esa

number 115 - august 2003

bulletin

SPACE FOR EUROPE

Europe visits MARS

European Space Agency
Agence spatiale européenne

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 Organisation for the Development and Construction of Space Vehicle Launchers (ELDO). The Member States are Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, 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, co-operation 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:

(a) 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;
(b) by elaborating and implementing activities and programmes in the space field;
(c) by co-ordinating 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;
(d) 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:

THE EUROPEAN SPACE RESEARCH AND TECHNOLOGY CENTRE (ESTEC), Noordwijk, Netherlands.

THE EUROPEAN SPACE OPERATIONS CENTRE (ESOC), Darmstadt, Germany

ESRIN, Frascati, Italy.

Chairman of the Council: P. Tegnér

Director General: J.-J. Dordain

---

agence spatiale européenne

L'Agence Spatiale Européenne est issue des deux Organisations spatiales européennes qui l'ont précédée – l'Organisation européenne de recherches spatiales (CERS) et l'Organisation européenne pour la mise au point et la construction de lanceurs d'engins spatiaux (CECLES) – dont elle a repris les droits et obligations. Les Etats membres en sont: l'Allemagne, l'Autriche, la Belgique, le Danemark, l'Espagne, la Finlande, la France, l'Irlande, l'Italie, la Norvège, les Pays-Bas, le Portugal, le Royaumi-Uni, la Suède et la Suisse. Le Canada bénéficie d'un statut d'Etat coopérant.

Selon les termes de la Convention: l'Agence a pour mission d'assurer et de développer, à des fins exclusivement pacifiques, la coopération entre Etats européens dans les domaines de la recherche et de la technologie spatiales et de leurs applications spatiales, en vue de leur utilisation à des fins scientifiques et pour des systèmes spatiaux opérationnels d'applications:

(a) en élaborant et en mettant en oeuvre une politique spatiale européenne à long terme, en recommandant aux Etats membres des objectifs en matière spatiale et en concertant les politiques des Etats membres à l'égard d'autres organisations et institutions nationales et internationales;
(b) en élaborant et en mettant en oeuvre des activités et des programmes dans le domaine spatial;
(c) en coordonnant le programme spatial européen et les programmes nationaux, et en intégrant ces derniers progressivement et aussi complètement que possible dans le programme spatial européen, notamment en ce qui concerne le développement de satellites d'applications;
(d) en élaborant et en mettant en oeuvre la politique industrielle appropriée à son programme et en recommandant aux Etats membres une politique industrielle cohérente.

L'Agence est dirigée par un Conseil, composé de représentants des Etats membres. Le Directeur général est le fonctionnaire exécutif supérieur de l'Agence et la représente dans tous ses actes.

Le SIEGE de l'Agence est à Paris.

Les principaux Etablissements de l'Agence sont:

LE CENTRE EUROPEEN DE RECHERCHE ET DE TECHNOLOGIE SPATIALES (ESTEC), Noordwijk, Pays-Bas.

LE CENTRE EUROPEEN D'OPERATIONS SPATIALES (ESOC), Darmstadt, Allemagne.

ESRIN, Frascati, Italy

Président du Conseil: P. Tegnér

Directeur général: J.-J. Dordain

Editorial/Circulation Office
ESA Publications Division
ESTEC, PO Box 299, Noordwijk
2200 AG The Netherlands
Tel.: (31) 71.5653400

Editors
Bruce Battrick
Barbara Warmbein

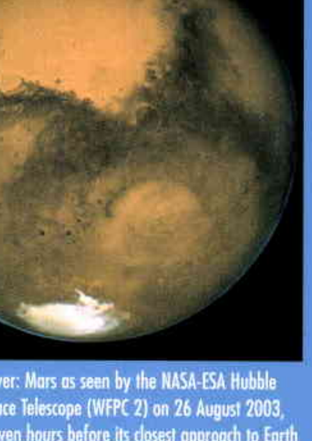
Layout
Carel Haakman

Montage
Isabel Kenny

Advertising
Barbara Warmbein

The ESA Bulletin is published by the European Space Agency. Individual articles may be reprinted provided the credit line reads 'Reprinted from ESA Bulletin', plus date of issue. Signed articles reprinted must bear the author's name. Advertisements are accepted in good faith; the Agency accepts no responsibility for their content or claims.

Printed in the Netherlands ISSN 0376-4265



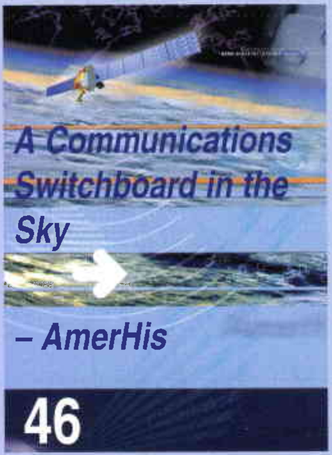
Cover: Mars as seen by the NASA-ESA Hubble Space Telescope (WFPC 2) on 26 August 2003, eleven hours before its closest approach to Earth
Image courtesy of: NASA, J. Bell (Cornell Univ.) and M. Wolff (SSI)

European Space Agency
Agence spatiale européenne

www.esa.int

Mars Express - *Closing in on the Red Planet*

Putting the International Space Station to Work



Mars Express - *Unravelling the Scientific Mysteries of the Red Planet*

Aurora – *The European Space Exploration Programme*

esa bulletin 115 - august 2003

Contents

Contraves Space

Standard Space Radiation Monitoring

Under a contract with the European Space Agency (ESA) **SREM** (Standard Radiation Environmental Monitor) has been developed and manufactured by Contraves Space in co-operation with the Paul Scherrer Institute (PSI) in Switzerland.

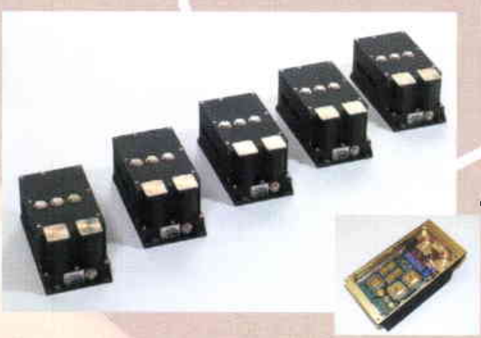
Performing a wide range of in orbit Radiation Monitoring functions, the Radiation tolerant SREM helps keeping your Spacecraft onboard instruments safe from major Radiation events.

SREM is compatible with all common spacecraft interfaces and mission constraints.

Main Features :

- Compact size
- Low weight
- Low power

- Three (3) precision particle detectors
  Internal dose measurement
  Internal temperature measurement
- Microprocessor, memory and data storage capacity for autonomous operation during several days
- Data downloading on request via host spacecraft telemetry
  Operational monitoring accessible from host spacecraft data handling system

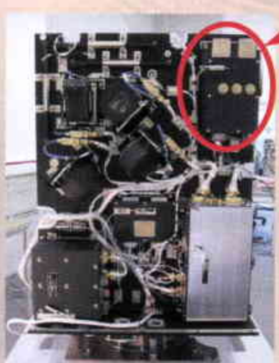


Manufactured SREM's have been attributed to specific missions:

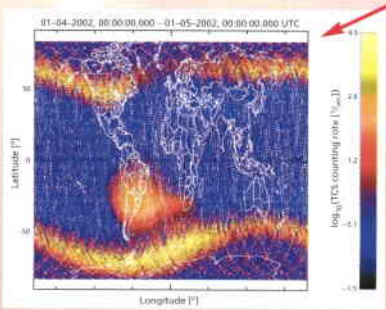
• STRV-1C	Now flying
• PROBA	Now flying
• Integral	Now flying

and are selected for upcoming missions:

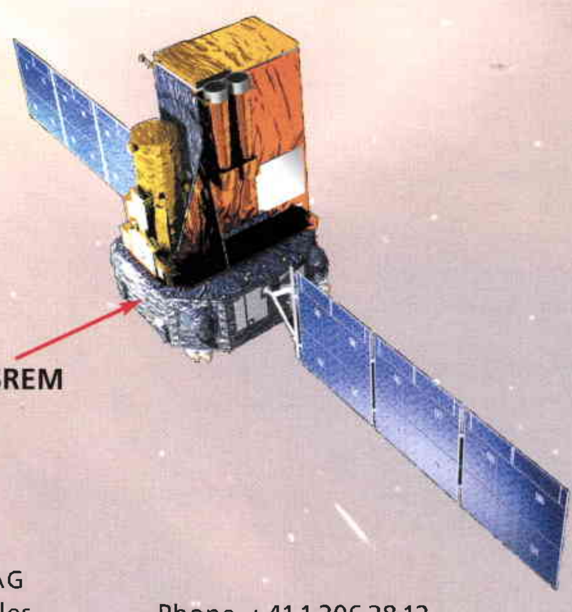
- Rosetta, Mars Express, GSTB, PROBA 2, Herschel, Planck.



SREM on PROBA



SREM in orbit data



SREM on INTEGRAL

a unaxis company

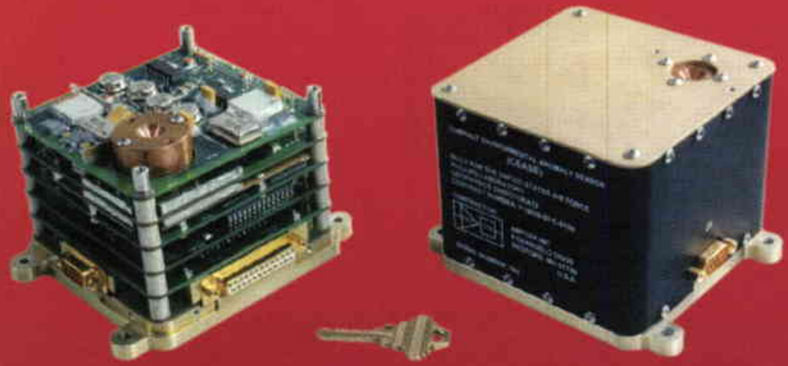
Contraves Space AG
Marketing and Sales
Schaffhauserstrasse 580
CH-8052 Zurich, Switzerland
www.contravesspace.com

Phone +41 1 306 28 12
Fax +41 1 306 22 10
eric.staub@unaxis.com
jack.schneider@unaxis.com

Space Radiation Alarm

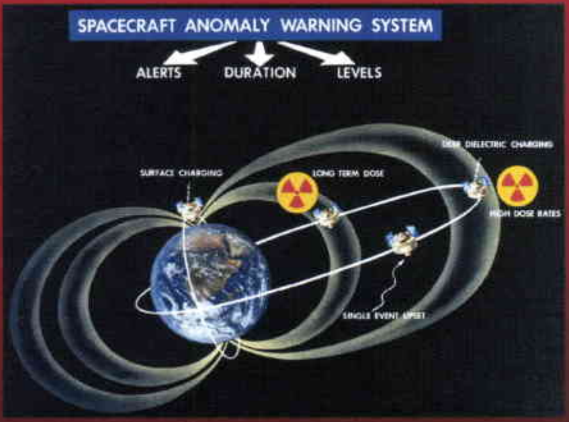
"CEASE"

COMPACT ENVIRONMENTAL ANOMALY SENSOR



FEATURES:

- **Compact: 10 x 10 x 8.1 cm^3, 1 kg**
- **Low Power: 1.5 W**
- **Flexible I/O: Supports 1553B and RS422**
- **Full GSE and operational software**
- **On-board determination of hazardous conditions**



CEASE is a compact, radiation hard, low power, space "weather" hazard sensor developed to monitor the local radiation environment and to provide autonomous real-time warnings of:

- Total Radiation Dose
- Radiation Dose Rate
- Surface Charging
- Deep Dielectric Charging
- Single Event Effects
- Solar Cell Damage

CEASE radiation data are used to forecast hazardous conditions before they affect the mission, and to pinpoint causes of spacecraft anomalies. The spacecraft or operator, in turn, can re-prioritize its operations, inhibit any anomaly sensitive tasks such as attitude control adjustments, or initiate other prudent actions as indicated by the **CEASE** warning flags. Device degradation mechanisms and radiation tolerance of components can also be monitored.

The US Department of Defense has selected **CEASE** for several missions, including TSX-5, STRV-1C, and the DSP operational spacecraft. **CEASE** has also been chosen by SES Americom for its Space Bus 4000 satellites.

Amptek has a long and distinguished track record in the manufacture of space instrumentation. Mission examples include: DMSP, TIROS, CRRES, NEAR and APEX.

Current off-the-shelf Amptek sensors measure spacecraft charging, thermal and suprathermal, and high energy particles. In addition, Amptek provided the X-ray Detector on the Mars PATHFINDER Mission.

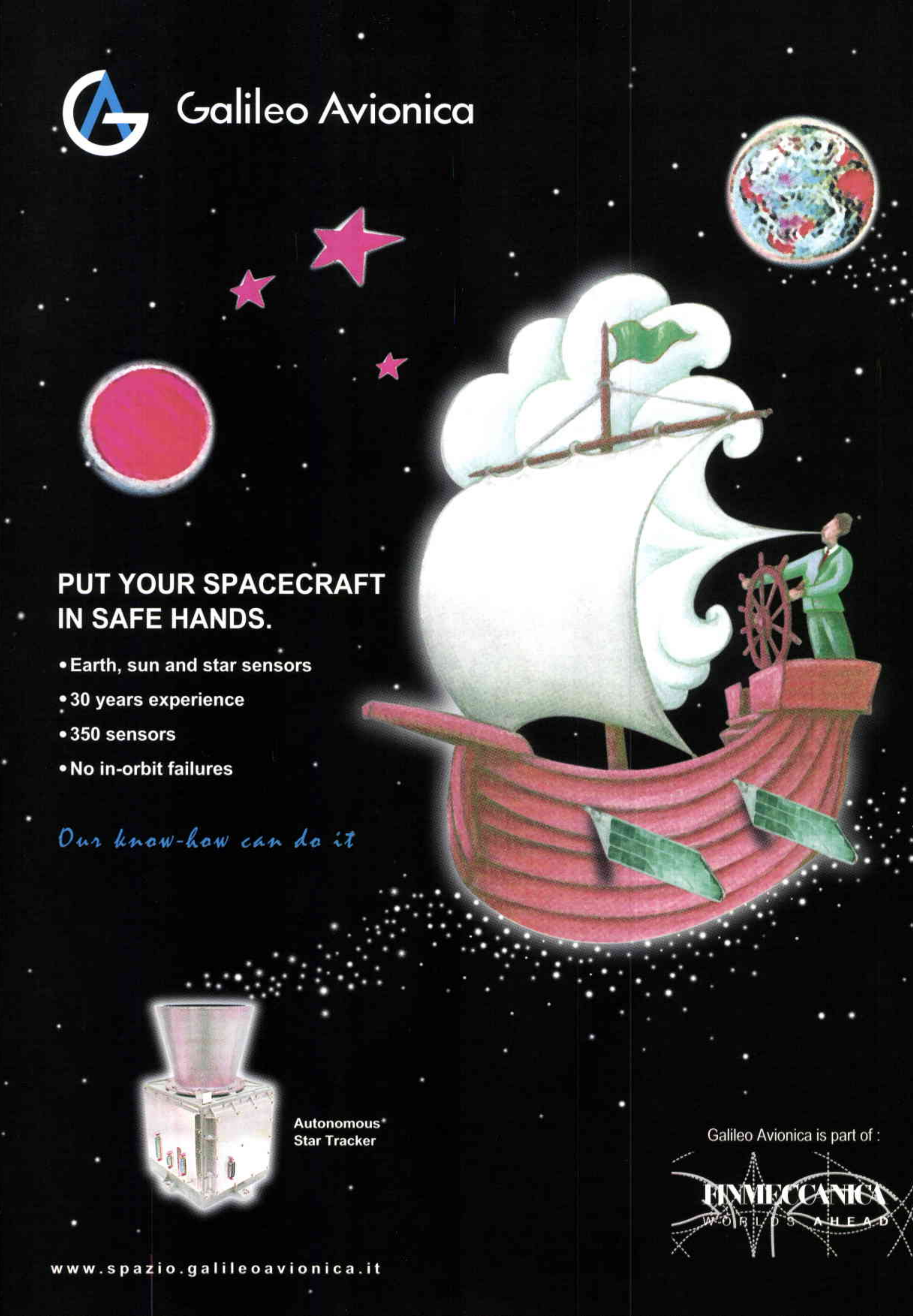
High reliability components from Amptek have been the number one choice of many missions, including: GALILEO, CASSINI, GIOTTO, Chandra, SUISEI, CLUSTER, SOLAR, GEOTAIL, SOHO, INTEGRAL, WIND and AMPTE.

AMP TEK®

AMPTEK INC.

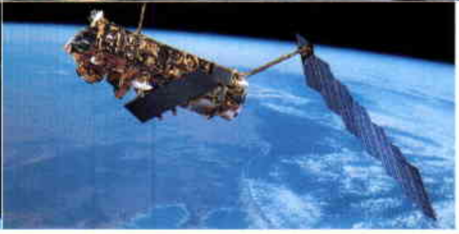
6 DE ANGELO DRIVE, BEDFORD, MA 01730-2204 U.S.A.

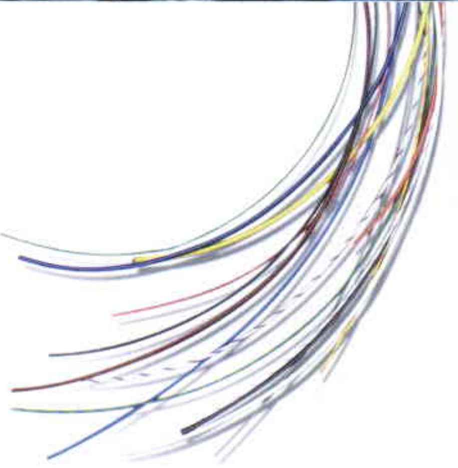
Tel: +1 (781) 275-2242 ***Fax:*** +1 (781) 275-3470 ***email:*** sales@amptek.com **www.amptek.com**



Galileo Avionica
PUT YOUR SPACECRAFT IN SAFE HANDS.
• Earth, sun and star sensors
• 30 years experience
• 350 sensors
• No in-orbit failures
Our know-how can do it
Autonomous Star Tracker
Galileo Avionica is part of :
FINMECCANICA
WORLDS AHEAD
www.spazio.galileoavionica.it


GORE Space wire and cables for
mission success
- ESA Qualified
Manufacturing Facility
- DIN EN ISO 9001 Certified
- Corrosion testing on every
space cable production lot
- Engineering Assistance
- After Sales Support





eurosim

.... the European Real-Time Operations Simulator

- hard-real-time simulations
- non-real-time and faster-than-real-time simulations
- knowledge management for complex systems
- multi-disciplinary project teams
- multi-user simulation solutions
- transfer of knowledge throughout the full project life-cycle

Operations/ Training

Production/ Testing

Prototype

Engineering

Feasibility

Availability

EuroSim is available as a licensed product, leased, or as part of a turn-key simulation solution supported by the EuroSim consortium.

An add-on product is available for automatic integration of models from MATLAB®/Simulink®/Stateflow®

EuroSim Consortium

EuroSim is developed and supported by

Dutch Space

NLR

Atos Origin

Information

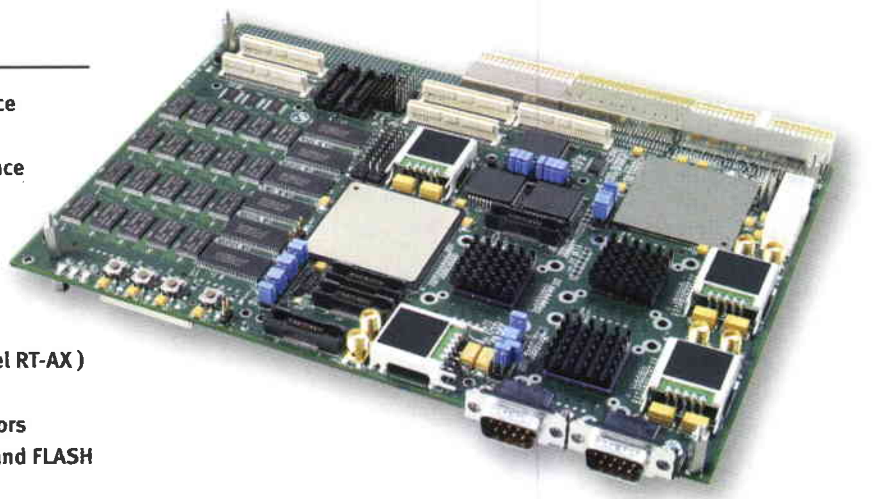
Find out more about EuroSim at **www.eurosim.nl**

or contact EuroSim Marketing & Sales at:

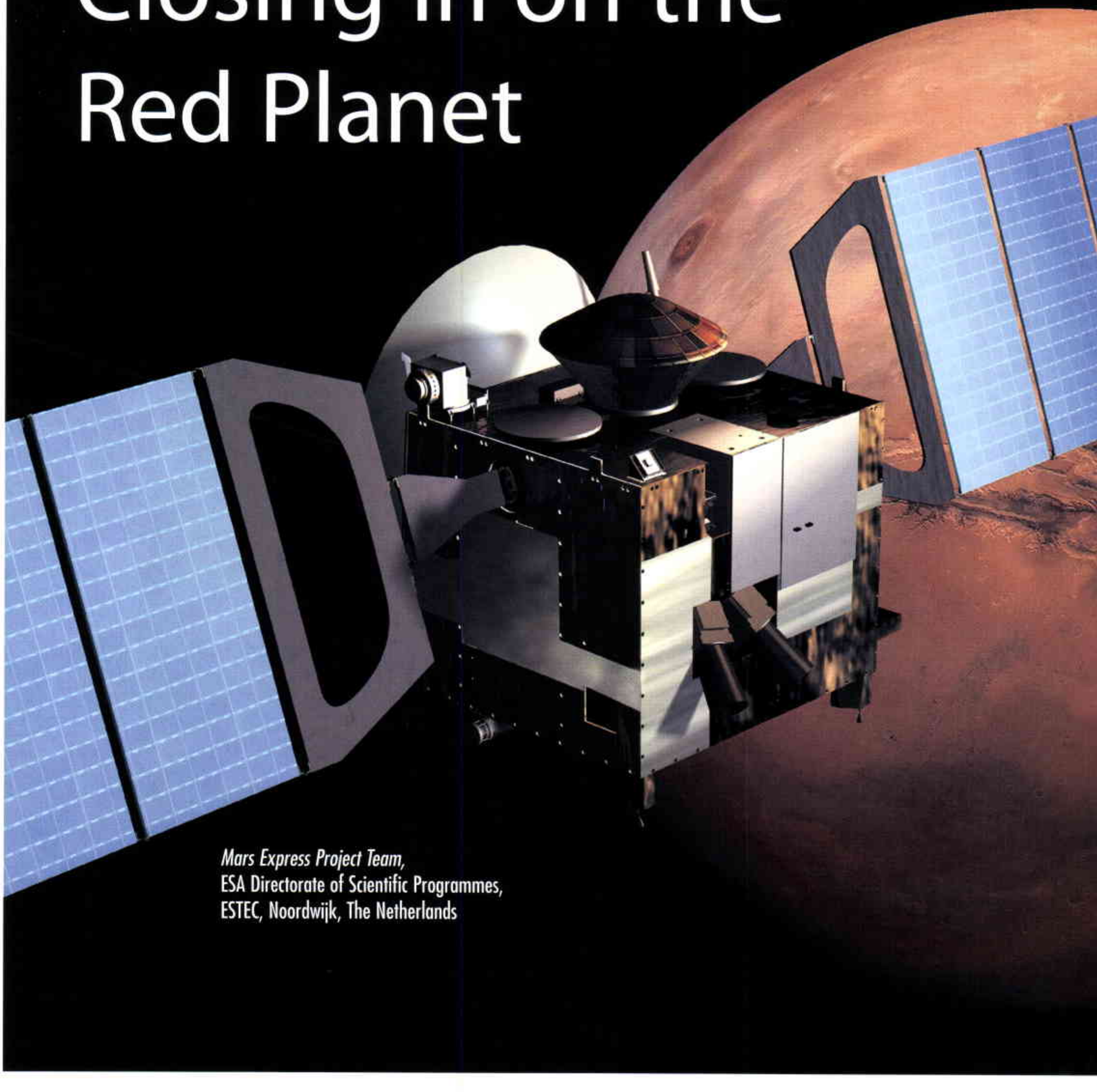
Dutch Space	+31 (0)71 5245263
NLR	+31 (0)20 5113424
Atos Origin	+31 (0)30 2994584

or e-mail the helpdesk:
esim-info@dutchspace.nl

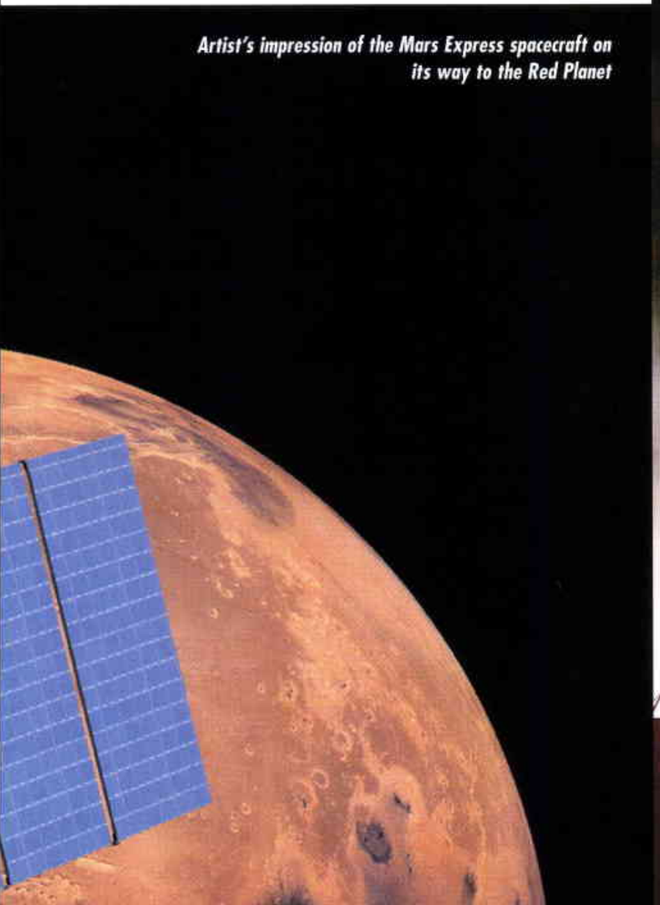

Spacelink[NGT]
Next Generation Technology TTC and TM/TC equipment
Simulation
Test
Operation
SpaceLink[NGT] TM/TC Baseband Processor
IF Transceiver
Satellite Services B.V.
Scheeepmakerstraat 40
2222 AC Katwijk aan Zee
The Netherlands
T: +31-71-402 8120
F: +31-71-402 7934
info@satserv.nl
www.satserv.nl
www.SpacelinkNGT.com
Satellite Services BV



Mars Express – Closing in on the Red Planet



Mars Express Project Team,
ESA Directorate of Scientific Programmes,
ESTEC, Noordwijk, The Netherlands



Artist's impression of the Mars Express spacecraft on its way to the Red Planet

The launch of Mars Express from Baikonur on 2 June 2003

Europeans are now closer to Mars, at least metaphorically speaking. The first planetary mission managed entirely by Europe, Mars Express, is currently on its way towards the Red Planet, where it is due to arrive in December this year. The spacecraft goes into orbit around the planet, having first released a lander designed to search for Martian life!

The whole European space sector will then have all the more reason to celebrate. Thanks to the Mars Express mission, European engineers and scientists will have mastered not only how to land on another planet, but to do it with 'state of the art' technology, developed in a record-breaking time and at half the usual cost. This is their story.

The Mars Express adventure began on 2 June 2003, with the spacecraft's launch by a Russian Soyuz-Fregat rocket from the Baikonur Cosmodrome in Kazakhstan. The total 'time-to-destiny' will be less than seven months, which is especially short for the long trip from Earth to Mars because ESA's engineers are participating in a game of 'planetary billiards'.

Launch opportunities to go to Mars from the Earth occur every 26 months, when the Sun, Earth and Mars form a straight line. However, because the orbits of both planets are elliptical, not all such 'oppositions' are equal. During this year's opposition, Mars and the Earth will be especially close, the closest they have been in nearly 60 000 years. The benefits for space agencies to go this year are clear – swinging from one planet to the other takes less time and fuel. It is as if this particular space trip is currently 'on sale'. This is one of the prime reasons why so many missions are visiting the Red Planet in 2003: two NASA Rovers and the Japanese Nozomi will arrive shortly after Mars Express. These new adventurers will join two other NASA orbiters, Mars Global Surveyor and Mars Odyssey, which have been on the scene since 1997 and 2001, respectively.

Mars Express is now speeding silently through interplanetary space. With its cubic structure, wrapped in its black thermal insulation and about a man's height in length, it could be seen as a giant 'space insect' with its two silver solar panels extending like wings. The lander, called Beagle 2, travels attached to one side, folded up rather like a very large pocket watch. Moving away from the Earth at an average speed of 3 kilometres per second, the spacecraft will conserve energy, doing almost nothing until about a week before its arrival at Mars. Right now there's little activity on board.

But silence and low activity are not the norm for this Mars mission. Only a few weeks ago, the ground controllers were still checking out the spacecraft configuration, as well as the post-launch survival of the seven instruments on board. Some very delicate operations took place, during which a major part of the mission was at stake. One of them was the release of the special clamps holding Beagle 2 in place during the launch.

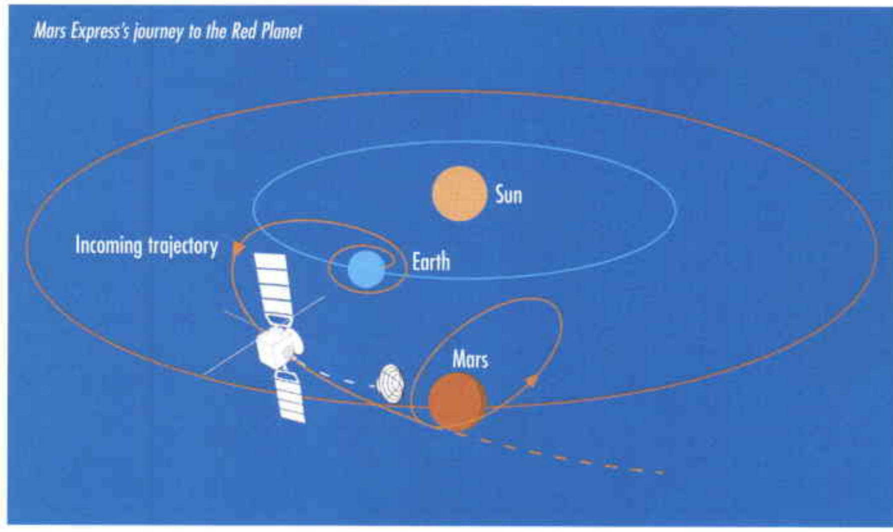


Illustration by Medialab, ©ESA 2001

"These clamps are extra means of making sure that the lander stayed perfectly attached to the spacecraft during the launch," explains Con McCarthy, Beagle 2 Principal Systems Engineer. *"Releasing them three days after the launch was a very critical operation, because if the clamps were not released correctly Beagle 2 could not be ejected on arrival at Mars, and Mars Express would go into orbit around the planet with the extra 65 kg of the lander on top."* This extra weight could have affected Mars Express operations considerably, not to mention the fact that the lander's mission would have ended before it even began.

For the Mars Express team, delicate operations like this and time pressure became routine many months before the launch. After all, this mission is not called Mars Express by chance – it has been developed quicker than any other comparable planetary mission. The design and development phase took less than four years, compared with up to six years for previous similar missions. If anything went wrong, ESA could not simply postpone the launch date. Calculations had shown that the best combination of fuel use and travel time could only be achieved by launching Mars Express in the period between 23 May and 21 June 2003. *"If we had missed the launch window, there was an 'emergency opportunity' on 28 June, with some re-arrangements in the mission. If we missed that one, we would have had to wait until 2007,"* explains Rudi Schmidt, Mars Express Project Manager.

Pioneering New Ways of Working

Mars Express has been developed quicker than any other comparable planetary mission, and at about half the cost. It took only one year to go from engineering concept to the start of development, compared to the usual five years, and it has cost 300 million Euros, compared to Rosetta's one billion Euros. What is the secret? It lies in the new managerial approach being used, which includes distributing tasks and responsibilities differently within the whole team, and the re-use of existing hardware.


Rudi Schmidt, ESA Mars Express Project Manager

Mars Express Project Manager Rudi Schmidt explains, *"Giving more responsibility to industry was a key factor. The Project Team allowed industry to take decisions faster than in the past. Also, we have enabled industry to interact directly with the launch-service provider and the scientific community. This speeds up the decision-making process and frees manpower for other tasks. Realising that all three - ESA, industry and the launch-service provider - are in the 'same boat' to Mars, we have managed to establish an excellent team spirit from the very beginning, which has helped a lot during times of high stress or technical problems."*

However, safety of the mission was never compromised. *"To ensure that quality did not suffer, we imposed a rigorous review process. We also carried out a complete test programme to ensure that we get a very reliable spacecraft. Although we had immense time pressure towards the end of the project, we did not drop any of the planned tests to save time. I call this a fast design phase followed by a thorough testing activity."*

The best way to find out how the Mars Express team dealt with their extremely tight schedule is to take a peek at their diary...

Leaving for Baikonur

"As the date for shipping the spacecraft to Baikonur draws closer, the stress and tension levels have increased dramatically, of course. Delays of minutes rather than hours, or even days, now take on a new and sometimes frightening significance," wrote John Reddy, Principle Electrical Systems Engineer for Mars Express, back in February. At that time, all development, integration and testing activities were being completed at the Toulouse facilities of Astrium, the Mars Express prime contractor. By mid March, the spacecraft had to be transported to Baikonur, almost fully integrated. *"Time waits for no man, or spacecraft,"* said Reddy.

Experienced planners well know that time is merciless, however, especially when unforeseen problems show up. This is why last-minute surprises always need to be included in the schedule. In fact, this extra provision allowed the Mars Express team to cope perfectly with its own last-minute problem. *"Just before the spacecraft was due to leave Toulouse, engineers discovered a fault in one of the electronics modules,"* said Rudi Schmidt with a smile. *"Of course, it was the most difficult box to remove from the spacecraft! When you open an electronic box in a spacecraft, you can't imagine how many wires and connections there are. It's very easy to mess something up, so you must be extremely careful."*

In the end, changing the box did not create any extra problems. The team had been working with the first days of the launch window in mind; so they simply moved the launch date back by just a few days.

The launch campaign

The spacecraft, the lander and all their accoutrements, gathered into a 100-tonne cargo shipment onboard two Russian Antonov planes, arrived at Baikonur on 20 March. A two and half month launch campaign then began. Baikonur became the temporary home of more than 70 people from all over Europe, mainly from companies such as Astrium, Starsem (responsible for the launch) and Alenia (in charge of the assembly and testing programme). Work at the launch site went on for 12 hours a day, seven days a week. As the average age of the team was 40, most of them are too young to remember the excitement that surrounded the first missions to Mars in the 1960s, when people still expected to see green creatures waving to the cameras. Nevertheless, the launch team still felt the thrill of working on a mission heading for the Red Planet.

"Being here, we sometimes feel like pioneers too," wrote Don McCoy, Mars Express Assembly Integration and Verification Engineer, on 2 May. *"It's been hard work to play our part in getting Mars Express ready to go to Mars, but we are all happy to be a part of it! The schedule to get the spacecraft ready in time for the launch is very tight. There is no room for error!"*

The first weeks of the launch campaign were devoted to tests. Only when the 'all clear' was given, did the team take the final steps to get the spacecraft ready, with the installation of the thermal blankets and the solar arrays.

The Mars Express spacecraft with its solar arrays and thermal blanket installed; Beagle is visible on the right-hand side of the craft

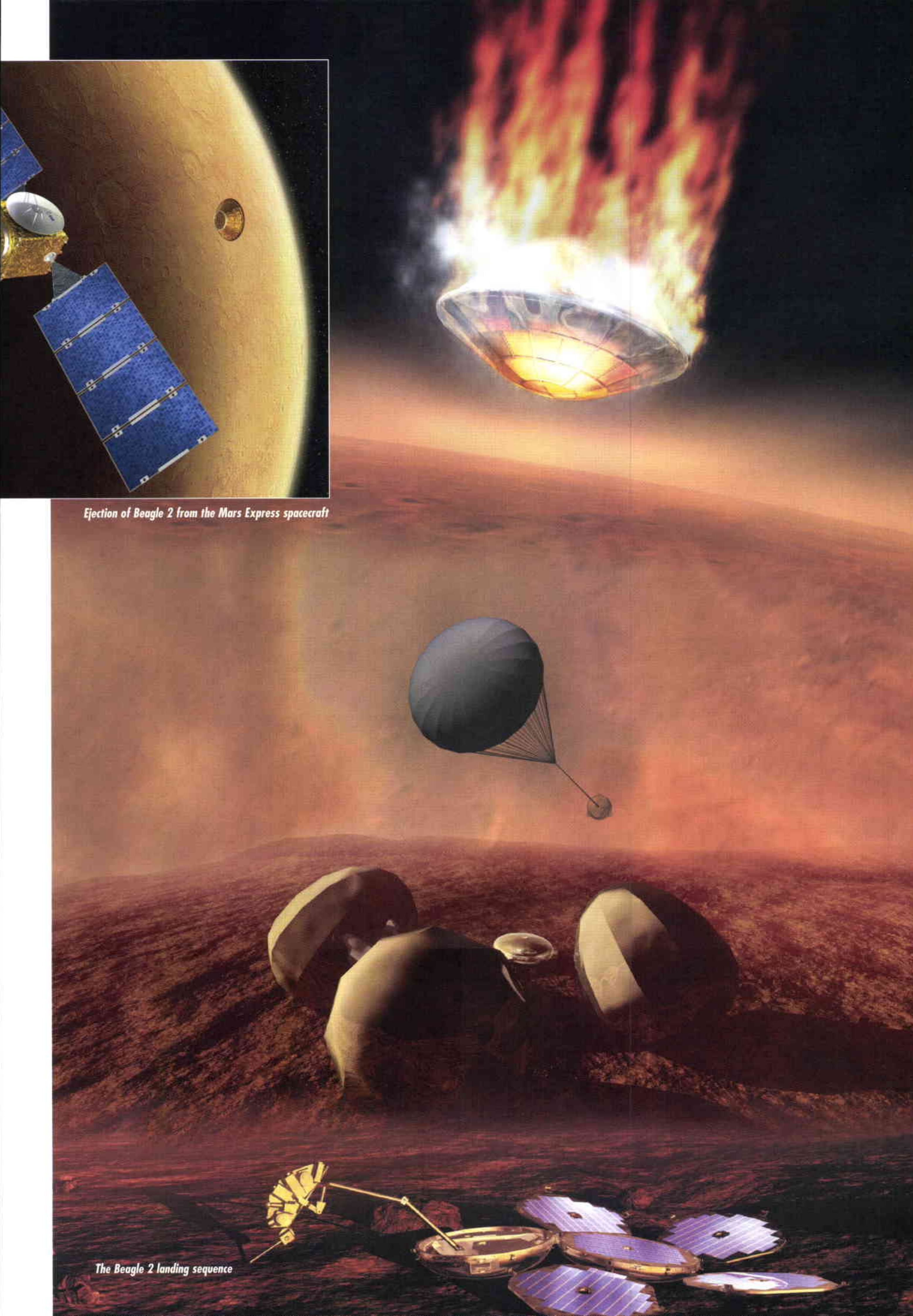
By the end of April, the spacecraft was ready to be fuelled with propellant, a delicate process that lasted for a whole week and took place in the Hazardous Process Facility. The next step was to mount the spacecraft on Fregat, the Soyuz upper-stage rocket, and then the whole structure onto the Soyuz launcher. This 'marriage' process took place on 24 May. The whole structure was subsequently rolled out to the pad four days before launch. *"Seeing everything taking shape as scheduled was the best reward for all of us, after having put so much effort and dedication in the launch campaign,"* said Michael Witting, Mars Express Launch Campaign Manager.

When Mars Express was finally ready for launch, what could the team still do in the days before launch? The answer is rehearse, rehearse and rehearse again. *"Once the spacecraft was mounted on the rocket and sitting on the launch pad, it doesn't mean we could sit back. We still had to perform several operations to get it ready for its voyage. Mars Express is a very complex satellite and we wanted a perfect send-off. We spent about eight hours talking to it via computers to configure it,"* wrote Don McCoy.

The future

Of course the most interesting part of the mission is not yet written in any diary. Full activity on board the spacecraft will resume six days before arrival at Mars with the ejection of the lander. That operation will also be one of the 'hold-your-breath' type. Beagle 2 must land on a region called Isidis Planitia, a flat sedimentary basin straddling the northern plains and the southern highlands of Mars. The landing area has the shape of a large ellipse, 300 kilometres long and 150 kilometres wide. But Beagle 2, which weights only 65 kilograms, is too light to carry a steering mechanism, and it will be unable to receive commands from Earth. So, how will it manage to land where planned? The answer is simple: engineers have calculated very precisely where and at what speed Beagle 2 has to be ejected from the Mars Express orbiter. Putting theory into practice, however, won't be as simple. The operations leading up to Beagle 2's release will take two days, and engineers regard it as one of the most complex phases of the whole mission.

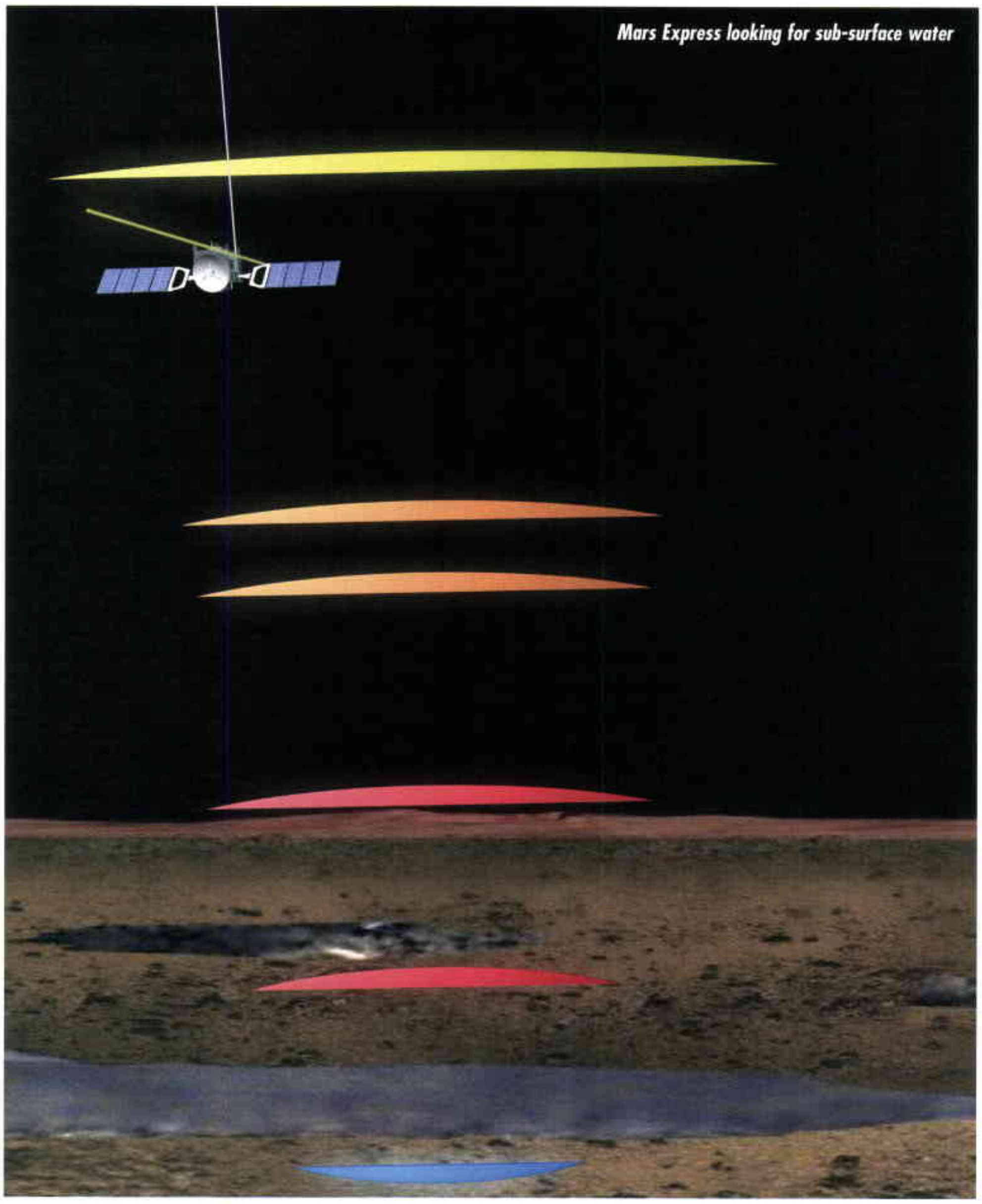
The integration of Mars Express into the launcher's fairing



Ejection of Beagle 2 from the Mars Express spacecraft

The Beagle 2 landing sequence

"Beagle 2 is fixed to the spacecraft with a spin-up and eject device," explains Rudi Schmidt. *"This device will be released by firing a pyrotechnic charge six days prior to Mars arrival. This will give Beagle 2 a certain forward speed - about 0.5 metres per second - and a rotation at the same time. The rotation has pretty much the same effect as with a child's spinning top. It stabilises Beagle 2 while it flies towards its landing site on the surface."*



The mechanism and its operation is complicated. A lot of testing has gone into ensuring that it reliably releases Beagle 2 from the orbiter. Mission controllers at the European Space Operations Centre (ESOC), in Darmstadt, Germany, have been training for months with simulators that resemble sophisticated computer games. However, a failure when in orbit around Mars will cost you much more than a few points!

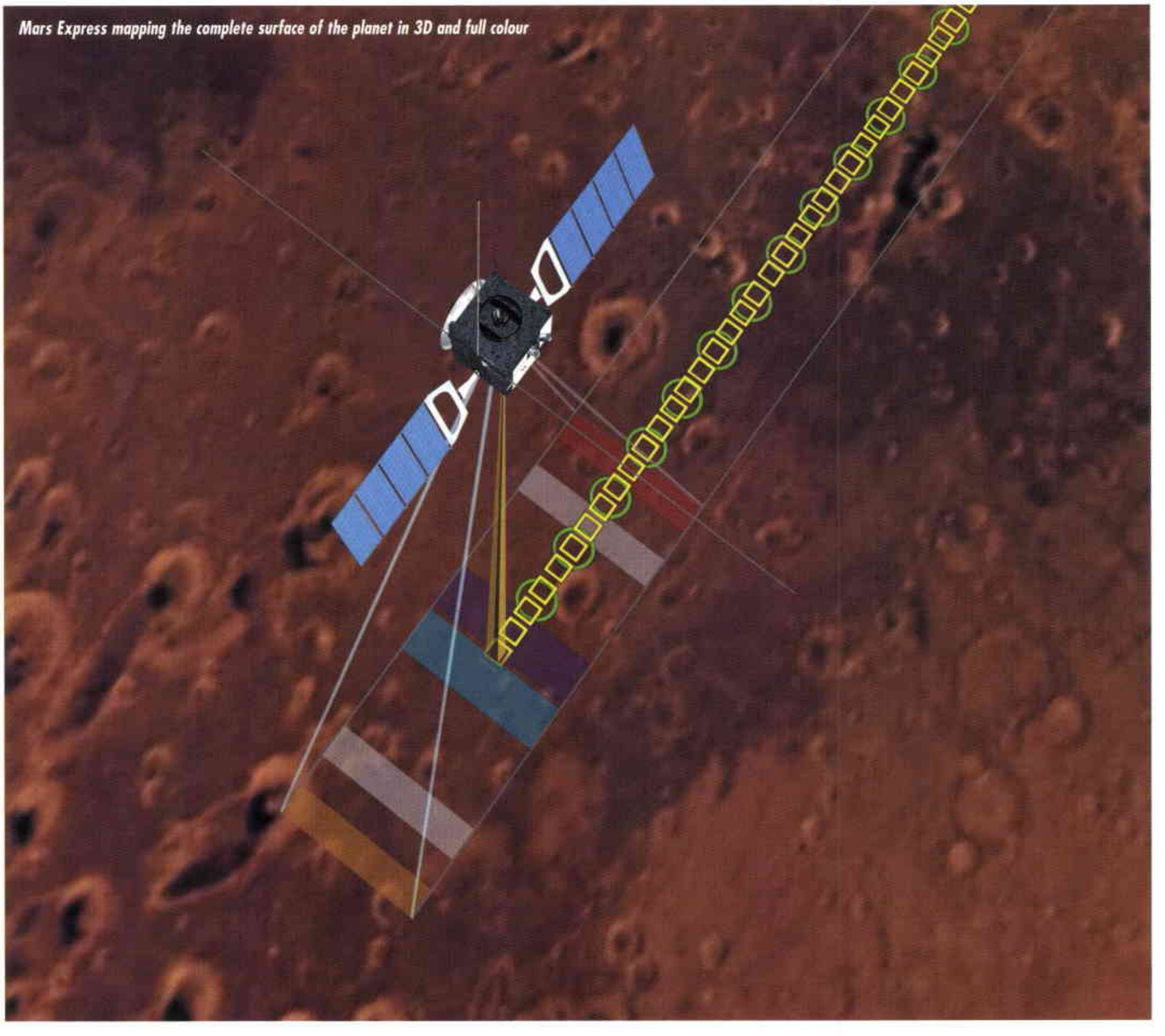
After ejecting the lander, the Mars Express orbiter will be on a collision course with the planet. Three days before arrival, therefore, ground controllers must manoeuvre the spacecraft onto the right trajectory. They will also reduce its speed by 1.3 kilometres per second to allow the planet's gravity to 'capture' Mars Express and put it into Mars orbit. Several manoeuvres will still have to be performed to get the spacecraft into its final operational orbit. The latter is highly elliptical, taking Mars Express from within just 260 kilometres of the Martian surface, to more than 11 000 kilometres away from it at its furthest point.

In the meantime, while the orbiter is still getting into its chosen orbit around Mars, Beagle 2 will have already touched down on the planet's surface. The landing will also be a very complicated and challenging operation, given that the lander will enter the Martian atmosphere at a speed of several thousand kilometres per hour. Friction with the planet's atmosphere will slow it down to about 1600 kilometres an hour, at which point parachutes will be deployed. Just before it reaches the surface, large gas-filled bags will inflate to protect the lander as it bounces. Once the lander comes to a halt, the bags will be ejected and scientific operations can begin.

One of the reasons why Isidis Planitia was chosen is that it is not too rocky to preclude a safe landing, but rocky enough to be interesting for the experiments. Isidis Planitia has few steep slopes, it is not too dusty, and its elevation is low enough to provide enough atmospheric depth to allow the parachutes to brake the lander's descent in the thin Martian atmosphere.

After landing, Beagle 2 will begin emitting a 'beeping' signal, which will be picked up by the Jodrell Bank radio telescope in England. Arrival of this 'life sign' from Beagle will tell the engineers that it has landed successfully. Several 'overflights' by Mars Express and NASA's Mars Odyssey will be needed to determine its exact position. One or two days after the landing, and once the outer case has been opened and the solar panels unfurled, Beagle will start making observations. The Payload Adjustable Workbench (PAW) at the end of the robotic arm, where most of

Mars Express mapping the complete surface of the planet in 3D and full colour



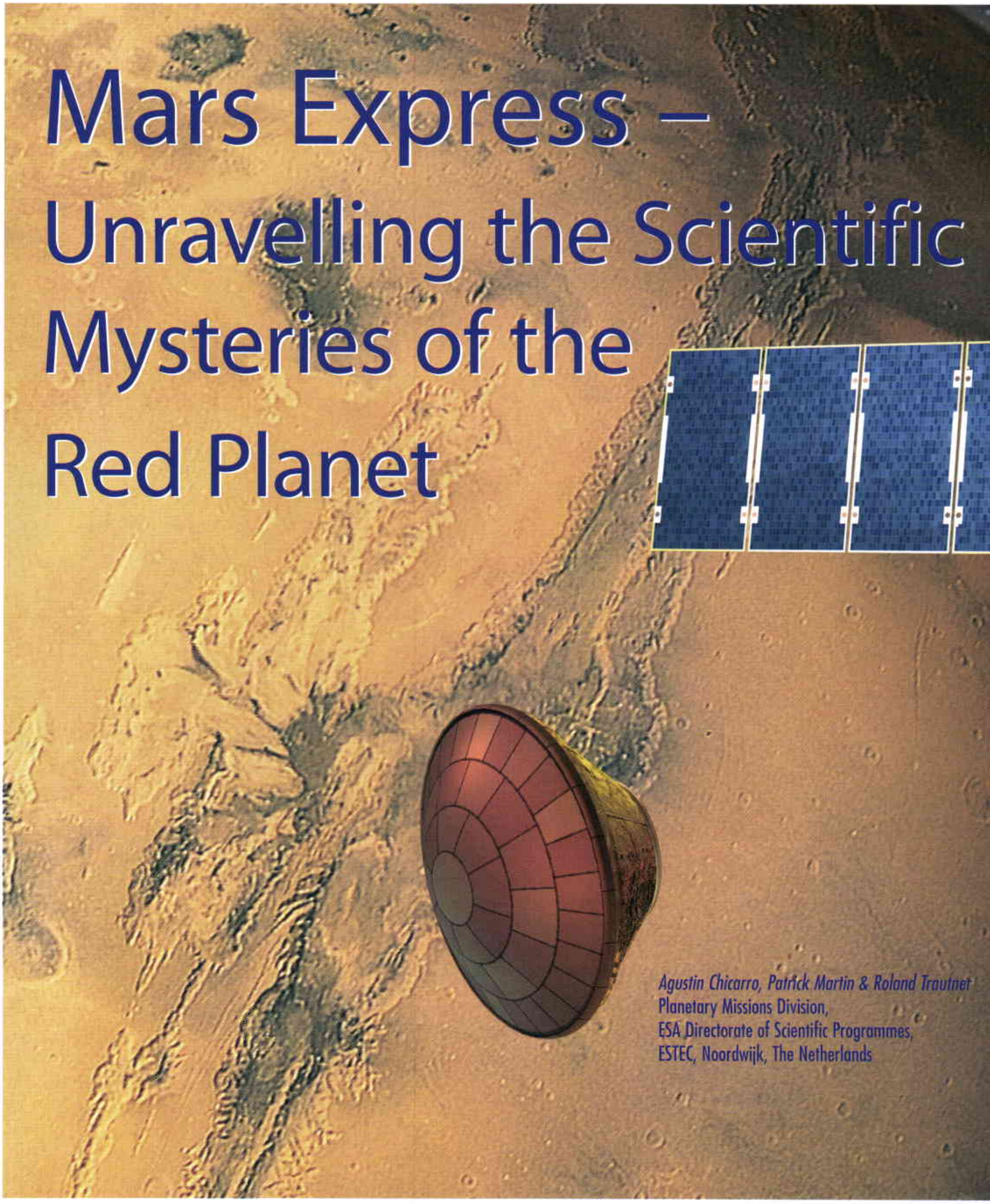
the instruments are located, will unfold and rotate to give its two stereo cameras a panoramic view. With the help of these and other images, rocks and soil samples will be selected and analysed in detail.

In the meantime, the orbiter will be imaging the entire planet at very high resolution in 3D and in full colour. It will also scan the subsurface with a radar altimeter, looking for water and ice, and map the mineral composition of the surface with great accuracy.

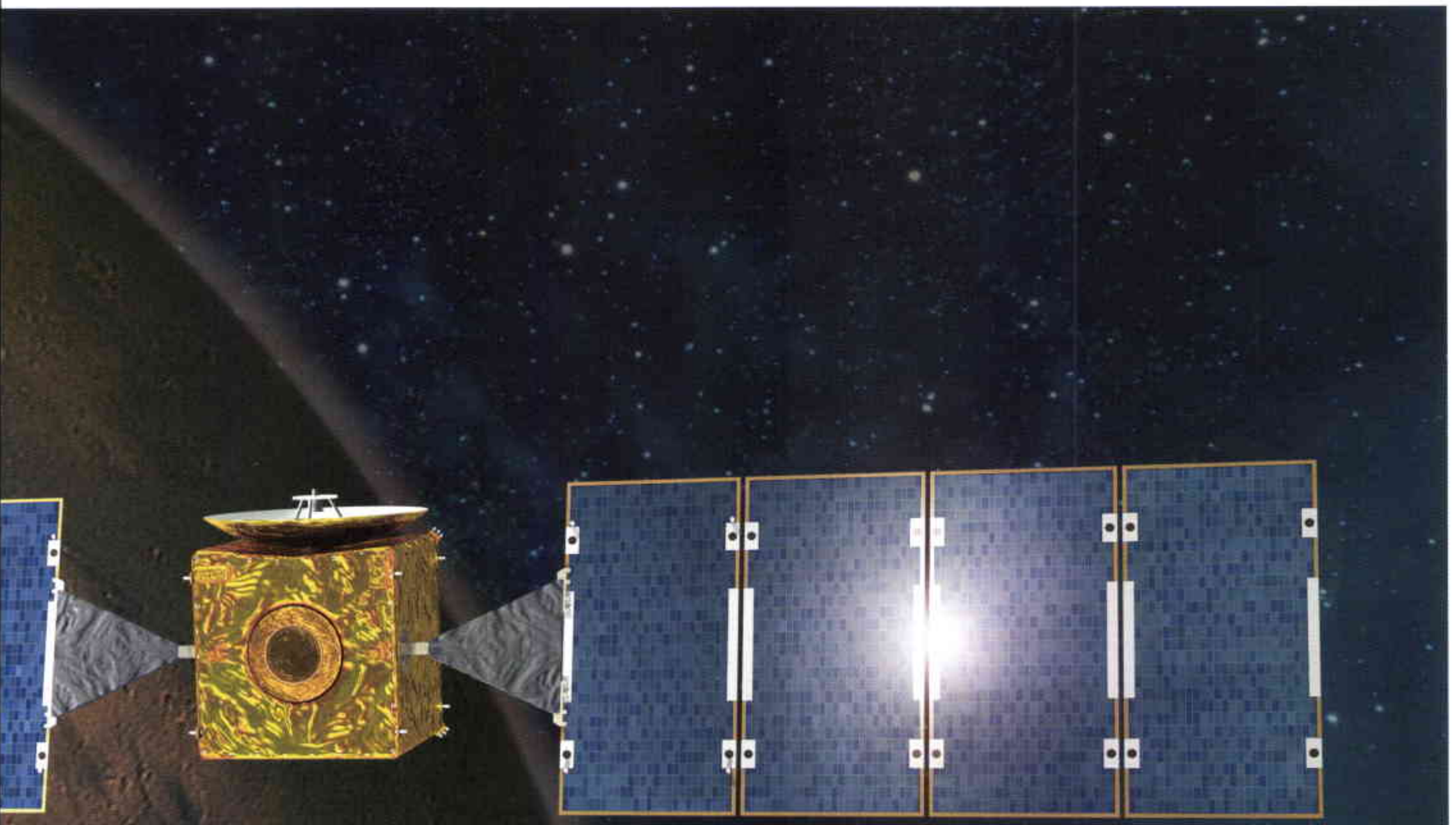
Then it will be the turn of the scientists. Data from the orbiter will be returned to Earth via the 35-metre dish at New Norcia, near Perth, Australia. From there, they will be sent to ESOC and then to the instrument scientific teams. Data from the lander will also be relayed via the orbiter, except for some periods when NASA's Mars Odyssey will pick up Beagle 2 data and send them to Earth. This will happen during the first 10 days after the landing, when Mars Express and Beagle won't be able to 'see' each other.

So what will Mars Express and Beagle 2 discover? Maybe water, maybe life... *"In any event we will get the most thorough view of the planet ever, which is of fundamental importance"*, says Agustin Chicarro, ESA's Mars Express Project Scientist. *"In the global international effort to explore Mars, Mars Express is a key mission, since it will provide the framework within which all further Martian observations will be understood."*

Mars Express – Unravelling the Scientific Mysteries of the Red Planet



Agustin Chicarro, Patrick Martin & Roland Trautner
Planetary Missions Division,
ESA Directorate of Scientific Programmes,
ESTEC, Noordwijk, The Netherlands



Mars Express is the first ESA mission to the Red Planet, and is in fact the first European mission to any planet. Launched on 2 June 2003, it includes both an orbiter spacecraft and a small lander, called 'Beagle 2' after Charles Darwin's sailing ship 'Beagle'. As the first 'flexi-mission' in the revised long-term ESA Cosmic Vision Science Programme, it has been developed in record time - about five years from concept to launch - and much more cheaply than any previous scientific mission to Mars

Historical Perspective

Before embarking on the Mars Express mission, ESA and the scientific community had conducted several feasibility studies of potential future European missions to the Red Planet - including Marsnet and Intermarsnet. Conducted over a period of more than ten years, those studies focussed on a network of surface stations complemented by an orbiter. The network concept was considered a high scientific priority in Europe until the demise of the Russian Mars-96 mission, which included many outstanding European scientific instruments. In addition to taking over several of the major goals that had been set for Mars-96 in terms of global study of the planet, Mars Express also addresses two major new themes: water and life.

Importantly, the scientific investigations to be conducted with Mars Express are absolutely complementary to those of recent US Mars Global Surveyor and Mars Odyssey orbital missions, as well as the Mars Exploration Rovers, have been launched this year. Very close collaboration has also been established with the Japanese Nozomi mission, the orbital characteristics and scientific objectives of which also fit well with those of Mars Express.

ESA has provided the launcher, the Mars Express orbiter, the mission operations and part of the Beagle 2 lander, the rest of the lander being funded by a UK-led consortium of space organisations. The orbiter's instruments have all been provided and funded by scientific institutions throughout the ESA Member States. Other countries, including the USA, Russia, Poland, Japan and China, are also participating in various scientific capacities. The ground segment includes the Mission Operations Centre at ESOC in Darmstadt, Germany, and ESA's new deep-space ground station at New Norcia in Western Australia. Support from NASA's Deep Space Network (DSN) will help to increase the scientific data return early in the mission. The Mars Express orbiter was built by Astrium in Toulouse (F), as Prime Contractor, and involved a large number of other European companies as subcontractors.


Artist's impression of the Mars Express spacecraft in polar orbit around the Red Planet

THE SCIENTIFIC PAYLOAD OF MARS EXPRESS

Acronym	Instrument	Principal Investigator	Lead Institute	Countries Participating
Orbiter				
HRSC	Super/High-Resolution Stereo Colour Imager	G. Neukum	DLR, Berlin FU Berlin	D, F, RU, USA, SF, I, UK
OMEGA	IR Mineralogical Mapping Spectrometer	J.P. Bibring	IAS, Orsay	F, I, RU
PFS	Planetary Fourier Spectrometer	V. Formisano	CNR, Frascati	I, RU, PL, D, F, E, USA
MARSIS	Subsurface-Sounding Radar/Altimeter	G. Picardi & J. Plaut	Univ. of Rome NASA/JPL	I, USA, D, CH, UK, DK, F, RU
ASPERA	Energetic Neutral Atoms Analyser	R. Lundin & S. Barabash	RFI, Kiruna	S, D, UK, F, SF, I, USA, RU
SPICAM	UV and IR Atmospheric Spectrometer	J.L. Bertaux	CNRS, Verrieres	F, B, RU, USA
MaRS	Radio Science Experiment	M. Pätzold	Univ. of Cologne	D, F, USA, A
Lander				
Beagle 2	Suite of imaging instruments, organic and inorganic chemical analysis, robotic sampling devices and meteorological sensors	C. Pillinger & M. Sims	Open Univ. Leicester Univ.	UK, D, USA, F, CH, RU, PRC, A, E

The Scientific Goals

The Mars Express orbiter spacecraft represents the core of the mission, providing unprecedented global data on the planet, and its surface, subsurface and atmosphere in particular. The Beagle 2 lander was selected on the basis of its innovative scientific goals and very challenging payload. The resulting orbiter-lander combination constitutes a very powerful tool with which to focus on two largely related issues, namely the current inventory of ice and/or liquid water, and possible traces of past or present biological activity on the planet.

The broad scientific objectives of the orbiter are: global colour and stereo high-resolution imaging with 10 m resolution and imaging of selected areas at 2 metres per pixel, global mineralogical mapping of the surface in the infrared, radar sounding of the subsurface structure down to the permafrost, global atmospheric composition and circulation studies, study of atmosphere/surface/interplanetary medium interactions, as well as radio science to derive critical information about the planet's atmosphere, ionosphere, surface and interior.

The ultimate scientific objective for the Beagle 2 lander is the detection of evidence of extinct and/or extant life on Mars, a more attainable goal being the assessment of whether conditions at the landing site were ever suitable for the emergence and evolution of life. Beagle 2 will therefore perform in-situ geological, mineralogical and geochemical analyses of selected rocks and soils at the landing site. It will also study the Martian environment via chemical analysis of the planet's atmosphere, via localised geomorphological studies of the landing site, and via the investigation of dynamic environmental processes. Further lander studies will include analysis of the subsurface regime using a ground penetration tool and a first attempt at in-situ isotopic dating of rocks on another planet.

The Science Instruments

On the Orbiter

The orbiter's scientific payload, weighing about 116 kg, consists of six instruments, in addition to a radio-science experiment that does not involve any hardware. The six instruments fall into two catagories: those dealing primarily with the solid planet by observing its surface and subsurface – namely the Super/High-Resolution Stereo Colour Imager (HRSC), the Infrared Mineralogical Mapping Spectrometer (OMEGA) and the Subsurface-Sounding Radar Altimeter (MARSIS) – and those studying the Martian atmosphere and environment – namely the Planetary Fourier Spectrometer (PFS), the Ultraviolet and Infrared Atmospheric Spectrometer (SPICAM) and the Energetic Neutral Atoms Analyser (ASPERA). The Radio-Science Experiment (MaRS) will provide insights into the planet's internal structure, surface roughness, neutral atmosphere and ionosphere.

The ***HRSC*** instrument is based on the second space-qualified flight model of the instrument developed for the Mars-96 mission, with the addition of a Super Resolution Channel (SRC). Scientific interpretation of its global-coverage high-resolution images (10 metres/pixel in stereo, colour and with different phase angles) will focus on the role of water and climate throughout Martian history, the temporal evolution of volcanism and tectonics, the surface/atmosphere interactions, the establishment of an accurate chronology, and observations of the planet's moons Phobos and Deimos.

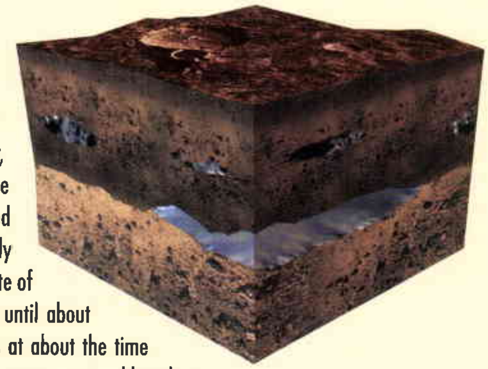
OMEGA is a visible and near-infrared mapping spectrometer derived from the spare model built for the Mars-96 mission. Operating at wavelengths between 0.38 and 5.1 μm, it will provide global coverage of Mars with 1 to 5 km resolution from orbital altitudes of between 1000 and 4000 km, and higher-resolution (few hundred metres) snapshots of selected areas of the surface. OMEGA will characterise the composition of surface materials, study the temporal and spatial distribution of atmospheric carbon dioxide, carbon monoxide and water vapour, identify the aerosols and dust particles in the atmosphere, and monitor the processes transporting surface dust. It will contribute to our understanding of the planet's evolution on seasonal to geological time scales and provide unique clues for understanding the water and carbon-dioxide cycles throughout Mars' evolution.

MARSIS is a low-frequency radar sounder and altimeter with ground-penetrating capabilities. It uses synthetic-aperture techniques, two 20 m booms and a secondary receiving antenna to isolate subsurface reflections, and will be the first radar sounder to investigate both the surface and subsurface of Mars. Its primary objective is to map the distribution of water, both liquid and solid, in the upper portions of the Martian crust to a depth of 3 to 5 km. Detection of such water reservoirs addresses key issues in the geological, hydrological, climatic and possibly biological evolution of the planet. Secondary objectives for MARSIS include subsurface geological probing, surface-roughness and topography characterisation on scales ranging from tens of metres to kilometres, and ionospheric sounding to characterise the interactions of the solar wind with the ionosphere and the upper Martian atmosphere.

PFS is an infrared spectrometer optimised for atmospheric studies. Also derived from a similar instrument developed for the Mars-96 mission, it is able to cover the wavelength ranges of 1.2 to 5 μm and 5 to 45 μm with a spectral resolution of 2 cm^{-1} and a spatial resolution of 10 to 20 km. Its main scientific objectives are global long-term three-dimensional monitoring of the temperature field in the lower Martian atmosphere, measurement of the variations in water vapour and carbon monoxide, determination of the size distribution, chemical composition and optical properties of the atmospheric aerosols, dust clouds, ice clouds and hazes, and study of their global circulations and dynamics. PFS will also determine the daily temperature variations (thermal inertia) of the planet's surface and the nature of the surface condensate and the seasonal variations in its composition, as well as studying surface-atmosphere exchange processes.

SPICAM is an ultraviolet and infrared spectrometer devoted to studying the Martian atmosphere, including its photochemistry, density/temperature structure (from 0 to 150 km), upper-atmosphere/ionosphere escape processes, and interaction with the solar wind. The infrared sensor will be used to determine column abundances and the water, carbon dioxide and ozone cycles. SPICAM's measurements, which will complement those of PFS, will therefore address key questions regarding the present state of the atmosphere of Mars, its climate and evolution. SPICAM can also perform nadir viewing measurements of the atmosphere, and uses limb viewing and stellar occultation to infer atmospheric parameters.

The Issue of Water



Today, liquid water cannot exist on the surface of Mars due to the low density of its atmosphere (6 mbar). There is, however, ample evidence to suggest that during the planet's early history liquid water flowed freely, such as the dry riverbeds in the heavily cratered Southern Highlands. The early climate of Mars appears to have been warm and wet until about 3.8 billion years ago, much like the Earth's at about the time when life appeared on our planet. It therefore seems reasonable to hope that biological activity flourished on Mars also! Soon afterwards, however, surface conditions on Mars changed dramatically, turning it into the cold, dry place that it is today, as the modest erosion rates found at the Mars Pathfinder site have illustrated. There is also growing evidence that the young smooth Northern Plains were once occupied by an ocean, covering about one-third of the planet. Thus, the tantalizing question is: Where has all this water gone? Was it lost into space through natural evaporation, including atmospheric erosion through large impacts, or is it still somewhere on the planet, maybe below the surface in an icy form like the Earth's permafrost? Recent Mars Odyssey gamma-ray spectroscopy data have revealed a significant concentration of H^+ hydrogen ions adsorbed in the first few millimetres of soil in both polar areas on Mars. However, in light of similar Lunar Prospector data from the Moon - where we know from rock samples that there is no water present - these data only indicate the presence of a mechanism concentrating H^+ from the solar wind towards the poles. Hence, most of the Mars Express orbiter's instruments are directed towards settling this issue one and for all, through radar subsurface sounding (MARSIS), surface mineralogical mapping (OMEGA), the establishment of a detailed geological chronology (HRSC), the imaging of atmospheric escape (ASPERA), and study of the atmosphere's water, carbon dioxide and dust cycles (PFS and SPICAM). Never before has a mission to Mars been so focused on making a water inventory of the planet, and never has one been so well equipped to do so.

ASPERA is an energetic neutral-atom analyser with which to study plasma domains at different points on Mars Express's orbit, examine the interaction of the upper atmosphere with the interplanetary medium and the solar wind, and characterise the near-Mars plasma and neutral gas environment. It will also be used to characterise quantitatively the impact of plasma processes on atmospheric evolution, and obtain the global plasma and neutral gas distributions in the near-Mars environment. It will also make in-situ measurements of ions and electrons and provide data on the undisturbed solar wind. A similar instrument is being flown on the Japanese Nozomi mission.

The ***MaRS*** experiment, which does not involve any dedicated hardware, will make radio soundings of the Martian atmosphere and ionosphere (occultation experiment) to derive vertical density, pressure and temperature profiles and the diurnal and seasonal variations in the ionosphere. It will also determine the dielectric and scattering properties of the Martian surface in specific target areas with a bi-static radar experiment, and determine gravity anomalies for the investigation of the structure and evolution of the planet's interior. Precise determination of the mass of the Martian moon Phobos and radio sounding of the solar corona during the superior conjunction of Mars and the Sun are also among the MaRS objectives. The telemetry and telecommand subsystem links between the orbiter and Earth will be used (observing the phase, amplitude, polarisation and propagation times of the signals transmitted) for this experiment, which has a significant heritage from the one on the Rosetta mission.

Although not considered part of the scientific payload, two subsystems located on the spacecraft will particularly benefit the deployment and operations of the

Beagle 2 lander. The Mars Express Lander Communications (MELACOM) subsystem is the radio orbiter-to-lander data-relay transponder, whose primary role is to provide data services for the lander. Mars Express will fly over the Beagle 2 landing site every 1 to 4 Martian days and will relay scientific data to the UK-based Lander Operations Centre (LOC) via ESOC. Another device attached to the spacecraft is the digital Visual Monitoring Camera (VMC), which will monitor the release and separation of Beagle 2 five days before Mars orbit insertion.

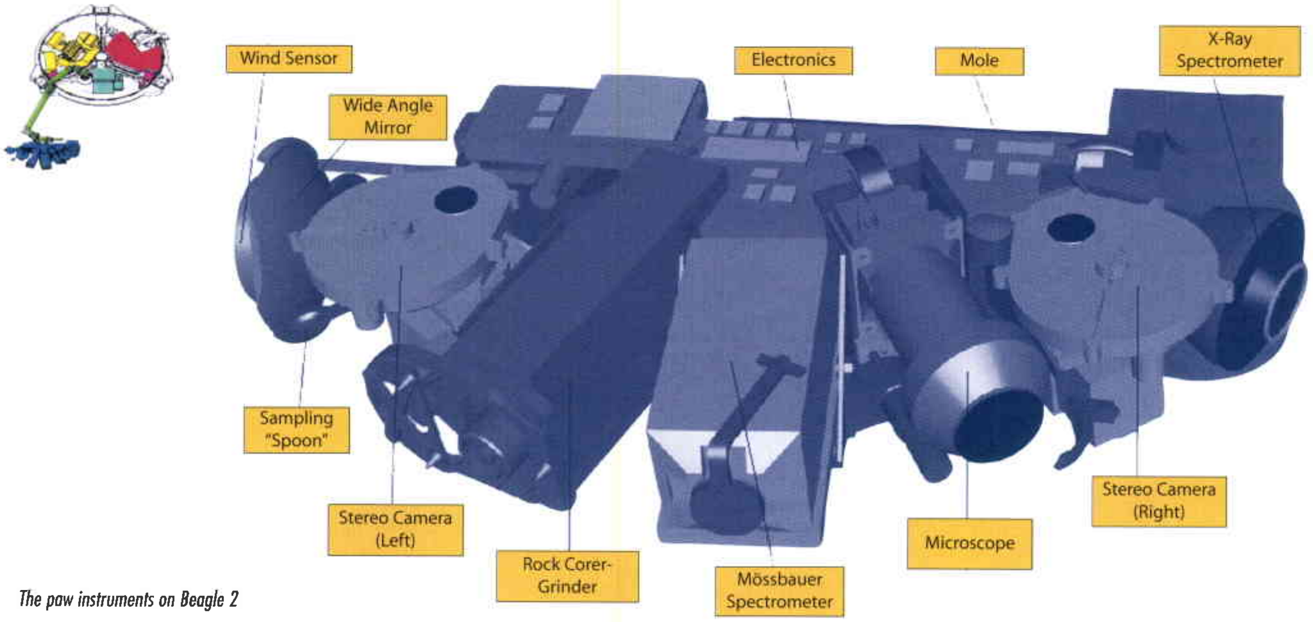
On the Lander

Beagle 2's scientific payload, which weighs just 10 kg, consists of six instruments and two dedicated tools with which to study the Martian surface and subsurface materials, and a robotic sampling arm with five degrees of freedom. The eight experiments can be divided into two catagories: those mounted directly on the lander platform – namely the Gas Analysis Package (GAP) and the Environmental Sensor Suite (ESS) – and those housed within an innovative structure called the Payload Adjustable Workbench (PAW) located at the end of the robotic arm – namely the Stereo Camera System (SCS), the Microscope (MIC), the X-ray Spectrometer (XRS), the Mössbauer Spectrometer (MBS), and a set of tools that includes the Rock Corer Grinder (RCG), the Planetary Underground Tool (PLUTO), and other support equipment such as a sampling spoon, a torch and a wide-angle mirror. The science-payload/landed-structure ratio is about 1:3, the highest of any planetary lander to date.

GAP, which is accommodated in the lander's base, will make both quantitative and qualitative analyses of sample composition, as well as precise isotopic measurements. It can process atmospheric samples as well as material acquired by the sampling tools in the form of soil or rock chippings, which are deposited into one of eight miniaturised ovens. Gases can be analysed directly (e.g. those present in the atmosphere), after their release from samples by heating, or as by-products of chemical processing (e.g. CO_2). GAP can therefore investigate: processes associated with atmospheric evolution, circulation and cycling, the nature of gases trapped in rocks and soils, low-temperature geochemistry, fluid processes, organic chemistry, formation temperatures and surface exposure ages, and can also assist in isotopic rock dating.

ESS will contribute to characterisation of the landing site and permit meteorological studies using the data from 11 sensors scattered throughout the lander platform and the PAW. Measurements of the ultraviolet radiation flux at the surface together with the oxidising capability of the soil and air will provide insights for exo-biological investigations. Measurements of atmospheric temperature, pressure, wind speed and direction, dust saltation and angle of repose will complement the in-situ environmental experiments.

Artist's impression of the Beagle 2 lander deployed on the surface of Mars



The paw instruments on Beagle 2

SCS, which consists of two identical CCD cameras and integrated filter wheels, will be used back on Earth to construct a Digital Elevation Model (DEM) of the landing site from a series of overlapping stereo image pairs. The DEM will then be used to position the PAW with respect to promising target rocks and soils. The landing-site investigations will include panoramic 360 deg imaging, multi-spectral imaging of rocks and soils to determine mineralogy, and close-up imaging of rocks and soils to infer their texture. Observations of the day and night sky, the Sun, the stars, and the Martian moons Deimos and Phobos will allow the assessment of such atmospheric properties as optical density, aerosol properties, and water-vapour content. The observation of the lander's surfaces and atmospheric effects will allow the dust and aerosol properties of the Martian atmosphere to be assessed.

MIC will investigate the nature of Martian rocks, soils and fines on the particulate scale (few microns), providing important exobiological data in the form of direct evidence of microfossils, microtextures and mineralisations of biogenic origin if present. By identifying the physical nature and extent of the weathering rinds/coatings on rocks and soils, it will also contribute to geological characterisation of the landing site. Atmospheric and the global planetary studies will also benefit from the more detailed knowledge of dust morphology. MIC will be the first attempt to directly image and assess individual particles with sizes close to the wavelength of scattered light on another planet. The acquisition of complete sets of images for each target will allow the 3D reconstruction of sample surfaces in both the visible part of the spectrum and the ultraviolet.

The primary goal with ***XRS*** is to determine, in-situ, the elemental composition, and by inference, the geochemical composition and petrological classification, of the surface materials at the landing site. It can detect major elements (Mg, Al, Si, S, Ca, Ti, Cr, Mn and Fe) and trace elements, and uses X-ray fluorescence spectrometry to determine the elemental constituents of rocks. It can perform radiometric dating of Martian rocks in-situ.

MBS will allow a quantitative analysis of iron-bearing materials in Martian rock and soil materials. Such measurements are particularly important due to the abundance of Fe-bearing minerals on Mars and their formation being linked to the history of water on the planet. It will also provide information about rock weathering in general and oxidation in particular. The MBS-generated spectra will allow the characterisation of the mineralogical makeup of rocks and soils, and hence a petrological classification. The MBS also complements the in-situ geochemical and petrological work, and provides support for the GAP measurements.

The ***RCG***, located on the PAW, addresses the latter's need for access to 'fresh', pristine material on a suitably prepared rock surface to avoid the effects of weathering rinds and geometric effects that can seriously compromise instrument performance. It allows the removal of the altered material and produces a flat, fresh surface suitable for the spectrometer measurements. After the in-situ analyses have been completed, a ground sample will be extracted using the device's coring action, and delivered to the GAP's inlet port for further chemical analysis.

The ***PLUTO*** subsurface sampling device is another PAW tool, which can retrieve soil samples from depths down to about 1.5 m and, depending on the terrain, from under a large boulder. This capability is very important for Beagle 2's exobiological investigations because materials preserving traces of biological activity lie deep within the soil or rocks, where they are unaffected by solar-ultraviolet radiation. PLUTO will make in-situ temperature measurements as a function of time and depth as it penetrates below the surface, and will also allow the soil's mechanical properties and layering to be assessed.

The Science Operations

The Mars Express orbiter will record onboard all of the scientific data gathered by its own experiments as well as those from the lander, and then transmit them back to Earth during the periods of ground-station visibility. The volume of data being downlinked will vary throughout the year from less than 1 Gbit/day to about 6 Gbits/day.

As one of several players involved in the Mars Express science operations, the Payload Operations Service (POS) established at the Rutherford Appleton Laboratory, Chilton, UK, is supporting the Mars Express Project Scientist Team (PST), the Principal Investigators (PIs), the Mission Operations Centre (MOC) and the Lander Operations Centre (LOC). The POS has been responsible, under a contract from ESA, for the development, imple-mentation, testing, and operations of the system and tools needed to support the Mars Express science operations.

The PST and the PIs are currently compiling a Master Science Plan (MSP) scheduling the acquisition of science data by Mars Express in a way that is consistent with both the scientific objectives for the mission and the resources available during the various periods of observation. The MSP will form the basis of all payload operations timeline planning during the various phases of the mission. The high-level scientific planning is to be performed by the Science Operations Working Group, which includes representatives of all PI teams. Both the PST and POS interface with the MOC on the one side, and with the PI institutes and LOC on the other.

International Collaboration

In developing the Mars Express mission, international collaboration from beyond the ESA Member States, either through participation in instrument hardware or through scientific data analysis, has been very much valued in order to expand the scope of and enhance the scientific return from the mission. Three major partners are therefore contributing to the mission: the USA, Russia and Japan. NASA is providing a major share of the MARSIS subsurface-sounding radar, as well as supporting Co-Investigators for most of the scientific payloads. It is also making its Deep Space Network (DSN) available for increased science data downloading during the early part of the mission and when critical manoeuvres are being carried out. Russian scientists are also involved in most of the orbiter experiments, many of which were originally destined for the Mars-96 mission as joint collaborations between European and Russian institutes. Other non-ESA Member States participating in the mission include Poland and China.

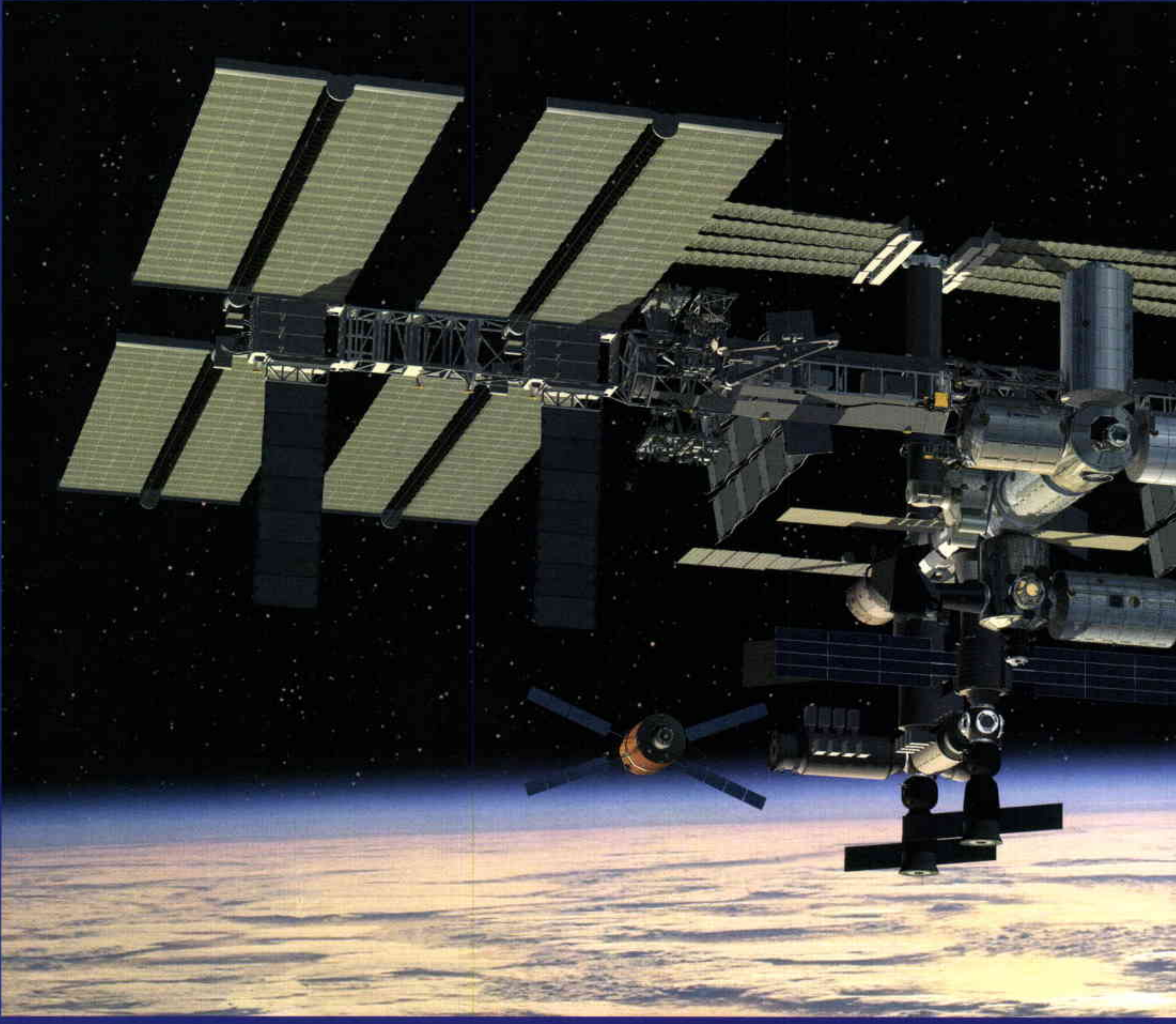
Collaboration with Japan is a special case. The Mars Express and Nozomi Science Working Teams have been collaborating closely since the unfortunate malfunctioning of the ISAS Nozomi spacecraft soon after its launch in 1998, because mutual benefit can be drawn from the fact that both missions will now reach Mars at almost the same time. This collaboration includes scientific data exchange and analysis, as well as the exchange of scientists between instrument teams. The two missions are highly complementary in terms of their orbits and scientific investigations, with Nozomi focusing from its highly elliptic equatorial orbit on the Martian atmosphere and its interaction with the solar wind, while a large part of the polar-orbiting Mars Express mission is devoted to studying the planet's surface and subsurface. Never before has a planet been simultaneously observed from two different viewing geometries by two orbiters from different space agencies. This tandem exploration programme for Mars could pave the way for even closer cooperation in the future between Europe and Japan for other targets of opportunity, including all terrestrial planets.

More information about the Mars Express mission and its Beagle 2 lander can be found at:
http://sci.esa.int/marsexpress/ and
http://www.beagle2.com/

The Issue of Life

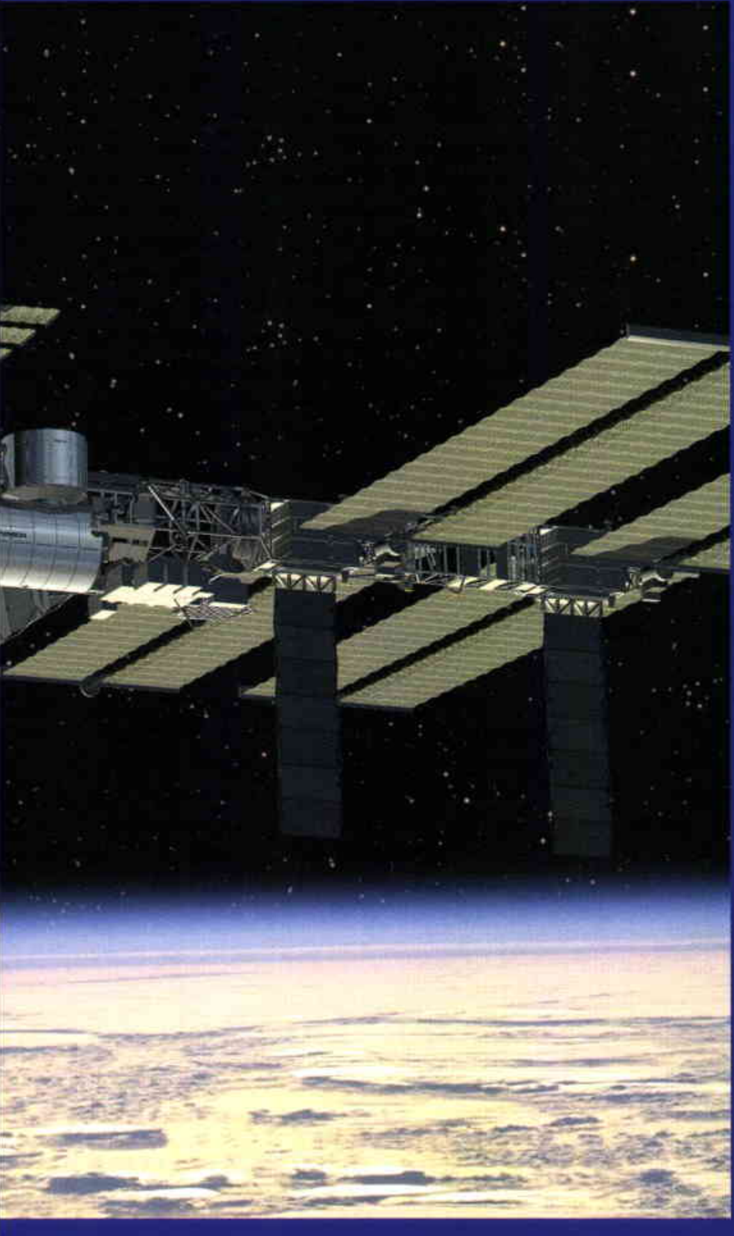
The Mars Express mission will address the issue of the emergence of life in the cosmos and in particular life signatures on Mars, both directly and indirectly. The majority of the orbiter's instruments will look for indications of conditions favorable for the existence of life, either now or during the planet's evolution. It will search in particular for traces of liquid, solid or gaseous water. Therefore, the HRSC camera will take pictures of ancient riverbeds, the OMEGA spectrometer will look for minerals with OH-radicals indicating in the presence of water, the MARSIS radar will look for subsurface ice and liquid water, the PFS and SPICAM spectrometers will analyse water vapour in the atmosphere, and finally ASPERA and MaRS will study neutral-atom escape from the atmosphere, and particularly oxygen coming from water and carbonates. The instruments on Beagle 2 will also look for water in the Martian soil, rocks and atmosphere, and in particular for traces of life with in-situ measurements. The presence of more of the lighter C^{12} isotope than heavier C^{13}, for example, would indicate the existence of extinct life, while the presence of methane (CH_4) would be indicative of extant life. Measurements from a single instrument will probably not settle the issue of life on Mars, but the sum of all of the Mars Express measurements will allow us to build up a picture pointing towards the existence of life on Mars, or not. In either case, the exo-biological implications will be far-reaching, as we will then know whether life is a common occurrence in the Universe or not. In the context of this debate, comparing the geological evolutions of Earth and Mars is obviously a potentially fruitful exercise, as both planets have seasons, polar caps, a transparent atmosphere, aeolian activity, etc. However, our other planetary neighbour Venus must not be forgotten in this respect, in view of its similarities with Earth in terms of internal activity and recent resurfacing. Comparative planetology is therefore key to our understanding the Solar System's evolution, including exo-biology. It is the first time since NASA's Viking missions in 1976 that an exhaustive search for life has been so central to a space mission to Mars.

Putting the International Space



Paul Clancy
ESA Directorate of Human Spaceflight, Research & Applications
ESTEC, Noordwijk, The Netherlands

Station to Work



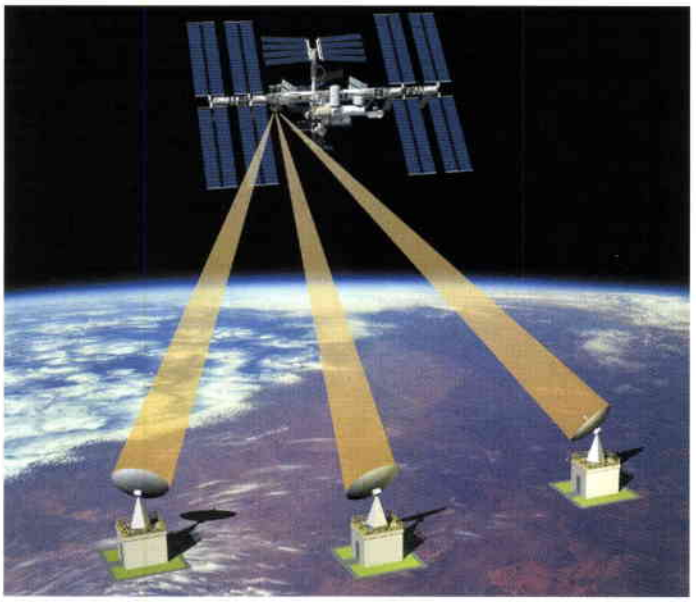
Introduction

The International Space Station (ISS) is the largest international cooperative science and technology project ever undertaken. Involving the United States, Russia, Japan, Canada and 10 ESA Member States, it is now rapidly becoming a reality in orbit, offering unprecedented access for research and applications under space conditions. Europe has invested heavily in this endeavour and plans to exploit that investment by a vigorous utilisation of the ISS for life and physical sciences research and applications, space science, Earth observation, space technology development, the promotion of commercial access to space, and the use of space for educational purposes.

In recent years, ESA has engaged in an intensive promotional effort to encourage potential user communities to exploit the novel opportunities that the ISS offers. It has also made significant financial commitments to develop both multi-user facilities for life and physical sciences studies in the Columbus Laboratory, and observational and technology exposure instruments using the external Columbus mounting locations, as well as giving financial support to promote commercial and educational activities.

ESA has now elaborated a European Strategy for the efficient utilisation of the ISS by European scientists and other users, which is being coordinated with the Agency's Member States contributing to the ISS Programme, and with the European Science Foundation (ESF). In cooperation with the European Commission, ESA is also fostering synergy with the European Commission's Framework Programmes in terms of shared R&D objectives. This article describes the plan that has been evolved to integrate all of these various elements.

Life and Physical Sciences

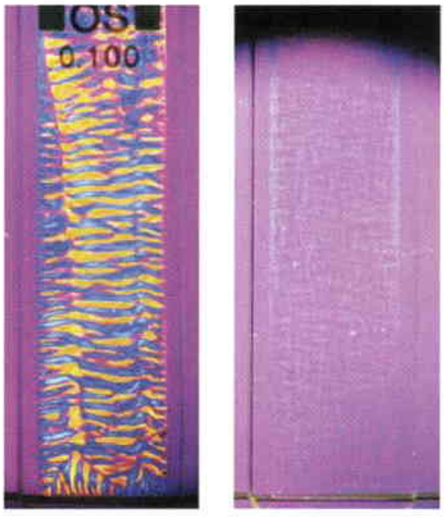


Research into cold-atom physics in space should lead to a factor 100 increase in atomic-clock frequency stability, with applications in fundamental physics, atmospheric physics and geodesy, navigation and telecommunications. This graphic shows the operational scenario for the Atomic Clock Ensemble in Space (ACES).

Through its microgravity programmes, ESA has supported space research in the life and physical sciences since the mid-1980s. Considerable scientific output has been achieved in such key areas as crystal growth, solidification physics, fluid sciences, thermophysical properties, molecular and cell biology, developmental biology, exobiology and human physiology. Many of these results have significant application potential, as demonstrated by the Agency's Microgravity Application Programme (MAP), which has attracted considerable interest not only from research institutes, but also from industry.

In the past three years, the Agency has received more than 700 new proposals in response to MAP Announcements of Opportunity. Among the more than 1000 scientists who are presently directly involved in approved projects, there are a significant percentage of newcomers, and the content of the proposals becomes ever more innovative. The existence of such a large and dynamic user community sets the stage for a strictly user-driven research strategy.

Society can rightly expect substantial benefits to flow back from research conducted on the ISS, given the heavy financial investments that have been made in its development and operation. In this respect, the strategy must encourage research likely to have good applications potential, but without interfering with the best science-driven peer-review process. An effective way to promote promising applications, therefore, is by teaming researchers from academia and industry, thereby fostering increased industrial engagement and benefits. Society will also expect to be regularly and reliably informed about the results of these ISS research activities, and here the role of the associated education and outreach activities is critical.



Exploring nature. Microtubules are important building blocks of biological cells. A recent experiment in space has shown that the self-organisation of these microtubules depends on gravity. This important finding has implications for understanding the biological functioning of cells. (Courtesy J. Tabony)

Developing the Research Plan

As part of the development process for the Research Plan, a comprehensive database of all peer-reviewed and accepted proposals was generated. To give structure to the Plan, ESA conducted a review of all proposals in hand as a result of recent Announcements of Opportunity (AOs). For defining the science and application objectives, it has taken the database of 'outstanding' and 'highly recommended' proposals that were presented to, and subsequently endorsed by, the Microgravity Programme Board. Then, with the aid of the Life and Physical Sciences Working Groups (LSWG, PSWG) and the Life and Physical Sciences Advisory Committee (LPSAC, formerly MAC), the proposals have been analysed in an iterative process that also involved the national delegations to the Microgravity Programme Board, as well as a Workshop organised by the European Science Foundation (ESF). Members of the European Low Gravity Association (ELGRA) have also provided inputs. The outcome of this process was the identification of four top-level objectives:

- Exploring Nature
- Improving Health
- Innovating Technologies and Processes
- Caring for the Environment.

In parallel, largely as a result of the ESF Workshop in November 2000 and after iteration with the LPSAC and its working groups, a set of Research Cornerstones was established to facilitate the Plan. These Cornerstones, which implicitly include the selected proposals as sub-elements, were then fleshed out in terms of the hardware development needed, the provision of flight opportunities, and the supporting ground-based work and future studies needed to implement the Plan. By carefully analysing all of the 'outstanding' and 'highly recommended' proposals, it was possible to allocate each of them to a specific Research Cornerstone and then, by examining the detailed activities within each proposal, to establish the appropriate relationship with the top-level objectives. This approach clearly showed that:

- the objectives set can indeed be met by means of research in the identified Cornerstones
- both the objectives and the Cornerstones are user-driven.

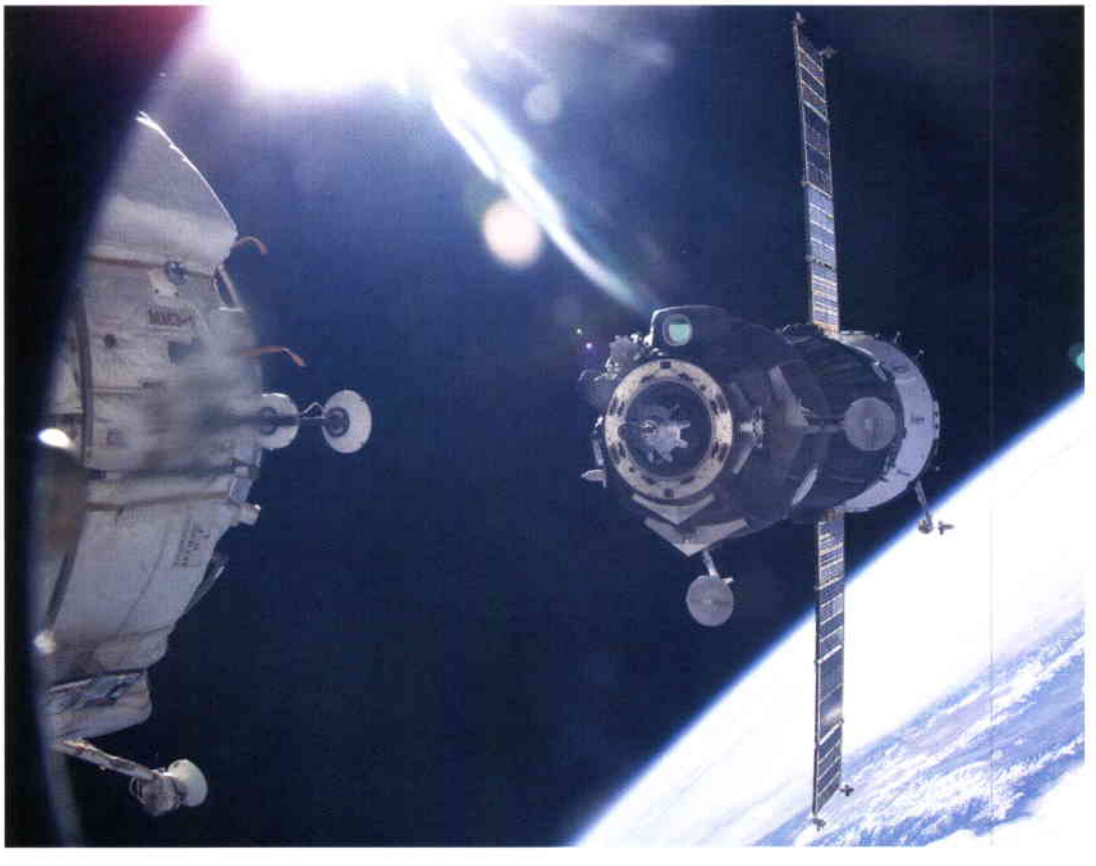
Implementing the Research Plan

Having established the Plan, with a total of 14 Research Cornerstones, the consequences for the space facilities being developed or about to be developed were addressed. This review highlighted the following programmatic consequences for ESA's European Life and Physical Sciences (ELIPS) Programme, which was approved at the Edinburgh Ministerial Council:

- There are research projects in all 14 Research Cornerstones that will require preparatory and supporting research activities, such as access to ground-based facilities, baseline data collection and bed-rest studies in the human-physiology area, the use of drop towers and aircraft in the materials, fluids, and combustion areas, and the assistance of User Support and Operations Centres (USOCs).
- There are research projects in many of the Research Cornerstones that will require continued use of the MFC facilities, namely the Materials Science Laboratory, the Fluid Science Laboratory, the Biolab and the European Physiology Modules, which will require new experiment containers/inserts to be developed and in some cases evolution/refurbishment of the facility in question.
- There are research projects in the majority of Research Cornerstones that will require use of non-ISS facilities, for example on Spacehab and Foton missions.
- There are specific research projects that will require the development of completely new facilities for the ISS.
- Some research projects will require the use of non-MFC facilities presently under development within other programmes.
- Many research projects, especially in the areas of materials, fluids, combustion and some areas of biology, will require sounding-rocket flights, particularly for preparatory work before the full ISS experiments are embarked upon.

The MFC and other facilities currently being developed to implement the Research Plan therefore include:

- Materials Science Laboratory (MSL): for industrial materials research, new materials development, and thermo-physical properties measurement, and including electromagnetic levitation for research into containerless processing
- Biolab : for cell-biology research and biotechnology
- Fluid Science Laboratory (FSL): for fluids research related to new materials and processes development
- European Physiology Modules (EPM): for biomedical research
- European Drawer Rack (EDR): for commercially developed payloads for research in the materials/fluid sciences
- European Modular Cultivation System (EMCS): for plant-biology research.



Soyuz-TMA1, carrying ESA astronaut Frank De Winne, moves in to dock with the ISS. This type of logistics flight is being used to bring experiments and the crew to operate them for early European utilisation of the ISS before Columbus is launched (photo NASA)

New facilities to be developed or presently under study include:

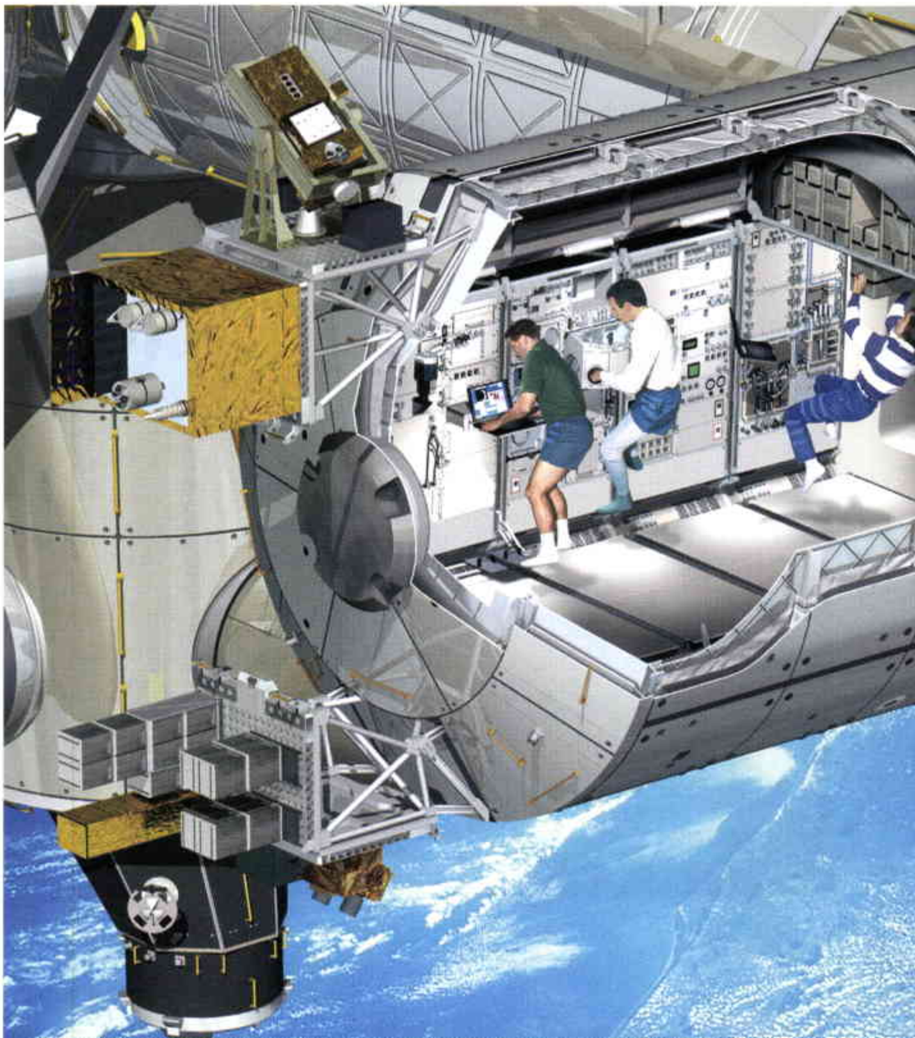
- Facility for Metal Foams: for research into metal foams
- Facility for Magnetic Fluids: for research into ferrofluids
- Facility for Complex Plasma/Cosmic- and Atmospheric-Particle Interaction
- Facility for Biotechnology Mammalian Tissue Culture.

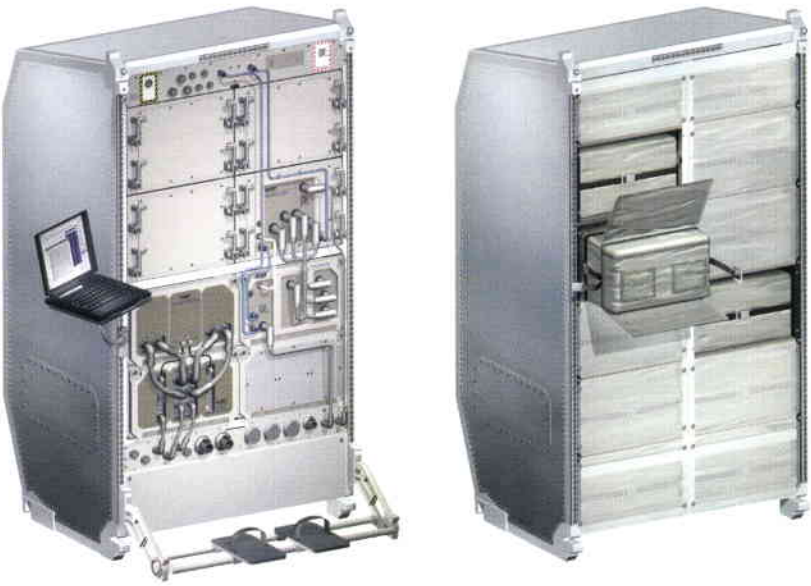
In addition, two externally mounted payloads are required to meet the needs of scientists conducting research in the life and physical sciences:

- The Atomic Clock Ensemble in Space (ACES): for studies to confirm that caesium clocks operated in space can have accuracies two orders of magnitude greater than on Earth
- The Matroshka (human phantom): for studying the radiation doses experienced by the internal organs of humans in space (to be located on the Russian segment of the ISS).

Space Sciences, Earth Observation, Technology, Commercialisation Promotion, and Education

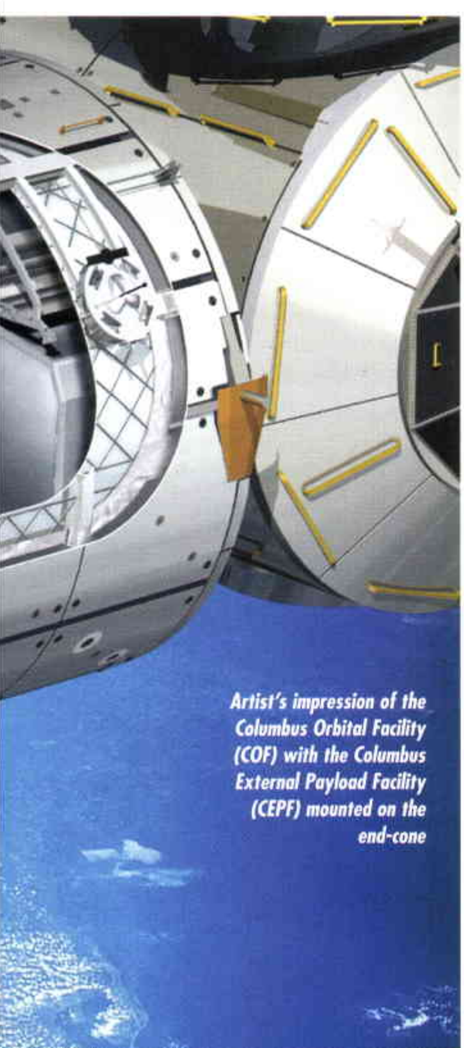
The proposals in these five domains were evaluated by the appropriate ESA user programmes, using external peer-review groups and applying the criteria defined in the AO. The results were presented first to the ESA User Advisory Bodies and then to the User Programme Boards. Based on the list of peer-recommended and technically feasible experiments, the European Utilisation Board (EUB) arrived at a balanced set of four payloads, covering atomic physics, technology exposure, exobiology, and astronomy and solar physics. Two additional instruments for radiation monitoring and global transmission services were also selected, for accommodation on the Russian segment of ISS.





From left to right The Microgravity Facilities for Columbus (MFC) Racks: FSL, Biolab, EPM, EDR and ESR

The four main payloads will be accommodated on the Columbus module. Although Columbus is primarily designed for accommodating pressurised internal payload facilities that are accessible for astronaut intervention, there is also the Columbus External Payload Facility (CEPF), which is a framework mounted on the laboratory's end-cone with four attachment points, each with power, data and command links.



Artist's impression of the Columbus Orbital Facility (COF) with the Columbus External Payload Facility (CEPF) mounted on the end-cone

Space Sciences

Two observatory instruments are being developed for inclusion in the CEPF for the Columbus launch. One, the SOLAR observatory, will allow measurement of the Sun's spectral radiance with unprecedented accuracy. Its three instruments – SOVIM, SOLSPEC and SOL-ACES – cover virtually the whole electromagnetic spectrum from 17 to 3000 nm, in which 99% of all solar energy is radiated. The other, the Sky Polarisation Observatory SPOrt, is an astrophysical instrument that will measure the sky's polarisation in an as yet unexplored microwave frequency range (20–90 GHz). The scientific goals include the first polarisation map of our Galaxy at 22, 32 and 60 GHz, as well as full-sky measurements in the so-called 'cosmological window' (90 GHz) with unprecedented high sensitivity, thereby providing observational testing of today's cosmological theories.

In addition to these two instruments, a number of others are currently being studied for use or assembly on the ISS:

- Lobster-ISS can alert astronomers to such unpredictable events as the appearance of a new X-ray source or unexpected behaviour by a known source anywhere in the sky. It will be the first true imaging X-ray all-sky monitor and will be able to locate X-ray sources to within 1 arc-minute, allowing the swift identification of new transient sources. Lobster-ISS will produce a catalogue of 200 000 X-ray sources every 2 months. It will also observe the long-term variability of Active Galactic Nuclei (AGN) and stars, the mysterious and difficult-to-study X-ray flashes, and the highly topical X-ray afterglows of gamma-ray bursts.

- EUSO (Extreme Universe Space Observatory) is designed to study extreme-energy cosmic rays (EECRs) from space, using the Earth's atmosphere as a giant cosmic-ray detector. It will observe the flash of fluorescent light and the reflected Cerenkov light produced when an EECR interacts with the Earth's atmosphere. These cosmic rays, which are believed to be mostly protons, are very rare and are the most energetic particles known in the Universe. Direct imaging of the light track and its intensity variations will allow the event's position in the sky, as well as the total energy involved, to be reconstructed.

- ROSITA (Röntgen Survey with an Imaging Telescope Array) is designed to make a systematic all-sky survey in the medium-energy X-ray band (0.5 - 10 keV), with a sensitivity 100 to 1000 times higher than anything achieved previously.

- The XEUS (X-ray mission for Evolving Universe Spectroscopy) spacecraft will have higher throughput than XMM and better angular and spectral resolution, thanks to its 10 metre aperture and 50 metre focal length mirror optics. The total of eight mirror sections needed will be assembled in space using the ISS robotics infrastructure.

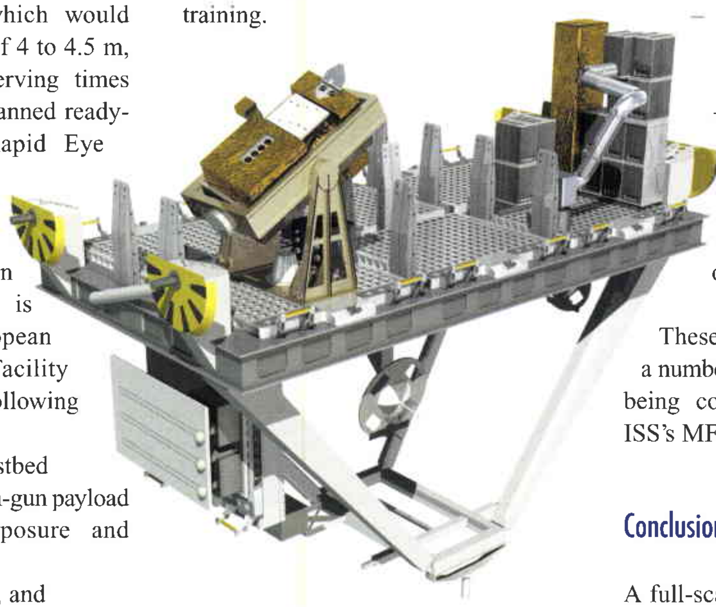
Earth Observation
A study is underway of a remote-sensing system for the ISS based on 'Rapid Eye'. The latter is a commercial system for agricultural applications and for observing man-made structures on Earth for insurance-verification purposes. The system consists of several free-flying cameras, one of which could be placed on the CEPF. Due to the inclination of the ISS's orbit, the system, which would achieve a ground resolution of 4 to 4.5 m, would provide varying observing times and observing angles. The planned ready-for-launch date for the Rapid Eye system is 2007.

Technology
The main ISS accommodation for technology experiments is provided by the European Technology Exposure Facility (EuTEF), which houses the following five instruments/experiments:
- TRIBOLAB: a tribology testbed
- PLEGPAY: a plasma electron-gun payload
- MEDET: a material exposure and degradation experiment
- DEBIE-2: a debris detector, and
- FIPEX: a flux-probe experiment.

In addition to this technology-experiment hardware, the EXPOSE facility for exo-biology studies is also located on the EuTEF.

Commercialisation Promotion
ESA is offering access to the European part of the International Space Station (ISS) on a commercial basis. The idea is to allow European companies to increase their competitive advantage by using Low Earth Orbit as a platform for commercial R&D or other innovative activities based on sponsorship, product placement, education, and edutainment. ESA has therefore forged a strategic alliance with 12 European industrial space companies via a Cooperation Agreement for Promotion and Preparation of Commercial ISS Utilisation.

Promotion support to selected utilisation projects will include:
- Precursor flights opportunities, such as on parabolic aircraft flights and sounding rockets.
- Payload and payload technology development
- Payload facility development
- Payload support-equipment development
- ISS services such as transportation, payload processing, integration, operations and communications, and astronaut training.



The European Technology Exposure Facility (EuTEF)

The ESA MFC facilities will also be made available for life- and physical-sciences research by commercial customers. In addition, three particular instruments have already been identified for customer access as part of the 'Commercial Instruments' concept: a blood-pressure monitor, an atomic-force microscope for very high-resolution imaging of new crystals and materials, and the 'biochip', whichis an advanced system for analysing fundamental biological processes by measuring the levels of thousands of individual genes in parallel.

Education
In its evaluation of the proposed content of the ELIPS programme, the European Science Foundation stressed the importance of ISS education and outreach, for which the following activities have been undertaken or are planned by ESA:
- generation of multimedia and interactive teaching material for 8 to 18 year olds, including an ISS Education Kit for 8 to 12 year olds
- activities for students of 18 years and older, including the SUCCESS 2002 student competition, the Student Parabolic Flight Campaigns, and collaboration with teacher-training colleges.
- activities for teachers, including co-location in ESA for the creation of the ISS Education Kits.
- HAM radio contacts with schools during ISS Taxi Flights, web chats with European Astronauts, educational activities in European science museums, or travelling exhibitions, etc.

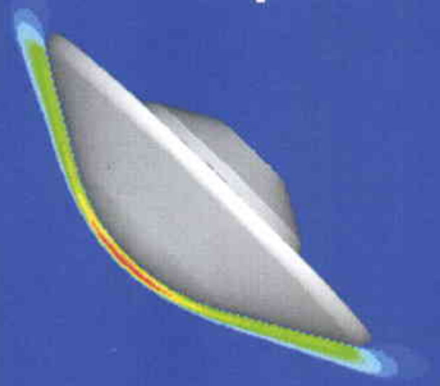
These activities are expected to lead to a number of education-related experiments being conducted by students using the ISS's MFC and other facilities.

Conclusion

A full-scale European Utilisation Plan has been elaborated for the ISS in a determined attempt to fully exploit Europe's significant investment through vigorous utilisation of its facilities for space life and physical sciences research and applications, Earth observation, space-technology development, the promotion of commercial access to space, and the use of space for educational purposes. A complete description of the Plan and the content, science targets and potential applications of all of the Research Cornerstones, can be found in ESA Special Publication SP-1270, titled *'The European Utilisation Plan for the International Space Station'*, which is available from ESA Publications Division. esa

1ST Announcement and Call for Abstracts

International Workshop on Radiation of High Temperature Gases in Atmospheric Entry



8-10 October 2003
Instituto Superior Técnico, Lisbon, Portugal

www.esa.int

CENTRE NATIONAL D'ETUDE SPATIALES

www.cnes.fr

INSTITUTO SUPERIOR TÉCNICO

www.ist.utl.pt

esa Aurora Programme
European Space Agency

http://www.esa.int/export/esaMI/Aurora/index.html

In the framework of ESA's Aurora programme and with the support of CNES, the Working Group "Radiation of High Temperature Gases" (WG RHTG) is organizing a workshop on Radiation of High Temperature Gases in Atmospheric Entry.Topics of interest include:

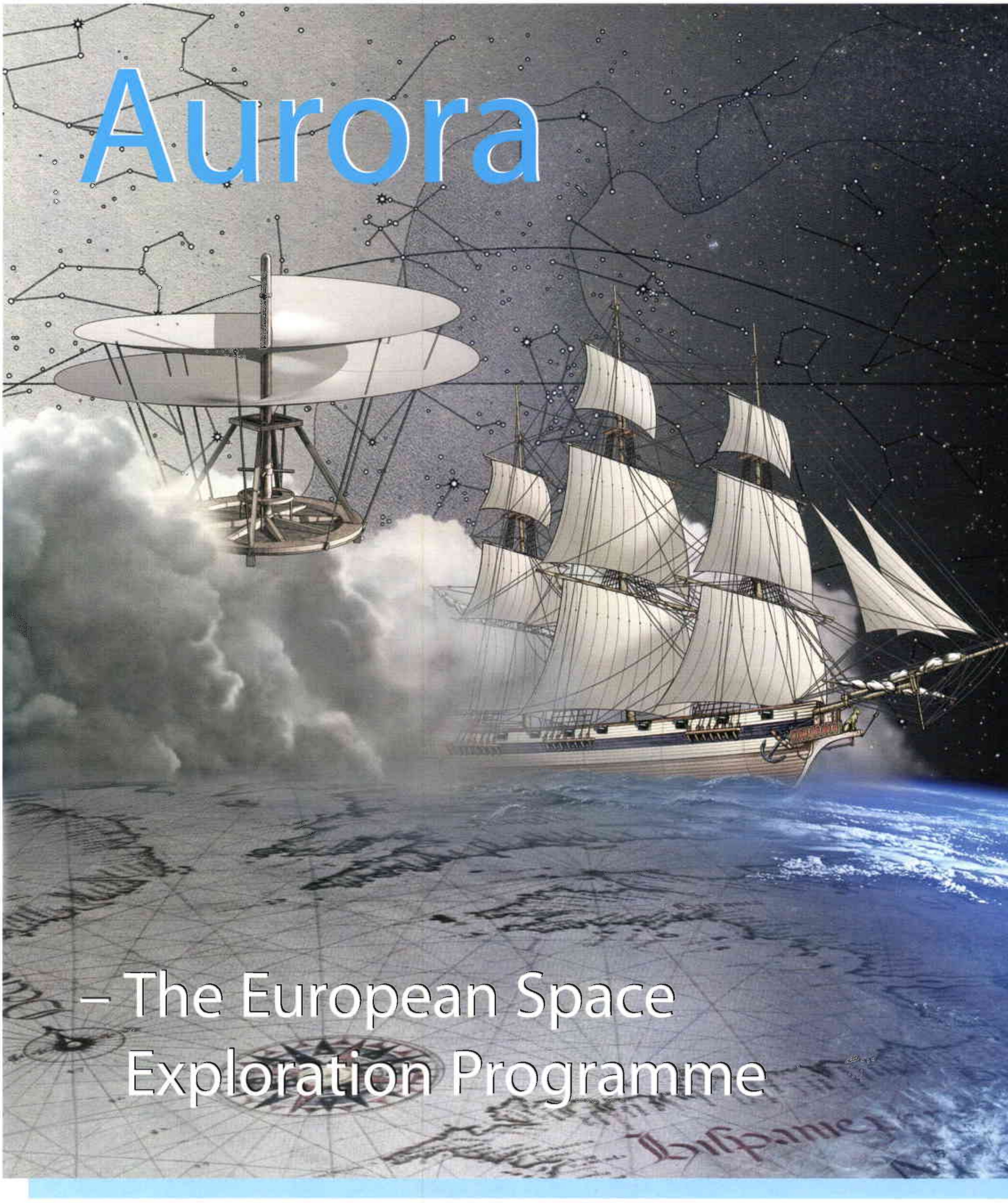
- Non Equilibrium Chemical Kinetics
- Hypersonic Flow
- Plasma Emission and Absorption
- Computational Fluid Dynamics
- Instruments and Facilities
- Flight Experiments
- Radiation Transfer
- Radiation emission & transfer database and models
- Re-building of selected radiative emission and absorption experiments
- Numerical axially-symmetric test-cases for flow and radiation emission and absorption calculations

For further information see the Workshop website at:

www.estec.esa.nl/conferences/

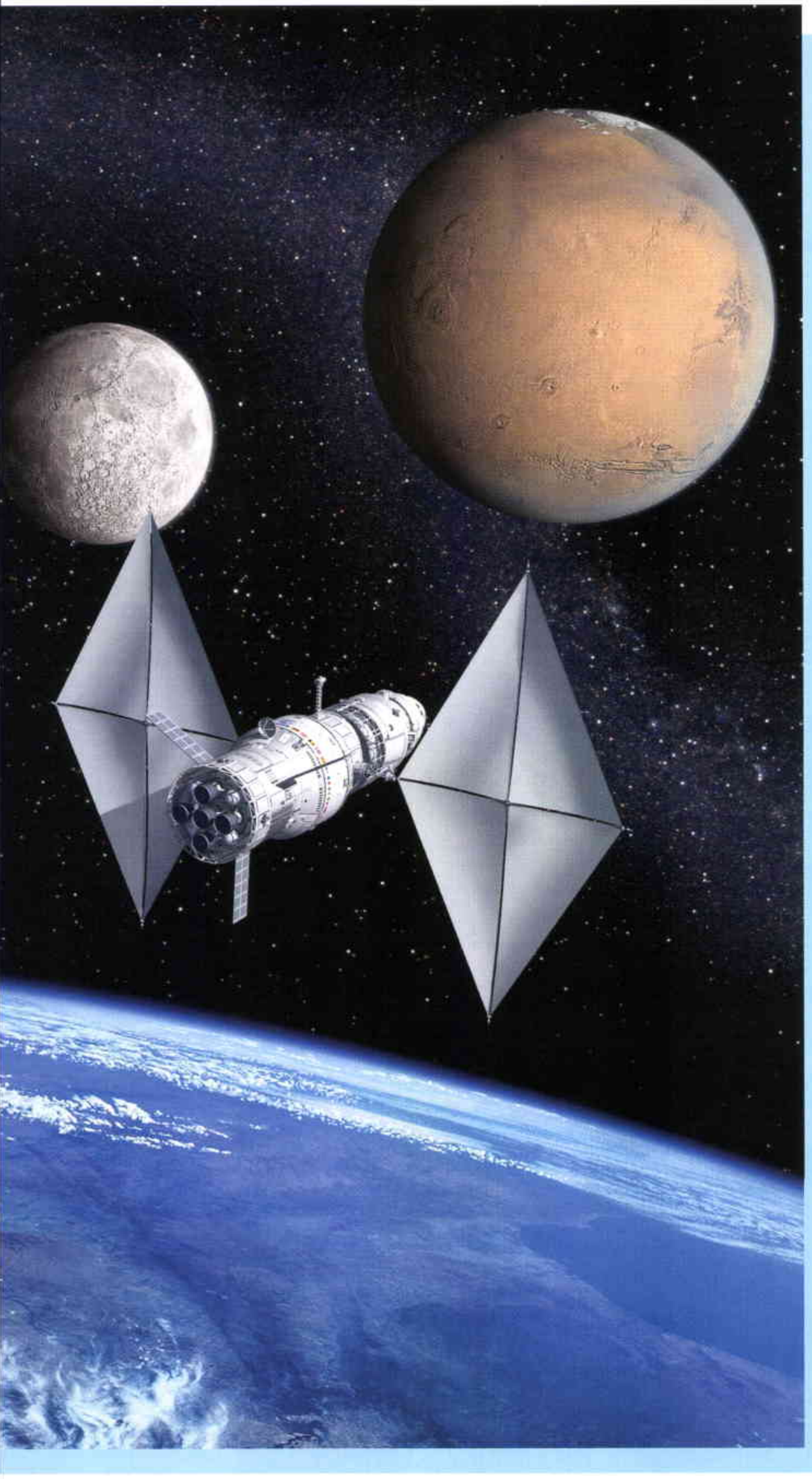
or contact

Prof. Paulo Gil
email: p.gil@dem.ist.utl.pt
Tel: +351 21 841 71 96 (direct)
Tel: +351 21 841 71 97 (secretariat)
Fax: +351 21 841 94 68



Aurora

– The European Space Exploration Programme



Pierro Messina & Franco Ongaro
Directorate of Strategy and External Relations, ESA, Paris

Introduction

A manned mission to Mars is bound to become a reality over the next decades. It is very likely to be an international mission carried out by those players who have developed the technologies and expertise needed to master the challenges of landing humans on Mars and returning them safely to the Earth.

Europe has been at the forefront of space endeavours for more than 30 years, with many successful missions and key contributions to international programmes. Its participation in the International Space Station, the experience acquired with the European astronauts, with leading-edge scientific missions and notably with the recently launched Mars Express and its Beagle 2 Lander, are all good examples of the degree of maturity that Europe, through ESA and its Members States, has gained as a result of its investment in space activities and the expertise developed within its work force and the scientific community.

Exploring Mars is still a risky business, however, as the low success rate of the robotic missions conducted to date is a constant reminder. Less than a third of the unmanned missions so far launched to the Red Planet have fulfilled their goal. Consequently, there is still much to be done before we can feel sufficiently confident to commit to sending humans to explore the more distant bodies in the Universe and to land on Mars.

The Aurora Programme is intended to prepare Europe to meet this challenge in a framework of international collaboration.This it to be achieved first through the formulation, and then the implementation of a European long-term plan for robotic and human exploration of the Solar System bodies, particularly those holding promise for finding traces of life.

The Aurora Programme

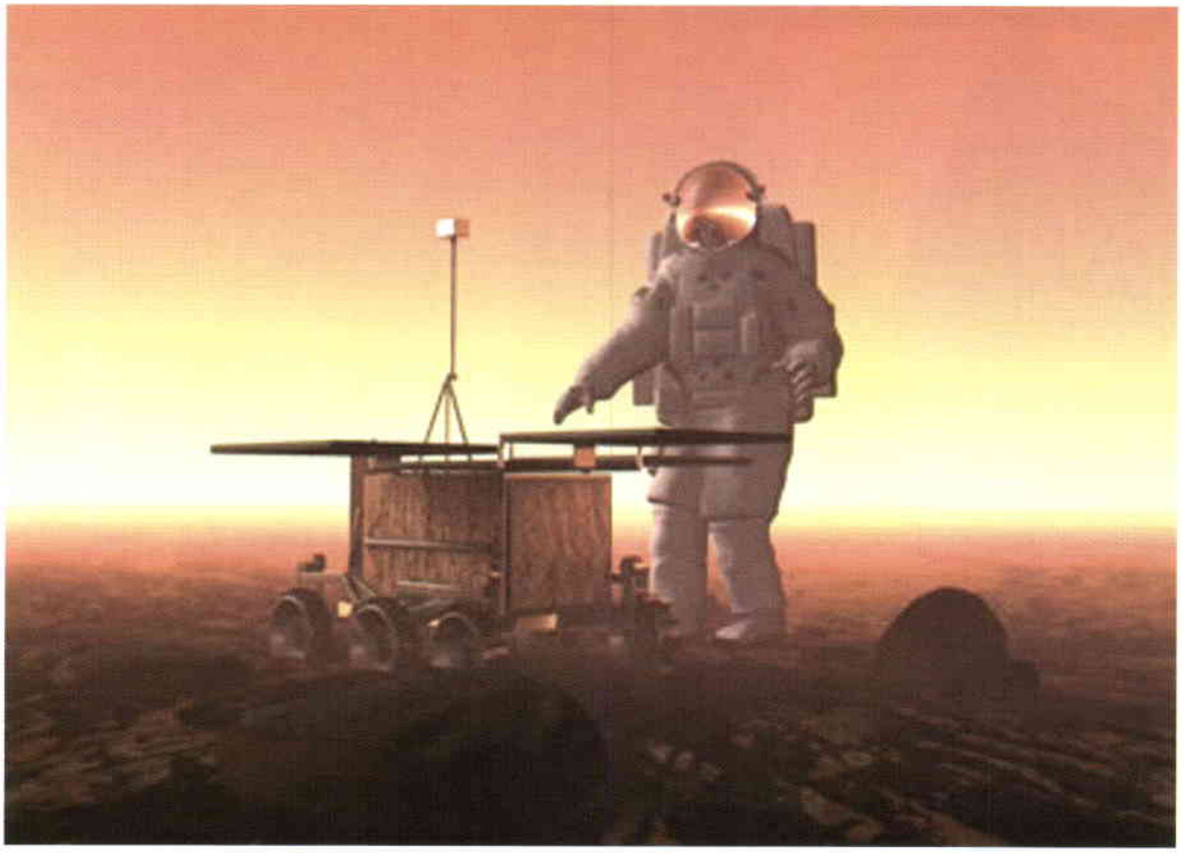
In order to give the Programme a sound scientific basis and appealing objectives, a Call for Ideas for Planetary Exploration was published in 2001 addressing scientists in Europe and Canada. Some 300 proposals were received and were subsequently assessed by a high-level panel of scientists. The results were presented at a special workshop at ESTEC in Noordwijk (NL) in April 2001. The responses demonstrated great interest in the further exploration of Mars, Europa, the Moon and the Asteroids and came from scientists in almost all ESA Member States and Canada.

The Aurora Programme was approved, as an ESA's Optional Programme, at the Edinburgh Council at Ministerial Level in November 2001. The major ESA Member States have subscribed to the Programme and its Preparatory Period, which began in January 2002 and is due to end in December 2004. At the conclusion of the Preparatory Period, we will have an updated Programme Proposal and a comprehensive long-term plan, the European Framework for Exploration (EFE). This will build on different European activities, at national and ESA level, in order to identify interests and priorities and come up with a set of goals. It will be a living document that will be updated as the Aurora Programme and the activities connected with it move forward.

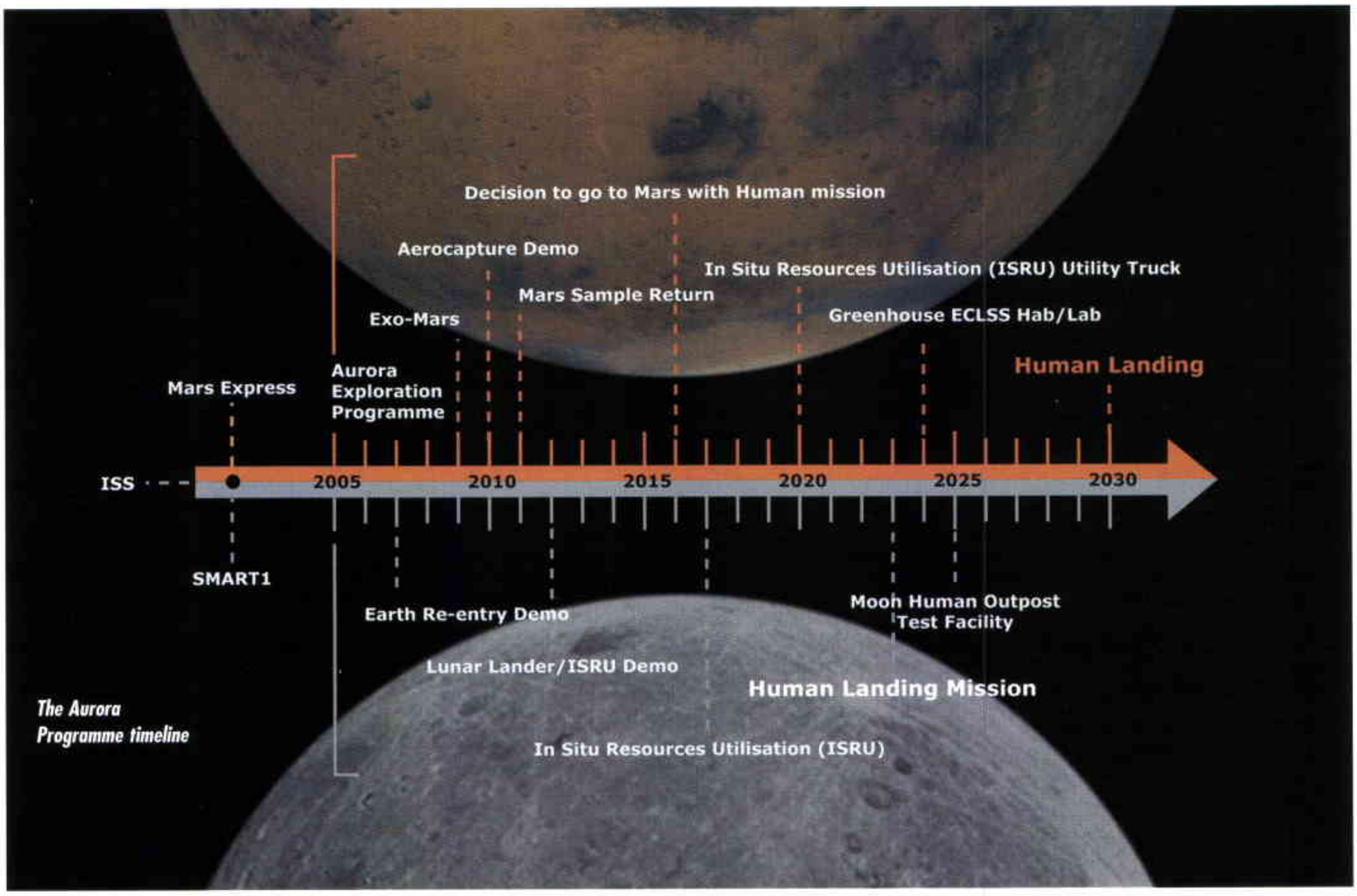
Like all other ESA programmes, Aurora has its own Programme Board (the Aurora Board of Participants) and an Exploration Programme Advisory Committee (EPAC), which brings together a balanced group of European experts in the various scientific and technological fields associated with the Aurora objectives.

Having set a clearly defined goal – to safely land humans on Mars by 2030 – Aurora will provide the roadmap of how to get there, as well the technologies that need to be developed and the knowledge that needs to be gathered in the meantime. A series of space missions, technology developments and other scientific work will provide the answers and lay the foundations for a European manned mission to the Red Planet, or for Europe's participation in an international endeavour with the same goal.

The Aurora Programme is structured into consecutive 5-year 'Periods', the first of which is due to start in 2005, subject to the results of the Preparatory Period and to a positive decision by the Participating States. Each 'Period' will include a Definition Component as well as a Development Component. The former represents the programmatic and forward-looking part of the Programme, while the latter covers the actual development of the technologies identified and their demonstration through space missions.



Robotic missions and new technologies wll pave the way for safe human missions to Mars



The Aurora Programme timeline

The Preparatory Period includes only a Definition Component. The Development Components of all subsequent Periods will cover the Phases-B/C/D/E of technology development and missions.

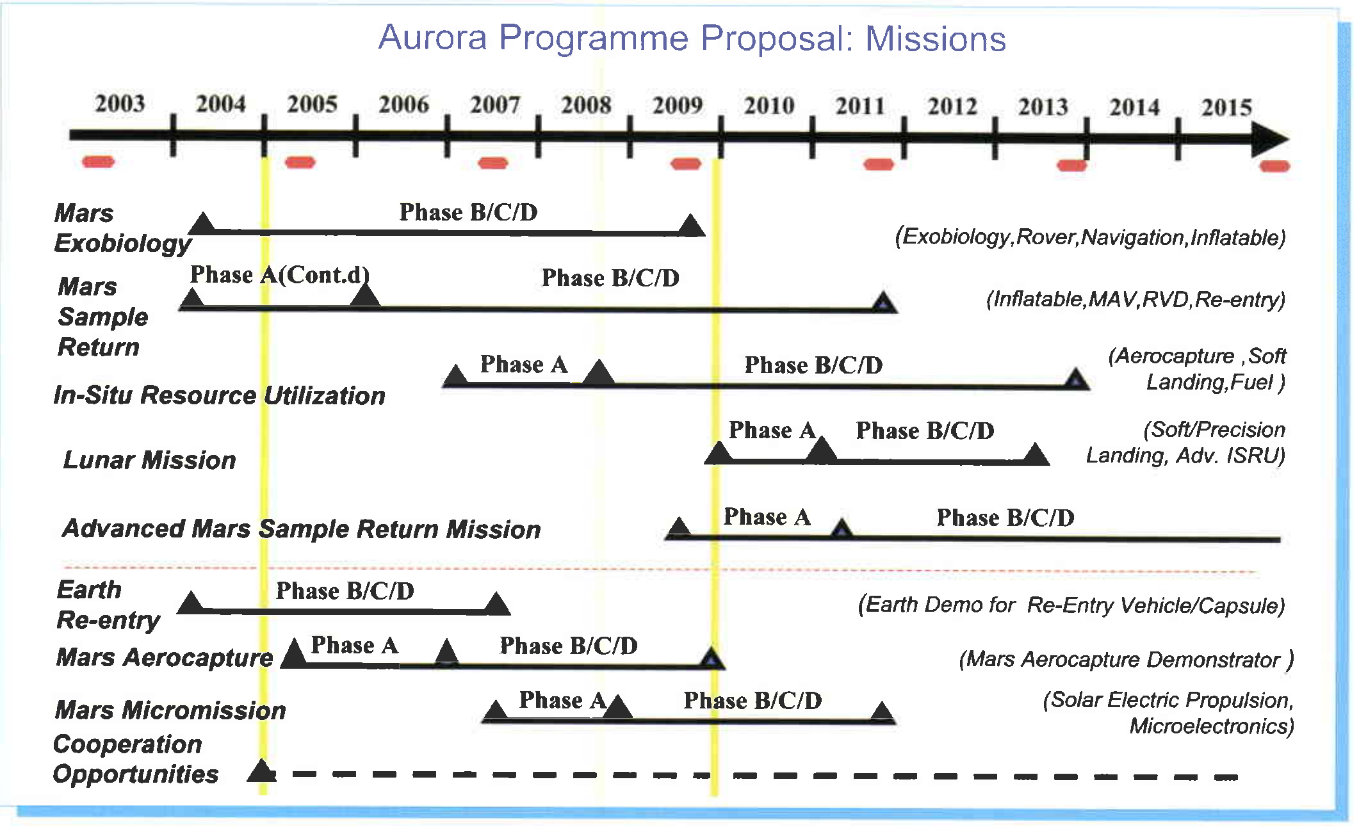
Preparing for Human Missions

The primary goal of the missions detailed below, and the further robotic missions to come, is to gather knowledge about the Martian environment and the risks that are associated with it and with the long interplanetary journey to and from the planet, as well as to develop and validate the key enabling technologies.

In parallel, the preparation of human exploration scenarios has started, always within the Definition Component of the Aurora Preparatory Period. While several years ago NASA developed its own 'Reference Mission', ESA has followed the path of entrusting European industry with a series of parametric studies to assess the requirements and constraints of various scenarios. Many different parameters are currently being studied, including: mission philosophy (surface outpost, multiple landing sites, orbital base), crew size (3, 6 or 12), duration of stay (30, 100 or 600 days), mass in low Earth orbit (LEO), etc. Working meetings are held regularly with a number of European experts to monitor the progress of the industrial studies and prepare inputs for the European Framework for Exploration. These inputs generate further questions and comments that are injected into the subsequent reflections. This iterative process will be consolidated in a series of scenario trade-offs that will eventually lead to a baseline human-exploration scenario that will be a key element of the Aurora Programme strategy and the European position in upcoming negotiations with international partners.

Technologies and Instrument Development and Demonstration

Within the Development Component, the mission-specific technologies will have to be developed and brought to a degree of maturity that will allow a Phase-B/C/D programme to be started with an acceptable level of risk. A 'Technology Dossier for Robotic and Human Exploration' has been produced, which also takes into account the outcome of a dedicated Workshop held at ESTEC in spring 2001. A roadmap for enabling technologies has been worked out, with a series of key milestones. All such technological development work will be conducted taking into account the existing ESA and national technology programmes (e.g. TRP, GSTP), to avoid duplication of effort and to maximise the return on investment for Europe.



Robotic Missions

These Robotic Missions are intended to pave the way for human exploration and for the establishment of a manned outpost on Mars. On 7 October 2002, the Aurora Board of Participants approved the start of assessment studies for the first four Robotic Missions in the Programme. These missions were selected by the EPAC from the 300 proposals mentioned earlier, and then recommended to the Member States for endorsement.

Flagship Missions

These Flagship Missions will enhance the European capability for undertaking human planetary missions, whilst also providing significant scientific return in their own right. Within the agreed cost of a Flagship Mission, the Aurora Programme will nominally fund the development of the complete spacecraft, the ground-segment development (spacecraft operations and data processing), the launch, and a nominal period of operations. The payload funding mechanism will be decided by the Participants during the Preparatory Period. The mission's payload will be selected by the Aurora Board of Participants, taking into account the EPAC's recommendations.

Those elements identified so far are: Mars Exobiology, Mars Sample Return, In-Situ Resource Utilisation, a Lunar Mission, and an Advanced Mars Sample Return Mission. The first two selected for industrial Phase-A studies are ExoMars and Mars Sample Return.

ExoMars

This mission, to be launched in 2009, will study the Martian environment and search for evidence of life, past or present, on the planet's cold and arid surface. The large spacecraft will take advantage of the planet's thin atmosphere to aerobrake it into Mars orbit. A descent module will then deliver a large rover to the Martian surface using an inflatable braking device or a parachute system.


Artist's impression of the ExoMars mission

The autonomous roving vehicle, powered by conventional solar arrays, will spend many months exploring the hostile terrain. The 40 kg payload, called 'Pasteur', will include a drill and a sampling and handling device that will enable it to analyse soil from sites that may be hospitable to primitive Martian life forms. The rover navigation system, including optical sensors, onboard software and autonomous operational capability, and the life-detecting payload will constitute a significant technological challenge for European and Canadian industry. Testing of rendezvous and docking techniques for the ExoMars mission will pave the way for the second Flagship Mission, namely Mars Sample Return.

A recently launched Call for Ideas for experiments to be included in the Pasteur payload attracted a very large response, with over 580 investigators from 30 countries having expressed the desire to participate in the ExoMars mission.

Mars Sample Return

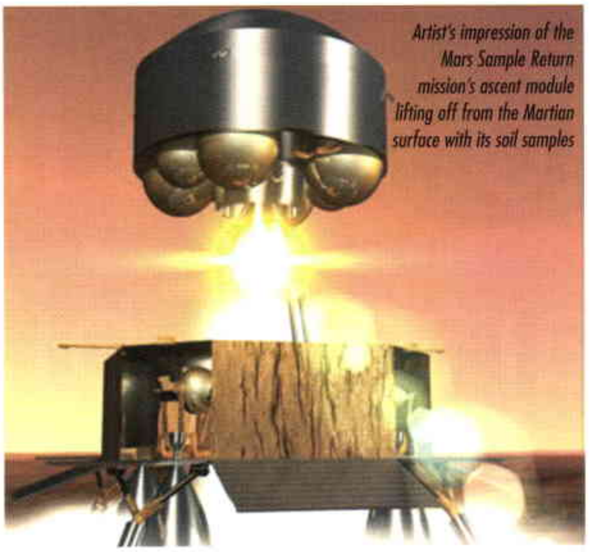
Scheduled for launch in 2011, this mission will bring back the first sample of Martian soil for analysis in laboratories here on Earth. After braking into Mars orbit, a descent module will be delivered to the planet's surface. A robotic 'scoop' will collect a soil sample and place it in a small canister on the ascent vehicle. The latter will then lift off from the surface and rendezvous with the mother spacecraft in Martian orbit. An Earth-return vehicle will bring back the capsule and send it plummeting into the atmosphere. Slowed by a parachute or inflatable device, it will make a gentle touchdown before recovery teams retrieve the precious sample from the Martian landing site.

Arrow Missions

The Arrow Missions will follow a flexible selection approach and allow fast response to upcoming opportunities, in the form of:
- small exploration missions
- technology demonstration missions, to demonstrate new technologies and mission techniques
- participation in another programme, for instance another international programme, a European national programme or another Agency programme, within an agreed co-operation framework.

Arrow Missions will be cost-capped and have a set development time limit. The first two to be studied are:

• *an Earth Re-entry Vehicle / Capsule*
This mission will place a small spacecraft in a highly elliptical (egg-shaped) orbit around the Earth. The re-entry vehicle will then be fired Earthwards in order to test the performance of its heat shield and other onboard technologies under conditions similar to those experienced by a capsule returning from Mars. This mission is a necessary forerunner of the first Mars Sample Return mission.



Artist's impression of the Mars Sample Return mission's ascent module lifting off from the Martian surface with its soil samples

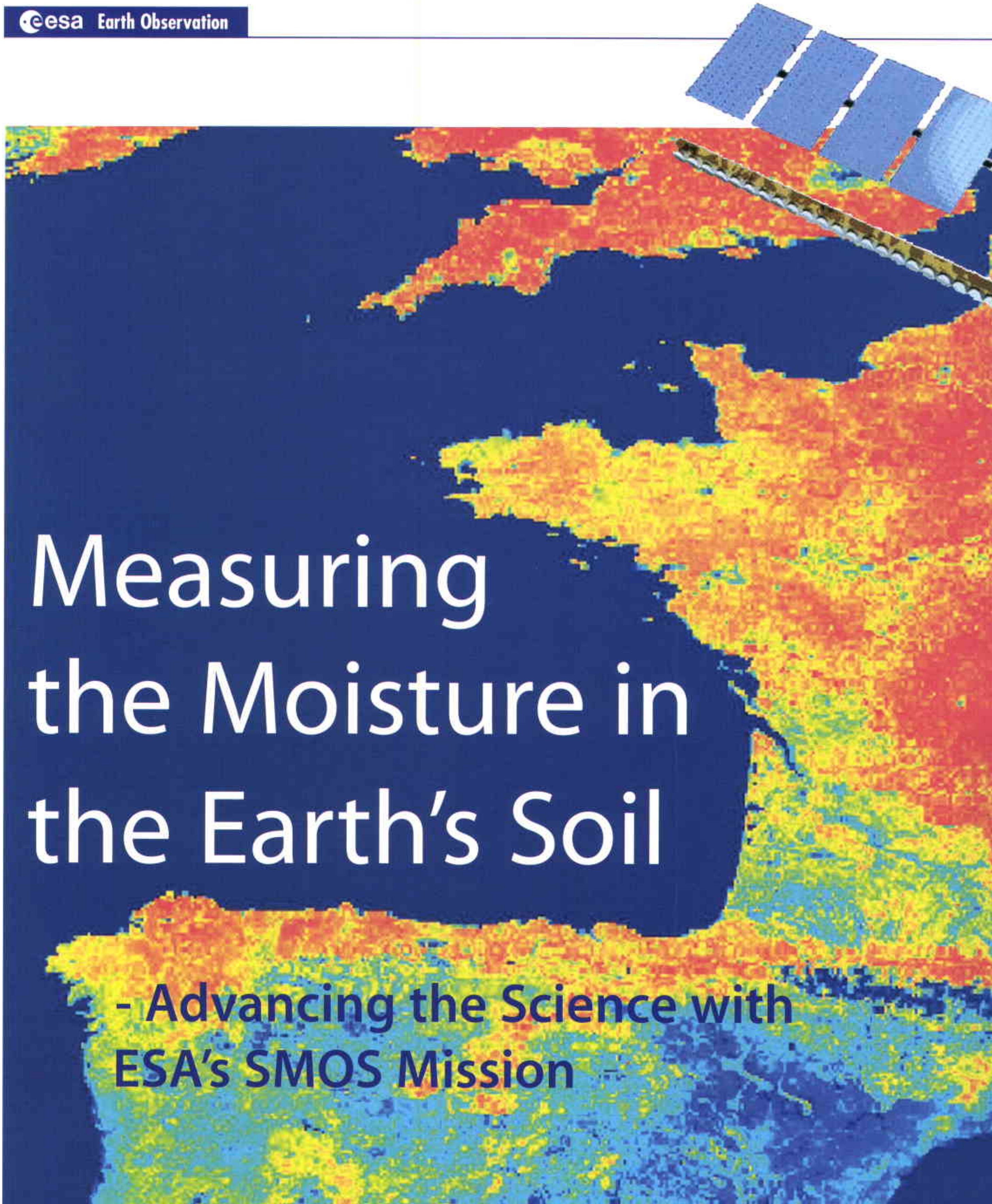
• *a Mars Aerocapture Demonstrator*
Aerocapture is a means of slowing a spacecraft through friction in a planet's upper atmosphere. By avoiding the use of onboard propulsion, the spacecraft can be considerably smaller and less expensive to build. The Mars Aerocapture Demonstrator is a small mission that will be sent to Mars in order to validate the technology before it is applied to larger, more ambitious Flagship, and eventually human, expeditions.

Conclusion

Just as the image of the first man to stand on the Moon remains an icon of the 20th Century, so human exploration of the Solar System, most notably Mars, is likely to be a lasting symbol of the 21st Century. The strategic and political drivers that led the USA and the Soviet Union to engage in the space race have dramatically changed, but both space and exploration retain their strategic importance as sources of inspiration, innovation, economic development, and lasting spin-offs for daily life. The coupling of the two concepts in a single initiative like the Aurora Programme represents a unique opportunity for Europe to show its scientific, technical as well as industrial maturity and to be regarded as a key player in future international co-operative space ventures.

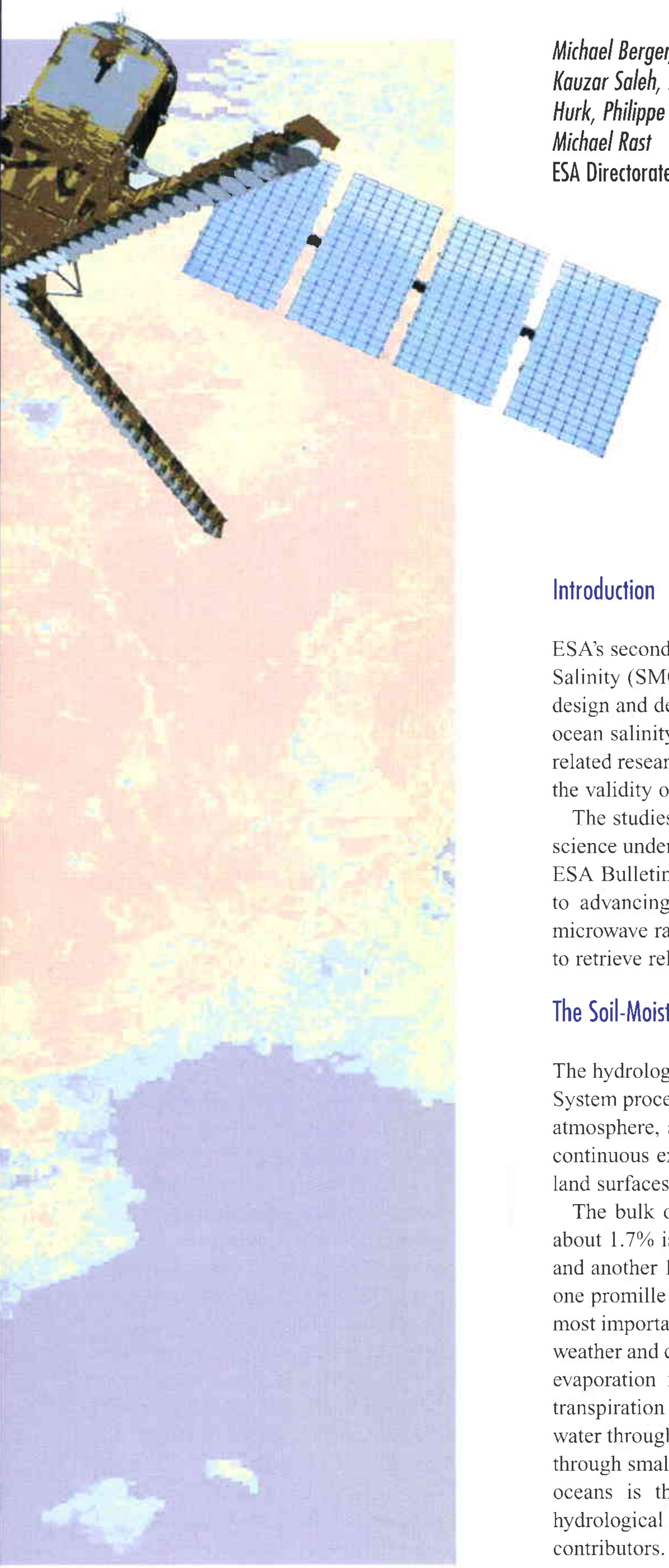
As a consequence of the technological developments needed to fulfil the Programme's goals, Aurora will quickly become a true source of innovation and spin-offs that will contribute to raising the living standards of Europe's citizens. At the same time, it will allow European industry to retain its present workforce and further enhance its skills, and it will offer European academia and research centres unique opportunities for first-class science and research.

Europe has set itself ambitious goals both in global terms (the Lisbon Declaration includes: *'being the most dynamic knowledge-based economy'*), and more specifically for its space policy. The Aurora Programme is a comprehensive and coherent response to both challenges. The vision embedded in the Aurora Programme is the continuation of Europe's historical tradition of exploration and discovery and an essential element of any European space strategy. esa



Measuring the Moisture in the Earth's Soil

- Advancing the Science with ESA's SMOS Mission -



Michael Berger, Yann Kerr, Jordi Font, Jean-Pierre Wigneron, Jean-Christophe Calvet, Kauzar Saleh, Ernesto Lopez-Baeza, Lester Simmonds, Paolo Ferrazzoli, Bart van den Hurk, Philippe Waldteufel, Francois Petitcolin, Adriaan van de Griend, Evert Attema & Michael Rast
ESA Directorate of Earth Observation, ESTEC, Noordwijk, The Netherlands

Introduction

ESA's second Earth Explorer Opportunity Mission, the Soil Moisture and Ocean Salinity (SMOS) mission scheduled for launch in early 2007, is currently in the design and development phase. Given that today's lack of global observations of ocean salinity and soil moisture is holding back progress in many environment-related research fields, the mission has broad and ambitious scientific objectives, the validity of which is internationally recognised.

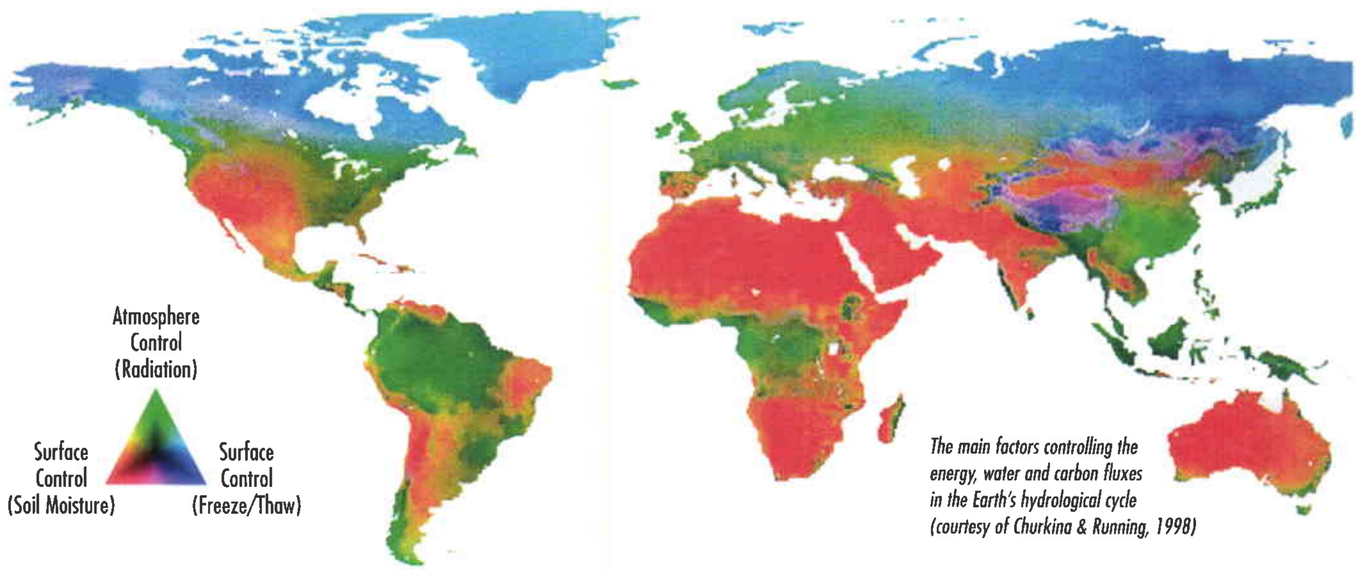
The studies and campaign activities undertaken by the Agency to advance the science underlying the ocean-salinity objectives of the mission were presented in ESA Bulletin No. 111. This article therefore focuses on the activities dedicated to advancing our knowledge of the 'brightness temperature' associated with microwave radiation emitted by the Earth's land surfaces and thereby our ability to retrieve reliable soil-moisture data.

The Soil-Moisture Objectives

The hydrological cycle is one of the most important but poorly understood Earth System processes. It involves the journey of water from the Earth's surface to the atmosphere, and back again. This gigantic system, which is responsible for the continuous exchange of moisture between our planet's oceans, atmosphere, and land surfaces is powered by the energy from the Sun.

The bulk of the Earth's water (about 96.5%) is stored in the global oceans, about 1.7% is stored in the polar ice caps, glaciers, and permanent snow fields, and another 1.7% is stored in groundwater, lakes, rivers, streams, and soil. Only one promille of our planet's water is present in the atmosphere, but it is still the most important 'greenhouse gas' and therefore has a very strong influence on our weather and climate. About 90% of this atmospheric water vapour is produced by evaporation from bodies of open water like oceans, lakes, and rivers. Plant transpiration and soil evaporation supply the remaining 10%. Plants take up water through their root systems to deliver nutrients to their leaves, and release it through small pores in their leaves, called 'stomata'. While evaporation from the oceans is the primary driver of the surface-to-atmosphere portion of the hydrological cycle, plant transpiration and soil evaporation are also significant contributors.

The unsaturated zone between the Earth's soil surface and the water table – known as the 'vadose' zone – is penetrated by the roots of vegetation, which take up some of the water. Hence the amount of water in this zone, which determines the 'soil moisture', varies with time as a function of the amount of precipitation and the root water take-up, governed by the degree of vegetation cover, the energy being received from the Sun, and run-off and percolation. The properties of the soil determine its storage capacity and the transport process within the soil.



The main factors controlling the energy, water and carbon fluxes in the Earth's hydrological cycle (courtesy of Churkina & Running, 1998)

Soil moisture therefore plays a crucial role in our planet's hydrological cycle. In most of the world, the water supply is the factor that most affects plant growth and crop yields, and hence food supplies. The strategic importance of world water resources and food production make soil moisture a crucial variable for policy decisions also. Remote sensing by satellite, if achievable with sufficient accuracy and reliability, would provide truly meaningful soil-moisture data for hydrological studies over large continental regions.

Soil-Moisture Retrieval

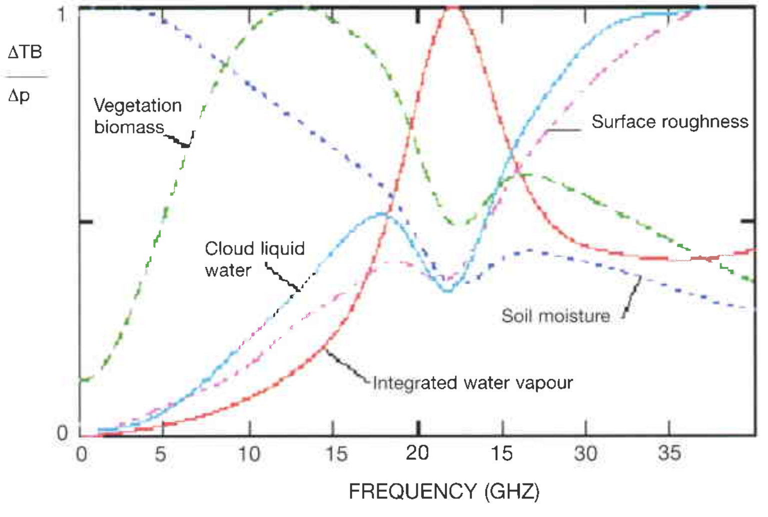
While both active and passive microwave remote-sensing techniques can be used in all weathers for land-surface monitoring, the signal-to-noise ratio from dry to wet soils is significantly higher for passive radiometers than for active radars. In addition, the radar signal is more sensitive to structural features such as soil roughness or vegetation canopy geometry than to soil-moisture variations. Correcting for the effects of vegetation is in fact the main issue in monitoring soil moisture using passive microwave measurements because the vegetation absorbs part of the microwave emission from the soil surface, and contributes to it. Research has shown that L-band (1.4 GHz – 21 cm) microwave radiometry has considerable advantages, because both vegetation attenuation and atmospheric effects are greater at higher frequencies. At L-band, however, this attenuation is moderate and can be corrected for, and the 'brightness temperature' signal is sensitive to soil moisture for vegetated areas with biomasses of up to 5 kg/m^2, which represents about 65% of the Earth's land surface.

The 'brightness temperature' of a given land surface depends on the vegetation layer's optical thickness, the effective surface temperature, and the soil type and roughness as well as the soil moisture. In order to discriminate between these effects, microwave radiometry offers the possibility of acquiring data at different polarisations, different incidence angles, and possibly different frequencies. The SMOS payload will therefore have dual-polarisation (optional full polarisation) and multi-angular imaging capabilities.

Since L-band microwave data only provide information about the moisture content of a relatively shallow surface layer (about 3–5 cm at L-band), special techniques have been developed to derive the moisture content within the vadose zone from time series of near-surface soil-moisture data. It was shown that surface soil-moisture values measured once every three days from space are sufficient to retrieve the water content in the vadose zone as well as the evapo-transpiration flux.

Scientific Support Studies

A number of scientific questions related to the physics of the signal-retrieval process and the derivation of near-surface soil moisture needed to be addressed at the beginning of the feasibility study phase for the SMOS mission. In addition, appropriate experiment campaigns had to be organised and conducted to provide suitable data. The following paragraphs briefly outline the main activities initiated by ESA and their preliminary results. Additional study and campaign activities were initiated by national programmes. Activities were coordinated via the SMOS Science Advisory Group and relevant workshops involving the various study and campaign teams.



Sensitivity of 'brightness temperature' to different variables as a function of frequency

Studies initiated by ESA have included:

• *'Soil Moisture Retrieval by a Future Space-borne Earth Observation Mission'*
This study, kicked-off in October 2000 and completed in March 2003, was managed by the University of Reading (UK) and involved 10 European institutes. The overall goal was to determine the soil-moisture product and accuracy requirements for a spaceborne Earth-observation mission for scientific and semi-operational applications. Specific objectives of the study were to:
- demonstrate the soil-moisture retrieval capability of polarimetric brightness-temperature observations acquired by an L-band interferometric radiometer, review existing soil-moisture retrieval techniques, and determine the attainable accuracy
- improve existing retrieval techniques and/or develop new retrieval algorithms for soil moisture taking due account of surface heterogeneity and rugged terrain, and
- validate the retrievals via case studies.

• *'Soil Moisture Retrieval for the SMOS Mission'*
This one-year study, kicked-off in July 2002, is managed by ACRI-ST and involves 5 research institutes within Europe. The main goal is to review existing, and develop and analyse new soil-moisture retrieval schemes compatible with the observation characteristics of the SMOS mission and by taking into account spatial and temporal land-surface variability. The study makes extensive use of the simulated dataset generated within the earlier study, and the resulting soil-moisture retrieval scheme will be implemented in the SMOS End-to-end Performance Simulator (SEPS).

Scientific Requirements for Soil-Moisture Measurements

The scientific requirements for the SMOS mission have been formulated to gain maximum information on the surface-emitted 'brightness temperature' to allow the retrieval of surface soil moisture with an accuracy in the range of its natural variability. These requirements are:

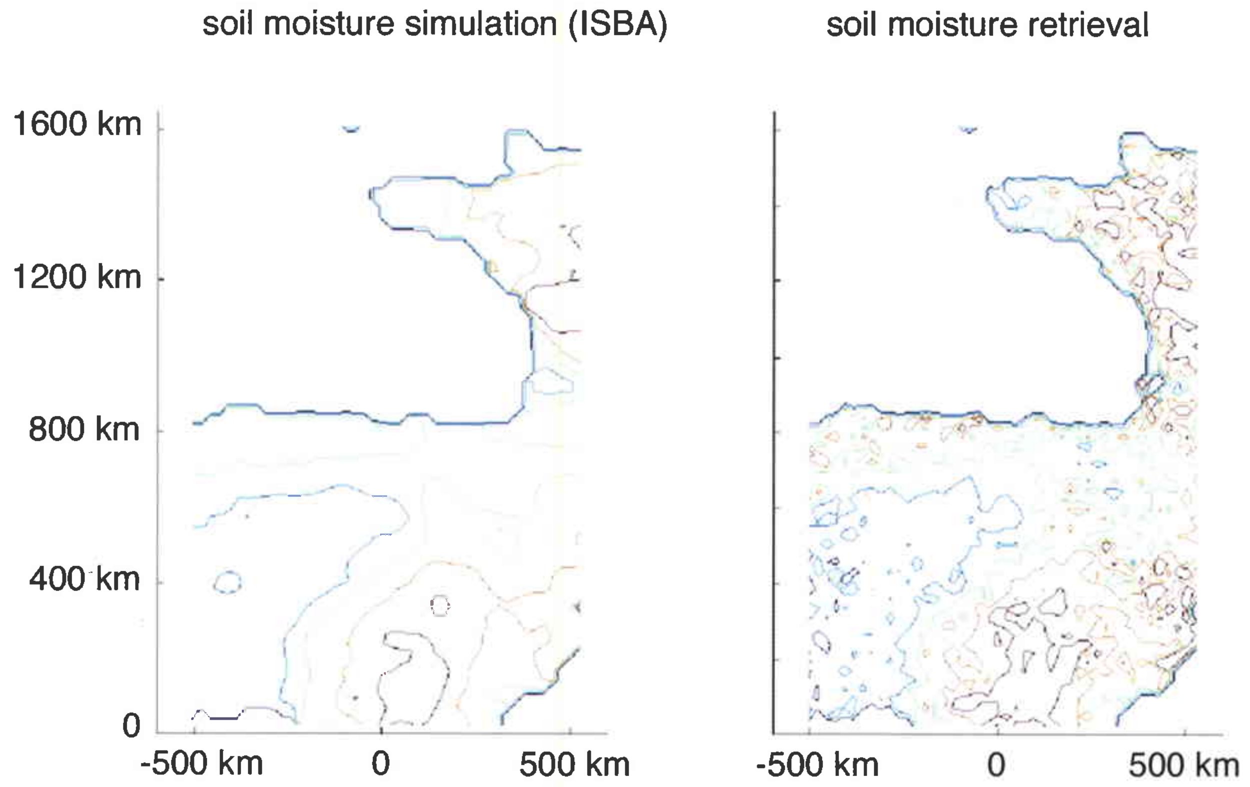
- Soil-moisture Accuracy: 0.04 m^3 m^{-3} (i.e. 4% volumetric soil moisture) or better
For bare soils, for which the influence of near-surface soil moisture on surface water fluxes is strong, it has been shown that a random error of 0.04 m^3 m^{-3} allows a good estimation of the evaporation and soil transfer parameters.

- Spatial Resolution: < 50 km
For providing soil-moisture maps to global atmospheric models, a 50 km resolution is adequate, and will allow hydrological modelling with sufficient detail for the world's largest hydrological basins.

- Global Coverage: ± 80° latitude or higher

- Revisit Time: 2.5 to 3 days
A 3 to 5 day revisit cycle is sufficient to retrieve vadose-zone soil-moisture content and evapo-transpiration, provided ancillary rainfall information is available. To track the quick-drying period after rain has fallen, which is very informative about the soil's hydraulic properties, a one- or two-day revisit interval is optimal. The stipulated 2.5 to 3 day bracket will satisfy the first objective always, and the second one most of the time.

- Observation Time:
The precise time of the day is not critical for data acquisition, but the early morning (about 06:00 h) is preferable, when ionospheric effects can be expected to be minimal and conditions are as close as possible to thermal equilibrium. The retrievals will then be more accurate, but dew and morning frost can sometimes affect the measurements.



Preliminary results achieved with the soil-moisture retrieval algorithm for the SMOS mission over Western Europe (summer season). Left: contours of reference surface soil moisture used to create the synthetic SMOS data. Right: contours of retrieved soil moisture. Dark blue, light blue, green, orange and chestnut-coloured contours correspond to soil moistures of 0.1, 0.15, 0.2, 0.25 and 0.3 $m^3.m^{-3}$, respectively

The study should also provide recommendations with regard to several open options in the design of the SMOS mission, including the polarimetric operating mode and the final design of the soil-moisture retrieval algorithm. The recommendations and conclusions will be based on a series of simulation scenarios, for which adequate assessment tools have already been defined.

The experiment campaigns that have also been carried out to refine the SMOS mission include:

• *EuroSTARRS*

The main objective behind the first use of the Salinity Temperature and Roughness Remote Scanner (STARRS) sensor in Europe, from 16 to 23 November 2001, was to acquire SMOS-like observations in order to address a range of critical issues related to the mission's soil-moisture objectives. The STARRS L-band sensor, belonging to the US Naval Research Laboratories, was operated for the campaign aboard a Dornier 228 by the German Aerospace Center (DLR).

The campaign objectives for the 'land' test sites were to:
- characterise the relationship between vegetation optical depth and incidence angle for a range of vegetation types (orchards, coniferous trees, deciduous trees, shrubs)
- study scaling issues and validate the retrieval techniques accounting for mixed pixel effects
- study the effects of topography
- investigate the L-band emission from urban areas and the level of radio-frequency interference.

Five very different test sites in France and Spain were used:
- a site northwest of Valencia (Requena) with low natural vegetation and agri-cultural fields (olive and almond trees)
- a deciduous forest site north of Toulouse (Agre)
- a coniferous forest site near Bordeaux (Les Landes)
- a site in the Pyrenees (for measuring topographic effects), and
- a flight path over the city of Toulouse.

Intensive fieldwork by large ground teams provided in-situ information for surface temperature, characterisation of the surface cover (vegetation type, biomass,

The STARRS instrument mounted beneath DLR's Dornier 228 aircraft for the ESA EuroSTARRS campaign litter mass, fractional vegetation cover, fractional soil cover, soil texture and roughness, etc.), and soil moisture (gravimetric and theta-probe measurements) during the aircraft overflights.

The data set generated by the EuroSTARRS campaign is extremely large, and a great deal of effort still has to be invested to analyse it in its entirety. The campaign itself was an opportunity to unite the efforts of several teams, and proved instrumental in structuring the SMOS scientific community.

Outlook

The studies and campaigns conducted so far have been instrumental in encouraging international collaboration and generating interest and momentum within the science community. Many potential applications have been identified, and retrieval concepts have been developed which are currently being fine-tuned. The studies and campaigns have also proved extremely useful in identifying the next steps to be taken in preparing for the mission.

When launched in 2007, SMOS will be able to observe the brightness temperatures of all of the Earth's land surfaces at least once every three days, regardless of weather conditions and largely unaffected by atmospheric effects. These observations will allow the retrieval of soil-moisture data with unprecedented accuracy, thereby greatly improving our knowledge of the water content of continental soils and its representation in our hydrological, meteorological and climatological models. This in turn will substantially improve our understanding of, and ability to monitor, the water resources of our planet on a global basis. These are critical factors in our mastery of the economic and political consequences of climate change and our ability to manage the world's food and water resources in the longer term.

Acknowledgement

The authors would like to express their gratitude to the study and campaign teams and to the SMOS Science Advisory Group for their invaluable contributions. esa

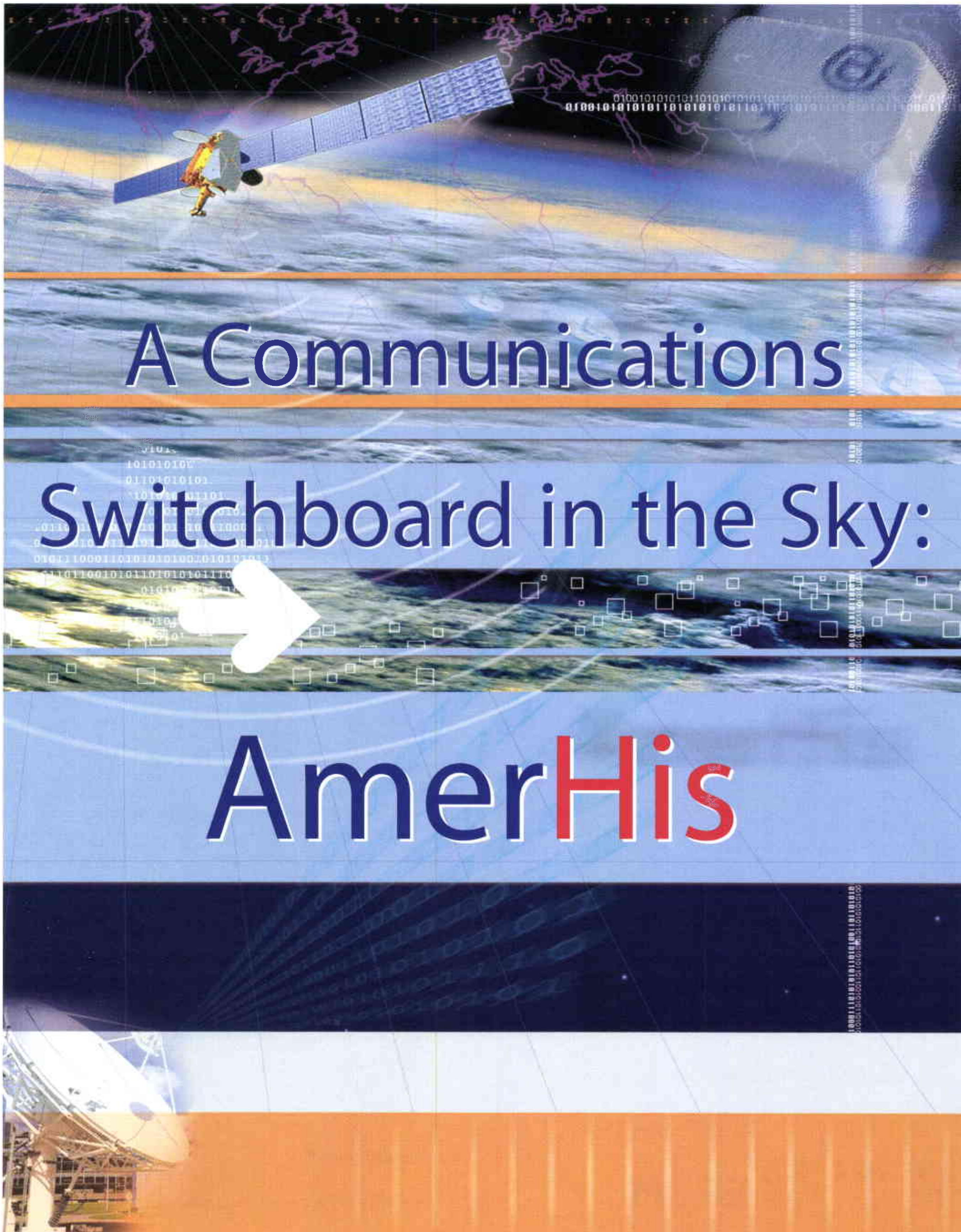


Illustration Alcatel Espacio

Manfred Wittig
Head of Multimedia Systems Section and AmerHis Project Manager, ESA Directorate of Applications, ESTEC, Noordwijk, The Netherlands

Jose-Maria Casas
Head of Service Projects Division, ESA Directorate of Applications, ESTEC, Noordwijk, The Netherlands

Background

Satellite communication is by far the largest commercial spin-off to date from space-technology developments. It has also been the main driver for the massive growth that occurred in the launcher sector in recent years. Companies active in the communications field made large profits and their stock market valuations soared. The arrival of the Internet, however, offering worldwide communication largely 'free of charge' led to a collapse in the global telecommunications market, and has ultimately drastically affected the commercial satellite communications sector also. In 2000, for example, about 31 communication satellites were ordered worldwide, in 2001 that dropped to 19, and in 2002 only 3 were ordered. Even more worrying is the fact that in 2000 European satellite manufacturers received 15 satellite-manufacturing contracts, one less than the leading American companies, but in 2001 they got only 3.

The collapse of the satellite communications market, however, is due not only to the general telecommunications melt-down, but also to the advancement of technology. For the last 20 years, communication satellites have been used mainly for TV broadcasting. For analogue TV, the frequency modulation (FM) scheme was established as a standard method of transmission, requiring a bandwith of about 36 MHz per TV channel. Consequently, communication satellites were equipped with several 36 MHz-wide transponders. Modern state of the art satellites have 40 to 50 such transponders. The introduction of digital TV was made possible by the invention of advanced signal-compression algorithms and the progress in digital technology allowed the realisation of cost-effective video encoders and decoders. With the introduction of the Digital Video Broadcast via Satellite (DVB-S) standard, developed in Europe, it is possible to transmit 6 to 10 digital video channels within the bandwidth needed for a single analogue TV channel.

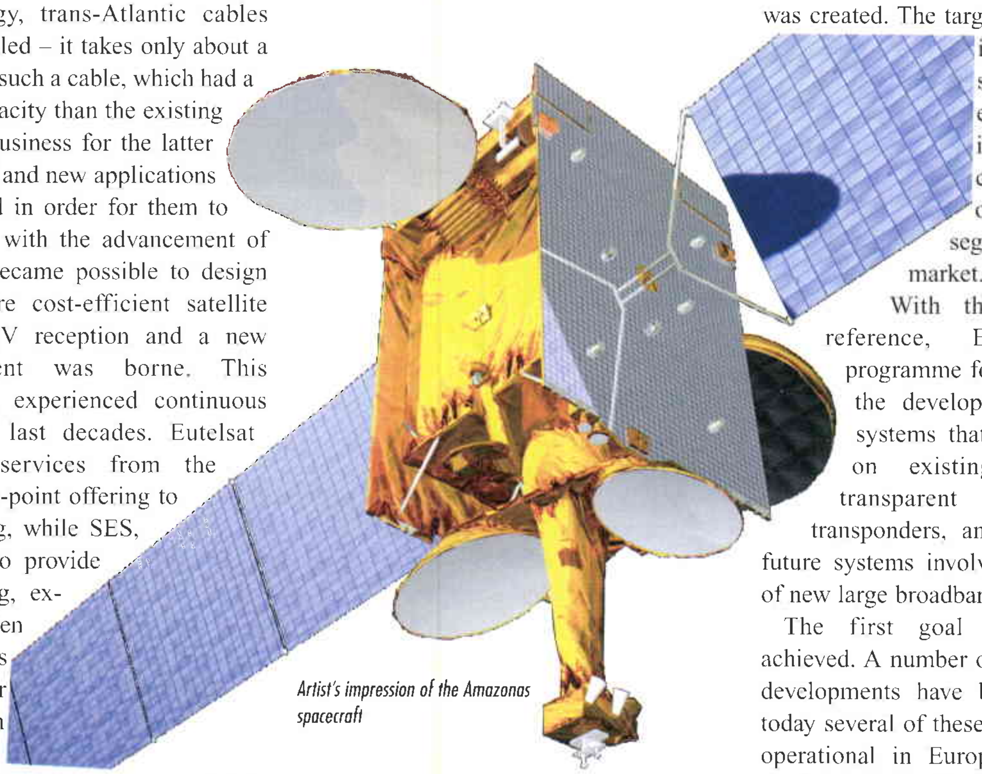
The result is that fewer transponders are needed to provide a large quantity of TV channels. The content providers therefore get cheaper satellite transponders from the satellite operators, who require fewer satellites in their fleets to provide the service. The satellite manufacturers, at the other end of this value chain, then have a hard time to sell more powerful satellites. Basically, only replacements for aging satellites are needed to satisfy the capacity demands for TV broadcasting. With fewer satellites being manufactured in the future, fewer launchers will be needed to deliver them to orbit. Hence, the crisis in which our industry – satellite and launcher manufacturers, satellite operators, and launch providers – currently finds itself will only by resolved when there is a demand for much greater communication capacity in the geostationary orbit. New services in addition to TV broadcasting are therefore needed.

There is an interesting analogy with the past. The first communication satellites were used to provide capacity for telephone connections between the continents. Large earth stations were installed and several hundreds, and later several tens of thousands of telephone channels were carried by these communication satellites. This kind of service was the domain of the international Satellite Organization (Intelsat) created in the 1960s. In Europe, ESA's development and launching of the European Orbital Test Satellite for communications led to the birth of the European Telecommunications Satellites Organisation (Eutelsat). OTS and the European Communications Satellite (ECS) family that it spawned were designed for point-to-point applications.

With the later rapid advances in fibre-optic technology, trans-Atlantic cables were soon installed – it takes only about a month to install such a cable, which had a much larger capacity than the existing satellites. The business for the latter was demolished and new applications had to be found in order for them to survive. Again, with the advancement of technology, it became possible to design and manufacture cost-efficient satellite receivers for TV reception and a new market segment was borne. This application has experienced continuous growth in the last decades. Eutelsat extended its services from the original point-to-point offering to TV broadcasting, while SES, created solely to provide TV broadcasting, experienced a sudden growth in its business after the reunification of Germany.

Having this historic lesson in mind, communication satellites have again to find new markets. One such new and very rapidly growing market segment is broadband access for multimedia applications – not only the Internet, but also interactive video, audio and games. With about 100 million satellite receivers already installed in Europe alone, communication satellites have the enormous bandwidth potential required to satisfy such needs. However, the existing satellites are not optimised to provide such services. New architectures are needed in which the satellite payload must be of the regenerative type, providing on-board switching capabilities.

ESA has already been working for more than a decade on such technologies, together with European and Canadian industry. As a result, when in early 2002 the opportunity arose to embark such an advanced on-board processor on a commercial communication satellite known as 'Amazonas', to be built by Astrium for Hispasat, European industry was in a good position to respond. The advanced payload for Amazonas – the only communication spacecraft procured in 2002 from a European satellite manufacturer – is called 'AmerHis', which stands for Advanced Multimedia Enhanced Regenerative Hispasat System. AmerHis is the first commercial communication-satellite payload able, thanks to its very advanced ESA-developed technology, to provide cost-effective in-orbit connectivity services for the above-mentioned applications.



Artist's impression of the Amazonas spacecraft

ESA's Preparations for the Multimedia Revolution

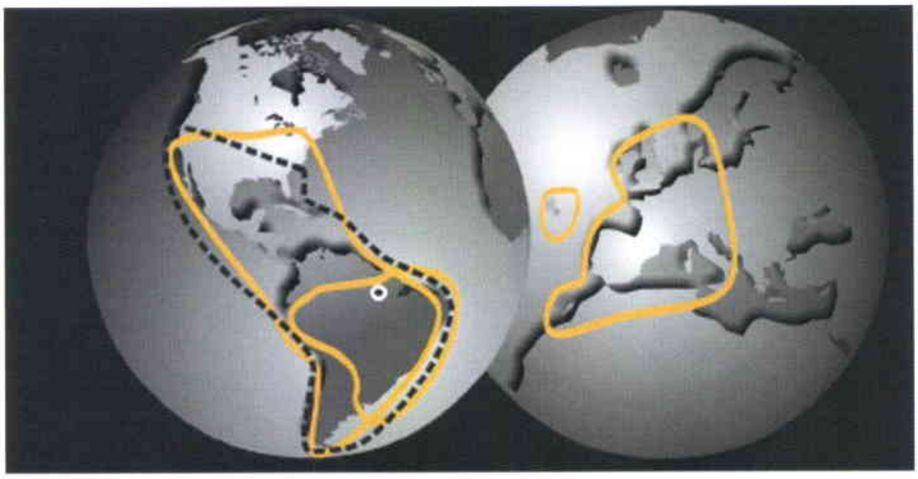
In the late nineties, after consulting with its Delegations, with satellite operators and with industry, ESA initiated a comprehensive programme designed specifically to prepare European industry for the next generation of interactive satellite communications systems.

A fundamental element of this action consisted of supporting the development of an open standard for interactive satellite broadband services, facilitating the open provision of services and open competition between manufacturers. For the delivery of data to the users, therefore, the already well-established DVB-S standard was adopted, while for the return channel from the users the so-called DVB-RCS standard was created. The target customers for this interactive satellite service, which is effectively 'an ADSL in the sky', are corporations, small offices and a certain segment of the domestic market.

With this background as reference, ESA's multimedia programme focused on two goals: the development of interactive systems that could be deployed on existing satellites with transparent Ku or Ka-band transponders, and the definition of future systems involving the deployment of new large broadband satellites.

The first goal has largely been achieved. A number of DVB-S/DVB-RCS developments have been supported and today several of these systems are already operational in European and American satellite systems. However, the cost of the terminals and the charges for the service are not yet at a level affordable by home users. Further efforts are therefore being devoted to reducing the cost of the terminals, providing additional functionality and ensuring compatibility between the different systems.

ESA has also addressed the medium/long-term horizon by awarding



The coverages of the Amazonas satellite's three spot beams

major contracts to three consortiums, led by each of the European prime contractors, for preparation of the key technologies needed for future broadband satellite systems. These projects - Domino led by Alcatel, EuroSkyWay led by Alenia and WeB/West of Astrium - have resulted in the thorough analysis and validation of the critical aspects and equipment involved in each of the systems.

The next step is to demonstrate their technical and operational performances. The ESA Multimedia Programme, approved at the Edinburgh Ministerial Council in November 2001, therefore foresees support to projects in which the multimedia technology developed will be deployed on in-orbit satellite systems in partnership with commercial satellite operators. AmerHis is the first such payload.

The AmerHis Industrial Consortium

The AmerHis system is being developed by an industrial team of Spanish, French, Canadian and Norwegian companies led by Alcatel Espacio.

As prime contractor, Alcatel Espacio (Madrid) is responsible for developing and delivering the complete AmerHis communication system, including the Base Band Processor (BBP). Alcatel Space (Toulouse) is responsible for development of the Network Control Centre (NCC), for validation of the AmerHis system and for developing the Ku-band modulators. Mier Communications (Barcelona) is developing the Ku-to Base Band Downconverter. Indra Espacio (Barcelona) will deliver the Gateway Stations. EMS (Montreal) and Nera (Oslo) will deliver the User Stations.

The Amazonas Satellite

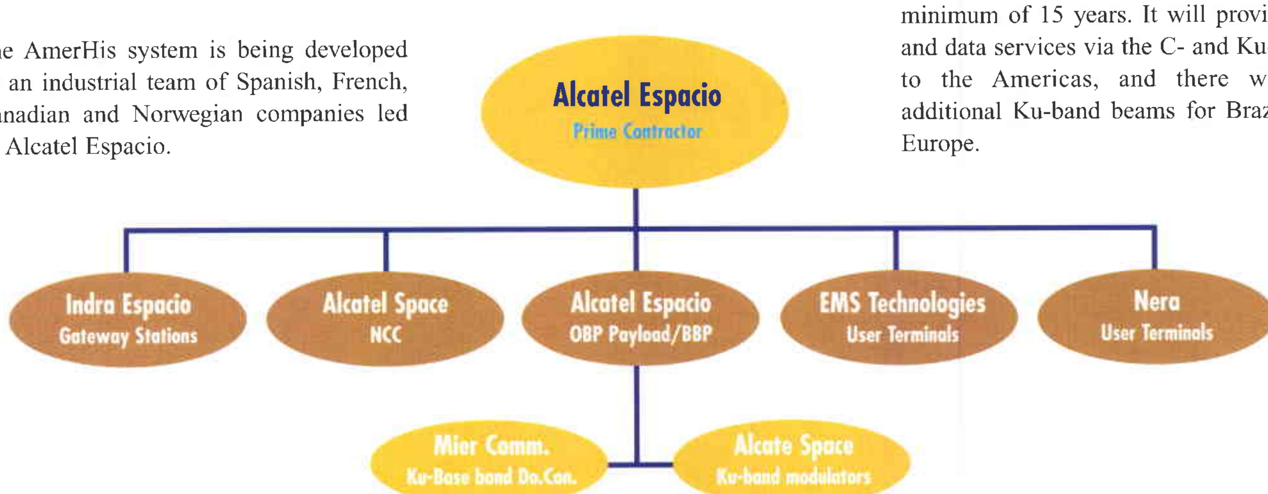
The Amazonas satellite has been ordered by Hispamar, a daughter company of Hispasat operating in South America, from Astrium for a launch in April/May 2004. Based on the generic Eurostar 3000 spacecraft platform, it carries 19 C-band and 32 Ku-band transponders. It will be located at 61 degW above the equator, just north of the Amazonas river.

The main role of Amazonas will be to provide spot-beam services covering North and South America and Europe for a minimum of 15 years. It will provide TV and data services via the C- and Ku-bands to the Americas, and there will be additional Ku-band beams for Brazil and Europe.

AmerHis – A Model of Institutional Cooperation

Following the approval of ESA's Telecommunications Long-Term Plan, the Agency entered into discussions with several satellite operators with a view to finding flight opportunities for the systems being developed within its multimedia communications programme. Hispasat SA reacted positively, expressing interest in the potential inclusion of a regenerative payload on the Amazonas satellite.

The commitment to the realisation of AmerHis is reflected in a formal trilateral Agreement between ESA, Centro de Desarrollo Technologico e Industrial (CDTI), and Hispasat, which defines the terms and obligations of the parties with respect to the implementation, accommodation, launch and exploitation of the AmerHis system. The ESA commitment is reflected in the contract awarded on 11 October 2002 to an industrial consortium led by Alcatel Espacio.



The AmerHis Payload

The AmerHis payload will be a 'switch-board in space' providing connectivity between the Amazonas satellite's different coverage areas and making a wide range of interactive services possible over the Atlantic. It will be the first such 'regenerative' switching payload to be flown on a commercial communications satellite. Based on novel on-board processing technology, it can provide high-speed Internet access and broadband data services to subscribers using the DVB/MPEG-2 standard. It also provides access to terrestrial networks through various gateways. These gateways provide such services as Internet access, voice over IP to ISDN/PSTN, and videoconferencing.

The AmerHis payload will connect small, cost-efficient user stations, built to meet the DVB-RCS and DVB-S standards. The link from the user station to AmerHis will work at a medium data rate, allowing low-cost transmitting stations to be used. The AmerHis payload then converts these medium-rate signals, received from many different user stations, into one high-rate data stream, which is transmitted by the Amazonas satellite. The user stations can receive the AmerHis signals with standard digital TV receivers based on the DVB-S standard. By combining the DVB-S and DVB-RCS capabilities into one unique regenerative and multi-spot satellite system, AmerHis integrates a broadcasting multi-media network with an interactive network.

The AmerHis Services and Connectivity

The AmerHis operational system will be an ideal platform from which to provide a wide selection of real-time and non-real-time multimedia services and applications, including:

- Distributed interactive TV.
- Video broadcasting on demand.
- Radio/news broadcasting on demand.
- Web browsing/News groups/e-mail.
- File transfer.
- Tele-medicine/tele-teaching.
- Videoconferencing/Video telephony/ Audioconferencing.
- Tele-shopping/Tele-banking.
- Interactive gaming.
- Collaborative working.
- Push applications.
- IP multicast streaming.
- LAN interconnection.
- Virtual Private Networking (VPN).

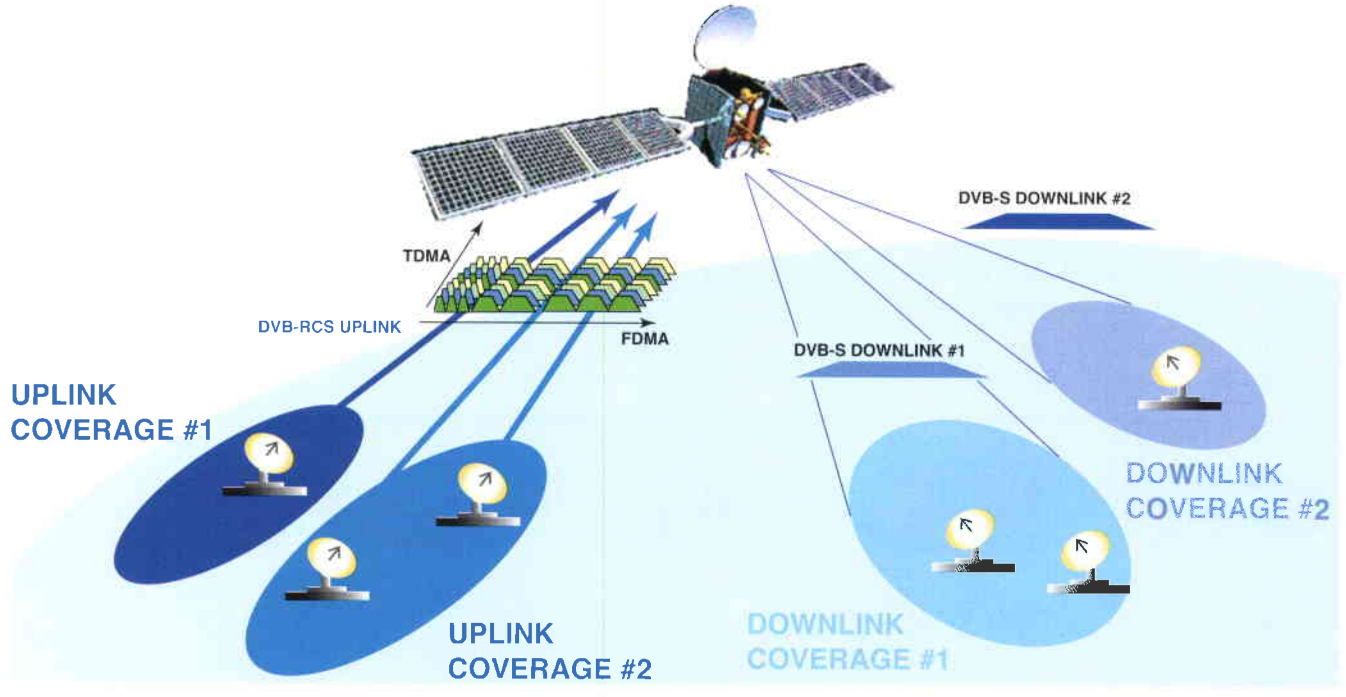
The AmerHis operational system will support IP services as well as native MPEG-based services with efficient multicast and quality-of-service support. Interconnection with terrestrial networks – ISDN and public switch telephone networks – is also supported through gateways.

A variety of different connectivities are possible for the various applications:

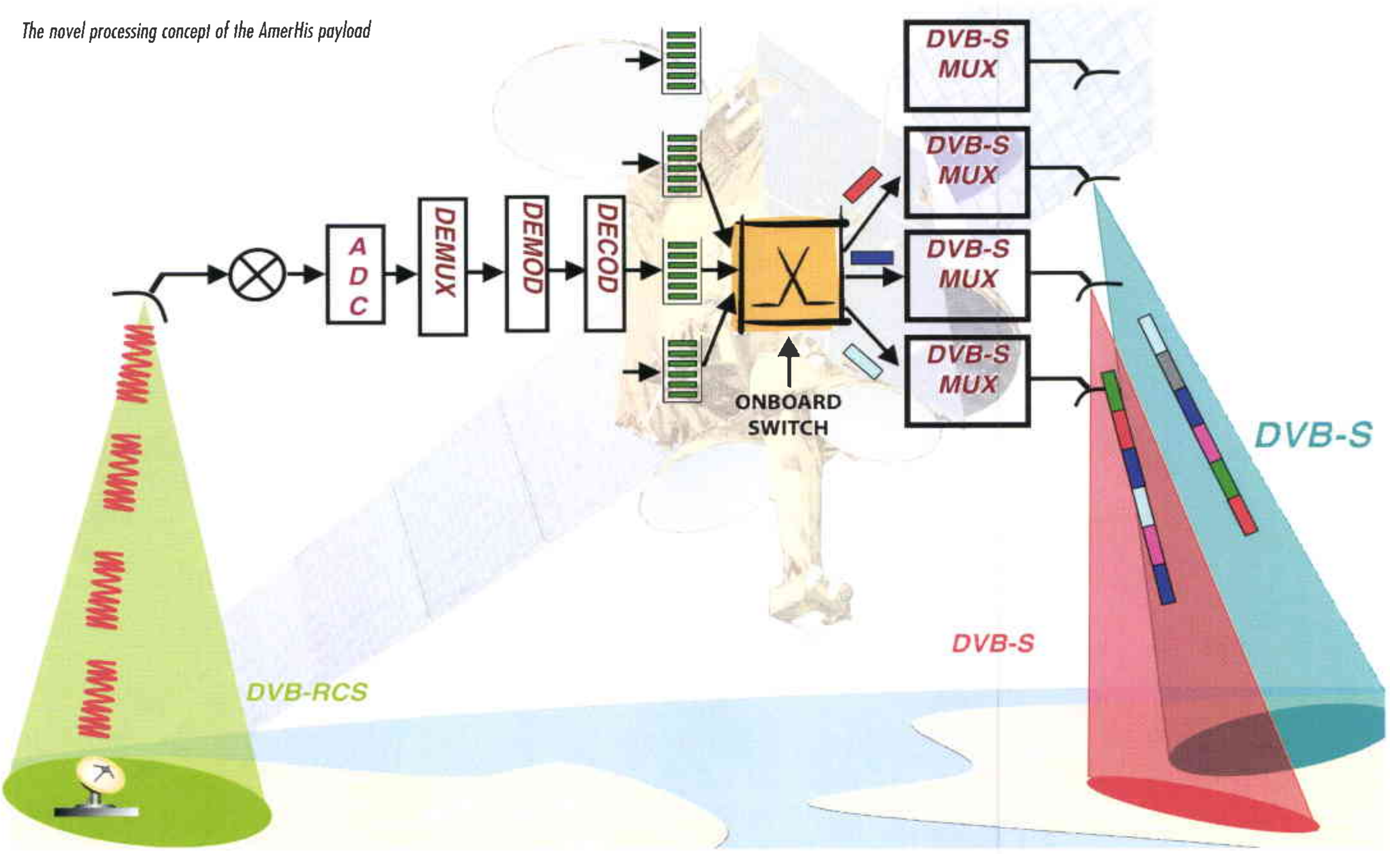
- Point-to-point: 'unicasting'
- Point-to-multipoint: 'multicasting'
- Point-to-multipoint: 'broadcasting', which differs from multicasting in that the network has no knowledge of, or control over the user.
- Multipoint-to-point: concentration/ multiplexing.
- Multipoint-to-multipoint: mesh or some-to-many.

The AmerHis Development Schedule

The AmerHis development schedule is very demanding. The procurement contract for the Amazonas satellite was signed in January 2002 and the possibility of embarking a piggyback payload only became known the following month. The



The novel processing concept of the AmerHis payload



industrial consortium, led by Alcatel Espacio, quickly prepared a proposal based on the work they had already done under the Domino 2 contract within the framework of the ESA Directorate of Applications ARTES-3 programme. The contract for the AmerHis payload's development was subsequently formally signed in October 2002. However, to meet the Amazonas satellite's tight development schedule, the industrial consortium had already started work. One of the schedule-critical items was the procurement of the ASICs (Application-Specific Integrated Circuits) for the baseband processor.

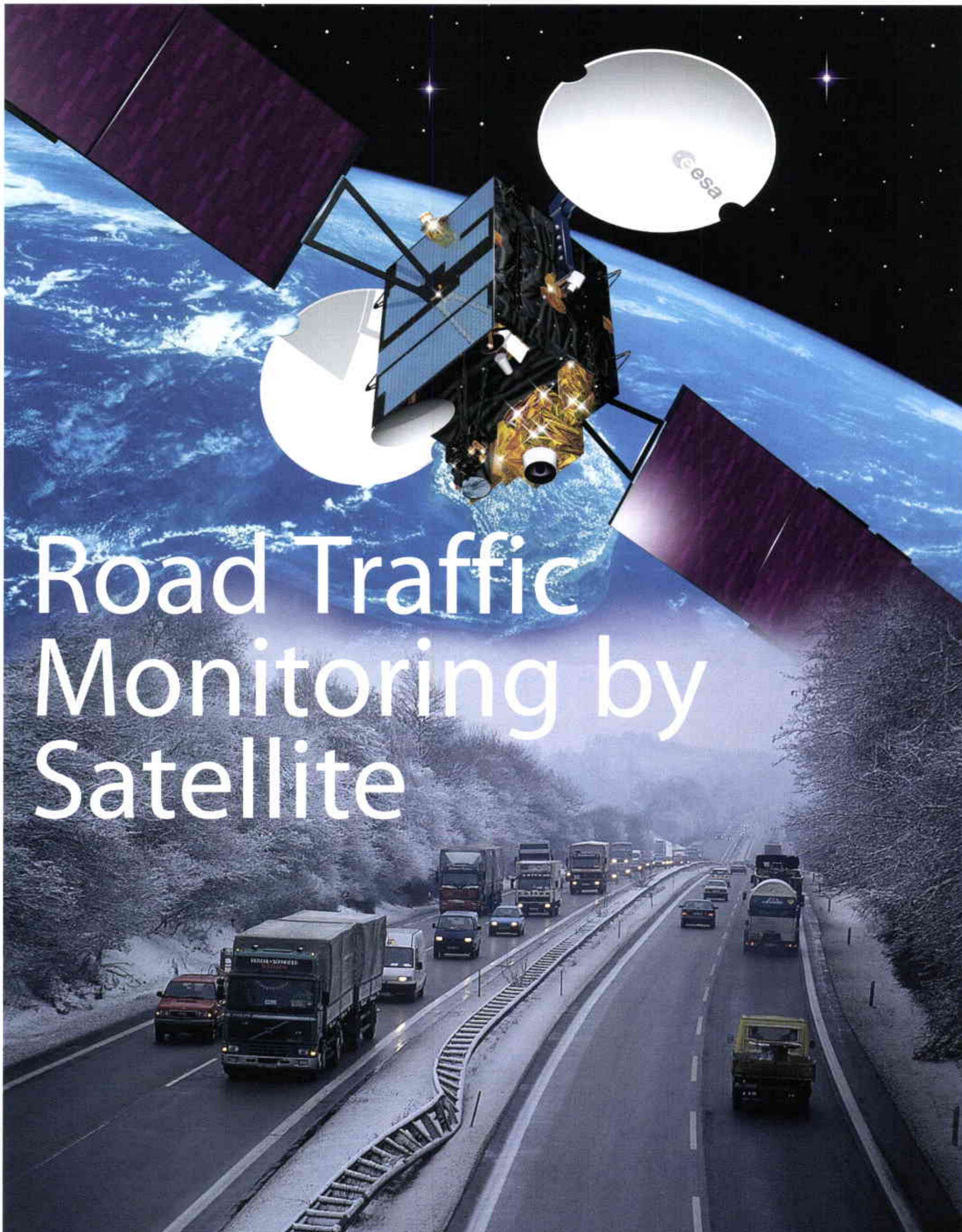
The Engineering and Qualification Model (EQM) of the On-Board Processor has been completed and was delivered to Astrium the end of May 2003 for integration and testing with the Amazonas spacecraft. It is thermally and mechanically representative of the final Flight Model (FM), which is scheduled to be delivered to Astrium in September 2003.

In parallel with the work on the space segment, development of the ground segment has also been taking shape, fortunately under less stringent schedule constraints. Before delivery of the payload Flight Model for integration on Amazonas, however, a complete end-to-end test of AmerHis including the ground segment needs to be performed to identify any potential incompatibility between the payload and the user stations. The AmerHis Multimedia System Validation Testbed (AMSVT) has been developed for this purpose. The AmerHis Operational System Validation Testbed (AOSVT) will facilitate the pre-launch and in-orbit acceptance tests and the final validation of the AmerHis system before delivery to Hispasat. The integration, testing and pilot operations will be performed during 2004. Delivery of the complete AmerHis communication network to Hispasat is currently scheduled for January 2005.

Conclusion

The AmerHis system is to be flown and demonstrated at a critical point in time for the whole communication satellite community, for whom it will hopefully open a new window of opportunity by providing very cost-effective, interactive broadband services to a very large user community. Of particular interest is the system's ability to provide these services simultaneously to the whole American continent and Western Europe under the auspices of a European satellite operator.

Thanks to AmerHis, Hispasat will be able to offer more and better services to its customers in Europe and North and South America without resorting to today's costly and cumbersome double satellite hops. These services include high-speed Internet access, digital audio and video broadcasting, and multi-casting services. With its two-spot-beam coverage of the Americas and one European beam, the AmerHis payload is an ideal vehicle with which to promote the use of European and Canadian communications equipment and services in other regions of the World. esa



Road Traffic Monitoring by Satellite

Erling Kristiansen
Software Systems Division,
ESA Directorate of Technical and Operational Support,
ESTEC, Noordwijk, The Netherlands

Claude Loisy
Service Projects Division,
ESA Directorate of Applications,
ESTEC, Noordwijk, The Netherlands

Willem v.d. Bosch
ARS Traffic and Transport Technology,
The Hague, The Netherlands

Introduction

Congestion of public road networks is a growing problem in many countries. Authorities are developing initiatives to manage the traffic, but no remedial strategy can be better than the information upon which it has to rely. Consequently, the traffic planners need information that is accurate, reliable, timely and complete. The road users too need good-quality traffic information in order to plan and adjust their routes.

Traffic information has traditionally been collected with inductive-loop detectors embedded in the roads and with video cameras. These fixed installations do not give any traffic information beyond the locations where they are installed, and their coverage is usually confined to congestion-sensitive motorways and a limited number of tunnels, bridges and intersections.

The gathering of 'floating-car' data is a totally different concept, whereby a relatively small percentage of the vehicle population generates real-time traffic information just by participating in the traffic flow. The data being collected by the participating vehicles is immediately communicated to a central facility for processing. This approach allows the collection of traffic data across the whole road network – including towns, cities, rural roads and currently unmonitored motorway segments. Floating-car data also has the potential to provide better-quality information. The tracer vehicles can log travel times over a series of road segments, whereas traditional systems measure the traffic only at specific points. In addition, tracer vehicles can detect and report various types of traffic 'events' as they occur.

A telecommunications system with wide coverage and operating at affordable cost is vital to the success of the floating-car concept, and the use of a satellite-based system has several advantages over terrestrial means. It provides coverage over large areas, including regions not covered by GSM, GPRS or UMTS. It can also have cost advantages, provided the system design is optimised for the specific nature of floating-car data. There is also the potential to share the in-car equipment and the satellite link with other applications, thereby providing additional cost benefits.

In an earlier project for the Dutch government, ARS Traffic & Transport Technology (ARS T&TT) conducted a successful field trial using GSM technology to collect traffic data from probe-type vehicles. As reported in ESA Bulletin No. 101, Aberdeen University has also studied and simulated the preliminary design of satellite-based floating-car data systems, and the trial reported here builds upon its results. A Road Traffic Monitoring by Satellite (RTMS) project has also been carried out by ARS, and the Technische Universität Dresden (TUD) has contributed to several tasks within the project. The work conducted to date has been financed under ESA's ARTES-5 programme.

Designing the System

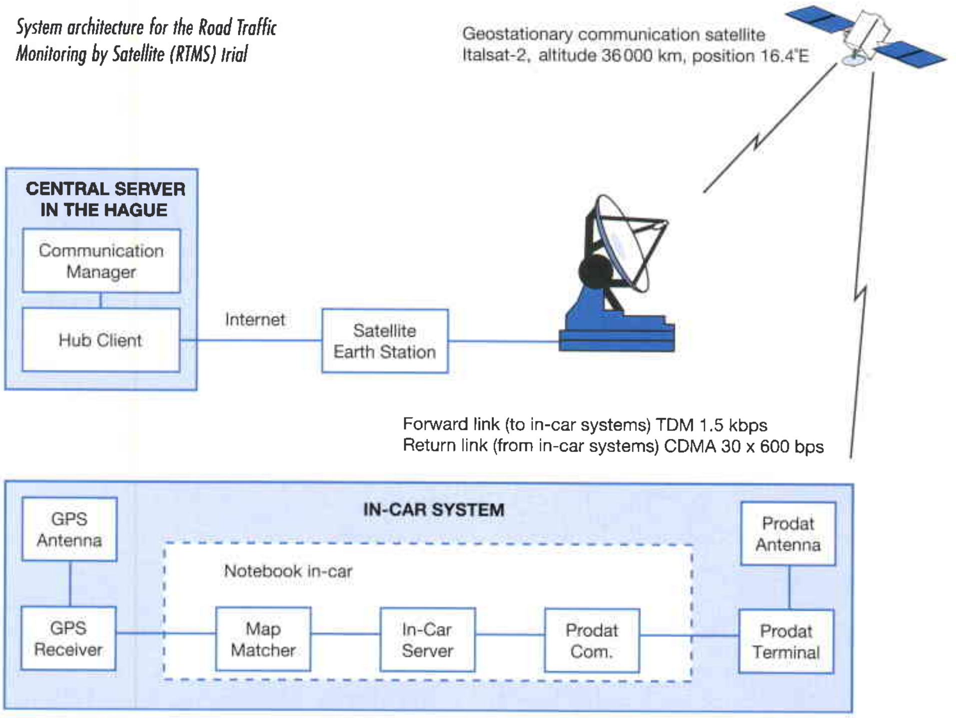
The trial system consists of three parts: an in-car unit, a central computer server and a mobile satellite communication system. The in-car system reads the vehicle's position every second using the Global Positioning System (GPS). An algorithm called the 'map matcher' uses that position and a digital road map to determine the vehicle's speed and to identify the road on which it is being driven. Any traffic congestion is automatically detected for each road segment, based on a priori knowledge of that road, such as the expected speed of traffic under non-congested conditions. If traffic congestion is detected, the in-car system sends a message to the central server. The in-car unit also handles other data flows between the mobile system and the central server, according to the communication protocol selected (see accompanying panel).

On the central server side, an application called the 'communication manager' interfaces with the satellite system. It is able to configure the in-vehicle unit remotely, broadcast requests for tracer vehicles, and receive traffic data from the vehicle fleet. For the trial, the server was located at ARS's premises in The Hague. It interfaced with the Telespazio Earth station in Lario, Italy, via the Internet. Lario was the access station to the L-band payload of the Italsat F2 satellite that was used for the trial.

In a full operational system, the central server would also connect with external service providers, such as a Traffic Information Centre and possibly providers of ancillary services such as locator services, emergency and breakdown call centres, and fleet-operation centres.

The mobile satellite communication system used for the trial was Prodat-2, developed 10 years ago by ESA as a technology demonstrator. It has been used in the meantime for many trials and demonstrations. For the RMTS trials it was operated on a good-will basis with the help of Telespazio (I) and the contractors involved in its design.

System architecture for the Road Traffic Monitoring by Satellite (RTMS) trial



Conducting the Field Trial

The three-month field trial, from April to July 2002, was intended to validate the RTMS concept by means of a pilot implementation, focusing on two aspects:
- technical performance: the ability to communicate effectively in various environments, and
- traffic-monitoring performance: the effectiveness of the system in detecting traffic congestion and determining traffic speeds.

During the trial, a small fleet of vehicles continuously recorded their positions, assessed the traffic situation and sent their findings to the central monitoring system. The fleet consisted of five postal trucks, eight container trucks, two sewer-cleaning trucks and a passenger car, all of which were operated intensively on weekdays in the Rotterdam-Rijnmond area of the Netherlands. The in-vehicle systems were installed on notebook computers and required no intervention on the part of the drivers. They were configured to log raw data for later analysis, including the GPS positional data and vehicle-satellite communication status every second. This allowed replays of completed trips for analysis and optimisation of the algorithms. A relational database and viewing tools were developed for analysis, demonstration and optimisation, and the filtering out of invalid or less useful data.

What the Field Trial Showed

With the Prodat-2 system, the hub station transmits a continuous carrier signal towards the mobiles (the so-called 'forward link'), and each mobile records the quality of its reception every second. The availability of the forward link is therefore easily computed for any given time interval, and can be plotted on a map. The quality of the return link is not so easily measured because no continuous transmission takes place. However, the quality of the forward and return links is highly correlated: either there is a clear view, or the signal is partially blocked by some obstacle and is unusable. On a longer time scale, the return link's quality can also be assessed by statistical recording of the success/failure of message transmission, and the number of attempts required for successful transmission.

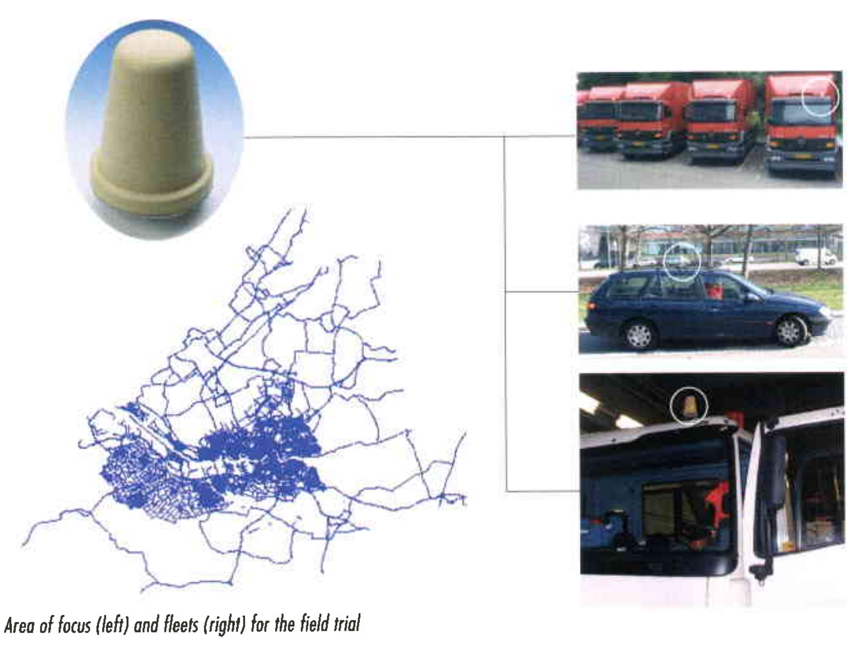
Choosing the Communication Protocol

As an RTMS system will ultimately provide data for existing Traffic Information Centres (TICs), its data format should preferably be based on an existing standard. A survey of today's traffic-information protocols led to the choice of the GATS standard (Global Automotive Telematics Standard), developed for cell-phone SMS communication, as the baseline. An adapted GATS protocol was therefore designed to allow the selection of relevant information elements and optimisation of the length and coding of individual information elements.

When many mobile units share a communication channel to a central station, a discipline has to be established for efficient sharing of that channel. In line with the Aberdeen study, three possible access schemes were investigated:

- Random-access mode (event driven): the vehicle transmits data about traffic events whenever they occur. The advantage is that transmission only takes place when an event of interest occurs. The drawback is the risk of collision of transmissions from different mobiles, reducing the effective capacity of the communication channel.
- Polled random-access mode (TIC driven): a subset of vehicles are invited to transmit if they meet certain conditions. For example, vehicles within a defined geographical region that are not already participating in data collection may be invited to join the system. The potential size of the addressed community must be adapted dynamically to avoid congesting or starving the channel.
- Addressed poll mode (fully coordinated access): the central system rigidly controls access by sending regular requests for information to specific vehicles, which return their replies in a specified time slot. This mode is collision-free, but involves complex management in deciding which vehicles to poll in order to make optimum use of the limited communication capacity available.

The RTMS trial implemented only one mode: return-link random-access event reporting in combination with forward-link broadcasting. This choice was driven by the access modes available with the unmodified Prodat-2 equipment. It was quite appropriate for a communication trial of this size, where system capacity was not an issue, and message collisions rare. For a full-size operational system, however, a combination of random and addressed polling should be considered, possibly augmented by random-access reporting of high-value events. Optimisation of when to use which mode, in order to balance the channel loading inefficiency inherent in random access against the inefficiency resulting from the addressed poll mode sometimes carrying data of less interest to the TIC, then becomes one of the design challenges.



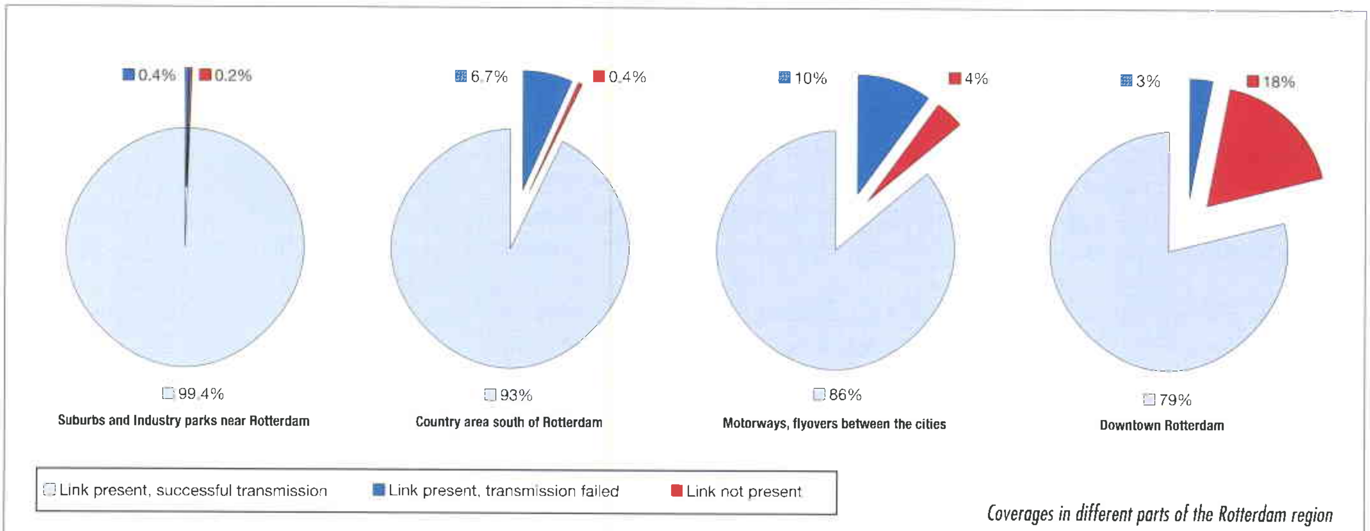
Area of focus (left) and fleets (right) for the field trial

In the densely populated and industrialised area between The Hague and Rotterdam, for example, both the return and forward links were found to be present during 96% of the time. Considering the particularly difficult, mainly urban, propagation environment, this was a remarkably good result. During the field trial as a whole, only 7% of the messages required retransmission, but in most cases several attempts were needed before success was achieved.

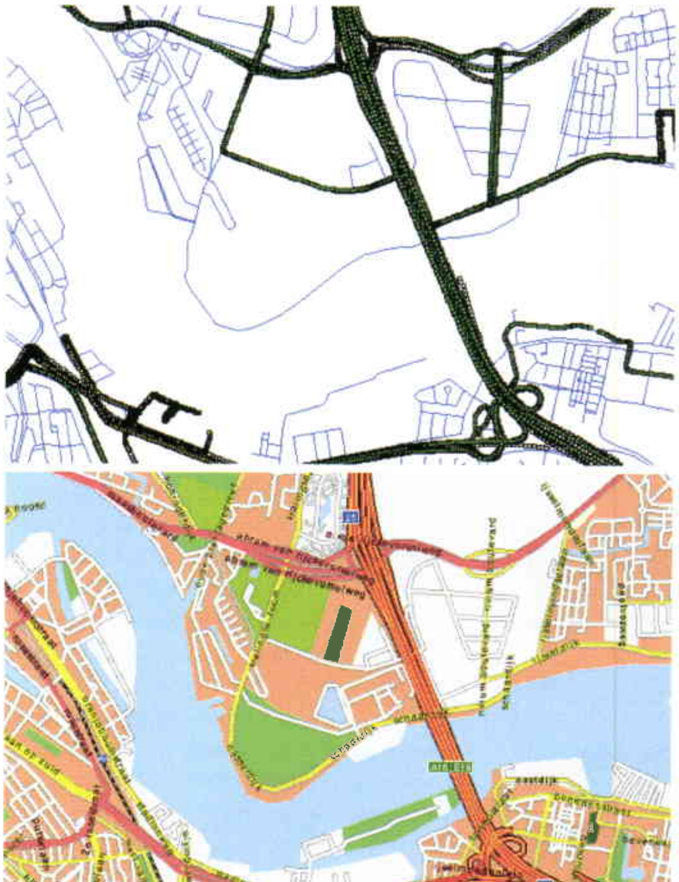
In terms of performance in different environments, satellites provide line-of-sight communication and so performance can be expected to be good in open areas, and to degrade when more and more obstacles are encountered in urban environments. This expectation was confirmed by the RTMS trial in that communication was best in rural, suburban and industrial areas, was somewhat degraded in areas with complex fly-overs and bridges, and was poorest in downtown areas with large concentrations of high buildings. Even in the downtown areas, however, communication remained intact for about 80% of the time.

The map matcher is a vital element in the detection of traffic data. If the vehicle's position is not properly matched to the road map, the vehicle's calculated speed and hence the 'normal speed' for the particular road segment on which it is traveling will be unreliable. The system's performance was therefore assessed by manually comparing a selection of map-matcher results against the actual itineraries. The results were very good, with 94% of each trip accurately matched, and there are reasons to expect that further improvements might be possible.

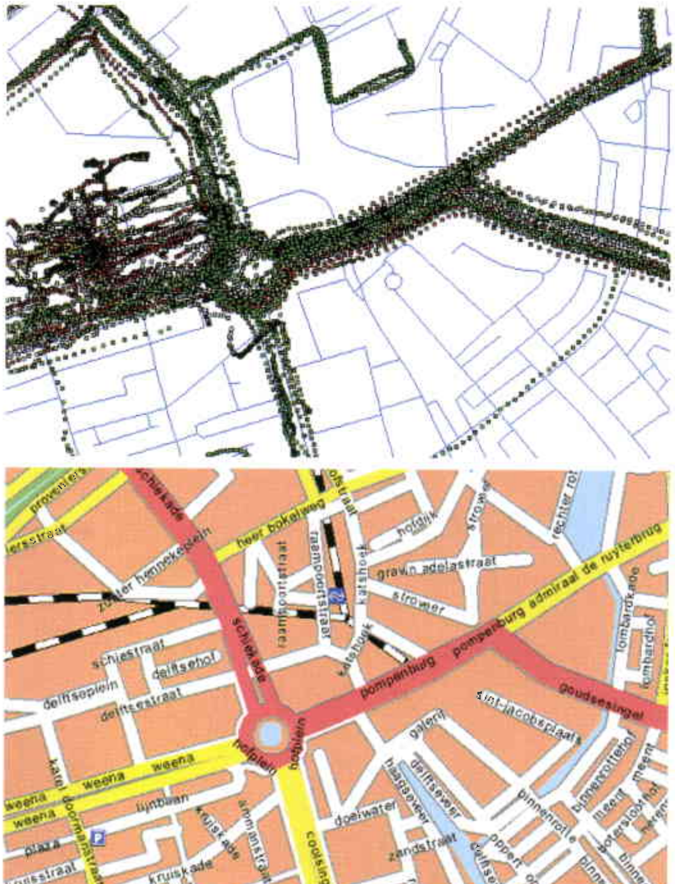
The ability to detect traffic congestion was assessed by manually comparing a selection of the traffic alarms generated automatically by the system against the real situation. A number of false alarms were generated during the tests for various reasons, but the nature of these false detections indicates that again improvement is possible by refining the algorithm and/or improving the map and the normative speeds.



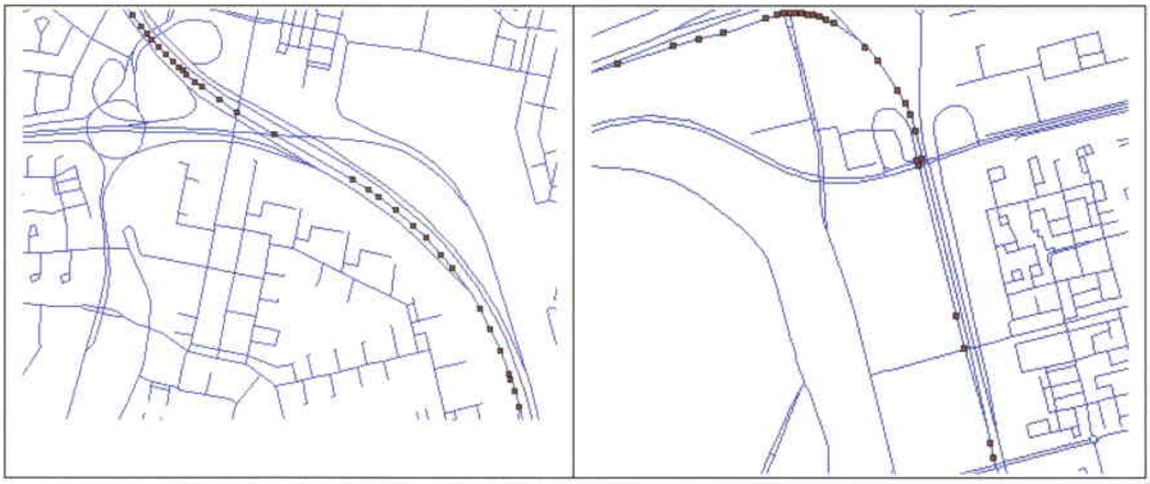
Coverages in different parts of the Rotterdam region



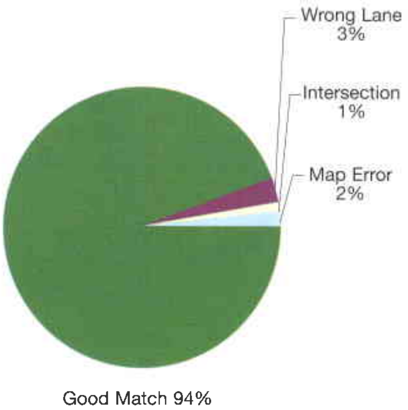
Communication performance in a relatively open suburban area surrounding the A16 motorway in Rotterdam, near the Brienenoordbrug bridge. Green dots indicate good-quality communication, while other colours indicate various degrees of loss of communication



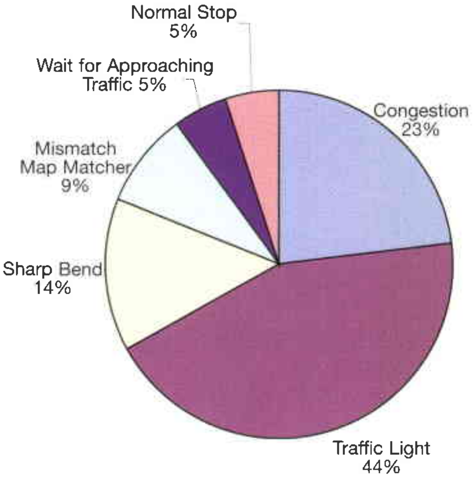
Communication coverage in the downtown area of Rotterdam with its many tall buildings is relatively poor, but the effect is very localised and disappears within 50 to 100 metres. The satellite being accessed is almost directly south, so north-south roads perform better that east-west roads



Examples of a good map match (left) and a failed match (right) in a complex motorway situation where the vehicle is erroneously located in the exit lane rather than in a motorway lane



Accuracy of the Map Matcher



Traffic events generated during the three-month field trial

The Road Ahead

At the time of writing, several issues must still be resolved to pave the way towards an economical full-scale implementation of RTMS:

- The costs of equipment and service must be brought to an acceptable level. If the equipment and operations can be shared with other valuable services, such as fleet management, emergency services, route guidance, etc., RTMS can certainly be economically viable.
- The 10-year-old Prodat-2 terminals used in the trial were heavy, bulky and power-hungry. With today's technology, small, lightweight terminals with low power consumptions are fully feasible, being in essence no more complex than a GSM phone. Economy of scale is essential.
- The RTMS trial used an available system and its equipment, and was thus somewhat constrained by that system's capabilities. A future operational system should be based on a design specifically optimised for RTMS functionality, for which some research results that already exist in the Aberdeen study can serve as a basis.
- Compatibility and/or interoperability with present and emerging standards for data formats is essential for smooth integration into the in-car environment.
- Further R&D is needed to optimise the behaviour of the detection algorithms. Specific situations like traffic lights, bends and stops must be dealt with and the map optimized accordingly.
- Due to the small scale of the trial, the anonymity of the participating vehicles was not given much attention. For an operational system, however, this is of paramount importance and the Aberdeen study suggests ways to achieve it. If the in-car equipment supports both RTMS and other services, it may need to have an anonymous identity for the RTMS and a known identity for the others. These dual identities must then be kept strictly separate.

Conclusions

The RTMS project has shown that the collection of valid and valuable traffic information by means of satellite is feasible from a technical point of view, even in built-up areas. RTMS will enable road authorities to cover the whole road network - not just the bottlenecks - without huge investments in infrastructure such as loop detectors, video detectors and the corresponding cabling. For drivers, it will lead to better information, particularly if combined with in-car route planners and navigation systems. Traffic information and advice can be broadcast by the RTMS system itself.

In the near future, a host of new applications and services can be expected to emerge for in-car usage. They will be provided and promoted by accessory and car manufacturers, and service, software and telecommunications providers. RTMS lends itself well to incorporation into such an in-car infrastructure. esa

Checking Whether SCOS is up to SPEC

Fernando Aldea
ESA Directorate of Technical and Operational Support, ESTEC, Noordwijk, The Netherlands

Michael Jones, Eduardo Gomez
ESA Directorate of Technical and Operational Support, ESOC, Darmstadt, Germany

Hendrik Schäbe
TÜV InterTraffic, Germany

Originally developed as operational software to support ESA's space missions, SCOS-2000 is now being promoted as an ESA product available to the worldwide space community and more than 40 customer licences have already been granted. To support its promotion, a certification activity is now in progress which involves benchmarking the product against a set of agreed quality criteria (the quality model) by an independent organization (TÜV InterTraffic). The evaluation and certification process is based on a method called 'SPEC' (Software Product Evaluation and Certification).

What exactly is SPEC?

SPEC is a software product evaluation and certification method that has been developed under ESA contract. Based on several international standards, it has already been used to evaluate a number of software packages, but SCOS-2000 is the largest one to date.

The quality model that underpins the SPEC method is composed of so-called 'goal properties' (e.g. functionality), which can be split into a set of second-level 'properties'. Each property can be quantified by a set of metrics, which are measured using one of several methods. The goal property of 'functionality', for example, can be broken down into the properties of completeness, correctness and efficiency. Efficiency can in turn be measured by looking at such numerical indicators, or 'metrics', as timing margins, memory margins, throughput and resource utilisation.

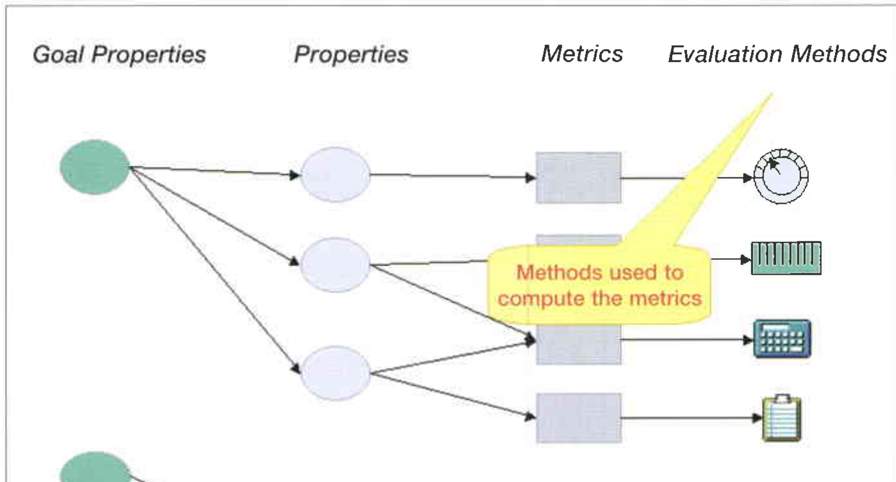
Software product quality depends on numerous factors. Some of them are inherent in the product, whereas others are derived from its development process and from the operational context in which the software must run. Consequently, indicators of the software development process and the developer organisation's capabilities are also needed in the context of software product evaluation and certification, as they provide valuable indications of product quality. For this reason, the SPEC method incorporates not only product-related, but also development-process-related goal properties, and also covers practices specific to the space sector (such as those defined in the ECSS-E-40 and ECSS-Q-80 European Standards).

What exactly is SCOS-2000?

SCOS-2000 is a generic reusable software system that facilitates the implementation of Mission Control Systems (MCS) for both small- and large-scale space missions. The typical SCOS-2000 configuration is a distributed system, running across a network of workstations, although it may be scaled down to a 'SCOS-2000 in-a-box' (i.e. single workstation) configuration for simpler missions. The functions covered are:

- Telemetry Processing (TM)
- Telecommanding (TC)
- Online Database (DB)
- Online Archive (ARCH)
- General Services and Utilities
- Operation Language (OL)
- Roles & Privileges (USER)
- Events & Actions (EVAC)
- On-board Software Maintenance (OBSM).

The inherent flexibility of SCOS-2000 allows client missions to configure the system to their own requirements using the database (containing spacecraft telemetry, telecommand and display characteristics) and the various system-configuration files.

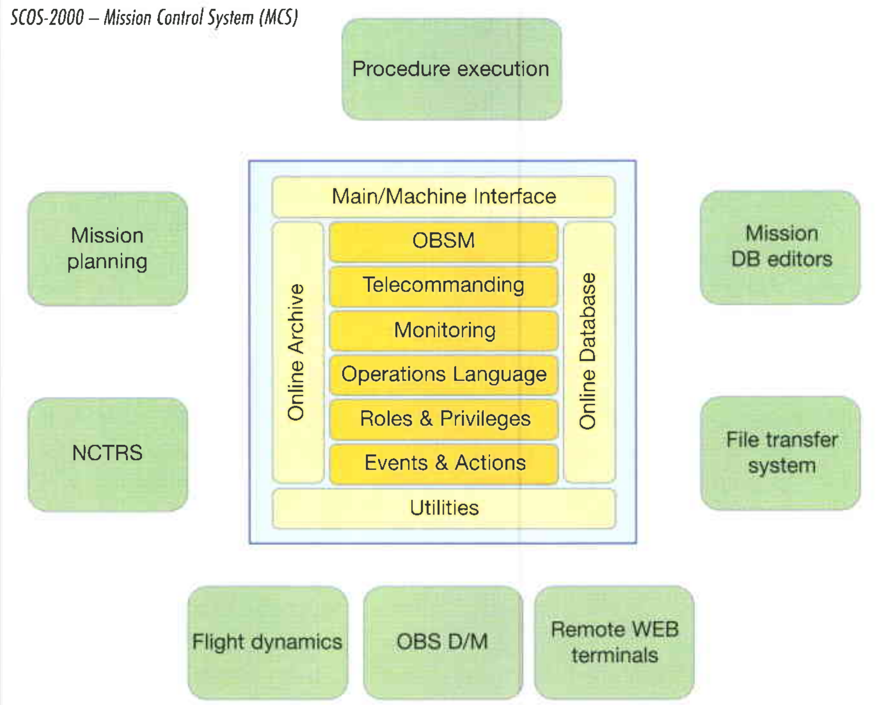


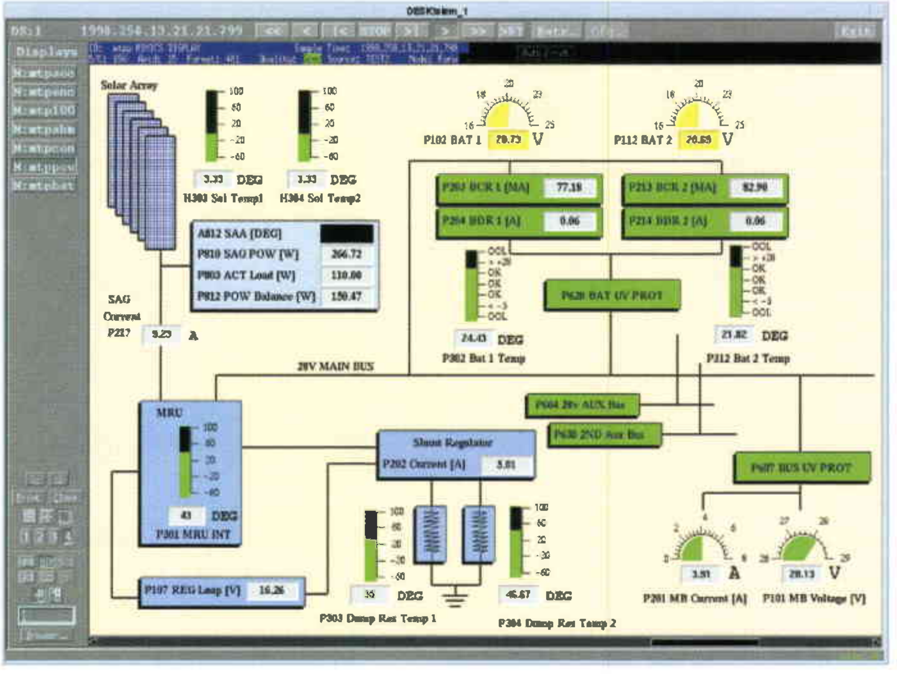
The SPEC generic quality model

SPEC Goal Properties

Product Related	Process Related
• Functionality	• Suitability for Safety
• Reliability	• Software Development Effectiveness
• Maintainability	• System Engineering Effectiveness
• Re-usability	
• Operability	
• Documentation Quality	

SCOS-2000 – Mission Control System (MCS)





Example of displayed SCOS-2000 information

Evaluating SCOS-2000 with SPEC

The evaluation and certification process was split into two phases:
- Phase I. Baseline Evaluation
- Phase II. Delta Evaluation and Certification.

During the first phase, a baseline version of the SCOS-2000 (version 2.1e) was evaluated and a set of recommendations for product improvement has been issued. In the second phase, the updated version of SCOS-2000 will undergo a 'delta evaluation' and will eventually be certified in a process agreed between ESTEC, ESOC and TÜV. The first phase was in fact preceded by a Software Criticality Analysis (SCA), based on the results of a Software Failure Modes, Effects and Criticality Analysis (FMECA software), which provided necessary input, but was not part of the SPEC method itself.

The results of the Baseline Evaluation (Phase-I) can be summarised as follows:
- Of the 85 metrics defined by SPEC, 10 were considered inapplicable.
- 3 metrics were not measured due to lack of an appropriate tool or evaluation method, but they were replaced with other similar metrics.
- 5 out of 72 metrics failed to reach the target value.

Thus, although SCOS-2000 met the target values in most cases, it still needs improvement before it can be correctly certified as Class-B (mission-critical) software. Possibly more important than the formal certification, is the critical review of the software itself and its production process and methods. In this context, a set of recommendations have been identified that will lead to further enhancement of the product, including:
- provision of a homogeneous quality level throughout the product documentation, including the older elements
- improvement of traceability documentation (e.g. from requirements to design, design to code, requirements to test cases)
- analysis of the current architecture to identify possible changes that can help reduce the complexity of some modules
- use of better/improved software coding standards.

In addition, a process-improvement programme has been initiated at one of the SCOS-2000 subcontractors, which should help increase the overall quality of the development and maintenance process.

The Next Steps

Most of the recommendations emanating from the SPEC Phase-I evaluation are currently being addressed by several activities designed to improve SCOS-2000 as a software product. The results will be incorporated into future versions of SCOS-2000, one of which will be subjected to the delta-evaluation exercise.

These improvements will be complemented with new coding standards that will take into account state-of-the-art software development methodologies such as Model Driven Architecture. The new standards will contain language-independent practices and conventions, but will also cover the specificities of the languages used to develop SCOS-2000, primarily C++ and Java.

In addition, a new SPEC-based evaluation activity has been initiated on RTEMS, a real-time operating system that is being proposed as onboard COTS software in some spacecraft systems. RTEMS is developed and maintained as Open Source Software (OSS), which makes it a real challenge in terms of application of the SPEC method, which was originally conceived for software products developed in a more traditional way. SPEC therefore needs really to be adapted to this particular type of software, but the RTEMS evaluation is expected to provide useful experience in how to apply the SPEC approach to COTS and OSS products.

Acknowledgement

The key players in the SCOS-2000 evaluation and certification process are:
- TÜV InterTraffic (Germany), acting as evaluator and certifier.
- Critical Software (Portugal), as the sub-contractor performing the Software Criticality Analysis (SCA).
- ESOC Ground Segment Engineering Department, responsible for SCOS-2000 development and the requester of the certification.
- The SCOS-2000 suppliers, providing information on SCOS-200 development.
- ESTEC Software Product Assurance Section, providing the Technical Officer for the activities and supervising the application of the SPEC method, developed under a previous contract run by them.

esa

Faster 3D Measurements for Industry - A Spin-off from Space

Carl-Thomas Schneider
AICON 3D Systems GmbH,
Braunschweig, Germany

Joachim Becker
ESA Directorate of Technical and Operational Support,
ESTEC, Noordwijk, The Netherlands

Susanne Marek
ESA Directorate of Industrial Matters and Technology Programmes,
ESTEC, Noordwijk, The Netherlands

Technology R&D for space applications can have an extremely stimulating effect on industrial development in general. Investments in R&D are important for European Industry both to maintain and improve its position in the global marketplace. However, the road from that first idea to an operational prototype is not always easy or without risk. ESA's Technology Transfer Programme therefore helps small and medium-sized enterprises to pursue novel ideas and bring them to market in a timely manner. The ProCam described here is one such example of a space-related development that is helping to improve our daily lives.

Introduction

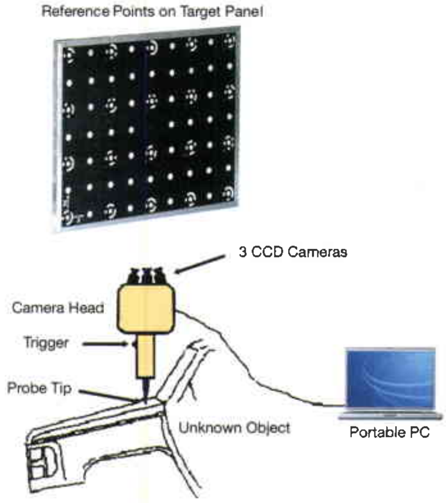
During the late nineteen eighties, in the field of microgravity research in fluid physics, there was a growing demand for non-invasive optical diagnostic tools to detect convective flow patterns, to measure velocity distributions and to determine the behaviour of bubbles in fluids and fluid columns. As such phenomena are usually highly dynamic and three-dimensional, all parameters involved must be measured simultaneously in real time. Moreover, methods that make use of mechanical scanning have an impact on the microgravity environment being measured, and also have limited temporal resolution. In 1991, therefore, ESTEC introduced 'Close Range Photogrammetry' as a non-invasive means of measuring position in three-dimensions and velocities by performing a sequence of measurements as a function of time.

The principle behind such 3D-measurements of position is used subconsciously by most human beings to orientate themselves in their local environment. It requires the two slightly different views from our two eyes and our brain to make good positional 'calculations' within a range of about 25 metres. Larger distances are only estimated by comparing the relative sizes of known objects. The invention of photogrammetry has extended our stereoscopic viewing performance to highly precise measurements by enlarging the number of views and by introducing a calibrated reference space. Spatial resolution to object size ratios of up to 1:100 000 have already been achieved with stationary photogrammetric set-ups and special cameras.

Development for Space

Within the framework of the ESA Technology Research Programme (TRP), the application of photogrammetry for space microgravity experiments (10 x 10 x 10 mm^3 to 100 x 100 x 100 mm^3) has been brought to a considerable level of maturity by miniaturising and generally refining methods already commonly used on the ground for large objects, and by making use of the first CCD (Charge Coupled Device) video cameras that became available at the beginning of the nineties.

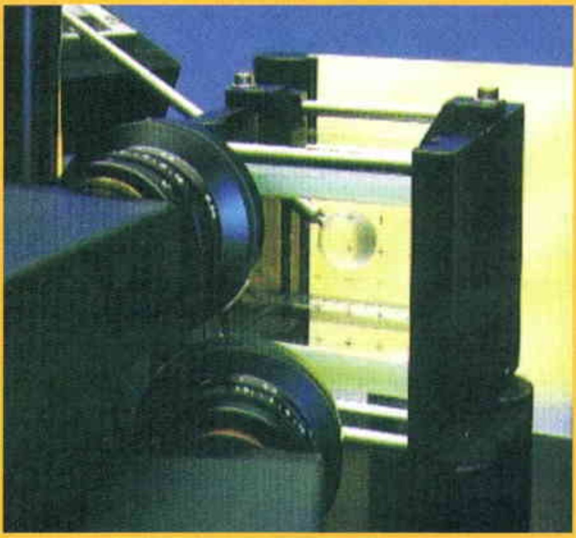
A camera head containing three or four small electronic cameras, looking from one main viewing direction, was found to be best suited for making the measurements needed with sufficient accuracy (i.e. ± 0.1mm within a 1 litre volume).

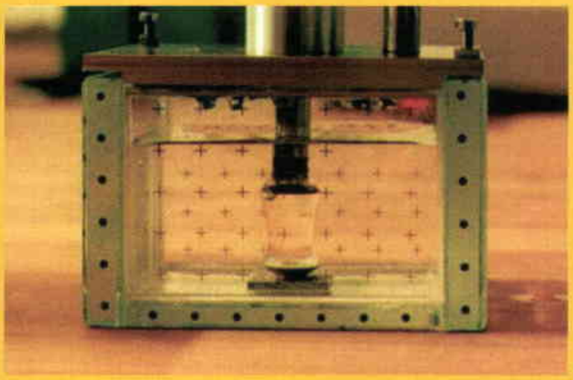


Schematic of the basic elements of the ProCam system

The experiment's calibrated 3D-reference space, a set of Réseau Crosses fixed to the fluid cell's temperature-stable quartz-glass windows, even allowed for relative movements between the camera head and the experiment. This is an essential feature for a modular space multi-user facility with exchangeable experiment containers, where the experiment and the diagnostics cannot be kept fixed and aligned with each other in the way that they can for a stand-alone experiment in a ground-based laboratory. Moreover, it allows measurement accuracies about an order of magnitude better than required (about ± 15 micron within 1 litre).

The first fluid-science experiment making use of photogrammetry was subsequently successfully flown by ESA/ESTEC in 1999 on the Maser-8 sounding-rocket flight.





The breadboard of an experiment fluid cell (above), and a fluid experiment cell with Réseau Crosses on its faces

Extrapolation to Industrial Applications

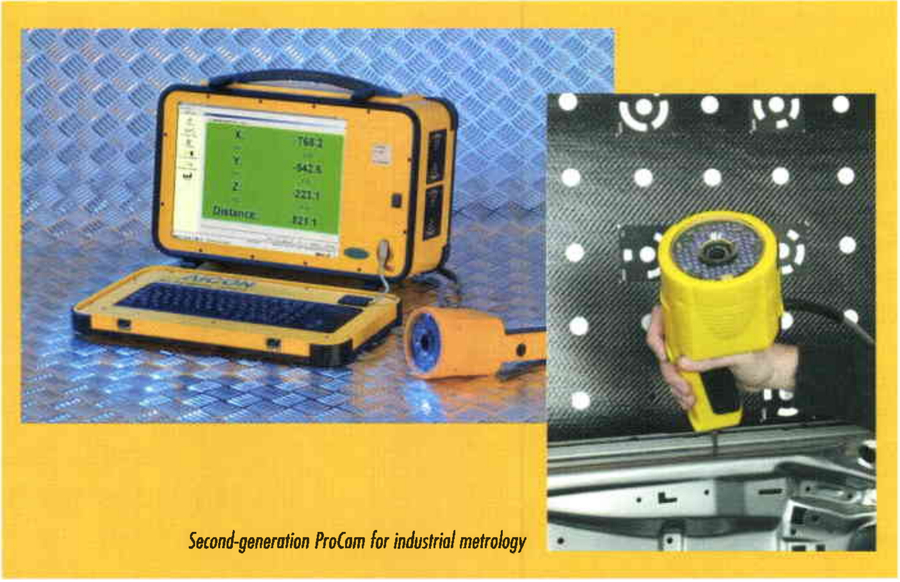
The mobility achieved with the compromise of sufficient, but not maximum state-of-the-art photogrammetric measurement performance, triggered the idea for the spin-off described here – a comparatively inexpensive, mobile tool for accurate 3D-photogrammetric measurements in industry!

The transportation of equipment in order to coordinate/calibrate different measuring machines is time-consuming and leads to delays and interruptions in production because of the extended set-up times. A mobile 3D-measuring system offers fast and flexible control on the factory floor, avoids expensive production interruptions, and reduces set-up times to minutes. Realising the benefits, therefore, that such mobile 3D-measuring technology could have for industry, ESA's Technology Transfer Programme (TTP) began at the end of 1999 to support the development of a first prototype of the mobile 3D-probe now known as 'ProCam'.

The first-generation ProCam consisted of an active probe with three medium-resolution CCD cameras and a portable PC for system control. It was equipped with a measuring tip to touch object points of interest. During the measurements, the cameras face a field of reference points located on nearby portable or fixed panels (equivalent to the Réseau Crosses on the fluid-cell windows), and the resulting 3D-coordinates are immediately shown on the display. The system proved suitable for general metrology purposes, as well as special applications in niche markets such as car crash-test measurements and examinations of large welded constructions.

These first successful applications and the experiences of and feedback from pilot users led to the conclusion that, for wider and hence more profitable business applications, some improvements to the first-generation ProCam would have to be made. The hardware components had to be reduced in number and complexity for easier manufacture and lower production costs. Use of off-the-shelf components would also lead to easier maintenance. The software also had to be redesigned to allow even more user-friendly operation. Development therefore continued, supported by the ESA Technology Transfer Programme, to get the second-generation ProCam onto the market.

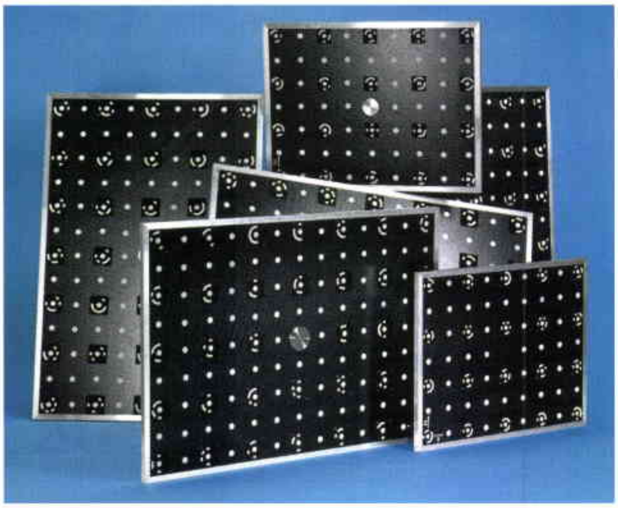
First-generation ProCam measurement head



Second-generation ProCam for industrial metrology

The probe of the latest ProCam has just one, high-resolution, off-the-shelf CCD camera, which both lowers production costs and simplifies calibration. An integrated infrared flash illuminates the target panels, enabling the system to be operated independently of the ambient light. Also, the probe tips are exchangeable and available in various shapes and lengths, allowing measurements to be made even in the most inaccessible places. The measuring probe is attached with a standard bayonet fixing and no recalibration is needed after exchanging probes.

By using calibrated, transportable, optically coded target panels (600 mm x 800 mm and 800 mm x 1200 mm carbon-fibre plates), it is possible to set up stationary or mobile measurement stations. For stationary operation, the reference targets can also be fixed to the walls and/or ceiling of a measuring room, and the coordinates of the reference points will again be calibrated with high precision. The measuring volume is unrestricted, allowing the ProCam to be applied to objects of any size, with a measuring accuracy of ± 0.1 mm + 0.1 mm/m distance to panel (e.g. distance 1 m, accuracy ± 0.2 mm). This offers sufficiently high accuracy potential for both large and small objects.



Some mobile target panels

Exchangeable ProCam probe tip

Preparing for ProCam measurements on a vehicle to be crash-tested with reference points on the walls of the measurement chamber

Applications and Markets

Aside from the obvious general-purpose metrology system market, other niche markets with very particular requirements, mainly in the fields of automotive and aerospace testing, are also emerging. Measurements on crash-test vehicles and position detection for intelligent sensors during modal-test analyses are just two examples of successful applications of the new-generation ProCam. The experience gained in these and other areas of application shows improved system stability and reliability during operation.

Manufacturing halls are another obvious potential major application for ProCam, as it is easy install several measurement stations in various places and then to use just one mobile probe for all of the measurements, particularly as the system can be ready for operation within a few minutes. Such a mobile application allows fast checks to be made on the factory floor, and the item to be measured no longer has to be transported to a special measurement room. This reduces set-up work and can thus shorten product-development and production start-up times.

More than 15 ProCam systems, costing between 60 000 and 80 000 Euros each, have already been installed in Europe and the United States. The short-term sales target is 20-30 installations worldwide per year and the long-term sales target 50 installations per year. To fulfil the long-term market expectations, a less expensive version of the second-generation ProCam, with a lower accuracy rating for less demanding applications, will be produced. In fact, the ProCam is expected to become AICON's (www.aicon.de) leading product for the next few years.

Outlook

One of the most promising of the niche applications has turned out to be the 3D-position detection of a new generation of intelligent sensors. For enhanced sound and vibration testing and reliable simulations, it is necessary to detect the position and orientation of those sensors with special accuracy. Current tools like rulers and tape measures are no longer accurate enough, but the second-generation ProCam is uniquely equipped for such a task.

A first demonstration in the ESTEC Test Centre quickly demonstrated the key advantages of the ProCam approach and the many benefits of its application in the field of sound and vibration testing, not least the significant reduction in instrumentation time. As the vibration testing of space hardware is almost a daily task at ESTEC, the ProCam promises considerable gains in efficiency and reliability, particularly during intensive testing periods involving large spacecraft and other sizable objects. This type of application could result in major worldwide market opportunities. esa

Benefits for our Daily Lives: The ESA Technology Transfer Programme (TTP)

Over the past 35 years, European space industry has gained considerable expertise in building, launching, controlling and communicating with satellites. From this long experience of how to overcome the hazards and problems created by such a hostile environment, many valuable new technologies, products and procedures have been developed.

In 1990, the European Space Agency launched a Technology Transfer Programme to provide space solutions for non-space markets, open new opportunities for the space industry and increase Europe's overall competitiveness on the global scene.

Objectives of the Technology Transfer Programme:

- Adapting space technologies for terrestrial applications leading to the improvement of our daily lives.
- Maximising ESA's return on investment in space research, thus benefiting ESA's Member States.
- Providing opportunities for researchers to collaborate with other organisations.
- Allowing the possibility for two-way transfer:
  - spin-off from space to non-space sectors, and
  - the natural spin-in of technologies developed in non-space sectors.

The TTP works in several ways:

- The ESA Technology Transfer Programme is carried out by a network of technology brokers across Europe and Canada. Their job is to identify technologies with potential for non-space applications on one side, and on the other side to detect the non-space technology needs. Subsequently they help exploit the technology and provide assistance in the transfer process.
- The TTP cooperates with National Agencies and with European Community Networks such as the Innovation Relay Centers (IRC's).
- ESA TTP's Partnership Concept: The TTP supports projects that adapt space technologies for non-space applications by providing funding, in partnership with others, for feasibility, prototype and pre-market studies.

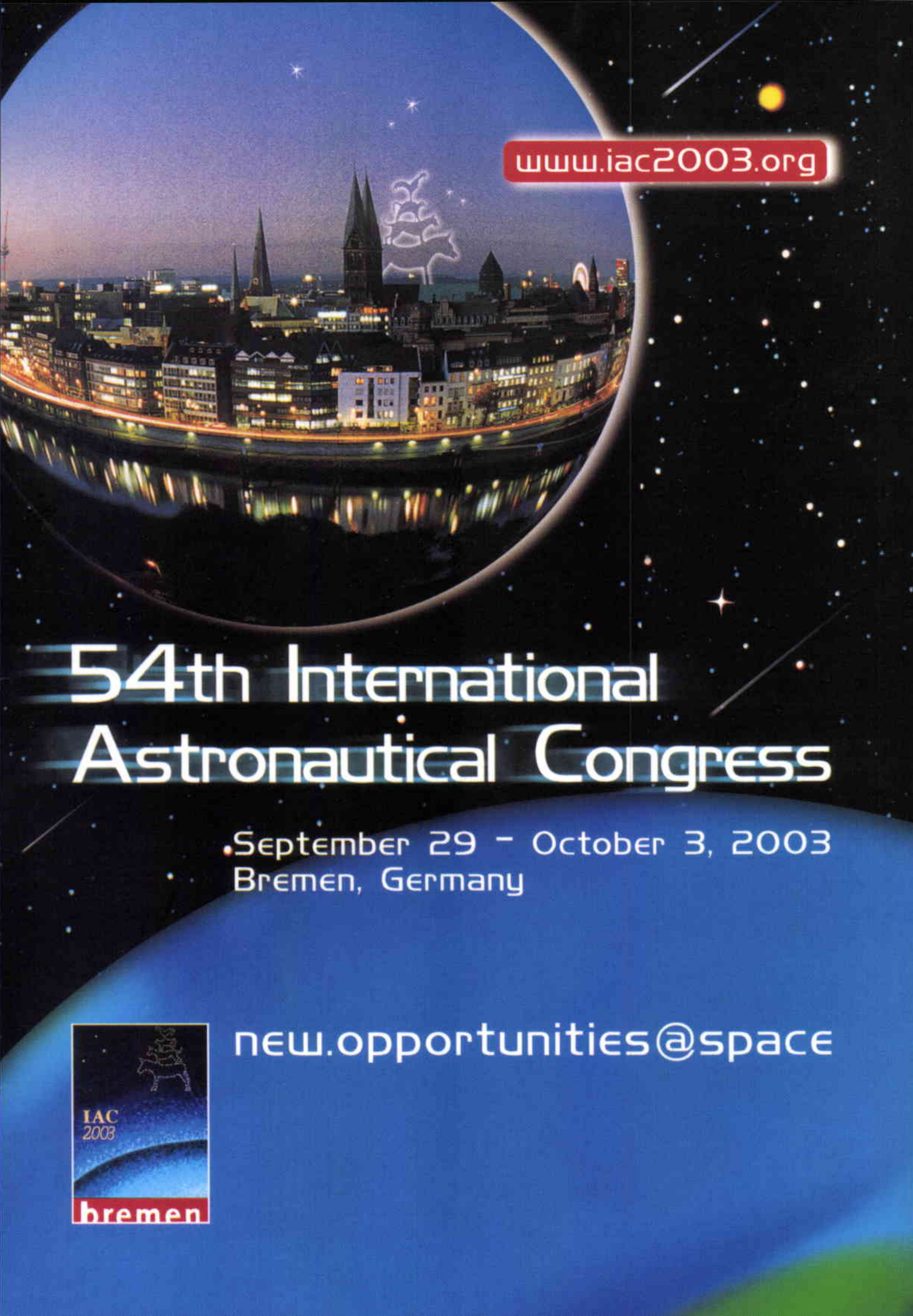
Results

The Programme has already achieved over 160 transfers or spin-offs from space to non-space sectors. This success is reflected by the fact that, since the start of the Programmme, technology transfer has generated more than 25 million Euros in turnover for European space companies and 300 million Euros for the non-space industries involved. By 2005, a turnover of more than 1 billion Euros is expected. Already 1500 jobs and 25 new companies have been created.

To learn more about ESA's Technology Transfer Programme, please contact:

Pierre Brisson
Head of the Technology Transfer and Promotion Office
ESA/ESTEC, PO Box 299
2200 AG Noordwijk, The Netherlands

Phone: +31 (0) 71 5655052
Fax: +31 (0) 71 5653854
E-mail: Pierre.Brisson@esa.int


www.iac2003.org
54th International
Astronautical Congress
September 29 - October 3, 2003
Bremen, Germany
new.opportunities@space
IAC
2003
bremen

Les lanceurs dans l'attente de la prochaine génération de satellites commerciaux...

Markus Bertschi
Direction Lanceurs, ESA, Paris

Michel Guyon
Journaliste indépendent, Paris

Après des années fastes, le marché des satellites commerciaux s'est brusquement contracté. Un processus aussi violent que logique, qui donne un caractère avant tout cyclique à cette crise, liée aux besoins du marché de la télévision. Reste à attendre la prochaine vague de renouvellement des équipements mis en orbite. C'est pour 2006...

C'est une première pour l'industrie spatiale. Plus qu'un ralentissement de l'activité, une espèce de trou noir, engloutissant les commandes en même temps que les espoirs. Le marché commercial des satellites s'est assoupi, entraînant dans son sommeil le marché des lanceurs. La crise était pourtant tout à fait prévisible, et ses prémices clairement identifiables, tout comme le réveil est d'ores et déjà programmé...

Pendant des années, marché commercial a rimé avec marché télécoms. Mais comme le rappelle Marc Giget, Fondateur et Président du cabinet de conseil Euroconsult, *« ça fait bien longtemps qu'il n'y a plus un coup de fil entre New York et Paris qui passe par satellite »*. Ce sont en fait les satellites de télévision qui constituent aujourd'hui l'essentiel du marché commercial. Pour comprendre la crise actuelle de ce secteur, et ses implications sur les lanceurs, il faut ainsi en chercher les racines dans les bouleversements intervenus au cours des vingt dernières années. On pourrait presque parler de 'Vingt Glorieuses', tant la période était à l'euphorie.

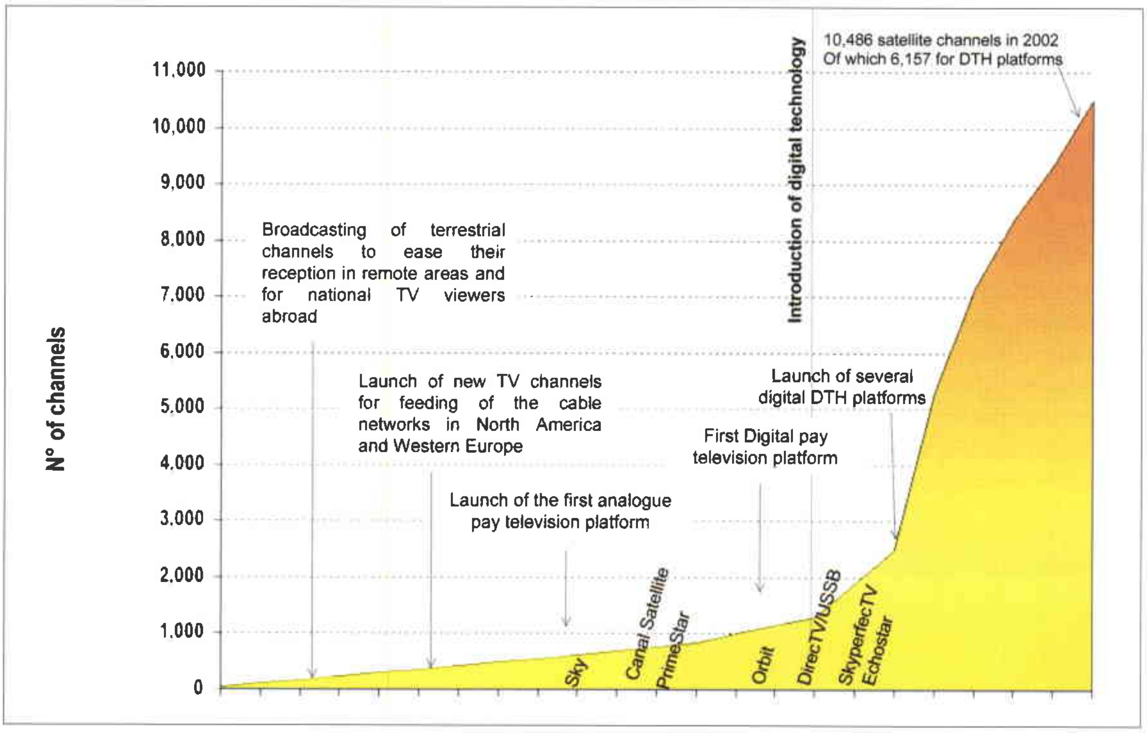
Le panorama international s'est en effet radicalement métamorphosé depuis les années 80. A l'époque, les marchés dans leur ensemble sont orientés à la hausse. La demande institutionnelle progresse à un rythme soutenu en Europe. Les budgets des agences ne cessent d'augmenter, celui de l'ESA se voit par exemple multiplié par trois en l'espace de 10 ans, de 1982 à 1992. Les matériels scientifiques se renouvellent à une cadence élevée. Même chose pour l'observation météo. On assiste même à l'émergence d'un marché militaire non négligeable, une nouveauté en Europe. C'est alors que, venant parfaire ce tableau, le secteur commercial va connaître son premier envol. Derrière ce succès se profilent en fait des marchés finaux très variés, qui annoncent la révolution de l'information à venir. L'un de ces créneaux est occupé par les télécommunications proprement dites - téléphone mais aussi transfert de données par fax et par Internet, un réseau alors naissant, passant par les lignes téléphoniques, à bas débit. L'autre grand acteur de ce boom commercial est la télévision, qui prend soudain une nouvelle dimension, les chaînes passant désormais par le satellite pour être directement servies à l'utilisateur, à domicile. C'est l'explosion du concept dit DTH, autrement dit, le 'Direct to Home' et ses millions de mini paraboles qui fleurissent aux balcons un peu partout dans le monde. Un débouché qui allait bientôt représenter l'essentiel du marché des satellites. *« C'est bien simple, relève Marc Giget, au milieu des années 80, quand Ariane-4 décolle, huit vols sur dix sont alors dédiés à des satellites de télécommunications »*. Des engins encore mixtes à l'époque, servant aussi bien aux réseaux de télévision qu'à la téléphonie.

Mais une autre révolution attend l'industrie du petit écran: la compression numérique, qui débarque au milieu des années 90. Une technologie qui va fortement influer sur le domaine spatial. Et pour cause: au lieu de faire passer une seule chaîne par canal, on va pouvoir en faire passer 12. D'où la naissance des bouquets numériques, les plateformes DTH. Aux pionniers comme BSkyB et Canalsatellite allaient très vite s'ajouter de nouveaux acteurs. DirecTV, Echostar, TPS ou encore SkyPerfecTV... ils seront rapidement plus d'une cinquantaine dans le monde à occuper et se disputer le créneau. Autant de distributeurs qui ont profité de la compression numérique pour créer des centaines de chaînes de télé, diffusables à grande échelle et à un coût marginal. Résultat: sur les six dernières années, on est passé de quelque 800 chaînes dans le monde à plus de 10 000...

Ce phénomène est d'autant mieux accueilli dans l'industrie spatiale que les budgets publics, qui avaient soutenu l'activité tout au long des années 80, connaissent alors un important ralentissement. La forte croissance de la télévision va ainsi venir combler un vide et compenser l'essoufflement du marché institutionnel. Les besoins des fournisseurs DTH sont à l'image des engins mis en orbite, certains occupant un quart de satellite, d'autres - les plus gros clients - utilisant jusqu'à quatre ou cinq satellites. Des satellites toujours plus puissants, toujours plus imposants, toujours plus lourds, capables d'envoyer 450 chaînes de télé à la fois ! Un marché haut de gamme, taillé sur mesure pour Ariane.

On en est aujourd'hui à la deuxième génération de satellites DTH. A la différence de leurs prédécesseurs qui arrosaient la France (avec Telecom-2) ou l'Allemagne (avec DFF), les satellites 'Hot Bird', comme on les appelle, beaucoup plus puissants, couvrent l'ensemble de l'Europe, et même le Moyen-Orient et l'Afrique. Le tout, avec un seul satellite, en alimentant plusieurs centaines de canaux à la fois. Résultat, *« un satellite lancé en 2002 a une capacité de diffusion équivalente à celle de 187 satellites lancés 10 ans plus tôt »*, indique Marc Giget.

La situation qui prévaut à la fin des années 90 incite pour le moins à l'optimisme. Les commandes affluent, les investissements sont massifs, la production s'accélère. Arianespace capte plus de la moitié du marché des lancements, lui-même alimenté à hauteur de 20 à 25% par des constructeurs de satellites européens. Alcatel Space, Astrium et Alenia AeroSpazio parviendront même à doubler leur part de marché au plus fort de la croissance, en l'an 2000, quand un total de 42 satellites seront vendus (le record absolu est de 45, atteint en 1995). Les quatre plus gros opérateurs mondiaux (GE Americom, SES, Intelsat, Inmarsat) ont ainsi renouvelé leur flotte avec des satellites made in Europe. Dans un tel contexte, qui aurait pu prédire la crise à venir? *« Le marché lui-même, alors intrinsèquement porteur d'un ralentissement, au mieux »*, note Marc Giget, graphiques à l'appui : *« Dans notre étude de 2000, on s'est rendu compte qu'on allait passer d'une moyenne de 25 satellites par an à lancer en GTO à une petite quinzaine seulement, et ce, pendant deux ou trois ans. On a fait des modèles de demande, en analysant plus de 9000 chaînes de télé. Or, on voyait que la demande commençait à s'infléchir et que dans le même temps, les commandes et les perspectives de capacités montaient très fortement. On voyait ce gap se créer. Dès lors, on savait qu'il faudrait se résoudre à atterrir, tôt ou tard »*.



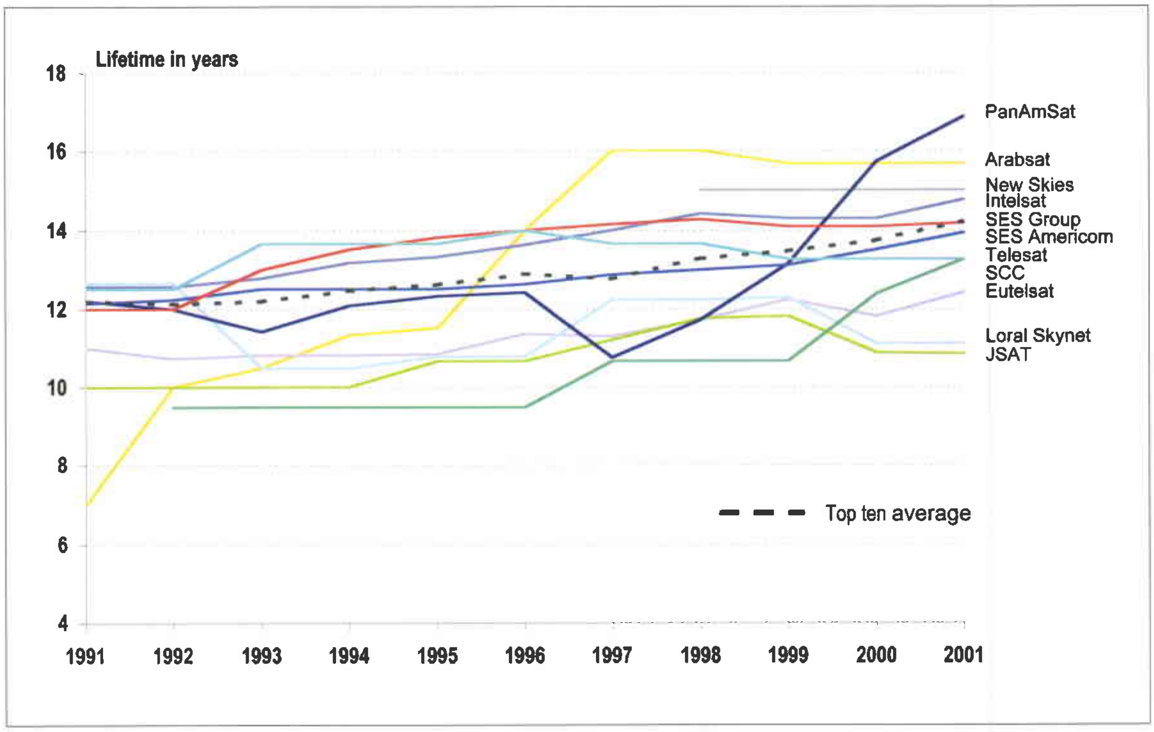
Chronologie des chaînes de télévision sur satellite 1980 - 2002 (Source : Euroconsult)

Un secteur réputé 'artisanal' allait bientôt découvrir qu'il était un secteur industriel comme les autres. Concernant les télécommunications et la télévision, les satellites procèdent en effet, en quelque sorte, du bien d'équipement. Un domaine qui, suite à l'installation initiale, implique différentes étapes, l'une d'elle étant l'utilisation effective du matériel, doté d'une durée de vie impartie, en l'occurrence, une quinzaine d'années pour les plus performants. *« La crise est donc loin d'être structurelle, elle est simplement cyclique »*, précise le spécialiste d'Euroconsult, comparant le domaine des satellites avec d'autres secteurs, celui des centraux téléphoniques, des avions, ou mieux, celui des ordinateurs, dont le parc doit, suivant la même logique, être également renouvelé à intervalles réguliers. Entre deux générations, il y a automatiquement une période de creux, que constructeurs et fournisseurs doivent gérer au mieux, à défaut d'avoir pu l'anticiper.

Pour les satellites, la tâche est d'autant plus rude que d'autres marchés, censés prendre la relève, allaient au bout du compte faire défaut. Le jeu de balance sectorielle observée dans les années 90 ne se produira pas cette fois-ci. En 2001-2002, les budgets publics, toujours en crise, n'ont pas la capacité de combler le vide laissé par les satellites DTH, pas plus que les constellations en LEO, dont la faillite - partielle - a signé la fin d'un mythe, *« quand certains annonçaient le lancement de centaines de satellites, quasiment à la chaîne, faisant penser qu'on allait les produire comme on construit des voitures... »*, rappelle Marc Giget. Dans le même temps, les applications broadband sont loin d'avoir tenu toutes leurs promesses. Pour preuve : pas moins d'une quinzaine de fournisseurs d'accès Internet haut débit ont fait faillite. Un constat plutôt sombre, auquel se sont greffées les difficultés rencontrées par les grandes compagnies de télécoms et de médias.

De quoi déprimer encore un peu plus le marché des satellites, et par contrecoup, celui des lanceurs. Avec une logique implacable: les commandes de satellites arrivent deux ans en moyenne avant qu'ils soient fabriqués et environ trois ans avant qu'ils soient lancés. Les constructeurs ont donc été les premiers touchés, avant que la vague ne touche l'industrie des lanceurs. La conjoncture s'étant retournée, certains opérateurs se sont retrouvés dans l'incapacité de lancer leurs satellites. Une dizaine d'engins sont ainsi stockés en attendant de trouver preneur ! Analyse de Marc Giget: *« La crise est arrivée au moment où les principaux opérateurs sont devenus privés. Du coup, les investisseurs ont refusé d'avaliser le lancement de satellites 'vides', autrement dit, sans que les capacités ne soient vendus au préalable. A une certaine époque, au temps des monopoles, Intelsat pouvait se permettre de fonctionner avec 40% de surcapacité pendant cinq ans. On lançait alors des satellites qui se remplissaient petit à petit. Personne ne miserait sur une telle logique aujourd'hui »*.

Les surcapacités ne sont pas forcément un handicap. Limitées, elles peuvent même constituer un atout, soit pour trouver de nouveaux clients, soit pour servir de back-up, en cas de panne d'un autre satellite. Ces surcapacités sont en général de l'odre de 20%. Aujourd'hui, mis à part l'Asie qui enregistre des surcapacités avoisinant les 30%, on est à 10% sur l'Europe et les Etats-Unis. *« On a annulé les surcapacités avant même qu'elles n'existent. Parce que les opérateurs ont dit 'Je ne lance pas', quitte à annuler une commande »*, selon Marc Giget. L'avantage? Le marché est très



Durée de vie moyenne des flottes de satellite (Source : Euroconsult) sain. Une base solide dans la perspective d'une reprise. Car reprise il y aura. On sait quand les satellites ont été lancés. On sait donc quand il faudra les renouveler, aux alentours de 2006 pour les premiers d'entre eux, placés en orbite au milieu des années 90. D'après les estimations d'Euroconsult, entre autres, ce sont ainsi plus de 180 satellites qui seront à remplacer en 7 ans, soit un fond de marché de 20 à 25 satellites par an. A l'opposé de la situation actuelle, diverses projections font même apparaître une situation de cycle très haut dans la deuxième partie de la décennie, avec, sans doute, de nouveaux projets de mobiles et multimedia, mis en œuvre dans un contexte plus favorable. Sans oublier de vastes entreprises comme Galileo, dont le déploiement pourrait encore booster la reprise.

Sans le remettre en question, il n'en demeure pas moins plusieurs éléments d'incertitude susceptibles de chahuter quelque peu ce scénario prometteur. La durée de vie effective des satellites notamment. A la différence de certains satellites américains (comme la série 702 de Boeing, par exemple), dont les problèmes de fiabilité mettent en péril la durée de vie programmée, la plupart des satellites actuellement en orbite tournent rond. A l'image de nombreux engins scientifiques, les satellites commerciaux pourraient s'avérer plus résistants que prévu. Et durer plus longtemps. Il ne serait donc plus aussi urgent de procéder à leur renouvellement... Sans compter que certaines plateformes DTH, par manques d'abonnés, ne parviennent pas à amortir leurs bouquets, alors que les droits de diffusion ne cessent d'augmenter dans le même temps, comme on le voit pour la diffusion des championnants de football notamment, de l'Italie à la France.

Reste par ailleurs à savoir comment va s'articuler le marché des satellites commerciaux dans les prochaines années. Outre la fusion probable de certains bouquets DTH, on pourrait assister à une concentration des opérateurs (sur le modèle du récent rapprochement entre SES et GE Americom), prélude à une rationnalisation des flottes. A moins qu'on se dirige vers un processus de régionalisation. De ce nouveau panorama en gestation dépendra également la taille et le nombre des futurs satellites. Ainsi que les besoins adaptés en lanceurs... esa

Cost Engineering for Cost-Effective Space Programmes

David Greves & Herve Joumier
Cost Analysis Division, ESA Directorate for Industrial Matters and Technology Programmes, ESTEC, Noordwijk, The Netherlands

The discipline of 'cost engineering' can be considered to encompass a wide range of cost-related aspects of engineering and programme management, but in particular cost estimating, cost analysis/cost assessment, design-to-cost, schedule analysis/planning and risk assessment. These are fundamental tasks which may be undertaken by different groups in different organizations, but the term cost engineering implies that they are undertaken throughout the project life-cycle by trained professionals utilising appropriate techniques, cost models, tools and databases in a rigorous way, and applying expert judgement with due regard to the specific circumstances of the activity and the information available. In most instances, the output of a cost engineering exercise is not an end in itself but rather an input to a decision making process.

What is Cost Engineering and Why is it Important?

No one who has responsibility for managing major, complex, high-tech programmes with a high development content will dispute the importance of the cost and financial aspects of the work, or the particular difficulty of assessing and controlling costs. Cost will be a constant source of concern, but will be particularly to the fore when considering different technical options, in conducting cost/technical trade-offs, in establishing budgets, in the submission and evaluation of price proposals, in preparing for contract negotiations, and in assessing the cost impact of introducing changes to existing designs. The question is how to tackle these aspects to be best able to predict or assess cost, how to minimise the risk and impact of overspends against budgets, and how to ensure that there is an appropriate balance between technical aspects and the related costs.

With these goals in mind, cost engineering essentially attempts to capture practical experience in a systematic way, to analyse that experience in order to develop tools and models which, together with expert judgement, can be applied under different circumstances to make predictions of likely cost or assessments of whether a proposed cost is reasonable. An assessment of the likely cost and risk is made taking account of past experience with similar activities and the assessment of associated trends, and of any changes in working practices and productivity gains.

But cost engineering extends beyond the estimation and assessment of cost, because these capabilities can also be applied to support the aim of achieving more cost-effective results. Awareness of the related cost is a key factor in the choice of approaches and design solutions, but traditionally the roles of establishing design solutions and of assessing the related costs have been separated both in time and responsibility. Typically, in the first instance the designer produces a design solution, which is then passed to other functions such as manufacturing and testing to add their inputs, and finally ends up with the estimator to calculate the cost of implementing this solution. Unfortunately, this is likely to be too late, as these exercises are often subject to time pressures that do not allow for a solution that is too expensive to be changed in a controlled way, which would normally require the design loop to be repeated.

The alternative offered by cost engineering is to have cost information available when design choices are being made, so that they will be made in the knowledge of approximately what the different potential solutions are likely to cost. This awareness of the likely cost is essential to be able to make effective cost/benefit trade-offs. In other circumstances where cost is a critical factor, this awareness of costs can be applied in a design-to-cost approach whereby the cost influence directly drives the choice of solution.

Cost engineering therefore embraces many facets of project management and engineering. The European Aerospace working group on Cost Engineering (EACE), in which ESA actively participates, has developed a Cost Engineering Capability Improvement Model (CECIM) in which 20 domains and more than 120 processes are identified which can be said to fall within the broad scope of cost engineering. Responsibility for these tasks varies from one organisation to another; in ESA responsibility for the schedule analysis/control and risk-assessment elements usually rests with the function within a project management team known as 'Project Control'.

Cost engineering is a discipline with relatively few full-time practitioners, who are to be found mainly in larger organisations. Therefore, cost-engineering groups and professional bodies like EACE - originally known as the ESA/Eurospace Working Group on Cost Engineering - are very important in helping to maintain the level

Cost-Estimating Methods

There are many different approaches and methods for estimating or assessing costs, all of which have advantages and disadvantages under particular circumstances. Factors determining the most appropriate method will include the nature of the activity to be costed or assessed, the degree of familiarity of the organisation with the item or activity to be costed, and the extent to which reference can be made to previous exercises, the availability of reliable design information and the time available to prepare the estimate. Other key aspects are the stage in the overall cycle at which the estimate is being made, the specific customer requirements in terms of presentation of cost details, and the degree of accuracy required. Usually several methods will be applied as a "sanity check" on means to verify that the results are valid. The most common approaches to estimating/cost assessment are:

- *"Rule of thumb" approach*
This approach is often used for the rough and rapid sizing of an activity in terms of cost. Its application is usually limited to very specific areas of activity and it implies expert judgement and close familiarity with that field of activity. It is not very sophisticated, but the rapidly available cost approximation may be sufficiently accurate in certain circumstances.

- *Detailed "grass-root" or "bottom-up" approach*
With this method, detailed estimates are made at relatively low levels in the work breakdown structure, typically at work-package or task level. This approach is closely related to scheduling, planning and resource allocation and is both time-consuming and costly. It requires a good knowledge of the activity and there also needs to be a reasonable level of definition for the exercise to be meaningful. Very often, and certainly in the case of ESA tender actions, such an approach has to be followed by bidders in order to be able to present the detailed costing information that the Agency requires. One potential problem, apart from the time and effort involved and the spurious accuracy implied by the process, is that the inclusion of contingencies for each element may well lead to an excessive amount of aggregate contingency, resulting in an unrealistically high estimate.

- *Analogy*
This commonly applied method essentially relies on being able to ascertain the cost of previous activities or items and using that as a reference for predicting the cost of a proposed new activity or item. It therefore depends on the accuracy of existing data, on being able to identify differences between the present and past activity or item, but also on taking due account of any observed cost trends and any changes in circumstances that might have a bearing on costs.

- *Competitive supplier proposals*
Where it is intended to subcontract an activity, committing subcontractor proposals submitted on a competitive basis are likely to be the most reliable estimate possible. However, customers should retain the ability to estimate and analyse the cost of work to be subcontracted, particularly when there is little or no real competition, or where there is the likelihood of subsequent customer-generated changes.

- *Parametric approach*
Parametric estimating entails the analysis of cost, programmatic and technical data to identify cost drivers and develop cost models. The approach essentially correlates cost and manpower information with parameters describing the item to be costed. This process results in sets of formulae known as "Cost-Estimation Relationships" (CERS), which are applied to produce cost outputs for different elements of an estimate. Parametric models may be developed by any organisation from analysis of its own data, but there are also external models available, some of which are marketed on a commercial basis. In the case of commercially developed models, it is important that they are calibrated by reference to specific data from the user organisation. Whilst there may be significant costs in developing such models or licensing commercial models, they have a number of advantages, particularly in that they allow estimates or assessments to be made fairly rapidly and at little cost.

of expertise and awareness of new tools and techniques. The ESA Cost Engineering team also has frequent and close contacts with NASA cost-engineering groups within the framework of an agreement on cooperation in cost-engineering practices.

Cost Engineering in ESA

In ESA there is a centralised Cost Engineering Section within the Cost Analysis Division, which forms part of the Agency's Directorate of Industrial Matters and Technology Programmes. This centralisation ensures that there is systematic gathering of cost, technical, programmatic and schedule information for all areas of activity according to a standard format. It also facilitates the development and application of methodologies and tools that would not be cost-effective for individual Directorates to do because of the relative infrequency of major procurement actions in each Directorate. Moreover, the fact of being involved in the full range of ESA domains permits a cross-fertilisation of experience.

A further feature is that the Cost Engineering Section is neutral, being hierarchically independent of the customer Directorates and therefore able to offer an independent assessment that is unbiased and objective, something which may not be possible for engineering/project staff closely associated with the activity. In any estimating or assessment exercise, the Section's sole motivation is to produce the fairest estimate possible based on the available information.

Over the last four years or so, the Cost Engineering Section has made significant changes in its working approach. One problem was that whilst previously the Section was fully involved in assessing the cost of proposals submitted by industry it was not getting involved sufficiently early in programme life-cycles and its tools and databases were not being fully exploited and were not contributing optimally to the effort of finding cost-effective solutions for the Agency's projects. A strategic decision was therefore taken to try to become more involved in projects in their formative stages. Fortuitously, this coincided with the setting of the Concurrent Design Facility (CDF) at

What Cost Engineering now does for its Users

- *Programme preparation*
Programme Directorates often enlist the services of Cost Engineering when putting numbers together in order to present the financial elements of a programme proposal to Programme Boards. This may involve coming forward with preliminary cost estimates when there may be few or no inputs from industry yet available. An example would be the early consideration of candidate projects for future Science missions.

- *ITT preparation*
The costing requirements expressed in ESA Invitations to Tender (ITTs) for major projects are quite standard in terms of the need to complete the Price Breakdown Forms (PSS-A forms) and to submit the financial proposal (ECOS files). There is also a standard format for expressing the costing requirements in early phases with respect to the format and content of the cost estimates that the Contractor is to produce.

- *Participation in TEBs*
Cost Engineering is systematically involved in the main procurement actions as Tender Evaluation Board (TEB) or Cost Panel members. The first responsibility when industrial financial proposals are received is to interpret them (using the ECOS files) in order to give Panel/TEB members the best possible understanding of the price as proposed by the bidder. In addition, a "should cost" analysis is usually prepared to support the assessment of the cost which has been proposed and to subsequently allow the ESA negotiation team to orientate its discussions with the selected or short-listed bidders. The Cost Engineering Section also works closely with the Industrial Cost Auditing Section with respect to determining the acceptability of the rates and overheads, profit rates and price-revision formulae proposed by tenderers.

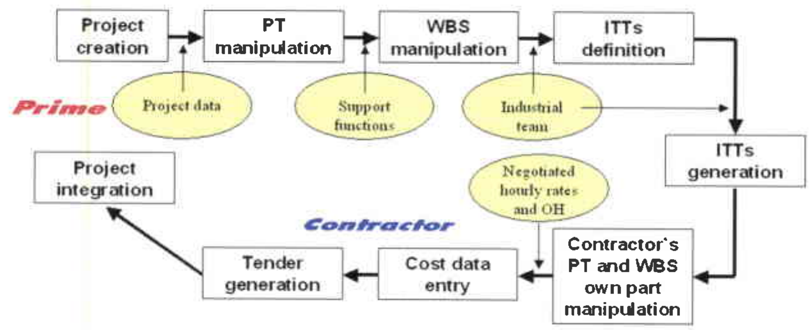
- *General support to Projects*
For the early phases of major projects, Cost Engineering has the capability to define and animate Design-to-Cost exercises in cooperation with the Contractor and the ESA Project Team. There is also the possibility to carry out an internal independent cost-estimating exercise involving the Project Team members, thus combining the benefits of cost-engineering tools and experience and the specific knowledge of those closest to the work. This may be then be used in support of decisions concerning the project, or to provide inputs in order to reinforce the Agency's negotiating position.

- *Participation in Reviews*
Cost Engineering is sometimes invited to participate in design reviews, especially when there are some deliverables related to cost estimates or where there are cost implications with solutions adopted. This usually involves providing independent assessment and analysis of the concepts proposed by the Contractor.

- *Participation in CDF activities*
Cost Engineering participates in CDF activities as a member of the core team. In some ways this is the most fulfilling role as it is very much proactive, permitting the cost engineer to make a real contribution to finding cost-effective design solutions.

ESTEC on a trial basis at the end of 1998, when Cost Engineering Section was invited to participate as part of the core team. This was a real step forward because, by being involved from the outset in each study, it became possible to participate in a pro-active manner, making timely cost/benefit analyses allowing the early identification and discarding of unaffordable solutions.

There are instances where the Section is requested to prepare completely independent cost estimates as an input to the Project team. However, in the same way as its involvement in the CDF, the Section has also been able to become more proactive in other programmes where it has worked together with project teams and their technical support, co-ordinating the preparation of an in-house estimate benefiting from the input of all available experience.



ECOS PROCESS FLOW

Tools of the Trade

The Cost Analysis Division is the custodian of the ESA PSS-A series of price-breakdown forms required in the submission to the Agency of all price proposals. The use of these forms ensures the breakdown of cost so as to give adequate visibility, but also a standard breakdown and presentation as regards the different categories and elements of cost. The Division has had developed software called ECOS (ESA Costing Software) that allows bidders to prepare and present their financial proposals in an efficient and rigorous manner. Both Industry and the Agency have a strong interest in using ECOS, because the complexity of the Industrial teams for major space programmes makes the calculation and aggregation of the financial contributions a difficult exercise. An important feature of ECOS is the computerised integration of data at successive levels of the contractual hierarchy, thereby avoiding the onerous task of manual integration of data from several sources, a task that is both time-consuming and error-prone.

ECOS also imposes a product-tree approach to the work breakdown, so that there is a uniform definition of the project's constituent systems, subsystems and equipment. A major advantage of this is that it ensures a degree of standardisation so that there is a consistent approach to cost/work breakdown not only through the contractual hierarchy on a particular project, but also between projects.

Several other space organizations, including the Italian Space Agency, also regularly use ECOS for their own purposes. One of the strong features of ECOS is the ability to compare normalised work-breakdown structures. For both ESA and Industry, it guarantees the ability to identify each activity properly through a checklist system, and it also provides the possibility to compare similar activities from one project to another.

To be effective and bring the right level of expertise to all of its activities, the Cost Engineering Section is constantly developing or acquiring the most extensive and pertinent set of cost models possible. The first step is to properly organise the accumulation of reference data, and this is done mainly using a cost/technical/ programmatic database called CEDRE (Cost Engineering Data Repository for Estimates). This database has some normalisation features that allow the data to be pre-processed, before being exploited in the development of cost models for the different applications. These cost models are then integrated into a cost-estimating software system such as RACE (Rapid Advanced Cost Estimate). This development allows the Section to produce cost estimates for a complete spacecraft, based on the mission requirements and payload definition, very rapidly, with a level of accuracy commensurate with the decision-making needs.

A lot of focus is placed on determining the value for money of proposed design concepts. There is therefore currently a broad action within ESA aiming at developing design-to-cost oriented models, with Cost Engineering working together with staff of the Directorate of Technical and Operational Support and other ESA Directorates. The Cost Engineering Section's participation in the CDF studies is also a major help in making progress in this area.

The cost-engineering tools used are not limited to internally developed cost models. The Section also makes extensive use of commercially available parametric packages such as PRICE, which includes a series of specialised cost models for hardware and software. These commercial parametric tools are sometimes very convenient for filling-in gaps in the more specialised set of internally developed models. Also, a number of models for specific activities and systems have been obtained free-of-charge as a result of ESA's cooperation in the development of those models.

The maintenance of a permanent state-of-the-art cost-engineering infrastructure also leads to the use of some integrated solutions, such as the Ace-It product. This tool, acquired under license, permits a number of different cost models to be managed in an integrated manner and also addresses the documentation and reporting needs.

The Accuracy of Cost Estimates and Cost Assessments

"It is the mark of an instructed mind to rest satisfied with the degree of precision which the nature of the subject admits and not to seek exactness when only an approximation of the truth is possible."

Aristotle

For any cost-estimating or cost-assessment exercise the achievable level of accuracy will be dependent on the level of understanding of the problem, the completeness and the correctness of the information relating to the cost-driving parameters, and the quality of the cost model itself.

The desirable level of accuracy is that which is sufficient to allow a correct decision-making process.

In many situations it will be sensible to give a range of projected costs from a "lowest" cost, to a "most likely" cost and a "highest" cost. This is known as a three-point estimate-with the width of the range or spread being indicative of the perceived degree of uncertainty as determined by a risk-assessment exercise.

Estimating the cost of project software is a great challenge. The difficulty in accurately predicting the size of software, the rapid evolution in languages and programming tools, the reuse of existing software modules and the inclusion of COTS (commercial off-the-shelf) products makes estimating software development costs really problematic. The Agency has therefore been striving for some years, with the help of the INSEAD business school, to establish reliable software development metrics for cost estimating and assessment purposes. INSEAD routinely gathers data on software projects not only in the space domain but also in other hi-tech sectors, and analyses it in order to produce predictive models.

Benefits of Cost Engineering for ESA and Industry

ESA and its industrial contractors have a mutual interest in practising and promoting cost-engineering in support of the goal of achieving cost-effective performance. Space projects tend to be inherently complex and costly, and so being able to control costs and to achieve cost-effective missions is extremely important for the Agency and its Member States who ultimately provide the funding. The industrial companies participating in the space programme also need to be able to properly assess costs and to achieve cost-effective solutions for their own financial health. If they fail to do so, they risk becoming uncompetitive in both institutional and commercial markets and unprofitable, either because they feel obliged to accept work on the basis of uneconomic prices in order to secure orders or because they have unwittingly underestimated the costs.

Therefore, in addition to endeavouring to consolidate and improve its own cost-engineering capabilities for its own purposes, ESA is also actively encouraging the development of the cost-engineering capabilities of its contractors. Apart from identifying cost-engineering principles and practices in its own Project Management Manual, in its support of the ECSS Management Standards, ESA's General Conditions of Tender for major projects will in future require not only the presentation of cost and pricing information in a certain format, but also the identification of the cost-estimating methods and tools applied by the contractor for the different elements. This should give both the contractor and ESA greater confidence in the costing details and make it easier for both parties to agree fair and reasonable prices.

Conclusion

Cost Engineering in ESA is established on a sound footing and is extending the scope and level of its activities with a rapidly increasing internal customer base. Whilst cost estimating and cost assessment remain fundamentally important activities, there is also a new focus on the added-value coming about as a consequence of earlier cost-engineering involvement in programme life-cycles. Its operations within the context of the CDF are a good model to illustrate its value and potential in this respect, namely working in a proactive way and making a major contribution to identifying affordable solutions to achieve programme objectives.

However, there are many other situations regularly encountered in the Agency's programmes where cost engineering is increasingly demonstrating its added value. It can be expected that in the future, with restricted budgets, with a changing industrial environment in which effective competition may not always be possible, and with an increasing momentum of technological development and programme complexity, the need for and benefits of effective cost-engineering services will become even more evident.

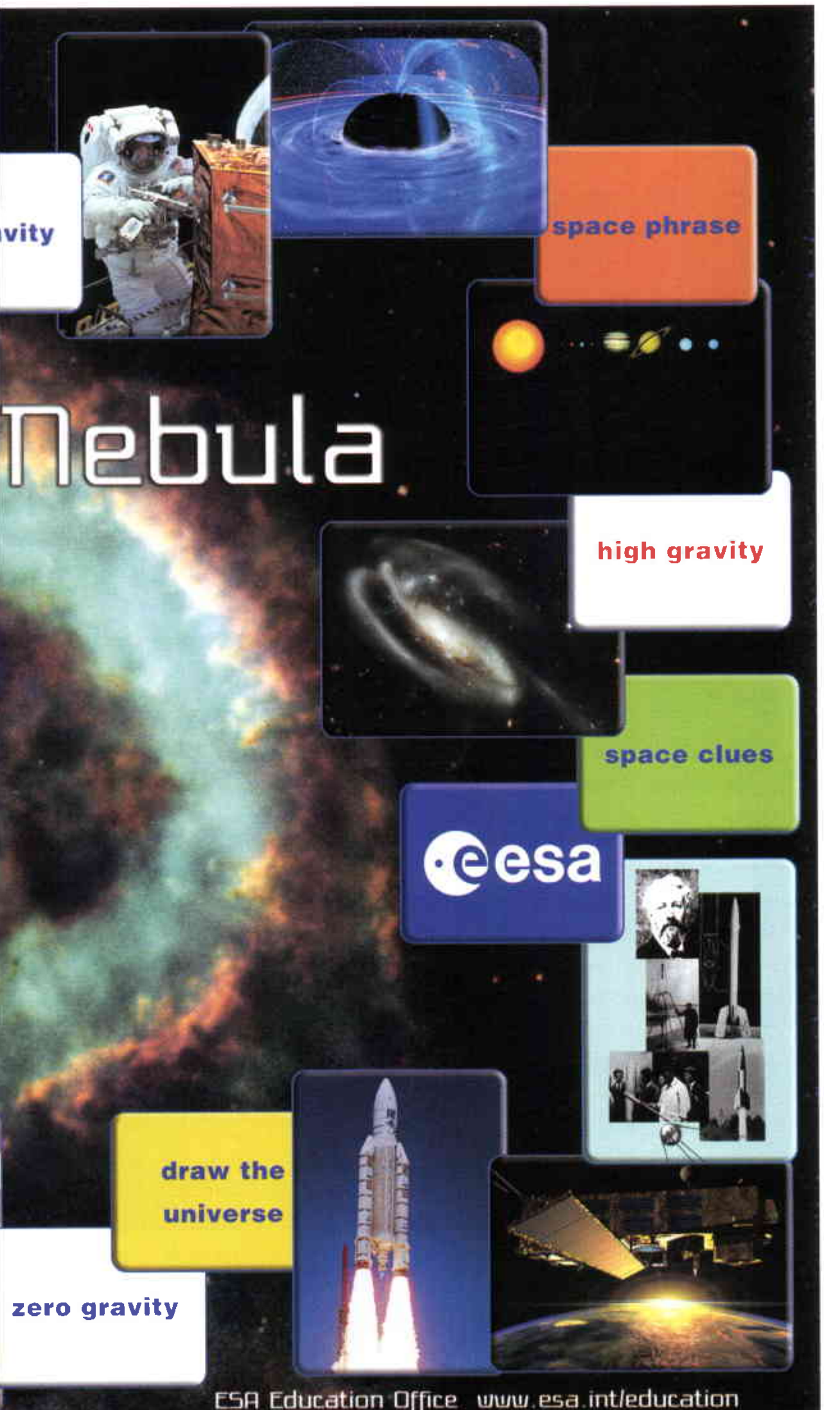
Having established a sound basis in organisational terms, with the changes in its working practices that have taken place over the last four years, the cost-engineering service is now in a good position to move forward, taking advantage of the rapidly developing software tools and consolidating its own experience in order to meet the challenges and opportunities that lie ahead. esa

ESA's Space

Isabelle Duvaux-Béchon
& Samuel Buisan-Sanz
Education Office,
Directorate of Administration,
ESA, Paris, France

The Board for the ESA Space Game

Board Game



Introduction

Education activities have always existed at ESA and the word 'education' even appears in the Agency's Convention. Until the mid-90s, however, most of the education activities at ESA were directed at university students, via training periods, fellowships and the Young Graduate Trainee (YGT) scheme. There were some activities aimed at younger children, but they were usually one-off activities or events.

Some years ago, it became evident that throughout ESA's Member States there was a steep decline in the interest of youngsters in science and technology and that there was a high risk that there would not be enough teachers, scientists or engineers in 10 or 20 years' time. This prompted the Agency to begin building a coordinated programme targeted not only at students, but also at children as young as six and their teachers (starting with the Physics On-Stage event in Geneva in 2000). The main rationale is to tap into the motivation and curiosity that children have at that age and hopefully steer some of them towards scientific studies and professions later in life.

One of the challenges that we are faced with in building a European space-education programme is that our Member States are very diverse, and their educational systems also, not to mention the problem of languages. There are 11 languages in use in today's 15 ESA Member States. Some countries have a national curriculum within a strong national education system, some a regional one, and it is very difficult to define products or activities that fit perfectly with all of these curricula. On the other hand, some concepts are universal and studied all over Europe and we are trying to benefit from that by identifying generic tools that teachers can easily adapt to their specific needs.

The Space Board Game presented here is a good example of such a tool. It is simple to use, adaptable to the needs and wishes of the teacher (way to play, duration, level of the questions), and it can be used as a complement to regular scientific or language classes. Teachers can also ask their pupils to enrich it by devising new questions.

The game is available from the ESA website (www.esa.int/education) to facilitate distribution and allow all those who have access to a computer and the Internet to download it free of charge. Most schools in Europe already have Internet access, or will have it very soon. New questions are prepared every month to maintain the children's interest and allow teachers to use the game several times. The game is available in English, French and Spanish in its first version, with German and Italian following. We are, of course, ready to incorporate new languages, where teachers or national bodies feel able to undertake the necessary translation.

The Principle

A comet, Saturn, the Moon, the Milky Way, Gagarin, Armstrong, Meteosat ... space always excites the curiosity. We are therefore trying to exploit this curiosity to encourage youngsters to find out more about space, not as a formal subject, but as a game, a game that can be played not only in school, but also at home and during the holidays.

Our first target group being teachers, the Space Board Game was developed by a teacher and tested with teachers. It is structured so that teachers can easily incorporate it into the school timetable and use it in different ways, and so that organisers of youth activities can also use it. Discussions with teachers at the ECIS (Berlin 2002), Teach Space (ESTEC 2003) and other educational events highlighted several possible scenarios for the game's use:

- as part of the study of subjects related to space, such as biology, geography and physics
- to assist in the teaching of foreign languages
- to build projects related to science, with the pupils developing their own questions
- at the end of the day when pupils become less attentive and can be re-motivated by a game
- whenever there is time left over
- during school side activities outside the classroom, e.g. Centres de loisirs in France.

The Home Page of the ESA Education Office on the Agency's web site

The important point is not that the pupils know how to answer all the questions, but that they remember the correct answers once the game is over, thereby learning about space and its importance in our everyday lives.

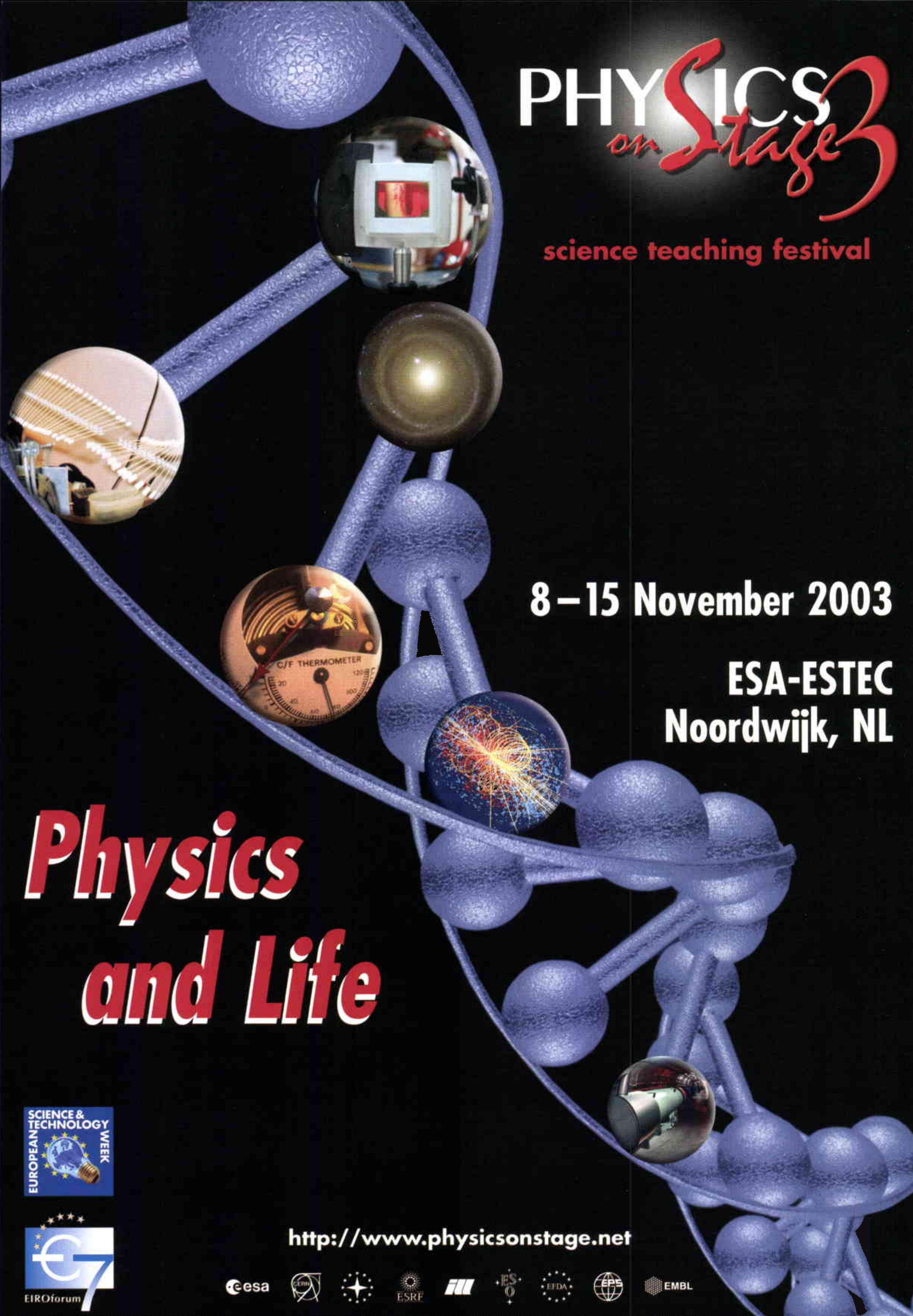
Teachers can also ask pupils to do some research into a specific subject in order to prepare for the game and attempt to answer the most difficult questions, even if they are relatively young. They can also be asked to prepare new questions on a specific topic for their fellow pupils and thereby enrich the game. Encouraging discussion and comments after each test or set of questions is also an essential part of achieving the objectives of the game.

It was conceived as a traditional board game, but with different sets of questions or problems depending on the square on which the counter falls. This can be answering a quiz-type question, making a drawing so that others in the team can guess the chosen word, or finding a word or subject by following a series of clues given by the teacher. Falling on special squares results in special actions, such as allowing you to move the counter of another team, blocking you on your current square, or sending you back to the start due to your counter falling on the 'Black Hole'!

The game started with 150 tests and questions directed primarily at 13 to 17 year olds, and it is being updated each month with 20 new questions and tests. Questions are graded according to three levels of difficulty, allowing teachers to select the easier ones so that primary level classes can also play the game. The board itself, which was designed by ESA Publications Division, is downloadable on two A4 sheets and suitable dice and counters are also suggested.

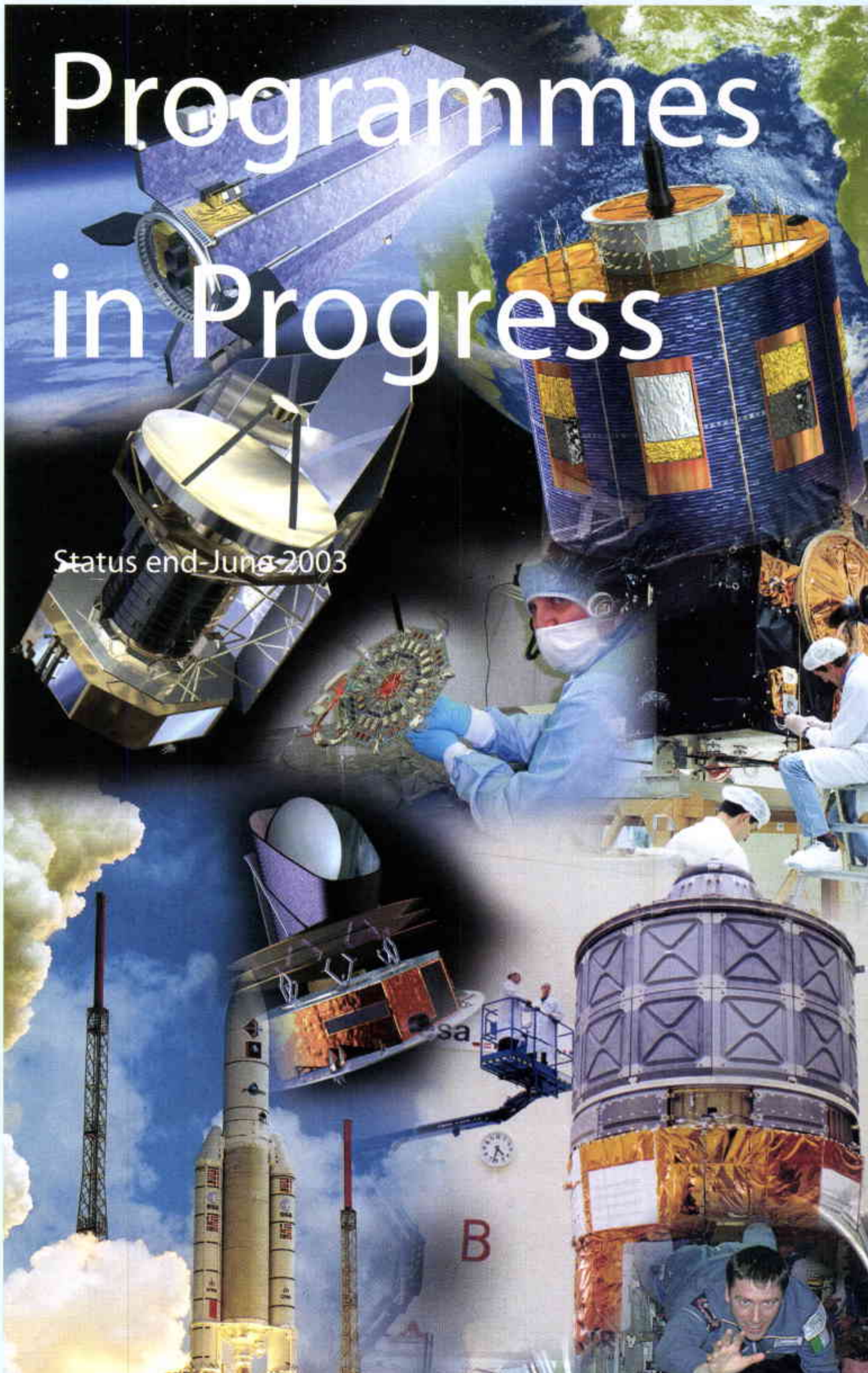
Our hope is that many schools will use ESA's Space Board Game regularly in their teaching, and that as a result pupils throughout Europe will become more aware of the immense possibilities of space and the benefits that it brings in our daily lives. We also hope that, as part of this learning process, ESA's work in general and the activities of its Education Office in particular will become much better known to the younger generation.

For any questions relating to ESA Education activities, please send an e-mail to education@esa.int, do not forget to make regular visits to the Education web site at www.esa.int/education to catch up on the latest news, and ***send us your own questions for incorporation into the game!***


PHYSICS on Stage 3
science teaching festival
C/F THERMOMETER
8 – 15 November 2003
ESA-ESTEC
Noordwijk, NL
Physics and Life
SCIENCE & TECHNOLOGY EUROPEAN WEEK
EIROforum
http://www.physicsonstage.net
esa
ESRF
ESO
EFDA
EPS
EMBL

Programmes in Progress

Status end-June 2003



In Orbit

	Project	Comments
SCIENTIFIC PROGRAMME	SPACE TELESCOPE	LAUNCHED APRIL1990
	ULYSSES	LAUNCHED OCTOBER 1990
	SOHO	LAUNCHED DECEMBER 1995
	HUYGENS	LAUNCHED OCTOBER 1997
	XMM-NEWTON	LAUNCHED DECEMBER 1999
	CLUSTER	RE-LAUNCHED MID 2000
	INTEGRAL	LAUNCHED OCTOBER 2002
APPLICATIONS/ TECHNOLOGY PROGRAMME	MARECS-B2	DEORBITED EARLY 2002
	METEOSAT-5 (MOP-2)	OPERATED BY EUMETSAT
	METEOSAT-6 (MOP-3)	OPERATED BY EUMETSAT
	METEOSAT-7 (MTP)	OPERATED BY EUMETSAT
	MSG-1	LAUNCHED AUGUST 2002
	ERS-2	LAUNCHED APRIL 1995
	ENVISAT 1/ POLAR PLATFORM	LAUNCHED MARCH 2002
	ECS-4	REMOVED FROM ORBIT DEC. 2002
	ARTEMIS	LAUNCHED JULY 2001
	PROBA	LAUNCHED OCTOBER 2001

Under Development

	Project		Comments
SCIENTIFIC PROGRAMME	ROSETTA		LAUNCH FEBRUARY 2004
	MARS EXPRESS		LAUNCH JUNE 2003
	VENUS EXPRESS		LAUNCH NOVEMBER 2005
	SMART-1		LAUNCH AUGUST 2003
	HERSCHEL/PLANCK		LAUNCH FEBRUARY 2007
	EDDINGTON		LAUNCH EARLY 2008
	DOUBLE STAR	DSP-E	LAUNCH DECEMBER 2003
		DSP-P	LAUNCH JUNE 2004
COMMS./ NAV. PROG.	GNSS-1/EGNOS		OPERATIONS START 2004
	GALILEOSAT		FIRST LAUNCH 2005
EARTH OBS. PROG.	EOPP		
	EOEP/CRYOSAT/GOCE/ SMOS/ADM-AEOLUS	CRYOSAT, GOCE, SMOS, AEOLUS	CRYOSAT SEPT. 2004/ GOCE FEB.2006 SMOS FEB. 2007/ADM-AEOLUS OCT. 2007
	METOP-2		LAUNCH OCT. – DEC. 2005
	MSG-2/3		LAUNCH MSG-2 JAN. 2005 LAUNCH MSG-3 2008
HUMAN SPACEFLIGHT PROGRAMME	COLUMBUS		LAUNCH OCTOBER 2004 (UNDER REVIEW)
	ATV		FIRST LAUNCH SEPT. 2004
	NODE-2 & -3		LAUNCHES FEBRUARY 2004 (UNDER REVIEW)
	CUPOLA		LAUNCH JANUARY 2008 (UNDER REVIEW)
	ERA		LAUNCH UNDER REVIEW
	DMS (R)		LAUNCHED JULY 2000
	MELFI		LAUNCH UNDER REVIEW
	GLOVEBOX		LAUNCHED MAY 2002
	HEXAPOD		LAUNCH JUNE 2008 (UNDER REVIEW)
	EMIR/ELIPS	FLUIDPACK/ BIOPAN; APCF-6/BIOBOX-5/ ARMS/BIOPACK/ FAST-2/ERISTO; MATROSHKA; EMCS; PCDF/EXPOSE – MAXUS-6; MARES/PEMS	
	MFC	MSL	BIO, FSL, EPM, with COLUMBUS
LAUNCHER PROGRAMME	ARIANE-5 DEVELOP.		OPERATIONAL
	ARIANE-5 PLUS		QUALIF. LAUNCHES UNDER REVIEW
	VEGA		FIRST LAUNCH JULY 2006

DEFINITION PHASE — MAIN DEVELOPMENT PHASE — LAUNCH/READY FOR LAUNCH

OPERATIONS — ADDITIONAL LIFE POSSIBLE — RETRIEVAL — STORAGE

ISO

Version 6 of the ISO Data Archive was released in July. This upgrades the functionality associated with, and visibility of the Highly Processed Data Products (data reduced systematically 'by hand'), and allows for the continuous ingestion of ISO catalogues and atlases from the community. Projects focussed on reducing data from selected observing modes are also underway.

ISO continues to have a significant presence in the refereed literature, with more than one thousand articles drawing upon ISO data, and covering almost all areas of astronomy, having appeared since late 1996! A press release was issued to mark this milestone.

The Proceedings of the symposium 'Exploiting the ISO Data Archive – Infrared Astronomy in the Internet Age' have been published (ESA SP-511) by ESA Publications Division, and the Proceedings of the conference 'The Calibration Legacy of the ISO Mission' are in press (ESA SP-481). The Legacy version of the 5-volume ISO Handbook is also being finalised by ESA Publications Division.

Ulysses

Ulysses mission operations continue to run smoothly, with the spacecraft and all scientific instruments in good health. On 1 August, Ulysses was 5 AU (750 million km) from the Sun, 11° north of the solar equator, on its way to aphelion at Jupiter's orbit. An autonomous switchover from the prime to the redundant Travelling Wave Tube Amplifier (TWTA) and Power Conditioning units (EPC) occurred on 15 February. A commanded switchback to the prime units on 6 March was unsuccessful. The redundant EPC/TWTA units are operating nominally, and no further attempts will be made to switch back to the prime units for the time being. A failure of the prime travelling wave tube is considered possible, since it has been in continuous operation for 12 years. The investigation into the anomaly is still in progress.

A possible extension of spacecraft operations beyond the current end-of-mission date (September 2004) was discussed by the ESA Solar System Working Group (SSWG) at its meeting in April, and was presented to the NASA Sun-Earth Connections (SEC) Senior Review in June. The prime motivation for continuing the mission is to follow the evolution of the Sun and heliosphere in the aftermath of the magnetic polarity reversal that occurred in connection with the recent solar maximum. If approved, the extended mission would include high-latitude passes in 2007 and 2008. Both the SSWG and the Senior Review panel recognised the scientific importance of continued Ulysses observations.

The scientific productivity of Ulysses remains high, with collections of papers appearing in three special issues of scientific journals during 2003.

Integral

Integral continues to operate smoothly, performing observations on behalf of the astronomical community and guaranteed-time holders. 93% of the available time is allocated for scientific observations, with the remainder being used for spacecraft manoeuvres and maintenance activities. With this good overall efficiency, all available high-priority targets should be observed by the end of 2003, as planned. The Integral Science Operations Centre (SOC) at ESTEC is busy preparing the Announcement of Opportunity to the scientific community for proposals to cover the second year's observing programme.

A shortage of telemetry had been a concern since launch, but the situation is now much improved after a software patch uploaded in May increased the telemetry rate by 25%. At the same time, the necessary improvements in the ground segment were introduced to cope with the increased telemetry rate.

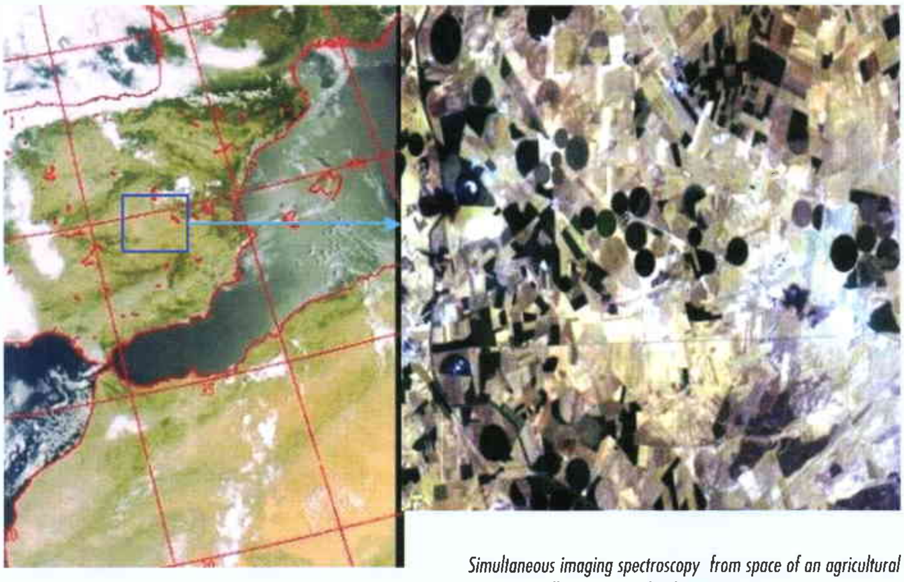
Integral passed a major milestone when the Mission Performance Verification Review was successfully completed: *"The Board concluded that the Integral spacecraft, instruments, and ground segment are all performing extremely well, and that there are no major open issues"*. The Board did not find any reason *"to doubt that Integral would be able to carry out its foreseen 5-year mission (2 year nominal and 3 year extended) and that further extensions might be possible."*

The Integral Science Data Centre (ISDC) is routinely sending data and processed science products to observers. In addition, the ISDC has released the Off-line Science Analysis software to allow observers to perform more detailed analysis of their data at their home institutes. On 1 May, a gamma-ray burst (GRB030501) was detected in the field of view of Integral's gamma-ray imager by the automatic software running at the ISDC, and an alert was sent to the astronomical community giving the burst's position to within 4 arcmin (about 1/10th the diameter of the full Moon) just 30 seconds after the burst started.

A special issue of Astronomy & Astrophysics later this year will provide detailed descriptions of the instrument performances and calibration and the first scientific results from the early mission phase. One of the highlights is the clear detection by the gamma-ray spectrometer (SPI) of line emission from radioactive aluminium (^{26}Al) after only a few months of operation. This gamma-ray line reveals where new atoms have recently been created by supernovae – the huge explosions signalling the end of massive stars. The clear detection of this line so early in the mission opens up the exciting possibility of making more detailed studies of this and other gamma-ray lines using Integral.

PROBA

The PROBA spacecraft has continued to perform well. This has allowed the planned Earth-observation science programme to be pursued and more complete exploitation of the data products delivered by the CHRIS instrument on board PROBA. The installation of the receiving equipment at ESA's Kiruna station in Sweden has been completed and it now routinely receives CHRIS data, which are then fed into the processing chain to generate added-value products.



Simultaneous imaging spectroscopy from space of an agricultural area near Albacete, Spain by the MERIS instrument on Envisat with 300 m spatial resolution (left) and the CHRIS instrument on PROBA with 20 m spatial resolution (right)

The EO science programme has been augmented with a dedicated field experiment in support of the SPECTRA Phase-A. Successful image acquisitions were made over the Barrax test site near Albacete, Spain, on three consecutive days in July. An extensive field measurement campaign involving 10 different European institutions and some 40 scientists, and including soil, vegetation and atmospheric measurements, was carried out in parallel with the CHRIS acquisitions

The performance of the CHRIS instrument in particular, and of the PROBA platform as a whole, indicate that further exploitation of the platform and EO instruments is desirable, and the necessary funding is therefore being actively sought.

SMART-1

In the early months of the year, the SMART-1 flight model successfully completed all of its system tests. The Mission Flight Acceptance Review (MFAR) Board, meeting on 8 July, confirmed the spacecraft's readiness for air shipment to the Kourou (Fr. Guiana) launch site, which will take place on 15 July. The launch campaign itself has already been prepared in detail, and all of the main spacecraft preparation activities will be completed before the end of July. The spacecraft will then be handed over to Arianespace for the combined operations. The MFAR also confirmed the flight-readiness of the payload, so that everything is now in place to start the launch campaign.

Preparation of the Mission Operations Centre (MOC) at ESOC and the Science and Technology Operations Co-ordination (STOC) at ESTEC is proceeding on schedule. The Ground Segment Readiness Review for the STOC has been successfully completed, and the MFAR confirmed the overall readiness of the SMART-1 Ground Segment.

The Final Mission Analysis Review took place on 25 June at Arianespace in Evry. No technical issues remain unresolved concerning either the launcher interfaces or the launcher itself, but a few minor issues need to be formally closed out at the Launch Readiness Review on 11 July. Launch preparations are on schedule for the Ariane-5 vehicle (V162) carrying its triple cargo of Insat-3E, e-Bird and SMART-1 to lift off on 28 August at 23:04 GMT.

Placing of SMART-1 into its transport container for shipment to Kourou

Herschel/Planck/ Eddington

The Herschel/Planck development effort is proceeding at a good pace, with the detailed design of the components for the two spacecraft fully underway. Some critical hardware elements are already being manufactured, including the helium tanks and the vacuum vessel for the Herschel cryostat, the cryogenic radiator baffle for the Planck payload module, and a number of other components that need to be ready early next year in time for the first integration activities. Similarly, the activities associated with the software definition for the two spacecraft are progressing and being used as inputs for the definition of the spacecraft operations. All of these activities are being consolidated at spacecraft level, and form the inputs for the next major overall technical review in the life of the project, namely the Critical Design Review (CDR) to be held in spring 2004.

Good progress has been achieved in the preparation and manufacture of the very specialised facilities needed to validate the performance of Herschel and Planck under cryogenic conditions, in particular the Belgian facilities for the optical testing of the Planck reflectors and the 3.5 m Herschel telescope at ultra-low cryogenic temperatures. Another special facility, the Cryogenic Vibration Facility, has already been used to vibration test an early model of the Herschel PACS instrument's cryogenic optical unit.

Progress is also being made on the scientific instruments themselves, with the instrument teams building and integrating elements of the qualification models of the focal-plane units. However, uncertainties in the funding status of the instrument consortia in some countries are affecting the activities and impacting completion of the instrument activities and unit deliveries. Activities are focussed on solving short-term problems, but the tight funding situation is expected to continue.

For the new Eddington mission that is now part of the programme, two parallel definition studies were started in April (at Alcatel Space and Astrium GmbH) and the first major results will be presented in September. Another contract has been placed with the British company E2V for the development of the CCDs for the Eddington instrument. In parallel, ESA has formally exercised a contractual option with Alcatel for the delivery of a recurrent Herschel spacecraft bus for Eddington.

Mars Express

Two Antonov heavy-lift cargo aircraft left Toulouse (F) airport on 19 and 21 March carrying 48 tonnes of equipment for the launch campaign in Baikonur, Kazakhstan, including the Mars Express spacecraft and Beagle-2. Their departure was preceded by the Flight Acceptance Review, which gave the green light for transport to the launch site.

The preparations at Baikonur went very smoothly and no problems were encountered during the 12-week-long campaign. This allowed the launch to be moved forward by a few days to 2 June. The Soyuz/Fregat launch vehicle blasted off at 23:45 local time, injecting the spacecraft onto a perfect departure trajectory to Mars.

The spacecraft has since been checked out and the near-Earth phase of the scientific-instrument commissioning has been successfully completed. Whilst these activities are coming to an end, the preparations for Mars arrival will soon commence with simulation and training sessions.

Venus Express

The Venus Express project has seen two major reviews: the Mission Preliminary Design Review was successfully completed in March and more recently the Intermediate Design Review for the Ground Segment has been successfully concluded. The contract for provision of the launch services has been signed with Starsem, which means that Venus Express will be launched on a Soyuz/Fregat vehicle from Baikonur, like Mars Express. The launch window will open on 26 October 2005.

The spacecraft mechanical structure is now ready at Contraves in Zurich (CH) and is awaiting transportation to Astrium Ltd. for integration of the propulsion system. In terms of electrical testing, the transfer of the electrical test bench from Mars Express to Venus Express is nearly complete. Integration of the first engineering models of the scientific instruments has started.

Mars Express during its pre-launch integration in Baikonur

Rosetta

At its May 2003 meeting, the ESA Science Programme Committee decided on the new Rosetta baseline mission. This will be to comet Churyumov-Gerasimenko, with a launch by an Ariane-5 G+ in February 2004. The scientific community has confirmed that this comet is as interesting scientifically as Wirtanen and various observation campaigns to better characterise it have already commenced. Back-up scenarios, including a launch to the same comet one year later using a more powerful launch vehicle (Ariane-5 ECA or Proton), will continue to be studied.

The flight-model spacecraft will remain in Kourou until the start of the new launch campaign at the end of October. The fuel has been off-loaded from the spacecraft but, due to concerns about stress corrosion cracking, the oxidizer has been left in the tank. Minor payload refurbishments are taking place and the final version of the flight software will be tested during the summer.

The engineering qualification model is still being used at ESOC to validate flight procedures, and is also serving as a test bed for the latest, more robust flight software.

All other new mission-preparation activities have been defined and are on schedule.

Double Star

All European payload elements for DSP-E, the equatorial satellite, had been readied for acceptance and delivery to Beijing by mid-May as planned. The sudden outbreak of SARS in April, however, posed a significant threat to the Double Star Project. Planned preparatory meetings were quickly replaced by video-conferences, but acceptance and interactive tests requiring interactive working by both parties became impossible due to the severe travel constraints.

A recovery plan was established and detailed test support was provided through remote data transfer, web cams and interactive messaging dialogues with European teams working especially early in the mornings. This allowed all pre-launch activities to be completed very successfully and both the payload and the CSSAR subsystems were delivered to Beijing by 10 July for integration into the spacecraft.

The 6th CNSA-ESA Coordination meeting held in Paris from 15 to 18 July confirmed the December 2003 launch date target for DSP-E. The spacecraft environmental test programme has been adjusted to compensate as much as possible for the SARS-induced delay. The Ground Segment Implementation Review was also successfully held in Paris, and the delayed installation of Chinese equipment at ESA's Villafranca ground station has been successfully completed.

After the current spacecraft functional system testing, DSP-E will begin its environmental test programme in August with the thermal testing. The launch campaign at Xichang is planned to start at the beginning of November.

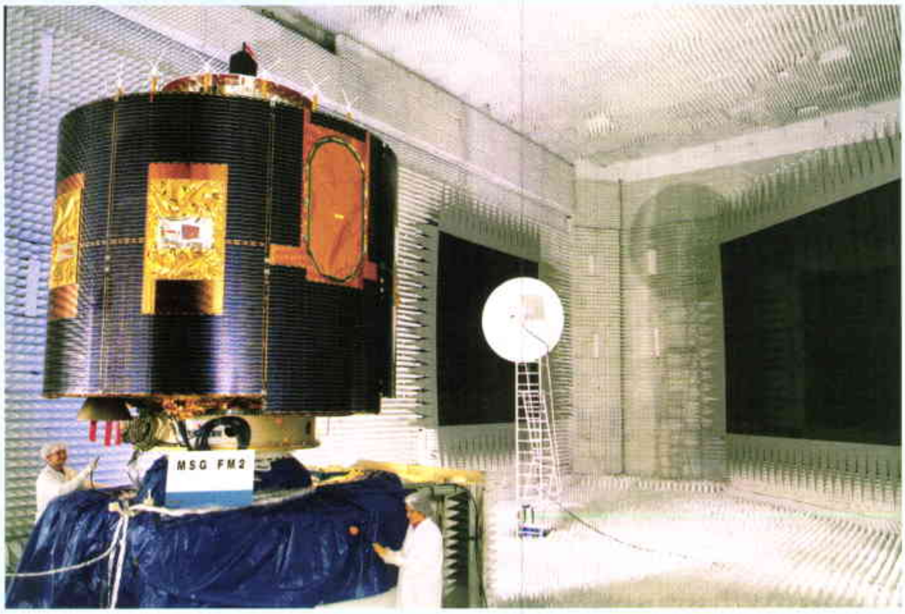
MSG

The in-orbit commissioning activities for the first of the Meteosat Second Generation (MSG) spacecraft, MSG-1, have been completed. The second part of the Commissioning Results Review, conducted by Eumetsat, will take place in mid-July. All tests have confirmed better than specified performance by the Imaging system. Due to the RF power-amplifier failure already reported, meteorological products and data are now being distributed using an alternative dissemination system.

The tests on the Search and Rescue transponder have also been completed and its performance is fully compliant with requirements.

The MSG-2 satellite-level ground testing activities have also been completed. The Pre-storage Review (PSR) was successfully held in early June, allowing the satellite to be put into storage. Pending a confirmation of the launch date, currently scheduled for January 2005, activities will resume in spring 2004.

For MSG-3, electrical integration activities started in May. Integration of the satellite bus is complete and integration of the main payload is in progress. Completion of satellite integration is planned for end-July, with the Integrated System Test (IST) due to start in August.



Testing of MSG-2's electronically de-spun antennas on the Compact Antenna Test Range (CATR) at Alcatel in Cannes, France (photo courtesy of Alcatel)

MetOp

A number of major milestones have been reached in the MetOp programme: firstly the Satellite Qualification Review, combined with that of the payload module and ASCAT, has been successfully concluded. The Review's findings were, in general, very positive and the recommendations made have been or are being implemented.

Secondly, although with a little delay, assembly and integration of the first flight-model satellite (MetOp-1) has started at Astrium Toulouse (F), following the deliveries of the payload and service modules. The major test campaign now underway includes radio-frequency compatibility and vibration testing at the Intespace facilities in Toulouse.

Thirdly, the first flight model of the IASI instrument, provided by CNES, has been completed and is being delivered for integration on MetOp-2. Some problems remain with this model, which will necessitate an exchange with flight model 2 towards the end of 2004. This first delivery will, however, allow interface verification for this important instrument.

A solution has been identified for the degradation found in the GOME-2 instrument gratings, and it is anticipated that it can be implemented in time to exchange this instrument prior to the first MetOp launch.

Other instrument issues are under control, and the impacts on the assembly, integration and test (AIT) schedule are being worked through. The programme scheduling remains consistent with Eumetsat's recently defined launch period as the 4th quarter of 2005.

Work within the MetOp project team is now focussing on definition of the so-called 'variable baseline tasks', covering such activities as the launch campaign, the commissioning phase, the support to routine operations, and the storage/destorage activities for the second and third MetOp spacecraft. In addition, the case for enhancement of the MetOp-3 payload is being examined, to allow Eumetsat to take a decision on this option - which would replace the AVHRR and AMSU instruments by more state-of-the-art sensors - by the end of the year.

ADM-Aeolus

Almost all of the subsystem Invitation-to-Tender (ITT) packages have been issued, and the majority of subsystem suppliers have been selected. Negotiations with Galileo Avionica for supplying the critical laser transmitter have been completed and the subcontract kicked-off. The latter includes a realistic programme for the qualification and life-testing of the solid-state laser pump diodes.

The project internal Instrument Baseline Review has been held and preparations for the Satellite Preliminary Design Review in August and September are well underway.

Svalbard in Norway has been chosen as the primary station for the reception of measurement data. It will be complemented for marginal orbits by existing Canadian facilities, so that no new ground station will be required.

The contract proposal for Phases-C/D/E1 will be presented to ESA's Industrial Policy Committee (IPC) in September, with the Phase-C/D kick-off tentatively scheduled for 1 October.

CryoSat

Development of the CryoSat satellite is progressing well and more of the protoflight-model equipment has been delivered to EADS-Astrium in Friedrichshafen (D). Mechanical integration of the structure manufactured by Contraves (CH) is planned to start this summer.

On the payload side, development of the SIRAL altimeter is also progressing. A major milestone has been achieved with the successful vibration testing of the antennas manufactured by Saab (S). They are now being prepared for electrical performance testing.

The Critical Design Review has recommended optimisation of the Assembly, Integration and Verification (AIV) approach, which is a critical activity in such a challenging schedule- and cost-driven programme. As a consequence, however, the Cryosat launch has to be rescheduled to end-September 2004.

Following the review conducted in April in Moscow, a detailed technical agreement has been reached with Eurockot/Khrunichev for procurement of the CryoSat launcher.

The ground-segment-related activities are progressing according to plan. The algorithms for Level-2 processing of the scientific data have been delivered. The CryoVex campaign, which forms part of the CryoSat Calibration/Validation activities, was successfully conducted in April in the Fram Strait.

GOCE

Activities on the space-segment side continue to focus on detailed consolidation of the satellite's design. To date, following a top-down approach, about two-thirds of the equipment-level Preliminary Design Reviews (PDRs) have been successfully closed out, allowing development of the engineering models needed for the overall test and verification programme to start. The PDR for the

The CryoSat SIRAL antennas ready for electrical performance testing at Saab (S)

Gradiometer Front-End Electronic Unit (FEEU) is among those successfully completed, allowing release finally of the important engineering-model manufacturing activities.

Inspection of the accelerometer sensor head, which had been submitted to mechanical testing during the second half of March, revealed an unacceptable transfer of material between one stop and the proof mass. It was subsequently decided to modify the shape of the stops and to repeat the test to have final confirmation that the current accelerometer sensor head design is able to withstand the launch environment.

An endurance test conducted on three emitters for the Micro-Newton Propulsion Assembly (MPA) terminated anomalously. Although sparking has been identified as the most probable cause of the failure, further time-consuming investigations are needed to resolve the problem conclusively. The overall schedule is therefore likely to be affected.

Turning to the Ion Propulsion Assembly (IPA), test activities relating to micro-vibrations induced by the xenon feed assembly have yet to be completed. These breadboard-based tests are needed to verify that tiny vibrations induced by the feed system do not cause significant disturbances within the bandwidth of the Gradiometer instrument. On a positive note, a 500 h endurance test on the ion thruster has been successfully completed, and a 4500 h test started in June.

The procurement proposal for a non-competitive launcher procurement from Eurockot was approved by ESA's Industrial Policy Committee (IPC) in June. The documentation supporting the related Request for Quotation (RFQ) has been also completed.

On the ground-segment side, the contractor responsible for the Payload Data Segment (PDS), including the Instrument Data Processor (Level-0 to Level-1), was selected in June. The study of the functions and tasks to be performed by the Calibration and Monitoring Facility, responsible for science data quality monitoring and calibration monitoring, is progressing according to plan. A first Announcement of Opportunity (AO) for GOCE Level-1B product external calibration and validation was released in May; proposals from the scientific community are due in July.

SMOS

A programme proposal for the full ESA part of the SMOS programme is being prepared for approval by the Agency's Earth Observation Programme Board (PB-EO) in September. In anticipation of a positive outcome, an RFQ was sent to the payload Prime Contractor, EADS-CASA (E), in June; its proposal is expected in mid-September.

The ground-segment Phase-A will be concluded in July. Continuation into a Phase-B for the Payload Data Processing Centre is under negotiation with the Spanish authorities, who are funding this as a national undertaking.

The MIRAS Demonstrator Pilot Project 1 (MDPP1) has come to an end with the successful image validation test and a full three-segment arm deployment test. MDPP2 is continuing with various demonstrations of critical subsystems at breadboard level.

International Space Station

Highlights

On 27 May the ESA Council, meeting at Ministerial Level, approved the unblocking of 124.1 MEuro of the Exploitation Programme Period-1 funding (2002-2004) for the International Space Station (ISS); a decision on the unblocking of the remaining 171.9 MEuro should be taken before end-2003.

The October 2003 Spanish Soyuz mission carrying ESA astronaut Pedro Duque has been named 'Cervantes' and the April 2004 Dutch Soyuz mission carrying ESA astronaut André Kuipers will be called 'DELTA'.

Space infrastructure development

The qualification test campaign on the flight model of the Columbus laboratory has been completed and the Qualification Review is underway. The Rack Level-Test Facility (RLTF) qualification/acceptance has been completed and the RLTF has already been used with Biolab.

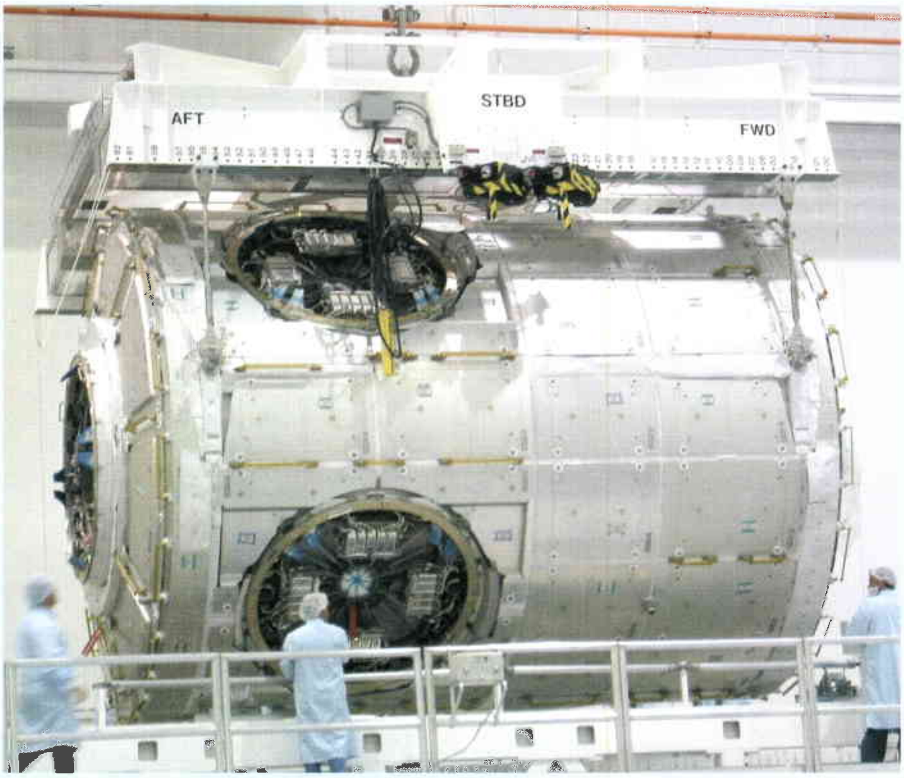
Node-2 for the ISS arrived at Kennedy Space Center (KSC) on 1 June and the transfer of ownership to NASA took place on 18 June.

The Crew Review for the Cryogenic Freezer (CRYOS) took place on 19/20 May at KSC and the System Requirement Review (SRR) action closeout meeting was held on 13 June.

Integration of the Cupola flight unit is continuing, but the start of the acceptance test campaign for the flight unit is on hold pending completion of technical investigations involving the window titanium springs.

Automated Transfer Vehicle (ATV) flight-model manufacture and integration is progressing well. The first flight model of the Russian Docking System has been delivered and manufacture of the Refuelling System flight

The flight model of Biolab during its testing in the Columbus Rack-Level Test Facility (RLTF) in Bremen, Germany



ISS Node-2 arrives in the Space Station Processing Facility at KSC in Florida

model has been completed. The ATV Flight Segment System Critical Design Review (CDR) was also concluded successfully.

Testing of the flight model of the European Robotic Arm (ERA) has been completed except for the ground-to-space Integrated Mission Test. The Qualification/Acceptance Review (QR/AR) has been declared successful pending the completion of some identified actions/activities.

The –80 degC Freezer (MELFI) was checked at KSC after its removal from the Multi-Purpose Logistics Module (MPLM) and is being kept in storage pending the resumption of Space Shuttle flights.

The Hexapod's delivery is now planned for November 2003.

Operations and related ground segments
A company has been selected to build the Columbus Control Centre (COL-CC) Infrastructure subsystem, and offers for provision of the Wide Area Network service have been evaluated. The COL-CC development schedule is still critical, but its credibility is substantially improved. The communications nodes for Houston and Huntsville (USA) have been successfully installed and tested, and the Interconnect Ground Subnet (IGS) phase-2 communications nodes have been delivered.

The ATV Control Centre (ATV-CC) Design and Development and Operations Preparation contracts were signed on 17 April.

Following its return to nominal operation, the Microgravity Science Glovebox (MSG) has been in use for NASA's experiments.

The DMS-R computer on-board the ISS Service Module is continuing to perform without problem.

Utilisation planning, payload development and preparatory missions
Four of the Microgravity Application Promotion (MAP) continuation proposals recently received have been recommended for continuation and have been endorsed by the Life and Physical Science Advisory Committee (LPSAC) and the European Utilisation Board (EUB).

EuTEF development is progressing, with its Critical Design Review (CDR) successfully completed in May, while the CDR for SOLAR was initiated in May and is to be completed in September 2003. EXPOSE's relocation from the EXPORT assembly (with coarse pointing device) to the EuTEF assembly (without such pointing) has been implemented.

The Columbus External Payload Adaptor (CEPA) developed by NASA for delivery to ESA and required to mount the external payloads has completed its CDR. However, some technology-transfer issues are hampering its development and the availability of data required for analytical integration.

The contract for the main development phase (Phase-C/D) for the Atomic Clock Ensemble in Space (ACES) is ready to be awarded, as CNES has confirmed the development of PHARAO.

The procurement of parts and hardware manufacture for Matroshka is in progress, with launch planned for January 2004.

The flight model of Biolab has successfully completed the interface testing with Columbus.

Integration of the flight model of the European Physiology Module (EPM) has been completed and the interface testing with the Columbus laboratory is planned for July.

System flight-model integration for the Fluid Science Laboratory (FSL) is complete and testing will be completed during the summer.

All of the laboratories to be carried into space in the Columbus module are on schedule for the October 2004 launch, with flight-model deliveries now approaching.

NASA's Human Research Facility (HRF-2), including the ESA Pulmonary Function System, is installed in the Multi-Purpose Logistics Module (MPLM). However, it will be de-integrated because of the launch delay due to the grounding of Shuttles following the Columbia disaster.

Flight-model integration of the Materials Science Laboratory (MSL) is progressing, with the delivery of several subsystems.

ISS education
Habla ISS, the first ESA website for primary schools, was launched in Spain on 16 April. Some 13 000 Spanish schools have been asked to participate in educational activities linked with the visit of ESA astronaut Pedro Duque to the ISS in October 2003.

The Spanish Soyuz Mission VIDEO-2 hardware and student experiments APIS, Thebas, and Winograd Kit were successfully launched on a Progress vehicle in June.

Commercial activities
The study phase (Phase-A) for RapidEye was initiated in April.

ISS Branding definition has been completed, and the communication plan defined. Contacts with major European corporations are continuing for prime and mission sponsorship, and contacts with Dutch companies for sponsor-ship of the Dutch Soyuz Mission have been initiated. The ISS Business Club statute has been approved and the Business club formally created. The club was publicly launched at the Paris airshow in Le Bourget on 19 June.

Astronaut activities
The Training Readiness Review for the ESA-provided Advanced Payload Training was successfully concluded on 15 April. A total of 27 Payload Training lessons for all four ESA Payloads - EDR, FSL, MSL, EPM - are ready for implementation.

The ATV Crew Training Mock-up, and the refurbished Columbus Crew Training Mock-up were delivered to the European Astronaut Centre (EAC) in Cologne-Porz, Germany, in April.

An Instructor Training Course took place at EAC from 5 to 23 May for participants from industry and User Operations Centres (USOCs). Three EAC instructors gave some of the lessons and are now also certified to teach the corresponding lessons in NASA Instructor Training Courses.

The Multilateral Crew Operations Panel (MCOP) meeting on 18/19 June at the Gagarin Cosmonaut Training Centre near Moscow resulted in formal flight assignments for ESA astronauts Pedro Duque and André Kuipers as On-Board Engineers for Soyuz Missions 7S and 8S, respectively. Both will fly in the left seat of the Soyuz TMA during all flight phases. ESA astronaut Gerhard Thiele was proposed as the back-up for André Kuipers.

Artemis

Artemis commissioning in geostationary orbit was successfully completed by the end of March. It was demonstrated that satellite performance is very satisfactory and that all functions and services can be provided as specified, often with good margins. The propellant lifetime is nominally 10 years without inclination control, the satellite's attitude being controlled to offset the effects of orbit inclination on the users. Interface tests with users have also been completed, and all elements of the system are functioning well.

The following operational services are currently being provided:
- The L-band land mobile payload is being utilised to about 50% capacity for the EMS service under contract to Telespazio, providing low-data-rate and voice services to small mobile users (trucks, boats).
- Spot-4 is using the optical data relay for Spot Image data reception in Toulouse (F). Currently about one link per day is being used, but this will increase to several passes per day later in the year.
- Envisat has now increased its usage to 5 links per day for reception of its ASAR and MERIS instrument data at ESRIN (I).

In the operational period from 1 April to 30 June, there were some 160 communications sessions to Envisat and 100 to Spot-4. The optical ground station at Tenerife also used 50 links with Artemis for atmospheric attenuation-experiment purposes.

Data relay offers a number of benefits to earth-observation missions: longer contact times, real-time transmissions, higher volume of data, and greater flexibility of data selection. To date, several hundred successful data links have been provided and, although there are occasional service failures, the success rate of link acquisition is now very high, increasing from 98% towards 100% as the process becomes routine.

More recently, Artemis supported an Envisat Earthwatch data acquisition in response to an emergency Charter request by the Portuguese Civil Protection authority – hence the European Data Relay service is a reality.

The Artemis navigation transponder will form an invaluable element of the operational EGNOS system. EGNOS is currently preparing its operational interfaces from its Scanzano earth station in order to integrate the navigation payload on Artemis into the EGNOS system over the next few months, in preparation for the operational phase in 2004.

Artemis also continues to support technology programmes and a number of experimental uses of the LLM payload are planned in the near future. As a result of the cost of the recovery operation, new funding is needed to continue planned operations beyond the first year in orbit. A series of meetings with Participating States has been held to seek agreement on a proposed programme extension.

In Brief

Galileo: First contracts signed

After the appointment of Rainer Grohe as Director of the Galileo Joint Undertaking in June, contracts for the first Galileo satellites were signed on Friday 11 July at ESTEC, the European Space Agency's research and technology centre in Noordwijk (NL).

"Galileo is taking shape with every passing day. These first contracts are symbolic of Europe's collective resolve to develop the first civil global satellite navigation system", said Claudio Mastracci, ESA's Director of Application Programmes.

The contracts are for two experimental satellites. One contract, worth 27.9 million Euros, has been awarded to the British firm Surrey Space Technology Limited. The main task of this test satellite is to transmit the Galileo signals from one of the orbits to be used by the constellation. It will also test various critical technologies that it will be flying, including the rubidium atomic clock and a signal generator. It will also measure the physical parameters of the orbit.

In order to minimize risks of delays, launch failure, etc. a contract worth 72.3 million Euros to build another test satellite has been placed with the consortium Galileo Industries. With a payload very similar to that of the satellites that will form the complete constellation, this satellite will serve to validate all the technologies to be flown. It might also be used in the system validation phase itself.

The appointment of Rainer Grohe means that the Joint Undertaking can now proceed with the various steps towards setting up the Galileo network. The Joint Undertaking's main task is to prepare for the Galileo programme deployment and operational phase, which should culminate in the selection of a concession holder to take charge of running the future Galileo operating company. Three or four test satellites will subsequently be launched for validation of the system around 2006/2007.

The core of the Galileo system is its constellation of 30 satellites (27 operational, 3 spare) circling in medium Earth orbit in three planes inclined at 56° to the equator at 23 616 km altitude. This constellation will provide excellent global coverage. Two centres will be set up in Europe to control satellite operations and manage the navigation.

Claudio Mastracci, ESA Director of Application Programmes (left) and Sir Martin Sweeting of Surrey Space Technology Limited sign one of the first contracts for Galileo

Green Paper on European Space Policy

After a four-month consultation on the Green Paper on European Space Policy, key measures to drive forward Europe's space ambitions were proposed at a conference in Paris in June. Other priorities outlined at the conference included better co-ordination between all sectors at EU and international levels, guaranteed independent access to space for Europe and a flexible system of programme funding.

Participants stressed the need to develop space technology, such as Internet by satellite and security applications. The conference provided important input for the forthcoming EU White Paper on Space Policy, due to be published by the European Commission in October this year.

"People expect the EU to play a greater role in space, and we must be ready to meet those expectations", said Philippe Busquin, European Commissioner for Research. *"We will build on the lessons learnt from the consultation to devise an ambitious action plan for European space policy. With strong political commitment from all key space stakeholders and sustained interest among the public, we can turn Europe into the space leader of the 21st century."*

The Green Paper on European Space Policy, adopted by the European Commission on 21 January, is a strategic document developed in co-operation with the European Space Agency, which opens a new era for Europe in space. Its aim was to initiate a broad debate on the medium- and long-term future use of space for the benefit of Europe.

With six meetings scheduled in European capitals, workshops, bilateral presentations and an on-line forum, this consultation prompted several thousand contributions from a whole host of interested parties. Institutional users, industrial managers, researchers and scientists, NGOs and ordinary citizens in Member States, applicant-member countries and other countries associated with European space activities have thus had ample opportunity to voice their opinions and help usher in a new era for Europe in space.

Through an open, transparent and democratic debate, a broad consensus on a number of key actions has taken shape. During the consultation, space sector players addressed a series of options, including:

- Upgrading the space policy institutional framework, possibly by creating a Council of Space Ministers;
- Using the same satellite systems for both civil and defence/security purposes (multiple-use systems);
- An institutional market which recognises space potential in addressing civil policy objectives such as communication and navigation;
- Independent, reliable and affordable access to space through the European Guaranteed Access to Space (EGAS) programme;
- The need for a European Security and Defence Agency;
- Improved career prospects, training and development for people working in space research and technology;
- A doubling of funding for European research;
- Harmonising data collection and processing at European level, with the Commission supporting a powerful data processing system for climate forecasts and global change monitoring;
- Establishing the International Space Station as a base for microgravity research;
- Further support for ESA's Aurora programme;
- Developing space applications to underpin technological and scientific development and the security of citizens;
- Developing a programme to achieve seamless broadband communications for everyone in Europe; and
- Supporting the enlargement process and European integration through satellite technologies and shared policy objectives.

In October 2003, the Commission is expected to release the White Paper on European Space Policy, with subsequent submission to the Council and Parliament. The White Paper will include an action plan setting out a future strategy for space activities in the European Union. It will acknowledge the contributions received, and include proposals for the content, organisation and level of future European space activities. In November 2003, the White Paper is on the agenda to be discussed by the Council of the European Union in the Competitiveness Council under the Italian Presidency. esa

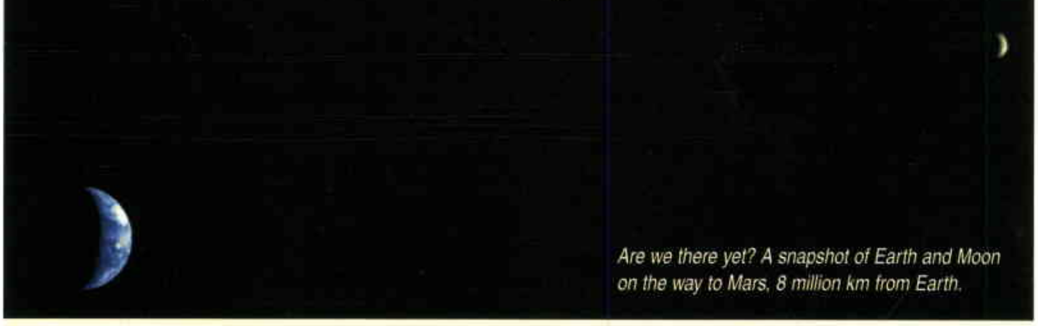
First EGNOS signal in space

The European Geostationary Navigation Overlay Service (EGNOS) system has started its first signal transmission tests. This system is Europe's first venture into satellite navigation and by early next year will deliver the first European Satellite Navigation service. It will augment the two military satellite navigation systems now operating, the US GPS and Russian GLONASS, making them suitable for many mass-market applications such as car navigation, bus and truck fleet management, but also for specific applications such as assisting blind people when walking in an unknown area. In addition, after a certification process, EGNOS will be used for safety-critical applications such as controlling aircraft or navigating ships through narrow channels.

When completed, EGNOS will consist of three geostationary satellites and a network of ground stations that will transmit signals containing information on the reliability and accuracy of the positioning signals sent out by GPS and GLONASS. It will enable users in Europe and beyond to determine their position to within 2 m, compared with about 20 m with GPS alone.

EGNOS is a joint project involving the European Space Agency, the European Commission and Eurocontrol. It is Europe's contribution to the first stage of the Global Navigation Satellite System (GNSS) and is a precursor to Galileo, the full global satellite navigation system under development in Europe. esa

Mars Express successfully tests its instruments



Are we there yet? A snapshot of Earth and Moon on the way to Mars, 8 million km from Earth.

One of the first data sets coming from ESA's Mars Express is a unique view of our home planet and the Moon. *"It is very good news for the mission,"* says ESA's Mars Express Project Scientist, Agustin Chicarro. These and other data, such as those recording the major constituents of Earth as seen from space, are the actual proof that the instruments on board Mars Express, launched on 2 June 2003, are working well.

The views of Earth and Moon were taken on 3 July 2003 by Mars Express's High Resolution Stereo Camera (HRSC), when the spacecraft was 8 million kilometres from Earth. The image taken shows true colours; the Pacific Ocean appears in blue, and the clouds near the Equator and in mid to northern latitudes in white to light grey. The image was processed by the Instrument Team at the Institute of Planetary Research of DLR, Berlin (Germany). It was built by combining a super resolution black and white HRSC snapshot image of the Earth and the Moon with colour information obtained by the blue, green, and red sensors of the instrument.

The experts will carry on testing Mars Express's instruments until its arrival at the Red Planet next December. The instruments will increase our understanding of the morphology and topography of the Martian surface, of the geological structures and processes and of Mars's geological evolution. With such tools, Mars Express is also able to address the important "water" question, namely how much water there is today and how much there was in the past. Ultimately, this will also tell us whether Mars had environmental conditions that could favour the evolution of life. esa

Argentina's CONAE joins the International Disaster Charter

The International Charter on Space and Major Disasters has a new member, Argentina's Comisión Nacional de Actividades Espaciales (CONAE).

The Charter is the expression of a joint effort of global space agencies to put space technologies at the disposal of rescue authorities in the event of major disasters. This help is given by providing space-acquired data and associated information and services to civil protection agencies worldwide. CONAE's accession to the Charter represents an important addition to the only operational service making co-ordinated use of multiple Earth Observation satellites, bringing the South American region within the scope of the Charter for the first time. esa

Keeping in touch with probes in deep space

ESA is going to build a deep space ground station in Cebreros near Avila in Spain. ESA's Director General Jean-Jacques Dordain and representatives of the Spanish Government, the Secretary of State for Defence Fernando Díez Moreno and the Secretary of State for Science and Technology, Pedro Morenés Eulate, signed an agreement to this effect in Madrid on 22 July.

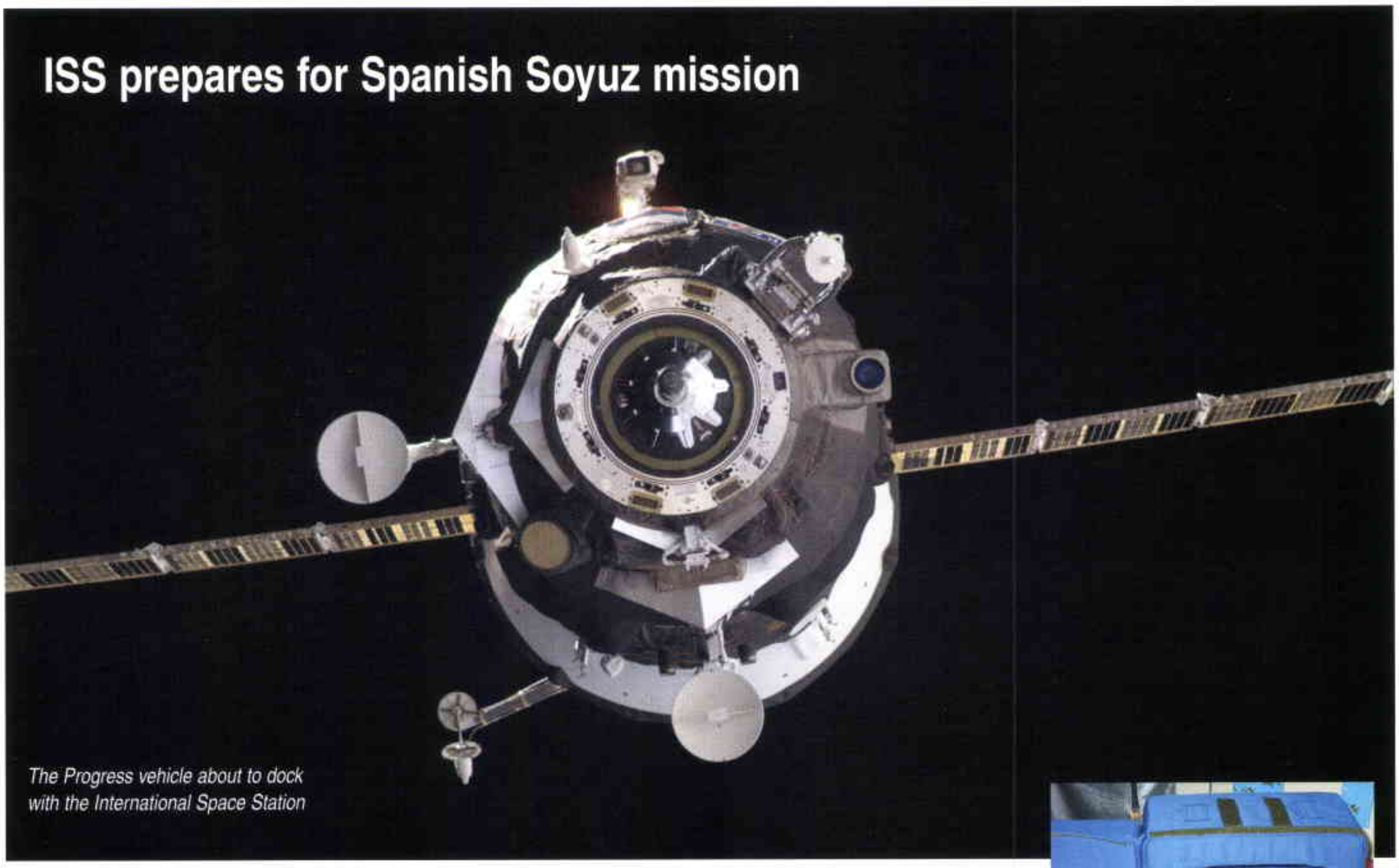
Communicating with spacecraft, such as Mars Express, over very long distances, and probes that have to be controlled remotely, together with their onboard instruments, at distances up to 900 million kilometres from Earth (more than six times the distance from the Earth to the Sun) requires large and powerful antennas.

The new ground station is scheduled to start operations in September 2005. The Government of Spain will grant ESA a 75-year lease on two plots of land. One plot will accommodate the space tracking facilities and the 35 m diameter deep-space antenna. The other will house the calibration tower, used to simulate the signals transmitted by spacecraft for testing purposes. Construction work is scheduled to start in September this year.

"In terms of radio-electric conditions, the Cebreros environment is perfect, and will give this new site an important growth potential," said ESA's Director of Technical and Operational Support, Gaele Winters.

The network of antennas in Spain – at Cebreros, Villafranca del Castillo (ESA) and Robledo (NASA/JPL) – will soon be one of the most important groups of satellite tracking stations in the World, due to their optimum environments free of radio-electric disturbances. They will make a valuable contribution to the scientific and technological infrastructure for European space activities. esa

ISS prepares for Spanish Soyuz mission



The Progress vehicle about to dock with the International Space Station

The Spanish Soyuz mission to the International Space Station (ISS) planned for October took another step forward with the arrival of European experiment hardware at the ISS on an unmanned Progress M1-10 spacecraft on 11 June.

The European cargo included a 3D-camera, a new crew restraint system and a major component of the NANOSLAB experiment, which first flew with ESA astronaut Frank De Winne in November 2002 as part of the Belgian Odissea Mission. It has since been modified for the Spanish Soyuz Mission in October.

Another European experiment to arrive was PROMISS-2, which is designed to investigate the fundamental processes that underly protein crystallisation. A number of educational experiments have also arrived on the Progress M1-10, including APIS, a motion experiment, Thebas, to test basic principles of mechanics, and Video-2, which is designed to demonstrate Newton's three laws of motion under microgravity conditions.

Spanish ESA astronaut Pedro Duque will be flight engineer on the new Soyuz TMA-3 spacecraft, which will take him and the ISS Expedition 8 crew to the ISS. He will return in the Soyuz TMA-2 spacecraft with the Expedition 7 crew (US astronaut Ed Lu and Russian cosmonaut Yuri Malenchenko) who are currently on the ISS.

The new Soyuz TMA spacecraft has been fully approved for operations. In May, the first spacecraft of the new series TMA-1 had touched down 400 km short of the intended landing site when it returned to Earth with the ISS Expedition 6 crew on board.

In the meantime, around 5000 school children in more than 250 Spanish primary school classes entered the 'Habla ISS' contest to win a chance to talk live via radio with ESA astronaut Pedro Duque during his stay on board the ISS. The evaluation committee has selected the two best drawings and the two best stories, and the winning classes will spend one day in the 'Verbum' museum of Vigo, Spain, from where the radio-contact will be established with the Space Station. esa

3D camera with its launch container

ESA's science fleet makes headlines

Cluster

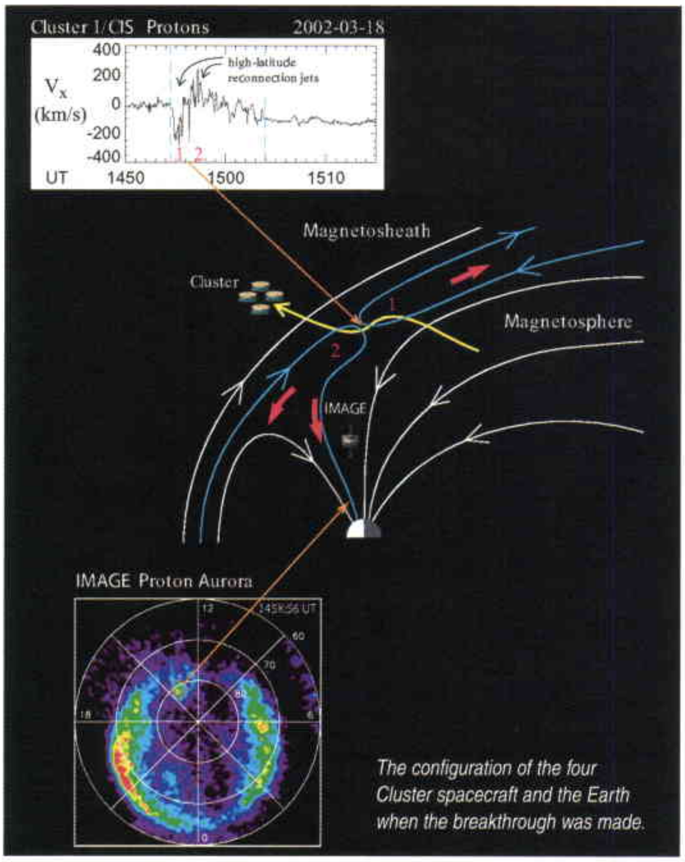
ESA's four Cluster spacecraft have made a remarkable set of observations that has led to a breakthrough in understanding the origin of a peculiar and puzzling type of aurora.

These aurorae – seen as bright spots in Earth's atmosphere and called 'dayside proton auroral spots' – occur when fractures appear in the Earth's magnetic field, allowing particles ejected from the Sun to squirt through and collide with the molecules in our atmosphere. This is the first time that a precise and direct connection between the two events has been made.

Philippe Escoubet, ESA's Cluster Project Scientist, comments:

"Thanks to Cluster's observations scientists can directly and firmly link for the first time a dayside proton auroral spot and a magnetic reconnection event."

Tai Phan, leading the investigation at the University of California, Berkeley, United States, now looks forward to a new way of studying the Earth's protective shield. He says, *"This result has opened up a new area of research. We can now watch dayside proton aurorae and use those observations to know where and how the cracks in the magnetic field are formed and how long the cracks remain open. That makes it a powerful tool to study the entry of the solar wind into the Earth's magnetosphere."*



The configuration of the four Cluster spacecraft and the Earth when the breakthrough was made.

XMM Newton

Also XMM-Newton has provided a first in astronomy – it measured the magnetic field of a neutron star for the first time. The results provide deep insights into the extreme physics of neutron stars and reveal a new mystery yet to be solved about the end of this star's life.

A neutron star is very dense celestial object. It is the product of a stellar explosion, known as a supernova, in which most of the star is blasted into space, but its collapsed heart remains in the form of a super-dense, hot ball of neutrons that spins at an incredible rate.

One such neutron star is 1E1207.4-5209. Using the longest ever XMM-Newton observation of a galactic source (72 hours), Professor Giovanni Bignami of the Centre d'Etude Spatiale des Rayonnements (CESR) and his team have directly measured the strength of its magnetic field. This makes it the first ever isolated neutron star where this could be achieved.

X-rays emitted by a neutron star like 1E1207.4-5209 have to pass through the star's magnetic field before escaping into space. En route, particles in the star's magnetic field can steal some of the outgoing X-rays, imparting on their spectrum tell-tale marks, known as 'cyclotron resonance absorption lines'. It is this finger-print that allowed Prof. Bignami and his team to measure the strength of the neutron star's magnetic field.

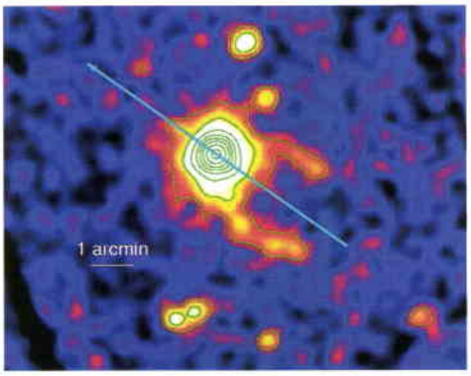
All previous values of neutron star magnetic fields could only be

The first image from the XMM-LSS survey, the world's deepest 'wide screen' X-ray image of the cosmos to date. It represents a region of the sky eight times larger than the full Moon and contains around 25 clusters.

estimated indirectly. This is done via theoretical assumptions based on models that describe the gravitational collapse of massive stars, like those which lead to the formation of neutron stars. A second indirect method is to estimate the magnetic field by studying how the neutron star's rotation slows down, using radio astronomy data.

In the case of 1E1207.4-5209, this direct measurement using XMM-Newton reveals that the neutron star's magnetic field is 30 times weaker than predictions based on the indirect methods.

How can this be explained? Astronomers can measure the rate at which individual neutron stars decelerate. They have always assumed that 'friction' between its magnetic field and its surroundings was the cause. In



Geminga and its tails.

this case, the only conclusion is that something else is pulling on the neutron star, but what? We can speculate that it may be a small disc of supernova debris surrounding the neutron star, creating an additional drag factor.

The result raises the question of whether 1E1207.4-5209 is unique among neutron stars, or is the first of its kind. The astronomers hope to target other neutron stars with XMM-Newton to find out.

This is not XMM Newton's only headline. Astronomers using it have discovered a pair of X-ray tails stretching 3 million million kilometres across the sky. They emanate from the mysterious neutron star known as Geminga. The discovery gives astronomers new insight into the extraordinary conditions around the neutron star.

A neutron star measures only 20-30 kilometres across and is the dense remnant of an exploded star. Geminga is one of the closest to Earth, at a distance of about 500 light-years. Most neutron stars emit radio emissions, appearing to pulsate like a lighthouse, but Geminga is 'radio-quiet'. It does, however, emit huge quantities of pulsating gamma rays, making it one of the brightest gamma-ray sources in the sky. Geminga is the only example of a successfully identified gamma-ray source from which astronomers have gained significant knowledge.

ISO

Scientists are celebrating the thousandth scientific publication from ESA's veteran Infrared Space Observatory (ISO). ISO is becoming one of the world's most productive space missions, even though its operational life ended in 1998.

ISO was the world's first space observatory able to see the sky in infrared light. Through its 'eyes', we have discovered many new phenomena that have radically changed our view of the Universe.

"ISO results are impacting most fields of astronomical research, almost literally from comets to cosmology," explains Alberto Salama, ISO Project Scientist. *"Some results answer questions. Others open new fields. Some are already being followed up by existing telescopes; others have to await future facilities."*

When ISO's operational lifetime came to an end in 1998, its observations became freely available to the world scientific community via ISO's data archive. In May 2003, the 'milestone number' of 1000 scientific papers was reached. Even now, ISO's data archive remains a valuable source of new results. For example, some of the latest papers describe the detection of water in 'protostars', which are stars just in the process of being born.

esa

SOHO resumes full operation

ESA/NASA's SOHO spacecraft is back to full operation after its predicted 9-day high-gain antenna blackout. Engineers and scientists are now confident that they understand the situation and can work around it in the future to minimise the data losses.

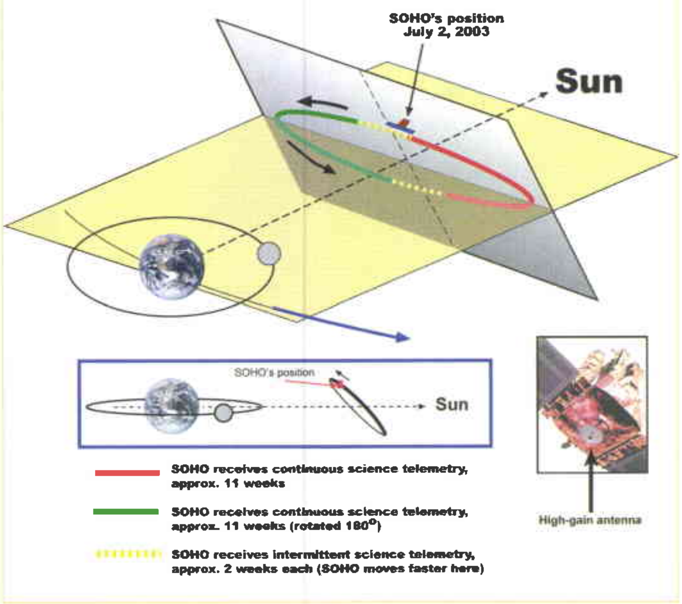
Since 19 June SOHO's high-gain antenna (HGA), which transmits high-speed data to Earth, has been fixed in position following the discovery of a malfunction in its pointing mechanism. This resulted in a loss of signal through SOHO's usual 26-metre ground stations on 27 June, while 34-metre radio dishes continued to receive high-speed transmissions from the HGA until 1 July.

Since then, astronomers have been relying primarily on a slower transmission rate signal, sent through SOHO's backup antenna. It can be picked up whenever a 34-metre dish is available. However, this signal could not transmit all of SOHO's data. Some data was recorded on board, however, and downloaded using high-speed transmissions through the backup antenna when time on the largest, 70-metre dishes could be spared.

SOHO itself orbits a point in space, 1.5 million kilometres closer to the Sun than the Earth, once every 6 months. To reorient the HGA for the next half of this orbit, engineers rolled the spacecraft through a half-circle on 8 July 2003. On 10 July, the 34-metre radio dish in Madrid re-established contact with SOHO's HGA. Then on the morning of 14 July 2003, normal operations with the spacecraft resumed through its usual 26-metre ground stations, as predicted.

With the HGA now static, the blackouts, lasting between 9 and 16 days, will continue to occur every 3 months. Engineers will rotate SOHO by 180 degrees every time in order to minimise data losses.

esa



ESA at the 2003 Paris Air Show

From Saturday 14 to Sunday 22 June, ESA was present at the 2003 Paris Air Show at Le Bourget with a special pavilion dedicated to the European space programmes. The 1000 square metre exhibition area was used to host a wide range of exhibits and events highlighting ESA's activities in Space Science, Space Transportation, Human Spaceflight, Telecommunications and Navigation, Earth Observation, Industrial Matters and Technologies, Future Concepts and Education.

As the largest international air show, Le Bourget represented an excellent opportunity for the general public and the space community to get acquainted or keep up to date with the latest European space projects. The media in particular benefitted from the special opportunities that were provided for briefings and interviews with ESA's Directors and experts in various disciplines.

Highlights of the media programme during the week included:

• *'ESA Achievements and Perspectives'* - Press Breakfast with ESA's Director General Antonio Rodotà and future Director General Jean-Jacques Dordain.

• *'European Strategy for Satellite Navigation:* From EGNOS to Galileo' - Press Briefing with Claudio Mastracci, ESA's Director of Applications.

• *'European Launchers: The Way Forward'* - ESA's Director of Launchers Jean-Jacques Dordain, and representatives of CNES and Arianespace, outlined to managers from European industry the decisions concerning the European launcher sector taken at the ESA Ministerial Council Meeting on 27 May and the impact that they will have.

• *'Observing the Earth: Why is it Important?'* - Conference chaired by ESA's Director of Earth Observation José Achache, in which distinguished speakers outlined to potential users and European policy makers the importance of satellite images for understanding and securing our planet.

• *'Overview of ISS Status'* - Jörg Feustel-Büechl, ESA's Director of Human Spaceflight, briefed the media on the present status of and outlook for European participation in the International Space Station.

• *'Launch of the European ISS Business Club'* - The launching of an ESA-initiated forum for commercial entities associated with the design, development, operation and utilisation of the European elements of the International Space Station.

• *'Technology Transfer: An Everyday Reality'* - Pierre Brisson, Head of ESA's Technology Transfer Programme, was present to demonstrate what things like an anti-UV suit for babies suffering from Xeroderma Pigmentosum, the C 60 prototype cars of the Pescarolo Sport Team, an air-decontaminating device for hospitals, an alarm to monitor elderly people and the new sailing catamaran of French yachtsman Yves Parlier have in common, and what all of these items have to do with space.

• *'Women in the Space Industry'* - A debate chaired by ESA's Director of Administration Daniel Sacotte, in which women from industry, universities, international organisations and the media shared their experiences in their professional careers.

• *'The European Space Technology Master Plan'* - A debate chaired by Hans Kappler, ESA's Director of Industrial Matters and Technology Programmes, addressing how technology harmonisation is able to support the competitiveness of European industry and the creation of a balanced industrial landscape.

The accompanying photographs were taken during these and the many other events that took place in the ESA Pavilion during the week.

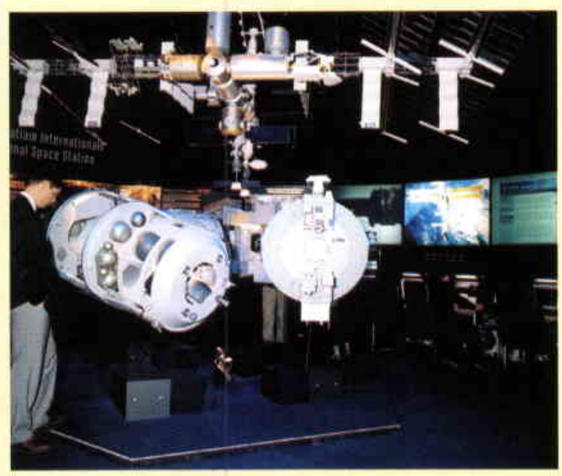
The visit of President Jacques Chirac (left) to the ESA Pavilion on 14 June, accompanied by ESA's current and future Director Generals, Antonio Rodotà (centre) and Jean-Jacques Dordain (right) (photo: ESA/S. Corvaja)

The media briefing on Tuesday 17 June on 'European Launchers: The Way Forward', hosted by Jean-Jacques Dordain (third from left)

Signature, on 18 June by the Director General of UNESCO, Koichiro Matsuura, and ESA's Director General, Antonio Rodotà, of the ESA-UNESCO Agreement on the use of European space technology to help preserve more than 700 natural and cultural World Heritage Sites designated by UNESCO

A visit to the ESA Pavilion by a group of German schoolchildren, accompanied here by ESA astronaut Phillippe Perrin

The 'Observing the Earth: Why is it Important?' conference on Wednesday 18 June, chaired by José Achache, ESA's Director of Earth Observation (third from left)



(photos: ESA/A. v.d. Geest)

Getting ready for Physics on Stage 3

For the second year, ESA/ESTEC will host the teaching festival Physics On Stage. This third edition of the unique international event will take place from 8 to 15 November. More than 400 delegates – experts on physics teachers, university lecturers, researchers and others – from 22 countries will take part in this big week of information exchange organised around the theme of 'Physics and Life'.

The overall objective of the Physics on Stage project is to raise the quality and increase the attractiveness of science teaching in Europe. This year's theme, 'Physics and Life', reflects the decision to broaden the Physics on Stage activities to encompass all sciences in an interdisciplinary approach.

The festival is only the culminating event of a year-long programme. Many activities take place throughout the year in the various countries involved in the project (see panel) and a national steering committee chooses the delegates to the festival. Each delegate has been selected for his or her projects or outstanding and original ideas dedicated to making science more attractive.

Physics on Stage is organised by EIROforum (European Intergovernmental Research Organisations Forum) (see Bulletin 108, November 2001), and is co-funded by the European Commission, as part of European Science and Technology Week 2003.

The week's programme will include spectacular and original performances, a large fair with a stand for each country, where teachers can exchange ideas, and dedicated workshops. A new innovation this year will be seminars organised and presented by EIROforum members. Also on the agenda are a mystery cultural event and an award ceremony for the most popular project.

For more information about Physics on Stage 3 and the national events, visit the web site: http://www.physicsonstage.net.

esa

Students performing at the Bulgarian National Event

This year's topic is "Physics and Life"

List of National Events in 2003

15-18 May Silistra, Bulgaria
16 May Gothenburg, Sweden
28 May Gent, Belgium
31 May Varna, Bulgaria
7 June Varna, Bulgaria
August / September Finland
27 - 29 August Ceske Budejovice, Czech Republic
6 September Poznan, Poland
12-14 or 19-21 September, Hungary
12 September Aarhus, Denmark
19 - 21 September Geneva, Switzerland
19 - 20 September Athens, Greece
20 September, Slovak Republic
25 - 26 September L'Aquila, Italy
26 - 28 September Terrassa, Spain
2 October Utrecht, The Netherlands
4 October Lisbon, Portugal

Earth observation on a global scale

High-level delegates from 30 countries and 22 international organisations agreed at the Earth Observation Summit, held on 31 July in Washington, to improve cooperation on Earth observation and to remove barriers to the exchange of information between countries and organisations.

ESA already carries out its Earth observation programmes in cooperation with other agencies or countries through mechanisms such as CEOS, the Committee of Earth Observation Satellites and IGOS-P, the Integrated Global Observing Strategy Partnership. Another good example of the way cooperation between space agencies can lead to increased utilisation of EO data is the International Charter on Space and Major Disasters. This provides data at short notice to civil protection agencies to help them deal with emergencies.

ESA is an active member of these organisations and also leads, together with the European Commission, Europe's major contribution to integrated global observation of the Earth – the Global Monitoring for Environment and Security (GMES) initiative. GMES also involves Eumetsat and European national space agencies in an integrated approach to support European policy.

Important though these initiatives are, what is still lacking is a truly global partnership to encompass all countries, rich and poor, which will allow the transfer and use of Earth-observation information by all. The meeting was an important step in the right direction because it showed that the political will is now there to bring this about.

The declaration issued at the end of the meeting emphasised the need for timely long-term information as the basis for sound decision making; the need to coordinate strategies and systems; to assist developing countries to use and contribute to Earth observation data; and, to foster the exchange and integration of information obtained from the ground, as well as from aircraft and satellites. The Earth Observation Summit also agreed to prepare a 10-year Implementation Plan to build on existing systems and initiatives.

ESA's delegation to the Summit was led by the new Director General Jean-Jacques Dordain.

As a member of the Panel on 'How to identify needs and how to fill the gaps', ESA's Director of Earth Observation Programmes, José Achache, described how a number of ESA's Earth Explorer missions – such as the SMOS satellite to measure soil, moisture and ocean salinity; CryoSat to measure changes in the Earth's terrestrial and marine ice fields; and the ADM-Aeolus mission to provide global observations of three-dimensional wind fields – will make a unique contribution to global monitoring. These missions will improve our understanding of the Earth system, but there will remain a need to support long-term continuity of such observations beyond the research stage.

"For its part", says José Achache, *"ESA has already demonstrated, through its GMES and Oxygen initiatives, that it is a strong believer in global monitoring and improving access to Earth observation data. It is important that we contribute to the proposed global coordination, while maintaining the independent capacity to make observations in support of European policies in environment and civil security. A strong independent programme is a prerequisite for successful partnership. We support the Summit declaration and will play our part to ensure that it is implemented."*

Work will now proceed with preparing the framework for the 10-year Implementation Plan in time for the next Ministerial Conference to be held in Tokyo before next summer. This will enable the Plan to be presented at the Ministerial Conference to be hosted by the European Union towards the end of 2004.

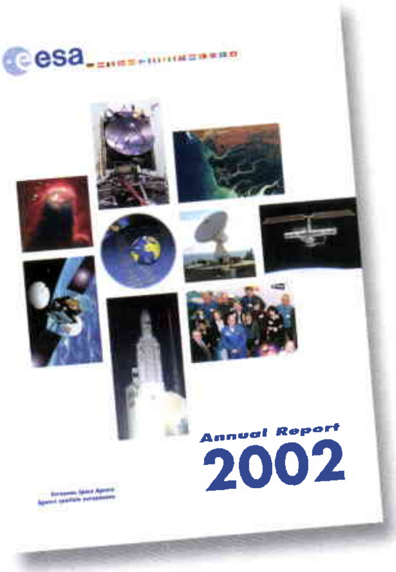
Publications

The documents listed here have been issued since the last publications announcement in the ESA Bulletin. Requests for copies should be made in accordance with the Table and Order Form inside the back cover

ESA Annual Report

ANNUAL REPORT 2002 (JULY 2003)
BATTRICK B. (ED.)
ESA ANNUAL REPORT 2002 // 138 PAGES
NO CHARGE

RAPPORT ANNUEL 2002 (AOUT 2003)
LACOSTE H. & BATTRICK B. (EDS.)
ESA RAPPORT ANNUEL 2002 // 140 PAGES
NO CHARGE



ESA Newsletters

ON STATION NO. 13 (JUNE 2003)
NEWSLETTER OF ESA'S DIRECTORATE OF HUMAN SPACEFLIGHT
WILSON A. (ED.)
NO CHARGE

ECSL NEWS NO. 25 (JUNE 2003)
NEWSLETTER OF THE EUROPEAN CENTRE FOR SPACE LAW
MARCHINI A. (ED. B. BATTRICK)
NO CHARGE

EARTH OBSERVATION QUARTERLY NO. 71 (JUNE 2003)
NEWSLETTER OF ESA'S DIRECTORATE OF EARTH OBSERVATION
LACOSTE H. (ED.)
NO CHARGE

ESA Brochures

EUREKA (MAI 2003)
– THE ESA TECHNOLOGY TRANSFER PROGRAMME
BATTRICK B. (ED.)
ESA BR-184 (XIII) (IN FRENCH) // 16 PAGES
PRIX: 10 EURO

A THREAD FROM SPACE TO YOUR BODY (JUNE 2003)
– THE ESA TECHNOLOGY TRANSFER PROGRAMME
BATTRICK B. (ED.)
ESA BR-184 (XIV) // 12 PAGES
PRICE: 10 EURO

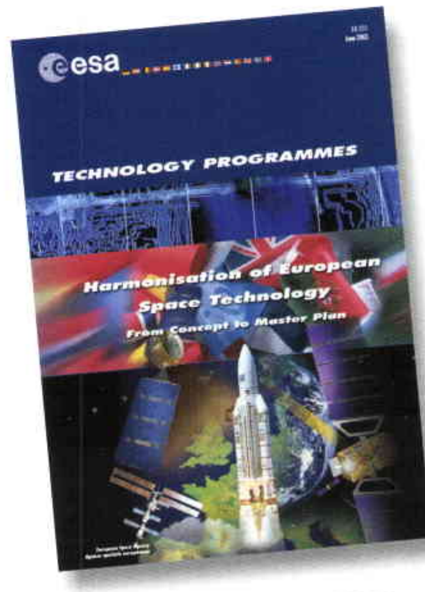
SMART-1 – TILL MÅNEN MED SOLENERGI (JULI 2003)
EKSTRAND E. (ED.)
ESA BR-191 (IN SWEDISH) // 20 PAGES
PRICE: 7 EURO

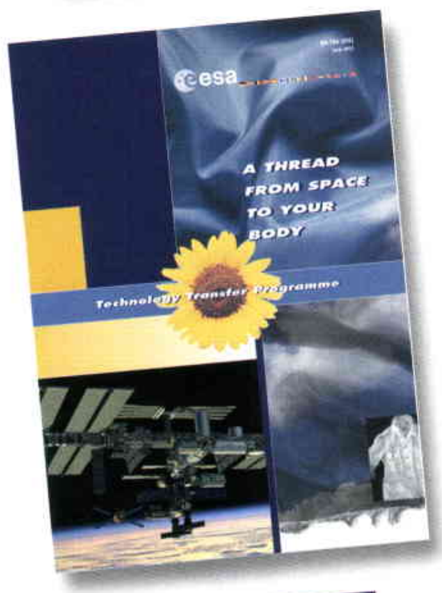
SATELLITE POWER SYSTEMS – SOLAR ENERGY USED IN SPACE (MAY 2003)
– THE ESA TECHNOLOGY PROGRAMMES
JENSEN N.E. & BATTRICK B. (EDS.)
ESA BR-202 // 10 PAGES
PRICE: 10 EURO

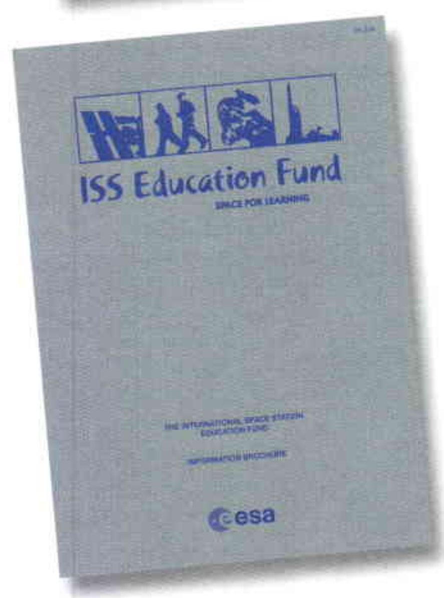
BUSINESS WITH ESA TELECOM (AUGUST 2003)
MENNING N. (ED. B. BATTRICK)
ESA BR-206 // 40 PAGES
PRICE: 7 EUROS

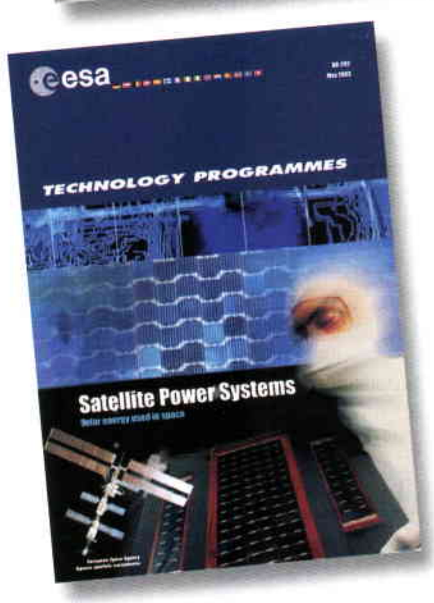
HARMONISATION OF EUROPEAN SPACE TECHNOLOGY – FROM CONCEPT TO MASTER PLAN (JUNE 2003)
– THE ESA TECHNOLOGY PROGRAMMES
BATTRICK B. (ED.)
ESA BR-203 // 12 PAGES
PRICE: 10 EURO

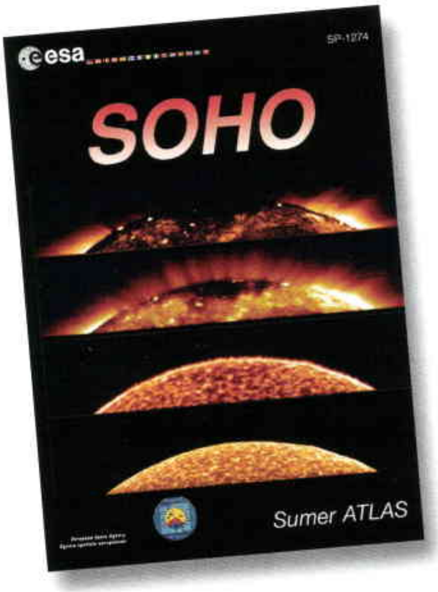
THE INTERNATIONAL SPACE STATION (ISS) EDUCATION FUND – INFORMATION BROCHURE (AUGUST 2003)
WARMBEIN B. (ED.)
ESA BR-204 // 12 PAGES
NO CHARGE

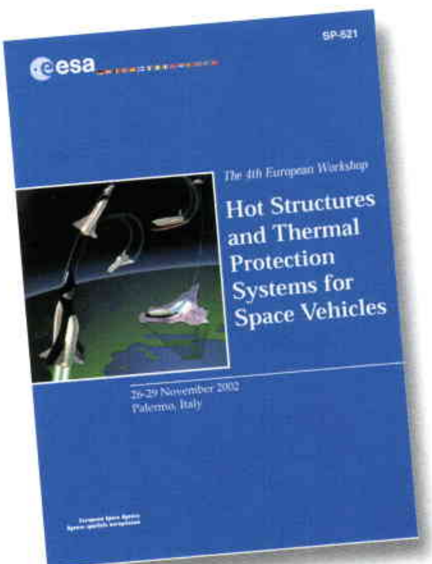


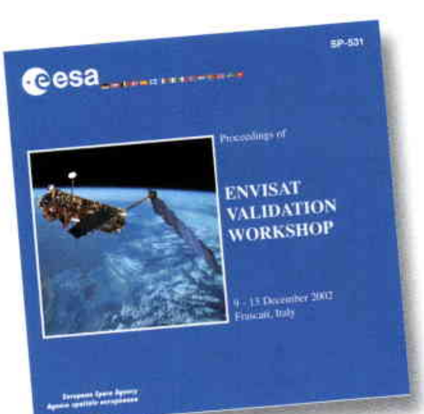












CD-ROM

ESA Special Publications

THE ISO HANDBOOK (AUGUST 2003)
VOL. I: ISO MISSION AND SATELLITE OVERVIEW
VOL. II: CAM – THE ISO CAMERA
VOL. III: LWS – THE LONG-WAVELENGTH SPECTROMETER
VOL. IV: PHT – THE IMAGING PHOTO-POLARIMETER
VOL. V: SWS – THE SHORT WAVELENGTH SPECTROMETER
SALAMA A. ET AL.
ESA SP-1262 // 1200 PAGES
PRICE: 150 EURO

ATLAS OF IMAGES OF THE SOLAR UPPER ATMOSPHERE FROM SUMER ON SOHO
FELDMAN U. ET AL. (ED. B. BATTRICK)
ESA SP-1274 // 244 PAGES
PRICE: 50 EURO

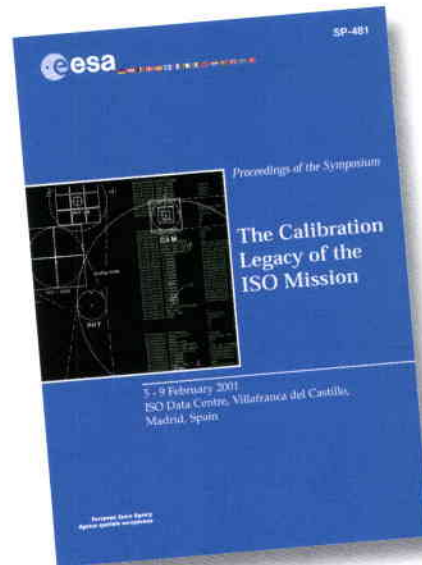
THE CALIBRATION LEGACY OF THE ISO MISSION – PROCEEDINGS OF THE WORKSHOP, 5-9 FEBRUARY 2001, VILSPA, SPAIN (MAY 2003)
METCALFE L. ET AL. (EDS.)
ESA SP-481 // 566 PAGES
PRICE: 50 EURO

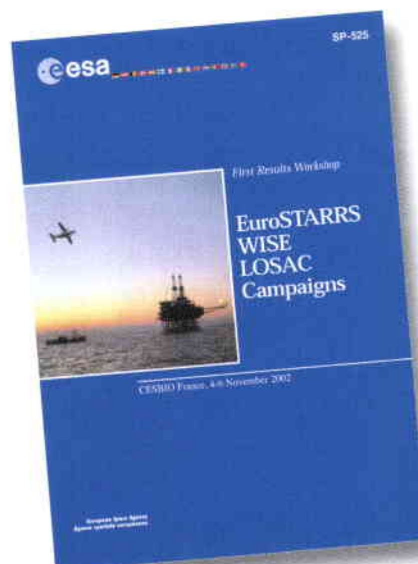
HOT STRUCTURES AND THERMAL PROTECTION SYSTEMS FOR SPACE VEHICLES – PROCEEDINGS OF THE 4TH EUROPEAN WORKSHOP, 26-29 NOVEMBER 2002, PALERMO, ITALY (APRIL 2003)
WILSON A. (ED.)
ESA SP-521 // 428 PAGES
PRICE: 50 EURO

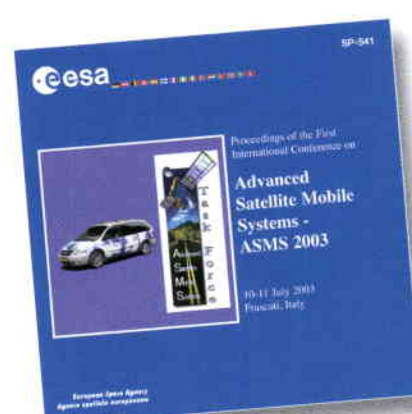
THE EUROSTARRS, WISE, LOSAC CAMPAIGNS – PROCEEDINGS OF THE FIRST-RESULTS WORKSHOP, 4-6 NOVEMBER 2002, TOULOUSE, FRANCE (MARCH 2003)
HARRIS R.A. (ED.)
ESA SP-525 // 262 PAGES
PRICE: 40 EURO

THE ENVISAT MISSION – PROCEEDINGS OF THE WORKSHOP, 9-13 DECEMBER 2002, FRASCATI, ITALY (AUGUST 2003)
LACOSTE H. (ED.)
ESA SP-531 // CD-ROM
PRICE: 40 EURO

ADVANCED SATELLITE MOBILE SYSTEMS: AMS 2003 – PROCEEDINGS OF THE FIRST INTERNATIONAL CONFERENCE, 10-11 JULY 2003, FRASCATI, ITALY (JULY 2003)
LACOSTE H. (ED.)
ESA SP-541 // CD-ROM
PRICE: 30 EURO







CD-ROM

ESA Procedures, Standards and Specifications

SPACE ENGINEERING – MULTIPACTION DESIGN AND TEST (MAY 2003)
ECSS SECRETARIAT
ESA ECSS-E-20-01A //28 PAGES
PRICE: 10 EURO

SPACE PROJECT MANAGEMENT – PROJECT BREAKDOWN STRUCTURES (JUNE 2003)
ECSS SECRETARIAT
ESA ECSS-M-10B //28 PAGES
PRICE: 10 EURO

SPACE PROJECT MANAGEMENT – PROJECT ORGANIZATION (JUNE 2003)
ECSS SECRETARIAT
ESA ECSS-M-20B //26 PAGES
PRICE: 10 EURO

ESA Contractor Reports

DELTASS – TRIAGE AND MEDICAL EMERGENCY DEMONSTRATION IN MOBILE FIELD HOSPITAL (MFH) – DEMONSTRATION REPORT (JANUARY 2003)
CNES, FRANCE
ESA CR(P)-4384 // CD-ROM
PRICE: 25 EURO

M-NOR – MULTI-NETWORK OPTIMISING ROUTER – FINAL REPORT (OCTOBER 2002)
GWT, GERMANY
ESA CR(P)-4381 // CD-ROM
PRICE: 25 EURO

esa

Credit Card Payments for ESA Publications

The Agency's publications can be purchased from the ESA Publications Division 'Bookshop' using your corporate or your personal credit card (Eurocard/ Mastercard, Visa or American Express).

You can telephone or telefax your orders to the numbers given below, quoting your card's number, security code (where applicable), and its expiry date.

The Bookshop
ESA Publications Division
ESTEC
Keplerlaan 1
2200 AG Noordwijk
The Netherlands

Telephone: (31) 71 565 3405 – Telefax: (31) 71 565 5433

Other methods of payment are also accepted. Please call or fax for details.

A list of past publications can be accessed via ESA Publications Division's Home Page at: *www.esa.int*

Contractor Reports

ESA CR(P) documents are also available on microfiche from either of the following addresses:

British Library - Doc. Supply Centre
Customer Service
Boston Spa
Wetherby, West Yorkshire
LS23 7BQ England

Universitaetsbibliothek und TIB
Welfengarten 1B
D-30167 Hannover
Phone: (+49) 511/762-2268
Fax: (+49) 511/715936

Fifth ESA/CNES International Workshop on

Applications of Pyrotechnics in Space Systems

ESTEC, Noordwijk, The Netherlands
21 – 23 October 2003

Aims

As previously, the aims of this Workshop are to stimulate discussion and exchange of ideas and to promote contacts between all those interested in or affected by the use of pyrotechnics in space systems.

Organisation

Presentations will be given by invited speakers on topics of special interest. Time will be made available for questions and discussion to explore these topics more fully. Further opportunities will be provided by several breaks. Any topics and questions raised will be welcomed for inclusion in the group discussions. Included in the programme will be presentations on contract work performed for ESA and CNES in their respective R&D programmes. Suggestions for subjects and proposals for individual presentations to be included are welcome. Please send details to the address below.

No fees are payable for this ESA/CNES Workshop. Registration and accommodation arrangements can be made when the Preliminary Programme is published. Forms for these purposes will be available in both paper and electronic form.

Programme

Topics to be covered will include: Reliability and Statistical Methods, Pyrotechnic Composition and Pyrotechnic Device lifetime, Shock Measurement and Testing, Approaches to Cost Reduction, Release Nut Development, Pyrotechnic Valve Development, Laser Ignition, Subsystem Design, Computer Simulation, Spacecraft Solid Propulsion, Testing, Standards for Pyrotechnics (ECSS, ISO, GTPS, etc.), Databases, Information Media, and current and future ESA and CNES activities.

Contact

Neil Cable
Thermal and Structures Division (TOS-MC)
ESTEC, PO Box 299
2200 AG Noordwijk, The Netherlands

E-mail: neil.cable@esa.int

Available from ESA Publications Division

Publication	Number of issues per year	Scope/Contents	Price	Source
Periodicals				
ESA Bulletin	4	ESA's house magazine	Free of charge	ESA Publications Division
Earth Observation Quarterly	4	Remote-sensing newsletter	"	"
Reaching for the Skies	4	Space Transportation System newsletter	"	"
On Station	4	Space Station and Microgravity newsletter	"	"
Preparing for the Future	4	Technology Programme newsletter	"	"
ECSL News	4	News from the European Centre for Space Law (under ESA auspices)	"	"
Monographs	**Code**			
Conference Proceedings	(SP-xxx)	Collections of papers presented at ESA conferences	Prices vary	ESA Publications Division
Special Publications	(SP-xxxx)	Detailed monographs on ESA programmes/projects	"	"
Brochures	(BR-xxx)	Concise summaries on ESA programmes/projects	"	"
Scientific & Technical Reports	(STR-xxx)	Reflecting ESA's position on a given subject	"	"
Scientific & Technical Memoranda	(STM-xxx)	Latest but not finalised thinking on a given subject	"	"
Procedures, Standards & Specifications	(PSS-xxx)	Definitive requirements in support of ESA contracts	"	"
Training Manuals	(TM-xxx)	Series for education of users or potential users of ESA programmes, services or facilities	"	"
Public-relations material		General ESA literature, posters photographs, films, etc.	ESA Communication Dept. 8-10 rue Mario-Nikis 75738 Paris 15, France	

All periodicals are also available via the Internet at:

http://esapub.esrin.esa.it/

Public-relations material and other ESA information is available at:

http://www.esa.int

Order Form for ESA Publications

No publications sent before receipt of payment in Euros (€).

No. of copies	ESA reference no.	Title	Price per copy/€	Total €
			Total amount:	

Mailing Address *(please print carefully):*

Name

Function Organisation

Address

Post Code Country

Date Signature

❍ Cheque enclosed (made payable to ESA Publications Division)

Return Order Form with cheque to: ESA Publications Division
P.O.Box 299 – 2200 AG Noordwijk – The Netherlands

❍ Items ordered are free of charge

Charge to: ❍ Eurocard/Mastercard* ❍ Visa ❍ AmEx

Card No. Expiry date:

*Mastercard: include Security Code located on back of card above signature - 3 digits

Card Holder's Name

Return Order Form to: The Bookshop – ESA Publications Division – ESTEC
P.O.Box 299 – 2200 AG Noordwijk – The Netherlands; Fax: +31 (0)71 565 5433

Telephone orders (and further information): +31 (0)71 565 3405

Payment *(please tick as appropriate):*

Information via e-mail: esapub@esa.int
Internet – a list of past publications: http://esapub.esrin.esa.it/

Member States

Austria
Belgium
Denmark
Finland
France
Germany
Ireland
Italy
Netherlands
Portugal
Norway
Spain
Sweden
Switzerland
United Kingdom

Etats membres

Allemagne
Autriche
Belgique
Danemark
Espagne
Finlande
France
Irlande
Italie
Norvège
Pays-Bas
Portugal
Royaume-Uni
Suède
Suisse

European Space Agency
Agence spatiale européenne

Contact: ESA Publications Division
c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Tel (31) 71 565 3400 - Fax (31) 71 565 5433
Visit ESA Publications at: http://www.esa.int