BR-200

ESA ACHIEVEMENTS

more than thirty years of pioneering space activity

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European Space Agency
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Contents

It is a privilege to be part of an organisation with such a rich heritage and exciting potential as the European Space Agency (ESA). The Agency is at a turning point in its history, so it is an appropriate moment to document and reflect on the many successes of the past and those still underway, while preparing to head in new directions for the future.

The remarkable record stretches from humble beginnings in the 1960s to ESA's leading position today among the front rank of space organisations, generating enormous benefits for its Member States and their citizens. The Agency has been responsible for developing systems that are now accepted as everyday – and profitable – parts of our lives, leading to the creation of new entities and companies responding to our needs.

Foreword

The Ariane rocket alone has provided an impressive return on investment. It has long dominated the world's commercial launch market, operated by the Arianespace company. The new heavy-lift Ariane-5 is already building a significant reputation as the latest addition to the Ariane family. The Meteosat weather satellite system developed by ESA similarly led to the creation of Eumetsat. The ECS communications satellites led to Eutelsat, and the Marecs maritime satellites were vitally important to Inmarsat. These are all now enterprises of global importance. Likewise, ESA's science programme is second-to-none, and our Earth-observation satellites continue to return torrents of data. Our expertise is such that we are welcomed as one of only five major Partners in the International Space Station. These missions are all included in this volume. Individual entries cover past, current and approved future missions beyond this decade.

Despite this record, the Agency cannot afford to stand still. In 1999, European Ministers called on ESA and the European Commission to elaborate a coherent European Strategy for Space. In November 2000, the Councils of ESA and the European Union adopted resolutions constituting a common framework within which all European players involved in space activities will develop their respective plans of action. Through these resolutions, European space policy took the first step into a new phase in which space systems become an integral part of the overall political and economic efforts of European states – whether members of ESA or the EU – to promote the interests of European citizens.

The European Strategy for Space identifies three lines of action:

- strengthening the foundations for space activities,
- enhancing scientific knowledge,
- reaping the benefits for society and markets.

The first line encompasses broadening space technology and guaranteeing access to space through a family of launch vehicles. The second sees Europe continuing to pursue cutting-edge themes of space science and space contributions to the understanding of our planet's climate. It includes human spaceflight and optimisation of the use of the International Space Station as an infrastructure for European research in all disciplines of space science. 'Aurora' is Europe's proposed long-term plan for the robotic and human exploration of the Solar System. The third line of action has the objectives of seizing market opportunities and meeting the new demands of our society. It bears on satellite communications and the information technology sector, satellite navigation and positioning (Galileo), and global monitoring for environment and security (GMES). This is where close cooperation between ESA and the EC will be most instrumental in putting space systems at the service of European policies responding to citizen's expectations.

The European Strategy for Space also covers industrial aspects and pays specific attention to small and medium-size enterprises. Public/private partnerships are seen as a model for committing the public sector along with the complete industrial chain to an operational project.

In addition to being a partner in setting up joint programmes responding to political initiatives of the European Union, ESA will act as the implementing organisation for the development and procurement of the space and ground segments associated with such initiatives. ESA is preparing programme proposals on the basis of this strategy and will submit them to the ESA Ministerial meeting scheduled for November 2001.

With these new directions, we can be hopeful that the Agency has an equally productive future and a crucial role in the success of Europe.

Antonio Rodotà

Director-General, European Space Agency

Launches of ESA, ESRO, ELDO and related missions

	Launch date	Mission
Europa-I F1	5 Jun 1964	Launcher: test of stage-1
ESRO-2A*	29 May 1967	Science: cosmic rays, solar X-rays
ESRO-2B	17 May 1968	Science: cosmic rays, solar X-rays
ESRO-1A	3 Oct 1968	Science: Earth auroral and polar-cap phenomena, ionosphere
Europa-I F7*	30 Nov 1968	Launcher: first orbital attempt
HEOS-1	5 Dec 1968	Science: interplanetary medium, bow shock
ESRO-1B	1 Oct 1969	Science: as ESRO-1A
Europa-II F11*	5 Nov 1971	Launcher: orbital demonstration
HEOS-2	31 Jan 1972	Science: Earth polar magnetosphere, interplanetary medium
TD-1	12 Mar 1972	Science: UV, X-ray and gamma-ray astronomy
ESRO-4	26 Nov 1972	Science: Earth neutral atmosphere, ionsphere, auroral particles
Cos-B	9 Aug 1975	Science: gamma-ray astronomy
Geos-1	20 Apr 1977	Science: dynamics of Earth magnetosphere
OTS-1*	14 Sep 1977	Telecommunications: demonstrate European technologies
ISEE-2	22 Oct 1977	Science: Sun/Earth relations and magnetosphere
Meteosat-1	23 Nov 1977	Meteorology: pre-operational meteorological services
IUE	26 Jan 1978	Science: ultraviolet astronomy
OTS-2	12 May 1978	Telecommunications: demonstrated European technologies
Geos-2	24 July 1978	Science: Earth magnetospheric fields, waves and particles
Ariane-1	24 Dec 1979	Commercial launcher: first of 11 Ariane-1 launches
Meteosat-2	19 Jun 1981	Meteorology: pre-operational meteorological services
Marecs-A	20 Dec 1981	Telecommunications: maritime communications
Marecs-B*	10 Sep 1982	Telecommunications: maritime communications
Sirio-2*	10 Sep 1982	Meteorological data distribution & clock synchronisation
Exosat	26 May 1983	Science: X-ray astronomy
ECS-1	16 Jun 1983	Telecommunications: operational European Communications Satellite
Spacelab-1	28 Nov 1983	First of 22 manned Spacelab missions, plus multi-disciplinary First Spacelab Payload (FSLP)
Ariane-2/3	4 Aug 1984	Commercial launcher: first of 17 Ariane-2/3 launches
ECS-2	4 Aug 1984	Telecommunications: operational European Communications Satellite
Marecs-B2	10 Nov 1984	Telecommunications: maritime communications
Giotto	2 Jul 1985	Science: Comet Halley and Comet Grigg Skjellerup encounters
ECS-3*	12 Sep 1985	Telecommunications: operational European Communications Satellite
ECS-4	16 Sep 1987	Telecommunications: operational European Communications Satellite
Ariane-4	15 Jun 1988	Commercial launcher: first of 84 Ariane-4 launches (by end-1998; in service)
Meteosat-3	15 Jun 1988	Meteorology: pre-operational meteorological services
ECS-5	21 Jul 1988	Telecommunications: operational European Communications Satellite
Meteosat-4	6 Mar 1989	Meteorology: operational meteorological services
Olympus	12 Jul 1989	Telecommunications: technology demonstration
Hipparcos	8 Aug 1989	Science: astrometry
HST/FOC	24 Apr 1990	Science: astronomy (Hubble Space Telescope/Faint Object Camera)
Ulysses	6 Oct 1990	Science: probing heliosphere above/below ecliptic up to solar poles
Meteosat-5	2 Mar 1991	Meteorology: operational meteorological services
ERS-1	17 Jul 1991	Earth observation: pre-operational radar
Eureca	31 Jul 1992	Science: multi-disciplinary, reusable platform
Meteosat-6	20 Nov 1993	Meteorology: operational meteorological services
ERS-2	21 Apr 1995	Earth observation: pre-operational radar
ISO	17 Nov 1995	Science: infrared astronomy
Soho	2 Dec 1995	Science: Sun, from core to beyond Earth orbit
Ariane-5*	4 Jun 1996	Commercial launcher: new generation of heavy launchers
Cluster*	4 Jun 1996	Science: space plasma physics in 3D (FM1-FM4; launch failure)
Meteosat-7	2 Sep 1997	Meteorology: operational meteorological services
Huygens	15 Oct 1997	Science: Titan atmosphere/surface probe
TeamSat	30 Oct 1997	Science/technology: experiments on Ariane-502 demonstration launch
ARD	21 Oct 1998	Technology: demonstration of Earth-return technologies
XMM-Newton	10 Dec 1999	Science: X-ray astronomy
Cluster	16 Jul 2000	Science: space plasma physics in 3D (first pair: FM6 & FM7)
Cluster	9 Aug 2000	Science: space plasma physics in 3D (second pair: FM5 & FM8)
Artemis	12 Jul 2001	Telecommunications: demonstration

*launch failure

Only the debut launches of Ariane-1/2/3/4/5, Europa and Spacelab are shown.

Planned launches of ESA and related missions

	Launch date	Mission
Proba	Sep 2001	Technology/Earth observation
Envisat	Jan 2002	Earth observation
Ariane-5ECA	Feb 2002	Launcher: 9 t GTO-capacity Ariane-5 debut
MSG-1	Jul 2002	Meteorology: Meteosat Second Generation
Integral	Sep 2002	Science: gamma-ray astronomy
SMART-1	Nov 2002	Technology/science: lunar orbiter
Rosetta	Jan 2003	Science: Comet Wirtanen rendezvous (2011-2013)
Sloshsat	Jan 2003	Technology
X-38 V201	Feb 2003	Space station: orbital test flight of Crew Return Vehicle prototype (in cooperation with NASA)
Mars Express	Jun 2003	Science: Mars orbiter & lander
MSG-2	Dec 2003	Meteorology: Meteosat Second Generation
Proba-2	2003	Technology: demonstration
CryoSat	Apr 2004	Earth observation: polar ice thickness
ATV	Sep 2004	Space station: Automated Transfer Vehicle debut
Columbus	Oct 2004	Space station: research laboratory
Galileo	2004	Navigation: debut of navigation system
ERA	~ 2005	Space station: European Robotic Arm
GOCE	Oct 2005	Earth observation: Earth's gravity field and geoid
Vega	Dec 2005	Launcher: debut of small solid-propellant launcher
Metop-1	Dec 2005	Meteorology: polar meteorological services
Ariane-5ECB[1]	2005	Launcher: 12 t GTO-capacity Ariane-5 debut
SMOS	2005/6	Earth observation: soil moisture and ocean salinity
SMART-2	Aug 2006	Technology/science: demonstration
Planck	Feb 2007	Science: map Cosmic Microwave Background
Herschel	Feb 2007	Science: far-IR/sub-mm astronomy
ADM-Aeolus	Jul 2007	Earth observation: global wind measurements
MSG-3	2007	Meteorology: Meteosat Second Generation
Earth Explorer (Opportunity Mission-3)[1]	2007	Earth observation: mission to be selected
Earth Explorer (Core Mission-3)[1]	2008	Earth observation: mission to be selected
BepiColombo	2009	Science: Mercury orbiters & lander
Metop-2	2009	Meteorology: polar meteorological services
NGST	2009	Science: Next Generation Space Telescope
Earth Explorer (Opportunity Mission-4)[1]	2008	Earth observation: mission to be selected
Earth Explorer (Core Mission-4)[1]	2010	Earth observation: mission to be selected
LISA[1]	2011	Science: gravitational wave detection
GAIA	2012	Science: astrometry
Solar Orbiter	~ 2012	Science: solar observations
Metop-3	2013	Meteorology: polar meteorological services
Darwin[1]	> 2013	Science: detection/analysis of Earth-like planets

[1]awaiting full approval

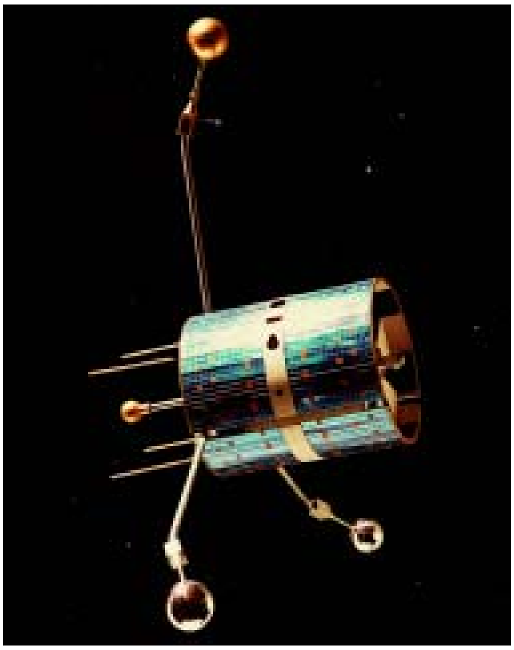
ESA Achievements

The impetus for creating an independent space power in Europe began in the early 1960s. Belgium, France, Germany, Italy, the Netherlands and the United Kingdom (associated with Australia) signed the Convention in March 1962 to create the European Launcher Development Organisation (ELDO), with the goal of developing a satellite launch vehicle independent of the two great space powers, the USA and USSR.

Similarly, Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland and the UK in June 1962 signed the Convention to create the European Space Research Organisation (ESRO), for undertaking scientific satellite programmes.

These partners subsequently decided to merge the activities of ELDO and ESRO into a single body, and in July 1973 a ministerial conference of the 10 European countries met in Brussels and laid down the principles for creating the European Space Agency (ESA). The Agency began operating on 31 May 1975, and on 30 October 1980 the final signature ratifying the Convention gave legal existence to ESA.

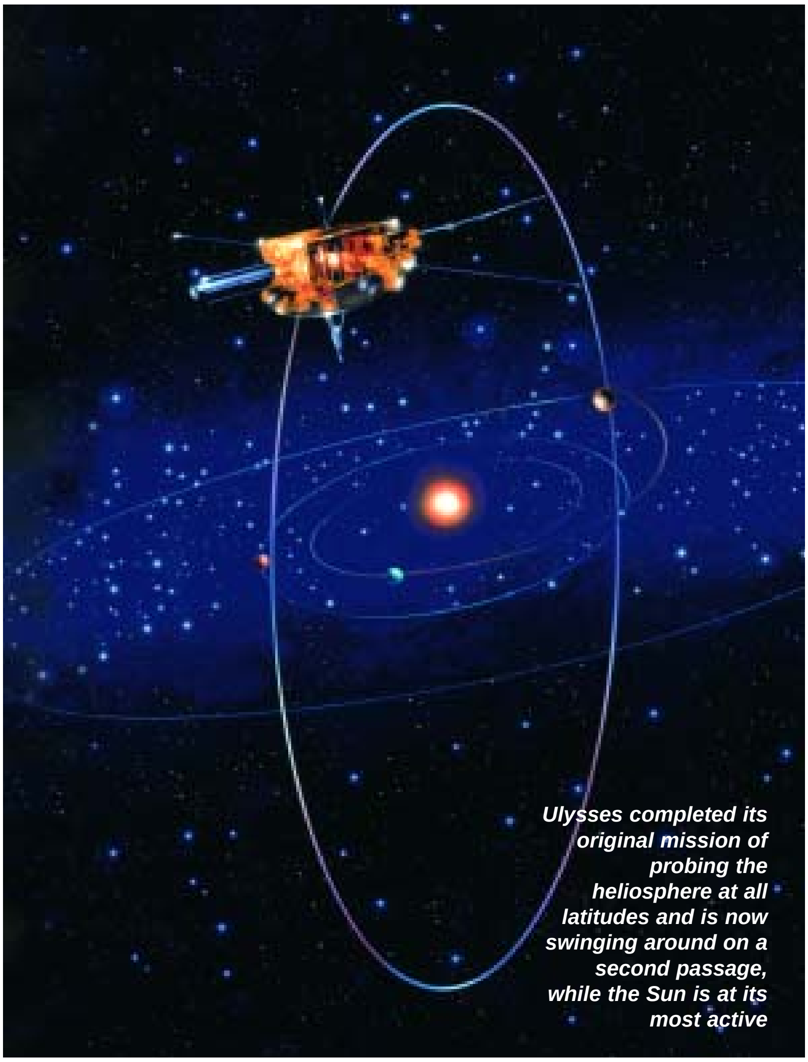
While ELDO had dramatic difficulties developing the Europa launcher, ESRO was becoming a mature organisation. Seven scientific satellites reached orbit by the end of 1972, proving that ESRO could compete with the major space powers and could manage important industrial contracts. By this time, there had been a fundamental change in ESRO's aims. Its Council resolved in December 1971 to include applications satellites, namely the Orbital Test Satellite for telecommunications, Meteosat for meteorology and Aerosat for aeronautical communications. While these would dominate the science element financially, they were optional, allowing Member States the choice of participating or not. The Science Programme became



From humble beginnings: the ESRO scientific satellites (ESRO-4 is shown here) were small by comparison with today's sophisticated spacecraft, but they laid a firm foundation for the future.

mandatory, so that long-term planning became possible for the first time. Three more optional programmes were added in 1973: Spacelab, Europe's contribution to the US Space Shuttle programme; the Ariane launcher; and the Marots (later Marecs) maritime communications satellite.

All of these programmes were underway in May 1975 when ESA assumed de facto responsibility.



Ulysses completed its original mission of probing the heliosphere at all latitudes and is now swinging around on a second passage, while the Sun is at its most active

ESA and Science

The Science Programme is one of the Agency's mandatory activities, in which all Member States participate. Much of the advanced technology used today stems from the scientific programme: over the years it has been the driving force behind many other ESA activities.

The origins of the Science Programme, the oldest in the Agency, hark back to the days of ESRO. ESRO's seven successful scientific satellites paved the way for ESA's remarkable series of pioneering missions that have placed Europe at the vanguard of disciplines such as X-ray, gamma-ray and infrared astronomy; astrometry; Solar System sciences, especially cometary, solar and heliospheric physics, as well as space plasma physics. Driven by the limited available means, ESA's Science Programme has consistently focused on missions with strong innovative contents. All of the missions launched or approved so far are covered in separate entries in this volume, and summarised below.

Cos-B (1975): ESA's first satellite mapped the little-explored gamma-ray sky.

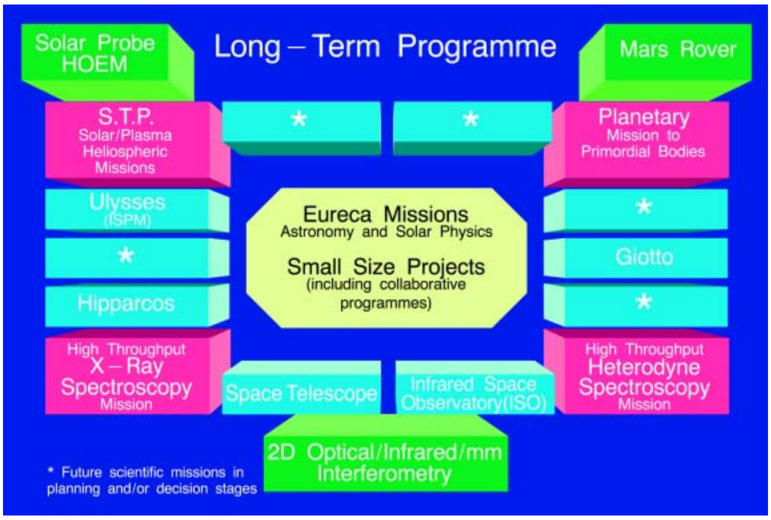
Geos (1977/78): two satellites studied the particles, fields and plasma of Earth's magnetosphere.

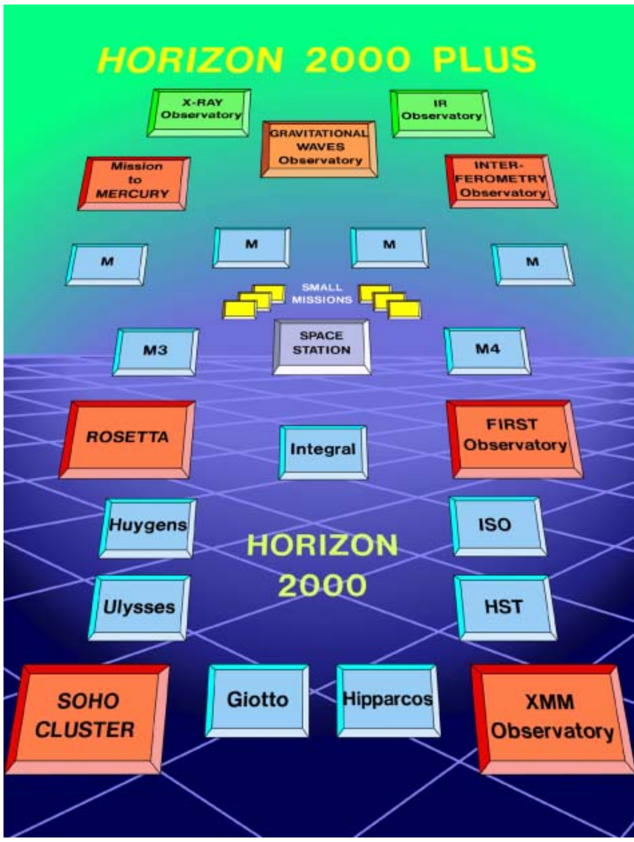
ISEE-2 (1977): worked in tandem with NASA's ISEE-1 studying Earth's magnetosphere.

IUE (1978): the International Ultraviolet Explorer was the world's longest serving and most prolific astronomy satellite, returning UV spectra on celestial objects ranging from comets to quasars until 1996.

Exosat (1983): studied the X-ray emissions and their variations over time of most classes of astronomical objects in 1780 observing sessions.

Giotto (1985): first close flyby of a comet (Comet Halley, March 1986), followed by bonus encounter with Comet Grigg-Skjellerup in July 1992.





Above: the Horizon 2000 space science plan was formulated in 1985. Right: it was extended by Horizon 2000 Plus 10 years later, and jointly termed Horizons 2000. Financial constraints and the Cluster launch failure led to the later Medium (blue) missions being replaced by Flexi and SMART missions.

1985 was an important milestone in the history of ESA's Science Programme. It saw the approval of the long-term Horizon 2000 programme of scientific research in space, designed to ensure that Europe would play a key and balanced role beyond the end of the century. Executing Horizon 2000 required a special financial effort from the Member States, amounting to a progressive budgetary increase of 5% per year from 1985 to a steady plateau in 1994. Horizon 2000 encompassed the missions already approved (Hubble Space Telescope, Ulysses, Hipparcos and ISO) and added four Cornerstone missions, plus Medium-size ('M') missions selected competitively. Cornerstone-1 combined two missions into the Solar-Terrestrial Science Programme: Cluster and Soho. The CS-2 High-Throughput X-ray Spectroscopy Cornerstone is XMM-Newton; the CS-3 Cometary Cornerstone is Rosetta; the CS-4 Far-Infrared and Submillimetre Spectroscopy Cornerstone is Herschel. The selected Medium missions are: M-1 Huygens Probe; M-2 Integral; M-3 Planck.

Hipparcos (1989): produced the most accurate positional survey of more than 100 000 stars, fundamentally affecting every branch of astronomy.

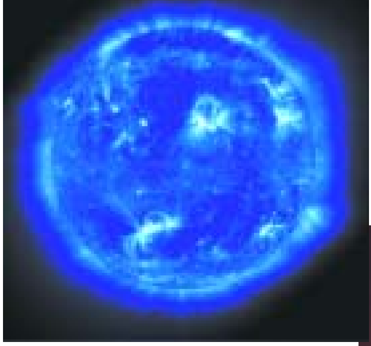
Hubble Space Telescope (1990): 15% contribution, including the Faint Object Camera, to this major international space telescope.

Ulysses (1990): continuing the fields and particles investigation of the inner heliosphere at all solar latitudes, including the solar poles.

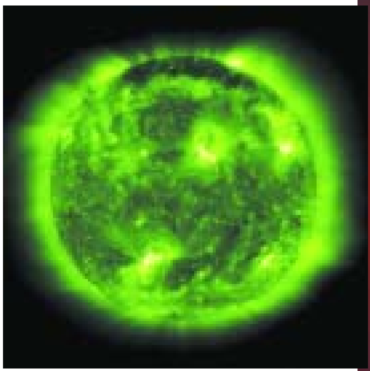
ISO (1995): world's first infrared astronomical observatory has provided a fresh perspective on the Universe.

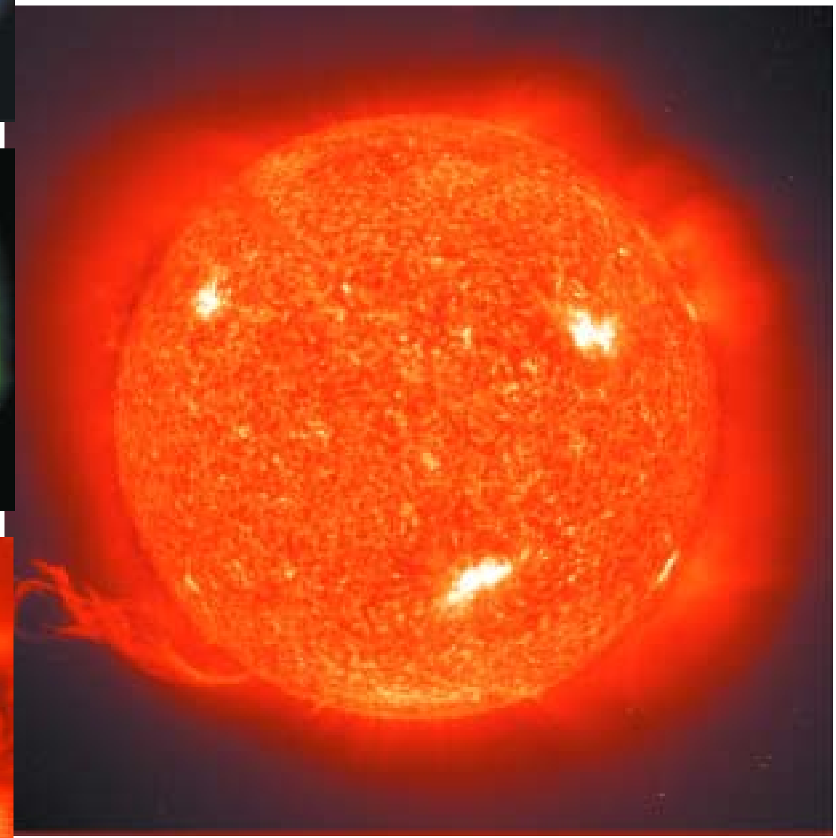
Soho (1995): first Horizon 2000 Cornerstone, studying the Sun's interior, as well as the corona and its expansion into the solar wind.

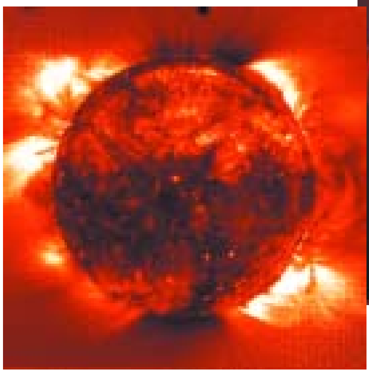
Cluster (1996): part of first Horizon 2000 Cornerstone, to investigate



Viewing the Sun with Soho's Extreme Ultraviolet Imaging Telescope (EIT). EIT keeps a daily watch on the Sun's weather at four different ultraviolet wavelengths. (ESA/NASA/EIT)







plasma processes in Earth's magnetosphere using four satellites. Lost in first Ariane-5 launch failure; replacements successful in mid-2000.

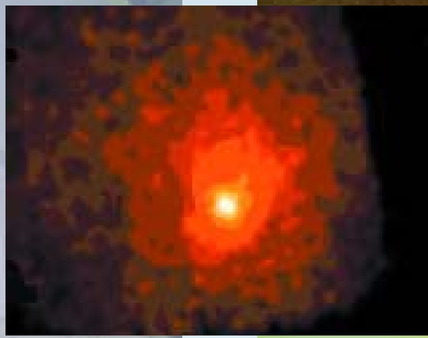
Huygens (1997): the first probe designed to descend through the atmosphere of Saturn's moon Titan, arriving in 2004.

XMM-Newton (1999): the X-ray Multi-Mirror mission is the most sensitive X-ray astronomy satellite yet, finding millions of new objects.

Cluster (2000): duplicate replacements of the four Cluster satellites, observing plasma processes in Earth's magnetosphere.

Preparatory work began in 1993 on the follow-up Horizon 2000 Plus programme to cover new missions for 2007-2016, including three new Cornerstones. The Ministerial Meeting in September 1995 approved the long-term programme but imposed a 3% annual reduction in purchasing power on the Scientific Directorate. Then, when the four Cluster satellites were destroyed by the Ariane-501 failure in June 1996, it became inevitable that the Science Programme had to be revised.

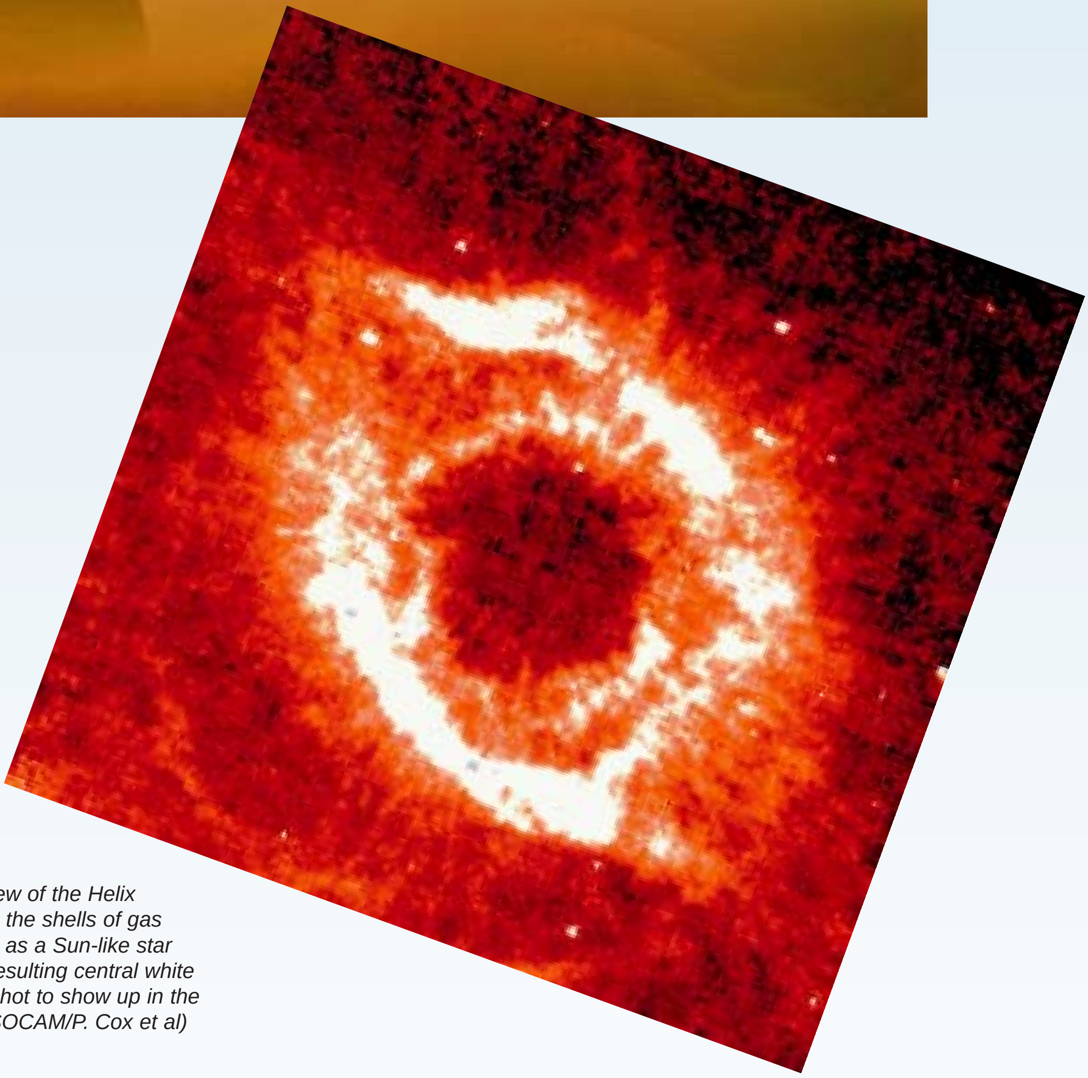
The Cornerstones were maintained, but the medium M-missions were replaced by smaller missions in order to regain programme flexibility. The new classes are 'F' (Flexible) with purely scientific goals, and 'SMART' (Small Missions for Advanced Research in Technology), which can provide in-orbit proof of technologies, particularly for Cornerstones, and carry, as a secondary goal, scientific experiments. Mars Express was conditionally approved in November 1998 as the first Flexi mission (F1) and confirmed following the May 1999 Ministerial Council meeting. SMART-1 (2002) will demonstrate



Scientists hope that XMM-Newton will help to solve a number of cosmic mysteries, ranging from the enigma of black holes to the origin of the Universe itself. Inset: soft X-ray image of Comet McNaught-Hartley, January 2001.

The first four Cluster satellites were lost in 1996, but a replacement set was launched successfully in pairs in 2000.

ESA's Huygens Probe will parachute through the atmosphere of Saturn's moon Titan in 2004.



ISO's infrared view of the Helix Nebula, showing the shells of gas and dust ejected as a Sun-like star collapsed. The resulting central white dwarf star is too hot to show up in the infrared. (ESA/ISOCAM/P. Cox et al)

Giotto was the first spacecraft to venture close to a comet, but Rosetta will make intensive in situ observations for 2 years.

technologies for the Mercury Cornerstone, and SMART-2 (2006) for LISA and IRSI/Darwin. On 1 October 1999, ESA requested proposals for F2 and F3, selecting five of the 50 for assessment studies March-May 2000: Eddington, Hyper, MASTER, Solar Orbiter and Storms; the Next Generation Space Telescope was already part of the process.

In October 2000, the Science Programme Committee approved a package of missions for 2008-2013. BepiColombo became CS-5 (2009, Mercury Cornerstone) and GAIA CS-6 (2012). LISA is also a Cornerstone (Fundamental Physics) but to fly in collaboration with NASA at a cost to ESA of a Flexi mission. F2 and F3 are Solar Orbiter and NGST; their order depends on NASA's schedule for NGST. A reserve Flexi mission, Eddington (to map stellar evolution and find habitable planets), was also selected in case the NGST and LISA schedules of NASA slip beyond 2013.

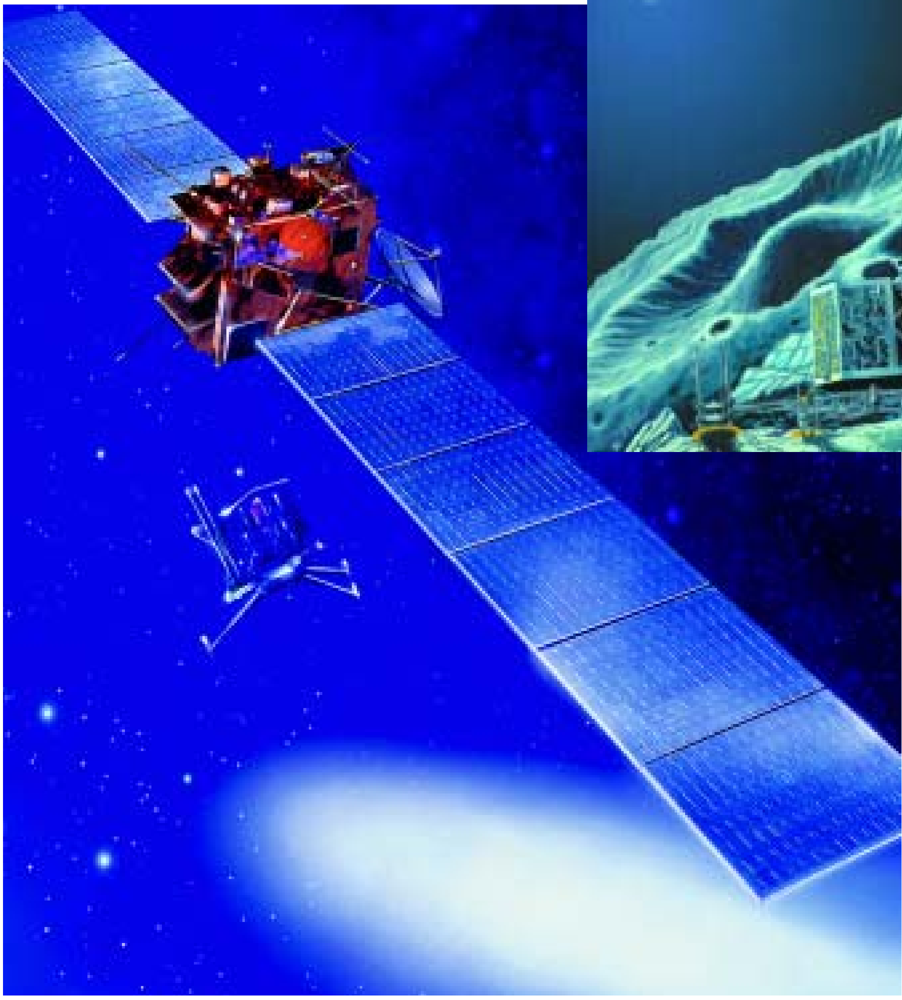
The Cornerstone IRSI/Darwin Infrared Space Interferometer, to search for Earth-like planets around other stars, falls beyond the horizon but work on it continues towards future funding.

Future Science Programme launches are therefore planned as:

Integral (2002): the International Gamma-Ray Astrophysics Lab will observe gamma-ray sources within our Galaxy and beyond, including exploding stars, black holes, gamma-ray bursts and pulsars.

Rosetta (2003): arriving at Comet

Integral will observe the most energetic events in the Universe. (ESA/D. Ducros) Inset: a calibration image from Integral's SPI imaging spectrometer (CESR).



Wirtanen in 2011, Rosetta will orbit the nucleus for 2 years of intensive studies, depositing a lander.

SMART-1 (2002): to demonstrate key technologies, including primary propulsion by a solar electric thruster, critical for BepiColombo.

Mars Express (2003): this orbiter and exobiology lander will intensively study Mars.

SMART-2 (2006): to demonstrate key technologies for LISA and IRSI/Darwin.

Planck (2007): the mission to map the structure of the Cosmic Microwave Background, in unprecedented detail. Launched in tandem with Herschel.

Herschel (2007): using one of the least explored windows on the Universe, it will observe the births of stars and galaxies throughout the history of the Universe. Launched in tandem with Planck.

BepiColombo (2009): two Mercury orbiters and a lander, arriving 2011, in collaboration with Japan.

NGST (2009): 15% contribution to NASA's infrared observatory for probing back to the time of the very first stars.

LISA (2011): three satellites in formation to detect gravitational waves for the first time, in collaboration with NASA.

GAIA (2012): building on Hipparcos to create a high-precision 3-D map of 1000 million stars in our Galaxy and beyond.

Solar Orbiter (2012): Soho successor to study the Sun to within 45 solar radii.

The series of seven Meteosats has returned hundreds of thousands of Earth images from geostationary orbit. (Meteosat-7 image, Eumetsat)

ESA and Earth Observation

It has become increasingly recognised over the past 20 years that many key aspects of monitoring and managing our planet can be adequately addressed only by observing the Earth from space. In this respect, ESA's role has been critically important.

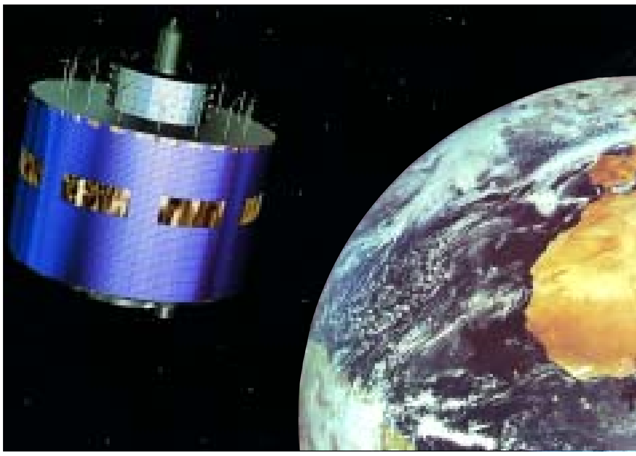
The Earth's environment and climate are determined not only by complex interactions between the atmosphere, oceans, land and ice regions, but also by mankind's ability to affect them. Our future depends on the careful management of our resources and on an improved understanding of the interactions creating our ecosphere.

The first of seven Meteosat meteorological satellites, originating under ESA's auspices, appeared in 1977 to monitor the weather of Europe and Africa from a vantage point over the Equator. The success of that first satellite led to the formation of the European Organisation for the Exploitation of Meteorological Satellites (Eumetsat) in 1986, which took over direct operational control in December 1995.

It has been estimated that the total benefits from improved weather forecasts due to Meteosat alone equate to about €125 million annually in cost savings for all industries and €137 million in saving of life and reduction in environmental damage. Agriculture alone saves €30 million and civil aviation €11 million each year. In addition, the capacity of weather satellites to gather long-term measurements from space in support of climate-change studies is of growing importance.

Meteosat will soon be replaced by the Meteosat Second Generation (MSG) will be introduced. Jointly funded by ESA Member States and Eumetsat, the programme began in 1994 to enhance the performance of today's satellites, incorporating a much-improved imager and the first instrument capable of observing the Earth's radiation balance from geostationary orbit.

Polar-orbiting meteorological satellites will be added in late 2005 with the first of three Metop (Meteorological Operational) spacecraft developed by ESA and Eumetsat. This will not only continue and improve meteorological observations previously provided by US NOAA satellites in the 'morning' polar orbit, but it will also endow Europe with an enhanced capability for routine climate monitoring. Notable improvements include routine observations of sea-surface wind fields, ozone levels and much higher-



The Meteosat Second Generation (MSG) will debut in 2002 to extend services to Europe's meteorological agencies.

Final preparations for the launch of Meteosat-5. (ESA/CNES/CSG)

resolution temperature and humidity profiles.

ESA's first remote-sensing satellite, ERS, continues to make major contributions in areas as diverse as global and regional ocean and atmospheric science, sea ice, glaciological and snow cover investigations, land surface studies and the dynamics of the Earth's crust. For example, global maps of sea-surface winds are routinely provided as inputs to numerical weather forecasting. The 1991 launch of ERS-1 was followed in 1995 by ERS-2, which added the Global Ozone Monitoring Experiment to address an area of growing concern, namely atmospheric chemistry, and in particular to generate global ozone maps every 3 days.

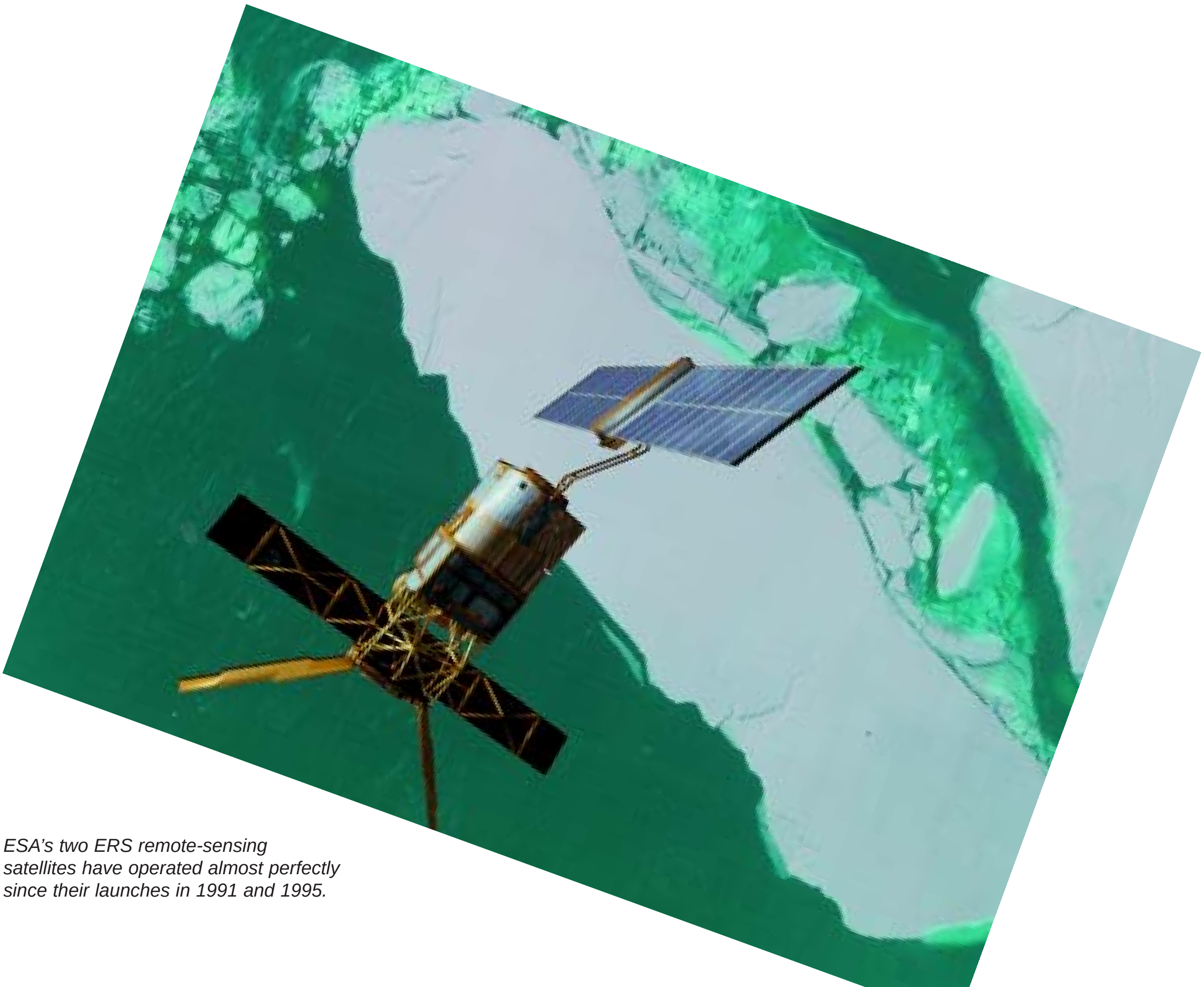
ESA's large Envisat second generation remote-sensing satellite is expected to be in orbit in 2001. It will not only ensure continuity of many ERS observations but will add important new capabilities for understanding and monitoring our environment, particularly in the areas of atmospheric chemistry and ocean biological processes.

The Agency's strategy for Earth observation beyond 2000 was endorsed by ESA's Council in March 1998 after being approved in principle by the Ministerial Council of October 1995 in Toulouse. ESA's 'Living Planet' programme follows on from Envisat, and is designed to cover the whole spectrum of user interests ranging from scientific research to applications. Research-driven Earth Explorer missions will be paralleled by Earth Watch missions, designed to focus on specific applications and service provision to satisfy market needs.

Member States subscribe to the overall Explorer financial envelope, so that each project no longer has to be approved separately. As has long been the case in ESA's Science Programme, this allows a coherent, long-term set of missions to be developed.

Envisat flight model during integration and alignment tests at ESTEC. (ESA)

The Earth's environment is a highly complex system coupling the



ESA's two ERS remote-sensing satellites have operated almost perfectly since their launches in 1991 and 1995.

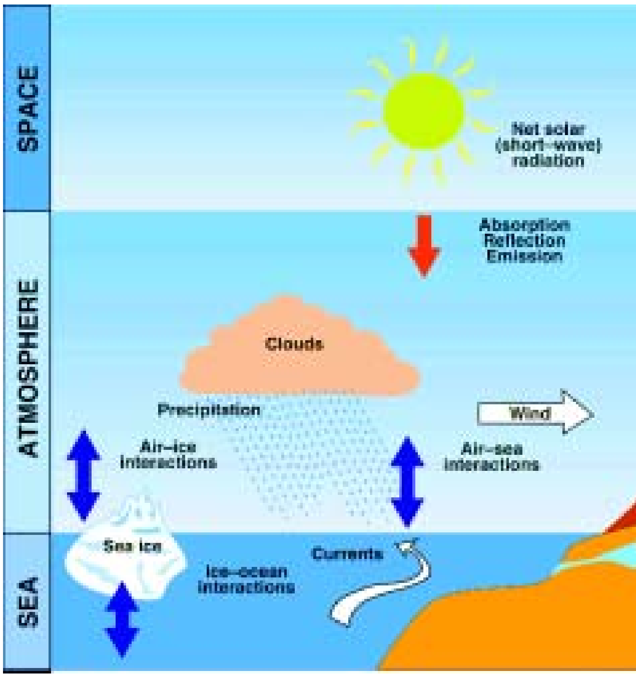
atmosphere, oceans, biosphere and cryosphere. Despite its importance, many aspects of this Earth system are still poorly understood and we are struggling to assess global threats such as climate change, stratospheric ozone depletion and tropospheric pollution, as well as more localised events such as the 1999 El Niño event, fires in South East Asia and the devastating earthquakes in Turkey. Observations from space can provide the required globally coherent data.

Explorer offers two mission types: Core and Opportunity. The larger Core missions are selected through a traditional process involving extensive consultation with the user community. Opportunity missions are intended to respond quickly to flight opportunities or to user requirements, and are not necessarily ESA-led. In this way, the programme combines stability with flexibility, notably the ability to respond quickly to an evolving situation. Core missions cost the Agency no more than €400 million, while Opportunity missions cost an average €110 million (€150 million maximum). The goal is to fly a Core mission about every 2 years, interspersed with Opportunity missions.

Explorer Core Missions

An Earth Observation User Consultation Meeting at ESTEC in October 1994, followed by other consultations, identified nine candidate Core missions. These were assessed by ESA working groups and four were selected in November 1996 for June 1998 to June 1999 Phase-A studies: Earth Radiation Mission (ERM), Gravity Field and Steady-State Ocean Circulation Mission (GOCE), Land Surface Processes and Interactions Mission (LSPIM) and Atmospheric Dynamics Mission (ADM). GOCE and ADM were selected in order of priority in November 1999. GOCE immediately began Phase-B for launch in 2005, while

ERS radar imagery is unhindered by cloud cover. Shown here is The Netherlands.



ADM will begin Phase-B in 2002 for launch in 2007.

GOCE will measure the Earth's gravity field and geoid with unprecedented accuracy and resolution using a 3-axis gradiometer. This will improve our understanding of the Earth's internal structure and provide a much better reference for ocean and climate studies.

ADM will make the first direct observations on a global scale of wind profiles over the depth of the atmosphere, a notable deficiency in current observing methods. This is important for understanding atmospheric processes – particularly in the tropics – as well as improving the numerical modelling used in weather forecasting.

The second Call for Ideas for Core missions was issued on 1 June 2000, receiving ten proposals by the 1 September 2000 closing date. On 20 November 2000, ESA selected five for assessment studies:

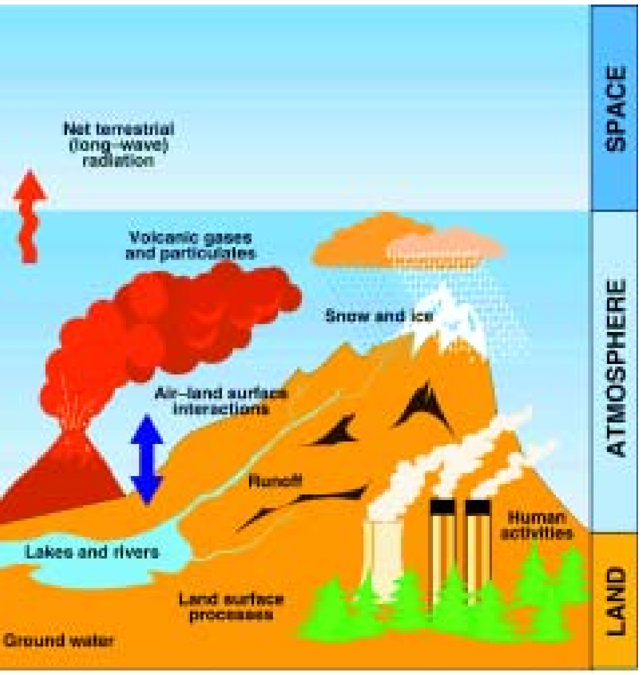
ACECHEM: Atmospheric Composition Explorer for Chemistry and Climate Interaction to study climate-chemistry interactions and man-made effects
EarthCARE: Earth Clouds Aerosol and Radiation Explorer (encompasses ERM) to measure the physical properties of clouds and aerosols to improve climate modelling and our understanding of Earth's radiation balance; joint mission with NASDA
SPECTRA: Surface Processes and Ecosystems Changes Through Response Analysis to measure vegetation parameters for studying the carbon cycle and the effects of climate variability on ecosystems (builds on LSPIM)
WALES: Water Vapour Lidar Experiment in Space to measure water vapour and aerosol distribution in the troposphere
WATS: Water Vapour and Wind in Atmospheric Troposphere and Stratosphere to monitor water distribution for assessing climate change (encompasses the ACE hot standby from the Opportunity missions).

Up to three will be selected in November 2001 for Phase-A, for a first launch in about 2008.

Explorer Opportunity Missions

The AO for Opportunity missions was released on 30 June 1998 and 27 proposals were received by closure on 2 December 1998. On 27 May 1999, ESA approved Cryosat as the first for Phase-A/B (2003 launch), with an extended Phase-A for SMOS (2006 launch). Cryosat will measure the variations in the thickness of the polar ice sheets and the thickness of floating sea ice. SMOS will measure soil moisture and ocean salinity – two key variables in the Earth system.

Work continues on ACE (Atmospheric Climate Experiment) as a hot backup should the first two suffer problems. It would monitor GPS signals refracted through the upper atmosphere to measure temperature



The Earth's environment is a highly complex, coupled system. Understanding it requires observations from space.

and humidity. SWARM and SWIFT are held in reserve and, like ACE, may fly in other forms (see below). Multiple SWARM satellites would measure Earth's magnetic field at high resolution, providing new insights into Earth's structure. SWIFT (Stratospheric Wind Interferometer for Transport studies) would map winds and ozone in the stratosphere.

In fact, SWIFT (largely funded by Canada) was approved in October 2000 by Japan's NASDA space agency to fly on the GCOM-A1 mission in 2006. It remains part of Earth Explorer but flying cooperatively leaves the funding intact for further full ESA missions.

The next Opportunity AO was made on 1 June 2001, with a submissions deadline of January 2002. Three will be selected in May 2002 for 12-month Phase-A studies, and then two for Phase-B. Flights are expected in 2007 and 2009.

GOCE, ADM, Cryosat and SMOS are covered in separate entries. Further information on Earth Explorer can be found at *http://www.estec.esa.nl/explorer*

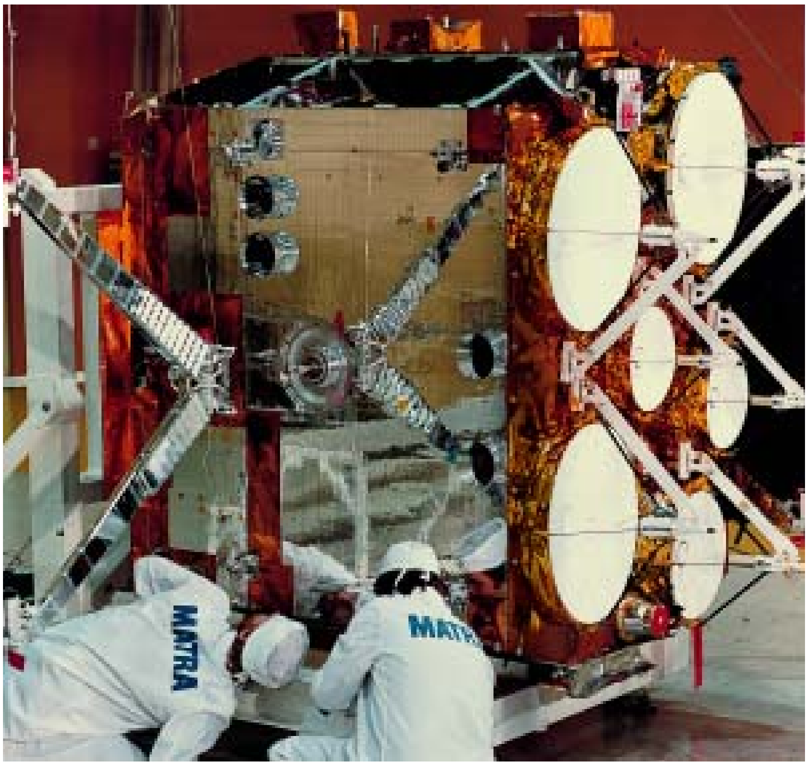
Earth Watch

Earth Watch missions are the prototypes for future operational systems, focusing on specific applications and service provision to satisfy market needs in partnership with industry and operational entities. The Agency plans to make a programme proposal to its Ministerial Conference in 2001. Operational meteorological missions post-MSG/Metop are being discussed with Eumetsat. Institutional needs include the emerging requirements of the inititiative for global monitoring for environment and security (GMES) being defined as part of the European strategy for space jointly established with the European Commission. The GMES initiative centres on three major environmental themes: global changes, including management of treaty commitments; natural and manmade hazards; environmental stress. In addition, peacekeeping and security require all-weather high-resolution imagery. GMES itself is not a satellite programme, but is the link between Europe's political requirements and the capabilities provided by observation satellites, ensuring that the integrated information required at the political level is available.

The first batch (2001-06) of Earth Watch programmes could include:

- GMES Earth Watch,
- Ocean Earth Watch, altimeter and visible-IR,
- C-band synthetic aperture radar,
- IR element,
- L-band element,
- X-band element,
- multispectral very high resolution,
- superspectral and hyperspectral elements.

The MSG and Metop successors would be part of batch 2 (2006) and batch 3 (2011), respectively.



The European Communications Satellite (ECS) series developed by ESA has so far provided more than 48 years of aggregate service.

ESA and Telecommunications

ESA has played the lead role in developing space communications for Europe, with the Orbital Test Satellite (OTS), European Communications Satellite (ECS), Maritime ECS (Marecs) and the direct-broadcasting Olympus. Public telecommunications services have made full use of ESA satellites, through Eutelsat and Inmarsat; some satellites, more than 10 years old, remain in service. Artemis was launched in 2001 to demonstrate further innovative techniques.

After a relatively late start, European space industry has achieved a high level of technical competence. In 2000, its provision of commercial telecommunications satellites exceeded that of US industry for the first time. ESA's long-term telecommunications plan is to help European industry maintain and improve its competitiveness. Its proposals include mobile and multimedia communications, in-orbit demonstrations and development of a large platform to satisfy future demands.

ESA's telecommunications programme accounts for a cumulative expenditure in excess of €1 billion, but it is estimated that more than €2.7 billion has been generated in service revenues and about €3 billion in industry turnover.

OTS was the first-ever Ku-band satellite with 3-axis stabilisation, a concept that has since become the standard for telecommunications satellites worldwide. Some 30 satellites built in Europe were derived from the original OTS design.

ESA's second technology demonstration mission, Olympus, began in 1989. Its four advanced payloads helped to push back the frontiers of new telecommunications services such as direct-to-home TV, business networks, narrowcasting and videoconferencing.

ESA continues to help European industry gain a foothold in the market for second-generation satellite systems for personal and mobile communications. The new generation of European services will be tested by ESA's Artemis satellite, designed to perform three specific functions:

- provide voice and data communications between mobile terminals, mainly on cars, trucks, trains and boats;
- broadcast accurate navigation information as an element of the European Geostationary Navigation Overlay Service (EGNOS), designed to augment the US Global Positioning System (GPS) and the similar Glonass Russian system. The combined use of GPS positioning data and the pan-European mobile communications capabilities of Artemis will offer more efficient transport management;
- provide high-rate data links directly between satellites, putting Europe in a stronger position to reap the benefits of its investment in Earth observation from space by bringing data directly to the user where it is needed most.

Artemis is designed to demonstrate new technologies such as mobile communications and inter-satellite laser links.

ESA and Navigation

For the first time, the Agency has taken a lead role in the navigation segment. ESA and the European Commission have joined forces to design and develop Europe's own satellite navigation system, Galileo. Whereas GPS and Glonass were developed for military purposes, the civil Galileo will offer a guaranteed service. It will be interoperable with GPS and Glonass, so that a receiver can use any satellite in any system. However, Galileo will deliver positioning accuracy down to 5 m, which is unprecedented for a public system.

The EC, ESA and private industry are expected to meet the €3250 million estimated cost of Galileo through a public/private partnership. Early studies suggest that Galileo will repay its initial investment handsomely, estimating that equipment sales and value-added services will earn €90 billion over 20 years.

The fully-fledged service will be operating by 2008 when 30 Galileo satellites are in position in circular orbits 24 000 km above the Earth. The first will be launched in 2004 and by 2006 sufficient should be in place to begin an initial service. Development is planned to begin at the end of 2001, with a formal decision by the end of 2003 on deployment of the full constellation.

Europe's first venture into satellite navigation is EGNOS, a system to improve the reliability of GPS and Glonass to the point where they can be used for safety-critical applications, such as landing aircraft. Working in close cooperation with the EC and the European Organisation for the Safety of Air Navigation (Eurocontrol), ESA will have EGNOS operational in early 2004 using payloads on Artemis and two Inmarsat-3 satellites working with a network of ground stations to increase navigation receiver accuracy (5 m instead of 20 m) and reliability.

The first Galileo navigation satellite is expected to be launched in 2004

Ariane-5 entered commercial service in 1999 as Europe's new heavy-lift launcher. (ESA/CNES/CSG)

ESA and Launchers

Through the Ariane launcher programme, ESA has provided Europe with autonomous access to space – the strategic key to the development of all space applications. Moreover, having been developed initially for the sake of European independence, the Ariane launcher has become Europe's most spectacular commercial space success by virtue of the volume of business and the share of the world market it has achieved. It is one of the most important factors in Europe's credibility as a space power.

The space ministers of 10 countries decided in Brussels in July 1973 to develop a competitive satellite launch vehicle that would capture a significant share of the expected market for launching applications satellites. ESA is responsible as design authority for Ariane development work, owning all the assets produced. It entrusts technical direction and financial management to the French space agency, CNES. Arianespace was established by CNES in 1980 to contract, manage production, finance, market and conduct the launches.

Everyone agrees that Ariane is a resounding technical and commercial success. In 1998 alone, the profit reported by Arianespace was €12.6 million on revenues of €1.07 billion from 11 launches involving 14 satellites. Taxpayers' investment of €6 billion between 1974-2000 has been handsomely rewarded by the more than €18 billion generated by launch contracts.

Beginning with the first launch in December 1979, there were 129 launches by the end of 2000, successfully delivering 178 main satellites and 25 auxiliary payloads. The 1.85 t capacity into geostationary transfer orbit (GTO) by the initial Ariane-1 model has grown into more than 4.95 t for the current Ariane-4.

A total of 144 vehicles is planned before the radically new Ariane-5 completely assumes the mantle of Europe's main launcher in 2003. The ESA Ministerial Council meeting in November 1987 endorsed the development of this first European heavy-lift launch vehicle. Although Ariane-1 to -4 have been outstandingly successful, it was clear that a larger vehicle would be required to handle the ever-growing telecommunications satellites dominating the payload market. Ariane-5's goal is to reduce the payload cost/kg by more than 40%.

The maiden launch, in June 1996, was unsuccessful, but two further

The current ESA launch vehicle family of Ariane-4 (left) and Ariane-5 (centre) will be joined in 2005 by Vega (right). Studies are underway on the next-generation launcher (front). (ESA/R. Roussel)

launches by the end of 1998 proved the vehicle's capabilities. Ariane-5 is now in the hands of Arianespace for commercial exploitation. But the market does not stand still and the current target capacity of 5.97 t into GTO will soon be unable to handle paired satellites – essential for profitability. The October 1995 ESA Ministerial Council meeting therefore approved the Ariane-5 Evolution programme to expand capacity to 7.4 t, now expected by mid-2002. But even that is insufficient to satisfy the market. ESA's Council in June 1998 approved the Ariane-5 Plus programme that will offer 12 t into GTO from 2006 using a new, large cryogenic upper stage.

At the end of 2000, ESA approved the development of the Vega solid-propellant launcher for smaller payloads – up to 1.5 t into a 700 km polar orbit from the Ariane launch base at Kourou, French Guiana. The cost to users will be held to $20 million (15% lower than equivalent US vehicles) by synergy with Ariane-5 production and operations. First launch is planned for the end of 2005.

To prepare for the next generation of launcher after Ariane-5, to drastically reduce the cost of access to space, ESA is carrying out a technology programme to prepare the best options for decisions on major developments around 2006. The FESTIP Future European Space Transportation Investigation Programme studied several concepts from 1994 to 2000, with more than 30 companies pooling their efforts towards the goal of a Reusable Launch Vehucle (RLV) capable of placing 7 t into a low equatorial orbit and 2 t into polar. This was equivalent to 4 t in geostationary orbit – now clearly well short of today's market needs as satellites grow larger, showing how difficult a game market prediction can be. So the current FLTP Future Launchers Technologies Programme, approved at the May 1999 Ministerial Council, upped the target to 10 t to LEO. A follow-on programme worth about €600 million will be requested at the November 2001 Ministerial Council, to run from 2002 to 2006, with the first experimental vehicle flying in about 2005. By then, it should be clear if there are genuine market prospects for an RLV. The goal is to have an operational vehicle by about 2015.

The Columbus laboratory (front left) is a key element of the International Space Station research facilities. ESA is also developing the Automated Transfer Vehicle (docking at rear), the ERA robot arm (on the vertical tower), two Nodes and, in partnership with NASA, the Crew Return Vehicle. (ESA/D. Ducros)

ESA and Manned Spaceflight

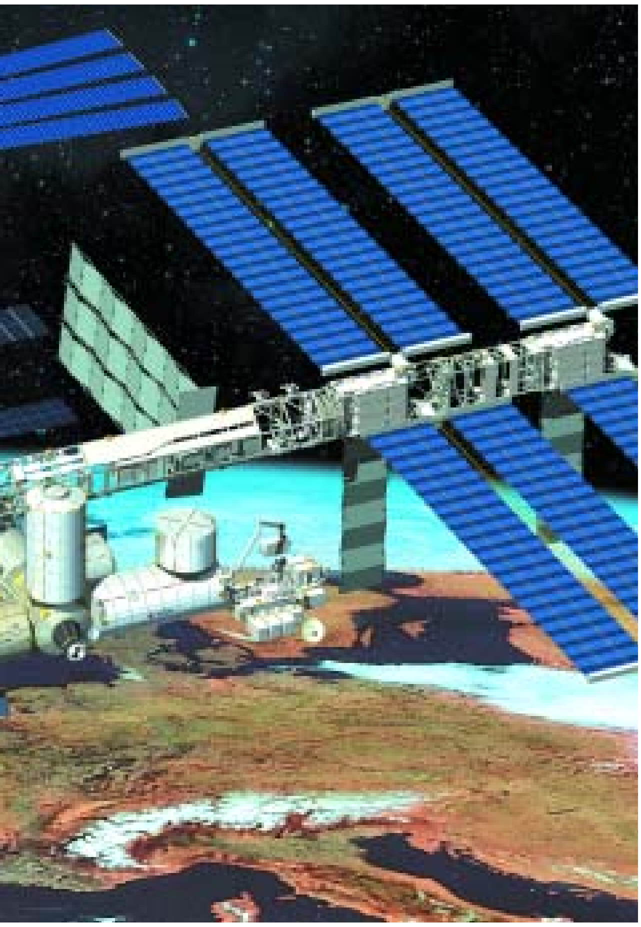
European involvement in manned spaceflight stretches back to 1969, when NASA issued an invitation to participate in the post-Apollo programme. Europe opted in December 1972 to develop the modular Spacelab as an integral element of the Space Shuttle. Spacelab's 22 missions between November 1983 and April 1998 made outstanding contributions to astronomy, life sciences, atmospheric physics, Earth observation and materials science.

Spacelab's debut also saw the first ESA astronaut, Ulf Merbold, venturing into space. By the end of 2000, ESA astronauts had made a total of 17 flights, comprising 14 aboard the Space Shuttle and three long-duration stays aboard Russia's Mir space station. The Agency's first three astronauts were selected in 1977, six were added in 1992 and in 1998 a Single European Astronaut Corps was formed, creating a cadre of 16 astronauts by 2000.

Some 44 ESA astronaut missions have been identified for 1998-2013 and most, of course, will involve the International Space Station. This largest-ever international cooperation is an unprecedented opportunity for the whole of mankind. For the first time, more than 40 years after the dawn of the Space Age, scientists and engineers will maintain a permanent international presence in space. While orbiting at an average altitude of 400 km, they will continuously perform scientific and technological tests using laboratories comparable with the best on Earth. The Station will be a research base like those built in the Antarctic or on the ocean floor, but it uniquely involves five international Partners (USA, Europe, Japan, Russia and Canada) and embraces almost all fields of science and technology.

Physicists, engineers, technicians, physicians and biologists will work together pursuing fundamental research and seeking commercially-oriented applications. Research will extend far beyond basic goals such as puzzling over the mysteries of life: the Station will be a test centre for developing innovative technologies and processes, speeding their introduction into all areas of our lives.

Despite significant budget reductions in space activities, Europe in March 1995 committed itself to full partnership in the International Space Station and to providing elements on a very strict schedule. This major multi-year investment immediately boosted Europe's aerospace industry, hard hit since the late 1980s by budget cuts in defence and aviation. Opting for this new space policy ensured that established teams of engineers and



ESA astronaut missions*		
Astronaut	*Launch date*	*Mission*
Ulf Merbold	November 1983	STS-9/Spacelab-1
Wubbo Ockels	October 1985	STS-22/Spacelab-D1
Ulf Merbold	January 1992	STS-42/Spacelab IML-1
Claude Nicollier	July 1992	STS-46/TSS-1 + Eureca-1
Claude Nicollier	December 1993	STS-61/Hubble servicing
Ulf Merbold	October 1994	Euromir-94
J.-F. Clervoy	November 1994	STS-66/Atlas-3
Thomas Reiter	September 1995	Euromir-95
Maurizio Cheli	February 1996	STS-75/TSS-1R
Claude Nicollier	February 1996	STS-75/TSS-1R
J.-F. Clervoy	May 1997	STS-84/Mir
Pedro Duque	October 1998	STS-95
J.-P. Haigneré*	February 1999	Perseus/Mir
Claude Nicollier	December 1999	STS-103/Hubble servicing
J.-F. Clervoy	December 1999	STS-103/Hubble servicing
Gerhard Thiele*	February 2000	STS-99/SRTM
Umberto Guidoni*	April 2001	STS-100/ISS + MPLM
Planned		
Claudie Haigneré*	October 2001	Soyuz-TM33/ISS
Roberto Vittori	April 2002	Soyuz-TMA1/ISS
Frank De Winne	April 2003	Soyuz/ISS

**mission flown under national agency*

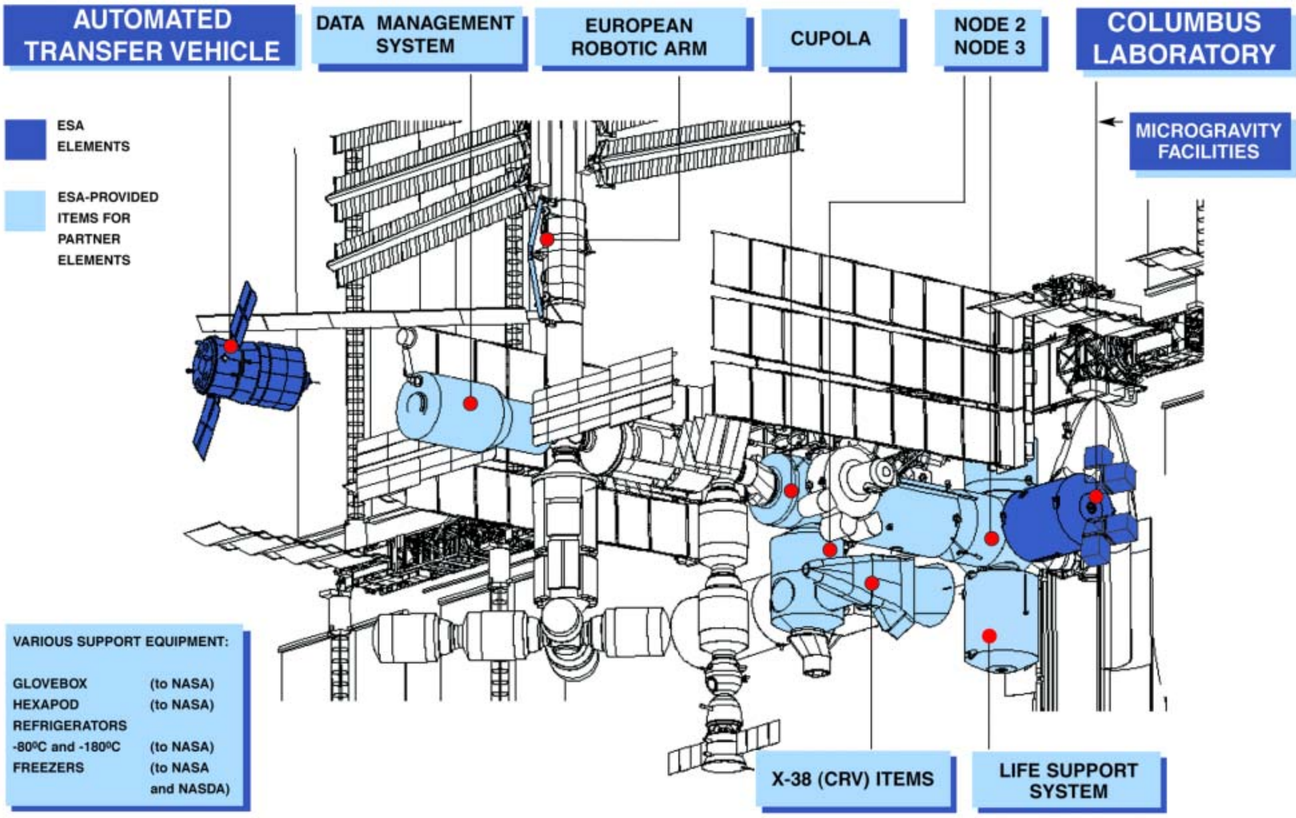
The ESA Astronaut Corps, May 2000. From left, front: Eyharts, Thiele, C. Haigneré, Guidoni, Ewald; second row: Duque, Nicollier, Tognini, Fuglesang, Clervoy, Vittori; back: Kuipers, Schlegel, De Winne, Reiter.

scientists could remain intact, assuring the future of European high technology.

Fully assembled, the International Space Station will total about 420 t in orbit and offer 1200 m^3 of habitable volume – equivalent to the passenger cabin of two Airbus aircraft. With a length of 108 m, span of 80 m and vast solar panels, it will shelter a permanent crew of three astronauts during the assembly phase and 6-7 once it becomes fully operational in about 2007. There will be six laboratories, including Europe’s Columbus. Italy may provide a habitation module to succeed the early Russian Zvezda module’s crew living quarters. There will be European, Japanese and Russian research modules, all maintained with Earth-like atmospheres. Additional research facilities will be available in the connecting Nodes. The central 90 m ‘truss’ girder connecting the modules and the main solar power arrays will also carry Canada’s 17 m-long robotic arm on a mobile base to perform assembly and maintenance work. An emergency descent vehicle – initially a Russian Soyuz and later a Crew Return Vehicle (CRV) developed with ESA involvement – will always be attached now that permanent habitation has been underway since 2000.

ESA’s major contribution to the Station is the Columbus laboratory. Columbus provides Europe with the possibility for continuous exploitation of an orbital facility. In this

ESA CONTRIBUTIONS TO THE INTERNATIONAL SPACE STATION



ESA's principal contributions to the International Space Station.

pressurised laboratory, European astronauts and their international counterparts can work in a comfortable shirtsleeve environment. This state-of-the-art workplace, launched in late 2004, will support the most sophisticated research in weightlessness for at least 10 years. Columbus is a general-purpose laboratory, accommodating astronauts and experiments studying life sciences, materials science, technology development, fluid sciences, fundamental physics, biology and other disciplines.

In combination with the Ariane-5 launcher, the Automated Transfer Vehicle (ATV) will enable Europe to transport supplies to the International Space Station. Its 7.4 t payload will include scientific equipment, general supplies, water, oxygen and propellant. Up to 4 t can be propellant for ATV's own engines to reboost the Station at regular intervals to combat atmospheric drag. Up to 860 kg of refuelling propellant can be transferred for Station attitude and orbit control. Up to 5.5 t of dry cargo can be carried in the pressurised compartment.

ATV offers about four times the payload capability of Russia's Progress ferry. Without ATV, only Progress could reboost the Station. Both technically and politically, it is essential that the Station can call on at least two independent systems.

An ATV will be launched on average every 15 months, paying Europe's 8.3% contribution in kind to the Station's common operating costs. It can remain docked for up to 6 months, during which time it will be loaded with Station waste before undocking and flying into Earth's atmosphere to burn up.

Another major ESA contribution to the Station is the European Robotic Arm (ERA). Mounted on the Russian Segment's Science and Power Platform (SPP), the 11.4 m-long ERA manipulator arm will be launched with the SPP by the Space Shuttle, possibly in 2005. Once installed, it will be used for SPP's in-orbit

ESA's Automated Transfer Vehicle will deliver 7.4 t of supplies to the International Space Station on each mission. (ESA/D. Ducros)

assembly – particularly the solar array – and be available for in-orbit maintenance tasks and support of extravehicular activities.

As part of the barter agreement with NASA for launching Columbus aboard the Space Shuttle, ESA is providing two of the Station's three Nodes, the connecting elements between various laboratory and habitation modules. ESA has entrusted responsibility for the development of Nodes-2 and -3, which use the same structural concept as Columbus, to the Italian Space Agency (ASI).

In a highly successful partnership, NASA, ESA and European industry are building the X-38 spacecraft, the prototype of the Crew Return Vehicle (CRV) for the International Space Station. Once attached to the Station in about 2007, the CRV will provide a route home for the crew at short notice. ESA is responsible for 15 X-38 subsystems or major elements. Subscriptions by ESA Member States to the CRV programme will allow significant participation in the development and production of this next manned spacecraft. The X-38 test programme will culminate in 2003 with a return from orbit.

Major experiment facilities being developed by ESA include Biolab, the Fluid Science Laboratory, the Material Science Laboratory and the European Physiology Modules. ESA is also supplying –180°C and –80°C freezers for storing biological samples, the Microgravity Science Glovebox, and the 6-degrees-of-freedom Hexapod positioning and pointing unit for external payloads. ESA is also providing the Cupola – a domed element with windows for the crew to control and directly view remote manipulator operations – in exchange for Shuttle launch/return services for five European external payloads.

ESA's philosophy in all of these barter arrangements is to pay in kind for services and responsibilities rather than through hard cash. Once Columbus is operational, ESA will have the right, on average, for a 3-month stay aboard the Station by an astronaut every 8 months.

Further information about ESA's contributions to the International Space Station, and its other manned spaceflight activities, can be found at *http://www.esa.int/export/esaHS*