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bulletin

→ space for europe

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, Portugal, 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.

Chairman of the Council: M. Lucena

Director General: J.-J. Dordain

On cover:
ESA's XMM-Newton celebrates 10 years since its launch on the first commercial Ariane 5 on 10 December 1999. This year, the Ariane programme also celebrates its 30th anniversary.

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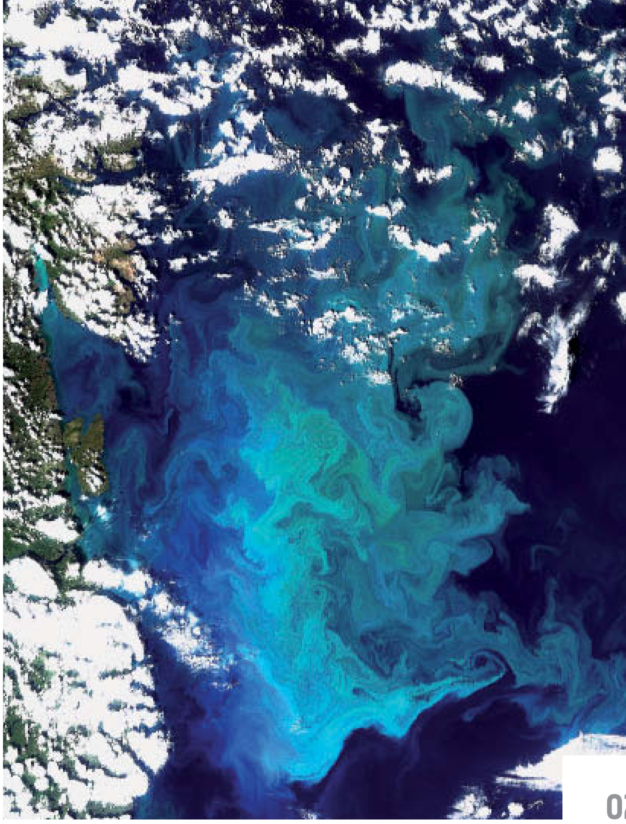

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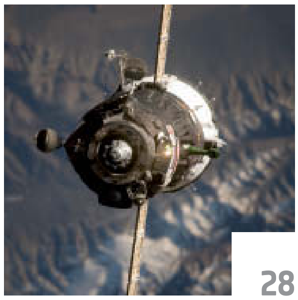

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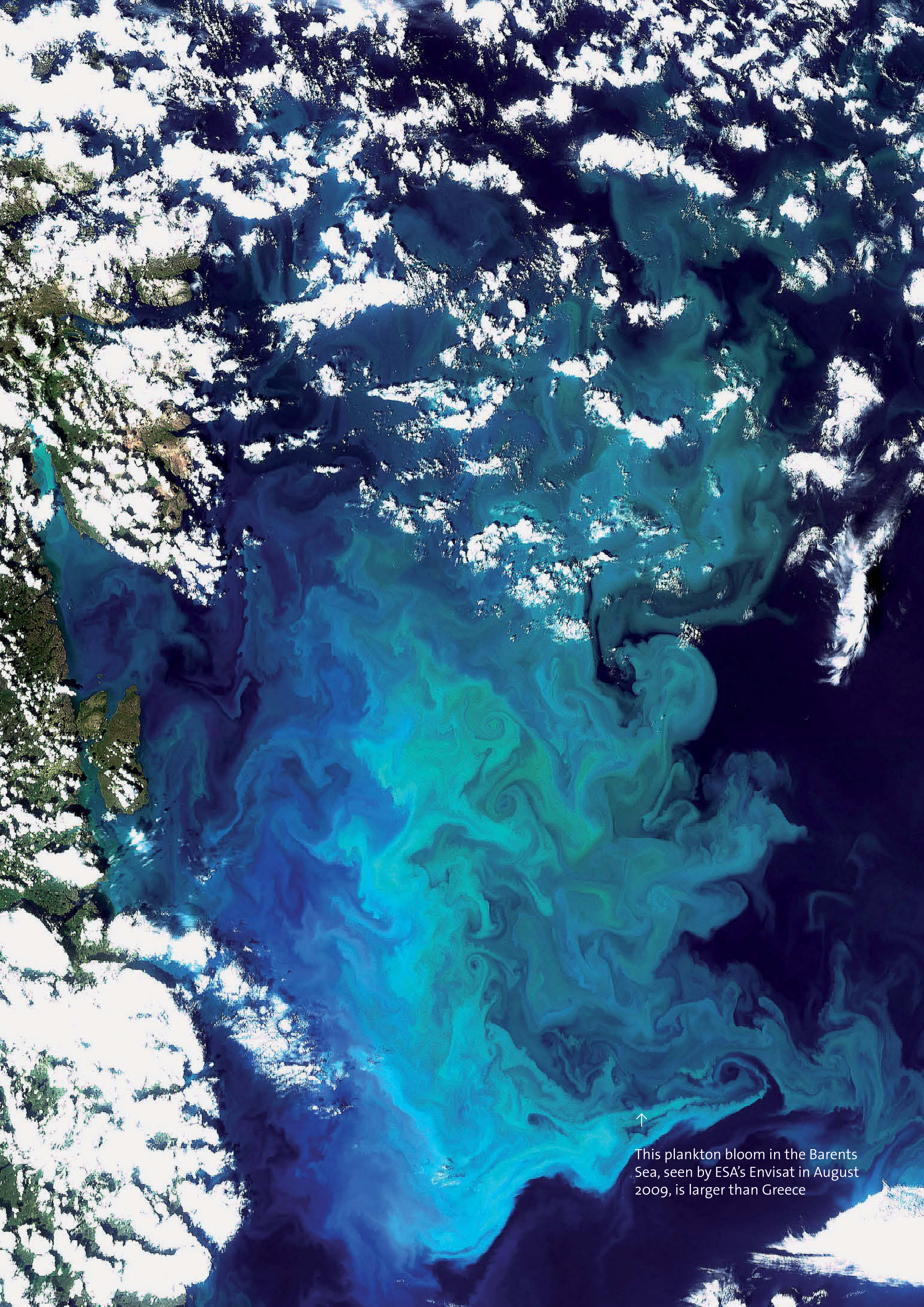

This plankton bloom in the Barents Sea, seen by ESA's Envisat in August 2009, is larger than Greece

→ NEW POSSIBILITIES FOR SCIENCE

ESA's operational Sentinel missions

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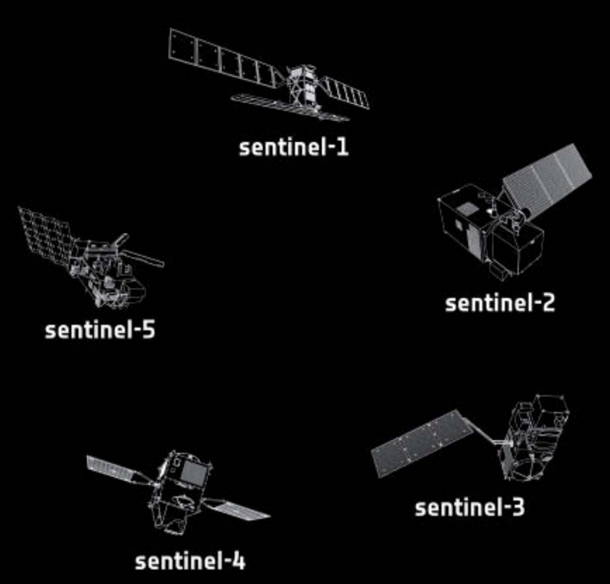
An exciting new period of integrated Earth observation science is set to begin, with the scientific exploitation of data from ESA's Earth Explorers and the upcoming Sentinel missions.

Since Earth observation from space first became possible some 40 years ago, it has been demonstrated as a key tool for the monitoring and studies of how our Earth system works. Now we have arrived at a point where operational observations become a reality while new observation techniques continue to emerge. Such balance between innovation and continuity is one of the core aspects of the Earth Observation Programme.

The Sentinels are a set of five mission 'constellations' being implemented by ESA in cooperation with the European Union. Although primarily designed to provide routine observations for operational Global Monitoring for Environment and Security (GMES) Space Component programme, the Sentinel missions will also support and stimulate innovative Earth system science.

Their ability to operate various sensors with global coverage and rapid revisit times, covering different spectral and spatial resolutions, makes Sentinel missions also highly useful in advancing our understanding of Earth system processes and interactions.

The continuity of data already widely used within the science communities, with a long-term operational commitment, is essential for the parametrisation of long-trend forecasting. Furthermore, the high revisit time, well suited for capturing rapid changes, are strengthening model



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The Sentinel satellites

validations and their subsequent improvements. Long-term climate forecasting will certainly benefit from this development.

In addition, the Sentinels offer an increased spectral coverage which supports data harmonisation, a prerequisite in establishing a fundamental climate data record, and additional science products with many potential applications, fostering knowledge transfer into the GMES service domain.

A key part in the exploitation of the Sentinels will be 'data synergy'. Such synergistic exploitation of data coming from the different Sentinel systems will increase the potential for the development of new tools and advanced products, leading to new capabilities for scientific exploitation. Another asset of the Sentinels is the timeliness of their data. All of the missions will be operational simultaneously from the middle of 2015 onwards. It is expected that most Earth Explorers will be operating complementarily, offering a range of synergies starting from the provision of auxiliary information, to substantial inputs for addressing scientific challenges.

The timeliness calls for integrated data exploitation strategies that are very important for the development of a holistic Earth system model. Integrated data analysis will be further stimulated by ESA Announcements of Opportunity for dedicated theme-oriented exploitation, tailored to specific aspects of Earth system modelling and coordinated with international science communities.

Scientific use of the Sentinel data will in no way impact on or compromise the dedicated use of the data in support of GMES operational services. In practice, improved understanding of the data in pursuit of scientific questions, and the methods developed in addressing them, might in fact be of great benefit to the execution of existing operational services and the development of new ones. Hence, ESA will strive to ensure that data from the Sentinels are made available to the science community openly and freely.

The combined Sentinel and Earth Explorer missions programme is expected to reduce observation limitations and strengthen our ability to monitor the state and changes of our planet Earth. By filling in current gaps in our knowledge and improving our quantitative understanding, we will be able to develop more reliable model- and data-based assessments and predictions of the Earth system.

Relevance to Earth sciences

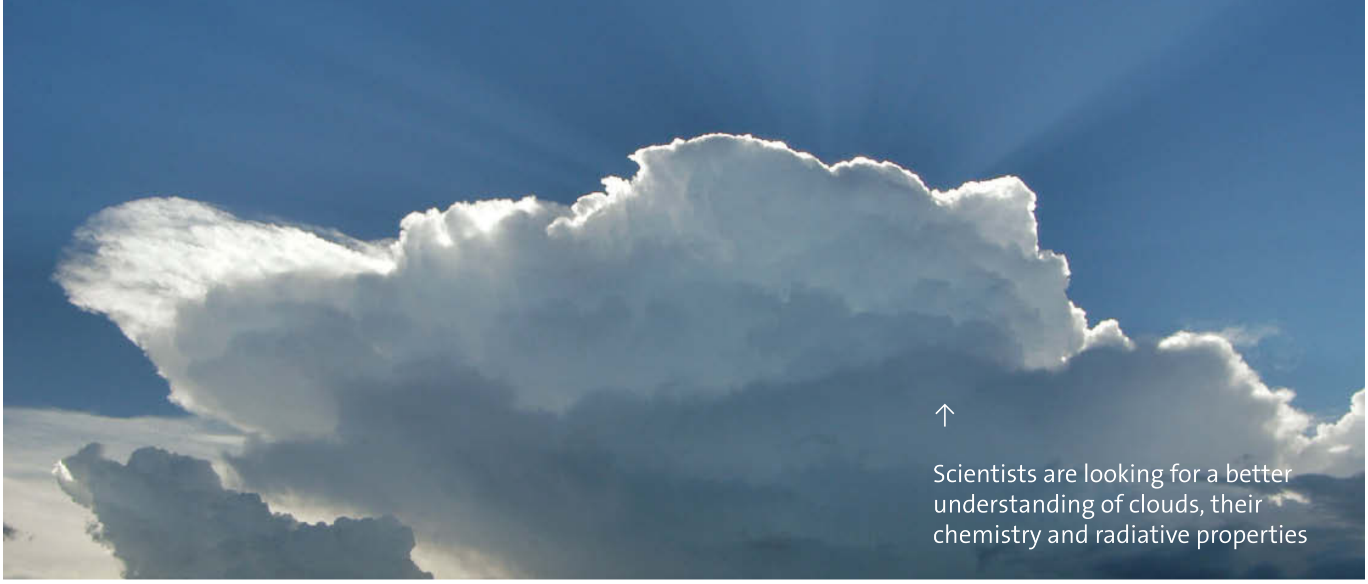
ESA's 'Living Planet' Programme - The Changing Earth (SP-1304) outlines the scientific challenges for Earth system sciences as defined by the European science community. Some of these challenges are addressed below with regard to the Sentinels and in conjunction with the Earth Explorer missions.

Atmosphere

The atmosphere is a central component in the Earth system and acts as a natural transport system for energy, water, nutrients and pollutants. It exchanges momentum, heat, water, carbon and all trace gases and aerosols between the oceans and land surfaces. Atmospheric circulation is driven by these interactions, as well as sea-surface temperature, soil moisture and surface albedo.

Since water vapour is the most abundant greenhouse gas, accounting for one to two thirds of the 'greenhouse effect', scientists are looking for a better understanding of the coupled processes of clouds, aerosols and atmospheric chemistry, including the global water cycle.

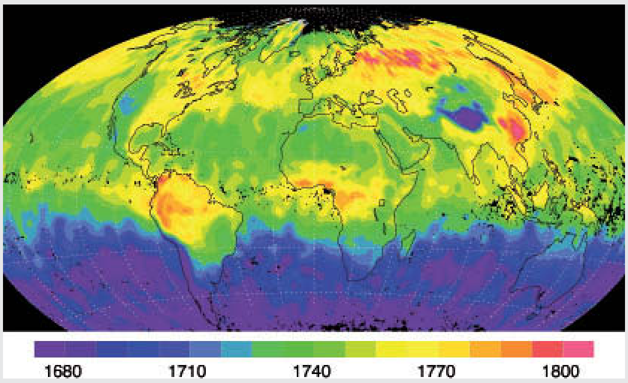
Clouds and their radiative feedback processes also require wind, temperature and humidity profile observations. Aerosols produce a direct radiative forcing by their scattering and absorption of solar radiation, and an indirect forcing by changing the radiative properties of clouds. A quantitative understanding of the various sources of aerosols, their



Scientists are looking for a better understanding of clouds, their chemistry and radiative properties

chemical composition and their sources and sinks is needed. This focuses on the role of aerosol particles and microphysical cloud processes, convection and the properties of cirrus clouds and how they link atmospheric composition and climate change. New aspects in this area are the roles of reactive carbon species of natural origin and the coupling of the nitrogen and carbon cycles.

It is now well established that the chemical composition of the atmosphere is changing as a result of human activities. These changes have a direct impact on the environment, on climate, and on air quality and health on global and regional scales. These effects need to be better understood and it is becoming very urgent to have access to reliable, global, vertically resolved observations with high horizontal resolution of both atmospheric gas phase species and particles, due to an accelerating global population growth, massive urbanisation, and increased transportation and further industrialisation in developing countries.



Global atmospheric methane averaged distribution (column averaged dry air mole fractions in parts per billion) obtained from ESA's Envisat between 2003 and 2005 (ESA/University of Bremen)

In addition, the complementary Earth Explorer ADM-Aeolus mission will provide wind profiles to improve our understanding of atmospheric dynamics, the global atmospheric transport and the cycling of energy, water, aerosols and chemicals. EarthCARE will provide vertical profiles of natural and anthropogenic aerosols, vertical distribution of atmospheric liquid water and ice and better knowledge of the interactions between cloud, radiation and aerosol processes.

Sentinel-4 and -5, and the Sentinel-5 precursor mission, will be dedicated to atmospheric chemistry observations, air quality assessment and climate research issues. Products will support the science issues related to the atmospheric transport system and any alterations in it caused by climate change, such as the long-range transport of long-life compounds and aerosols, their impact on air quality and possible trends in oxidising capacity. Sentinel-3 Ocean and Land Colour Instrument (OCLI) data will also be instrumental in improving atmospheric products, including estimates of aerosols, water vapour and cloud properties.

Ocean

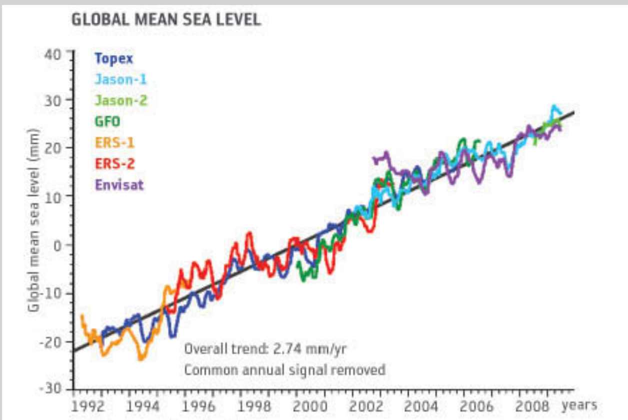
The oceans and their interactions with the atmosphere and land play a major part in driving the global climate through the large amount of heat and mass transported by ocean currents, the evaporative fluxes and momentum exchange. More than 70% of Earth's surface is covered by oceans, which absorb more than half of Earth's total absorbed solar radiation. Moreover, about 40% of the anthropogenic carbon dioxide emission is absorbed in marine biological processes.

Complex ocean–atmosphere interaction and feedback mechanisms occur across a wide range of temporal and

More than 70% of Earth's surface is covered by oceans spatial scales, including momentum exchange, radiative and turbulent heat fluxes and freshwater fluxes through evaporation, precipitation, sea-ice growth and melt, ablating ice sheets and mountain glaciers and river discharges. Added to this are exchange processes with the land biosphere as well as oceanic biogeochemical processes invoked by shortwave absorption and scattering, the biological CO_2 pump and the exchange of gases, aerosols, dust and other natural or man-made chemicals.

A broad spectrum of phenomena, such as global warming and sea-level rise, decline in fish stocks, seasonal oxygen depletion, acidification, episodic harmful algal blooms and loss of biodiversity, are all now showing troubling trends in their magnitude and frequency in open oceans as well as in many coastal areas. In the context of climate change the challenges of seasonal-to-decadal-to-centennial prediction are further aggravated by the existence of several unresolved key scientific problems, such as the coupling between wind-driven gyres and the thermohaline circulation, the convective overturning and the connection between tropical and extra-tropical disturbances at seasonal to decadal timescales.

In addition to securing provision of data to reduce knowledge gaps and meet the complicated challenges as



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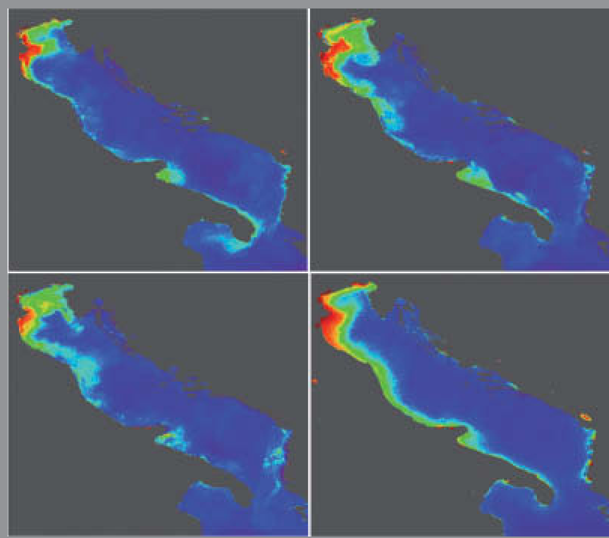
Global sea-level rise derived from radar altimeters carried on various satellite missions. The overall trend shows an increase of 2.89 mm over the period 1992–2008 (R. Scharroo/Altimetrics LCC)

mentioned above, the Sentinels-1, -2 and -3 will moreover support a range of Earth observation capabilities that are needed to develop and implement knowledge-based operational marine information and prediction systems for delivery of Marine Core (e.g. MyOcean) and Downstream Services. In so doing, the missions ensure data continuity with ERS and Envisat sensors with increased radiometric, spectral and temporal resolution.

The Sentinel-3 ocean colour sensor will allow estimation of marine productivity, the detection and monitoring of algal blooms and estimation of the eutrophication state of the ocean through monitoring of water constituents like chlorophyll, yellow substances and sediments. Sentinel-3's thermal sensor will monitor sea-surface temperature and its variability connected with both global climate change and mesoscale frontal dynamics and upwelling zones. Near-surface wind and wave information will be obtained from Sentinel-1 C-band synthetic aperture radar (SAR) and Sentinel-3 SAR radar altimeter (SRAL) data. The SRAL will moreover allow the highly needed monitoring of the mean sea-level change. Monitoring and studies of surface current, upper-ocean mesoscale dynamics and air–sea interaction will also be carried out using Sentinel-1 and -3 (SRAL).



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Adriatic Sea chlorophyll concentrations (µg/l), top left: 1–10 July 2009 mean, top right: 11–20 July 2009 mean, bottom left: 21–31 July 2009 mean, and bottom right: June 2006 – August 2008 mean percentile 90 (ESA/MERIS and NASA/MODIS, Planetek and ACRI/MarCoast)

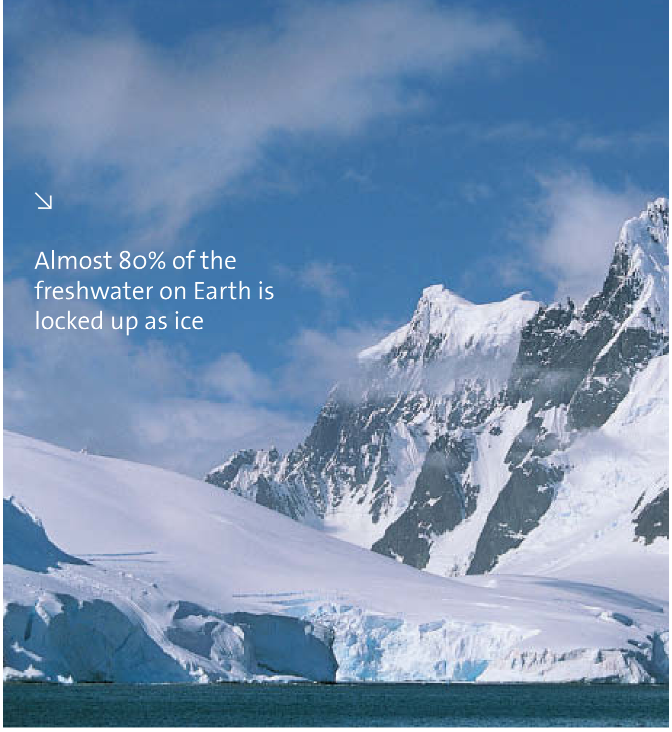
The synergistic use of Sentinel missions will furthermore support investigation of sea-level change, physical and biochemical air–sea interaction processes, internal waves, mesoscale processes and wave–current interaction. Sentinel-2 data, in combination with Sentinel-3 data, may also provide useful information in the study of coastal areas, with potential applications in monitoring coral reefs and their bleaching caused by warming oceans.

Important complementary contributions to many of these challenges are expected from the Earth Explorers, notably SMOS and the Gravity field and steady-state Ocean Circulation Explorer (GOCE). These missions will observe the sea-surface salinity and the marine geoid, which will provide new and highly valuable data for advancing the exploration of ocean circulation and quantifying its transport of mass and heat, as well as large-scale patterns of evaporation and sea-level change.

Cryosphere
The cryosphere refers to regions of Earth's surface where water is frozen, including sea ice, lake and river ice, snow, glaciers, ice caps and ice sheets, and frozen ground (including permafrost). This plays an integral part in all other Earth system components because of the high shortwave reflectivity of snow and ice, and because of all the freshwater locked up as ice (almost 80% of the freshwater on Earth). It has a strong influence on the surface energy and moisture fluxes, precipitation, hydrology, sea-level rise and atmospheric and ocean circulation. (Note that the freshwater provided by the melting of glaciers and land ice sheets is responsible for an increase in sea levels of 18 cm during the last century.)

Scientists need to better understand cryosphere–climate coupling and their mutual feedback through the freshwater cycle and the surface energy balance. This is not only including changes imposed by global warming on ice sheets, the ablating of glaciers, oceanic thermodynamics, rivers, lakes and ice, but also the freeze–thaw conditions in permafrost soils. Current trends show that our models by far underestimate these effects. Space observations can contribute to advancing our knowledge of state, changes and mutual feedback of the cryosphere by regular monitoring of the physical properties of snow and ice surfaces including their roughness, emissivity, dielectric characteristics, surface reflectance and temperature.

Sea-ice monitoring is not only a well-established remote sensing application for assessing ship navigation in ice-infested waters, but also as a climate change indicator. In addition to its impact on the albedo, the salinity and thus the density of the upper–ocean is strongly influenced by growth of sea ice. Reduction in sea ice growth will thus affect local salinity and convective processes, water mass properties and ocean circulation.



↘ Almost 80% of the freshwater on Earth is locked up as ice

↑ Envisat's Advanced Synthetic Aperture Radar captured the early stage of the disruption of the ice bridge that connects the Wilkins Ice Shelf to Charcot and Latady Islands in Antarctica in April 2009. The new rifts that developed along the length axis of the ice bridge are visible (ESA/A. Humbert/Munster University)

Current observations of sea ice show a considerable seasonal, regional and interannual variability in both hemispheres, with larger amplitudes in the Arctic. The Sentinel-1 and -3 missions will ensure data continuity for monitoring changes of the cryosphere, including its surface roughness and elevation, temperature and albedo. In addition, the interferometric capability of Sentinel-1 is suitable for monitoring polar glacier outlets and ice streams by determining velocities which in turn can be converted into mass flux data.

Adding to this, the Earth Explorer CryoSat will provide new and precise quantitative estimates of the thinning and thickening of polar land and marine ice. The improved spatial resolution of its two-antenna radar altimeter, coupled with its interferometric cross-track capability, will also allow repeat observations of the steeper ice-sheet margins and smaller ice caps. These highly needed observations can also be complemented with the SMOS brightness temperature observations as well as the GOCE gravity and geoid data.

Solid Earth
The 'solid Earth' processes are those affecting the surface and interior of the planet. Tectonic processes driven by mantle convection and associated deformation at the surface, leading to earthquakes and volcanic activity, are affecting daily life for millions of people. The global distribution of gravity is indicative of such processes in the interior, a driver for ocean currents, and sensitive to mass redistribution, for example, due to melting land ice. Anomalies in the magnetic field tell us more about Earth's geological history and mass motion in its fluid core.

Earthquakes, tsunamis and volcanic eruptions in some of the most densely populated areas on Earth continue to take their toll, so there is an urgent need to better understand such processes. Whereas seismic stations are able to pinpoint locations and focal mechanisms, it is poorly understood how strain accumulation over many decades is eventually relieved, and how earthquakes interact in fault systems. Direct observation of the surface deformation related to strain accumulation is essential, and is needed over vast areas of the world. The scale of such (interseismic) deformations is in the range of 'millistrain', or deformation of millimetres per horizontal kilometre per year.

Sentinel-1, with its multi-pass polarimetric interferometric observation capability and rapid revisit time, will strongly benefit solid Earth science. Radar interferometry provides accurate measurements of ground deformation, with millimetre precision. Maps of ground deformation can be produced over regions spanning hundreds of kilometres, with a horizontal resolution of a few tens of metres, to assess seismic hazards by monitoring the rate of strain accumulated within that region. Radar interferometry is also used to monitor the activity of volcanoes and subsidence caused by the extraction of ground water.

Earth's gravity field varies due to uneven mass distribution and the dynamics of the surface and Earth's interior. These include high mountains, deep ocean trenches, ground water reservoirs, oil, gas and mineral deposits, tidal effects, sea-level rise, Earth's rotation, volcanic eruptions and changes in topography. A precise knowledge of the 'geoid' – a virtual surface with an equal gravitational potential – is needed for many applications, such as levelling and construction, and for understanding ocean currents and monitoring sea-level dynamics.

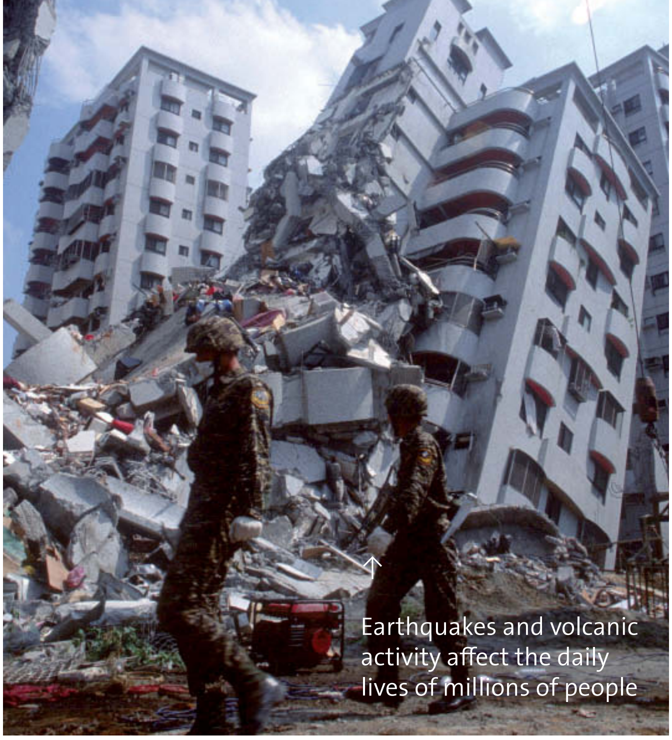
The Earth Explorer GOCE is currently measuring such density variations in Earth's interior. Hereby, it is effectively monitoring processes occurring in the lithosphere and upper mantle, down to a depth of 200 km. These, together with seismic data, allow a better understanding of the processes that lead to earthquakes and volcanic eruptions.

Our planet's magnetic field, which is to a large part generated by a 'dynamo' effect in Earth's fluid outer core, plays an important role in shielding us from hard cosmic rays, which was essential for the development of life. The field and its temporal change provide insight into Earth's interior processes.

The Earth Explorer Swarm mission will provide the best-ever survey of the geomagnetic field and its time-variability aspects, allowing the decoupling of the spatial and temporal variations of the geomagnetic field. The geomagnetic field models resulting from Swarm will further our understanding of underlying processes and will have practical applications in many areas, such as space weather and radiation hazards.

Land surface

Land surface processes are currently the least represented in operational numerical weather predictions and Earth system models. This is because the modelling of the different processes of land surfaces is very difficult owing to the heterogeneity and the diversity of spatial and temporal scales involved in matter and energy exchanges.



↑ Earthquakes and volcanic activity affect the daily lives of millions of people

Processes within soil and vegetation control the fluxes of energy, water and carbon (and greenhouse gases such as methane) to and from the atmosphere. The changes in land-use and land-cover due to human exploitation of natural resources, or those induced by natural disasters (fires, erosion, floods), introduce effects that also need to be considered when monitoring land surface processes.

There are limited Earth observation capabilities to observe variables directly related to organic soil processes, such as decomposition and the related carbon dioxide (CO_2) release. However, indirect observation is possible via the coupling of different processes through modelling. The freeze–thaw conditions of permafrost soils in northern latitudes are of particular interest because the process of their large storage of CO_2 and methane being released on thawing can be indirectly observed through the monitoring of surface temperature and soil moisture conditions. The Earth Explorer Soil Moisture and Ocean Salinity (SMOS) mission will provide global soil moisture observations of relevance for such assessment.

Particular attention is being devoted to the dynamics of ecosystems because of their important role in the carbon and water cycles. The terrestrial ecosystem uptake of carbon amounts to about 120 gigatonnes (Gt) per year through photosynthesis, which is much larger than the annual fossil fuel emission estimated at 6–7 Gt. Thus, small changes in this balance are likely to have a major impact on the variations of atmospheric CO_2 concentration. To simplify representation of flora in these processes, ecology modellers introduced the concept of Plant Functional Types (PFT) based on plant traits, describing the functioning of the plants under certain environmental conditions. Modellers working at the regional and global scale prefer to use coarse PFT classifications based on a small number of plant traits (life form, phenology and photosynthetic pathway), while experimental scientists focus on a larger range of plant traits, and nowadays even prefer avoiding discrete plant type classifications. In either case, the global time series to be provided by Sentinels offer a range of tools for assessing and quantifying plant traits and provide essential inputs to these modelling communities.

Data from Sentinel-1, -2 and -3, including the polarimetric interferometric capability of Sentinel-1, are well suited for the parametrisation of land surface processes, providing improvements over the above mentioned biogeophysical products taking advantage of the increased temporal and spectral resolutions and including their synergistic use. These data products will undoubtedly support the development of a range of new applications and the large and consistent time series are of very high scientific value.

Specifically designed for land applications, Sentinel-2 with its five-day geometric revisit time at the equator (based on two satellites operating simultaneously) will allow global and systematic acquisitions with high spatial resolution and with a high revisit time tailored towards the needs of land monitoring. Current optical observations have been limited by revisit time, the lack of proper cloud screening and atmospheric corrections, but the dedicated wavebands available on Sentinel-2, which allow the needed corrections, represent an important step towards a proper exploitation. These will guarantee consistent time series, showing actual variability in land surface conditions without the artefacts introduced by atmospheric variability.

Contrary to previous missions, the optical instruments of the Sentinels are designed to allow for systematic atmospheric corrections and precise cloud screening, providing reliable multitemporal data series and making possible higher-level applications. Expected operational products (such as land cover maps, Leaf Area Index or Fractional Vegetation Cover) will be enhanced with new scientific applications through

→ Increased capabilities

The five Sentinel missions, their ground segments and contributing missions are the space component of the EU's GMES initiative. Their designs are driven by the needs of GMES services for the continuity of data from current operational Earth observation missions, such as ERS-2, Envisat, Jason-2, SPOT-HRV and SPOT Vegetation. To provide robust datasets, revisit and coverage requirements were also taken into account. This led to the series of Sentinels with an operational commitment up to 2025. In addition to continuity of data, the Sentinels offer increased observation capabilities.

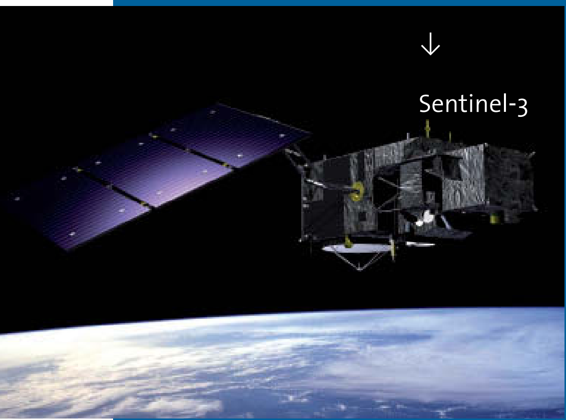
Sentinel-1
(SAR) has one main operational mode (>250 km interferometric wide swath mode) that satisfies most service requirements identified under GMES core and downstream services. The operation of this mode simplifies mission planning, optimises revisit times for priority services and decreases operational costs. Apart from the main operational mode, the SAR is capable of observing in the strip map mode (>80 km), wave mode (20 km), or extra wide swath mode (>400 km) to accommodate future user requirements or ERS/Envisat continuity requests. All Sentinel-1 modes offer dual polarisation and single-look spatial resolution ranging from 5 m (strip-map) to 40 m (extra wide swath).

↑ Sentinel-1

Sentinel-2
Besides data continuity of 'SPOT-HRV'-type observations in the visible and near-infrared spectral range, the Sentinel-2 Multispectral Imager instrument offers 13 spectral bands in the visible, near-infrared and shortwave infrared regions, with resolutions of 10–20 m, including dedicated bands for atmospheric corrections and cloud screening with a resolution of 60 m. Narrow spectral bands positioned along the vegetation 'red-edge' allow improved quantitative estimates of key biochemical parameters that will provide potential new applications and enhanced capabilities for scientific exploitation. The increased swath width of about 290 km together with the global revisit time of five days is very advantageous for assessing rapid changes such as vegetation characteristics during growing seasons and improved change detection techniques.

↓ Sentinel-2

Sentinel-3
In comparison to Envisat's Medium Resolution Imaging Spectrometer (MERIS), Sentinel-3's Ocean and Land Colour Instrument (OLCI) offers a sunglint-free design, a slightly larger swath, six additional spectral bands in the visible and near-infrared and an improved global

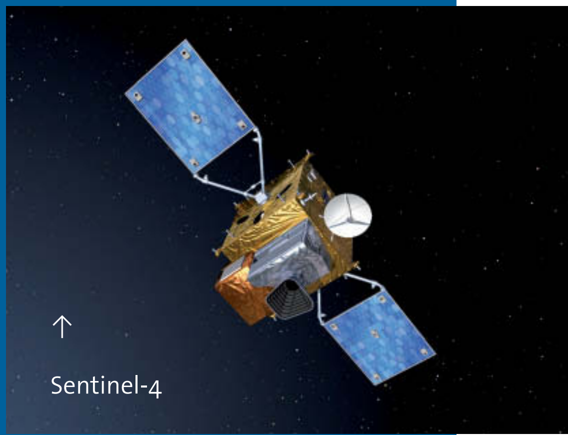


revisit time of one day instead of four. The additional spectral bands are tailored towards optimised land and ocean products including those needed for atmospheric correction.

Unlike Envisat's Advanced Along-Track Scanning Radiometer (AATSR) and MERIS, Sentinel-3's Sea and Land Surface Temperature instrument has a total overlap with the OLCI instrument, offering a major advantage for many applications. Compared to AATSR, it has an increased spatial resolution in the visible bands (500 m instead of 1 km) and additional spectral coverage (nine bands instead of seven) to support atmospheric correction.

The Sentinel-3 SAR radar altimeter (SRAL) offers dual-band acquisition, Ku-band for height determination and C-band for ionospheric correction. In comparison to Envisat's radar altimeter, SRAL features along-track SAR operation tailored to advance the discrimination of ocean and sea ice and the transitions from land to sea in coastal or inland water areas. SRAL will measure the topography over all types of surfaces such as sea, coastal areas, sea ice, ice sheets, ice margins and in-land waters with higher coverage and increased accuracy.

Sentinel-4/5 and Sentinel 5 precursor
The Sentinel-4/5 and Sentinel-5 precursor missions will be devoted to atmospheric composition monitoring for the GMES Atmosphere Service. There will be two families of atmospheric chemistry monitoring missions, one in geostationary orbit (Sentinel-4) and one in low Earth orbit (Sentinel-5 precursor, Sentinel-5). The Sentinel-4 mission will consist of an Ultraviolet-Visible-Near-Infrared (UV-VIS-NIR) spectrometer accommodated on Meteosat Third Generation Sounder (MTG-S) platforms. In addition, TIR sounder data on the same platform, and a cloud imager on the MTG-Imager platform will be exploited by the services. The low Earth orbit Sentinel-5 mission will consist of an UV-VIS-NIR and Shortwave Infrared spectrometer on post-EPS which will also house a TIR sounder and imager. The Sentinel-5 precursor mission will bridge the data gap from the end of the Envisat mission to the launch of Sentinel-5. It will provide data continuity and support the transition into an



operational scheme. The UV-VIS-NIR instrument will be provided as a national contribution from the Netherlands, which will be complemented by a Shortwave Infrared module.

synergy among the different Sentinels. The Earth Explorer SMOS mission will provide new insight of the large-scale soil moisture conditions and their influence and interaction with the biosphere.

Access to Sentinel data

Access to Sentinel data is governed by the Sentinel data policy, which is formulated within the framework of a wider GMES data and information access policy. Principles of such a Sentinel data policy have been defined by ESA and the EC and were recently approved by ESA Member States in September 2009. EC approval is part of a co-decision process involving the European Parliament and EU Council and is expected to occur in the course of 2010. These Sentinel data policy principles stipulate free and open access to Sentinel data to the largest possible user community. Only technical constraints, such as processing/access limitations, or security constraints are today considered to eventually limit such free and open access. Prioritisation among different user communities will be governed through a high-level operations plan. Users will be required to accept specific Terms and Conditions for Sentinel data access through a web-based acknowledgement process.

The Sentinel data policy, which will result from the current Sentinel data policy principles, aims at providing such free and open access also to the scientific community, recognising the community's catalytic impact in improving operational GMES services apart from the expected significant advancement of our Earth's scientific understanding through this vast data source.

↑
The first Mars500 crew (back) Oleg Artemiev, Sergei Ryazansky, Oliver Knickel, (front) Alexei Baranov, Cyrille Fournier and Alexei Shpakov

→ LIFE… ON THE WAY TO MARS

The Mars500 programme

Jennifer Ngo-Anh
Directorate of Human Spaceflight,
ESTEC, Noordwijk, The Netherlands

An extraordinary journey ended on 14 July 2009. An international crew of six was welcomed 'home' from a simulated mission to Mars and back to Earth.

During this mission, lasting 105 days, the crew had to be autonomous, for the most part solving problems on their own or with the support of an 'Earth-based' mission control centre. They had only limited contact to the outside world and had to cope with the confinements of a habitat that was designed to resemble a Mars-bound spacecraft.

This study was part of an ambitious collaborative project between ESA and the Institute of Biomedical Problems (IBMP) in Moscow, Russia – the Mars500 programme, which is investigating the effects of isolation and confinement on a six-person crew in preparation for a real mission to Mars. This 105-day pilot study will be followed by the full 520-day study, slated to start in the first half of 2010.

Why do we need such a programme?

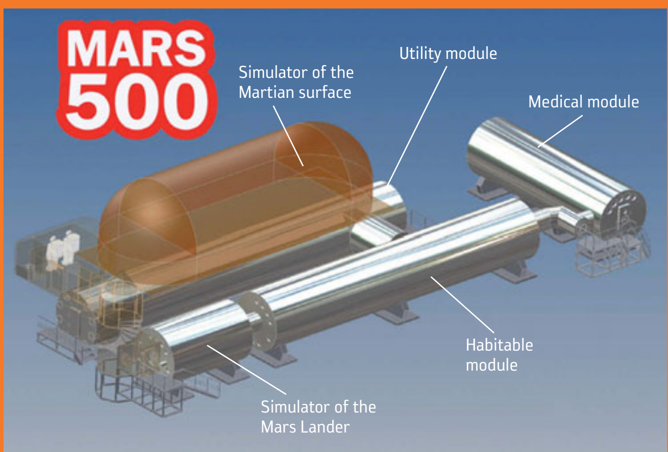
Human exploration of our Solar System is an important focus for ESA, which has started on the path to making this a reality in the future. Making sure that astronauts are prepared mentally and physically for the demands of long-duration spaceflight is imperative to a mission's success. ESA has a long history of conducting research on the psychological and physiological aspects of spaceflight, but never before has a long-duration spaceflight such as a mission to Mars been simulated.

When considering embarking on such an ambitious project like a flight to Mars, medical and psychological aspects become an issue of major importance. Daily crew life and operational capabilities may be affected by the hazardous space environment, and the need for crew autonomy and resourcefulness, psychological effects of isolation, interaction with fellow crew members but also mission control, are just a few aspects to consider when preparing a mission to Mars. A better understanding of these aspects is essential for development of all necessary elements of an exploration-class mission.

In both the 105-day and 520-day studies, two out of the six crewmembers are recruited from ESA Member States. The other four members of the crew are Russian. They all have to perform tasks related to a long-duration mission to Mars and are responsible for control and maintenance of systems including life support, control of resource consumption, carrying out standard and non-standard cleaning and maintenance tasks and implementing a comprehensive scientific programme. They have to be self-reliant, organising most of their own daily tasks, and are responsible for monitoring and maintaining the health and psychological states of themselves and each other.

For the first study of 105 days, the crew was sealed in the isolation facility in Moscow on 31 March 2009. Part of this chamber was a mock-up of the spacecraft that would transport them to Mars, and the other part represented a landing module that would take them to and from the martian surface. A landing on Mars was not simulated in the 105-day study but will be an important element of the 520-day study. During 'Mars surface operations', the crew will be divided into two groups of three. Once the first group leaves

→ The facility



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A diagram of the isolation facility; 1. Medical module, the main living and work area; 2. Crew personal sleeping quarters; 3. The tunnel to the Mars lander simulator; 4. Berths in the Mars Lander simulator; 5. Part of the greenhouse in the Utility Module for the 'martian surface', the hatch between the simulated martian lander module and the rest of the facility will be closed by the 'orbiting' group and only opened again when the Mars surface stay simulation ends. The isolation facility itself was housed in a building on the IBMP site in Moscow. This building was home to the mission control room, technical facilities and offices.

The isolation facility consists of four hermetically sealed interconnected habitat modules with a total volume of 550 m³.The crew spent most of their time in the module containing their individual compartments, a kitchen-dining room, a living room, the main control room and a toilet. A medical module contained equipment needed not only to treat medical problems, but also to perform routine medical and telemedical examinations, laboratory and diagnostic investigations. The storage module contained all consumables needed for the mission, a greenhouse and a gym.

Life in the chamber

Once the doors were closed, the crew only had personal contact with each other plus voice contact with mission control and family and friends, as would normally happen on a human spaceflight mission. During one part of the mission, a 20-minute delay was built into radio communications with the control centre to simulate the distance travelled by an interplanetary mission.

The crew followed a seven-day week, with two days off with a rotational system in place to account for night shifts. Non-standard and emergency situations were simulated to determine the effect of a decrease in work capability, sickness and failures of onboard systems and equipment.

The two European crewmembers of the 105-day study, Cyrille Fournier from France and Oliver Knickel from Germany, were recruited following a Call for Candidates in summer 2007, to which more than 5600 space enthusiasts applied. Applicants had to meet certain requirements, such as age, height, weight, nationality (only citizens from ESA Member States were accepted), academic background, experience and good health.

What made so many people apply to be isolated for such a long time? Most candidates said the prospect of being part of an adventurous, ambitious, unique project and contributing to future human spaceflight missions to Mars were their main reasons for applying. Following the initial application, potential crewmembers were interviewed and underwent medical and psychological tests in Europe, at the European Astronaut Centre, Cologne, and in Russia to assess their ability to work and live under the special circumstances imposed by the programme. Eight finalists were then sent to Russia, where they were trained for their upcoming mission.

The training included lectures on the medical/technical facility, as well as on the communication, information and life-support systems from IBMP experts. The crew also received instructions on how to perform the scientific programme of the study.

↑

Off duty: Cyrille makes himself popular playing poker; Oliver talks by phone with his girlfriend on his 29th birthday; the crew helps Oliver celebrate in style

The scientific experiments were solicited in an Announcement of Opportunity, to which scientists from all ESA Member states were able to submit experiment proposals. Nine of the received proposals were carried out in the 105-day study, and 13 will be performed in the 520-day study.

The science of isolation

The crew acted as test subjects in these investigations to assess the effect that isolation and confinement has on various psychological and physiological systems of the human body, such as stress and hormone regulation, immunity, sleep quality, mood and effectiveness of dietary supplements. All experiments centred around the questions on how to cope with and counteract the effects of isolation and confinement.

Scientists are evaluating and analysing the results obtained in the 105-day study. Preliminary results indicate new findings and lessons learnt that may not only benefit the full 520-day study, but also add to the knowledge and experience that will form the basis for the preparation and planning of worldwide efforts to go back to Moon and beyond.

Preparations for the simulated full-duration Mars mission are now taking place. The level of complexity and challenges are significantly higher than in the pilot study, and indeed a lot of gathered information and experience obtained are helping to shape the 520-day study.

This study will include more experiments and will simulate features such as gradually increasing the communications delay, separation of the crew during the Mars landing (three of the crew will spend 30 days in the simulated Mars lander module) and the subsequent return to Earth. ESA and IBMP are duly preparing for this unique campaign, in order to ensure that the success of the 105-day mission is repeated.

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ESA Director of Human Spaceflight, Simonetta Di Pippo, talks to the crew at their halfway point of the mission

→ The experiments

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Some of the experiments carried out on Mars500; 1. A small sensor worn around the neck to monitor light levels; 2. Preparing Oliver for night time EEG monitoring; 3. Oliver collects saliva samples; 4. Cyrille analyses the hydrogen content of his breath

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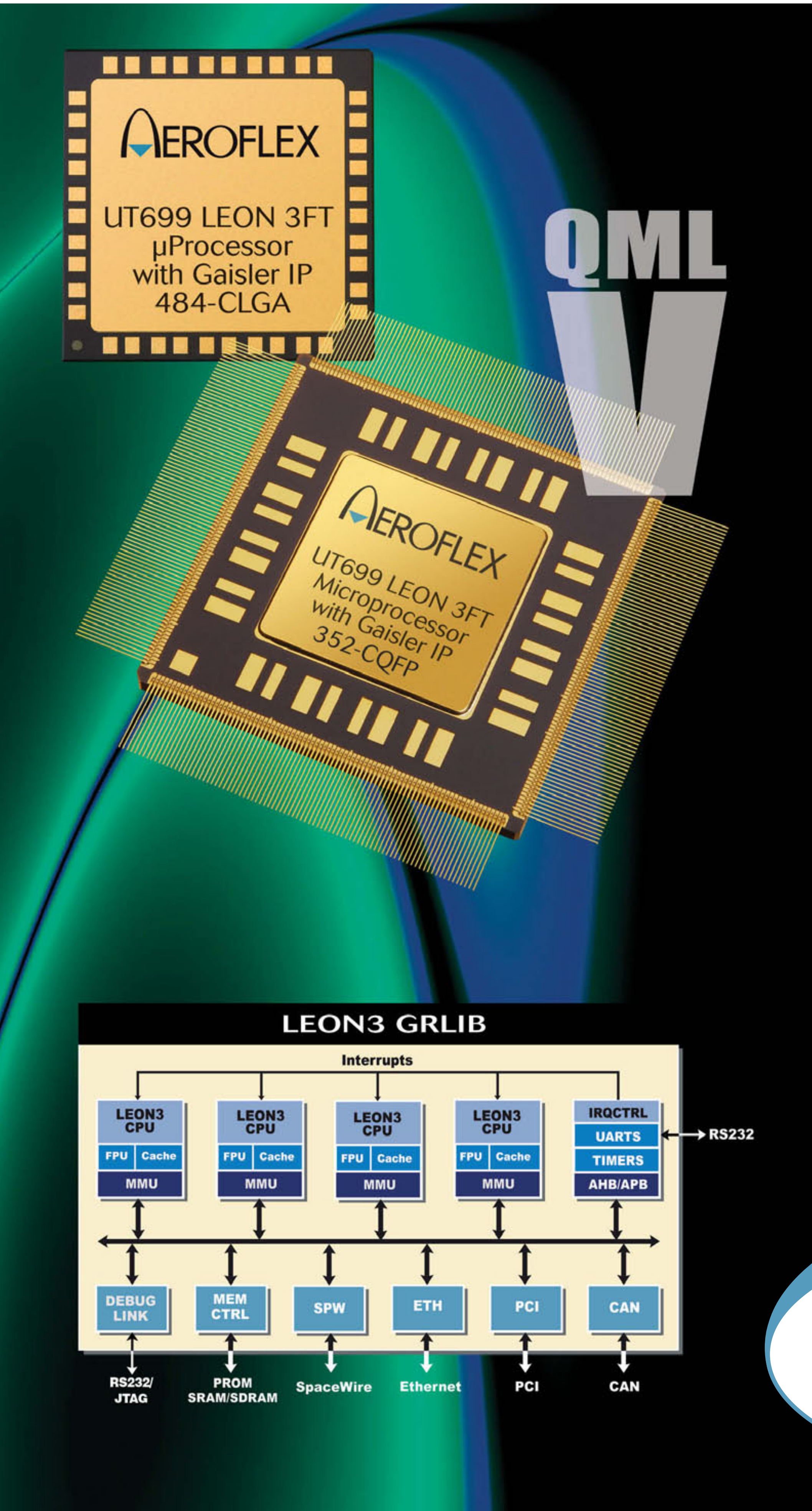

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→ WHERE SPACE MEETS YOUR DAILY LIFE

Telecommunications and Integrated Applications at ESA

Magali Vaissiere and the TIA team
Directorate of Telecommunications and Integrated Applications (TIA),
ESTEC, Noordwijk, The Netherlands

Most of us use satellite telecommunications every day, often without realising it. But when the Telecommunications Programme was created in the new European Space Agency of 1975, European industry had virtually no commercial satellite capability.

When we listen to the radio or watch television, we receive signals that in most countries have been distributed to the local transmitters by satellite. Newspapers are printed on remote printing presses with the information generated by their central offices, banking systems use satellites to connect branches all over the world and even lottery players in several European countries have their details transmitted over satellite systems.

Today, over 24 000 TV channels are handled by telecommunication satellites operating in geostationary orbit. Nearly 200 million homes have antennas and set-top boxes that allow them to receive signals directly from orbit. Thousands of telephony circuits allow communication between international or remote local exchanges and thousands of Internet Service Providers get their access to the core network by satellite. In the USA alone, nearly 20 million subscribers receive radio programmes in their cars directly from satellites.

↑

Over 24000 TV channels are handled everyday by communications satellites, monitored by control rooms at broadcast centres as above

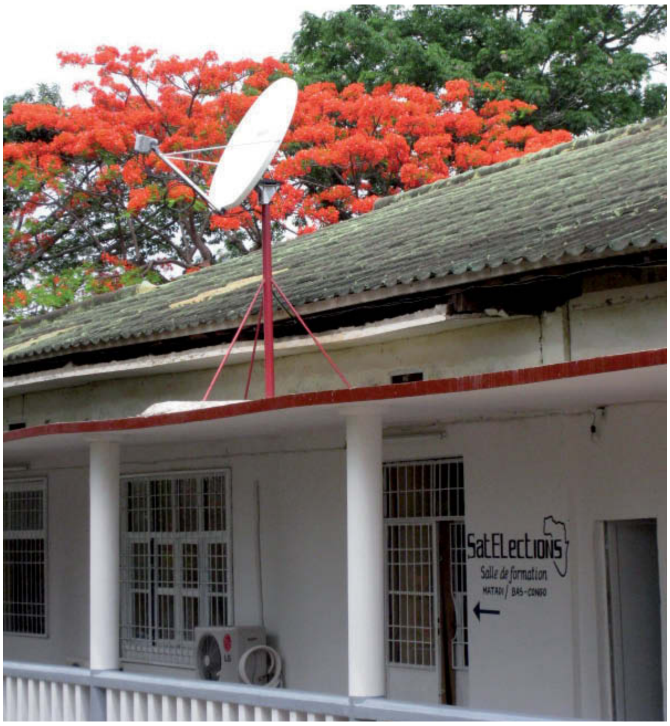
In many disasters or emergencies, satellite communications remain working when other terrestrial communications systems may have been cut down. In times of crisis, it is often only telecommunications satellites that allow disaster management and rescue activities to be coordinated.

In a world that is becoming increasingly 'mobile', satellite telecommunications have played a very important role. Satellite operators, such as Inmarsat, offer services to maritime, aeronautical and land mobile users practically anywhere over the surface of the planet to several hundred thousand terminals. Other mobile systems, based on either low-Earth orbit constellations or very powerful geostationary satellites, allow local and global handheld telephone coverage.

↑

Whether you are on land, sea or in the air, satellite operators offer services to users anywhere on the planet (Inmarsat)

New and more powerful satellite systems are in the pipeline. High-capacity broadband access systems designed to offer internet access to millions of subscribers will be launched in 2010–11. Some of those satellites, using the Ka-band, have a traffic handling capability of 50–100 times more than conventional Ku-band satellites. As their efficiency increases, the cost of the service should decrease and within a few years it is projected that several millions of subscribers in Europe and USA will be connected to the World Wide Web by satellite. The rest of the world will follow.



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New satellite systems offer internet access to millions of subscribers around the world, even in the remotest locations

Figures published by the Association of European Space Industry (Eurospace) show that practically 40–45% of all space industry effort is related to the production of telecommunications satellites. Interestingly, more than 90% of all Ariane launches were dedicated to telecommunications (of 155 spacecraft placed in orbit by Ariane 4, 139 were telecommunication satellites).

The projections for the future demand of satellite communications systems are optimistic. While the more settled Broadcasting and Fixed Satellite Services (BSS and FSS) are expected to grow at about 5% per year, other areas are less mature and therefore more open to new opportunities and faster growth. In particular, the mobile services and the broadband interactive markets are likely to grow at much higher rates, driven by the new systems being launched in the next year or two, which will introduce a dramatic improvement of the cost/performance ratio.

But this is not all: producing and launching satellites are only the tip of the iceberg of the 'satcom' market. The sale of satellite capacity by satellite operators multiplies threefold the space segment industry turnover. The ground segment sector produces sales that are ten times greater than those derived from the procurement and launch of satellites, and the turnover produced by the provision of services is more than 20 times larger.

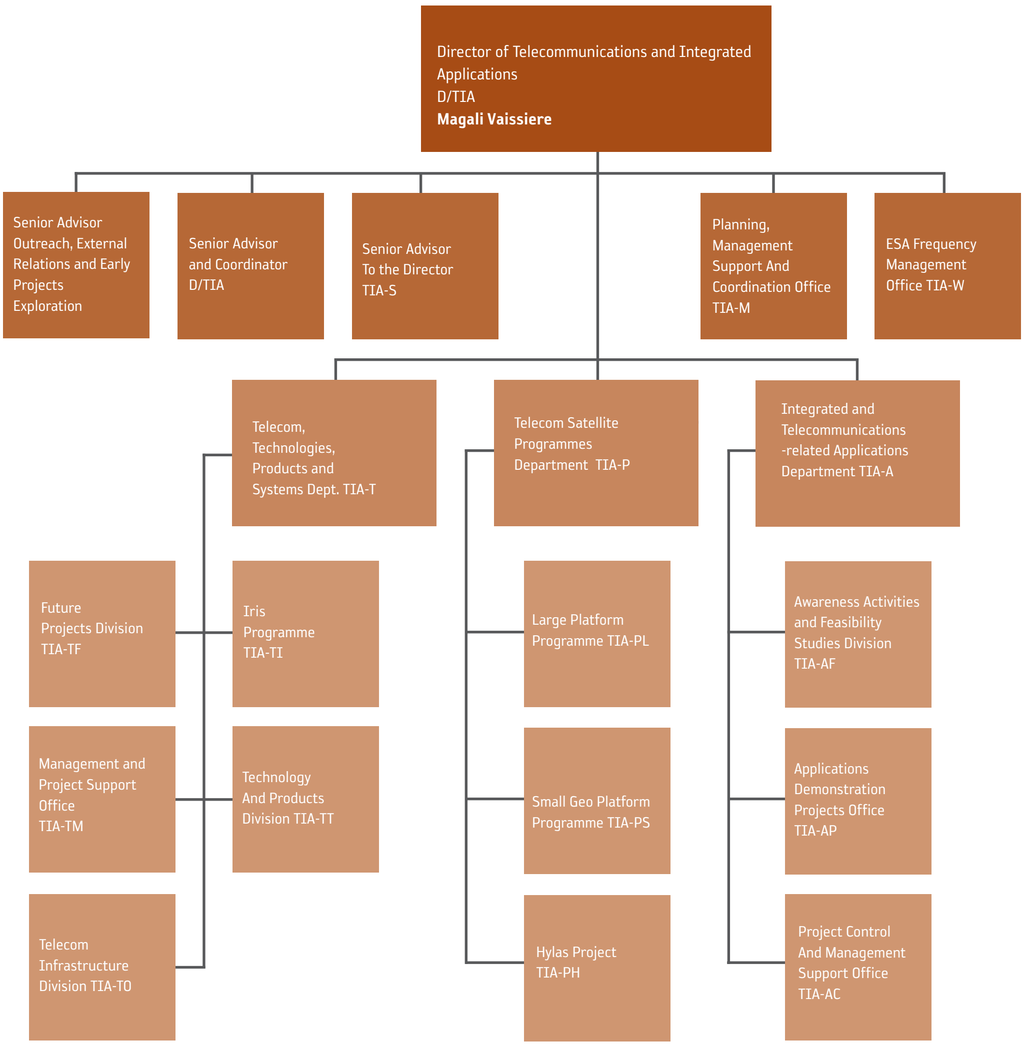
A cornerstone in ESA's past, present and future

The Telecommunications programme was created at the inception of ESA in 1975, at a time when European industry had virtually no commercial capabilities at satellite level. European companies could provide equipment to mainly US prime contractors. There was neither a European Operator of Satellites, nor many commercial ground stations. There was a lot of competence, but not a genuinely competitive industry.

The continuous effort made by European industry with the support of ESA has paid off. Today, almost 40% of all commercial satellites are built and sold by European prime contractors, and some of the most important Fixed and Mobile Satellite Services (MSS) operators are based in Europe. The successful ESA Telecommunications programme was one of the key factors in the emergence of this competitive industry in Europe.

At one point, it was claimed that ESA's support to satellite communications was no longer necessary, since the industry was commercially driven and competitive enough. When the satellite telecommunications market was fully deregulated, this led to a complete transformation of the sector and the ESA Telecommunications programme was downsized.

However, it was realised that the need to maintain support to research and development in telecommunications was essential, to ensure a healthy space industry. Industry and ESA's delegations saw that, without a competitive telecommunications industry, the sustainability of the European space effort would be in jeopardy. This awareness has been reflected in an enhanced level of support to ESA's Telecommunications programme and, more recently, in the outcome of the Ministerial Council 2008 that reinforced existing programmes and created new ones. Today, Telecommunications, incorporating Integrated Applications, is a well-endowed ESA programme with a bright future ahead.



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Since 2008, the organisation behind the programme is again a full Directorate: Telecommunications and Integrated Applications (TIA). On consolidation of the results of the Ministerial Council, the Director of TIA began to adapt the organisation of the requirements of the programmes that were approved

The ARTES programme

Because of its maturity, the satellite communications market is extremely competitive, and very innovative. The roles of satellite systems are redefined every few years, new services are identified constantly, new orbital architectures are often proposed and the performance of different types of payload is always being enhanced.

At the same time, satellite communications is very strategic. The ability to compete in this market allows a flow of competences to be applied in defence communication systems, and vice versa. International industries may receive institutional support in a variety of ways, and certainly in ways not available to European industry. In this context, ESA's Telecommunications programme is the most important mechanism of support to research and development (R&D) in satellite communications systems available to European industry.

ESA's Telecommunications programme has a specific name: Advanced Research in Telecommunication Systems (ARTES). ARTES has two objectives:

- to enhance the competitiveness of the European industry in satellite communications through a comprehensive R&D action;
- to contribute to identifying and implementing space-based solutions to a wide range of institutional and societal problems.

ARTES is in many aspects very different from other ESA programmes. On one hand, it has to deal with its purpose having a strong commercial component. Industrial contractors compete with each other and each company wants to retain the rights derived from their respective developments. On the other hand, ESA's intervention is constrained by open trade rules defining the intensity of funding according to the level of maturity of the development in question. Duplication of developments is in itself not avoided, in as much as competitiveness is welcome in a commercial environment. However, ESA requests a credible justification for the proposed developments backed up by a prospective business case.

Yet another difference in ARTES relates to the elements of aggregation of the Telecommunications R&D chain, namely technology, equipment, systems, mission, services and applications. Some of the activities that are included in the programme can be considered generic, i.e. typical of a revolving continuous envelope programme that rolls on through the years. Others are project or mission specific, so that they correspond to the implementation, development and qualification of a specific satellite or system.

→ ARTES Generic (Roll On/Envelope) Elements:

- ARTES 1: Preparatory,
- ARTES 3-4: Products,
- ARTES 5: Technology,
- ARTES 20: Integrated Applications

→ ARTES Specific (Project/Mission Driven) Elements:

- ARTES 7: EDRS,
- ARTES 8: Alphabus/Alphasat,
- ARTES 10: Iris,
- ARTES 11: Small Geo

> **"Satellite communications can provide solutions to the needs of European society, contributing to solving some of our most pressing problems."**

ARTES is also an optional ESA Programme and therefore has to cater for different initiatives from delegations that may require specific programmatic frameworks.

Altogether, these requirements have led to a flexible programmatic instrument that can satisfy the majority of needs of the delegations and industry. ARTES has been developed, and evolved, from its inception in 1994 around the concept of ARTES Elements. These are specific lines of programmatic action that implement the provisos of the ARTES Declaration and the Telecommunications Long-term Plan. Each of the ARTES Elements has a specific purpose, participation and implementation rules. All ESA Member Countries participate in the ARTES programme, but specific subsets participate on each of its elements.

Currently ARTES is made up of eight active Elements, four of which are generic, i.e. 'envelope' type programmes, while the others are specific, i.e. 'project' programmes.

→ ARTES 1: Preparatory

The Preparatory Element of the ARTES programme contains the seed from which new programme Elements are generated. ARTES 1 activities are mainly studies and analyses that investigate the evolution of telecommunications in general, and satellite telecommunications in particular, to identify trends in the demand and the needs for future developments. A wide range of enabling technology and system feasibility studies are also performed under ARTES 1. Other ARTES 1 activities include those carried out in support to the standardisation of satcom systems.

ARTES 1 is the only Element with compulsory participation for all ARTES-participating Member States. Its activities are initiated by ESA to a yearly workplan and are 100% funded.

→ ARTES 5: Technology

ARTES 5 is the Element dedicated to the development of long-term technology, this refers to technological concepts that cannot be incorporated directly into products but require a previous effort of characterisation and validation. Under ARTES 5, two types of activities are envisaged:

ARTES 5.1 corresponds to activities identified and proposed by ESA in a yearly workplan and which are subject to open Invitations to Tender. These are 100% funded. ARTES 5.2 corresponds to activities submitted by industry. They are co-funded by ESA up to a maximum of 75% of their cost.

→ ARTES 3–4: Products

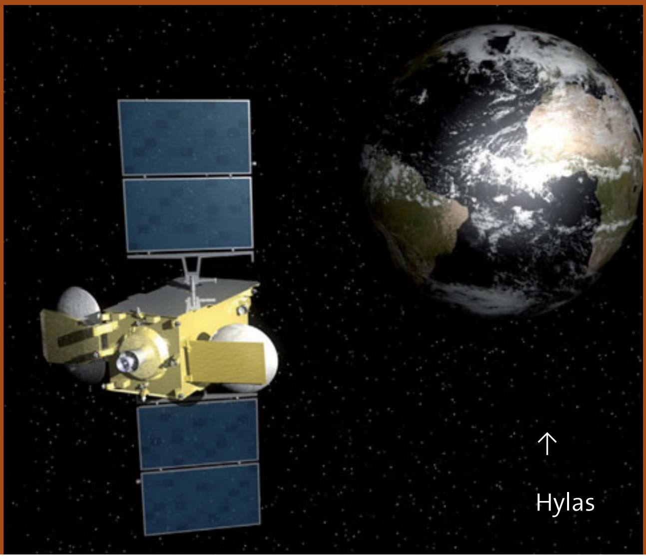
ARTES 3–4 is dedicated to the development of products with a predefined set of standards. This Element is a merger of two previous elements, ARTES 3 and ARTES 4, and is the main instrument used by industry to develop anything related to satellite communications that has a product specification and a market objective, from terminal antennas to user software, or from payload equipment to specific systems. This is for all types of service, e.g. FSS, BSS, MSS and specific actions on Broadband systems and Mobile broadcasting. Additionally the scope of ARTES 3–4 allows the development of telecommunications applications related to any of the services above.

ARTES 3–4 activities are initiated at the request of the industry in reply to a generic invitation and they are co-funded by ESA to a maximum of 50% of their cost.

A mission developed under ARTES 3: Hylas

Hylas is an advanced Ka-band satellite with multiple spot beams, aiming to provide cost-effective Internet access throughout Europe. The main characteristic of Hylas is its flexibility. Multiple spot beam systems have to cope with changing traffic demand by location and varying with time. The flexible payload incorporated in Hylas allows the assignment of the main satellite resources: power and bandwidth, to each spot commensurately with the demand.

The Hylas project has been undertaken under ARTES 3 after the proposal of Avanti Communications Ltd who will look after the provision of the intended broadband services.



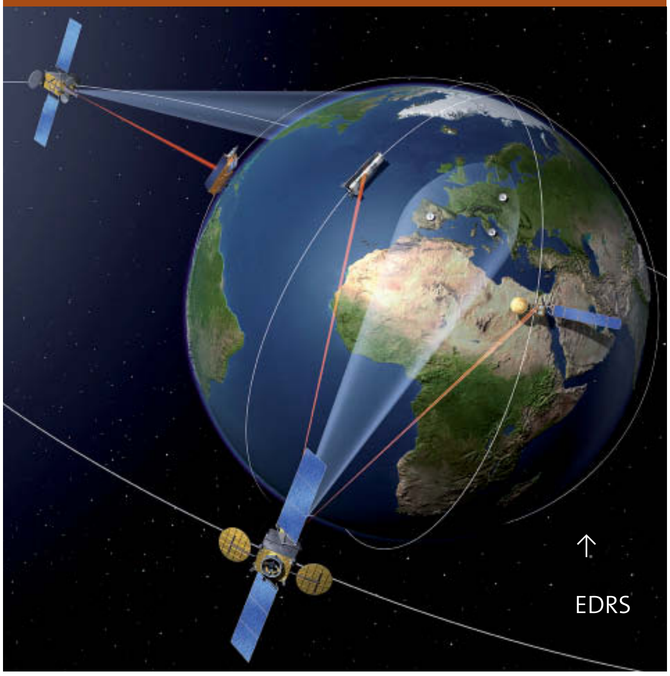
↑ Hylas

→ ARTES 7: EDRS

ARTES 7 is developing the European Data Relay Satellite system. The EDRS is intended to be a geostationary system comprising several payloads that provide links to low Earth orbit satellites, and possibly other spacecraft, enabling real-time communication between these spacecraft and their respective Control Centre.

ESA initiated already a precursor data-relay oriented programme with the development and launch of Artemis in 2001. Artemis has demonstrated the many operational and performance benefits that the availability of a data-relay satellite offers. In the meantime, the demand for real-time high volume files is expected to increase dramatically with the beginning of operation of the GMES/Sentinel system and future Earth observation and other missions. At the same time, the capacity of optical intersatellite links and their reduction in terms of mass and power requirements have jumped forward by at least one order of magnitude, as also radio systems have improved.

The EDRS programme aims to create a new type of satellite services. It intends to bring the development and implementation of the system to a sufficiently mature stage, so that the resulting services can be provided by a satellite operator on a commercial basis.



↑ EDRS

→ ARTES 8: ALPHABUS/ ALPHASAT

ARTES 8 is dedicated to the development of a European large telecommunications platform (Alphabus) and its qualification in orbit on its first mission (Alphasat).

The growth of the demand for telecommunications satellites has been accompanied by an increase in the capacity requested of each satellite. As the traditional FSS/BSS Satellite Operator's fleet consolidate, a benefit of scale emerges by increasing the amount of transponders that are fitted in a given spacecraft. New operators, offering services such as Mobile Broadcasting satellites, new generations of broadband internet access systems and Mobile Interactive systems, call for very large platform capabilities.

In this context ESA, in coordination with CNES, has undertaken a joint project with the two main European prime contractors Astrium and Thales Alenia Space to develop a new platform product range. Alphabus is designed to accommodate payloads with power requirements of up to 18 kW at present, and up to 25 kW in the future, with payload masses over 1 ton.

For the first mission, the development of the platform will be concluded in partnership with Inmarsat. Inmarsat was chosen after an Announcement of Opportunity and a very thorough selection procedure of interested bidders.

→ ARTES 11: Small GEO, LUXOR platform and Hispasat AG

ARTES 11 is devoted to the low-end of the platform market. While the average size of communications satellites has been increasing, a significant number of orders have been placed on small geostationary systems. This demand has been mainly triggered by either established or new entrants, with limited resources, intending to open new orbital locations or initiate new services. An industrial team lead by OHB has proposed to ESA the development of a small geostationary platform, called LUXOR, aimed to the 3 kW market segment. This proposal has resulted in the commitment to producing the first flight unit.

In a manner similar to ARTES 8, ESA has invited proposals from operators to embark a payload and have LUXOR flown and qualified in orbit. This process has resulted

Alphasat, or Inmarsat XL as it is named as part of the Inmarsat fleet, will enlarge, complement and back up the existing Inmarsat 4 system.

↑ Alphasat

in the selection of the offer of Hispasat which proposes a mission (Hispasat AG) with a payload that combines conventional Ku-band capacity with an advanced set of developments: regenerative onboard processors and active Ku-band antennas, collectively known as the REDSAT programme.

↓ Small GEO (OHB-Technology AG, Bremen)

→ ARTES 10: Iris

ARTES 10 is dedicated to the development of the satellite-based complement to the next-generation 'Air Traffic Management System' currently under development in the EU-supported SESAR (Single European Sky ATM Research) Programme.

The air traffic management systems of today use VHF radio. This has a number of limitations in the performance and capacity of the services that can be offered, as well as on their ability to cope with the foreseen growth of air traffic demand. Furthermore, all communications today need line-of-sight channels, implying a vast network of VHF transmitters and limited oceanic coverage. The upgrade and redefinition of air traffic management systems is being undertaken in SESAR, with the objective of defining a communication standard that can be submitted to worldwide standardisation at the International Civil Aviation Organization (ICAO).

A satellite-based complement to the proposed new system will bring undoubted benefits. ARTES 10 proposes the development and preliminary implementation of a satellite-based system called Iris. Iris will demonstrate and help to qualify the exigent security of life standards required by the different services all elements of the communication network, i.e. space segment, ground network and the airborne terminals.

↓ Iris

→ ARTES 20: Integrated Applications

ARTES 20 is dedicated to the development of space-related applications combining the resources of multiple space domains, e.g. telecommunications, Earth observation, navigation, etc. The Integrated Applications Element aims to provide space-based solutions to a wide range of issues that face European society, such as those related to health, transport, development, security and energy.

An initial objective of this Element is to trigger awareness of the benefits that satellite-based solutions can offer. These are not always known by many of the institutions responsible for these respective issues. Once awareness is created of space-based solutions, and interest is confirmed, a second stage of the process takes over. This is the implementation in partnership with the interested institution, possibly with the creation of pilot systems that allow evaluation and demonstration of the performance of the proposed Integrated Application.

There are several ways to participate in Integrated Applications projects. Feasibility studies initiated by ESA are fully funded. Developments proposed by industry, typically with a well-defined commercial objective, are co-funded up to 50%. If the project is the result of an agreement between ESA and an institution, the terms of the partnership are determined on a case-by-case basis.

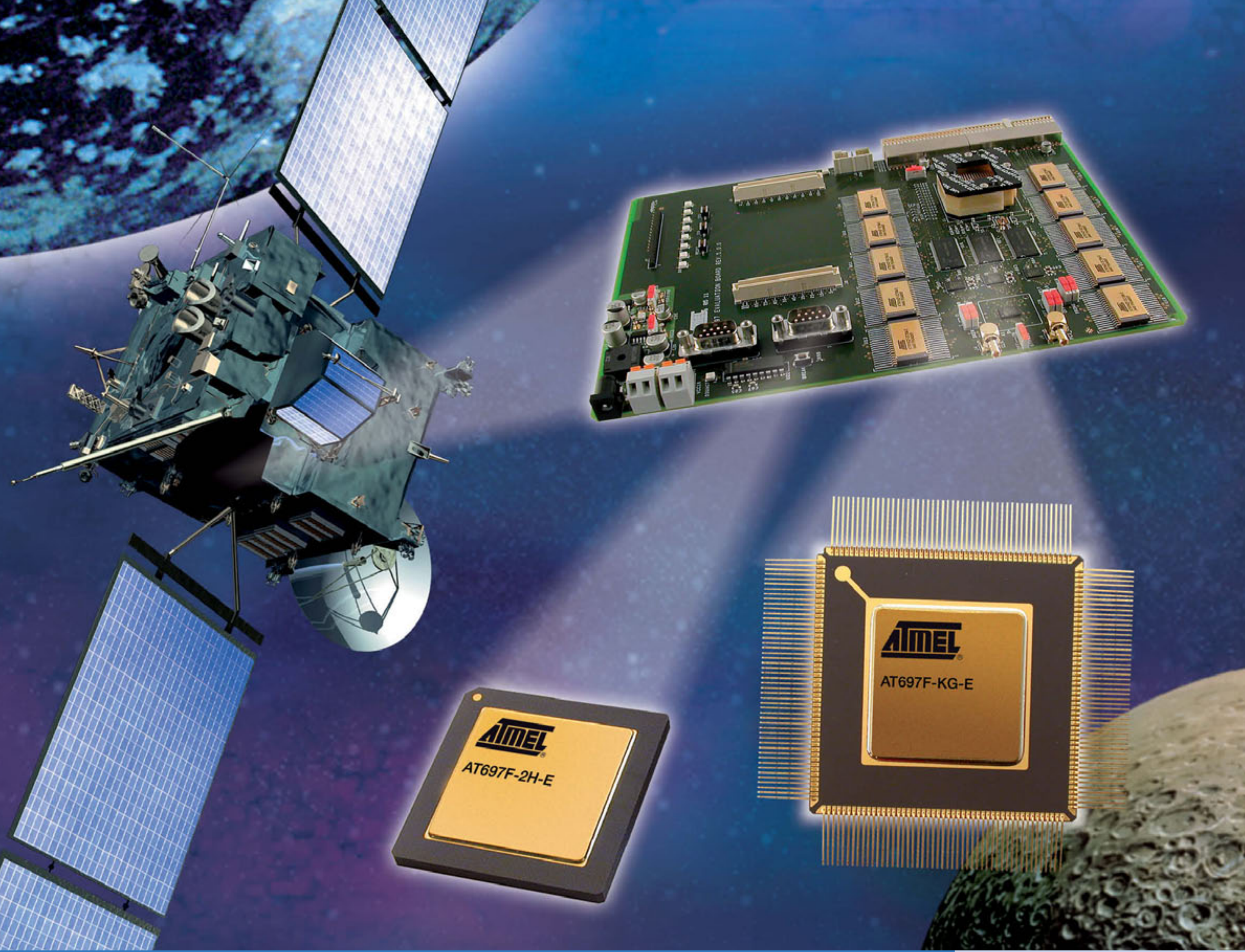
↑ IAP

R&D is essential for future competitiveness

The satellite telecommunications sector is definitively the main commercial driver of the space industry. But the sustainability of the industry as a whole depends to a large extent on maintaining competitive telecommunication capabilities. However, the telecommunications world, and the satellite communications industry, is in a constant state of flux, with new services and systems constantly evolving. To ensure competitiveness tomorrow, it is necessary to keep up levels of investment in R&D today.

Satellite communications, in combination with other sectors of space, can provide solutions to the needs of European society, contributing to solving some of our most pressing problems.

The Telecommunications and Integrated Applications Directorate of ESA, with the support of delegations participating in their programmes, aims to make sure that European industry and institutions are ready to meet these challenges.



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Soyuz TMA-15 approaches the ISS with mountains of central Asia below

→ LIFE IN THE OASISS

ESA's second long-duration ISS mission

Martin Zell & Eric Istasse
Directorate of Human Spaceflight,
ESTEC, Noordwijk, The Netherlands

OasISS is another achievement in ESA's International Space Station (ISS) programme, coinciding with the start of six-man crew operations, the maiden flight of Japan's HTV carrier and first European commander of the ISS.

27 May 2009. Baikonur Cosmodrome, Kazakhstan. Frank De Winne waits in a Soyuz capsule for the start of the engines of the rocket that will take him into space. The situation is not new to him. In 2002 he was in a similar capsule, waiting for the start of the Odissea mission. However, this time the roar of the engines means the start of a six-month stay on the ISS.

Sitting beside him in the Soyuz TMA-15 capsule are crewmates Roman Romanenko, the young Soyuz Commander about to fly into space for the first time, and Canadian Bob Thirsk, who has already been in space with the Space Shuttle in 1996.

After a flawless launch, the two days before docking with the ISS are punctuated by operations and radio contacts for the crew inside the Soyuz. This time is also used to get their bodies accustomed to the weightless conditions. On 29 May, the Soyuz nears the ISS and enters Earth's shadow. The coast of China passes by underneath the spacecraft. The spacecraft is light on. The Station is there. Contact. After pressure checks and the hatch opening, the next expedition on the ISS begins.

This is the first six-man crew on the ISS, and a crew where all ISS partners are represented. For the new crew, it is like a dream. The hatch slowly opens, and there are the first handshakes, and the pleasure of meeting friends and colleagues again. They feel the joy that many people on Earth, above all their families, are sharing these moments simultaneously on TV, and hear the message of congratulations received from Mission Control.

After the greetings, the astronauts get on with the content of the flight, beginning many carefully planned and

↑

(Above) Canadian Bob Thirsk, Flight Engineer 2 on Expedition 20, enters the ISS

(Above right) Frank De Winne, new Expedition 20 Flight Engineer, autographs the ISS bulkhead and his mission sticker

scheduled activities. The life of an astronaut on the ISS involves the activities such as maintenance and repair of the Station's systems and performing scientific experiments, but there are also lesser known tasks, such as the relocation of hardware, support to the docking of the Shuttle, preparation of spacewalks, robotic operations and, of course, public relations and education activities.

First guests

The Space Shuttle *Endeavour*, STS-127, docked with the ISS on 17 July. An external platform was attached to the Japanese 'Kibo' laboratory and, together, the Shuttle and Station crews make five spacewalks to complete the operational programme. Then it's time to relax. For the first time, 13 astronauts are seated around the ISS's main table for dinner. This is impressive, with so much life and noise on the Station, and what better way to celebrate the 40th anniversary of man's first steps on the Moon. The Japanese astronaut Koichi Wakata leaves, to be replaced by Tim Kopra from NASA. The Space Shuttle departs. Another arrives. On 31 August, Space Shuttle *Discovery* brings with it the Multi-purpose Logistics Module 'Leonardo' and also a second ESA astronaut, Christer Fuglesang from Sweden. Fuglesang performs two spacewalks. Again there are 13 astronauts around the dining table. The second European-built Minus Eighty-Degree Laboratory (MELFI-2) freezer, delivered with the MPLM, is literally a cool piece of kit, but to warm up there is the brand new treadmill 'COLBERT'.

Visitor from Japan

Time goes by, and the Shuttle *Discovery* leaves too. The very first Japanese logistics vehicle, the H-II Transfer Vehicle (HTV-1), docks with the ISS. Different to an ESA Automated Transfer Vehicle, which docks automatically with the ISS, the HTV-1 remains at a safe distance from the Station and waits

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De Winne gets down to work on the Water Recovery System in the Destiny laboratory

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A colourful Expedition 20 crew, clockwise from lower left: Mike Barratt, Gennadi Padalka, Tim Kopra, Bob Thirsk, Roman Romanenko and Frank De Winne to be grabbed by the ISS robotic arm. NASA astronaut Nicole Stott is in charge of 'grabbing', assisted by Frank De Winne and Bob Thirsk.

On 17 September, the HTV-1 is grappled and manoeuvred for docking to the nadir port of Node-2 Harmony. Next, De Winne transfers the external payloads brought by the HTV-1 to the external 'Exposed Facility' platform on Kibo using the Japanese robotic arm.

'Take your classroom into space'

During a live in-flight call on 21 September, Frank De Winne demonstrated a curriculum-relevant experiment on the conditions in freefall, to hundreds of secondary school students in four science centres in Barcelona, Mechelen, Milan and Thessaloniki. The demonstration was about mass measurement ('Do objects have weight in space?'). During the live link recording, Frank wore a T-shirt printed with a logo designed by schoolchildren.

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Video still of De Winne making his live science demonstration to students on 21 September

The challenge of exploration

At the time of printing, about a month of the OasISS mission remains. So much has already been achieved, but there is still an interesting time ahead. On 11 October, Frank De Winne became the first non-American and non-Russian Commander of the ISS. It is a tribute to the quality of European astronauts that they are now regularly assigned highly demanding tasks. It is also a challenge, but human exploration is always a matter of challenges.

This mission has seen a number of firsts, and coincided with the transition from assembly to utilisation of the ISS. It has provided ESA with significant utilisation opportunities, and another boost to operational experience in human

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With the arrival of the STS-127 crew in July, there are 13 people around the dinner table!

spaceflight. These are essential for the upcoming ISS lifetime extension decision (until 2020) and use of the ISS as a first major step towards human exploration of the Solar System.

Each day in space brings more experience, which will be needed when astronauts eventually go 'beyond the horizon' of Earth orbit, travelling further into space. To do that, European astronauts know they can count on the knowledge and expertise of all their predecessors and colleagues in European Human Spaceflight programmes. ■

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De Winne monitors the approach of the Japanese H-II Transfer Vehicle on the ISS video screens

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The H-II Transfer Vehicle seen station-keeping with the ISS before being 'grabbed' by astronaut Nicole Stott (Japanese Kibo laboratory and Node-2 Harmony are visible above)

→ Experiment programme

Left: Investigating the 'Structure of Paramagnetic Aggregates from Colloidal Emulsions' (InSPACE) experiment in the Microgravity Science Glovebox; right: Frank stores biological samples in the MELFI freezer in Kibo

During OasISS, there is full programme of European experiments in a range of scientific areas, many using the internal and external research facilities of the Columbus laboratory. These ESA scientific and technological experiments are to be carried out by Frank De Winne and members of the Expedition 20/21 crew, and also by visiting crews of Soyuz and Shuttle flights. The experiments, mainly funded by the European ELIPS Programme, address research in biology, human physiology, fluid sciences and materials sciences. Various in-flight demonstrations of basic physics principles to the benefit of secondary level students were also performed.

Human physiology

This research area is important for tackling problems of the human body during long-duration spaceflight, as well as for tackling similar health problems in the ageing human population on Earth. Most medical experiments require up to ten different human subjects to get a representative statistical significance of the science data.

NeuroSpat

This was the very first experiment to fully utilise the advanced capabilities of the Columbus laboratory's European Physiology Modules (EPM) facility, specifically the MEEMM unit that provides 'electro-encephalograms' (EEGs). Frank De Winne and Bob Thirsk set up the EPM and all instrumentation and performed the experiment as the first two human subjects, assisting each other.

NeuroSpat is actually a combination of two experiments: Neurocog-2 and Prespat. The purpose of Neurocog-2 is to study brain activity that underlies cognitive processes involved in four different tasks that humans and astronauts may encounter on a daily basis: visuomotor tracking, perception of self-orientation, 3D navigation and the discrimination of the orientation of objects. These tasks are designed to produce changed responses of the sensorimotor system, responsible for the body's coordination and stability, in the presence or absence of gravity. The roles played by gravity on these neural processes will be analysed by different methods including EEG during virtual reality stimulations.

The Prespat experiment uses physiological and behavioural measures to assess changes in general activation, prefrontal brain function and perceptual reorganisation. The Prespat experiment is funded as part of the European Commission's SURE project.

The first NeuroSpat experiment results have just been returned on data drives to Earth with the STS-128 flight.

3D-Space

This new physiology study investigates the effects of weightlessness on the mental representation of visual information during and after spaceflight. Accurate perception is a prerequisite for spatial orientation and reliable performance of tasks in space. The experiment has different elements including investigations of perception of depth and distance carried out using a virtual reality headset and standard psychophysics tests. First runs of the experiment have already been made by the ISS crewmembers Greg Chamitoff, Koichi Wakata, Mike Barratt during Expeditions 17, 18 and 19, and continued during Expedition 20 with Frank De Winne, Bob Thirsk and Tim Kopra.

Card

Long-term exposure to weightlessness increases our body's cardiac output and causes dilation of arteries in the face of increased activity in the sympathetic nervous system (which normally constricts arteries). The CARD experiment will examine these effects in order to provide a thorough picture of how the circulatory system changes during a prolonged stay in weightlessness.

CARD includes collection of blood samples, 24-hour urine collection, hourly blood pressure measurements for 24 hours, and cardiac output measurements with rebreathing every four hours except during sleep, using the ESA/NASA Pulmonary Function System.

This experiment has been carried out with Koichi Wakata during Expedition 19, and blood and urine samples returned with STS-127. Mike Barratt and Frank De Winne will also perform the experiment during Expedition 21.

SOLO

The SOLO experiment is carrying out research into salt retention in space and related physiological effects. It is a continuation of extensive research into the mechanisms of fluid and salt retention in the body during bed rest and spaceflights and subsequent effect on bone metabolism. Frank De Winne has already performed the two subsequent SOLO study phases, six days each, back-

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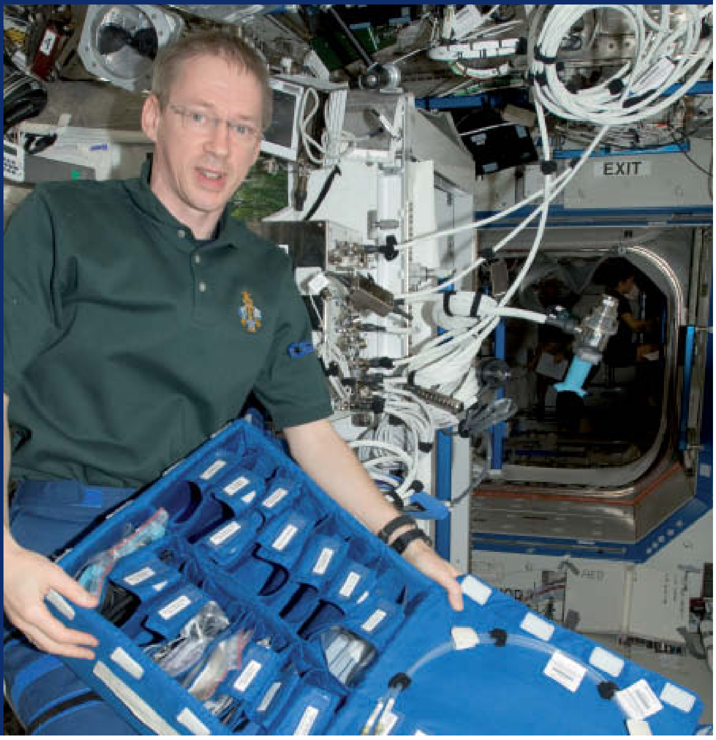
Frank holds a Portable Pulmonary Function System (PPFS) stowage bag in the Destiny laboratory



to-back. He followed a diet of either constant low or normal sodium intake, fairly high fluid consumption and isocaloric nutrition, the theory being that a lower sodium intake acts to decrease bone loss in space.

Portable Pulmonary Function System and ThermoLab

The Portable Pulmonary Function System (PPFS), just launched on HTV-1, is a new autonomous multi-user instrument supporting a broad range of human physiological research experiments in the areas of respiratory, cardiovascular and metabolic physiology.

ThermoLab investigates the hypothesis that heat balance, thermoregulation and circadian temperature rhythms are altered in humans during long-term spaceflights. These changes occur because of the natural convective heat transfer from the body surface to the environment, fluid shifts along the body axis from peripheral to central parts, changes in the cardiovascular and autonomous nervous systems and changes in metabolism and body composition.

Since these factors are all connected with each other in thermoregulation, an integrative study of the topic under weightless conditions was needed. This experiment investigates thermoregulatory and cardiovascular adaptations during rest and exercise in long-term weightlessness. After a functional checkout of PPFS, ThermoLab and VO2Max, experiments will be performed by Frank De Winne, Bob Thirsk, Nicole Stott and Jeff Williams.

European Flywheel Exercise Device

Astronauts on the ISS exercise on average two hours per day to counteract the adverse effects of weightlessness on bone and muscle. Strength training is an important part of this training, and a new piece of resistance training kit, the European Flywheel Exercise Device, has been sent up to the ISS. It is a novel exercise system that uses a rotating flywheel that replaces weighted plates or other means of resistance that rely on gravity. Frank De Winne will test this training device.

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Frank works at the Biolab incubator in the Columbus laboratory

Ground experiments (baseline data collection)

This category of experiments is performed by the astronauts before and after their space flights. Most of them are continuations of previous experiments in order to increase the statistical significance of the results produced.

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Frank and the ESA Foam Stability experiment floating freely in Columbus

EDOS

Early Detection of Osteoporosis in Space (EDOS) is a study into the mechanisms underlying the reduction in bone mass, which occurs in astronauts in weightlessness. It evaluates the structure of weight and non-weight-bearing bones (lower leg and arm respectively) of astronauts before and after flight using the method of computed tomography, together with an analysis of bone biochemical markers in blood samples.

Spin

This neurophysiology experiment is a comparison between pre-flight and post-flight testing of astronauts using a centrifuge and a standard tilt test. Orthostatic tolerance, or the ability to maintain an upright posture (without fainting), will be correlated with measurements of otolith/ocular function, the body's mechanism linking our inner ears and eyes that controls our sense of balance.

Biology experiments

Yeast B1 and B2

The Yeast In No Gravity (YING) experiment is the second to be performed in the Biolab facility. It studies the influence of weightlessness on 'flo' proteins that regulate flocculation (clumping together) and adhesion of cells. Both cell-surface interaction on solid media and cell-cell interaction in liquid media in yeast cells (*Saccharomyces cerevisiae*) will be investigated. The goal is to obtain a detailed insight into the importance of weightlessness on the formation of organised cell structures, and on 'flo' processes, which are of considerable interest for fundamental science, industry and the medical field. Frank De Winne received the Yeast experiment carried on the Soyuz TMA-16 (20S) flight and installed the experiment containers immediately in the Biolab incubator. The processed yeast samples were returned with the downgoing Soyuz flight a few days later

Fluid science experiments

Foam Stability

This project studies aqueous and non-aqueous foams in a weightless environment. The questions addressed are: how long are these foams stable? What is the role of solid particles in the liquid in water foam stabilisation? Is it possible to create very 'wet' foams in weightlessness? Frank De Winne performed this comprehensive demonstration experiment as Voluntary Science during his weekend spare time. A part of the experiment consists of a session to be compared with students in Europe who will perform the same experiment on ground.

IVIDIL/DSC

De Winne and Bob Thirsk installed the first of the three Selectable Optical Diagnostics Instrument (SODI) experiments in the European Microgravity Science Glovebox rack. The two SODI experiments 'Influence of Vibrations on Diffusion in Liquids' (IVIDIL) and 'Diffusion and Soret Coefficient Measurements' (DSC) will measure the thermal and isothermal diffusion coefficients of model mixture of fluids relevant to the oil industry. In the case of IVIDIL, the samples will be vibrated with a linear motor to measure the possible thermo-vibrational convective contribution to the mass transport process. The SODI experiments will provide reliable data, which will be used in current models of natural reservoirs in relation to oil exploitation and CO_2 sequestration.

Materials science experiments

Materials Science Laboratory (CETSOL & MICAST)

These two complementary projects will carry out research into the formation of microstructures during the solidification of metallic alloys using the European-developed Materials Science Laboratory (MSL). This was sent up to the ISS in the MPLM Leonardo on Space Shuttle flight STS-128 and installed by the crew in the Destiny lab according to a bilateral cooperation agreement with NASA.

The goal of MICAST is to study the formation of microstructures during casting of technical alloys. In space, buoyancy convection is eliminated and the dendritic solidification of the alloys can be quantitatively studied either under purely diffusive conditions or under controlled convection induced in the melt by rotating magnetic fields.

The complementary objective of CETSOL is to study the transition from columnar growth (that is, a front of dendrites developing into the melt as studied in MICAST) to equiaxed growth that occurs when crystals start to nucleate in the melt ahead of the dendrites and grow independently.

De Winne and his crewmembers performed the MSL checkout, and the processing of the first six sample cartridges has already started in the Low Gradient Furnace insert. The results obtained with the joint experimental programme in space will allow validation of advanced numerical models, in turn helping to optimise industrial casting processes.

FOCUS

Foam Casting and Utilisation in Space (FOCUS) is an industrial materials science experiment, which will investigate foam formation and stability in weightlessness. This focuses on the development of a multi-capillary foam generator, capable of producing foam without the effect of gravity. The results of experiments with model fluids will be used to develop a computational model of the foam generator.

Radiation, exobiology, space technology and physics

Frank De Winne installed the new DOSIS instruments in Columbus, and very interesting first results have been seen to date. De Winne is also supporting the relocation of the Matroshka radiation 'phantom' from the Russian segment to the Kibo laboratory.

The EuTEF platform, with nine instruments making up 13 experiments, was returned on STS-128 after one and a half years of exposure to open space. The nine exobiology long-term exposure experiments in Expose-R still continue, as well as the SOLAR external payload which measures the whole solar irradiance spectrum on the Columbus External Platform.

esa

→ Daily life on the ISS

As well as being the first European Commander of the ISS, Frank De Winne has barber duties! Tim Kopra evaluates...

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Frank and Bob demonstrate shaving in zero-g

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In another morning ritual, Frank squeezes water onto his toothbrush

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Daily exercise is vital. Equipped with a bungee harness, Frank exercises on the Treadmill Vibration Isolation System in the Zvezda module

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The glowing exhaust plume of Ariane 5 flight V181, carrying ESA's ATV *Jules Verne*, during the early morning of 9 March 2008

→ THIRTY YEARS OF ARIANE

Guaranteeing access to space for Europe

Carl Walker & Frédéric Castel
Directorate of Legal Affairs and External Relations,
ESTEC, Noordwijk, The Netherlands

As Europe celebrates the 30th anniversary of the first Ariane launch on 24 December 2009, we look at the achievements of this ESA-developed launcher.

When ESA came into being in 1975, one of its first objectives was to build a European launcher. The reason was simple: no launcher – no independent access to space – no space programme.

Although the Member States of ESA had different interests and priorities – some were interested in carrying out research in space while others were more concerned in developing satellites – on one point they were unanimous: Europe needed to have independent access to space and its own space programme. This meant that it had to develop launchers and have its own Spaceport.

In 1964, the French government had chosen Kourou in French Guiana as a base from which to launch its satellites. When ESA was created, the French government offered to share its Centre Spatial Guyanais (CSG) with the new space agency. For its part, ESA approved funding to upgrade the launch facilities at the CSG to prepare the Spaceport for the Ariane launchers under development.

The first flight of an Ariane rocket was scheduled for 15 December 1979. On that day, in front of a large and expectant audience at Kourou, the countdown reached zero and the rocket motor underneath the launcher roared into life – and then went out.

Fortunately, the fault was not serious and the launch was rescheduled for 23 December, but then bad weather and a few small problems led to yet another delay. The next attempt proved to be third time lucky. On 24 December, at 14:14 local time, Ariane 1 blasted into space from Europe's Spaceport and Europe's independent adventure in space had begun.

Ariane's roots

France had become the world's third space power with the launch of its Diamant A in 1965. The French success

↑ Ariane's first flight on 24 December 1979

continued with Diamant B in 1970, but these small launchers were not suitable for the larger payloads and could not respond to the market demand. A precursor of ESA, the European Launcher Development Organisation (ELDO), was developing the Europa rocket, which had been proposed at the Lancaster House Conference in UK in 1963 as a civilian satellite launcher based on elements from the different European countries.

Tasks were distributed between nations: the United Kingdom would provide the first stage (derived from the Blue Streak missile), France would build the second and Germany the third stage. The project was marred by technical problems. Although the first stage launched successfully on each occasion, it was the second or third stage that failed. By February 1973, Europe's rocket programme had been scrapped.

For France, independent access to space was of paramount strategic importance from the outset. At a European Space Conference in December 1972, the French Minister of Industrial and Scientific Development, Jean Charbonnel, had already proposed a plan to develop in Europe some independent capability to launch telecommunication satellites. (At the same meeting, the British Minister for Space proposed that a single space agency should be built from ELDO and ESRO).

A tough battle among Europeans lay ahead to achieve what would ultimately become the world's premier commercial launch system. The United Kingdom had given up on the ambition of an autonomous European launcher industry and was content to use US rockets. Germany appeared to be losing interest in Europa III, despite its support to the project being essential. Then, in March 1973, before any European agreement was reached, France announced that it would shoulder a major part of the funding for the development of a 'third-generation substitution launcher' (L3S) replacement for Europa.

By July, the European partners attended the sixth European Space Conference. France was going to build a launcher, Germany wanted collaboration on NASA's Spacelab and the United Kingdom was promoting a maritime communications satellite, MAROTS. The conference finally managed to bring the three nations together. Each partner knew it would only get what it wanted if it agreed to cooperate on each other's projects. Paradoxically, though, this agreement was also in part reached due to a policy of the United States.

"The USA was the only Western nation to possess launch vehicles, but the conditions they set for launching European satellites were totally unacceptable. They wanted our satellites to be functional exclusively over the European zone, which of course would have prevented Europe from extending its political and cultural influence around the world and from competing with them on the global marketplace," said Charles Hanin, then Belgian minister for science. At this same July conference, the words 'European Space Agency' were mentioned for the first time. It was agreed that ELDO and ESRO would merge sometime in 1974 or 1975 to form the future single space agency, and one of its catalysts was to be Ariane which, since its inception, was linked to the question of institutional reform.

The spirit of Ariane

The outstanding success of the first Ariane launch was also a human achievement of team spirit. All the odds were stacked on the other side of the Atlantic. The United States

→ Naming Ariane

By Dr Peter Creola, formerly Head of the Swiss Space Office (SSO) and Swiss delegate to ESA Council

"On the day after the final meeting in Brussels, the Swiss delegation seized this opportunity to propose that the unwieldy working name of the launcher, L3S (which stood for 'lanceur de troisième génération de substitution'), be replaced by a definitive and more attractive name. Only the French delegate, André Lebeau, backed Switzerland.

All the others did not think the name of the launcher was important. However, I insisted that it was, and passed around a sheet of paper on which delegates could suggest names. Some of these were simply jokes, like 'William Tell' and 'Edelweiss', which came about because the meeting was being held on 1 August 1973, the Swiss national holiday. Other suggestions, such as 'Orion' and 'Vega', were more usable. The latter name came up three times, and it therefore won the informal competition. A name had still not, however, been officially decided upon. In the text of the launcher agreement, which was still under negotiation, the name of the launcher was left blank.

Then, in September 1973, the day came when the documentation of the agreement had to be approved by the Administrative and Finance Committee. By coincidence, I was chairing this committee. When I proposed that we now bite the bullet and insert the name Vega in the text, the French delegation objected. French minister Jean Charbonnel pointed out that Vega was the name of a French beer.

The French deemed only three names to be acceptable: 'Penelope', 'Phoenix' and 'Ariane'. The German delegation immediately objected to Phoenix, because the ashes of ELDO were still hot. Penelope was also thought to be unsuitable, and so Ariane was chosen [Ariane is the French version of the Greek mythological character Ariadne, whose famous thread led the way out of the Minotaur's labyrinth]. Nobody could have foreseen that, almost 30 years later, ESA's small launcher would be called Vega."

was winding up its fleet of expendable launchers in favour of the reusable Space Shuttle. This was supposed to cut costs, with launches of production-line satellites set to become a weekly occurrence. Faced with such an outlook, who would have banked on a conventional rocket proving successful?

But for six years, the industrial teams of each ESA Member State participating in the programme worked hard without any doubt on the outcome. They produced a three-stage launcher capable of placing a nearly one-tonne satellite into a geostationary orbit. After a difficult three-month launch campaign and a frustrating launch abort, the first Ariane was sent aloft.

There was both joy and astonishment at the same time. Not only could the Europeans – as a new united force – build a rocket launcher after all, but Ariane came to symbolise an open market in which the first commercial launch system was marketed worldwide. The night following the first launch, all the launch team was partying in the Hotel Les Roches in Kourou. Not far away, in the middle of a loud post-launch party in the open air, a new tradition started. The director of launch operations was thrown, fully dressed, into the swimming pool by his colleagues. And then, one after the other, all the managers of the launch team were also pulled into the water to loud applause from the audience. This tradition has always remained for every successful launch.

The Ariane family

Ariane 1 was designed primarily to put two telecommunications satellites at a time into orbit, thus reducing costs. But after the first Ariane success, it soon became apparent that the lift capability of the original Ariane was no longer sufficient to meet international market demand, for satellites were increasing in size and mass. ESA reacted promptly.

In 1981, it embarked on a programme designed to improve the performance of the European launcher. Ariane 1 gave way to the more powerful Ariane 2 and Ariane 3 launchers. All three launchers were slightly different. The first and third stages of Ariane 2 and Ariane 3 were longer than those of Ariane 1, while Ariane 3 had strap-on boosters containing liquid or solid propellant, making it the most flexible and powerful of the three launchers, capable of launching a payload of 1.7 tonnes.

Altogether, 11 successful Ariane 1 launches took place between 1979 and 1986, and five successful Ariane 2 flights between 1987 and 1989. Ariane 3 made a record 11 flights from 1984 to 1989, all of which were successful.

Arianespace

As early as the mid 1970s, Frédéric d'Allest, the CNES Launchers Director, had been working on these future versions of Ariane in order to increase its payload launch

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Left: Giotto's launch on an Ariane 1, 2 July 1985; Right: the first Ariane 3, launched on 4 August 1984

capability. The idea behind this was to be able to promote the future European rocket in the international launch service market. Considering the US monopoly in this field, this approach by the Ariane project was considered by some as arrogant and doomed to failure.

However, everything changed in December 1978. One year before the inaugural launch of Ariane, the Intelsat organisation decided that it did not want to put 'all its eggs in one basket'. Intelsat ordered two US Atlas-Centaur rockets, three US Space Shuttle launches and three Arianes.

While a number of ESA Member States held that space agencies were the appropriate entities to provide launch services, this possibility for ESA's supply of launch services being reflected in the Convention, it was finally decided to officially set up in 1980, three months after the first launch of an Ariane, the world's first private-sector launch service provider, Arianespace, to handle Ariane operations and in particular its commercialisation,. Its shareholders were drawn from European space industry and French State participation through CNES.

Ariane 4

Ariane 4 was justly known as the 'workhorse' of the Ariane family. From its first flight on 15 June 1988 until the last in 2003, it made 113 successful launches carrying over 180 satellites. The Ariane 4 proved ideal for launching communications and Earth observation satellites as well as payloads for scientific research. This launcher was extremely versatile. The first stage could hold two or four strap-on boosters, or none at all. This meant that it could lift satellites weighing from 2 tonnes to nearly 4.3 tonnes into geostationary transfer orbit, nearly three times more than Ariane 3.

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The Ariane 4, first launched on 15 June 1988, would prove to be an extremely versatile launcher

During its working life, Ariane 4 captured over 50% of the commercial geostationary orbit satellite market, showing that Europe could more than hold its own in the commercial launch field. Ariane 4 grew to become the undisputed star of the Ariane family and was one of the most reliable and economically successful launchers in the world.

Europe's latest workhorse

ESA had originally designed Ariane 5 to further reduce the cost of launching commercial satellites and to launch the manned 'spaceplane', Hermes, in the 1980s. Despite abandoning the Hermes project, it still was remarkable that Ariane 5 proved to be ready at exactly the right time. By the mid 1990s, Arianespace realised it had to adapt to a changing market for bigger satellites. To keep its ranking as one of the leading launch companies in the world, it had to replace the highly successful but ageing Ariane 4 with a totally new vehicle, the Ariane 5.

The new Ariane 5 was designed to lift a payload of up to 6 tonnes into geostationary transfer orbit and 9.5 tonnes into Sun-synchronous orbits and Earth-escape trajectories. Standing 52 metres high, each rocket was composed of a central core and upper stage, and two solid rocket boosters. To launch this huge rocket, ESA had to build another launch site at Kourou, as well as facilities to integrate the solid boosters and to produce the solid propellant used in the boosters.

A lot was at stake. Unfortunately, the inaugural test of the new heavy launcher in 1996 ended in failure. There was a serious software problem related to the inertial guidance system. ESA, CNES and industrial teams worked for 16 months to ready the second Ariane qualification flight, V502, but it was only a partial success. The rocket's main engine shutdown prematurely, and even though the upper stage operated successfully, it could not reach the intended orbit. A subsequent test flight proved successful, and the first commercial launch (L504) occurred on 10 December 1999 with ESA's XMM-Newton x-ray observatory. In the meantime, Ariane 4 had ensured continuity for Arianespace's customers. In the last half of 1999, Arianespace broke a new record by completing eight launches in a year. On 15 February 2003, with Ariane 5 at full operational capability, an early morning launch marked the final flight of an Ariane 4, and the 116th mission of this launcher version.

→ Ariane 5 shown with the Hermes spaceplane

↓ ESA's Hermes manned spaceplane concept planned in the 1980s

↑ The first Ariane 5 was lost during its test flight on 4 June 1996 when it exploded 40 seconds after lift-off

Ariane 5 evolution

Between 1996 and 2003, the Ariane 5 Generic launcher made 16 launches from Europe's Spaceport. This rocket could launch single, dual or even triple payloads (as in flight 162 on 27 September 2003). Apart from the initial qualification flight which ended in failure 39 seconds after lift-off, and the 10th flight where a problem with the storable propellant stage placed one satellite in an unrecoverable orbit, the Ariane 5 Generic launcher had demonstrated its robustness and reliability.

To improve the performance of this first Ariane 5 version, a limited number were produced with modifications such as Ariane 5 Generic Plus. Responding to changes in market demand, further upgrades were made to Ariane's launch capacity, leading to the Ariane 5 ECA, GS and ES ATV versions.

The Ariane 5 GS is the latest evolution of the Generic launcher, and a limited number were produced, with its first flight taking place on 11 August 2005. The latest version, Ariane 5 ECA, was designed to place payloads weighing up to 9.6 tonnes into geostationary transfer orbit. This new version would help to maintain Europe's competitiveness in the commercial space transport sector by offering customers the opportunity to launch a wider range of heavier satellites while allowing for cost reductions.

The ES ATV version, designed to launch ESA's Automated Transfer Vehicle, is capable of lifting almost 21 tonnes into a low Earth orbit. Its maiden flight took place in 2008, carrying the ATV *Jules Verne* to the ISS.

From 1996 to October 2009, Ariane 5 has made an impressive total of 43 successful launches, and set many space records. In May 2007, an Ariane 5 ECA set a new commercial record, lifting into orbit two satellites with a combined weight of 8.6 tonnes. Later the same year, another Ariane 5 ECA broke this record when it launched a payload with a total weight of 9.5 tonnes. Ariane's record-making continued, when on 1 July 2009, an Ariane 5 ECA launched TerreStar-1, the largest commercial telecommunication satellite ever built.

"Ariane 5's capabilities will be further enhanced when its payload lift performance is increased by late 2010. This will be accomplished by using lessons learned from the launcher's operating experience, including the optimisation of mission trajectories," said Jean-Yves Le Gall, Chairman of Arianespace.

The balance between a working and reliable system and the need for technical development is being constantly evaluated by ESA and the European launch industry. The choices for the future are often difficult to make, but there are perhaps some lessons to be drawn from this glorious past.

"The 30-year achievement of Ariane is history of a political, technical and commercial success, which has become one of the symbols of a winning Europe. Nothing would have

The first successful flight of Ariane 5, flight 503, on 21 October 1998

The last flight of Ariane 4, on 15 February 2003 happened without the initial impulse of France and its space agency CNES, but nothing would have happened either without the other ESA Member States which provided the know-how of their industry, the corresponding finance and solidarity which made possible the transformation – all together – of failures into successes," says Jean-Jacques Dordain.

Further reading

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↓ View of today's Ariane 5 from the launchpad

↑ The night sky is illuminated by the engines of Ariane 5 flight 511, its exhaust plume in shadow, carrying Envisat in 2002

Innovative Solutions for Space Applications

Photos: ESA / EADS

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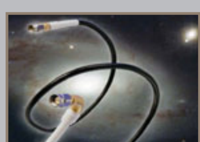

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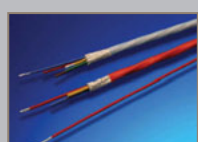


ESA astronaut Christer Fuglesang during one of his spacewalks on the STS-128 flight

→ ALISSÉ MISSION

Special report

ESA's Alissé mission was ESA astronaut Christer Fuglesang's second spaceflight. As a Mission Specialist for STS-128, a principal focus of Fuglesang's mission was his spacewalk activity.

The 13-day STS-128 flight marked the continued supply and assembly of the International Space Station (ISS), as well as many important milestones for ESA, European astronauts, and European science and industry.

The mission began with the launch of Space Shuttle *Discovery* from NASA's Kennedy Space Center in Florida on 29 August 2009. A few days later, on 31 August, *Discovery* docked with the ISS allowing Fuglesang and his crewmates to be welcomed on board the Station by fellow ESA astronaut and member of the Expedition 20 crew, Frank De Winne.

As part of his mission, Fuglesang carried out a programme of experiments, educational and public relations activities. He

STS-128 and Expedition 20 crew members pose for a photo

A thumbs up from his colleague Frank De Winne, Fuglesang is ready for his first EVA participated in medical experiments: one measuring spinal elongation in space, another on logging sleep time. He also took part in an ESA-sponsored investigation into the effect of weightlessness on an astronaut's perception of motion and tilt, as well as his level of performance before and immediately after flight.

Amazing sight

Fuglesang took part in two of the three STS-128 spacewalks (EVAs). Together with NASA astronaut John Olivas, he performed the second mission spacewalk on 4 September, installing a new Ammonia Tank Assembly (ATA) on the ISS and stowing a depleted ATA for return to Earth. He also participated in the third spacewalk on 5 September, carrying out work to prepare for the arrival and installation of the European-built Node-3 and Cupola in February 2010.

Commenting on his spacewalk experience afterwards, Fuglesang said: "With the experience I gained in 2006 on the Celsius mission, it was easier to adapt quickly this time around. However I was still a little bit surprised when I exited the airlock for the first of my STS-128 spacewalks and looked down at Earth. An amazing sight! I hadn't quite expected to feel this way."

Problem-solving in real time

"During my second spacewalk, the last of STS-128, I simply enjoyed the feeling, moving around. The most spectacular moment came when I was handling the 800 kg Ammonia Tank Assembly, claimed to be the biggest element to have been moved around by one person in space to date, but actually it was more a mental than a physical exercise," said Fuglesang.

"I enjoyed this last spacewalk the most, as we had to improvise several times, problem-solving in real time, which we managed to do efficiently, given the sound and effective training that we had received pre-flight. In terms of preparing for the arrival of Node-3, we laid out two cable bundles close to where Node-3 will be docked to Node-1 which was easier to do in space than it had been in the buoyancy training facility on ground."

Fuglesang and Frank De Winne install new crew quarters in the Japanese Kibo laboratory

Fuglesang meets an 'old friend', his Extravehicular Mobility Unit, or spacesuit...

On his second spacewalk, Fuglesang installs two GPS antennas and prepares for Node-3 installation next year

Fuglesang checks out a 3D still camera on the ISS

Important tasks

As well as ISS maintenance during spacewalks, Fuglesang had to oversee the transfer of equipment from the European-built Multipurpose Logistics Module (MPLM) Leonardo, carried in the payload bay of the Space Shuttle. The MPLM contained the Material Science Research Rack, containing the Materials Science Laboratory (MSL), the MELFI-2 Minus Eighty-Degree Laboratory Freezer for stowage in the Japanese Kibo laboratory, and the Fluids Integrated Rack (FIR).

The Space Shuttle *Discovery* undocked from the ISS on 8 September, carrying the Leonardo MPLM packed with cargo items for return to Earth. These included the European Technology Exposure Facility (EuTEF), a suite of nine scientific experiments that had been exposed to the harsh environment of space outside the ISS over the last one and a half years.

On the flight deck of the Shuttle, Fuglesang takes some photos at the end of his mission

Space Shuttle *Discovery* lands at Edwards Air Force Base, California, on 12 September

↑

Fuglesang handling the 800 kg Ammonia Tank Assembly, the largest ISS element moved by one person to date. His feet are attached to the Canadarm2 foot restraints

EGNOS - Follow the new star

As Europe's first contribution to satellite navigation, EGNOS is now operational and provides powerful augmentation of the GPS signals. It provides high vertical and horizontal positioning accuracy and its current coverage area already includes most European states. The Open Service of EGNOS is available free-of-charge since 1 October 2009.

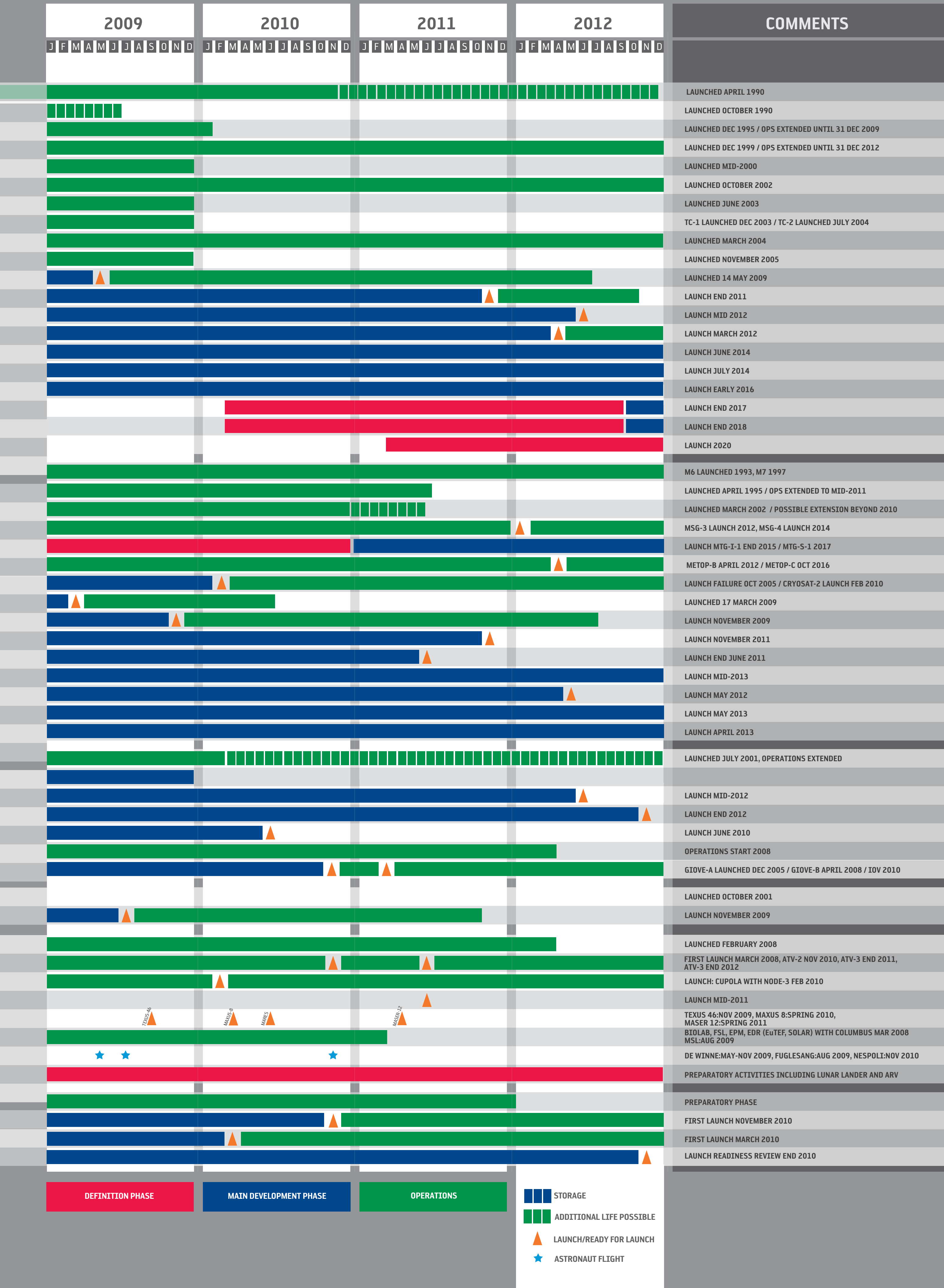
EGNOS

Navigation solutions powered by Europe

→ PROGRAMMES IN PROGRESS

status at end September 2009


2005
2006
2007
2008
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
ULYSSES
SOHO
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
DOUBLE STAR
ROSETTA
VENUS EXPRESS
HERSCHEL/PLANCK
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
EXOMARS
COSMIC VISION M1
COSMIC VISION M2
COSMIC VISION L1
EARTH OBSERVATION PROGRAMME
METEOSAT-6/7
ERS-2
ENVISAT
MSG
MTG
METOP
CRYOSAT
GOCE
SMOS
ADM-AEOLUS
SWARM
EARTHCARE
SENTINEL-1
SENTINEL-2
SENTINEL-3
TELECOMMS/NAV. PROGRAMMES
ARTEMIS
ALPHABUS
ALPHASAT
SMALL GEO SAT.
HYLAS
GNSS-1/EGNOS
GALILEO
TECH. PROG.
PROBA-1
PROBA-2
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS
ATV
NODE-3 / CUPOLA
ERA
EMIR/ELIPS
MFC
ASTRONAUT FLT.
TRANS. & HUMAN EXP.
LAUNCHER PROG.
ARIANE 5 POST-ECA
VEGA
SOYUZ AT CSG
IXV


2009
2010
2011
2012
COMMENTS
J F M A M J J A S O N D
LAUNCHED APRIL 1990
LAUNCHED OCTOBER 1990
LAUNCHED DEC 1995 / OPS EXTENDED UNTIL 31 DEC 2009
LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 31 DEC 2012
LAUNCHED MID-2000
LAUNCHED OCTOBER 2002
LAUNCHED JUNE 2003
TC-1 LAUNCHED DEC 2003 / TC-2 LAUNCHED JULY 2004
LAUNCHED MARCH 2004
LAUNCHED NOVEMBER 2005
LAUNCHED 14 MAY 2009
LAUNCH END 2011
LAUNCH MID 2012
LAUNCH MARCH 2012
LAUNCH JUNE 2014
LAUNCH JULY 2014
LAUNCH EARLY 2016
LAUNCH END 2017
LAUNCH END 2018
LAUNCH 2020
M6 LAUNCHED 1993, M7 1997
LAUNCHED APRIL 1995 / OPS EXTENDED TO MID-2011
LAUNCHED MARCH 2002 / POSSIBLE EXTENSION BEYOND 2010
MSG-3 LAUNCH 2012, MSG-4 LAUNCH 2014
LAUNCH MTG-I-1 END 2015 / MTG-S-1 2017
METOP-B APRIL 2012 / METOP-C OCT 2016
LAUNCH FAILURE OCT 2005 / CRYOSAT-2 LAUNCH FEB 2010
LAUNCHED 17 MARCH 2009
LAUNCH NOVEMBER 2009
LAUNCH NOVEMBER 2011
LAUNCH END JUNE 2011
LAUNCH MID-2013
LAUNCH MAY 2012
LAUNCH MAY 2013
LAUNCH APRIL 2013
LAUNCHED JULY 2001, OPERATIONS EXTENDED
LAUNCH MID-2012
LAUNCH END 2012
LAUNCH JUNE 2010
OPERATIONS START 2008
GIOVE-A LAUNCHED DEC 2005 / GIOVE-B APRIL 2008 / IOV 2010
LAUNCHED OCTOBER 2001
LAUNCH NOVEMBER 2009
LAUNCHED FEBRUARY 2008
FIRST LAUNCH MARCH 2008, ATV-2 NOV 2010, ATV-3 END 2011, ATV-3 END 2012
LAUNCH: CUPOLA WITH NODE-3 FEB 2010
LAUNCH MID-2011
TEXUS-46
MAXUS-8
MASER-12
TEXUS 46:NOV 2009, MAXUS 8:SPRING 2010, MASER 12:SPRING 2011
BIOLAB, FSL, EPM, EDR (EuTEF, SOLAR) WITH COLUMBUS MAR 2008 MSL:AUG 2009
DE WINNE:MAY-NOV 2009, FUGLESANG:AUG 2009, NESPOLI:NOV 2010
PREPARATORY ACTIVITIES INCLUDING LUNAR LANDER AND ARV
PREPARATORY PHASE
FIRST LAUNCH NOVEMBER 2010
FIRST LAUNCH MARCH 2010
LAUNCH READINESS REVIEW END 2010
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS
STORAGE
ADDITIONAL LIFE POSSIBLE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

→ HUBBLE SPACE TELESCOPE

On 9 September, NASA released the Hubble Early Release Observations (EROs). These are images and spectra designed and processed to show the excellent performance of the various instruments. Also in September, Hubble took its 900 000th photograph since its launch in April 1990.

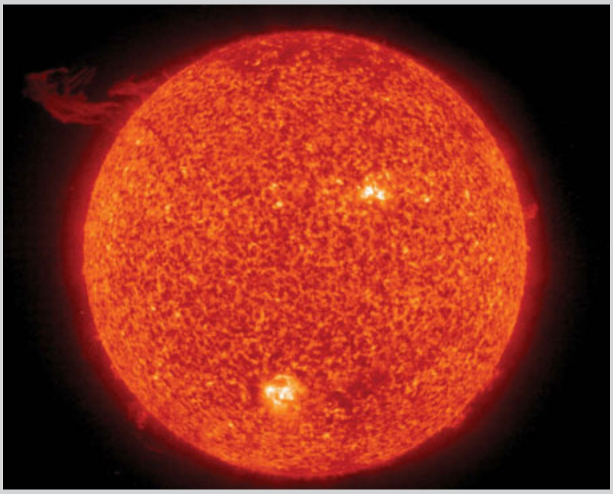
Stephen's Quintet, as seen by the new Wide Field Camera on Hubble. This group of five galaxies (HCG 92) is actually a misnomer, the galaxy at upper left, NGC 7320, is seven times closer to Earth than the rest of the group (NASA/ESA/ERO Team)

→ SOHO

For nearly 14 years, SOHO has observed the Sun, from its interior to the near-Earth solar wind. It is the first solar mission to observe a complete solar activity cycle and two successive solar minima. A SOHO-related workshop was held in Maine, USA, 21–25 September, for describing and understanding the peculiar properties of the current minimum, which has continued significantly longer than others during the space age.

The Sun is currently behaving in a way never seen since detailed observations from space began. The Sun entered its expected minimum period of activity in 2007 and has continued in this state for about a year longer than we have seen since about 1920. During this time, there has been a longer period of time without any sunspots than seen in any recent minimum. Observations of the solar interior indicate unusual flows in the subsurface of the Sun and unusual wave speeds at the base of the Sun's convection zone.

The total amount of light coming from the Sun is slightly less than in previous minima, and this can slightly lower Earth's global temperature, countering global warming to an unknown extent. The mean magnetic field of the Sun is lower than observed at any time during the space age and the structures of the Sun's outer atmosphere are different from anything observed during that time. Analysis of the ultraviolet and visible light from the Sun's corona indicate that the temperature of the corona is lower than usual, as is the magnetic field in interplanetary space and the density, temperature and pressure of the solar wind.

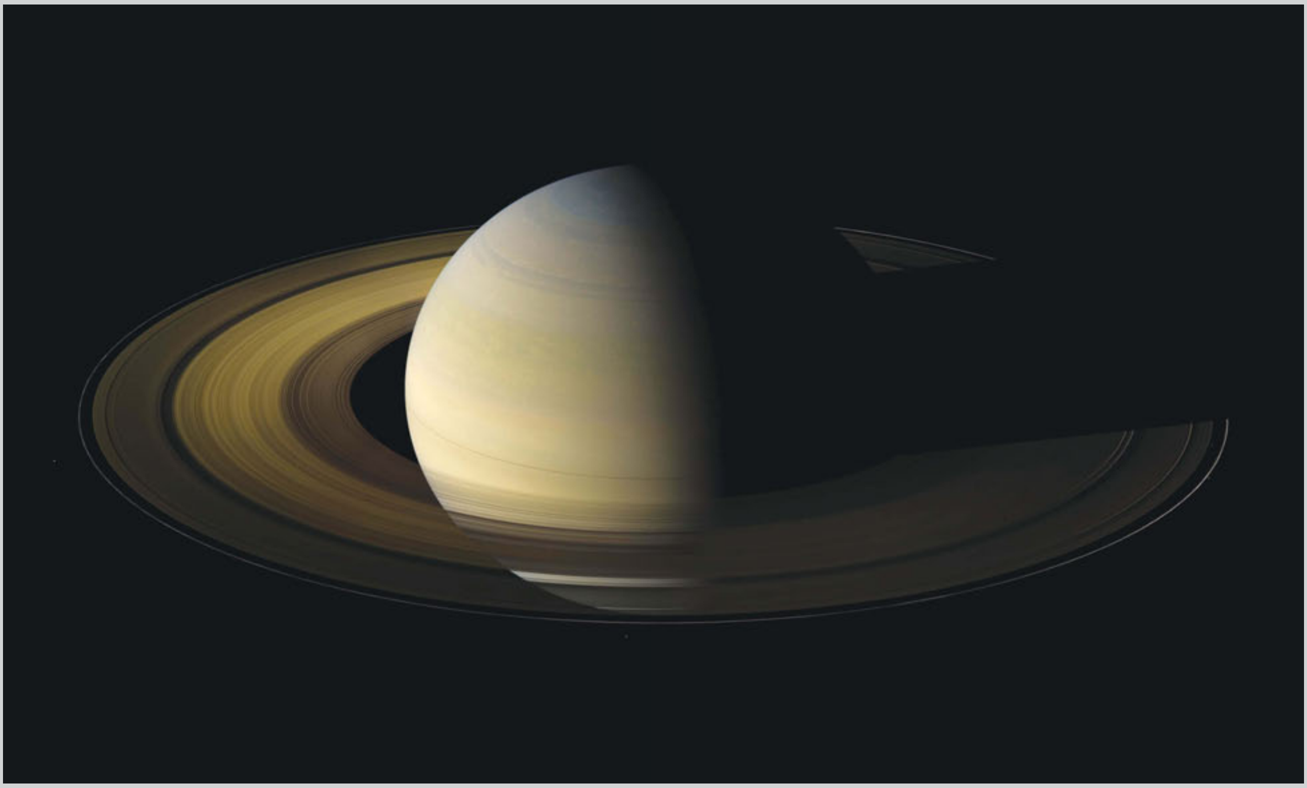


Is solar cycle 24 finally arriving? At the end of September, two new cycle active regions appeared on the Sun's surface, visible as bright regions in this SOHO/EIT image (ESA/NASA)

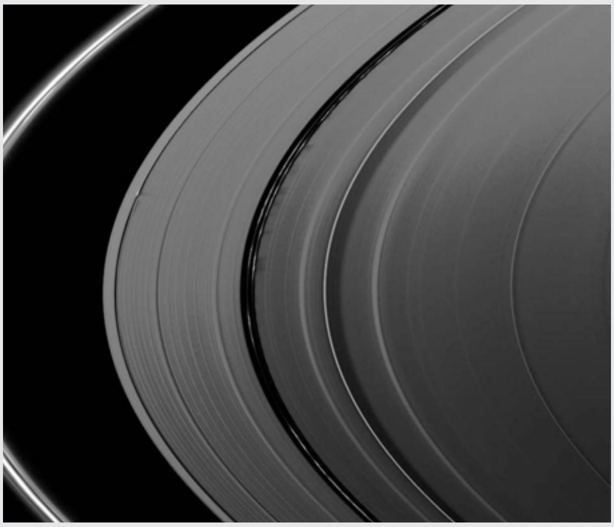
→ CASSINI/HUYGENS

As Saturn's ring plane was illuminated edge-on in August (Saturn's equinox day was 11 August), a series of unique observations by Cassini was made around that event. Discoveries will come from the analysis of observed shadows of moons and ring features. Once thought to be almost completely flat, new images of the rings reveal the heights of some newly discovered 'bumps' in the rings that are several kilometres thick.

Ring temperatures were continuously monitored by Cassini's Composite Infrared Spectrometer instrument. During equinox, the rings cooled to the lowest temperature ever recorded. The A ring dropped down to –230°C. Study of ring temperatures at equinox will help understand better the sizes and other characteristics of the ring particles.



Images taken by Cassini's wide angle camera form this mosaic, showing Saturn, its rings, and a few of its moons a day and a half after Saturn's equinox, when the Sun's disk was exactly overhead the planet's equator. The illumination geometry that accompanies equinox lowers the Sun's angle to the ring plane, significantly darkening the rings, and causes out-of-plane structures to look bright and cast shadows across the rings. These scenes are possible only once in about 15 Earth years (NASA/JPL/SSI)



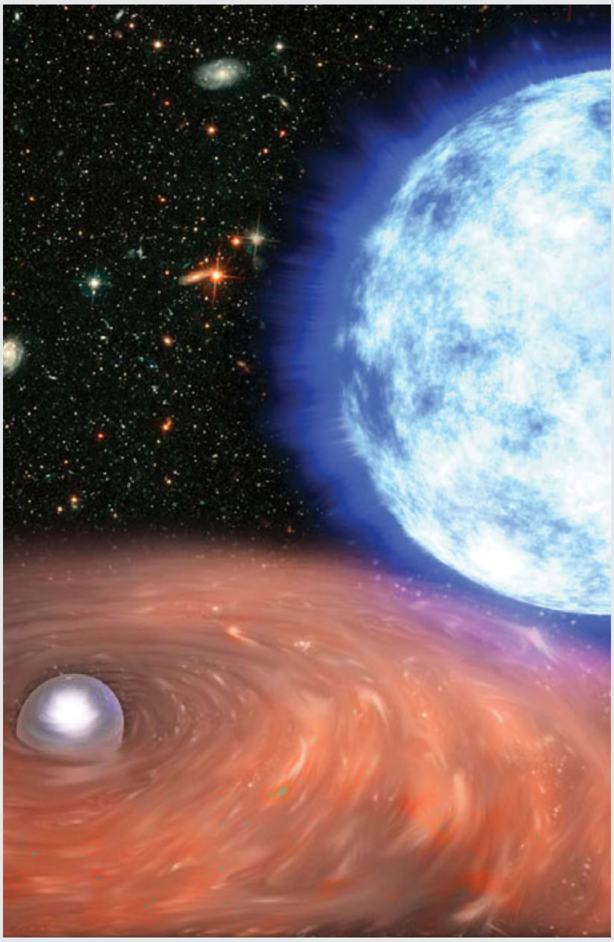
Several sets of shadows are cast onto Saturn's A ring in this image taken after Saturn's 2009 equinox. Near the middle, shadows are cast by vertically extended clumps in the discontinuous ringlets of the Encke Gap. These clumps are casting shadows about 275 km long, implying a clump height of 600 m above the ring plane. To the left, the waves created by the moon Daphnis on the edge of the Keeler Gap cast shadows that are about 450 km long, indicating waves that rise about 1 km above the ring plane (NASA/JPL/SSI)

→ XMM-NEWTON

XMM-Newton has uncovered a celestial 'Rosetta stone': the first close-up of a white dwarf star, circling a companion star, which could explode into a particular kind of supernova in a few million years. These supernovae are used to measure cosmic distances and, ultimately, help us understand the expansion of our Universe.

Astronomers have been on the trail of this mysterious object since 1997 when they discovered that something was giving off x-rays near the bright star HD 49798. XMM-Newton tracked the mysterious object along its orbit. The observations have shown it to be a white dwarf, the dead heart of a star, shining in x-rays. But it is no ordinary white dwarf. Its mass is more than twice that expected. Most white dwarfs are about 0.6 solar masses. This particular white dwarf contains at least double that mass, but has a diameter just half that of Earth. It also rotates once every 13 seconds, the fastest of any known white dwarf.

This white dwarf has grown to its unusual mass most likely by stealing gas from its companion star, in a process known as accretion. At 1.3 solar masses, the white dwarf is now close to a dangerous limit. The star is likely to explode in a few million years time. When it grows larger than 1.4 solar



Artist impression of the white dwarf and its companion star HD 49798

masses, a white dwarf will either explode, or collapse to form an even more compact object called a neutron star. The explosion of a white dwarf is the leading explanation for Type Ia supernovae, bright events that are used as standard 'beacons' by astronomers to measure the expansion of the Universe. Until now, astronomers have not been able to find an accreting white dwarf in a binary system where the mass could be determined so accurately.

→ CLUSTER

Cluster has passed through its magnetotail science phase and will go through a long eclipse season in October and November. During winter, Cluster will pass into the dayside magnetosphere where the science focus will return on the magnetopause and bow-shock. The Cluster Active Archive continues its success in adding to the scientific return of the Cluster mission by archiving the high-resolution measurements of the Cluster mission.

Cluster scientists have discovered a mechanism that can account for the heating of the solar wind. Cluster data were used to successfully discriminate between a number of theoretical models and, for the time periods analysed, a remarkable agreement was found with one model in particular. This result may be applicable in other astrophysical contexts such as the heating of the solar corona.

→ DOUBLE STAR

Contact with Double Star TC2 has still not been re-established. Because the end of the predicted operational mission lifetime is approaching, Chinese and European operations, project science and instrument teams are preparing to begin the archiving phase of the mission.

→ INTEGRAL

Seven years of Integral operations were celebrated at 'The Extreme Sky' workshop in Otranto, Italy, in October. During the workshop, the fourth IBIS/Integral catalogue of hard x-ray sources (Bird, et al.) was presented, which contains 331 new sources compared to the third catalogue (421 sources, published in 2007). Of these new sources, about 120 are associated with extragalactic sources while only about 25 are associated with known galactic sources, and the remainder are so far unidentified. The new sources comprise a very significant galactic component.

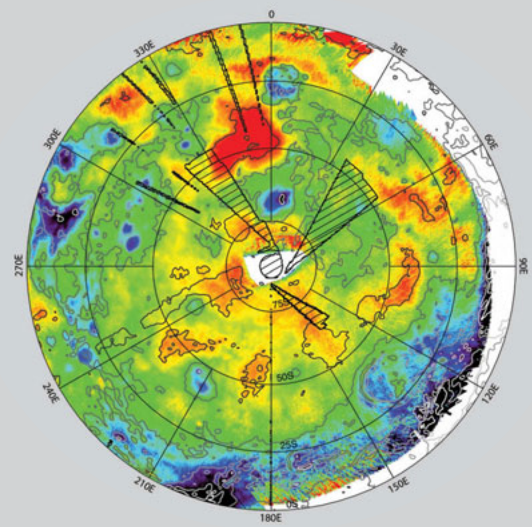
The fact that most of these are unidentified suggests that Integral observations along the galactic plane have reached a level of depth where previous x-ray observations are no longer always able to provide associations for the new sources. When combined with the variability of the galactic sources, this indicates that further observations of our galaxy will continue to uncover new sources, and prompt follow-up studies of these new sources are essential in understanding their true nature. However, it is not that simple: many of the new sources found in or near the galactic plane by Integral have been identified as 'extragalactic' sources, and Integral has proved particularly adept at uncovering this obscured population.

→ ROSETTA

Preparations for the third and last Earth swingby, scheduled for 13 November 2009, are proceeding. The closest approach will be at a distance of 2480 km above Earth's surface at about 07:45 UTC. After this swingby, the spacecraft will be correctly positioned for the encounter with asteroid (21) Lutetia and its heliocentric velocity will then be high enough for the rendezvous with its target Comet 67P/Churyumov-Gerasimenko in 2014.

→ VENUS EXPRESS

Out of the many exciting results featured in two special issues of *Journal of Geophysical Research*, the first published map of the surface temperature of the full southern hemisphere is notable. This map has been constructed based on hundreds of images, recorded between May 2006 and December 2007, from the VIRTIS infrared spectrometer. Because Venus is covered in clouds, normal cameras cannot see the surface, but Venus Express used a particular infrared wavelength that can see through them. This map obtained will serve as a basis for the further research of the surface properties and thermal anomalies.



The first full surface temperature map of the southern hemisphere of Venus from Venus Express (VIRTIS)

→ HERSCHEL

Since mid-July, Herschel has been in the performance verification phase. After three months, there will be a gradual transition into the science demonstration phase. All science instruments have now produced observations, demonstrating both photometry and spectroscopy modes of operation. The initial results are very good. Recently the 'parallel' observing mode using both the SPIRE and PACS cameras simultaneously to image large areas of the sky has produced stunning results for a section of our galaxy, the Milky Way.

Herschel SPIRE and PACS images have been combined in this composite of a section of the Milky Way in the constellation of the Southern Cross. Material cooler than 10K has most of its emission in the Herschel bands. It would be very difficult to see these star- forming filaments in images made at a single far-infrared or submillimetre wavelengths. The image contains a network of filamentary structures, with surprising features which seem to be chains of near-simultaneous star-formation events (ESA/SPIRE/PACS)

Unfortunately, the HIFI spectrometer malfunctioned in August and has been out of operation as a precautionary measure while the necessary investigations are conducted. This has led to a reshuffling of some activities, including executing science demonstration observations (and making data available to observers) earlier than planned. Plans for restarting HIFI operations are being finalised.

→ PLANCK

Planck's Calibration and Performance Verification (CPV) phase was completed on 27 August and marked the start of the routine phase of the mission. Images acquired during the CPV phase were released on 18 September.

All the satellite functions are nominal. The pointing performance is excellent. The cryo-chain, a key element of the Planck payload, is stably supporting all the low-temperature stages required for the operation of the instruments. The performance of the two instruments has been extensively characterised during the CPV phase. Within the current measurement uncertainties, all the detector sensitivities are as predicted from the on-ground calibration campaigns. Overall, the payload performance in flight is excellent and allows meeting the scientific objectives of the mission. Planck's total lifetime is limited by the active coolers, which are required to operate the detectors (now determined to be around 14 months above the nominal mission span). Increasing the operations of Planck by this amount will allow it to complete at least four full surveys of the sky instead of the nominal two.

→ AKARI

Akari continues routine operations in its post-helium phase with no major problems. By the end of September, 653 AO-2 warm phase observations were executed. This scheduling rate is consistent with completion of the European programme by the end of this Announcement of Opportunity period.

→ COROT

The spacecraft continues to operate after more than 1000 days in space this September, except that the payload is still operating with only half the field-of-view because of an anomaly in a data processing unit. A final experiment using this unit will be carried out during the next re-pointing of the spacecraft. Observations are split in two parts: first pointing towards half of the originally planned field for 85–90 days, and then pointing at the second half of the field. The smaller field-of-view implies fewer stars per pointing, but more bandwidth for telemetry. This means more stars can be observed in three colours, as well as many more stars where the light curve is over sampled.

→ LISA PATHFINDER

The LISA Pathfinder industrial team has entered the main phase of satellite integration and testing. The harness, thermal hardware, onboard computer, power control and distribution unit, star tracker, batteries and other units have been mechanically integrated on the Science Module Flight Model (FM) and the electrical integration is ongoing. Virtually all platform units of the Science Module have been delivered and will be integrated in the next months.

The Propulsion Module FM structure, propulsion components and units have all been delivered. The integration is on schedule, with complete assembly by March 2010. The verification of the on-board software is continuing on the Software Verification Facility and on the two parallel Real-time Test Benches at Astrium Ltd for the Attitude Control and System Control and at Astrium GmbH for the Drag-Free Attitude Control.

The slit caesium thruster micropropulsion Critical Design Reviews have been held at subsystem level. A modification to the thruster unit has been implemented after minor current discharge problems and the new accelerator design has been finalised, according to the recommendation of a task force. The manufacturing of the new thruster is ongoing, while additional material tests are being performed. The new thruster will be integrated and tested before the end of the year.

The American Disturbance Reduction System (DRS) payload has completed all its activities and all the flight hardware and ground segment equipment have been delivered to Europe.

→ MICROSCOPE

Integration of the Sensor Unit Qualification Model (QM), including the QM Proof Masses, has started. Procurement of the critical components of the Sensor Unit FM was initiated and they will be delivered in mid-2010. The Protoflight Models (PFM1/FM2) of the front-end electronics are ready, only waiting for a component replacement. Functional QM tests with flight electronics will start in early November. A draft satellite specification for a cold-gas option was issued, now covering both thruster technologies. Development activities continue on both FEEP under LISA Pathfinder and cold-gas technologies. ESA and CNES teams are preparing an updated configuration design trade-off based on the results of the development activities presented at the next steering meeting (postponed until after the LISA Pathfinder microthruster system CDR) for a go-ahead on the selected system.

→ GAIA

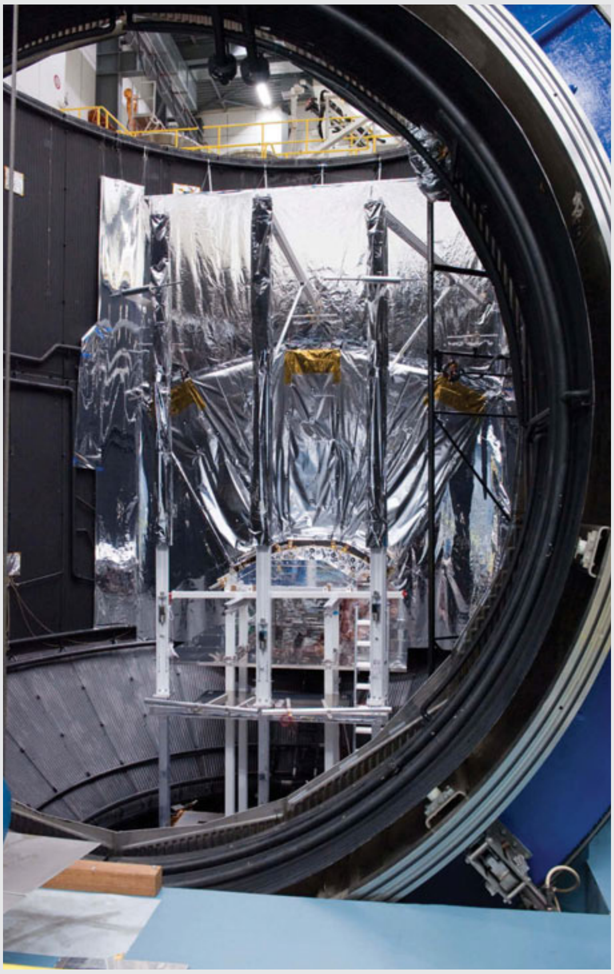
The Gaia optical bench ('torus') was delivered to Astrium SAS and is being prepared integration of the supporting 'bipods' and the folding structure that accommodates the optics. These activities are due to be completed by the end of 2009. Three of the ten mirrors have completed the polishing phase, including the last correction via ion beam figuring, and they are ready for the final coating.

The Service Module FM is now at Astrium Ltd and the integration of the chemical propulsion hardware has started. Activities on the spacecraft Avionics Model are progressing with many Engineering Model units integrated and first subsystem tests are ongoing using an advanced version of the central software. The scientific software, which runs in the Video Processing Unit, has passed its Critical Design Review.

The deployment in vacuum of the 10 m sunshield Qualification Model, a quarter-sized version of the real sunshield, failed in July in the Large Space Simulator at ESTEC. The failure was in the complex mechanical ground support equipment used to guide the unfolding and to compensate for gravity. The supporting hardware was modified and a second attempt at deployment will take place in October.

The integration of the Focal Plane Assembly Engineering Model is complete, including two rows of CCDs, the front-end electronics and power conversion electronics.

After IPC approval of the procurement proposal, the Request for Quotation to Arianespace for the procurement of the Soyuz launcher and related services was released in September.



Gaia's deployable sunshield Qualification Model in the Large Space Simulator at ESTEC

→ JAMES WEBB SPACE TELESCOPE

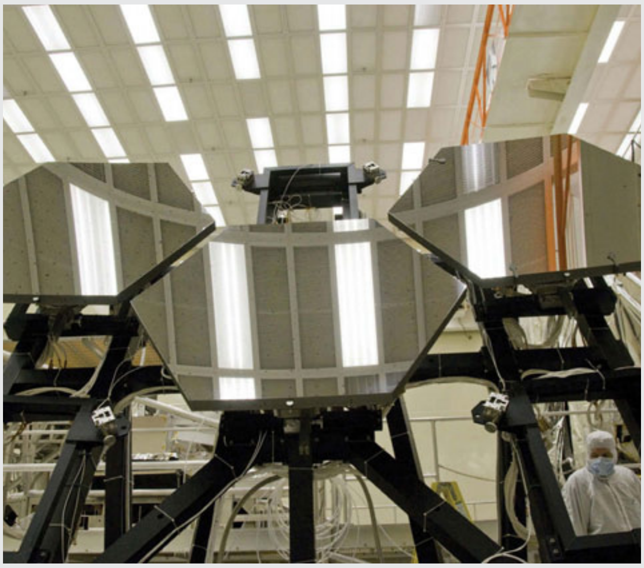
NASA completed the overall Preliminary Design Review of the spacecraft. The Critical Design Review (CDR) process is well advanced, with several key elements already concluded including the two instruments from Europe. The optical telescope element and the sunshield CDRs are planned for October and December, leading to an overall mission-level review in March 2010.

NASA is progressing well with the manufacturing of critical flight components. A second cryogenic test of three flight mirror segments is ongoing and all other mirrors are in final stage of polishing. The Integrated Science Instrument Module FM has been delivered.

The full-scale instrument Development Model of ESA's Near Infrared Spectrograph (NIRSpec) has completed its test campaign and is now ready for delivery to NASA. The flight collimator optics has been delivered and already integrated on the instrument optical bench. The camera optics have finished cryogenic testing, and are ready for integration. This completes the delivery of all the mirrors for the instrument.

The Mid-Infrared Instrument (MIRI) has been delivered and is ready for instrument integration. The flight filter wheel has completed testing and was delivered for integration and testing. The MIRI pre-optics spectrograph completed its testing and is now ready for integration of the dichroic/grating wheel assembly.

NIRSpec Flight Model camera optics during testing at cryogenic temperatures at the Centre Spatial de Liège, Belgium (CSL/Sagem Défense Sécurité)



JWST primary mirror segments being prepared for cryogenic testing in the X-ray & Cryogenic Facility at the Marshall Space Flight Center, Huntsville, Alabama (NASA/MSFC)

→ BEPICOLOMBO

Eight of the ten critical items identified for the Preliminary Design Review (PDR) are now considered acceptable and can be treated as part of the normal project work (this includes the total mass, now stabilised at a credible level). High-temperature (230°C) perpendicular high ultraviolet intensity tests on solar cell assemblies were completed with acceptable results. Tests with inclined irradiation (60° to 80°) show acceptable results at 200°C, however at 230°C, a large performance variation between samples appears. It was decided to define a minimum mission on the basis of a solar array qualification limit below 230°C to reduce development risk. The minimum power available for the payload will be analysed. Meanwhile, a root cause investigation on the solar cell degradation was started, and also into the effect of shielding the edge of the solar cells. The 1000-hour endurance test mark for the blocking diodes was reached with good results and tests are continuing as planned. The PDR Board considers that the present status allows the continuation of the review close-out activities as planned and confirmed the date of the final PDR Board would be at the end of October. The equipment procurement process continued with 86% of the subcontractors selected.

The instrument interface definitions for the Structural Thermal Model configurations were finalised and the manufacturing and test phase started in support of hardware deliveries scheduled in 2010. The ESA Mercury Planetary Orbiter (MPO) Interface Simulator was sent to the instrument teams. The assessment of the scientific return of BepiColombo, taking into account the PDR spacecraft design and operational capabilities, has been performed with inputs from all Principal Investigator teams and confirmed fully compatible with the scientific mission objectives of an ESA Cornerstone Mission.

The Japanese Mercury Magnetospheric Orbiter (MMO) development is progressing as planned. Following completion of the mechanical tests, the Structural Model is being prepared for the thermal test.

→ EXOMARS

The assumptions of the international cooperation between ESA and NASA for the ExoMars mission have changed. During the first half of the year, the assumed configuration was a launch of the Descent Module Composite with the Rover in 2016 on an Atlas launcher, with ESA providing an Ariane 5 for a later joint mission. After an ESA/NASA bilateral meeting at Director's level, it was decided to split the mission objectives over two launch opportunities (2016 and 2018) with the assumption that the Rover is launched on a NASA-led mission in 2018. During the summer, various scenarios were studied and a baseline decided. The 2016 mission remains an ESA-led mission, but is now an orbital science and Mars communications infrastructure mission, with an ESA-provided Entry Descent and Landing (EDL) Demonstrator, carrying a short-lived scientific payload. In 2018, the ExoMars Rover with its 2m drill and concentrating on exobiology will land on the surface of Mars using NASA's SkyCrane. The Rover will be operated from the Rover Operations Control Centre (ROCC) in Italy.

The technical baseline of ExoMars must be frozen within the coming year in order to secure the 2016 launch date. The subscriptions to the ExoMars mission will close at the end of December 2009. The next major decision point is ESA Council in early October.

→ ALPHABUS AND ALPHASAT

System and launch

Preparations are ongoing for the Alphasat System Critical Design Review that will start with the delivery of the platform data package by end of October. Launch of Alphasat on an Ariane 5 is scheduled for mid 2012.

Service Module

The structure assembly is progressing in Cannes, with the assembly of the internal deck and the central tube, constituting the backbone of the satellite. Assembly of the lower side panels and the network of heat pipes is ongoing. Propellant tanks and the pre-integrated chemical propulsion module will then be mounted on the structure in October.

In Toulouse, pre-integration and test of avionics flight or Qualification Model equipment on a mock-up of the spacecraft structure was completed. The majority of the planned test programme has been run, providing the feedback to check hardware behaviour and tune test procedures, in advance of the flight integration that will start early 2010 when the Service Module Flight Model is available.

Repeater Module

Nearly all structural elements and thermal components have been shipped from Cannes to Turin, where the finishing of the panels and the integration of the thermal control hardware is under way. The next major milestone is the delivery of the Repeater harness from CASA to Turin for installation on the large Repeater Module side walls. After this step, the Repeater Module will be assembled into two half modules and shipped to Portsmouth, UK, for payload equipment integration.

Payload

The Inmarsat extended L- band (XL) payload will support advanced geomobile communications and augment Inmarsat's Broadband Global Area Network (BGAN) service with its coverage centred over Africa and providing additional coverage to Europe, the Middle East and parts of Asia.

Development of the Inmarsat operational payload equipment is ongoing. For most of the equipment targeted for the payload, equipment Qualification Model manufacturing


The Alphabus Service Module at Thales Alenia Space Cannes (France) being prepared for chemical propulsion integration


The large propellant tanks produced by MT Aerospace (Germany) shown ready to be integrated within the central tube of the Alphabus Service Module

is under way. The state-of-the-art integrated processor remains a priority in the programme due to its pivotal role in the payload performance. The Application Specific Integrated Circuit required for the digital signal processing function has been manufactured and is undergoing testing.

The Alphasat payload CDR is planned early 2010. A first integration of payload elements to verify key performances is planned in the same period.

Technology Demonstration Payloads

The CDRs for the Technology Demonstration Payloads (TDPs) are progressing. The TDPs accommodation on the satellite has been finalised. The consolidation of software interfaces between TDP and the satellite is being completed.

Alphabus extension

The Alphabus extension will further extend the platform's power, mass and thermal rejection capabilities. The workplan includes the development of key enabling technologies, such as a deployable panel radiator for increased heat dissipation and an ultra-stable antenna module for future complex Alphabus satellites. The workplan was approved by the ESA

Programme Board for communication satellite programmes in September and will be implemented from January 2010.

Alphasat User Segment and Application

The programme work plan contains a set of activities defined together with Inmarsat, based on their plans for new services and terminal classes to be incorporated into Inmarsat's portfolio for Alphasat, as well as for the complete Inmarsat satellite constellation. The workplan was approved by the ESA Programme Board for communication satellite programmes and the Industrial Policy Committee, and the first two activities begin in October.

→ CRYOSAT

The main satellite computer, which was removed for repairs during August, was re-integrated into the satellite by mid September. Final tests required complete timelines of commands, replicating operations that will be performed during normal operations, as well as tests to patch onboard software. For these, the satellite was connected to the control centre in ESOC, who had received the timelines of commands from the CryoSat Mission Planning Facility in ESRIN.

The media were invited to view the satellite and hear about the mission before the satellite and its test equipment were packed into transport containers, ready to be shipped to the launch site at the end of the year. The Flight Acceptance Review began in September, complementing the Ground Segment Acceptance Review, which was completed in July.

The CryoSat-2 launch, on a Dnepr launch vehicle from Baikonur, has been delayed until the end of February 2010. This is due to a 'bottleneck' at the fuelling facility in Baikonur, which is delaying the Dnepr launch before CryoSat-2.

Unloading the SMOS satellite container from the Antonov aircraft at Archangelsk airport, Russia, on 16 September 2009

→ SMOS

The combined SMOS/Proba-2 launch campaign started, first with the transportation and preparation of Proba-2, then with transportation and preparation of SMOS. Fuelling of the SMOS satellite is imminent, after which operations with the launcher can begin. In the meantime, operator training is taking place both for the Flight Operations Segment in Toulouse and ESAC, and for the Data Processing Ground Segment also at ESAC.

→ ADM-AEOLUS

The ALADIN laser Engineering Model has completed the second phase of vacuum and low-pressure tests. In this phase, the laser was continuously operated for 16 days in flight-representative conditions. The large energy losses caused by laser-induced contamination as seen in previous tests were no longer present, demonstrating the efficacy of the measures taken to reduce the susceptibility to laser-induced contamination in the Engineering Model. Residual energy degradation was shown to be the result of an air-to-vacuum effect and is under investigation.

Preventive measures similar to those used in the laser will be implemented in the instrument transmit path (Optical Bench Assembly, OBA) in order to reduce the risk of laser-induced contamination also at this level. The preliminary design of the OBA upgrade is in progress.

Testing of the satellite platform began and the completion of the platform programme is expected in October 2009. After a Qualification Review in December, the platform will be put into storage until preparations for the instrument integration can start.

→ SWARM

The environmental test of the satellite Structural Model was completed at IABG, Munich, and several Flight Model units were delivered and ready for satellite integration. The first Flight Model of the Absolute Scalar Magnetometer is undergoing the test readiness review. The Flight Models of the star tracker and vector magnetometer instruments have been characterised. The Critical Design Review of the ground segment is ongoing. The Invitation to Tender for procurement of the launcher and the level-2 facility development was released on EMITS.

→ EARTHCARE

During Phase B2, the System Preliminary Design Review began in the summer, with the review board scheduled for October. Instruments PDRs were held for the Broadband Radiometer, the Multi-Spectral Imager and the Cloud Profiling Radar (CPR), with formal closure linked to the System PDR Board. The Atmospheric Lidar PDR was delayed to allow the detailing of a bistatic instrument configuration backup developed to overcome the laser-induced contamination as seen in ADM-Aeolus.

The CPR, developed by JAXA, completed an additional JAXA internal review in mid-September. Meanwhile, the draft ESA/JAXA Cooperation Agreement for EarthCARE was approved by JAXA and ESA's Earth Observation Programme Board. The Ground Segment Requirements Review took place, and included participants from JAXA Ground Segment and CPR teams.

→ METOP

MetOp-A

MetOp-A, launched on 19 October 2006, is in very good health. All instruments continue to perform excellently. Only the HRPT is transmitting in restrictive mode.

MetOp-B and MetOp-C

With MetOp-B launch planned for 2 April 2012, the Assembly, Integration and Testing (AIT) activities for both MetOp-B and C are being optimised in different blocks of activity on the different modules (PLM-1, PLM-3, SVM-1 and SVM-3), to ready the MetOp-C spacecraft for a 'quick relaunch' (within 12 to 15 months) in case of a MetOp-B launch failure.

→ MSG

Meteosat 8/MSG-1

Meteosat-8 reached its milestone of seven years in orbit on 28 August 2009. The satellite is in good health with instruments performing flawlessly. It will continue its Rapid Scan Service, complementing the 15-minute High Resolution Image data generated by the operational Meteosat-9. Two large routine orbit inclination control manoeuvres are still planned respectively for September 2009 and September 2010. By the end of 2011, Meteosat-8 will reach an inclination of 1 degree and will continue to operate normally at higher orbit inclination (5.6 degrees) until it runs out of fuel in mid 2018.

Meteosat-9/MSG-2
Meteosat-9 is Eumetsat's main operational satellite at 0° longitude, with Meteosat-8 as its back-up. Satellite and instrument performance are excellent

MSG-3
MSG-3 is in long-term storage at Thales Alenia Space Cannes, waiting for AIT campaign to begin in 2011. Launch is now planned not earlier than 2012.

MSG-4
The new SEVIRI Drive Unit (DU) is still in production. After re-integration of the new qualified DU, the satellite will go through mechanical, acoustic and reference testing.

→ MTG

The Phase A Extension activities were concluded with both industrial consortia at their respective Interim System Requirements Reviews in July. The B2 and C/D Invitations to Tender were released to industry in July and industrial offers are expected in October. The conclusion of the evaluation process, with the final TEB meeting, is scheduled for November 2009.

→ SENTINEL-1

The negotiation for Sentinel-1B was concluded with industry and the corresponding Contract Proposal approved by the IPC in September. The corresponding contract is under preparation. The Ground Segment Preliminary Design Review was completed on 30 September.

The ITT for the procurement of the launcher for Sentinel-1A was issued in July and the offers are being evaluated with the participation of European Commission representatives, in accordance with the ESA/EC GMES Framework Agreement.

All subsystem PDRs were completed, while a number of equipment CDRs are ongoing, with the last planned for early 2010. Together with the need to take advantage of the EM test results, this led to the decision to shift the System CDR to March 2010.

MSG-1 was launched by an Ariane 5 on 28 August 2002 and has now completed seven years of operation in orbit

Thanks to close management monitoring, activities on the Spacecraft Management Unit progressed, leading to a CDR date now compatible with system needs. The plating process of the low-loss waveguide radiating elements was finalised and QM/FM production has started. The achieved yield is still too low and a number of measures are being put in place to improve the FM production rate.

Despite all efforts and management focus, the development of the Receive Module (RM) in the SAR Electronic Subsystem is still unsatisfactory, with the PDR not yet closed at equipment level. In this situation, it was impossible not to delay the RM CDR and, subsequently, the System CDR.

Following the earthquake that struck L'Aquila in April 2009, hybrid production has been started on a temporary relocated line at Thales Alenia Space Italy in Milan. It is expected that by the end of November, the new hybrid area in L'Aquila and the substrate production area (Rome) will be ready. The qualification status of the relocated activities and the set of revalidation activities (needed to maintain the qualification status) have been agreed with ESA. Despite all efforts, there will be a significant impact on the launch date, which will be formalised as soon as measures needed to minimise the impact are agreed.

On 1 October, Antonio Tajani, EC Vice-President for Transport Policy, announces the official start of operations for EGNOS, the European Geostationary Navigation Overlay Service (EC)

→ SENTINEL-2

The Best Practice procurement phase is now very advanced. Equipment PDRs and first hardware deliveries are taking place, as in the case of the silicon carbide telescope mirrors and optical detectors.

Price conversion and contractual negotiations were completed with EADS Astrium, enlarging the baseline contract for the procurement of the second satellite model and the integration, test and in-orbit commissioning of two Laser Communication Terminals as an option.

→ SENTINEL-3

The first equipment CDR started this summer. At Ground Segment level, the Sentinel-3 Payload Data Ground Segment System Requirement Review will be concluded at the beginning of October.

At system level, an update of the micrometeoroid orbital analysis was performed, allowing a refinement of the possible satellite areas that require protection. Work on the Spacecraft Characterisation Data Base (SCCDB) ICD is continuing and collection of the satellite characterisation data has started. At optical and topographic mission level, the Critical Design Review of the optical Ground Prototype Processor was completed, and the CDR of the System Performance Simulator is ongoing.

On the launcher side, support studies are being made with Vega and Rockot launch organisations, in preparation for the final selection of the Sentinel-3 launcher, planned for next year through an ITT process.

On the satellite, most of equipment PDRs are complete. Concern remains with the overall satellite mass, still marginal with respect to the launcher capabilities and the Solar Array Deployment Mechanism (SADM) where, even if the introduction of an additional Solar Array Hold Down points has allowed a decrease in interface mechanical loads, qualification of the proposed solution still has to be achieved. In addition, a technical consolidation in the power area aims to improve the worst-case power budget during the extended lifetime period, specifically in case 'safe-mode' conditions occur.

On the instrument side, some problems appeared in the development of the Scrambling Window Assembly on OLCI, requiring the investigation of possible alternative solutions. On the SLSTR, very important improvement was achieved by establishing a new strategy for a vacuum window, needed for on-ground testing of the Focal Plain Assembly. The finalisation of the instrument structure remains, however, critical and affects the 'freezing' of a certain number of instrument subsystems. For the MWR, the latest assessment of the impact of the earthquake at L'Aquila indicates a reduced delay of three to four months for the RFFE components, much less than originally feared. The precise impact on the MWR overall schedule still needs to be assessed, even if it should not now affect the satellite schedule.

→ EGNOS

The European Geostationary Navigation Overlay Service (EGNOS) is Europe's first venture into satellite navigation. Following the project reviews held in March 2009, EGNOS was qualified operationally in its version 2.2. Subsequently, on 1 April, EGNOS assets were handed over to the European

Commission, and the EGNOS programme entered its operational phase. At the same time as the handover of EGNOS to the EC, ESA and EC entered a delegation agreement whereby ESA acts as design and procurement agent for EGNOS and its evolution.

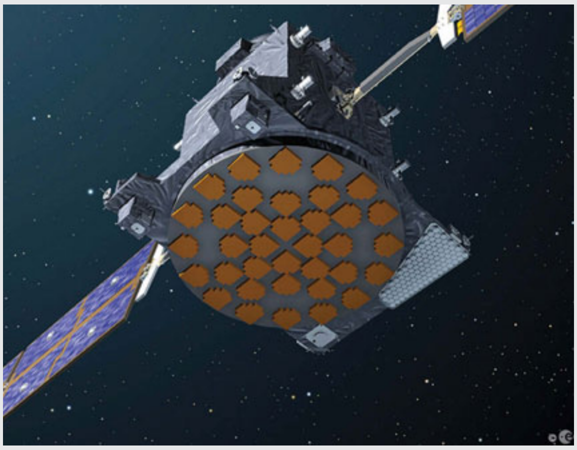
The availability of the Open Service provided by EGNOS was formally announced by the EC on 1 October. Next steps for EGNOS will be its certification for Safety of Life service and Commercial Data Distribution service, both planned for 2010.

→ GALILEO IOV

GIOVE-A and GIOVE-B are fully operational, allowing a real-time test of the expected Galileo mission performance, by using a worldwide network of sensor stations and a Galileo processing centre at ESTEC, Noordwijk, the Netherlands.

GIOVE-A underwent a series of slow manoeuvres in July and August 2009, repositioning the satellite 113 km above the operational Galileo orbits. This is standard procedure for navigation satellites, to avoid interference with operational spacecraft. GIOVE-A has resumed its navigation signal transmissions and still has a significant amount of propellant.

Four operational In-Orbit Validation satellites will be launched on two Soyuz rockets in late 2010 or early 2011. The integration of Engineering Models for these satellites is ongoing and the satellite Critical Design Review (CDR) started in September 2009. CDRs for both the Ground Mission Segment and the Ground Control Segment were completed and the deployment of ground facilities was subsequently initiated. The overall System CDR is planned for October 2009.



Artist impression of GIOVE-A

→ EUROPEAN GNSS EVOLUTION

As an optional programme 100% funded by participating ESA Member States, the European Global Navigation Satellite System (GNSS) Evolution programme was launched in 2007. The initial period of two years was extended in 2008 by three years and the programme now covers the five-year period from 2007–11 with a financial volume of €104 million.

The objectives of the European GNSS Evolution programme are to undertake technology research, development and verification related to GNSS and to accompany the introduction of GNSS operational systems, and prepare for evolutions and upgrades of the European GNSS Infrastructures EGNOS and Galileo.

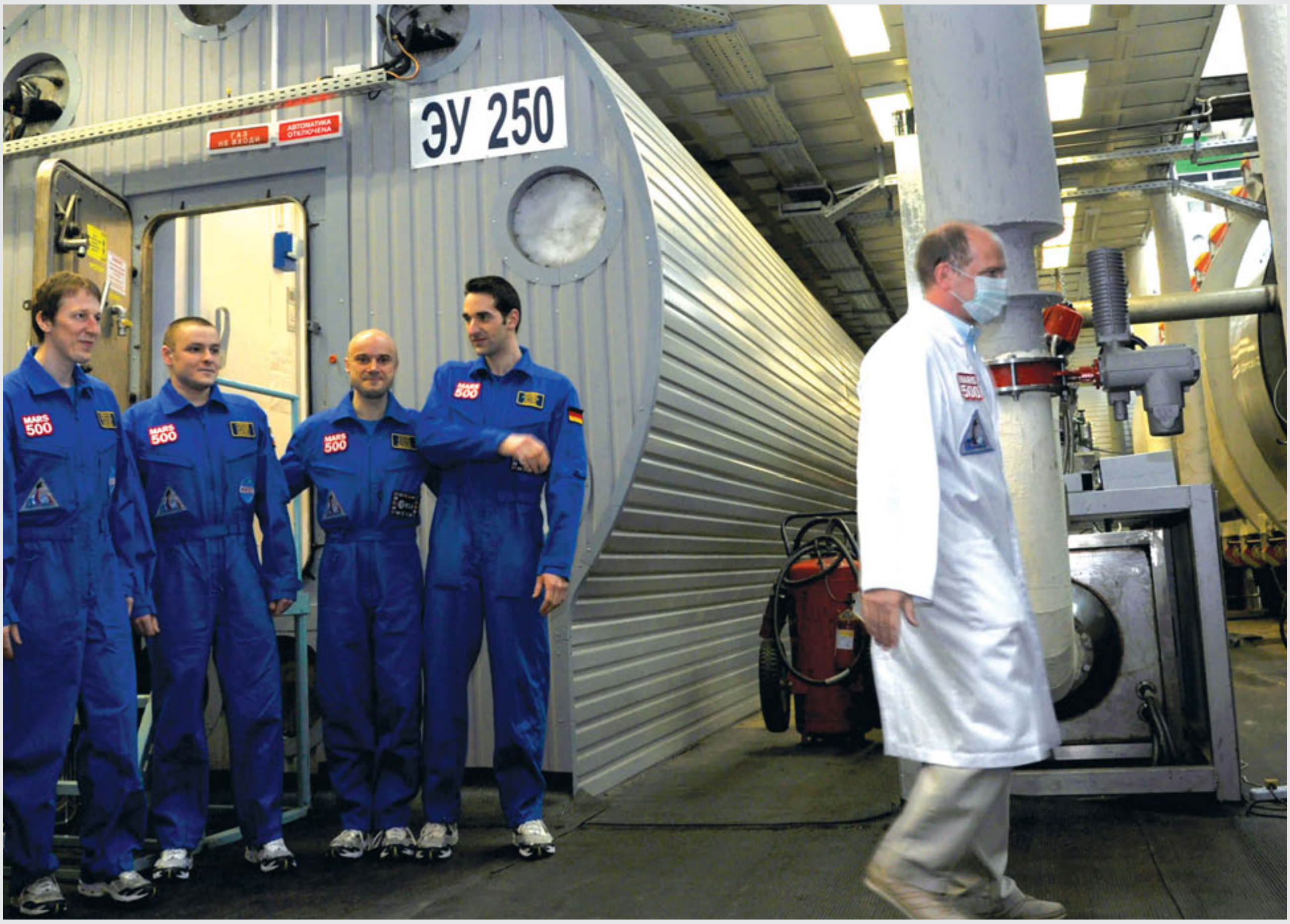
Approximately 40 activities have been defined in the work plan for the programme over these five years, including four dedicated testbeds. Activities span over assessment of new architectures, evolution platform for EGNOS, technology developments including clocks and a range of specific R&D activities.

→ HUMAN SPACEFLIGHT

On 11 September, ESA Director General Jean-Jacques Dordain and NASA Administrator Charles Bolden signed a Memorandum of Understanding, approved by ESA Council in June, that will allow further progress in the detailed definition of a common International Berthing Docking Mechanism (IBDM) interface for utilisation in the ISS and Orion, and exchange of information on the man-rating design of space vehicles.

The three ELIPS research solicitations closed on 14 September. 183 proposals have been received, as follows: 43 for the ESA-AO-09, 29 for the Bedrest AO, and 111 for ILSRA-09. The peer evaluation by European Science Foundation (ESF) is already in progress. A pre-announcement for a joint call with the ESA Directorate of Earth Observation has been published. The actual call for Earth observation payload for the ISS will be released in the course of the autumn.

The first crew of the Mars500 studies, including two ESA participants, completed their 105-day simulated Mars mission at the Institute for Biomedical Problems (IBMP) in Moscow, Russia. They left their special isolation facility for the first time since 31 March when the hatch was opened on 14 July. Preparations for the full 520-day mission in 2010/11 have already begun.



The Mars500 crew leave their special isolation facility in Moscow, Russia. The six-strong crew includes two ESA crewmembers: Oliver Knickel and Cyrille Fournier

→ INTERNATIONAL SPACE STATION

The Japanese space agency JAXA launched its first H-II Transfer Vehicle (HTV-1) from the Tanegashima Space Center on 10 September. The unmanned vehicle arrived at the ISS on 17 September and was attached to the Earth-facing (nadir) port on the Node-2 Harmony module using the Station's robotic arm.

Since 29 May, ESA astronaut Frank De Winne (BE) has been on the ISS for his OasISS mission, marking the beginning of a six-person crew capability. On 11 October, he became the first non-US and non-Russian ISS Commander.

On 29 August, Space Shuttle *Discovery* STS-128 transported the European Leonardo Multi-Purpose Logistics Module (MPLM) to the ISS, carrying cargo that includes the second European-built MELFI freezer rack and the ESA Materials Science Laboratory for NASA's Materials Science Research Rack-1 (MSRR-1). STS-128 crewmember Christer Fuglesang (SE) was welcomed on board the Station by his fellow ESA and CSA astronauts, De Winne and Robert Thirsk.

→ SPACE INFRASTRUCTURE DEVELOPMENT AND EXPLOITATION

Cupola and Node-3

The Cupola observation module was attached to Node-3 on 1 September, and both modules are planned for launch in February 2010. The Acceptance Review Board for Node-3 is scheduled in November and will mark the transfer of ownership to NASA.

ATV production and cargo integration

ESA's second ATV (ATV-2) has a launch window in November 2010. A dedicated schedule task force, held during July/August has streamlined activities and removed some redundant test activities. Further schedule improvement measures are under investigation.

The ATV-2 Equipped Avionics Bay arrived at ESTEC in August for the Thermal Vacuum Test. Test preparations and dry runs have been performed and the test readiness review is on going. The Integrated Cargo Carrier (ICC) was accepted and transported on a Beluga aircraft from Turin to Bremen on 9 September.

A close-up view of the H-II Transfer Vehicle, guided into position on the ISS by astronauts Nicole Stott, Robert Thirsk and Frank De Winne using the Station's robotic arm

ESA astronaut Christer Fuglesang seen during the STS-128 mission's third spacewalk for maintenance of the ISS

ICC complementary integration after transportation is now ongoing until the common ICC and spacecraft tests in January.

All post-flight analysis recommendations requiring implementation in ATV-2 have been transferred into change requests and are compatible with the above mentioned launch readiness schedule. The major changes are related to the pressure regulator, the MLI, the technological telemetry, the flight application software and the solar array driving mechanism.

The final ATV-2 cargo manifest is due for delivery by NASA in November 2009, followed by the ATV model adaptation and the final coupled load analysis with the launcher.

→ UTILISATION

The Increment 19 experiment programme was concluded on 29 May with human physiology and rack maintenance activities and the start of the protein crystallisation experiments in PCDF arriving on the Shuttle flight 15A. The Increment 20 experiment programme started on 29 May and is planned to run until the departure of Soyuz TMA-14/18S flight at the beginning of October.

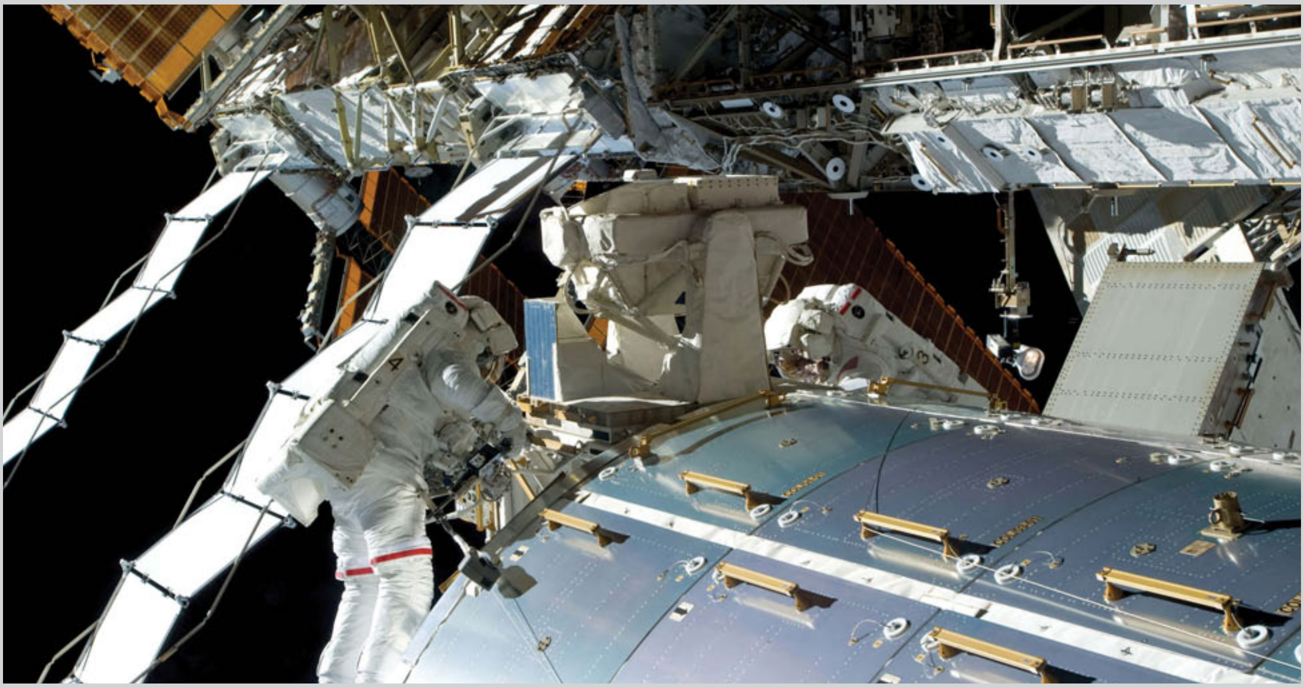
External payloads

The various instruments on the European Technology Exposure Facility (EuTEF) platform have operated continuously, with the PlegPAY experiment also reactivated for final long-duration runs. Before Space Shuttle STS-128 arrived, the EuTEF payloads were shut down and the whole platform retrieved from the external Columbus platform in the first spacewalk performed by NASA astronauts John Olivas and Nicole Stott during the STS-128/17A mission. It was returned to Earth on Space Shuttle *Discovery* for detailed analysis and evaluation of the space samples.

The SOLAR facility has so far produced excellent scientific data during the Sun observation cycles and the science team has requested a mission extension of about three years beyond the planned return on Shuttle flight 19A in spring 2010, in order to acquire the whole solar cycle spectrum from minimum (at the time of Columbus launch in 2008) to maximum. The Expose-R payload, comprising a suite of nine new long-duration astrobiology experiments (eight from ESA, one from IBMP, Moscow) is functioning well and will stay outside the Russian ISS segment until spring 2010.

ISS biology

The on-orbit maintenance activities of ESA's biology facilities Biolab and European Modular Cultivation System (EMCS) were concluded and declared ready for the next experiments. The YEAST-B experiment for Biolab arrived on Soyuz TMA-16/20S at the end of September and samples were immediately processed for return on Soyuz TMA-14/18S. It will be tentatively followed by the ArtEMISS-A experiment on later Shuttle flight. The second part of the Waving and Coiling of Arabidopsis Roots (WAICO) experiment in Biolab is planned in conjunction with the next MPLM flight, 19A, in spring 2010, where the science samples of the experiment can be launched in conditioned state. The WAICO-2 Experiment Containers are already in orbit. The next EMCS experiments will be TROPI-2 (NASA) followed by the first run of ESA's GENARA experiment.



NASA astronauts John Olivas and Nicole Stott (right) retrieve the EuTEF and Materials International Space Station Experiment (MISSE) from the Columbus laboratory

The six new ESA astronauts visit the Paris Air Show, Le Bourget. Left to right: Andreas Mogensen, Alexander Gerst, Samantha Cristoforetti, Thomas Pesquet, Luca Parmitano, Timothy Peake

The results of the Gravigen experiment (the effect of weightlessness on gene expression in rapeseed plants, *Brassica napus*), and the Polca experiment (the effect of weightlessness on the distribution of calcium in statocytes (gravity-sensing cells in plant root tips of rapeseed plant roots)), performed in April have been examined and delivered good results.

Human physiology and performance

The European Physiology Modules (EPM) facility was activated in June for the NeuroSpat experiment. On 3 June, Canadian astronaut Bob Thirsk performed his first session of the experiment, followed by Frank De Winne on 4 June. On 22 July, Thirsk performed his second and last session of NeuroSpat with De Winne assisting. On 26 July, De Winne performed his second and last session with Thirsk assisting. The experiment was a success and data for both sessions was sent back to Earth on 27 July.

Experiment samples for the CARD experiment from ISS Flight Engineer Koichi Wakata, which were returned to Earth on 31 July on STS-127, were delivered to the science team laboratory.

After four sessions of the 3D-Space experiment (Mental Representation of Spatial Cues During Space Flight) with astronauts Koichi Wakata and Mike Barratt, the EPM facility was activated again in June to perform the first sessions with the next subjects, Frank De Winne and Bob Thirsk.

Samples for Sodium Loading in Microgravity experiment from Expedition 18 Commander Mike Fincke, which were returned to Earth on 31 July on STS-127 Shuttle *Endeavour*, were delivered to the science team's laboratory. Between 8 and 19 August, Mike Barratt completed his sessions of the experiment and samples stowed in the European MEFLI freezer for return to Earth on STS-129.

Transfer and installation of new experiment hardware arriving on Space Shuttle *Endeavour* STS-127 (for the Dose Distribution inside the ISS, DOSIS, experiment) was completed by Frank De Winne on 18 July. This experiment will determine the nature and distribution of the radiation field inside the Columbus laboratory using different active and passive detectors. The EPM facility was activated on 31 July for downloading data from the DOSIS experiment.

The Matroshka radiation phantom has been prepared for the transfer from the Russian ISS segment to the Japanese Kibo lab. It will be equipped with a new suite of dosimeters for the next run until the end of 2010 under a cooperation agreement with Japan and Russia.

Materials research

Since the arrival of the processing unit of the Protein Crystallisation Diagnostic Facility (PCDF) on a Shuttle flight in March, the European Drawer Rack has been continuously active and providing power, data and cooling to the PCDF. On 23 July, a final interferometer measurement was taken on one experiment position to observe depletion zones around the protein crystals. With all the experiment runs completed, the PCDF processing unit was deinstalled on 27 July and transferred to the mid-deck of Shuttle *Endeavour* (STS-127) where it remained in an active temperature-controlled state until landing on 31 July. The facility's reactors exhibited the presence of good and stable organic crystals that will now undergo detailed analysis in various European science labs following return to Earth.

Under a cooperative agreement with NASA, the Material Science Lab was launched on the Space Shuttle and put in the US Destiny laboratory. The facility commissioning started, followed by the processing of the first sample cartridges ready for the next Shuttle flight.

Fluid physics

The Fluid Science Laboratory was activated on 29 May to acquire vibration measurements during the Soyuz TMA-15/19S docking. Further measurements were taken during crucial crystallisation periods in support of the PCDF activities. FSL was again activated between 21 and 23 July for continued commissioning of the Microgravity Vibration Isolation System, which provides a superior environment to sensitive FSL experiments.

The European Microgravity Science Glovebox was activated in August for sessions of the InSPACE-2 experiment performed by Frank De Winne and Mike Barratt. MSG will be used now during several months for ESA's experiments IVIDIL, DSC and Colloid.

Non-ISS Missions

The preparations for the TEXUS-46 launch in November with the EML-3 module and the Japanese Combustion Module are progressing according to plan. The 50th ESA Parabolic Flight Campaign took place on 4/15 May with 14 experiments on board, ten in physical sciences and four in life sciences.

The winter session of the Concordia Station experiments is still ongoing until November.

→ ASTRONAUTS

As a result of the latest ISS Multilateral Crew Operations Panel (MCOP) held in Houston on 21/23 July, it was announced on 5 August that André Kuipers (NL) will fly to the ISS at the end of 2011 for six months as the European crewmember of Expedition 30/31. On 11 August, it was announced that Roberto Vittori (IT) has been assigned, on an ASI flight opportunity, as a Mission Specialist on board Space Shuttle mission STS-134, which is currently scheduled for launch to the ISS in July or September 2010.

Crew training for ISS Expeditions 22–27 is progressing according to schedule. Training is ongoing for ESA astronauts Roberto Vittori and Paolo Nespoli (IT) for their planned missions in July or September 2010, and November 2010 respectively.

Basic Training for the new ESA astronaut class began on 1 September at the European Astronaut Centre and will run for 14 months.

→ CREW TRANSPORTATION AND HUMAN EXPLORATION

Advanced Reentry Vehicle (ARV)

The contract for ARV Advanced Phase A was signed on 7 July and a Request for Quotation for the full Phase A was issued to Astrium GmbH. The industrial proposal was received and is under evaluation.

The two Phase 0 industrial studies financed under the ESA General Studies Programme were concluded in March 2009 for Thales Alenia, and May 2009 for Astrium, providing initial inputs for the definition of the ARV Phase A.

A major technical Exchange Meeting took place with NASA Johnson Space Center in early June 2009, to gather the information required for the ARV to be included among the ISS servicing vehicles, including required type of payload, docking and interface requirements definition with the ISS. The capability to reboost the ISS was considered essential, while the possibility for deorbiting the ISS at the end of its useful life was considered an interesting asset.

A procurement proposal for the study of the Human Rating Aspects of the ARV on Ariane 5 has been jointly prepared with the Directorate of Launchers for an activity with the United Space Alliance, an experienced independent operator in human spaceflight. The proposal was approved in July 2009.

International Berthing Docking Mechanism (IBDM)

Two meetings to define an international standard for future docking and berthing systems for exploration and low Earth orbit activities have been held in recent months, involving NASA, ESA, JAXA, CSA and RSC Energia (representing Roskosmos). They identified the necessary trade-offs for both the hard-docking and soft-docking systems. There is general consensus that an initial standard interface should be achieved by October 2009, to be implemented in the development of the new transportation systems after the Shuttle.

At the ISS Multilateral Coordination Board meeting on 22 July, NASA declared its availability to develop with ESA the new ISS docking interface for the new adaptors of the US on-orbit segment, so as to be compatible with the European IBDM and US LIDS docking systems.

Canada has declared its willingness to participate in the IBDM development activities by increasing their subscription to the ARV Early Activities component by €1.2 million. This was approved by Participating States at the Human Spaceflight, Microgravity and Exploration Programme Board on 28 September.

EXPERT

Following confirmation of additional funding from Italy and the Netherlands, the industrial contract for the EXPERT Phase C/D/E was signed on 20 July by ESA Director of Human Spaceflight with Thales Alenia Space Italy. The EXPERT Launch Operations and Vehicle Recovery procurement contract with Makeyev is ready for signature.

Lunar Lander activities

The Lunar Lander Mission Objectives Definition Process

(LLL-MODP) document was released to the Delegations on 25 May. As a follow-up to the responses received to the Lunar Lander Request for Information, the preliminary review by ESA technical experts has been performed. The proposals have been submitted to the Lunar Exploration Definition Team with the objective to establish the lunar exploration requirements for the first Lunar Lander Mission.

The results of the feasibility and the technical definition studies of the MoonNEXT Phase A activities were presented at ESTEC on 16/18 June. The MoonNEXT Preliminary Requirements Review Board took place on 4 September. The review conclusions show a consistent design only for the static payload baseline. It is not obvious, however, that the design of propulsion and thermal control systems was feasible. From a technology point of view, a propulsion system with a large number of engines close to each other represents the most complex system ever flown on an ESA project. The use of radioisotope heater units to survive eclipses will have important programmatic and technical implications. The proposal for a dual-stage Lander is considered to be at the edge of feasibility and needs further assessment.

To progress in the mission design for a small mission on a shared Ariane 5 Geostationary Transfer Orbit launch, two Contract Change Notices (CCNs) were placed with the MoonNEXT industrial teams of OHB and Astrium GmbH.

Human Exploration Technology

Most of the technological activities focused on landing, approved in the Aurora Core Programme, are ongoing or are about to start. In parallel to system activities, four lines of development are being pursued to mature the technologies required for soft precision landing with hazard avoidance:

- Sensors, e.g. lidar
- GNC technique,: e.g. Robust EDL
- Validation and verification tools, e.g. EAGLE, PLGTF
- Landing system for touchdown, e.g. Landing System Development

The ARES development activities continue, albeit on a reduced scale. The CO_2 Concentration Assembly (CCA) testing was completed and a consent-to-ship review was held on 29 May. A Test Readiness Review for the performance tests was held on 29 June and the progress meeting was held on 30 June. Initial testing has started at Astrium Friedrichshafen. Agreement on the ARES bridging activity for GSTP-4 has been achieved and the procurement process has been initiated. GSTP-5 activities related to ARES Technologies, but with a broader application potential, are being prepared for submission to IPC. The full support to this plan of activities is crucial for the consolidation of the ARES bridging Phase. Progress has been made to secure the ARES launch.

International architecture development

The ESA/JAXA Comparative Architecture Assessment (CAA) Phase 1 was completed with associated reports identifying the similarities and differences between ESA and JAXA concepts for cargo and human transportation, as well as the surface infrastructure elements, such as the pressurised rover, power and mobility systems. The ESA/JAXA CAA formal Phase 1 closeout and Phase 2 kick-off meeting was held in Japan on 9 July.

For the ESA/NASA CAA, meetings were organised to consolidate the objectives and the workplan for Phase 2. The joint analysis activities focus on the development of reference scenarios for the collaborative missions involving the NASA Altair, the analysis of collaboration opportunities for development, testing and deployment of the In Situ Resource Utilisation capabilities, and the value assessment of the contributions to the international architecture.

A Lunar Architecture Workshop took place in June hosted by ESA. Work is now focusing on the development of a reference lunar exploration campaign, including 10 human missions in first five years of lunar exploration based on the NASA Constellation Architecture and an ESA and JAXA Cargo Lander. ESA has drafted a mission statement for human lunar exploration, which will be proposed to the 4th International Space Exploration Coordination Group meeting in December. The meeting will be chaired by ESA (Secretariat provided by ESA Directorate of Human Spaceflight).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