CLUSTER

A new study has shown improved precision in determining the source of a radio emission produced by Earth. The experiment involved tilting one of the four identical Cluster spacecraft to measure the electric field of this emission in three dimensions for the first time.

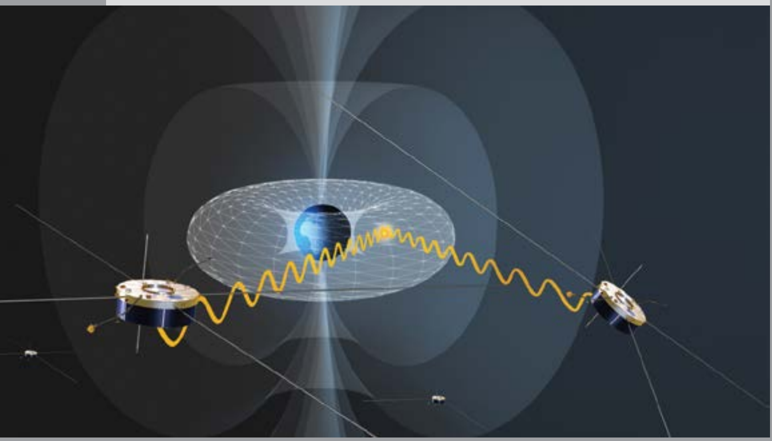
Two main types of radio waves, with different generation mechanisms, are known to be produced within Earth's magnetosphere: the auroral kilometric radiation (AKR) and the non-thermal continuum (NTC) radiation. Both have been observed in space around Earth since the 1970s, and within the magnetospheres of Jupiter, Saturn, Uranus and Neptune since the late 1980s. Radio waves can travel long distances, carrying with them useful information from the regions of the magnetosphere where they are generated.

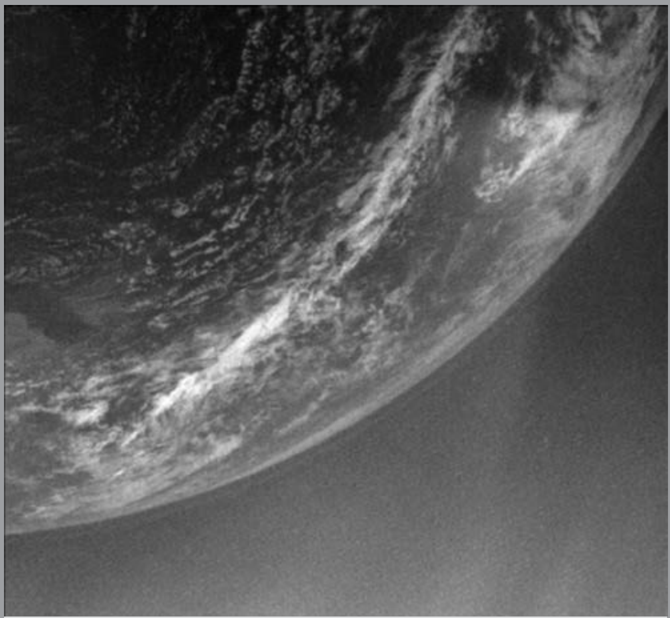
The study, published in *Annales Geophysicae*, presents two different approaches for locating the source of NTC, with differing results. The researchers analysed radio waves measured by the WHISPER instruments on board the four Cluster spacecraft. They showed that classical triangulation, in this case using three of the spacecraft situated thousands of kilometres apart, can lead to a source location nowhere near the boundaries where NTC generation occurs. NTC can emit from the plasmapause, and possibly from the magnetopause. The erroneous source location, far from these boundaries, given by triangulation is attributed to small deviation from the assumed polarisation of the emission.

The second method using the new 3D electric field measurements indicated a source located along the plasmapause at medium geomagnetic latitude, far away from the source location estimated by triangulation. Cluster observations reveal that this NTC source emits from the flank of the plasmapause towards the polar cap. Understanding the source of NTC waves will help with the broader understanding of their generation, amplification and propagation. The new 3D method involved placing two of the four identical Cluster spacecraft within 50 km of each other and tilting one of them by 45 degrees.

The long-term Cluster Archive at ESAC, Spain, made its first public release in November. During the first half of 2014, both the Cluster Active Archive (CAA) located at ESTEC (Netherlands) and the long-term Cluster Science Archive (CSA) are running in parallel. After that time, the CAA public access will be closed.

The Cluster spacecraft C3 and C4, in the foreground, were used as a single observatory for the study. The C3 spacecraft (right) is shown in the special 'tilt' configuration that was used for the observations for one month. The 45-degree tilt allowed for detection of the signal in 3D, and showed different results to the more typical triangulation method





For the first time, Integral 'sees' Earth. Image taken on 17 December 2013 with the Optical Monitor Camera on Integral, just when leaving Earth's disc, between South America and Africa. The full moon illuminated the clouds over the Atlantic Ocean. Kourou is at left (A.D. Garau/CAB/CSIC-INTA/OMC)

An enhanced false-colour image taken by Mars Express on 18 February 2013, giving a spectacular view of Gale crater where the NASA Curiosity Rover is carrying out its investigations (ESA/DLR/FU Berlin/G. Neukum/F. Jansen)

→ MARS EXPRESS

The health of the spacecraft and payload remains excellent. On 29 December, Mars Express made its closest-ever flyby of the martian moon Phobos, at a distance of about 45 km from its surface. The goal was to carry out a unique gravity experiment, with the spacecraft transmitting its radio signal to Earth, in order to measure its trajectory as accurately as possible. NASA and ESA ground-station coverage was organised for a 35-hour period around the closest approach. In addition, 37 radio telescopes from the Very Long Base Interferometry network acquired the signal for almost 24 hours, to complement the Doppler measurements from the prime stations and to measure the angular position of Mars Express very accurately. A secondary goal of the flyby was to measure solar wind protons reflected from the Phobos surface.

Because of the risk of impact of dust particles on the spacecraft during the close flyby of Comet Siding-Spring on 19 October, it was decided to perform a phasing manoeuvre in June at the cost of 20g of fuel. Mars Express will therefore hide behind Mars during and just after closest approach.

Display at ESOC in Darmstadt, 20 January: the spike in the middle of the green trace is the signal that the world was waiting for, indicating that Rosetta was operating again

→ ROSETTA

In late 2013, the Rosetta teams continued preparation for hibernation exit, marking the beginning of the main phase of the mission, the rendezvous, landing and escort of Comet 67P/Churyumov–Gerasimenko. At 10.00 GMT on 20 January, the Rosetta spacecraft ended its hibernation, some 5.39 Astronomical Units (AU) from Earth and a distance of 4.49 AU from the Sun. At 18.18 GMT, a signal was received at ESOC, whereby the ESA Spacecraft Operations Manager Andrea Accomazzo announced that Rosetta was in contact. Since 'wake up', the spacecraft health has been checked and everything is as expected. In the coming months, the instruments will be recommissioned and Rosetta will begin its observations and approach to the comet, with the main rendezvous manoeuvre in May, followed by actual rendezvous in August.

→ HERSCHEL

Now in the post-operations phase, the support of the science community exploiting Herschel data is continuing as planned. A major science symposium 'The Universe Explored by Herschel' took place at ESTEC in October 2013 with over 350 astronomers attending.

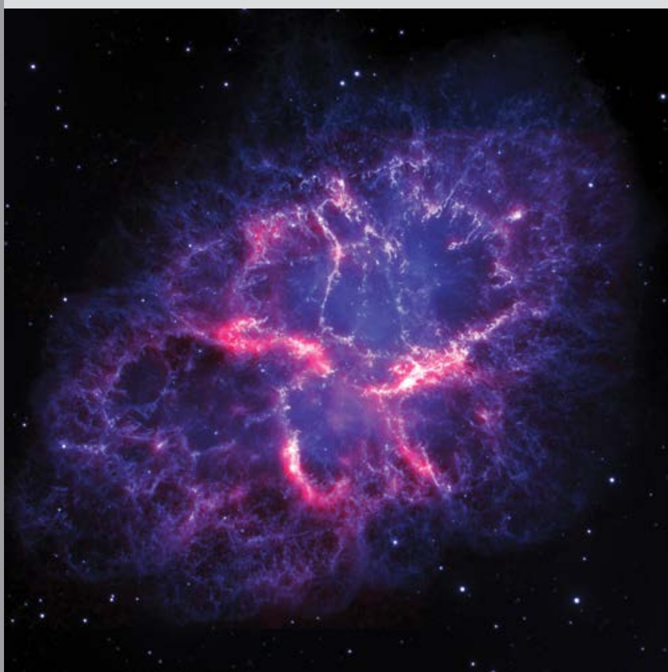
All Herschel science data are now publicly available to the entire astronomical community from the Herschel Science Archive (http://herschel.esac.esa.int/Science_Archive.shtml), and data products (such as images and spectra) offered are constantly refined with new ones added, including data products provided by the community. The result is more science out of Herschel and its data. Last year was the most productive so far, with over 300 papers published in refereed scientific literature.

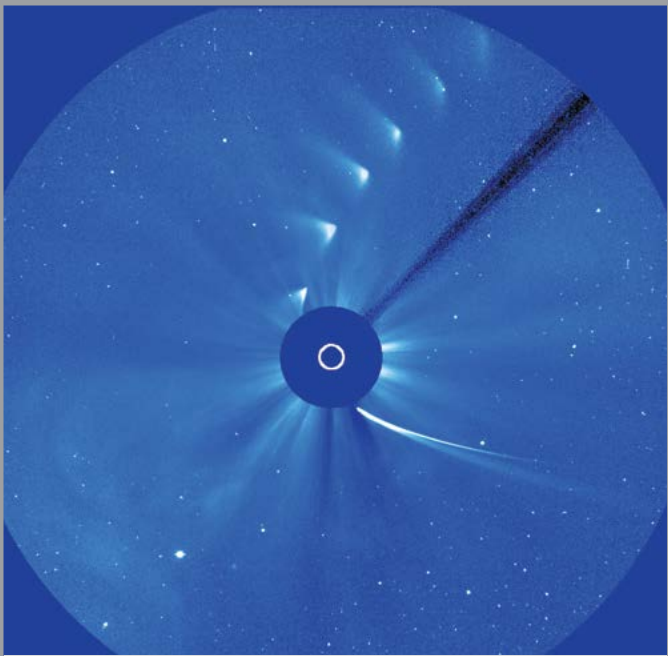
While Herschel was studying dust in the Crab Nebula supernova remnant, the noble gas molecular ion argon hydride $^{36}ArH^{+}$ was discovered. This serendipitous discovery lends direct support to the hypothesis that the Crab Nebula is the product of a core-collapse explosion of an 8–16 solar mass star, observed by Chinese astronomers in 1054 AD as what we now would call a supernova.

→ SOHO

The long-anticipated and unusual sungrazing Comet ISON made its closest approach to the Sun on 28 November, passing just 1.2 million km from the Sun's visible surface. Several SOHO instruments, in particular LASCO, made detailed observations of the nail-biting encounter. It was ISON's first (and last) visit to the inner Solar System. At first, the comet was thought to have disintegrated during its fiery encounter, with just a remnant of its tail continuing along ISON's trajectory. But, the next day, it seemed clear that something had survived after all – possibly a small chunk of ISON's nucleus, along with a lot of dust. This progressively

Composite view of the Crab Nebula from Herschel and the NASA/ESA Hubble Space Telescope. Herschel's far-infrared image at 70 micron (red) is combined with Hubble's view at visible wavelengths (blue) from emission from oxygen and sulphur ions (ESA/Herschel/PACS/MESS/NASA/Ariz. State Univ.)





SOHO's view of Comet ISON's encounter with the Sun in November (ESA/NASA)

faded as it edged towards LASCO's field of view on 30 November. The disintegration disappointed skywatchers across the northern hemisphere, who hoped for a naked-eye view of a bright comet as ISON emerged on the other side of the Sun. Over the following weeks, scientists were analysing the data collected during ISON's encounter with the Sun to decipher the exciting chain of events that took place.

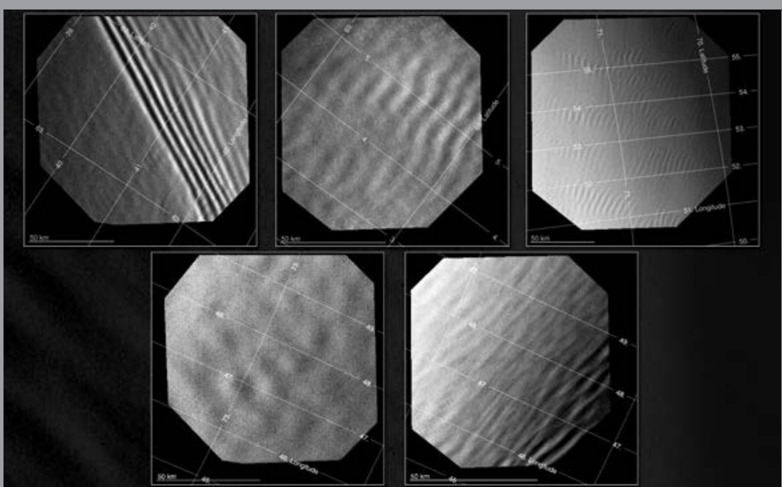
→ VENUS EXPRESS

The mysterious hurricane force winds in the atmosphere of Venus still cannot be properly understood and modelled accurately, but new analysis of data from Venus Express may now have revealed the missing clue to the problem.

Atmospheric waves were observed by the Venus Monitoring Camera, at the top of the cloud layer in the northern hemisphere, mostly at latitudes between 60 and 75 degrees. In addition, vertical propagating waves are seen frequently by the radio science investigators using radio occultation techniques to probe the atmosphere between 35 and 90 km altitudes. These different but related waves are possibly coupled and can be responsible for transfer of rotational momentum and energy between the different regions in the atmosphere. So, to a large extent, they provide the missing link for the atmospheric models used to try to visualise the fast-rotating atmosphere.

These type of waves, commonly referred to as 'gravity waves', should occur on all the terrestrial planets with atmospheres, including Earth. So far no definite evidence had been found for such waves on Venus. On Earth, they are well studied and frequently reveal their presence through cloud formations, such as in the case of waves on the lee sides of mountains. They often take the form of wave trains - a series of waves travelling in the same direction and spaced at regular intervals.

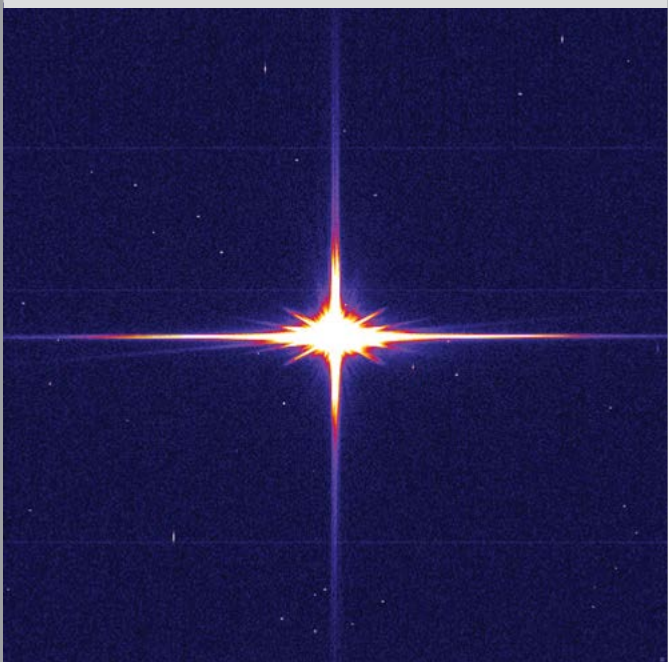
These waves occur predominantly in an area downwind of Maxwell Montes in the highland region of Ishtar Terra. It is believed that these high mountains disturb the constant flow of atmosphere along the surface and create waves downstream of the mountains, in a similar way as a rock or another object would do in a flowing river on Earth. That such waves are frequent in the venusian atmosphere was already suspected in 1985, after that the two Soviet Vega balloons, that followed the winds in the clouds at near equatorial latitudes, experienced strong turbulence above Aphrodite Terra, another mountainous region on the planet. These new results give strong evidence that this is actually the case, as many images and vertical profiles over an extended time show fully consistent results. Further analysis will show to what extent this will help understanding the complex motion of the atmosphere of Venus.



Atmospheric waves observed by Venus Express. Long waves (top left) appear as narrow straight features extending a few hundreds of kilometres or more, and with wavelengths (separation of crests) between 7 and 17 km. Medium-type waves (top centre) exhibit irregular wave fronts extending for more than 100 km and with wavelengths of 8–21 km. Short waves (top right) have a width of several tens of kilometres and extend to a few hundreds of kilometres, with wavelengths of 3–16 km. Irregular wave fields (bottom row) are likely a result of wave interference, with two wave trains crossing each other at an angle (ESA/VMC/A. Piccialli)

Gaia liftoff on 19 December 2013

The first star imaged by Gaia, Alpha Aquarii, in the constellation Aquarius. The shape is slightly elongated because of the focusing, which will be corrected during the calibration of the telescopes. The tiny white dots are energetic particles (e.g. solar protons or heavy ions) from space



→ GAIA

Gaia was launched on 19 December. Pre-launch and launch activities went smoothly. The sun shield was deployed perfectly about one and a half hours after launch. The spacecraft entered LEOP, which concluded on 23 December. The commissioning phase began, which will last to the beginning of May. The operational mission will start on 9 May. After a voyage of about 17 days and following two very critical orbit injection manoeuvres the spacecraft entered its final orbit 1.5 million km away from Earth.

All subsystems have been switched on and are operating normally. On 8 January, the spacecraft was set to spin by the micropropulsion system. It was not in its final science mode but the test confirmed that the micropropulsion system works and that the focal plane could see the first stars. Initial activities also confirmed that the ground segment works perfectly. Also the science ground system works well during this phase. Science telemetry is received at ESAC and the first processing of science data at DPAC is running well.

→ LISA PATHFINDER

The Science Module is being retrofitted with cold-gas micropropulsion equipment. Cold-gas micropropulsion engineering and procurement activities are in the acceptance process, except for micro-thrusters and associated electronics. Overall, the software development was completed. Following the qualification review of the Inertial Sensor Head (ISH), and with all flight hardware available, the integration of the two flight Sensor Heads started. CGS (IT) had readied two Class 100 rooms for parallel integration of the models. The Sensor Heads will be integrated on the instrument Core Assembly (the Core Assembly includes an optical interferometry ultrastable bench on its support frame, made of Zerodur, the two Sensor Heads, diagnostics equipment and support struts). The next step in Core Assembly integration will be the integration of the ISH.

→ BEPICOLOMBO

The BepiColombo CDR was completed. The Mercury Planetary Orbiter (MPO) PFM AIT continued at Thales Alenia Space Italy in Turin with Integrated System Tests (ISTs) on individual subsystems. ISTs for the Data Management Subsystem and the Communication Subsystem were completed. Three FM and two QM payload instruments (MERMAG, MERTIS, MGNS, PHEBUS QM and BELA QM) were integrated and functionally verified on the MPO. The SERENA instrument was delivered, while electrical integration of the PCDU FM is in progress.

Most of the spacecraft harness was integrated on the Mercury Transfer Module (MTM) PFM in Turin. Anomalies that occurred in MTM solar panel substrate manufacturing are being fixed with a dedicated sample test programme. MPO panel manufacturing is on hold, pending agreement on whether additional process modifications are necessary in addition to the general improvements in process control identified for MTM panel production.

The Mercury Magnetospheric Orbiter (MMO) Acceptance Vibration Test campaign was completed. Functional verification of the MMO started at JAXA. Launch remains planned for July 2016.

→ EXOMARS

The ESA/Roscosmos cooperation reached an important milestone on 17 December with the endorsement by the two agencies of a set of 2018 mission requirements.

The System CDR for the 2016 mission began in October. Progress was made on assembly of the Trace Gas Orbiter (TGO) and the Entry, Descent and Landing Demonstrator Module (Schiaperelli) FMs. Integration of the propulsion and major mechanical assemblies for TGO Mechanical, Thermal and Propulsion module (MTP) was completed in OHB Bremen ready for transfer to Thales Alenia Space France, in Cannes, to complete the TGO system integration.

The Schiaperelli landing platform structure FM was delivered from SENER Bilbao to Thales Alenia Space, Cannes, where the propulsion elements were installed. The integrated landing platform will then go to Thales in Turin for further integration activities. Software for the TGO and EDM is running in the respective test benches at Thales in France and Italy for each spacecraft.

For the 2018 mission, the PDRs of the Rover Analytical Design Laboratory (ALD) and the Rover Vehicle were completed. The next level of design is for the complex Sample Preparation and Distribution System in the ALD. Once this review is completed, QM construction will begin. The scientific instruments of the Rover will contribute QMs to support the qualification campaign of the ALD. A Rover Instrument Steering Committee meeting was held in November to discuss instrument developments in view of the ramp-up of the project activities for the Rover. The Lead Funding Agency representatives endorsed the project approach for the development activities.

The ExoMars 2016 Ground Segment Design Review was completed and the use of a Russian 64 m antenna to augment the science return from the TGO is under study for integration into the ground segment.

ExoMars 2016 mission Trace Gas Orbiter core module at OHB in Bremen (ESA/OHB)

→ SOLAR ORBITER

The Deep Space Transponder EM is being prepared for the pre-Radio Frequency Compatibility Test with the ground segment at ESOC. The Primary Structure STM is in Static Load Testing. Unit-level and subsystem level design reviews have been completed or are under way. The spacecraft CDR will be initiated this year as soon as all lower-level reviews have been completed.

The schedule of the solar generator continues to be a concern. Solar Orbiter depends on BepiColombo technology developments for the solar generator that are not yet completed.

Following application of a specifically qualified black surface treatment to the titanium sheets integrated in the STM front layer of the Heat Shield, samples of a white coating for possible applications elsewhere on the spacecraft are under ultraviolet tests.

Instrument CDRs are progressing. The SoloHI, MAG, SPICE, EUI and PHI CDRs have already been run and the EPD CDR is ongoing. The METIS coronagraph PDR will be rerun, following the restart of the development. The instrument CDR will follow.

Progress of both the science ground segment and the operational ground segment is on schedule. The US launch vehicle interface technical definition with NASA has made progress, so that NASA was able to proceed with procurement activities for the launch vehicle.

→ EUCLID

Prime contractor Thales Alenia Space Italy, Turin, and PLM contractor Astrium SAS, Toulouse, are proceeding in the definition of subsystem requirements, system design and subsystem/units procurement. The selection of all the subsytems and units for the PLM, which was started six months ago, is nearly complete. Some long-lead items, like the silicon carbide structures and mirrors are already being manufactured at Boostec. The PLM SRR was completed. On the SVM, the reaction wheels characterisation began. The ITT for the novel Fine Guidance Sensor was issued at the end of 2013.

Procurement of the Near Infrared Spectro-Photometer (NISP) detectors is proceeding. Performance tests on the detectors showed promising results and the triplet (detector, flex cable and proximity electronic) qualification test phase will be completed early this year followed by the FM production under NASA/JPL responsibility.

Following the completion of the Visible Imager SRR, the team at Mullard Space Science Laboratory is preparing the PDR for February. The NISP SRR has taken a little longer and the PDR has been now set for March. The science ground segment is working towards the SRR. Under a contract for launcher support (Soyuz from Kourou), Arianespace has performed the feasibility assessment required for the mission SRR. The mission SRR is ongoing.

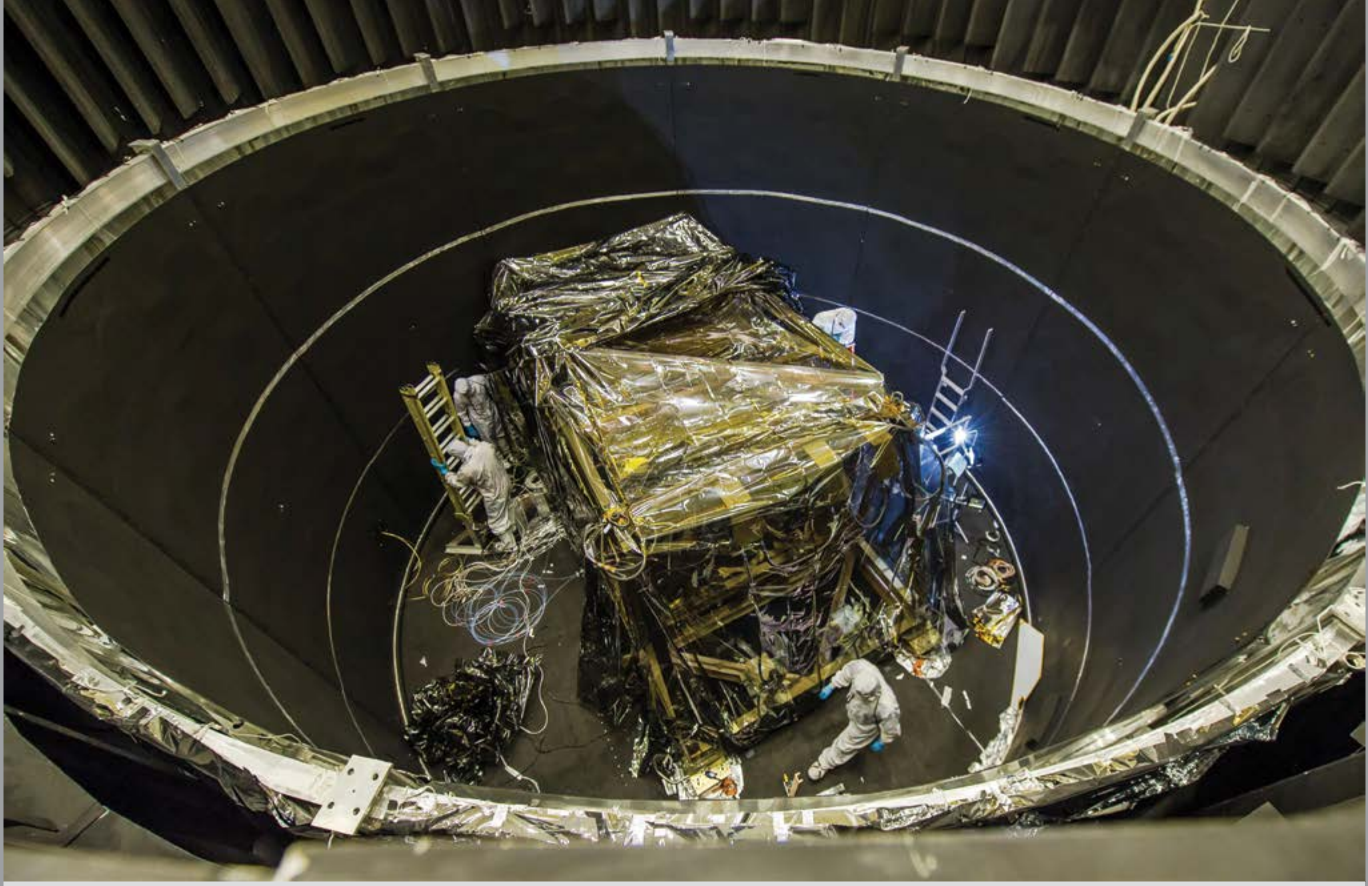
→ JAMES WEBB SPACE TELESCOPE

The first Integrated Science Instrument Module (ISIM) cryogenic vacuum test, including the Mid-Infrared Instrument and the Fine Guidance Sensor, was completed. The rebuilding of the actuators on all the primary mirror segments is complete, and all the primary mirror segment assemblies are now in storage for integration in 2015. Integration rehearsals have been performed. Manufacture and cryo-setting test of the telescope's main structure is complete. Manufacture of the first sunshade foils was authorised, and preparations for the spacecraft CDR in January were completed.

The NIRSpec flight instrument was shipped to NASA Goddard Space Flight Center, and the incoming inspection, verification of alignment and functional testing were performed followed by a formal hand-over of the instrument to NASA. The ESA JWST team's future focus will be to support the system-level integration and testing in parallel to building up the operational team at the Space Telescope Science Institute.

NASA completed the manufacturing of the first new spare micro-shutter array for NIRSpec, the best ever produced in terms of operational shutters. New NIRSpec detector arrays have been down-selected for the detector rebuild. Exchange of the micro-shutter assembly and detector is planned before the end of 2014. This will take place before the ISIM vibration test and final cryo-performance test.

All JWST primary mirror segment assemblies completed and in storage (NASA)



The James Webb Space Telescope's Integrated Science Instrument Module in the Space Environment Simulator, at NASA's Goddard Space Flight Center in January (NASA/C. Gunn)

Part of the cryogenic/vacuum test rig for the JWST Integrated Science Instrument Module in the Goddard Space Environment Simulator (NASA/C. Gunn)

→ SWARM

The three Swarm satellites lifted off on a Rockot launcher on 22 November from Plesetsk, Russia. The LEOP was performed in less than two days. All instruments were in good health (except one redundant Absolute Scalar Magnetometer on Swarm 'Charlie', which does not impact the mission).

The commissioning phase is ongoing with satellite manoeuvring, instrument calibration, level 1b and PDGS verification. The power spectral density of the Vector Field Magnetometers and Absolute Scalar Magnetometers surpass by several orders of magnitude the performances of precursor missions, paving the way for an excellent science observatory.

ESOC has demonstrated a full mastery of the control of a three-satellite constellation and the Payload Data Ground Segment has been able to deliver products from the three satellites.

→ ADM-AEOLUS

The first laser transmitter FM, delivered by Selex ES, passed the qualification test campaign and has been transported to Astrium SAS for integration into the ALADIN instrument. The second FM laser transmitter is undergoing final integration with the acceptance test campaign at the end of January. The Optical Bench Assembly of ALADIN completed its thermal stability test at Astrium Toulouse and is now in preparation for a second laser endurance test using the flight laser transmitter. The final system software test, mission timeline execution, was carried out on the real-time satellite test bench at Astrium Ltd, UK.

→ EARTHCARE

The Base-Platform (BPF) was delivered to the Astrium GmbH in December. Most of the FM avionics units have also been delivered to prepare for the continuation of the BPF integration. The development of Integrated System Tests (IST) is also progressing for the spacecraft subsystems and similar activities have been initiated for the four payload instruments.

CDRs for several ATLID subsystems were carried out. The lidar transmitter master oscillator environment qualification campaign was completed before Christmas at SELEX IT. The Broadband Radiometer (BBR) mechanism redesign, procurement and production were completed in December and the preparations for the life test at ESR Ltd, UK, went to plan. The formal TRR for this test is planned for January. In parallel, the BBR PFM manufacture is proceeding under the responsibility of SEA, UK. The test campaign for the Multi-Spectral Instrument (MSI) was completed at SSTL, UK, followed by the MSI CDR in December. In Japan, Cloud Profiling Radar PFM and PFM subsystem developments are progressing.

The first part of the ground segment PDR, focusing on the data segment, took place as planned while the operations aspects and review had to be rescheduled because of the SWARM launch.

→ METEOSAT

Meteosat-8/MSG-1

Meteosat-8 is located at 3.9°E longitude and operating normally. Operational backup for Meteosat-9 and 10.

Meteosat-9/MSG-2

The satellite is in good health and performance is excellent.

Meteosat-10/MSG-3

Eumetsat's operational satellite located at 0° longitude.

MSG-4

A spare Calibration Unit (CALU) motor was refurbished with new magnets and has been re-integrated in SEVIRI. SEVIRI will be delivered to Thales Alenia Space in January following the re-integration of the scan assembly and reference tests. Because of the delays caused by the CALU motor repair, Eumetsat has negotiated a new launch period from 1 August to 31 October 2015.

→ MTG

The MTG-S PDR was closed in November. The closure of the Platform PDR is well advanced, but awaits the consolidation of some subsystem activities in 2014, particularly on the Altitude and Orbit Control System.

Preparations are continuing for the PDR of the Lightning Imager (LI) instrument. The contract for the LI mission activities is now in place with Selex ES. The closure of the last platform subsystem issues the LI PDR will complete the PDR process for MTG programme main elements. This process has confirmed a very high level of compliance to the stringent MTG mission requirements. The focus of the consortium now moves on to subsystems and equipment, to confirm the system-level assumptions and consolidate the satellite baselines. The PDR for all associated flight equipment should conclude by the end of 2014.

The Flight Acceptance Review (FAR) of MTG-I is still set for July 2018, however, some delays in the IRS instrument have slipped the FAR for MTG-S to January 2021. Mitigation measures are being investigated to recover this delay, but the dates remain consistent with Eumetsat operational needs.

→ METOP

MetOp-A
Instruments continue to perform excellently. MetOp-A will operate in a dual operations scenario with MetOp-B until 2018 or the completion of MetOp-C calibration/validation.

MetOp-B
The operational Eumetsat Polar System satellite from 24 April 2013.

MetOp-C
The satellite is in storage. Launch is planned on Soyuz from French Guiana, with a launch slot starting in October 2017. If needed, the satellite can be readied in a short time, between 14 and 18 months after request.

→ SENTINEL-1

The fully integrated Sentinel-1A satellite passed the mechanical tests (vibration and acoustic), completing the environmental test campaign and confirming that it is ready for flight. The Flight Acceptance Review began in January and should be complete by 18 February, when the shipment of the satellite to French Guiana is to be authorised. Test results comply with mission requirements, confirming Sentinel-1 to be much better than any other Synthetic Aperture Radar ever flown by ESA.

The definition of the launch campaign is complete. LEOP is in preparation with simulations at ESOC, Darmstadt, and commissioning phase is being prepared with the support of the prime contractor, Thales Alenia Space Italy, and the SAR payload contractor, Astrium GmbH, Friedrichshafen. The Optical Communication Payload was integrated on the satellite before final environmental tests. Launch preparations on Soyuz from Kourou are also in place. The Final Mission Analysis Review was completed. Launch is set for no earlier than 28 March.

→ SENTINEL-2

The Sentinel-2A Multispectral Instrument PFM is at Astrium SAS, Toulouse, undergoing EMC qualification testing (before being shipped to Intespace for mechanical qualification and then to CSL, Belgium, for thermal qualification testing). Earlier performance tests revealed excellent radiometric, geometric and spectral stability performance. Following qualification, the instrument will be shipped to Astrium GmbH, Friedrichshafen, for integration on the satellite in April. In the meantime, the second instrument FM is being integrated and tested.

Satellite integration is complete except for the Optical Communication Payload, expected for delivery from TESAT and DLR in March, and the Reaction Wheel assemblies, expected in April. The system functional tests that do not require the missing items are being completed.

Sentinel-1A on the vibration shaker at the Thales Alenia Space test facilities, Cannes (Thales Alenia Space)

A second Sentinel-2 System Validation Test was carried out at ESOC in December. The second 'Sentinel-2 for science' workshop is being organised at ESRIN, 20–22 May, to gather the user communities that will present up-to-date plans regarding the exploitation of the Sentinel-2 operational mission.

→ SENTINEL-3

Sentinel-3A is in the payload integration and the test phase. The full topography payload including DORIS (Doppler Orbitography and Radio positioning Integrated by Satellite), the SAR Radar Altimeter and Microwave Radiometer, has been mechanically and electrically integrated on the satellite. Integrated System Testing has now started. Assembly of the OLCI (Ocean and Land Colour Instrument) and the SLSTR (Sea and Land Surface Temperature Radiometer) instruments is ongoing. Integration and testing of the Sentinel-3B platform was completed. The Final Mission Analysis Review with Rockot launcher provider was completed, determining the launch slot for Sentinel-3A, which opens in June 2015.

Testing the deployment of the Sentinel-1A radar antenna in the cleanroom at Thales Alenia Space in Cannes, France

→ SENTINEL-4

The instrument-level PDR was completed in November. Subsystems PDRs were held for the detector and the front-end electronics. Remaining subsystem PDRs should be completed by mid 2014. The last tests on three optical breadboards, to demonstrate Technology Readiness Level 5, started in October and should be completed by the end of January. Since its membership renewal in September, the Mission Advisory Group met in October working on a possible improvement of the instrument's east/west scan pattern. Preparation of the ITT for the prototype and operational Level-2 data processor was completed.

→ SENTINEL-5 PRECURSOR

Platform AIT is still on track, apart from the solar array (expected in June) and thermal hardware (July) for a fully mechanically integrated platform, including all flight software, for January. A CDR for the onboard software was scheduled for December 2013.

The TROPOspheric Monitoring Instrument (TROPOMI) payload EFM has undergone full EMC testing at NLR. AIT continues with integration of the UVN Optical Bench FM at TNO and thermal vacuum testing of the SWIR module at MSSL. The main TROPOMI flight structure and all flight electrical units will be delivered to Leiden in January.

Preparations are under way for a ground segment CDR in April/May. Prototypes of Level-1b and Level-2 processors were available for benchmarking testing on processing platforms at DLR. Negotiations were planned in December with Eurockot for procurement of a Rockot launcher.

→ SENTINEL-6/JASON-CS

In late 2013, following a request from the EC, it was agreed that the Jason-CS mission should become more closely associated with the other missions in the Copernicus family, and use the name Sentinel-6. However, there were reasons why the Jason-CS name should be retained. A compromise was adopted so that the Sentinel-6 mission will be implemented with the Jason-CS satellite, and partner organisations are able to use either name according to circumstances.

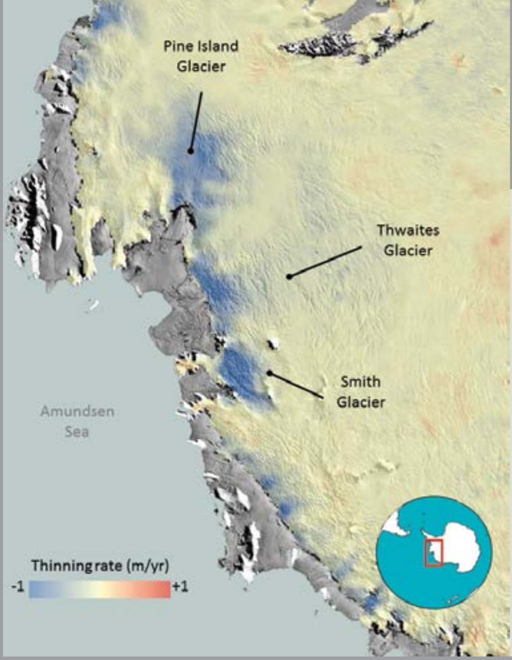
As part of the approval process on the Eumetsat side, the second meeting of potential programme participants was held in December. At this meeting, ESA announced that the new High Resolution Microwave Radiometer, which was still under technical investigation, would be suppressed for affordability reasons. The detailed technical definition continues in Phase-B2, including the selection of the subcontractor for the Mono-Propellant Propulsion System being performed according to ESA's Best Practice rules.

→ GOCE

After a spectacular final measurement cycle at only 224 km altitude, the satellite ended its fantastic mission on 21 October 2013 when it ran out of xenon gas (used by the drag-free control system). Thereafter, the satellite continued on a decaying orbit, with all other instruments and systems fully operational, until it reentered Earth's atmosphere in the early hours of 11 November after exactly 1700 days of flight. GOCE outperformed on all of its requirements and mission objectives, more than doubled its design lifetime and more than tripled its promised measurement return. The scientific community has been given a treasure of new data, on the gravity field and the geoid, on ocean circulation, on height systems, on solid earth physics as well as on the near-Earth environment, and the exploitation of these data will continue for many years to come.

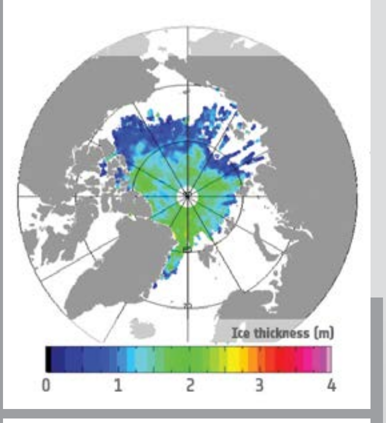
The reentry campaign was internationally coordinated and highly visible. Several hundred thousand people were following the reentry events on the internet as they unfolded, and many more through broadcast and print media. As GOCE gradually came closer to Earth, its robustness continuously exceeded all expectations and flight controllers were able to gather data from the satellite down to an altitude below 120 km (in the last pass over its ground station). The very peculiar reentry dynamics of GOCE has also left a wealth of information for further analysis. Essentially the spacecraft behaved very much like a winged vehicle and therefore reentered at a shallow angle and with a significant lift component.

While the science from GOCE will continue to thrive for decades, the mission now enters Phase-F and this is our last entry in the 'programmes in progress' pages. It is time for the mission team to thank all ESA *Bulletin* readers for your faithful following since the start of the GOCE programme in late 2000.

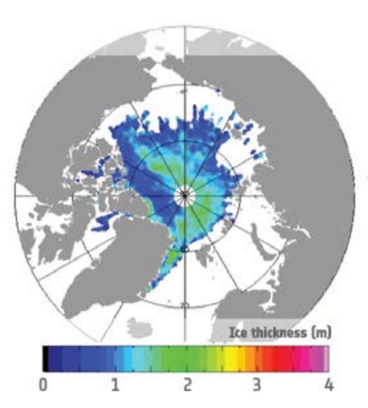


Three years of measurements from CryoSat show that the West Antarctic ice sheet is estimated to be losing over 150 km^3 of ice each year (CPOM/ESA)

Arctic sea-ice thicknesses in October 2010–13 based on data from CryoSat. In 2013, CryoSat measured about 9000 km^3 of sea ice – a notable increase compared to 6000 cubic km in October (UCL/ESA)



October 2010



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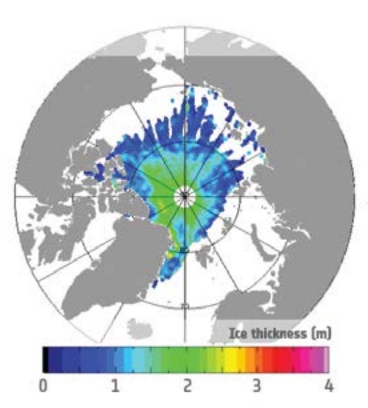

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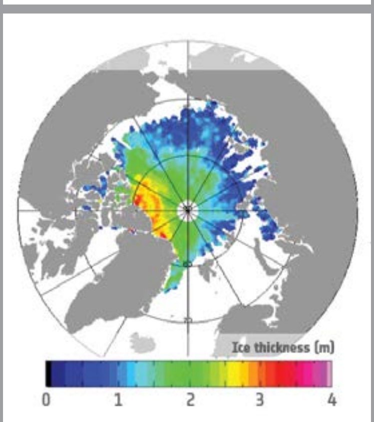


October 2013

→ SMOS

The satellite has been in orbit for four years (at November 2013). Thanks to the excellent technical and scientific status of the mission, SMOS continues to operate beyond its planned lifetime. All data have been available to the science community since 2010. The radio-frequency interference situation keeps improving, in particular over Europe. Results and achievements from the past four years in orbit were presented at ESA's Living Planet Symposium in September 2013. A second reprocessing of the entire SMOS data set is planned this year.

→ CRYOSAT

The satellite completed its first three years of operations and continues to work flawlessly, acquiring and generating science data systematically, to measure the variation of sea-ice mass floating in the Arctic and trend of land-ice volume over Greenland and Antarctica. An issue affecting the onboard power system forced operations to fall back to the redundant system with little impact on the science retrieval.

In December, two important results were published. The first showed that three years of CryoSat measurements suggest that the West Antarctica Ice Sheet is losing around 150 km^3 of ice each year, considerably more than that estimated so far. The increase of ice loss could be due to faster thinning, but that part of it may also be down to CryoSat's capacity to observe previously unseen terrain. The findings were from a team of UK researchers at the Natural Environment Research Council's Centre for Polar Observation and Modelling. The second result showed that the volume of sea ice in 2013, over the Arctic basin, has recovered by around 50% with respect to the previous year, in line with what was observed for the sea-ice extension at the end of the melting season.

The DLR-provided Laser Communication Terminal on Alphasat

→ ALPHASAT

The satellite is in good health and is being routinely operated from Inmarsat's control centre in London. The four Technology Demonstration Payloads were all tested by the end of 2013. In particular, the Laser Communications Terminal (DLR) correctly identified its target at ESA's ground station on Tenerife, the Canary Islands, for the first time on 4 November, proving that it can be pointed precisely enough at a target over 36 000 km away. The Aldo Paraboni Payload, the first civilian Q/V band payload in geostationary orbit (developed with ASI), was operated with ground stations in Tito, Italy, and Graz, Austria.

The Alphabus extension programme is aimed at increasing the power of an Alphabus-based satellite to 22 kW. A first CDR was completed at the end of 2013. A second CDR is planned early this year.

→ EDRS

The EDRS-A payload features an Optical Inter-satellite Link (OISL) via TESAT's Laser Communication Terminal, as well as a Ka-band ISL. It will be embarked on Eutelsat's EB9B commercial satellite, planned for launch in early 2015.

The payload CDR was completed in June 2013 and the space segment CDR in July. The mission CDR began in October and was concluded in January, thereby completing the EDRS-A detailed design phase. Payload FM equipment has already been delivered, and integration started at Astrium Ltd, Portsmouth. The first satellite-level integration activities are to start in February at Astrium SAS, Toulouse, followed by the EB9B satellite's environmental test campaign later in 2014.

The second EDRS node, carrying the EDRS-C payload, which includes a second LCT, will be launched into its geostationary position in early 2016 on a dedicated satellite built by OHB based on SmallGEO. It will also embark Avanti's Hylas-3 communication payload as a 'hosted payload'. The EDRS-C payload CDR began in October, the satellite CDR is planned for the first half of 2014, to be followed by the mission CDR.

All elements of EDRS ground segment required to be operational for EDRS-A were reviewed as part of the EDRS-A mission CDR. The first Ground Segment Validation Test is to be conducted in mid 2014.

→ ADAPTED ARIANE 5 ME & ARIANE 6

Adapted Ariane 5 ME

The Verification Key Point, a major milestone, was completed in December. Fairing industrialisation negotiations concluded with an Authorisation to Proceed and the contract was signed. In Phase-C implementation of the cryogenic test facility P5.2, the contract for the full design was signed in December. Payload Isolation Device Phase-B activities began, with a PDR planned for July.

Upper Stage and Commonalities

The fifth test of the Vinci M5 campaign took place in November (out of 14 tests planned). The final Post-test Review is planned in May. The contract for the Snecma PF52 test facility's upgrade was signed in October, starting Phase-C (the PF52 test facility is a cryogenic bench, unique in Europe, operated on behalf of ESA by Snecma, in Vernon, France). The PDR for the Upper Stage Hot Gas Reaction System is in preparation.

Ariane 6

The PRR marking the end of Phase-A was completed in November. The First Design Analysis Cycle took place in December and the Operational Key Point Steering Committee is foreseen in January.

A Vega fourth stage, or Attitude Vernier Upper Module (AVUM), being tested on the QUAD shaker at ESA's Test Centre at ESTEC, Noordwijk, in November 2013. The AVUM is being qualified for launch while partially filled with propellant rather than full, to increase its payload capacity

→ VEGA

Following VV02 flight analysis in October, the Steering Board was held in November. An MoU was signed in November between ESA, Arianespace and ELV on Vega exploitation. This MoU specifies the framework and the sharing of responsibilities, as well as the reference launch service cost commitments for the commercial exploitation of Vega.

The Flight Programme Software generic qualification tests are complete and qualification began in December. The Vega generic qualification loop started in December and the Qualification Review is planned for February. Negotiations for the Work Order for the Intermediate eXperimental Vehicle (IXV) mission are finalised; signature is in January.

The campaign for VV03 launch will begin in Kourou in February, for a commercial exploitation flight in April. The completion of VECEP Phase-A and Vega C SRR is expected in January, with signature of the VECEP contract expected in April.

→ IXV & PRIDE

IXV flight and ground segment qualification and integration activities are progressing to plan. Equipment-level qualification activities are complete, while subsystem and system-level qualification activities are progressing. The FM system-level integration is progressing, with the vehicle being integrated already with several subsystems. Integrated system tests by industry and environmental tests at ESTEC are being prepared.

The industrial proposal for PRIDE, including the in-kind documentation produced within the Italian USV national programme, was evaluated by ESA.

→ FUTURE LAUNCHERS PREPARATORY PROGRAMME

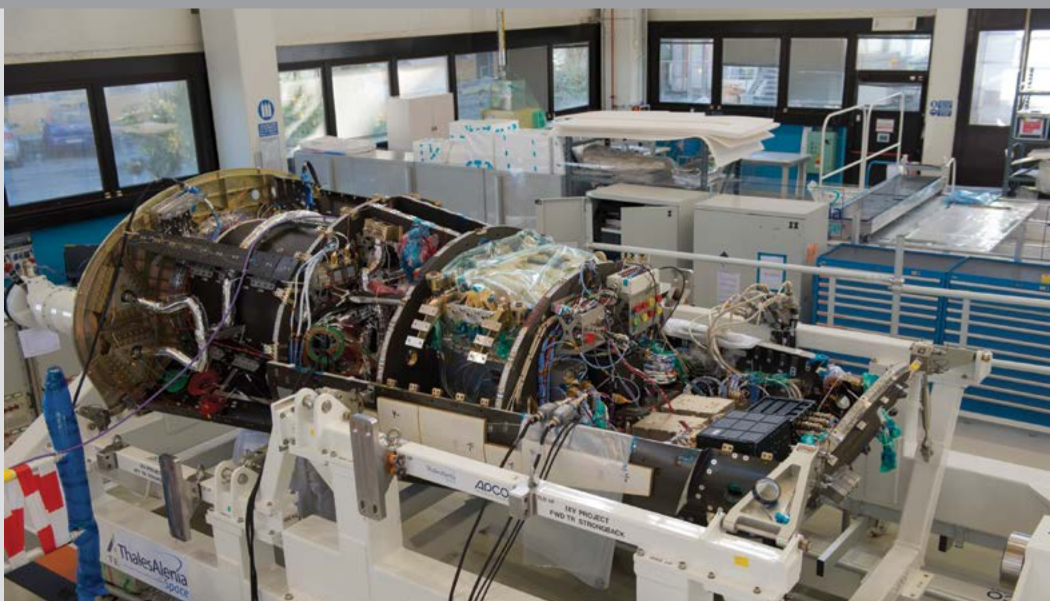
Propulsion

The first hot firing test of the Pressure Oscillation Demonstrator (POD-X) is planned for February. The contract for the Expander Cycle technology was signed in December. The storable propulsion project is preparing the technologies needed for pressure-fed engines in the thrust category 3–8 kN and, after the Manufacturing Release Review, work is progressing to plan with hot fire test confirmed for mid-2014.

Technologies

The implementation of integrated demonstrators is progressing with the Cryotank Demonstrator (incorporating sandwich common bulkhead). Negotiations on the frame contract for Upper Stage technologies are now finalised. Implementation

The Intermediate eXperimental Vehicle (IXV) Flight Model during integration at Thales Alenia Space, Turin, in February



Luca back on Earth after more than five months in space on the International Space Station, 11 November

of the Integrated Solid Rocket Motor composite casing demonstrator began and the first contract was signed.

→ HUMAN SPACEFLIGHT

Expedition 38/39 crew members Mikhail Tyurin (Roscosmos), Koichi Wakata (JAXA) and Rick Mastracchio (NASA) were launched on Soyuz TMA-11M on 7 November. They joined the Expedition 37 crew, bringing the permanent crew of the ISS temporarily up to a total of nine for the first time since October 2009. The crew remained at this level for a few days until the undocking of Soyuz TMA-09M, carrying ESA's Luca Parmitano (IT) with Fyodor Yurchikhin and Karen Nyberg, back to Earth on 11 November. On 20 November, the ISS celebrated 15 years in orbit.

The International Space Exploration Forum took place on 9 January in Washington DC with participants from 33 countries. The importance of international space exploration and cooperation was discussed and confirmed by all states. The US Government announced their intention to extend the ISS programme at least until 2024.

→ ISS TRANSPORTATION

ATV *Albert Einstein*

The Orbit Correction System thrusters of ATV-4 were used to carry out reboosts of the ISS on 2 and 24 October in order to set up phasing for future ISS traffic. ATV-4 undocked from the ISS on 28 October. The spacecraft made its planned destructive reentry into Earth's atmosphere on 2 November, completing a five-month mission in orbit.

ATV *Georges LeMaître*

The launch campaign for ATV-5 is proceeding with a launch scheduled for June.

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

The PDR was postponed to May in order to give more time to design trade-offs and to address the excess mass issue in more detail. A new PDR schedule was agreed with all parties and all milestones of this plan have been met. The mass was reduced close to the requirement. The impact of the PDR delay overall will be minimised by starting Phase-C/D activities that do not depend on the system PDR. A fully consolidated MPCV-level schedule will be agreed after the system PDR.

→ ISS DEVELOPMENT/EXPLOITATION

European Robotic Arm (ERA)

Because of an issue with cleanliness of the fuel transfer lines of the Multipurpose Laboratory Module (MLM), launch has been delayed and is planned for November 2015. The MLM was moved back from RSC Energia to Khrunichev at the end of December. Khrunichev is expected to produce a plan for resolution of the problems with the MLM's leaking and contaminated propulsion system by mid-March and RSC Energia should publish an overall schedule, including a launch date, by the end of March. In the meantime, the ERA FM electrical and software integration has been completed.

Japan Aerospace Exploration Agency astronaut Koichi Wakata, Expedition 38 flight engineer, participates in a session with ESA's Reversible Figures experiment (ESA/NASA)

→ ISS UTILISATION

The European ISS utilisation programme continued with the assistance of the Expedition 37/38 crew. Utilisation activities were affected by an External Thermal Control System loop failure on 11 December, though all systems were recovered by the end of December.

Human research

JAXA astronaut Koichi Wakata became a new subject for the Circadian Rhythms experiment, completing two 36-hour sessions of the experiment in December. The main objective of the experiment is to get a better understanding of alterations in circadian rhythms in humans during long-duration spaceflight.

Luca Parmitano completed his final three sessions of ESA's Skin-B experiment. Each session included three different non-invasive measurements taken on the inside part of the forearm. The Skin-B experiment will help to develop a mathematical model of aging skin and improve understanding of skin-aging mechanisms, which are accelerated in weightlessness.

Luca completed his participation in the 11-day Energy experiment. The experiment monitors the astronaut's diet, uses the ESA/NASA Pulmonary Function System to take cardiopulmonary measurements, and makes water and urine analysis, in order to generate data to be used to determine the energy requirements of astronauts. This will be used for future (exploration) missions in order to optimise the quantity of crew supplies.

Luca also completed the 'Space Headaches' experiment before his return, filling his 23rd and final weekly questionnaire on 8 November. The questionnaires are being analysed to help determine the incidence and characteristics of headaches occurring within astronauts in orbit, which can be a common complaint.

Michael Hopkins carried out his first four sessions as a subject of ESA's Reversible Figures experiment in October through to December, while Koichi Wakata carried out his first two sessions of the experiment in November and December. This neuroscience experiment is investigating the adaptive nature of the human neuro-vestibular system in the processing of gravitational information related to 3D visual perception.

Biology research

No biology research activities took place in the period October to December, though extensive facility maintenance activities were performed. Luca repaired the Biolab microscope cassette, returning full functionality to the miscroscope.

Fluids research

Even though the science programme of the FASES (Fundamental and Applied Studies of Emulsion Stability) experiment, installed inside the Fluid Science Laboratory, was affected by thermal control problems, experiment runs were made from October to December with good emulsification and images obtained in numerous samples. Results of the FASES experiment hold significance for applications in oil extraction processes, and the chemical and food industries.

The Selectable Optical Diagnostic Instrument (SODI) was installed back into the Microgravity Science Glovebox (MSG) in the US Laboratory in November. The SODI-DCMIX 2 experiment samples arrived on Progress 53P on 29 November and were installed in the MSG the following day and started immediate processing. Several science runs have been made since 1 December. 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.

→ NON-ISS RESEARCH

Parabolic flights

ESA's 59th Parabolic Flight Campaign flight campaign took place between 28 October and 8 November with ten experiments, five in physical sciences and five in life sciences. The 60th ESA campaign is being prepared for April 2014 including 13 experiments (eight in physical sciences and five in life sciences) and three back-up experiments.

NASA astronaut Michael Hopkins, Expedition 38 flight engineer, prepares to install and activate the Selectable Optics Diagnostic Instrument in the Microgravity Science Glovebox for the SODI-DCMIX 2 experiment (ESA/NASA)

Isolation studies

The latest Concordia winter-over season was completed in November. The pre-departure meeting with baseline data collection took place in October at EAC, as well as experiment-specific training for the research medical doctor in advance of the 2014 winter-over season scheduled to start in February.

Bed-rest studies

The third and final campaign of the medium-duration (21-day) study at MEDES, France, was completed on 20 October.

Drop tower flights

A new experiment campaign on Diffusive Wave Spectroscopy Measurements on Granular Media with 32 scheduled drops/catapult shots started in December. The Drop Your Thesis 2013 candidate project based on mechanisms of stripe formation in vibrated granular materials was completed in December.

Advanced materials and energy projects

The Casting of Large Ti Structures (COLTS) project was completed (developing centrifugal and gravity casting and to enhance strategic international co-operation between China and Europe in the field of casting of large titanium aerostructure components).

Other advanced materials research projects with the EC (ThermoMag, Accelerated Metallurgy, ExoMet, AMAZE) are progressing. Close links with ELIPS projects are exploited in terms of science team members and flight experiments.

→ ASTRONAUTS

The Volare mission of Luca Parmitano ended with the landing in Kazakhstan on 11 November. In addition to the European research activities, Luca has been involved in research for ISS partner agencies. He was a test subject for a number of NASA human research protocols (Pro K, Microbiome, Salivary Markers, Ocular Health, Spinal Ultrasound, Reaction Self Test), the Canadian Space Agency's Blood Pressure Regulation (BP Reg) experiment and JAXA's Biological Rhythms experiment.

Alexander Gerst (DE) had payload and ATV training, baseline data collection and medical activities at EAC in October and November. Training for Samantha Cristoforetti (IT) and Tim Peake (GB) was temporarily affected by the US government shutdown in early October, though Samantha completed ATV-5 training at EAC in November. Andreas Mogensen (DK) and Thomas Pesquet (FR) continued language training at EAC (Russian and Chinese for Thomas and Russian for Andreas), followed by training for Andreas' short-duration mission in Star City. In November, the two astronauts attended ATV Refresher training and pre-assignment training at EAC.

→ TRANSPORTATION/EXPLORATION

Advanced Reentry Vehicle (ARV)
Post-processing of the results of an aerodynamic dynamic test campaign, breadboarding/testing in support of MPCV-ESM (high-power solar array and enhanced solar array panel hinge) and of the Versatile Autonomous Concepts (advanced rendezvous sensor simulator) is completed. A rendezvous sensors simulator in an open-loop mode is being prepared.

International Berthing Docking Mechanism (IBDM)
The mechanical design of the IBDM data package continues. The avionic architecture definition has been completed and the new electro-mechanical actuators and the mechanism lock-down system have been tested. The Sierra Nevada Corporation confirmed their interest in the use of the IBDM on their Dream Chaser vehicle. Technical exchanges over the features of the IBDM and the main aspects of the mechanism to vehicle interface took place in December.

International Docking Standard System (IDSS)
Revision C of the IDSS Interface Definition Document was approved by the ISS Management Control Board. Revision C is based on a narrow soft-docking ring, the geometry of which is directly inherited from the Russian Androgynous Peripheral Attach System.

Operation Avionics Subsystem (OAS)
The SRR for the cockpit mock-up was performed on 15 November. A set of activities based on the work performed in the OAS was discussed with the Sierra Nevada Corp. for application in the development of Dream Chaser. These include cockpit layout definition, displays (based on X-38/CRV programmes), simulators, certification of software and electronic procedures. The first phase of development of Integrated Crew Aids (e.g. head-up display) for application to the new Russian crew vehicle PTK is being completed in cooperation with Energia.

European Experimental Reentry Testbed (EXPERT)
Comparisons of alternative launch system options are ongoing, now including also launchers under development in a cooperation between Brazil and DLR. Discussions continue with NASA/US Army and US potential industrial launch service providers in order to present launch and retrieval options by late spring 2014.

Lunar exploration
A workshop on importance of lunar exploration was held for delegates on the ESA Programme Board for Human Spaceflight, Microgravity and Exploration in January.

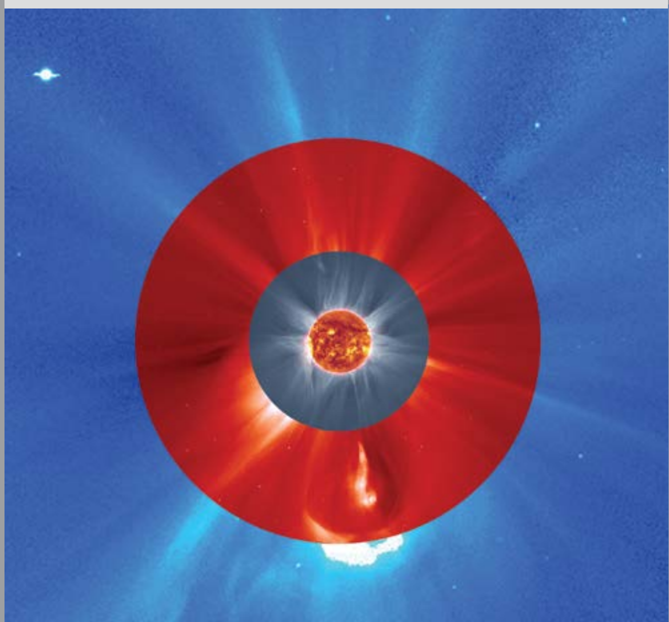
International Exploration Framework
The International Space Exploration Forum (ISEF) took place on 9 January in Washington with participants from 33 countries. The importance of international space exploration and cooperation was discussed and confirmed by all states. At the forum, the US Government announced their intention to extend the ISS programme at least until 2024.

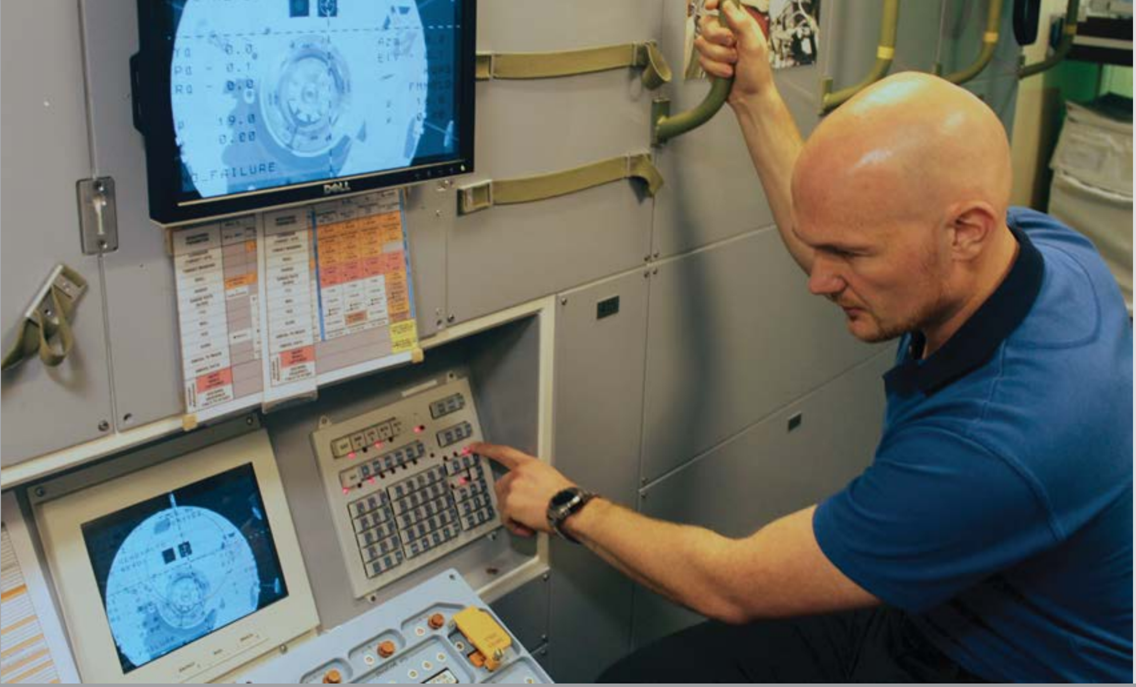
The first aircraft to land at the Concordia Antarctic base in November, ending the winter-over crew's nine months of isolation (ESA/IPEV/PNRA/E. Kaimakamis)

→ SSA (SPACE SITUATIONAL AWARENESS)

Space Surveillance and Tracking (SST)
The reentry of GOCE satellite provided the opportunity for a real-life validation test of the Reentry Prediction System. Data provided by the Centre for Orbit Determination in Europe, at the Astronomical Institute of the University of Bern, was used to generate predictions for the reentry. The first results are promising. This work is supporting the tasks and functions of ESA's Space Debris Office at ESOC. Meetings

Composite of space and ground-based observations in different wavelengths of the solar eclipse of 3 November. The result is an overall view of the Sun and its surrounding corona, extending far out into space. Close-in views of the solar disc in extreme ultraviolet light are from the SWAP instrument on ESA's Proba-2 satellite and instruments on NASA's Solar Dynamics Observatory mission (Univ. Athens/ESA/ROB/NASA)





ESA astronaut Alexander Gerst during an ATV rendezvous and docking simulation

were also held at the EISCAT headquarters in Kiruna, Sweden, to investigate how observation data from this scientific consortium could be used for test and validation purposes within the SST segment.

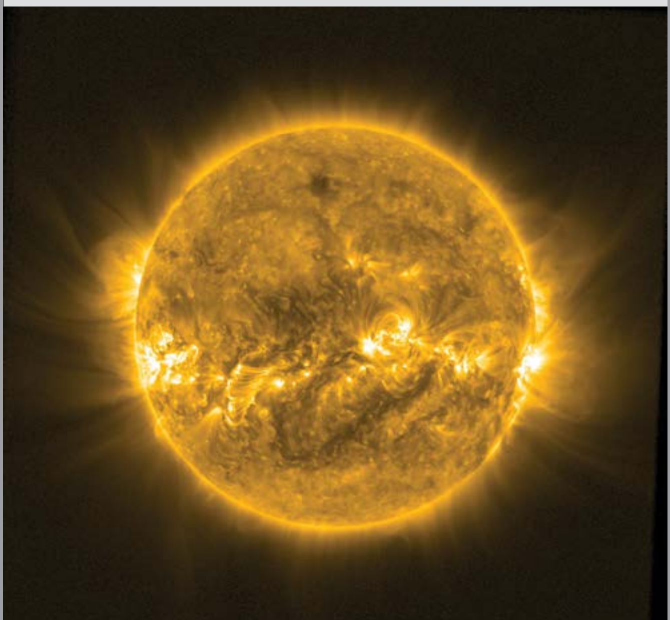
Space Weather (SWE)

New SWE services for ionospheric weather in the Arctic region, ionospheric weather in Europe based on ionosonde observations and the space radiation environment based on ground-based neutron monitor data have been made available through the SWE Service portal by the Norwegian Mapping Authority, National Observatory of Athens and National and Kapodistrian University of Athens. SWE system and the development activities were highly visible during the 10th European Space Weather Week in November 2013 in Antwerp.

Proba-2

In addition to normal solar observations, Proba-2 monitored two special events in November. The first event was a partial solar eclipse on 3 November. Because of its orbit, the satellite's SWAP (Sun Watcher using Active Pixel System detector and Image Processing) telescope observed three partial solar eclipses as it moved in and out of the Moon's shadow during the passage of the Moon between the Sun and Earth. Video of the partial eclipses can be seen at ESA's web video library (spaceinvideos.esa.int/Videos/2013/11/)

ESA's Sun-watching Proba-2 minisatellite shows the aftermath of a 'coronal mass ejection' on 18 February (ESA/ROB)



Proba-2 also supported the monitoring of Comet ISON. An off-pointing campaign was carried out to focus the SWAP telescope on the region of the perihelion of the comet orbit. The campaign was executed flawlessly and the instrument performance was excellent, but the comet is not visible in any of the very high-quality SWAP images. That the comet was not visible in extreme-ultraviolet raises many interesting scientific questions about the composition of the comet and what happened during its passage close to the Sun. Despite not seeing the comet, the off-pointing campaign in November was successful in collecting unique data of the solar corona in a region that has been rarely studied up to now.

Near Earth Objects (NEO)

At the end of 2013, there were 10 481 known Near-Earth Asteroids (NEA). This was the first year that over 1000 NEAs were discovered. An agreement was reached to use ESO's 8.2 m Very Large Telescope (VLT) for up to 11 hours every semester. The VLT was used to observe 2009 FD, an asteroid that is in the Top 5 of the impact risk list according to the Palermo Scale. It has a relatively high impact risk on the Palermo Scale. The observations refined our knowledge of its orbit and reduced the impact risk by about one order of magnitude.

Ground segment engineering

The development of the mono-static breadboard radar has been completed and the radar was delivered by industry to ESA. A series of test campaigns will now start in order to validate technologies used. For the bi-static breadboard radar, Phase-2 of the contract, aiming at developing the breadboard radar, has progressed. The factory assembly of the various subsystems has been completed and acceptance tests initiated.

→ ESA PUBLICATIONS

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Earth Explorers: Satellites to Understand our Changing Earth (June 2013)
BR-289 (4th ed.) // 8 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. 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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