Science

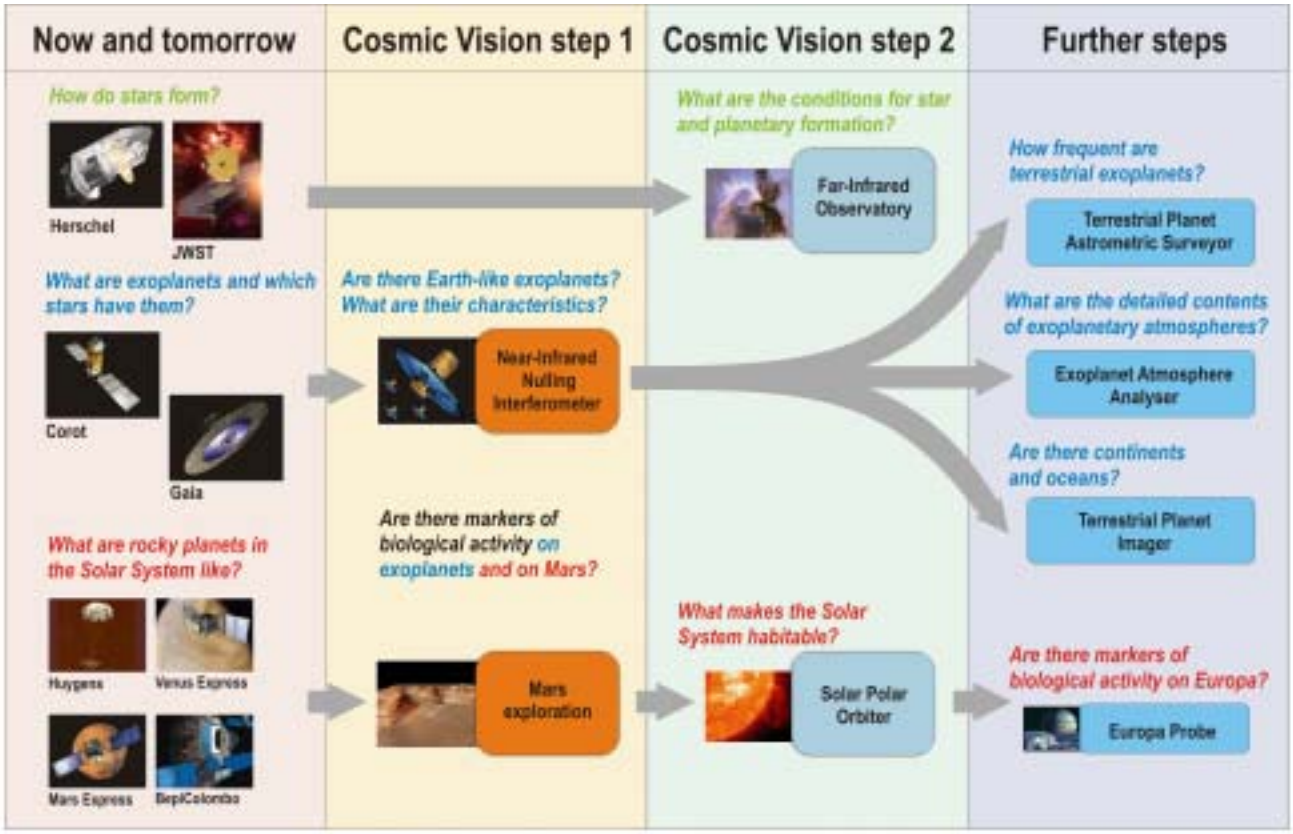
Planning for the Future – 'Cosmic Vision'

The Horizon 2000 Long-Term Plan for Space Science, formulated more than 20 years ago (1984), is almost completed. Its successor, Horizon 2000+, approved 10 years ago, is now coming to fruition, with a wealth of scientific satellites and space telescopes in orbit, producing excellent results. There is a need now to look ahead, building upon a solid past and working today to overcome the scientific, intellectual and technological challenges of tomorrow. 'Cosmic Vision', ESA's long-term scientific programme, is based on a vision built upon strong pragmatism and consolidated, proven ability. It is the starting point for the advancement of space science in a contemporary context. To ultimately explore our Universe, its mysteries and laws, and to advance our understanding of nature, this vision has to capitalise on:

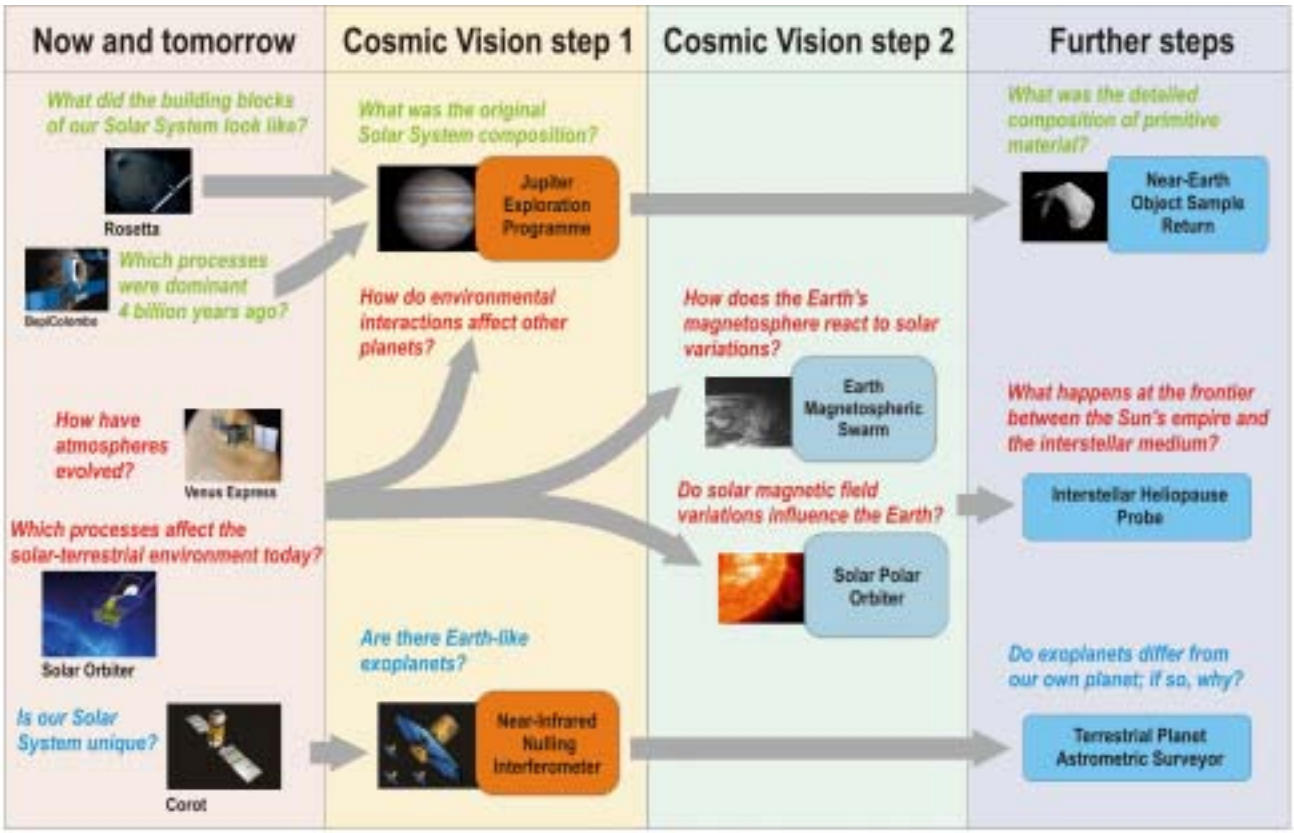
- current scientific challenges
- prevailing priorities in space research
- available knowhow, resources and technological investment aimed at maximum scientific return
- maintenance of European industrial and technological competitiveness
- consolidation of ESA's ability in worldwide space science.

Based on the massive response from the European scientific community and the priorities set by the scientific advisory structure, in May the Agency's Science Programme Committee (SPC) endorsed 'Cosmic Vision Space Science for Europe 2015 to 2025'. This plan identifies today's major scientific questions to be addressed by ESA's future space-science missions (see accompanying panels).

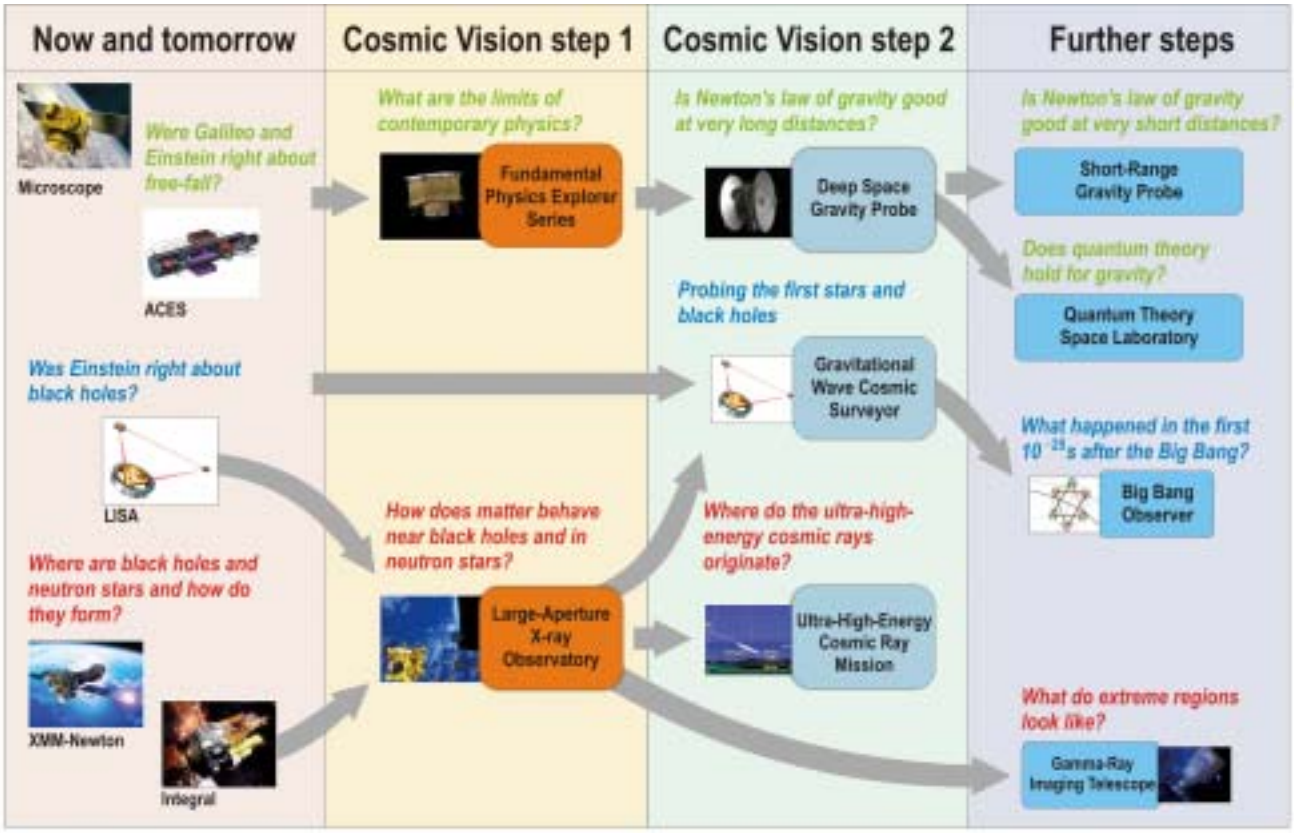
1. What are the conditions for planetary formation and the emergence of life? – Possible strategies



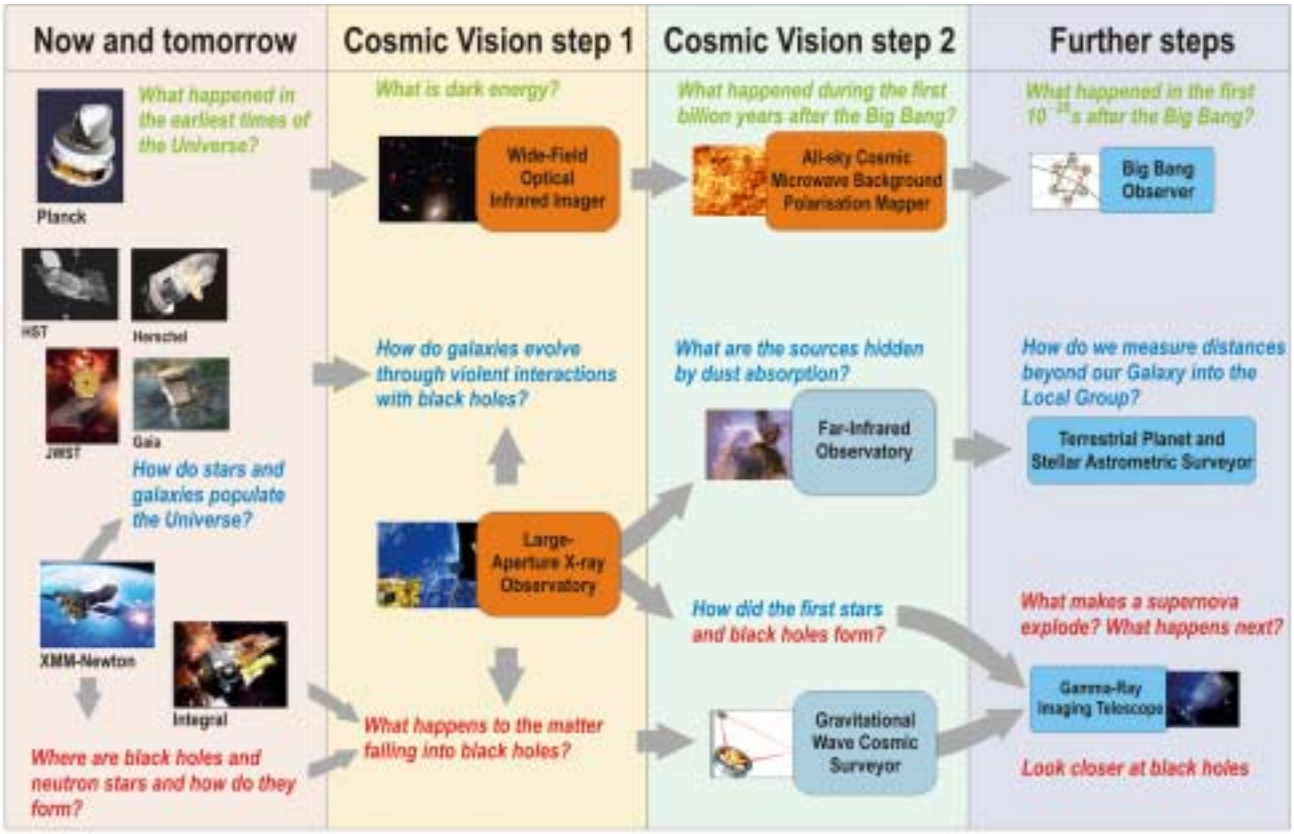
2. How does the Solar System work? – Possible strategies



3. What are the fundamental physical laws of the Universe? – Possible strategies



4. How did the Universe originate and what is it made of? – Possible strategies



Highlights of the Science Programme in 2005

For the Science Programme, the year started with one of the most publicly visible achievements to date – the successful landing on 14 January of ESA's Huygens probe on the surface of Titan. This is the only landing that has taken place in the outer Solar System, and the furthest from Earth, in the history of Solar System exploration.

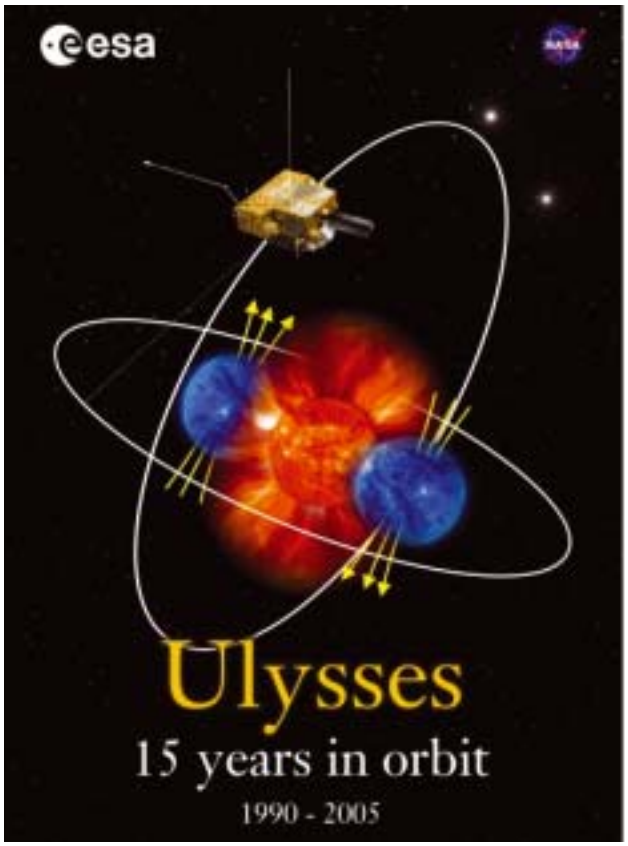
This was, however, only the first great achievement in a resoundingly successful year, which included the launch of Venus Express, the first results from the Mars Express MARSIS probe, and the Ministerial Council in Berlin, which reversed the trend of the previous 10 years by giving the Science Programme what it had requested in terms of funding.

The success of the Science Programme is rooted in a number of unique features:

- Its long-term planning approach initiated in the mid-eighties (Horizon 2000 followed by Cosmic Vision 2020): this has allowed the formulation of a plan with a mix of flagship missions (so-called 'Cornerstones') giving stability and credibility to the Programme, and a set of medium or smaller sized missions to provide planning flexibility.
- Its user-driven character: the Programme's content is determined by the European space-science community to serve their needs, a mechanism that has forged a strong reciprocal link between the users and the Agency.
- Its role as a technology driver: the highly ambitious missions of the Science Programme have always been a driver of new technology developments, which have led to spin-offs in other space areas.

Given its mandatory nature, which provides continuity and credibility and its long-term vision, technological challenges and world-class success, the Science Programme can be justifiably described as the backbone of the Agency. Approximately 3000 space scientists across Europe recognise the ESA Space Programme as their own, and also as the reference for their national programmes.

The Programme currently manages a fleet of 16 satellites.



A poster designed to celebrate the 15th anniversary of the Ulysses mission

Missions in Operation or in an Archival Phase

Ulysses

Launched: 6 October 1990

Ulysses was the first spacecraft ever to be placed in a polar orbit around the Sun. From this unique 'out-of-ecliptic' vantage point covering all solar latitudes, Ulysses is studying in-situ previously unexplored regions of space, such as those above the Sun's poles. It is providing the first four-dimensional survey (three spatial dimensions plus time) of the 'solar wind'. In 2005, Ulysses provided key observations of the unusually high solar activity in January and September from a perspective unavailable to any other space mission. At the same time, its instruments provided further insight into the nature of the outermost regions of the heliosphere. Because of its wide-ranging scientific impact, Ulysses remains a keystone in the 'Great Observatory', the international fleet of spacecraft currently observing the Sun and heliosphere. Since its launch in 1990, Ulysses has already travelled seven thousand million kilometres.

Glowing like a multi-facetted jewel, the planetary nebula IC 418 lies about 2000 light years from Earth in the constellation Lepus. In this image, the Hubble Space Telescope reveals some remarkable textures weaving through the nebula. Their origin, however, is still uncertain (Credit: NASA/ESA and the Hubble Heritage Team STScI/Aura)

Hubble Space Telescope

Launched: 24 April 1990

During 15 years of viewing the sky, Hubble has taken more than 700 000 exposures of more than 22 000 celestial objects. The spacecraft itself has circled the Earth nearly 88 000 times, travelling more than 4000 million kilometres. It generates about 15 gigabytes of data every day, and has already delivered 23 terabytes of data. Nearly 4000 astronomers from all over the World have used the telescope to produce a long list of scientific achievements, including:

- calculating the precise age of the Universe to be 13 700 million years
- confirming the existence of dark energy
- detecting small 'proto-galaxies' that emitted their light when the Universe was less than a 1000 million years old
- proving the existence of 'super-massive' black holes
- seeing a comet hitting Jupiter
- showing that the process of forming planetary systems is common throughout the galaxy.

SOHO

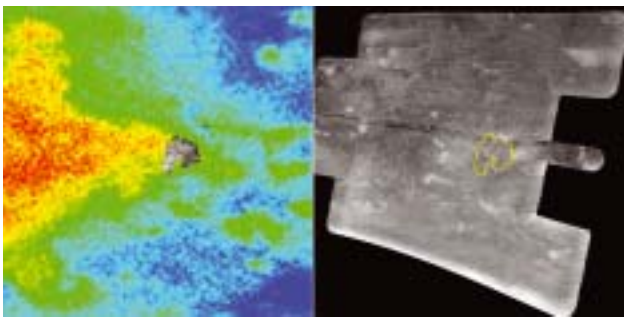
Launched: 2 December 1995

Originally planned to have a lifetime of just two years, SOHO's operations are set to continue until at least 2007, and this despite the spacecraft having been almost lost on three separate occasions. More than 3200 scientists around the World have been involved with the mission. Apart from unmasking the Sun and teaching us how it works, SOHO's images provide early warning of storms in space that can affect astronauts, spacecraft, and power and communication systems on Earth. In August, SOHO achieved a remarkable milestone with the discovery of its 1000th comet.

Cassini-Huygens

Launched: 15 October 1997

The route taken by the mission after its launch involved fly-bys of Venus, Earth and Jupiter to help give it the necessary energy to reach Saturn. On 14 January 2005, ESA's Huygens probe landed on the surface of Titan, the only landing to take place in the outer Solar System, and the furthest from Earth, in the history of Solar System exploration. The probe showed that Titan's surface exhibits Earth-like processes and morphology, complete with evidence of methane rain, erosion, stream-like drainage channels and dry lake beds.

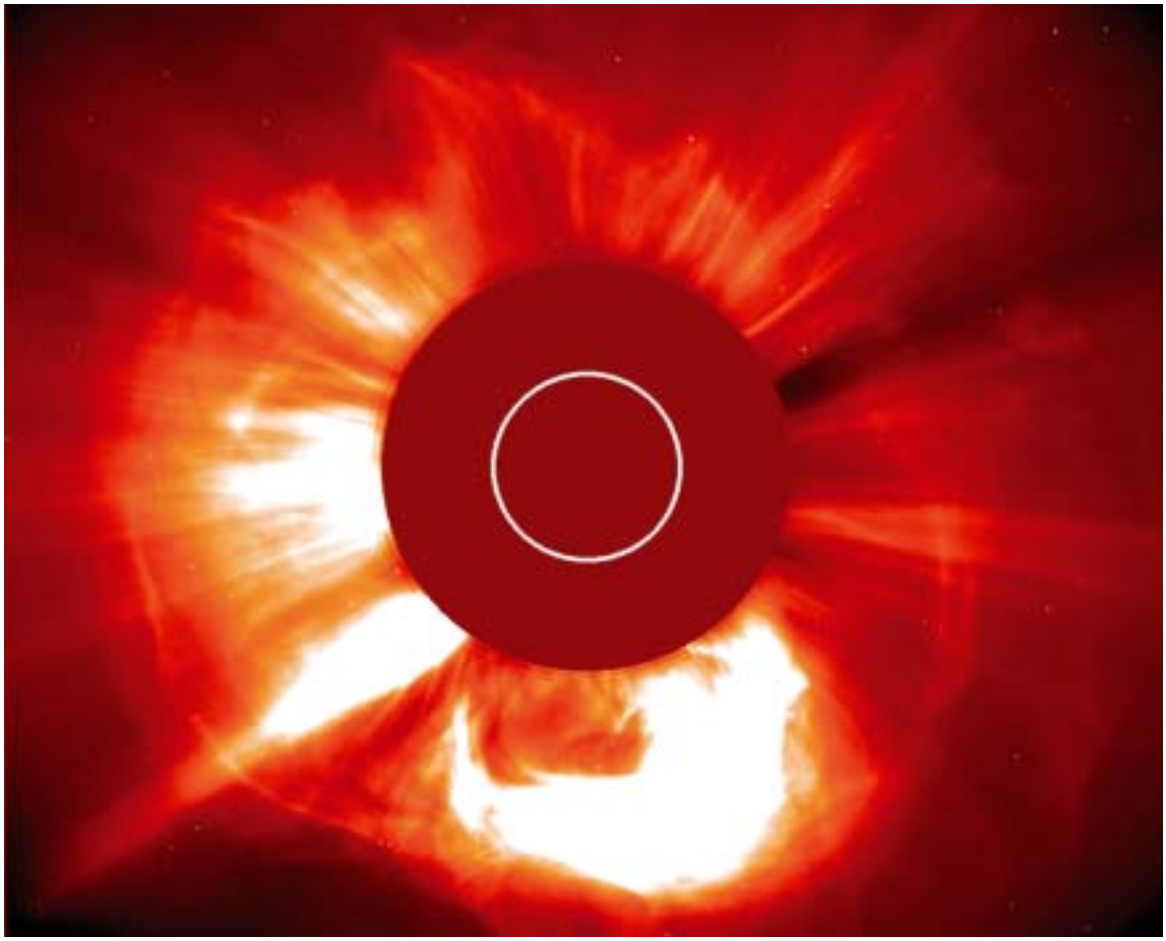


Infrared and radio images of the Huygens landing site, taken by Cassini on 28 October (Copyright: NASA/JPL/Univ. of Arizona/Space Science Institute)

XMM-Newton

Launched: 10 December 1999

The XMM-Newton mission has been routinely providing



SOHO image of Coronal Mass Ejection

high-quality, high-impact science data since its launch, and its operations are currently approved to continue until end-March 2010.

The response to the Call for Observing Time (AO-5) resulted in 632 proposals, representing an over-subscription factor of 7.4. The upgrading of the XMM-Newton ground segment to SCOS 2000 was completed on schedule during the year. Almost 1000 papers based either completely or partially on XMM-Newton observations had been published in the refereed literature by end-2005.

Cluster

Launched: 16 July and 9 August 2000

A Cluster and Double Star Symposium held at ESTEC in September, celebrating the fifth anniversary of Cluster in space, was attended by more than 150 international scientists. During this meeting the Cluster Active Archive was officially opened for beta-testing. The depository of processed and validated high-resolution Cluster data will be a major contribution by ESA and the Cluster science community to the International 'Living with a Star' programme. The ability of magnetic storms to create 'killer' electrons, responsible for damaging spacecraft and posing a serious hazard for astronauts, was reported in the journal *Nature*. For the first time, the currents in the Earth's radiation belts could be directly measured using the unique multi-point measuring capability of Cluster. In July, the four spacecraft underwent a series of manoeuvres (the most complex ever conducted by ESA) to make Cluster the first multi-scale mission, facilitating the simultaneous multi-point investigation of kinetic and macroscopic-scale phenomena in the magnetosphere.

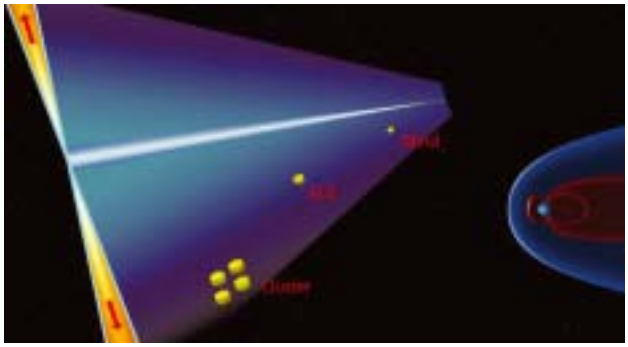
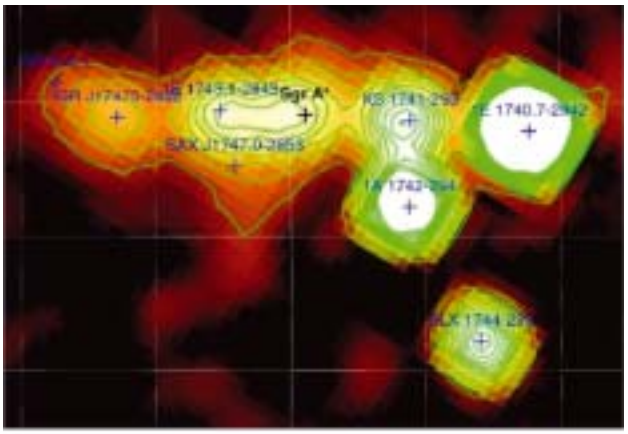


Illustration of the Cluster, ACE and WIND spacecraft observing the magnetic-reconnection region The directions of the plasma jets associated with the magnetic-reconnection process are represented by red arrows embedded in the flows
(Courtesy of Matt Davis and Tai Phan, SSL/UC Berkeley, USA)



An image of X-ray emission from the Galactic Centre taken in September by Integral (IBIS/ISGRI). The grid lines indicate galactic coordinates with a spacing of 0.5 degrees
(Credit: G. Bélanger et al./CEA Saclay)

Integral

Launched: 17 October 2002

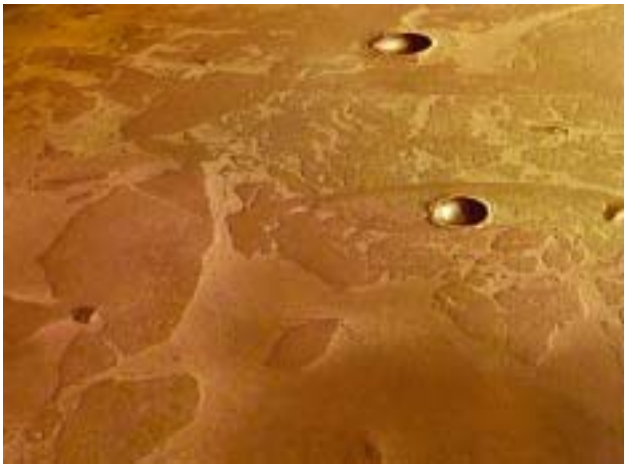
Integral's four instruments provide the possibility for the first time to carry out simultaneous, single-satellite observations at optical, X-ray and gamma-ray wavelengths of the most energetic objects and phenomena in the Universe. Integral thereby discovered a new class of highly-absorbed or 'cocooned' X-ray binary stars, not seen by previous missions. It makes many 'Target of Opportunity' observations of transient sources, and one of the most interesting of these in 2005 was of a new source IGR J00291+5934, which turned out to be the fastest-rotating neutron star known – spinning almost 600 times a second.

Mars Express

Launched: 2 June 2003

The radar booms (dipole and monopole) of Mars Express's MARSIS instrument were deployed in May and June, following comprehensive simulations of boom deployment in order to mitigate potential risks to spacecraft stability. The most significant scientific achievements during the year were:

- Strong MARSIS radar echoes coming from both the surface and the subsurface of the planet, allowing the identification of buried craters and tectonic structures. Also, probing of the planet's ionosphere revealed a variety of echoes originating in surface areas magnetised in very early times.
- The OMEGA instrument discoveries have provided new insights into the evolution of the Martian surface, showing that alteration of primordial volcanic material into phyllosilicates early in Mars' history and into sulphates in more recent times occurred during



This image, taken by the High-Resolution Stereo Camera (HRSC) on Mars Express, shows what appears to be a dust-covered frozen sea (part of the Elysium Planitia) near the Martian equator
(Copyright: ESA/DLR/FU Berlin (G. Neukum))

This Mars Express image taken by the High Resolution Stereo Camera (HRSC) on 25 February shows ice and dust at the Martian north pole in a perspective view for the first time. The cliffs are almost 2 kilometres high, and the dark material in the caldera-like structures and dune fields could be volcanic ash
(Copyright: ESA/DLR/FU Berlin (G. Neukum))

two different water regimes (and thereby climates): abundant liquid water in a warmer climate followed by much more episodic and modest water outflows in a colder and drier climate.

- The SPICAM instrument detected an aurora on Mars related to paleomagnetism in the ancient crust.

SMART-1

Launched: 27 September 2003

The primary technology mission of SMART-1 was successfully completed in February and the mission then entered its scientific phase. In August, a reboost manoeuvre achieved the optimum orbit for the extended mission, during which the emphasis will be on push-broom imaging with the AMIE camera. This reboost manoeuvre consumed all remaining fuel and the electric-propulsion engine was shut down in September.

Rosetta

Launched: 2 March 2004

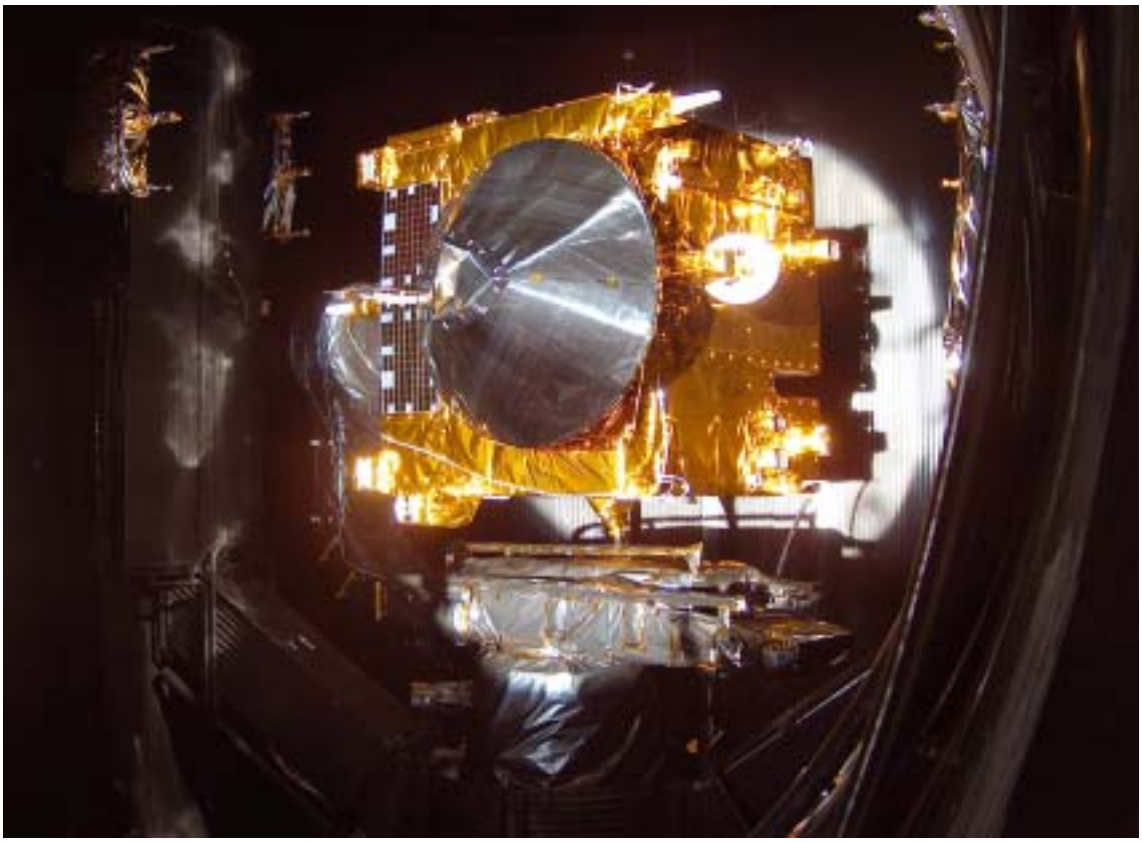
The Rosetta spacecraft performed its first Earth gravity-assist manoeuvre on 4 March, passing within 1954 km of the Earth's surface. Immediately after the closest approach, the asteroid-flyby scenario was tested using the Moon as a target. On 4 July, Rosetta participated in the campaign to monitor the Deep Impact encounter at comet Temple 1, which resulted in excellent data from the OSIRIS camera – the only instrument that could monitor the event continuously for a number of days. The spacecraft is now in a passive cruise phase on its way to Mars for its second gravity assist in February 2007.

Double Star

Launched: 29 December 2003/25 July 2004

Double Star is a landmark, being the first Chinese magnetospheric mission, and continues the collaboration between ESA and the Chinese National Space Administration. A paper based on unique Double Star and Cluster data was published in July, in which European scientists reported the first observational evidence of cracks in a neutron star crust during a star quake.

The Starsem Soyuz-Fregat launch on 9 November carrying Venus Express



The Venus Express spacecraft in the SIMLES thermal-vacuum chamber at Intespace in Toulouse (F)

Venus Express

Launched: 9 November 2005

Venus Express was successfully launched on 9 November from the Baikonur Cosmodrome in Kazakhstan on a Soyuz-Fregat rocket. The subsequent near-Earth commissioning phase proceeded smoothly and the entire spacecraft and payload complement was checked-out operationally before the end of December. The Venus Orbit Insertion manoeuvre is planned for 11 April 2006, to be followed by payload in-orbit commissioning and handover for nominal scientific operations by mid-2006.

Missions to be Launched in the Coming Years

COROT

Launch: Mid-October 2006

COROT is a small mission led by CNES with substantial contributions from the ESA Science Programme and several Member States, namely Austria, Belgium, Germany, Italy and Spain. Devoted to astero-seismology and planet finding, it is the third in the CNES series of missions based on the Proteus platform. It is slated for launch in mid-October 2006 by a Soyuz-Fregat from Baikonur. COROT is the first mission fully dedicated to accurate astero-seismic observations and the detection of extra-solar rocky planets, both of which require the stability and accuracy of space-based photometry.

Herschel-Planck

Launch: Early 2008

Practically all flight hardware for both satellites was completed, delivered and integrated during the year, and acceptance testing was started. With the spacecraft's development progressing well, the overall schedule is driven by the availability of the scientific payload, which has been experiencing some technical difficulties.

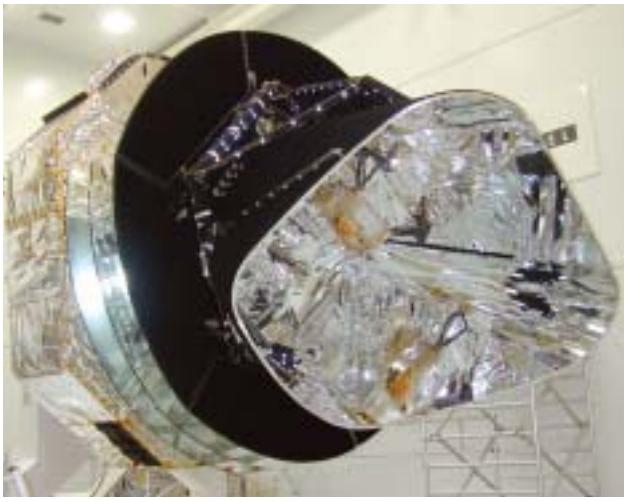
The testing of the Planck qualification model was completed during the year, and the service module was

delivered to the prime contractor Alcatel Alenia Space for system integration. The flight-model payload module was mated later in the year with the service module and the Planck spacecraft is being prepared for its first major environmental acceptance test in early-2006.

The structural model of the Herschel service module was delivered and integrated at the end of 2005 with the flight model of the payload module (the cryostat), to qualify the satellite for the expected mechanical launch loads. The thermal testing in the Large Space Simulator (LSS) facility at ESTEC has been completed.

The Herschel and Planck telescopes were fully assembled and aligned during the year.

The contract between ESA and Arianespace for the provision of the Ariane-5 ECA launcher has also been signed.



The Planck qualification model spacecraft

The Herschel structural and thermal qualification model spacecraft

Microscope

Launch: March 2009

The CNES/ESA scientific mission Microscope, for the measurement of the equivalence principle with extreme accuracy, is due to be launched in 2009 for a nominal duration of one year. ESA is providing the FEEP Electric Propulsion System (EPS) required to give the spacecraft a virtually pure drag-free environment. The EPS design and testing activities at thruster and subsystem level are progressing. An extended firing test concluded in May on the thruster core element accumulated a total impulse of 500 Ns, after 1650 hours of continuous operation. The complete thruster assembly was tested in November and showed very good performance.

LISA Pathfinder/SMART-2

Launch: 4th quarter 2009

LISA Pathfinder, the second of the Small Missions for Advanced Research and Technology (SMART-2), is dedicated to demonstrating key technological aspects of the Laser Interferometer Space Antenna (LISA), a spaceborne gravitational-wave detector mission to be undertaken jointly by ESA and NASA.

Artist's impression of the Gaia spacecraft

The spacecraft Preliminary Design Review was successfully completed in September and the procurement of all subsystems/equipment has been initiated. Development of the LISA Technology Package (LTP), the main experiment and hence the core of the mission, has started through several industrial and institutional procurements, involving seven national funding agencies (in CH, D, E, F, I, NL, UK) and ESA. The launch towards the Sun-Earth Lagrangian Point 1, by either a Vega or Eurockot launcher, is currently planned for the fourth quarter of 2009.

Gaia

Launch: December 2011

The two competitive definition-study phases came to a successful end in June, with the study contractors delivering their final presentations. Gaia requires a customised design and a very large number of CCDs. Therefore, to safeguard the December 2011 launch date, ESA placed the contract for the flight model's production in June, about nine months before the official kick-off of the Gaia implementation phase. Two companies, Astrium SAS and Alcatel Alenia Space, submitted their proposals for the development phase, and contractor selection will take place early in 2006.

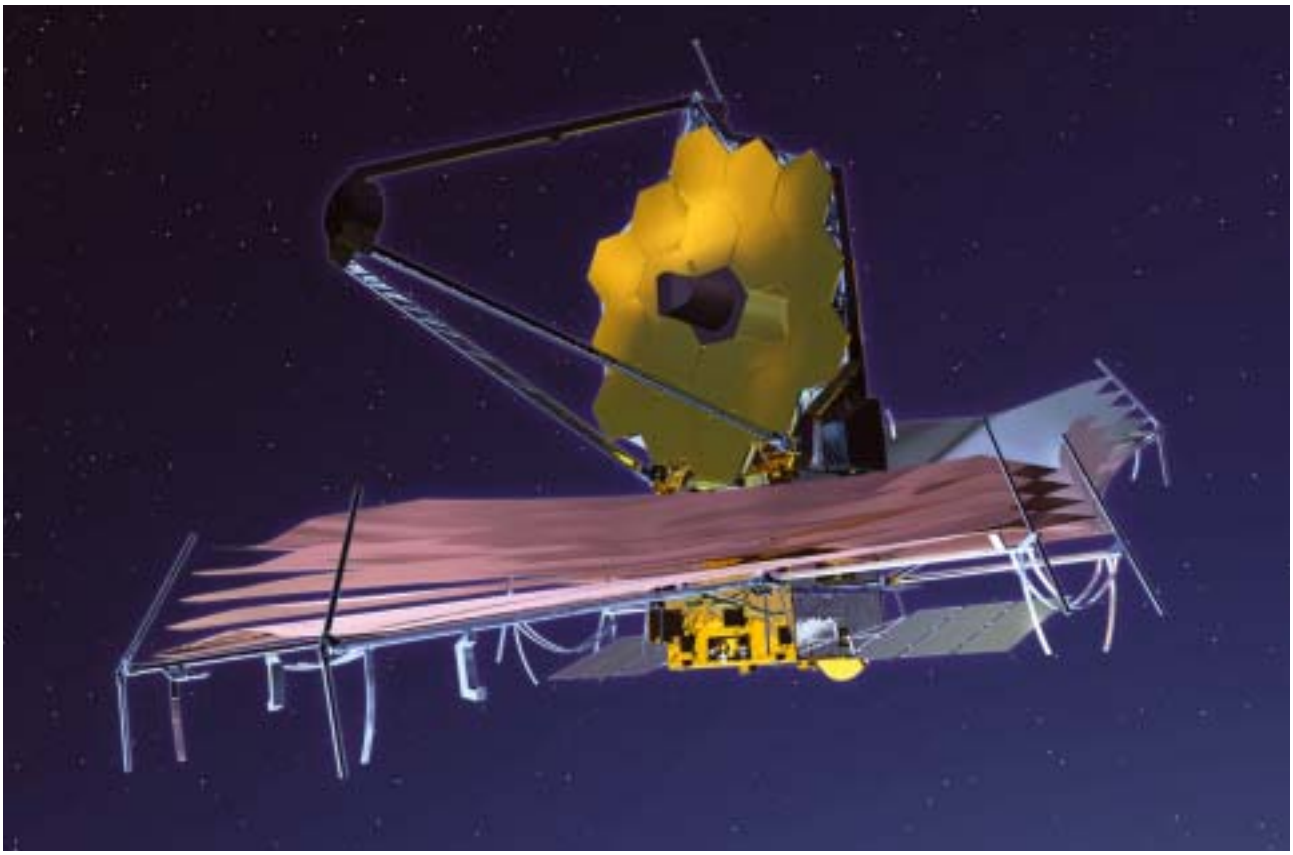
Two major activities were initiated in 2005, namely a competitive design activity on a cold-gas micro-propulsion system and the industrialisation of the proximity electronics for interfacing with more than one hundred CCDs.

Definition work on the Mission Operations Centre and the Scientific Operations Centre has begun, as well as the detailed work with the launch-service provider.

James Webb Space Telescope (JWST)

Launch: June 2013

Significant architectural design changes were made to recover the necessary margins, with cryo-coolers replacing the solid-hydrogen-based cryostat, and a bi-propellant



Artist's impression of JWST

system replacing the monopropellant propulsion system. Increased costs led to a substantial NASA review. Independent scientific and programmatic review panels confirmed that the mission design should remain unchanged in order to fulfil the intended science objectives, and that the increased cost was realistic. NASA subsequently introduced a launch delay of 22 months to accommodate the cost increase.

The MIRI instrument, developed by a European consortium of scientific institutes, successfully passed its Preliminary Design Review, and the structural thermal model completed its test campaign. The NIRSpec instrument procured directly under ESA's responsibility is presently at the Preliminary Design Review stage. NASA has made significant progress in the development of the micro-shutter chips used to isolate the target stars from the rest of the sky in the instrument field of view.

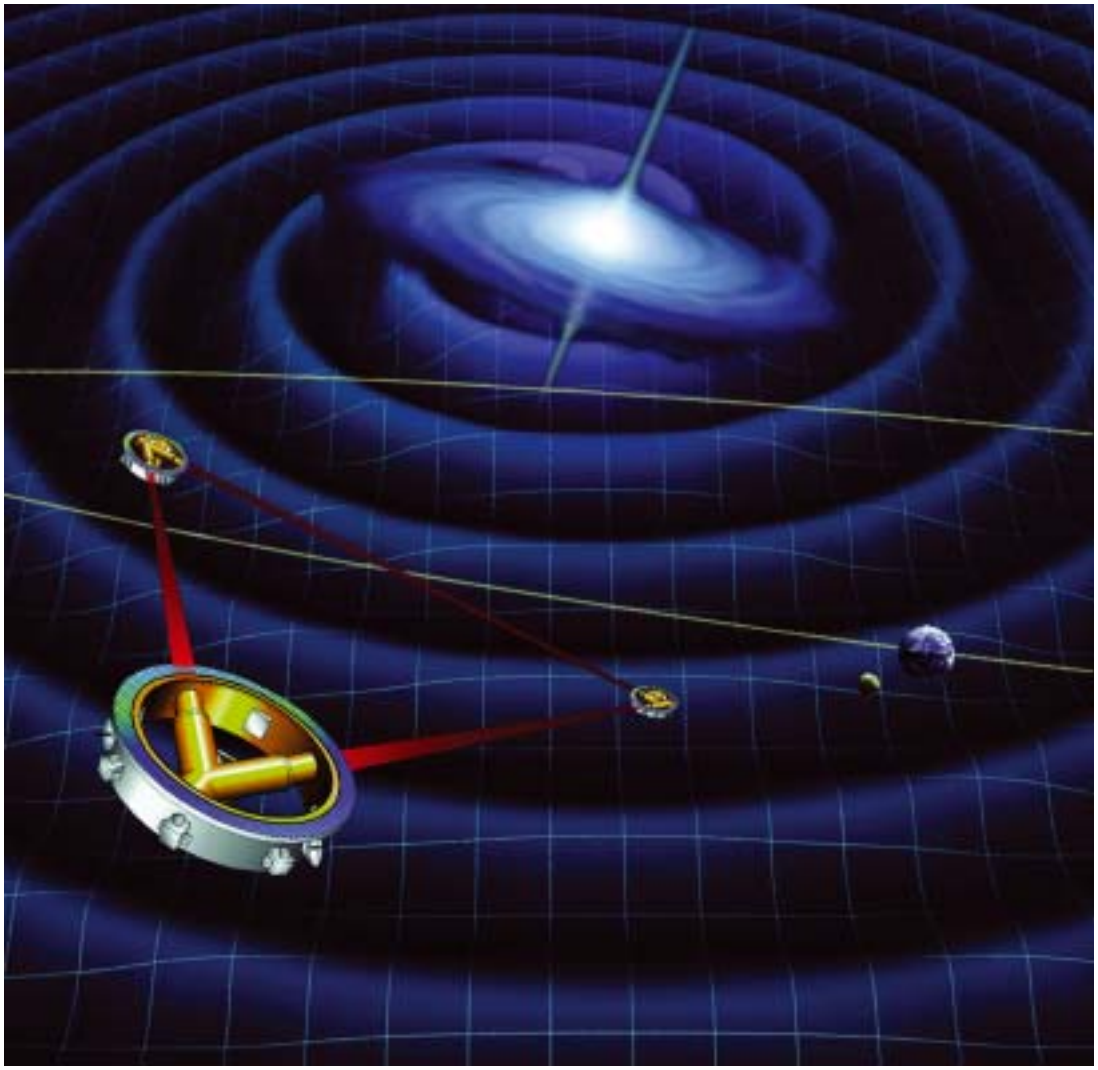
NASA has decided finally to launch JWST on an Ariane-5 ECA vehicle, with initial analyses having clearly demonstrated its compatibility.

BepiColombo

Launch: August 2013

BepiColombo is a collaborative ESA and JAXA (Japan Aerospace Exploration Agency) mission consisting of two scientific orbiters: the Mercury Planetary Orbiter to be provided by ESA, and the Mercury Magnetospheric Orbiter to be provided by JAXA. A Soyuz-Fregat launch in August 2013 is foreseen, leading to spacecraft arrival at Mercury in August 2019. The intervening six-year cruise phase will be achieved through a combination of planetary fly-bys and solar electric propulsion.

JAXA have formally started the Phase-B for the Mercury Magnetospheric Orbiter, with the funding secured in the governmental budget. An extension to the Letter of Agreement between ESA and JAXA is being signed and a joint Memorandum of Understanding is in preparation.



LISA, searching for gravitational waves

LISA

Launch: Mid-2015

The LISA mission, which involves flying three spacecraft separated by 5 million kilometres, is designed to detect the 'ripples' in space-time produced by massive objects such as black holes.

The LISA mission-formulation phase began in January with the kicking off of the industrial contract with Astrium GmbH. The Mission Architecture Review was successfully conducted in October. A Joint Project Management Office, co-led by the ESA and NASA Project Managers, is responsible for all decisions related to mission design, based on the proposals of the Mission System Engineering Managers Office, co-led by the ESA, GSFC and JPL System Engineering Managers. This system works very well and facilitated progress during the year with decisions regarding the consolidation of the mission baseline reference architecture.

Despite its Mandatory Programme status, the Science Programme has not been spared the stringencies in the Agency due to the current difficult economic situation. A major casualty has been the Cornerstone-mission philosophy, which was the basis on which the Horizon 2000 plan was built and through which Europe was brought to the forefront in world space science. Consequently, Gaia, LISA and BepiColombo, which were originally selected as Cornerstone missions, have had to be re-scaled to meet financial targets well below the level of a Cornerstone mission. Equally, the rate of launches is falling from 1 mission per year in the period 1998-2005, to about 1 every 2 years for the foreseeable future. Choices will have to be made in order to reconcile the conflicting demands for new missions and the requirements of missions that are already in the pipeline.

PRODEX/PECS

PRODEX is an optional Scientific Programme established to provide funding for the industrial development of scientific instruments or experiments proposed by Institutes or Universities, and selected by ESA for one of its research programmes in science, microgravity, Earth observation, etc.). The Agency provides both administrative and financial management knowhow and technical support. The countries currently participating in PRODEX are Switzerland, Belgium, Ireland, Austria, Norway and Denmark. The projects being developed range from small Earth-observation data-analysis programmes, to fully-fledged instruments for scientific payloads.

Major undertakings in 2005 included the industrial activities in the four PRODEX countries participating in the MIRI instrument for the James Webb Space Telescope (JWST), namely Belgium, Switzerland, Denmark and Ireland. The feasibility study of the Swiss contribution to the BELA instrument for the BepiColombo mission was also successfully completed.

Integration of the baffle and deployable cover on the COROT flight model (Courtesy of CSL)

At the ESA Ministerial Council in December, the way was cleared for the renewal of the PRODEX Declaration financial envelope for the period 2006-2010.

The PRODEX Office has also been entrusted with the setting up and implementation of the arrangements and management structure for the Plan for European Cooperating States (PECS). Hungary was the first Participating State in this programme, followed by the Czech Republic. Poland and Romania have now notified the Agency of their intention to join, and a first round of negotiations has been initiated.

PRODEX Experiments or Subsystems Finalised and/or Launched in 2005

HERSCHEL MISSION		
• HIFI instrument – various subsystems:		
- Common optics assembly, mixer assembly, intermediate amplifier IF2	A. Benz	Zurich (CH)
- Verification of optical design	A. Murphy	Maynooth (IRL)
• PACS instrument – various subsystems:		
- Cold Read-out Electronics subsystem (CRE), grating assembly	C. Waelkens	Leuven (B)
COROT		
. COROT instrument – various subsystems:		
- Baffle, cover	C. Jamar	Liège (B)
STEREO		
• PLASTIC	P. Wurz	Bern (CH)
• SECCHI		
- Heliospheric Imager (HI)	C. Jamar	Liège (B)
VENUS EXPRESS		
• SPICAV		
- Solar Occultation at Infrared (SOIR)	D. Nevejans	Brussels (B)
INTERNATIONAL SPACE STATION		
• SOVIM	C. Fröhlich & A. Joukoff	Davos (CH) Brussels (B)
• SOLSPEC	D. Gillotay	Brussels (B)
MASER-10		
• Interfacial Turbulence in Evaporating Liquids (ITEL)	P. Colinet	Brussels (B)
FOTON-M2		
• FLUIDPAC	J-C. Legros	Brussels (B)
• Soret Coefficients in Crude Oil (SCCO)	J-C. Legros	Brussels (B)
MAXUS-6		
• UNESTA material science experiment	L. Froyen	Leuven (B)