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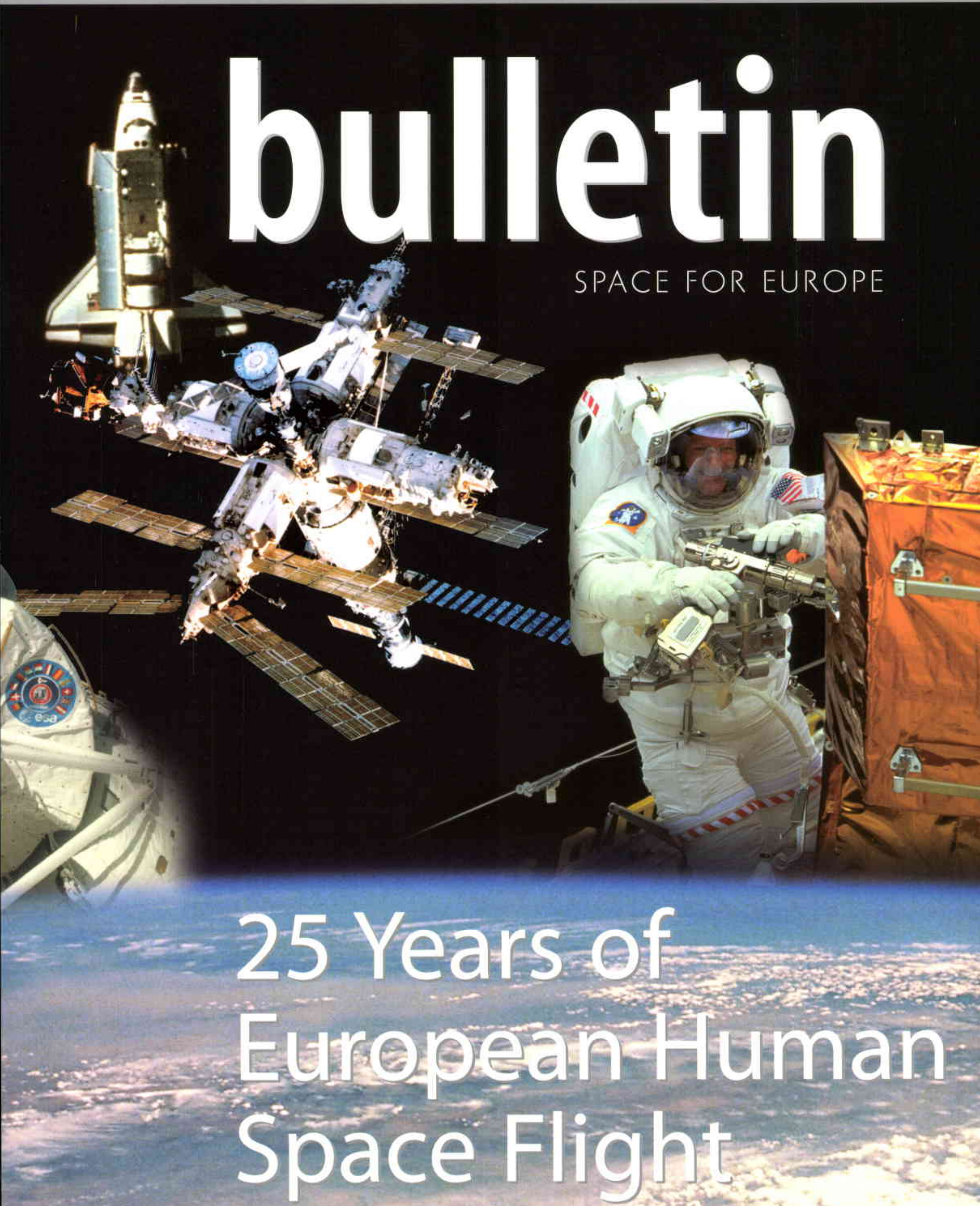
bulletin

SPACE FOR EUROPE



25 Years of European Human Space Flight

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

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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

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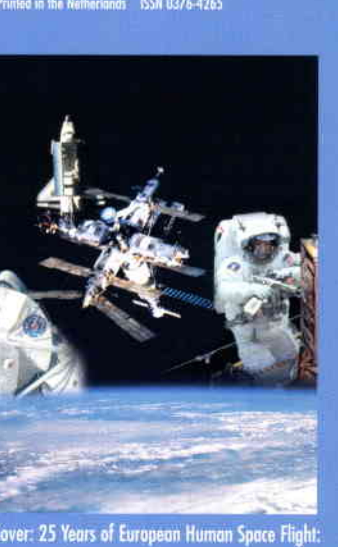

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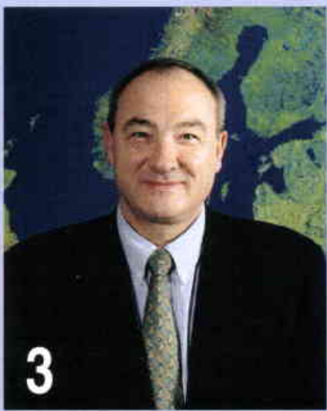

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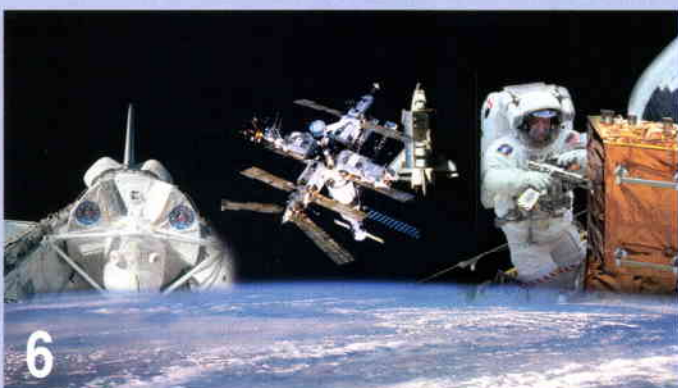

25 Years of European Human Spaceflight

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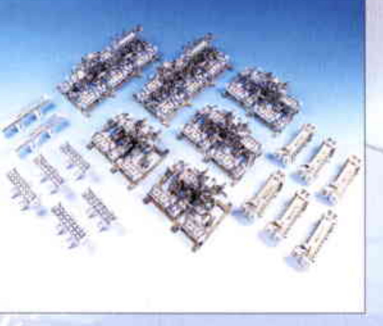

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Our track record includes participation in more than 45 programs satellites.

Alcatel Espacio is a Spanish subsidiary company of Alcatel Space Industries

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ESA's new Director General, Jean-Jacques Dordain, took office in July 2003. In September, he issued a four-year plan for the future of ESA called 'Agenda 2007'. In this interview he talks about the main points of how 'Agenda 2007' is going to change the roles of ESA, the European Union and European space industry.

After three months in office, you have issued a 41-page plan for the future of ESA in the next four years, called 'Agenda 2007'. Could you summarise the key points of this plan?

'Agenda 2007' is a big document, so naturally it is hard to sum up in a few sentences. At the moment we have the paradoxical situation in the space sector that the demand for space systems is going up while the public budget declines. On the one hand, every European citizen depends on space systems – I do not think that there is a single European who does not make use of space technology – and consequently the demand for systems is increasing. Because the European Union is enlarging its borders and widening its scope in the security domain, there is also new demand, for example to reduce the digital divide between old and new Member States. On the other hand, the public budgets dedicated to space are decreasing and space industry is in a crisis with its capability decreasing by around 30 percent. There is a clear discrepancy between increasing demand and decreasing supply. In 'Agenda 2007', I say that we have to close that gap. This largely depends on the relationship between ESA and the European Union, and the main objective of this relationship is the increase of resources for space to reconcile the supply with the demand. Our respective roles are clear: the EU is in charge of the demand, while ESA provides the solutions.

In recent years, restructuring in the European space industry has produced a small number of major players. How will 'Agenda 2007' change the scene for European space industry and what role does ESA play in strengthening its commercial competitiveness?

When we say we have to increase the resources dedicated to space, this implies that we have to reinforce the industrial capability in Europe and size it according to the demand. Industry is the condition *sine qua non* for providing solutions to the demand for space in Europe. Unfortunately, space is only a small element in a much wider context comprising aeronautics and the defence sector, and restructuring is not driven only by space. ESA has to make sure that future restructuring will not destroy capabilities that are necessary for developing and operating space systems. Another important role for ESA and Member State governments is to put European industry on an equal footing with international competitors in the commercial marketplace.

It is ESA's role to respond to the demand created by European citizens and for that we depend on industry for the supply. We have to make sure that industry is able to respond to the existing demands. One particular point where we can indeed help industry is to develop the technologies to make Europe more competitive. Europe is in a peculiar situation because industry cannot survive only on the money they receive from governmental programmes – the size of public programmes here is six to seven times smaller than in the United States.

The European Union will soon have ten new Member States. How will this influence cooperation between ESA and the EU?

The enlargement of the European Union will have tremendous effects on ESA. It increases the demand for space infrastructure, including the need to reduce the digital divide. Some new EU members will wish to join ESA, so we have to be ready and look at the conditions under which we could integrate them. These are important aspects for future collaboration.

With the first experiences in cooperating with the EU on the Galileo project, how will relations develop between our organisations in the coming years?

Of course, we are already successfully cooperating – the Galileo project is living proof of this – and we have to increase that cooperation. We need to increase resources for the further development of space systems, and a Framework Agreement between ESA and the European Commission with this content was adopted by the ESA Council on 12 November, after the EU Council had adopted it on 20 October. It was formally signed on 25 November. This Agreement provides the institutional framework to set up new programmes. As it is valid only for four years, however, we still need to

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further increase institutional relationships between ESA and the European Union. I believe that we must acquire legitimacy within the EU institutions. At the moment we are completely separated from them and cannot increase our cooperation without this legitimacy. We are therefore at the very beginning of the relationship between the EU and ESA.

How realistic is the envisaged 30% increase in ESA activities, based on an increased financial contribution from the EU?

The question is not whether this planned increase in activities is realistic, but what is demanded from us. I think 30% is the right order of magnitude. We need to take the increase step-by-step because more solutions mean more industrial capability and more competences, and we cannot increase these in one day. The increase is realistic in technical terms. As far as the budget is concerned, it really corresponds to the perceived demand.

Do you think that a dedicated Commissioner for space affairs and space budget could also be a solution for this? How important is this for ESA and the EU?

Of course it is not for me to define the new European Commission, but it is essential that there is a Commissioner not necessarily in charge of, but at least interested in space, like Commissioner for Research Philippe Busquin. The fact that he is interested in space has been instrumental in establishing the relationship between ESA and the European Community. However, in terms of meeting the demand, a space Commissioner alone is not sufficient – space covers many areas, such as transport, environment and security, and we need to maintain good relations with these officers as well. A Commissioner in charge of space is of course important to promote space within the Commission, but the demand stems from the individual policies. I am very happy with the White Paper that Commissioner Busquin presented on 11 November because it is fully coherent with 'Agenda 2007'. It is exactly what I was waiting for: it clearly states that there is a demand and it asks for the European Union to be more involved in space activities, including recruiting more resources.

You have mentioned the possibility of Russia becoming an Associate Member of ESA. What role does ESA play in drawing Russia closer to Europe?

In 'Agenda 2007', I propose that Russia becomes an Associate Member of ESA because it is Europe's neighbour. Russia has such a big potential in all areas of spaceflight and technology – and it is

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high time for us to have a closer relationship with them. A concrete example of that cooperation could be launching Soyuz from Kourou, but I personally think we need to go beyond mere cooperation and work together on an institutional basis.

Do you think ESA will cooperate more closely with China in the future?

China is already a large space power and has an impressive space capability. At the same time, they are a good customer for space infrastructure – in a country of that size and with such a population and huge economic growth and little ground infrastructure, there is certainly a high potential demand. They are a significant space player and we definitely cannot ignore them. Cooperation might be more difficult than with our long-standing partners the USA and Russia, but I do see possibilities, certainly within the Scientific Programme.

In your opinion, what problems does ESA currently have?

First of all, ESA has a long track record of successes in building up programmes, pulling together resources, development and operations. We have the ability to develop satellites, all of them successes, and launchers – achievements to be proud of. It is mainly thanks to ESA that European citizens can depend today on space-based products and services.

However, there are a few things that are limiting factors and are on the agenda for change. For example, ESA is funded almost exclusively by its Member States' research budgets, although our activities go far beyond research and development alone. At the moment, as I have already said, we are not part of the EU institutions and framework, but I think we are starting to remove this obstacle with the Framework Agreement. Clearly, however, we need closer bonds with the EU.

Thirdly, ESA is not involved in security and defence issues at the moment, and I think this should be changed, as there is no fundamental technological difference between civil and defence systems. The best examples are GPS, a US military system used for civil purposes, and Galileo, a civil system that will also be used by the defence community. In that sense, I would like ESA to be involved in the procurement of the space segments required by the defence sector. However, this is more extending rather than correcting the scope of ESA. We do not need to do different things, but to respond to the demand and do more and extend the scope.

Is it planned to perform future Earth Observation missions in cooperation with other agencies, such as the United States?

I think there will be more Earth Observation missions, but this is again a question of demand. We need to respond to the environment and security policies of our Member States. These cannot exist without a certain space infrastructure. We do not do Earth Observation and increase activities to please our own engineers, but because there is a strong demand from the outside. One of my maxims is 'Don't propose solutions without a problem!' This means that we have to understand the problem and the demand first, and only then design a solution.

How high is education on your list of priorities?

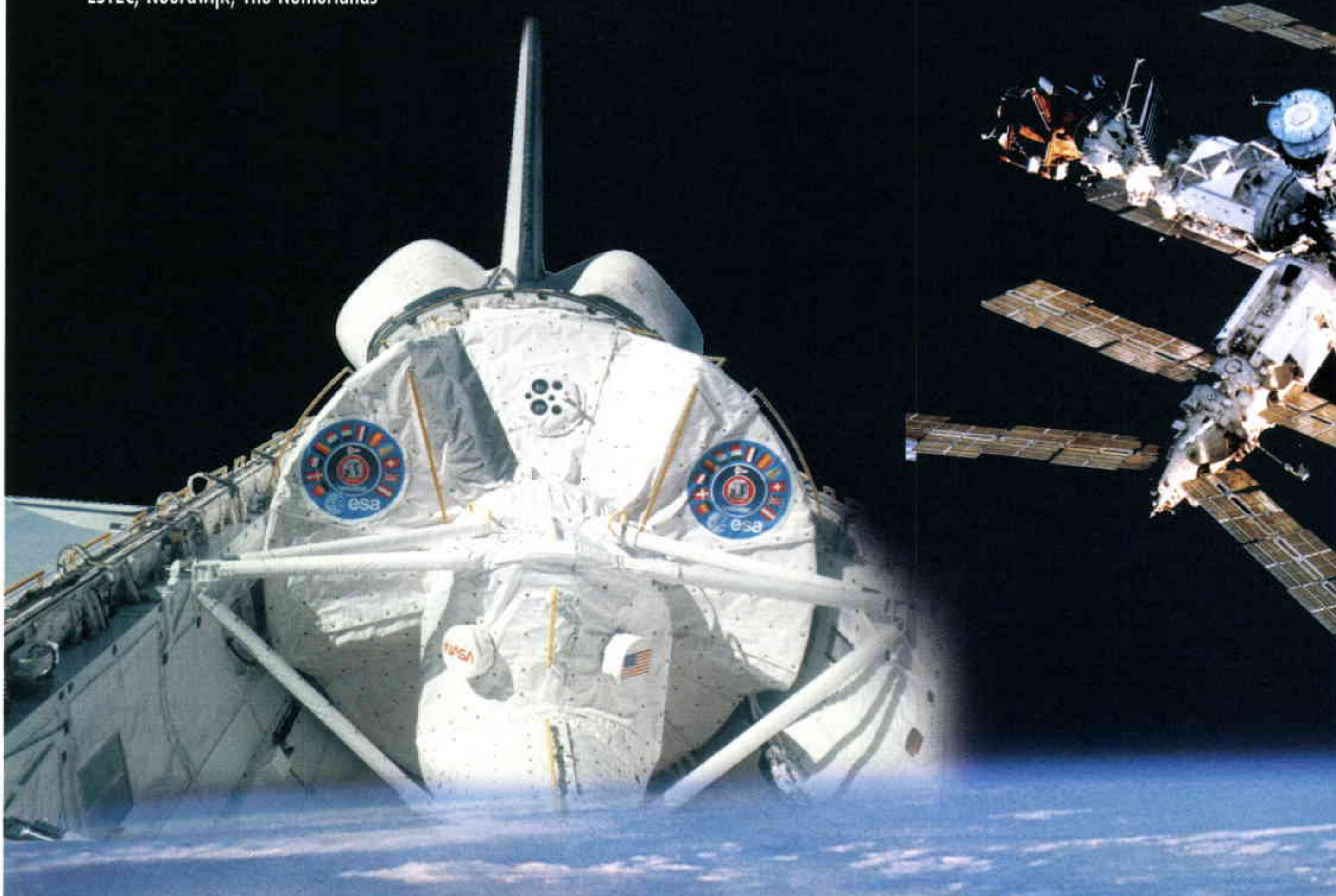
Education is a very, very important aspect for ESA. There is no space activity without scientists and engineers, and I must say that I am scared by the fact that interest in science is declining in most developed countries. In 20 years from now, this could really become a bottleneck, and ESA cannot wait until then – we have to address this problem as soon as possible. Tomorrow's engineers are still at school – even still at primary school – today. ESA is not in charge of education itself, but we can provide space-related tools to educators in Europe that could contribute to the revival of the attractiveness of science and engineering. Every schoolgirl and -boy is interested in space – astronauts, rockets and satellites, parabolic flights, everything – and we have to make sure that we provide a knowledge base so that we do not find ourselves without a skilled workforce in 20 years!

What is the relative value of manned and unmanned missions in the framework of 'Agenda 2007'?

Human spaceflight is now part of life and part of the history of mankind, and it goes far beyond space activities alone. Our curiosity did not come with the arrival of space activities, but long before that. Mankind has always been curious and we will definitely continue to explore space and send astronauts into space. At the moment, we in Europe are dependent on US and Russian flights, which means human spaceflight cannot be our number one priority. Because we have a lot to do to respond to the demands on Earth, I am doubtful that we can become independent of our partners soon. We are also dependent on our partners for the schedule for assembling the ISS. This, however, does not mean we will stop activities; on the contrary, I am convinced that human spaceflight is still at a very early stage and that we will never stop exploring.

25 Years of European Human Spaceflight

Jörg Feustel-Büechl
ESA Director of Human Spaceflight, Research and Applications,
ESTEC, Noordwijk, The Netherlands



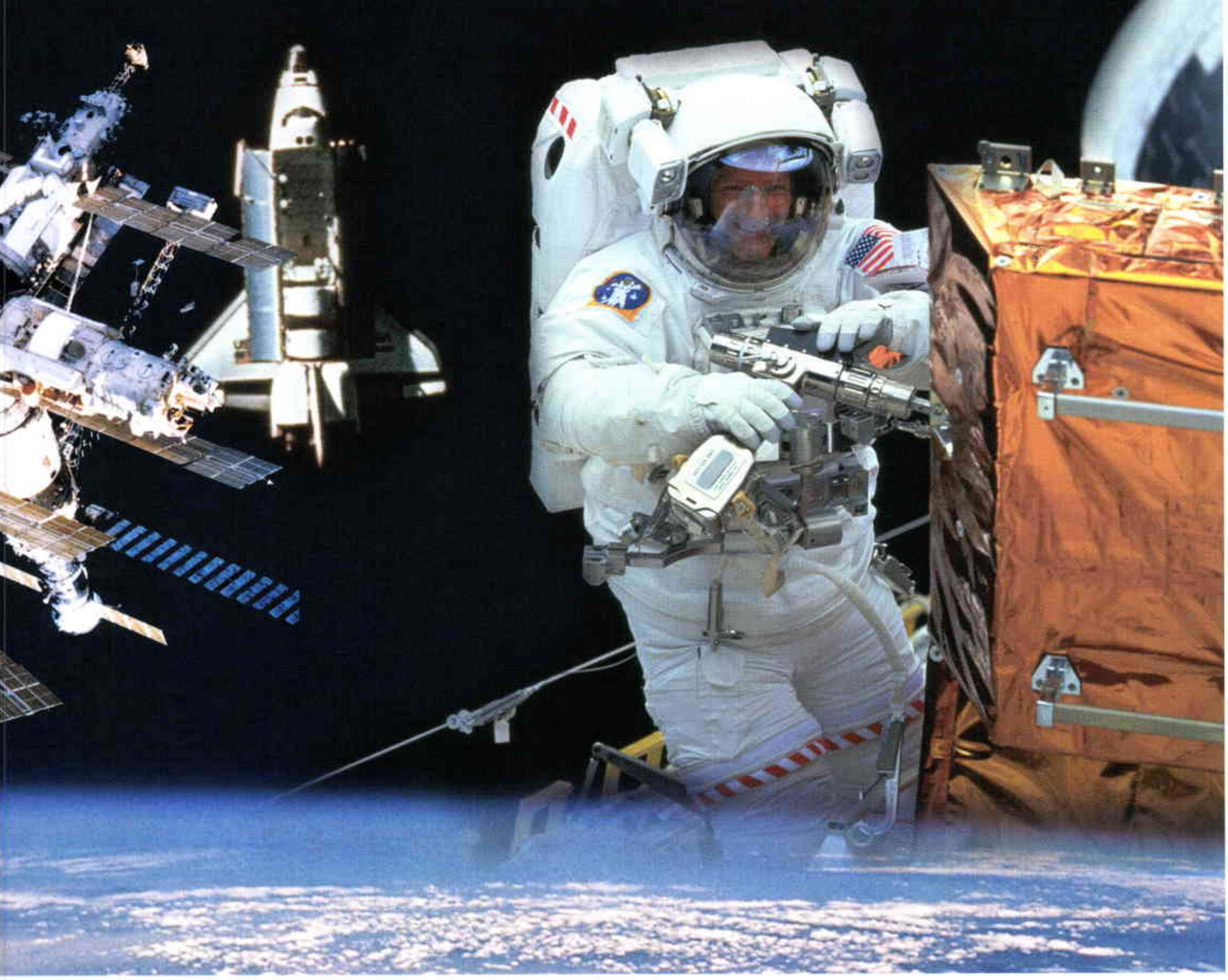
Just a few weeks ago, on 28 August 2003, in the company of the President of the Federal Republic of Germany, Johannes Rau, we celebrated the 25th Anniversary of Sigmund Jähn's flight to the Russian Salyut 6 space station aboard a Soyuz spacecraft. This flight lasted from 26 August until 3 September 1978 and was actually the third flight by a European astronaut, following those of Czechoslovakia's Vladimir Remek and Poland's Miroslav Hermascewski in 1978.

This year we also celebrate the 20th Anniversary of the first Spacelab flight (STS-9) with the ESA astronaut Ulf Merbold, who was in orbit from 28 November until 8 December 1978, together with five American astronauts. He had trained for more than five years for that flight, together with his ESA colleague Wubbo Ockels who served as his back-up.

A total of 44 missions involving 30 astronauts from ESA Member States have taken place, 26 of which were performed in co-operative programmes with NASA, whilst 18 flights used Russian space vehicles.

Two more missions are presently planned, one with the Soyuz vehicle and one with the Space Shuttle, all to the International Space Station (ISS). With an average of two flights taking place per year and a good balance of cooperative missions with Russia and the United States, Europe has achieved a high level of astronaut missions with outstanding scientific results and operational experience.

The integration of all European astronauts into a single European Astronaut Corps, presently comprising 15 astronauts, and the creation of an EAC Team made up of experts from several Member States and ESA, has created an efficient support organisation enabling Europe to master future missions and their effective preparation.



Cosmonauts and astronauts during the celebration of "25 Years of German Spaceflight" in August 2003, together with German President Johannes Rau and Edelgard Bulmahn, Minister of Education and Research (fourth and second from right in front row)

The Beginnings

The start of Europe's involvement in human spaceflight activities dates back to 1969, when NASA invited ESA to participate in the Post-Apollo Programme. In December 1972, Europe opted to develop the modular Spacelab system as an integral element of the US Space Transportation System. The maiden flight of Spacelab in November 1983 saw the first ESA astronaut, Ulf Merbold, venturing into space as the first non-American astronaut on a US space vehicle.

In 1971, while in the USA the Apollo Programme was still in full swing, the Soviet Union had launched and tested its first space station, Salyut 1. After making several modifications to the following Salyuts, the second-generation Salyut 6 and 7 stations appeared in 1977 and 1982, respectively. With an additional docking port to receive the unmanned Progress logistics spacecraft, the crews could stay aboard the station for a longer period, and visiting crews were able to join them. Cosmonauts mainly from other Soviet-bloc countries were invited during the 'Intercosmos Programme' to visit the stations. The first non-Russian was Vladimir Remek from Czechoslovakia in 1978, and the third was the German Sigmund Jähn from the German Democratic Republic in the same year.

Signing of the Memorandum of Understanding for implementation of the Spacelab programme on 24 September 1973

Ulf Merbold during the Spacelab-1 mission

Until the disintegration of the Soviet Union, the Russian-built space stations hosted other astronauts from ESA Member States, selected and trained for their missions through their national space agencies. The first of them was the Frenchman Jean-Loup Chrétien from CNES, who visited Salyut 7 in 1982.

The subsequent years were characterised by cooperative programmes between the two providers of human-rated transportation systems, the USA with its Space Shuttle and Russia with its Soyuz rocket on one side, and ESA, national agencies and even private ventures, with Helen Sharman as the first female European cosmonaut to visit Mir (in 1991), on the other.

The time after the first recruitment of European astronauts in 1977 by ESA, followed by the establishment of astronaut offices at CNES and DLR in 1980 and 1983, respectively, saw the cooperation between ESA and NASA grow within the Spacelab development and utilisation plan, and thus also the training of ESA astronauts as mission and payload specialists to fly on the Space Shuttle. During this period, DLR had its own cooperative bilateral programmes with N exploiting its national Spacelab-D1 and D2 missions. Also, CNES had a strong cooperative programme, with its astronauts flying on both the Russian and the US space vehicles.

Altogether, therefore, ESA, CNES and DLR astronauts made a number of such cooperative flights with the USSR/Russia on the Soyuz rocket to the Russian Salyut and Mir space stations, and with NASA on the Space Shuttle for science, satellite deployment and repair missions, and missions to the Mir space station and lately to the ISS.

When US President Ronald Reagan first announced the Space Station (called 'Freedom' at that time) project in 1984 and invited in following years the active participation of Europe, Japan and Canada, ESA began its own ambitious programme, encompassing the Columbus Programme with the Attached Pressurised Module for the Space Station, the Man-Tended Free Flyer, the serviceable Polar Platform and the manned Hermes spaceplane. In addressing the resulting long-term need for astronauts, ESA also established the European Astronaut Centre (EAC) in 1990 in Cologne (D), and initiated its second astronaut-selection process a year later. Only in 1998 did the ESA Council decide to create a single European Astronaut Corps by integrating astronauts from the Member States' national space agencies into the existing ESA Astronaut Corps.

Hence the legacy of Human Spaceflight in Europe is now being carried forward by ESA, based on the heritage of 44 astronaut missions with 30 European astronauts on 37 missions, 19 with the Space Shuttle and 18 with the Soyuz transportation system.

Milestones in Human Spaceflight

12 April 1961	1st human in space:	Yuri Gagarin
21 July 1969	1st human on the Moon:	Neil Armstrong
2 March 1978	1st European in space:	Vladimir Remek (CSR)
Nov/Dec. 1983	1st ESA astronaut in space:	Ulf Merbold (Spacelab-1)
May 1990	Birth of European Astronaut Centre (EAC)	
Sept. 1995/Feb. 1996	Longest European spaceflight:	Thomas Reiter (Mir)
March 1998	Formation of the single European Astronaut Corps, integrating all ESA Member State astronauts	
April/May 2000	First European visit to the ISS:	Umberto Guidoni (STS-100)

ESA and ESA Member State Astronauts in Space

Ass.	Name	Fl#	Organisation	Mission Programme/ Payload	Space Vehicle(s)	Year
1	(1) S. Jähn (D)	1	IKF (former GDR)	Interkosmos	Soyuz-31 / Salyut-6 / Soyuz-29	26 Aug. – 03 Sep. 1978
2	(2) J.-L. Chrétien (F)	2	CNES	Premier Vol Habité	Soyuz T-6 / Salyut-7	24 Jun. – 02 Jul. 1982
3	(3) U. Merbold (D)	3	ESA	Spacelab-1	STS-9	28 Nov. – 08 Dec. 1983
4	(4) P. Baudry (F)	4	CNES	Spartan-1	STS-51 G	17 Jun. – 24 Jun. 1985
5	(5) R. Furrer (D)	5	DFVLR	Spacelab-D1	STS-61 A	30 Oct. – 06 Nov. 1985
6	(6) E. Messerschmid (D)		DFVLR			
7	(7) W. Ockels (NL)		ESA			
8	(2) J.-L. Chrétien (F)	6	CNES	Aragatz	Soyuz TM-7 / Mir / Soyuz TM-6	26 Nov. – 21 Dec. 1988
9	(8) H. Sharman (UK)	7	Private Funding	Juno	Soyuz TM-12 / Mir / Soyuz TM-11	18 May – 26 May 1991
10	(9) F. Viehböck (A)	8	ASA	Austromir	Soyuz TM-13 / Mir / Soyuz TM-12	02 Oct. – 10 Oct. 1991
11	(3) U. Merbold (D)	9	ESA	Spacelab International Microgravity Lab IML-1	STS-42	22 Jan. – 30 Jan. 1992
12	(10) K.-D. Flade (D)	10	DARA / DLR	Mir'92	Soyuz TM-14 / Mir / Soyuz TM-13	17 Mar. – 25 Mar. 1992
13	(11) D. Frimout (B)	11	Belgium	ATLAS-1	STS-45	24 Mar. – 02 Apr. 1992
14	(12) M. Tognini (F)	12	CNES	Antares	Soyuz TM-15 / Mir / Soyuz TM-14	27 Jul. – 10 Aug. 1992
15	(13) F. Malerba (I)	13	ASI	Eureca-1, Tethered Satellite System	STS-46	31 Jul. – 08 Aug. 1992
16	(14) C. Nicollier (CH)		ESA			
17	(15) H. Schlegel (D)	14	DARA / DLR	Spacelab-D2	STS-55	26 Apr. – 06 May 1993
18	(16) U. Walter (D)					
19	(17) J.-P. Haigneré (F)	15	CNES	Altaïr	Soyuz TM-17 / Mir / Soyuz TM-16	01 Jul. – 22 Jul. 1993
20	(14) C. Nicollier (CH)	16	ESA	Hubble Telescope 1st Servicing Mission	STS-61	02 Dec. – 13 Dec. 1993
21	(3) U. Merbold (D)	17	ESA	Euromir 94	Soyuz TM-20 / Mir / Soyuz TM-19	03 Oct. – 04 Nov. 1994
22	(18) J.-F. Clervoy (F)	18	ESA	ATLAS-3; CRISTA SPAS 1	STS-66	03 Nov. – 14 Nov. 1994
23	(19) T. Reiter (D)	19	ESA	Euromir 95	Soyuz TM-22 / Mir	03 Sep. '95 – 29 Feb. 1996
24	(14) C. Nicollier (CH)	20	ESA	Tethered Satellite System-1 Reflight USMP-3	STS-75	22 Feb. – 09 Mar. 1996
25	(20) M. Cheli (I)					
26	(21) U. Guidoni (I)		ASI			
27	(22) J.-J. Favier (F)	21	CNES	Spacelab LMS-1	STS-78	20 Jun. – 07 Jul. 1996
28	(23) C. André-Deshays (F)	22	CNES	Cassiopée	Soyuz TM-24 / Mir / Soyuz TM-23	17 Aug. – 02 Sep. 1996
29	(24) R. Ewald (D)	23	DARA / DLR	Mir'97	Soyuz TM-25 / Mir / Soyuz TM-24	10 Feb. – 02 Mar. 1997
30	(18) J.-F. Clervoy (F)	24	ESA	6th Shuttle flight to Mir	STS-84	15 May – 24 May 1997
31	(2) J.-L. Chrétien (F)	25	CNES	7th Shuttle flight to Mir	STS-86	25 Sep. – 06 Oct. 1997
32	(25) L. Eyharts (F)	26	CNES	Pégase	Soyuz TM-27 / Mir / Soyuz TM-26	29 Jan. – 19 Feb. 1998
33	(26) P. Duque (E)	27	ESA	SpaceHab	STS-95	29 Oct. – 07 Nov. 1998
34	(17) J.-P. Haigneré (F)	28	CNES, ESA	Perseus	Soyuz TM-29 / Mir	20 Feb. – 28 Aug. 1999
35	(12) M. Tognini (F)	29	CNES	Chandra X-Ray Observatory	STS-93	22 Jul. – 27 Jul. 1999
36	(14) C. Nicollier (CH)	30	ESA	Hubble Space Telescope 3rd Servicing Mission	STS-103	19 Dec. – 27 Dec. 1999
37	(18) J.-F. Clervoy (F)					
38	(27) G. Thiele (D)	31	DLR, ESA	Shuttle Radar Topography Mission	STS-99	11 Feb. - 22 Feb. 2000
39	(21) U. Guidoni (I)	32	ESA	9th ISS flight (6A) Raffaello MPLM	STS-100	19 Apr. - 01 May 2000
40	(23) C. Haigneré (F)	33	CNES, ESA	Andromède – ISS flight	Soyuz TM-33 / Soyuz TM-32	21 Oct. - 31 Oct 2001
41	(28) R. Vittori (I)	34	ASI, ESA	Marco Polo	Soyuz TM-34 / Soyuz TM-33	25 Apr. – 05 May 2002
42	(29) P. Perrin (F)	35	CNES	ISS flight UF-2	STS-111	05 Jun. - 19 Jun. 2002
43	(30) F. De Winne (B)	36	Belgium, ESA	Odissea	Soyuz TMA-1 / Soyuz TM-34	30 Oct. – 10 Nov. 2002
44	(26) P. Duque (E)	37	Spain, ESA	Cervantes	Soyuz TMA-3 / Soyuz TMA-2	18 Oct. – 28 Oct. 2003
Mission assignments						
45	(31) A. Kuipers (NL)	38	Netherlands, ESA	Delta; back-up: (27) G. Thiele (D)		April 2004
46	(32) C. Fuglesang (S)	39	ESA	ISS assembly flight 12-A.1	STS-116	2005

30 European astronauts participated in 37 spaceflight missions, the sum of missions for all astronauts is 44
Flown as astronauts: D: 10; F: 9; I: 4; B: 2; NL: 2; A: 1; CH: 1; S: 1; E: 1; UK: 1 (including current assignments)
Assignments per Country: F: 16; D: 13; I: 5; CH: 4; B: 2; E: 2; NL: 2; A: 1; UK: 1; S: 1

Status November 2003

Cooperative Programmes with NASA

Umberto Guidoni, Mission Specialist on STS-100, training at the NASA Johnson Space Center

Within its cooperative programmes, and subject to the constraints of the Space Shuttle schedule, mission objectives and overall operations requirements, NASA offered 'best effort' flight assignments to ESA and national agency astronauts working and training at its Johnson Space Center in Houston. As far as possible, NASA treats these astronauts, once accepted and integrated into the NASA Astronaut Office, just like US astronauts in terms of flight assignments. In the past, its goal was to assign astronaut candidates to their first flight within three years of successful completion of their 'Basic Training'.

In this context, NASA and ESA have always recognised and supported the objective of a joint astronaut training approach under a 'Mission Specialist Training Agreement', to ensure the availability of qualified Mission Specialist members of the European Astronaut Corps as a key element in the continued success of ESA/NASA cooperation. This cooperation has led in the past to space flights developed through joint programmes such as Spacelab, Eureca, Hubble Space Telescope, Tethered Satellite, SRTM and MPLM, involving NASA, ESA and the ESA Member States, and now most recently the International Space Station.

Spacelab was the result of negotiations in which contributions to the Space Shuttle Programme and elements of space stations were discussed. Europe, at that time represented by the European Space Research Organisation (ESRO, which was ESA's predecessor), focused more and more on the development of a space laboratory in which scientific missions of up to nine days' duration could be conducted. The laboratory's initial design was as a 'Sortie Can' to be carried into orbit in the Space Shuttle's cargo bay. Its initially agreed free-flying mode was later abandoned, and it thus became 'Spacelab'. Unlike Skylab, the first US space station which had been integrated mostly from existing Apollo hardware and was launched in 1973, Spacelab was a new construction offering a much wider range of applications.

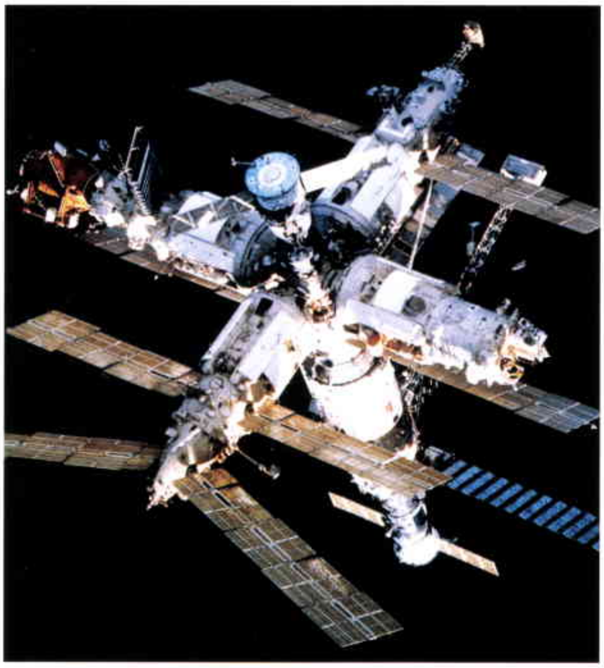
As a result of its numerous missions, Spacelab turned out to be the most important and most frequently flown Shuttle payload system to date. Between 1982 and 1998, when the Spacelab Programme was terminated after the NASA Neurolab mission, the Long Module of Spacelab flew 16 times, primarily for life and physical sciences payloads, and Spacelab Pallet-only missions were flown six times, primarily for disciplines like astronomy, astrophysics and atmospheric physics. Together with the non-ESA astronauts, nine Europeans worked aboard Spacelab, as researchers and systems and payload specialists.

Cooperative Programmes with the Soviet Union/Russia

The first generation of Soviet space stations, from Salyut 1 to Salyut 5, was characterised by a number of technological and operational achievements important for the sustained operation of space stations, but also by a number of failures. Although Salyut 1 was launched and tested successfully, this first mission ended tragically when all three cosmonauts lost their lives following the sudden decompression of their Soyuz capsule during reentry. After a brief pause and several redesigns, the crewed flights to the Salyut stations were resumed.

The second-generation Soviet space station Salyut 6 (1977-82) received 16 crews, carried aloft by 12 Progress capsules, and Salyut 7 (1982-1991) 10 crews, transported by 13 Progress capsules with 25 tonnes of equipment and propellant. Each of these

ESA astronauts Reinhard Furrer (left) and Wubbo Ockels conducting experiments during the Spacelab-D1 mission in 1985 stations hosted six long-duration flights, in which the stays onboard were increased from 185 days (Salyut 6) to 237 days. Thanks to the additional Progress logistics craft, many science-trained astronauts from Soviet-bloc countries were able to visit the two stations as part of the Interkosmos Programme. Vladimir Remek (CZ), Miroslav Hermascewski (PL) and Sigmund Jähn (GDR) were followed as non-Russian cosmonauts by G. Ivanov from Bulgaria in 1979, B. Farkas from Hungary in 1980, and D. Prunariu from Romania in 1981. The CNES astronaut Jean-Loup Chrétien followed in 1982 as the first astronaut from an ESA Member State to visit the Salyut station.



The Mir station

In February 1986, the third generation of Russian space stations was introduced with the launch of the Mir core module, and five other modules, Kvant (1987), Kvant 2 (1989), Kristall (1990) Spektr (1995) and Priroda (1996), followed. Unlike the earlier stations, Mir had at its front end a six-fold berthing adapter, which meant that four additional modules, besides Soyuz and Progress spacecraft, could be attached.

By 1990, the T-shaped Mir station measured 33 m in length, was 28 m high, and had an overall mass of 70 tonnes. However, the Soviet Union's political and social restructuring was already giving rise to public discussion about the aims and objectives of manned spaceflight. After the Union's dissolution this discussion continued, leading ultimately to the cancellation of the Buran spaceplane and Energia heavy-lift launcher programmes. Thus only one of the three main programmes survived, the Mir space station. Except for two short breaks, from July 1986 to February 1987 and from April to September 1989, this station was permanently crewed until just a few weeks before its de-orbiting in March 2001. European Astronauts made a total of 12 missions to Mir, including the record 179-day flight by Thomas Reiter in 1995/96.

Thomas Reiter during his mision aboard Mir in November 1995

Current and Future Activities at the European Astronaut Centre

The roots of ESA's European Astronaut Centre (EAC) in Cologne (D) reach back to 1977. At that time, the Agency's first four astronauts were selected, following a pre-selection process by the Member States, for training for the Spacelab-1 mission. The Centre was formally created, to meet the developing long-term need for astronauts, in May 1990, when the Host Agreement between ESA and the German national authorities was signed.

EAC rapidly became the home base for all European astronauts, following the selection of six more astronaut candidates in 1992. As Hermes, the Free-Flyer and the Polar Platform had all been cancelled by then, the Centre focused on supporting ESA's astronauts assigned to International Space Station precursor missions aboard the Shuttle/Spacelab and Mir. Their training programme was developed in close cooperation with NASA and Russia's Gagarin Cosmonaut Training Centre, and was first applied to the payload training for the Euromir-94/95 missions.

A key milestone for EAC was the ESA Council decision in March 1998 to integrate all European astronauts henceforth into a single European Astronaut Corps. This integration process, recently finally completed, has resulted in a Corps of presently 15 astronauts. Its structure, including the number and age distribution of the astronauts,

The European Astronaut Corps. From left-front: Duque, Thiele, Clervoy, Guidoni, Eyharts, Ewald, Vittori and Nicollier. From left-back: Nespoli, Reiter, Fuglesang, De Winne, Tognini (left Corps in May 2003 to become Head of Astronaut Division, EAC), Schelgel, Perrin and Kuipers

is driven by the capabilities required to support European human spaceflight missions for the pursuit of space exploration, science and technology, and their applications, consistent with approved and planned funding, and with particular emphasis on flights to the ISS.

In parallel with the coming together of Europe's astronauts, an expert staff for astronaut training and medical support was also assembled at EAC, with team members being seconded from the German, French and Italian space agencies. Started in April 2000 for an initial period of 4 years, this initiative has recently been extended until 2007. This very successful cooperative endeavour covers all aspects of astronaut activities, such as the management of the European Astronaut Corps, the training of ISS-bound astronauts from ESA and all of the Partners, and the necessary medical support.

The formation of the single European Astronaut Corps and the build-up of the EAC Team were important decisions that have ultimately provided Europe with an organisation matching its responsibilities as an ISS Partner and allowing for significant savings in the national budgets. However, an updating of the originally established European Astronaut Policy was eventually needed to take into account many new developments, including the expected number of flight opportunities, the evolution of the ISS programme and the Station's commercial utilisation aspects, together with the inclusion of tools for flexible management of the Corps.

In June 2002, therefore, the ESA Council approved an updated Policy, including such important aspects as: Selection and Recruitment, Mission Assignment, Management of the Astronaut Corps, Astronaut Public Appearances, Support to Commercialisation, Nationally Sponsored Missions, Other Roles for European Astronauts, and National Agency Support to EAC. With this updated Policy, there are now clear guidelines in place for the future activities of the Centre, with training focusing for the next decade on the preparations for and execution of astronaut missions to the ISS, be they short-duration (about 2 weeks) or full-increment (up to 6 months) missions, either with Soyuz vehicles or with the Space Shuttle.

Apart from being the home base of the European astronauts and the management and technical base for ESA's astronaut activities, EAC has become the focal point for all ISS astronaut training on European elements of the Space Station, including the Columbus module, its onboard scientific facilities, and the ATV. These activities have already started and will reach their peak in 2004.

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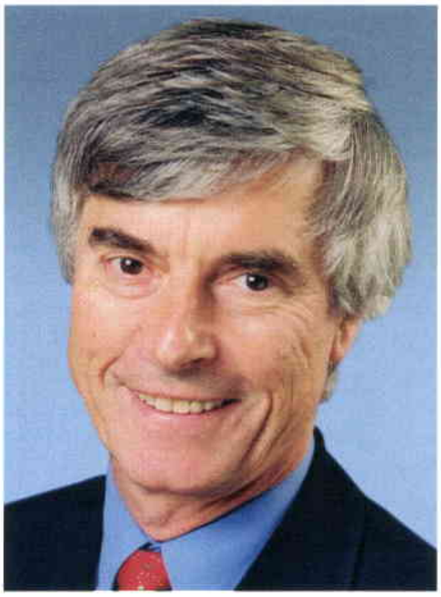

Ulf Merbold, born in June 1941 in Greiz, Germany, was the first ESA astronaut to fly in space and the first non-American aboard a US spacecraft. Twenty years ago, from 28 November to 8 December 1983, Merbold flew on the Space Shuttle as a Payload Specialist for the NASA-ESA Spacelab-1 mission. He returned to space in January 1992 for the Shuttle's IML-1 International Microgravity Laboratory Spacelab mission, and he then became the first ESA astronaut aboard Russia's Mir space station for the Euromir-94 mission of 3 October to 4 November 1994.

In spaceflight, has anything changed significantly since you first went up on Spacelab-1 in 1983 as the first ESA astronaut?

Yes – today, we have a very different and in my opinion better situation. First and most important of all is that the Cold War is now history and that consequently the major space powers have moved from confrontation to cooperation. All countries that have a potential to fly to space are involved in constructing the International Space Station (ISS). And on a more scientific and less political level: the ISS is a reality, it is a laboratory that is available to scientists not only for a few days, but for long periods of time – and they are using it 24 hours a day hopefully for the next 15 years.

Another very recent important change is that China has just launched its first 'taikonaut'. This should lead to a more intensified initiative in Europe than there has been in the last ten years – either to cooperate with China or to push European research and development. A new crew capsule from Europe, for example, would make the ISS much more valuable. We do not have a rescue system on the ISS that could bring six or seven astronauts and cosmonauts back to Earth in an emergency. Ignoring the impact of the *Columbia* catastrophe, there is only capacity for a crew of three onboard ISS in the near future. A rescue capsule would mean a crew of six or seven and more time and manpower for science, and at the same time it would upgrade Europe from a junior partner to a major player on an equal footing with the United States and Russia.

As far as science is concerned, Europeans are well established and recognised in this field. This was already the case at the time of Spacelab. Our experiments – past and future ones – are at least of the same quality as US experiments, if not better. On Spacelab, we had 72 experiments from a huge variety of scientific disciplines – plasma physics, earth observation, atmospheric physics, material sciences, physiology, astrophysics and many more. Resources, including astronaut time and energy, were shared equally between the US and Europe, even though there were 13 American and 59 European instruments. Although in comparison this meant an advantage in resources for the Americans, our experiments were more sophisticated and extremely well prepared, so they delivered the more impressive results!

How and why did you become an astronaut?

I have a strong curiosity and I love science. I worked for ten years in the Max Planck Institute for Metals Research in Stuttgart, studying point defects in metals in the field of experimental solid-state physics. It was a fascinating time because Max Planck Institutes are leading scientific institutions in Germany. However, I did not like concentrating on a single narrow field of science in order to be efficient and create new scientific knowledge. Science nowadays is such a tremendously vast field that it is impossible for one single human being to know everything. I was about 35 or 36 and felt that I was at a point in life to take a strategic decision, either to continue in my career and become a professor or to add new disciplines to what I knew already. I browsed through weekend newspapers and came across an ad where the German Aerospace Centre (DLR) on behalf of ESA announced the opportunity to fly on the first Spacelab mission as a payload specialist. In terms of scientific fields this was a very colourful and attractive programme. I loved flying anyhow, and so I applied. After one year I signed my ESA contract to become one of the first three ESA astronauts – and I do not regret this!

At that time it was still not certain whether human spaceflight would be accepted as a permanent programme within ESA or whether it would be terminated after Spacelab-1. There were times when I did not feel secure, but it was a great endeavour. It was fascinating to work with so many different scientists, to talk to and learn from so many people from different backgrounds. Wubbo Ockels and I put our noses into all of the various fields – vestibular research, plasma research (trying to produce artificial northern lights by firing powerful electron beams into the atmosphere), biology, physiology, etc.

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Space – Where Humans Make a Difference...

Twenty years since Spacelab-1! I remember the hard work, the excitement, the anticipation of great things, but also the concern about events possibly going wrong on this mission at the end of 1983. This was really a pioneering effort. The first time that ESA, NASA, aerospace industry groups and a large number of scientist teams from all over Europe and the United States worked together on a human spaceflight with the Shuttle freshly out of its official orbital test phase (and we know now that it never really got out of this test phase, even after more that 100 flights...), a laboratory made in Europe on its first flight, and an array of scientific experiments covering all disciplines of the space sciences. What a challenge! And what a success! I really think that Spacelab-1 set a positive tone for all the Shuttle-based space science missions that followed, and there were many of them. My congratulations to the whole team, and my gratitude for proving a capability that had never been demonstrated before! My deepest respect for the flight crew, also, led by John Young, with Brewster Shaw, Owen Garriott, Robert Parker, Byron Lichtenberg and, last but not least, Ulf Merbold.

As a member of the first group of ESA astronauts, together with Ulf Merbold and Wubbo Ockels, I followed the final steps of preparation for this mission and the mission itself with great interest, although I had stopped being directly involved with it since mid-1980. Wubbo successfully flew a couple of years later on the Spacelab-D1 mission. My turn came much later, in July 1992, and on a very different kind of mission: deployment of the Eureca Scientific Platform, and performance of the first test of the Italian-American Tethered Satellite System (TSS-1). I had the great privilege of taking part in three additional spaceflights before the end of 1999. Two of these were visits to the NASA/ESA Hubble Space Telescope (HST) for repairs and maintenance of the orbiting observatory. I did not fly on Spacelab but had the opportunity to serve the scientific community by other means!

Human intervention on HST has been very successful on all servicing mission so far. Although quite complex, the Telescope would have been immensely more complex and expensive had it been designed to be serviced by robotic means. It would have remained ineffective (spherical aberration caused by the faulty shape of the primary mirror, 1990; jitter caused by the original solar arrays, 1990), and later decommissioned (rate sensor unit failures, 1999) without in-orbit servicing capability. On numerous occasions during the three servicing missions so far the flexibility of human intervention was used to engage alternate vs. planned operational paths, which is typically the kind of action robots or automatic systems are not well suited for (solar array jettison, 1993; HST aft shroud door opening and closing problems, 1993 and 1999).

The Tethered Satellite System was another Shuttle payload whose operation was heavily dependent on humans. Satellite deployment and retrieval and the active damping of the satellite and tether oscillation modes were strictly dependent on manual intervention with the Orbiter's thrusters. Here again, this was a question of cost. The system was very experimental and it would have been unwise to pay the large cost of automation for a complex system in its early testing and development stage. The TSS concept has not been pursued in its dynamical and electrodynamical applications for International Space Station support, but it is only a question of time before the concept comes back as an effective way to control Station orbital altitude without the use of propellant.

In addition to Spacelab, HST and TSS are two examples of Shuttle-borne, operated or serviced systems where human involvement in orbit made a huge difference. In general, interactive space laboratory facilities, complex space systems servicing and maintenance, or new systems in their test or early development stage, benefit enormously from human intervention in space.

We have benefited tremendously from all aspects of space utilisation and exploration since we first ventured beyond the Earth's atmosphere more than forty years ago, and since the first Spacelab mission twenty years ago. I am absolutely convinced that we should continue the journey, build on what has been accomplished so far in research and exploration, and finally attempt to establish and exploit several working regions in space, properly interconnected. Achieving such objectives will make a significant difference to future human development.

Claude Nicollier
ESA Astronaut

In my opinion, a good experiment has to be at the border between the known and the unknown because it tries to find new results. We not only had to familiarise ourselves with the basics of the new fields, we actually had to reach the top of knowledge, the grey area between the known and the unknown, in order to understand and operate the experiment properly. We learned the means and methods of all the experiments and the reasons why they had to do it in orbit. It was a sparkling intellectual atmosphere!

Spaceflight is intensely emotional – but it is also intensely intellectual. I think I am really lucky to have had the opportunity to widen my views from a narrow field to a more general knowledge. We also had to learn many practical things, like drawing a blood sample, and got a lot of hands-on training. After all, performing experiments is like playing the violin or any other instrument: you have to know the theory to produce sounds, but you also have to develop skills and a sense for virtuosity.

You said that spaceflight is both emotional and intellectual. You have spoken a lot about the intellectual side – how about your emotions when you heard that you would fly?

That was a situation of mixed feelings – Wubbo and I were close friends, we had been working together for two years in Huntsville, Alabama and at the end of the training in the Marshall Spaceflight Center we knew that only one of us could be the first. However, when the German government decided to fly the German-D1 mission, Mr Finke, a high official in the Ministry, promised that the astronaut serving as backup for Spacelab-1 would fly on D1, so in the end it was not that complicated because we both had the guarantee that we would fly.

In Huntsville, we had been working with the computer system that simulated the complete Spacelab-1 configuration, scientific experiments and potential problems. We had the same knowledge, and in the end the investigators' working group had to take the decision between the two of us and their recommendation was in my favour. Of course I was happy, but I would have preferred to have the opportunity to share the experience with him. After all these years I am still grateful to Wubbo that he, after a very short moment of frustration, accepted to be the backup and to do his utmost to make Spacelab-1 a successful flight. The success of this mission was also a boost to continue with D1. After my flight, Wubbo and I went straight into training for the next mission, this time with reversed roles.

Let's talk about the flight itself. What do you remember most, both in terms of science and the flight experience?

Valery Polyakov taking a blood sample from Ulf Merbold during his Mir mission

I couldn't pick one memory above the other, there are so many... We as crew had different roles. For some experiments we were merely lab technicians – we put materials sealed in cartridges into furnaces, heated, melted, solidified the materials, pushed buttons and started computer programs. In other cases we were in scientific control of the experiments, and some of them were almost artistic – for example a silicon crystal experiment in a furnace called the Mirror Heating Facility. The investigator taught us to observe the liquid zone of the crystal rod, make an assessment of how long it would take until it would become unstable, what the material should look like and what to expect to be able to judge the next step. From a crew point of view, these experiments are more interesting of course.

I also remember experiments from a team from the University of Mainz in Germany – they had all sorts of different vestibular experiments, and we had to work in a team with one astronaut acting as test subject and another performing the tests. These experiments had many functional objectives, and after a lot of training the experimenters gave us carte blanche. "You have control because you know as much as we do, use your senses", they said. Of course this kind of relationship has two sides: we were proud that they trusted us, but we also felt a huge responsibility.

Many of the experiments were fantastic science with fantastic results. One of them is a phenomenon that is still unexplained today – the fact that the caloric nystagmus can also be stimulated in microgravity. Theory predicted it couldn't because it is a reflex that scientists thought had to do with convection in the inner ear. The nystagmus reflex originates from the inner ear and acts on the eye; the ear is in a way 'calling on the eye for help' to find out what kind of movement it experiences, and it can be stimulated either by spinning the test subject or heating one and cooling the other outer ear.

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The Road Ahead is Open...

Coming from an operational background, I would like to focus on the particular need of 'operational expertise'. In the fifties and sixties, the space budgets of the space-faring nations were almost unlimited and dreamers and explorers shaped the conquest of space. These dreams have given way to reality. Nowadays, space exploration is dictated by accounts and budgets. But space is more than just short-term investment in technology and research. People are not only scientists or engineers; they are also poets, dreamers, explorers and adventurers. In the past, these explorers and adventurers have discovered and opened new frontiers. Humankind has conquered the land, the oceans and the sky, and finally we have made our first steps into space. We will always try to go beyond the next horizon, to explore the unknown; it is in our genes. Every time we have done so, the long-term results have proved to be beneficial. Every day, we travel safely on the seas and in the air. Now the time has come for humankind to take the next logical step: the establishment of a civilisation that routinely ventures out in space. Despite budget difficulties and dramatic setbacks such as the loss of the Space Shuttle *Columbia*, we now have established a permanent human presence in space with the ISS. It is imperative that we continue to invest wisely. In the past, Europe has done this and has acquired independent unmanned access to space. However, if it wants to be a major player in further space exploration and in establishing day-to-day space travel, it will also have to establish a capability in human access to space. This will require not only the further development of new technologies but also the establishment of solid operational expertise. In my past career as a military pilot I have participated in several operations. Although technology has always played a big part in the success, the biggest contributor was without doubt the people (ground crew and aviators alike) who participated in the operations. Their motivation, resourcefulness and inventiveness to solve problems, their ability to adapt quickly to ever-changing situations and their capacity to work as a team made all the difference. These capabilities were acquired through many years of training and investment in operational skills. In reading the initial reports of the crew aboard the International Space Station, I find much resemblance to this. The years of investing in training, operation centres, procedures and Mir and Shuttle operations are really paying off. The role of Europe in manned spaceflight will depend greatly on the quality of its operators and on the will to invest in people as well as in technology. Therefore it is absolutely necessary as we move towards more operational capabilities by developing additional hardware that Europe also continues to invest in human operational expertise. The first steps into space have already been taken. The road ahead is open. All Europe really needs is the will to travel.

Frank De Winne
ESA Astronaut

We didn't have many real ESA Spacelab flights. It is a pity that we built this wonderful laboratory and did not have a utilisation programme. We participated as 'guest agency' in other Spacelab flights, for example the International Microgravity Laboratory, which was basically a NASA mission with ESA participation. Mission management, astronaut training, etc. were in the hands of NASA. ESA also participated in D1, which was a German flight. Again, there was no ESA mission management responsibility; we were just flying experiments, just like on D2. After D1 came the decision not to continue with vestibular experiments because space was needed for the Anthrorack, which concentrated more on cardiovascular experiments. So it is still an open question why the caloric nystagmus can be stimulated in microgravity.

How was life on board?

It was marvellous. Spacelab was a very comfortable lab, and it is sad that NASA stopped with it after roughly 20 flights and switched to Spacehab. Spacelab worked perfectly, it was quiet, had a good life support system, super air quality, nice illumination and other fantastic features, for example the airlock through which we could transfer experiments into space and back into the lab. There was also a high-quality optical window in the ceiling of the module, so you could turn the Shuttle so that the window faced Earth for an undisturbed view. A camera system took distortion-free pictures, and in the few free moments between experiments we had breathtaking views through the viewports. Next to all the other impressions, the views are what make an astronaut's life an incredible experience. Earth is incredibly beautiful, and so are the stars in the black sky, the Sun in the black sky…

How was working on Spacelab different from working on Mir?

Spacelab and Mir are two completely different science laboratories. On Mir, you had 15 years for experiments – on Spacelab ten days. That means that we had a strict timeline and there was almost no extra time if an experiment developed problems. On Mir, we were more flexible in that respect – but there were great deficiencies in data acquisition and

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German space jubilees: Sigmund Jähn, left, celebrates the 25th Anniversary of his flight with the Russians; Ulf Merbold, right, the 20th Anniversary of his Spacelab-1 mission.

transmission because it was only possible to transmit data to ground stations while we were crossing Russian territory, which was only about four hours per day. Spacelab used relay satellites, so we were in constant contact with the investigators on the ground. On Mir, data had to be recorded on board in various different ways. To sum up, I think Spacelab was a more powerful lab than Mir, with the strong disadvantage of the limited duration. Eventually, this led to our decision to participate in the ISS programme in order to have a laboratory of Spacelab quality in orbit for years rather than days.

Mir was also a chaotic lab to live in. I arrived there in 1994 after it been in operation for ten years. It reminded me of an old farmhouse in the country where many generations of people have lived and collected clutter. The Russians did not provide stowage for every piece of equipment and all the newly delivered material from Progress ferries had to go somewhere. It always took me a while to find what I was looking for...

How does flying on the Shuttle compare to flying on a Soyuz?

While there is more legroom in the Shuttle there is also much more vibration. I hope that, if Europe builds a new manned carrier system, we will learn from the different experiences with Soyuz and Shuttle. Although the small Soyuz capsule is less comfortable, it is safer than the Shuttle. For future systems escape capability during all phases of the flight needs to be a prime design requirement.

How was it to be the first non-American on an American spacecraft?

When we started training for Spacelab-1 in Huntsville we received a warm welcome. After all, it was also for them the first flight where they had operational responsibility, what we now call payload operation, meaning the execution of the experiments. They made sure everything was more than perfect. In Houston you could feel that not everyone was happy that Europe was involved; some also resented the new concept of the payload specialist 'astronaut scientist', who was not under JSC control like the pilots. A couple of small things made us realise that JSC management was suspicious. Now, of course, all this has changed. I think we broke the ice and all our colleagues who came after us had much easier lives.

Are there any direct descendants on Columbus of experiments you had on Spacelab?

There was one experiment on Pedro Duque's list that is a direct descendant of an experiment from D1 with fruit flies where it was discovered that the male flies died after a shorter lifetime. Pedro's experiment was based on these findings. Lots of general experiments have been done on many other flights; there are always follow-ups. In medicine, knowledge is based on statistical data, and it can never be a mistake to continue the collection of data on a group of test subjects in order to draw conclusions.

How is your relationship with Sigmund Jähn, the first East German astronaut who flew in 1978?

We know each other very well; I think it was me who managed to bring him back into the Western space programme. We met for the first time in 1984 at an event to celebrate Hermann Oberth's 90th birthday and in the following years at the IAF Congress. We discussed our experiences and views and we had a nice surprise: although we had lived our lives in controversial systems and directions we were born in places very close to each other in Germany. After school I had escaped a system I did not agree with and started a new life in West Germany, while he was an important officer for that same system I had rejected. Still we reached the same conclusion: it only takes 90 minutes to complete one orbit around Earth to experience a change in comprehension. The planet loses its large dimensions and becomes very small and fragile, and the worst that could happen to it is a global war. Remember that this was at the height of the Cold War, the Pershing missile crisis and the Star Wars Programme.

Then the world changed in November 1989 with the fall of the Berlin wall, and less than a year after that Germany was unified. Despite his immense experience, Jähn could not join the West German Bundeswehr, so I managed to install him in DLR and later on in ESA – much to everybody's advantage. All ESA people, especially astronauts training with the Russians, could draw on his experience.

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He knew Star City, the Russian training centre, inside out and could help ESA people when they moved there. He speaks Russian like a Russian and knows all the key figures of the Russian system. For him, this career move was a chance to continue working in the field he loves and use all the knowledge he had acquired over the years.

Do you think that the Spacelab programme was worthwhile for Europe?

Absolutely no question: yes! Without it we would not be where we are. Being a valid partner in the International Space Station would be inconceivable if Europe had not qualified as a partner in the Spacelab programme.

How do you see the future of spaceflight?

I think it is crucial that, even facing problems as we do now, we continue with the ISS Programme. I think it is vital that we build an escape system for emergency situations in order to be able to increase the crew size to six or seven and thus improve the value of the ISS as a laboratory. To keep the whole system in balance we need more people up there and to build up more exploration-related experiments.

The next big challenge is a flight to Mars. I think we need to know more before we decide to go straight to Mars or whether, as an intermediate step, we should return to the Moon first. We need more operational experience and can achieve that by using the ISS. We also need to investigate the human side of it – how do crew members behave in such a closed environment on longer trips? Only based on this kind of knowledge can we take a decision; it is impossible now. For a possible Mars flight we need to build better propulsion systems, for example plasma propulsion, to shorten the flight time.

European Flag on the ISS and Beyond...

I will never forget a comment from one of my classmates in the NASA astronaut class of 1996, composed of 35 Americans and nine people from other countries. He was confused because there were European astronauts coming from different national agencies: "I cannot understand, all Europeans look alike to me..." This example shows that overall, despite the fact that each country of Europe has its own history and culture, Europeans are much closer than we would like to admit. People from other continents, with diverse cultures, can recognise that at a glance.

I mention this episode firstly because we took a big step forward in creating an integrated European Astronaut Corps that represents the European identity. This identity combines our common heritage while at the same time preserving the diversity, the individuality of each nation.

Secondly, it is only by recognising our differences and unifying our strengths that we can look forward to the challenges of the new millennium. Among them is one that I consider worthwhile pursuing for the future of Europe and all humankind: building infrastructures and space ships that would allow a true human exploration of space!

The experience of building the International Space Station has demonstrated that space exploration is an endeavour that requires the cooperation of many countries and, among these, Europe has a leading role to play.

When I first stepped, or rather floated, into the US module I felt for a split second the responsibility of representing not only my Italian countrymen, but also the culture and history of Europe.

I had the same feeling of pride and responsibility when I spoke to the President of the European Commission, Romano Prodi. I was in the logistics module 'Raffaello', a beautiful piece of machinery designed and built in Europe and temporarily attached to the Space Station, and I was showing the European flag I brought with me. Mr Prodi was asking me about life on board when he saw the little flag drifting slowly in front of the camera; he was surprised, but also very pleased to see that little symbol of unified Europe present in this lone outpost orbiting the Earth.

I believe these memories from my last flight in 2001 are the best way to celebrate the 25th Anniversary of the first European in space. Since then, a great deal of experience has been gained in human spaceflight, and Europe is ready to face the challenge of leaving Low Earth Orbit and venturing out to explore the Solar System.

I hope to see again, in the not too distant future, another beautiful European flag on the harsh landscapes of the Moon and Mars. Europeans have always been bold explorers. We should not forget that exploration is an essential element of cultural and economic development.

Umberto Guidoni
ESA Astronaut

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Vladimir Remek, born in Ceske-Budejovice in Czechoslovakia in 1948, celebrated the 25th Anniversary of his flight to the Russian Salyut-6 space station this year. He was the first European – 'non-Soviet and non-Armerican', as he puts it – to travel into space. He now works in the Czech Embassy in Russia.

How did you become an astronaut, how did you plan your career?

That was long ago – there was no human spaceflight yet. I was a little boy of nine when Sputnik was launched and 13 years old when the first cosmonaut, Yuri Gagarin, flew. I found that very interesting and thought that I also wanted to be a cosmonaut. The first cosmonauts and astronauts were military pilots, so after finishing school in 1966 I went to a military flight college. I became a pilot and wanted to get a higher education, so I went to the same pilot academy that Yuri Gagarin studied at. It is now named after him. Sigmund Jähn, the first East-German cosmonaut, also graduated from this academy.

I graduated in1976, and at around that time the Soviet Union proposed for the first time that people from other countries could participate in their flights. I applied and, probably because I had the right education and quite some experience from my time in the Czechoslovakian air force, I was lucky enough to be selected. We were six new cosmonauts – two each from Czechoslovakia, Poland and the German Democratic Republic. The training in Star City started in December 1976, and it was extremely interesting! Everything was new and fascinating to me.

How and when did you learn that you were going to fly?

Well, I only really realised that I was a real cosmonaut when I was in orbit... Actually, we did not know who was going to go until it was announced only two days before the flight. We were two from each country, and we did not know which of the two of us was selected. When I heard that it was me I was very happy. I had dreamt of it all my life, and suddenly my dream comes true! I was still very young, 30 years old, and very excited.

Please tell us about your flight. What did you do, what did you see?

That's a very long story – I could talk about it for many, many hours! But to sum it up, it was one of the most interesting periods in my life to work with all the different people. We trained and worked together with the Soviet cosmonauts, we were an international team, and we were united byof spaceflight.

I only spent eight days in space, but I am very grateful to hawhat many other people can only dream about. The greatest impression that will stay with me my whole life is: Earth is really round. It has finite dimensions. You can actually fly around it in tens of minutes. What was equally impressive, though more of a detail, were the meteors. People usually say that these are 'falling stars', but when you're in space they are not above your head; I could see them far beneath my feet. Stars were shining above me and other 'stars' were falling below me at the same time. The spaceship with me in it floated between them. It was beautiful. Of course we only watched these phenomena outside our scientific schedule!

Our science programme wasn't as extensive as they are today. To give you a few examples, we had a couple of experiments to study microgravity, material science crystallisation experiments. We studied the stars and how they behave, the level of oxygen in tissue of the human body – we had a couple of very interesting experiments. One of them was from my hometown, which is well-known for its excellent beer. Unfortunately we didn't have any beer on board! Instead, we grew single-cell plants. In our short flight we grew a couple of generations. But of course it is quite difficult to speak about the details of the scientific experiments after 25 years.

You said that you enjoyed working and training in an international team. Do you think that your flight as the first European in space lay the foundation for a more international cooperation and collaboration in space?

Personally, I believe it has. Other cosmonauts and astronauts probably think the same. Projects like ours facilitate better understanding between different countries. One proof of the pioneering role my flight had is that the following Russian flights had more international crews, and nowadays they are international by default. It is a pleasant feeling and makes me proud to have been one of the first to start this tradition.

By the way, I never knew I was regarded as the first European in space until 12 years ago when I visited the Royal Military Museum and Space Information Centre in Belgium as a guest. In their space section I was surprised to see my name listed as the first European cosmonaut. I did not understand this at first – at that time, the Soviet Union still existed and to me,

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Soviet cosmonauts also belonged to Europe… but one thing is certain: I was the first non-Soviet and non-American in space – not a bad result after all!

What did you do after your stay on Salyut? Are you still involved in space?

For a while, I stayed in the space field until I switched back to the Military Service. I became Director of the Czech Air and Space Museum in Prague. Thanks to my function as Director, I came to Belgium and learned of my reputation!

I then retired from the military in 1995 and started working in Russia, representing Czech trade companies in Moscow. For a while I was the Director of the Moscow branch of a Czech company Z Strakonice, and since 2002 I have been a Counsellor at the Czech Embassy in Moscow. In my role as Head of the Trade and Economic Department I also deal a lot with scientific cooperation, and I often come across space issues, only this time I see them from the other side. I have a very interesting life at the moment, I meet many fascinating and talented people and have a position of high responsibility – but I do miss space!

How do you see the future of human spaceflight? What do you think will happen in the next 20 years?

I have always tried to avoid answering this question – I can only say what I hope. Let me explain this with an example from my flight. At one time aboard Salyut, I was floating; the only physical contact I had with the station were two fingers on a handle. Through a window I watched the Earth. At that moment, I felt my heart stronger than ever before, I heard each heartbeat, and I was aware of all my dreams and hopes for myself and the world. I asked myself: What will this world be like when I return? What will it be like in 20 years? I told myself that I don't want to guess or gamble – I can only hope.

Claudie Haigneré visited Mir in 1996 for two weeks during the Franco-Russian mission 'Cassiopée'. She then spent eight days on board the International Space Station in October 2002. She was the only woman in the European Astronaut Corps, until she was appointed Minister of Research and New Technologies in the French Government in 2001.

First Steps in Microgravity – Watching Earth from Space

When one arrives in orbit and the engines are turned off, all the noise and vibrations of the launch stop. Still fastened to the seat by seat belts, I did not immediately perceive the absence of gravity. I only noticed it by looking at the objects floating around me. I was very impatient to unfasten the seat belts and finally experience what I had studied, for a long time, in books and documents during training. The reality is very different. When you are on the ground, it is difficult to understand what floating upside down or on the ceiling really means.

I felt my body fluids flowing towards my head rather like when you stand on your head for a long time on Earth. This gave me a bit of a headache, which fortunately stopped after a few days. When I finally got on board Mir everything was like in the simulator used in training in Russia. Therefore, I knew the architecture of the modules and the position of all the objects well, so I knew how to move around. However, I required a few days to reconstruct a reference system that enabled me to orient myself. It took me 2-3 days to learn how to use my muscles again, adjusting them to move around or hold objects. I had to re-establish new rules to stabilise my body before attaching objects to velcro or elastic.

It only takes 3-4 minutes to pass over Europe. From space I could see the change of colours during every sunrise and sunset, the clouds and snow on the mountains. After a while I was able to recognise the continents that we were flying over from their colours or even from the position of the clouds. Due to my ability to read all the meteorological elements, I was able to identify the approaching coasts and to follow the meteorological events in the formation of a storm or a cyclone.

I will also never forget the impressive vision of the darkness of the Cosmos! Looking at all that blackness, I perceived the meaning of real infinity and of how small the Earth is inside our solar system. Realising how thin the terrestrial atmosphere is, I could not help thinking about the responsibility that all of us have to defend and preserve our magnificent planet. Looking at the Moon rising above the horizon of the Earth several times per day is an unforgettable and poetic memory that I will always carry in my heart!

Claudie Haigneré, former ESA Astronaut

We human beings always go further, we explore, we take the next step. Many people even lost their lives because they claimed that the world was round. I went up to see that it really is, and I am extremely grateful that I had the chance to do so.

I believe that the coming years will be very interesting for human spaceflight. I hope to be still alive to witness this – that mankind is clever enough not to destroy itself. I hope that spaceflight will be continued.

There is a lot of talk about going to other planets, and I hope that we don't just discuss it but do it. Future generations will certainly lead interesting lives.

There will always be two categories of people: optimists and pessimists. Optimists think that the world develops as it should, and pessimists think, "Unfortunately this is true." I am definitely an optimist.

A New Perspective for

- The Oxygen (0_2) Project

José Achache
Director of Earth Observation, ESA, Paris

Introduction

Europe has achieved worldwide leadership in many scientific areas of Earth Observation with Synthetic Aperture Radar (SAR) imagery, interferometry, oceanic altimetry, atmospheric chemistry, to name just a few. On the other hand, Earth Observation has so far failed to evolve into a mature and self-sustainable operational or commercial activity. Hence, it has not allowed the development of a service industry of any economic significance. We believe that the causes for these drawbacks are rooted in a number of characteristic features of the current approach to operational Earth Observation.

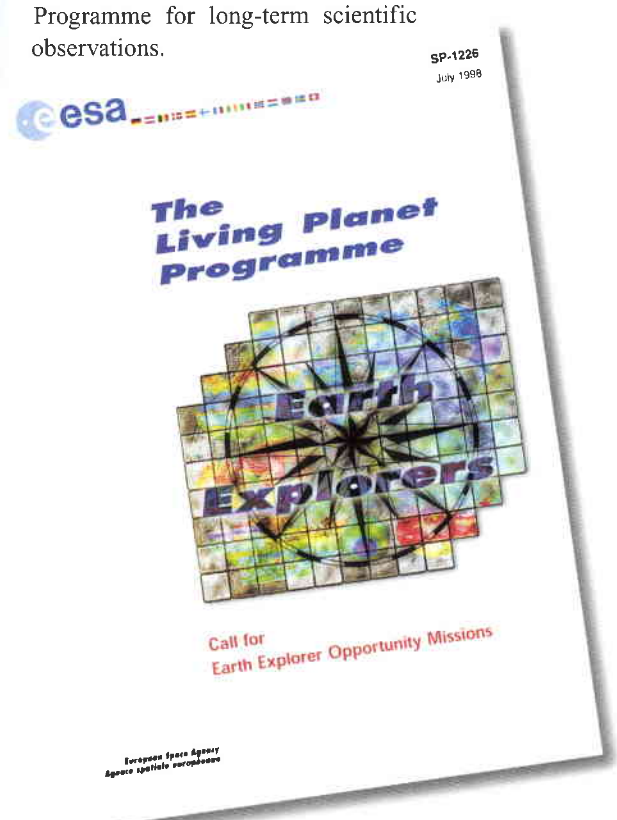
Drawing lessons from the failure at the Ministerial Conference in Edinburgh to coordinate national initiatives, we are proposing a new implementation strategy for the Earth Watch missions, which shifts from the current technology-pushed to a market-pulled, user-oriented approach. In the mid-term, this strategy should provide full interoperability of all European Earth-observing space systems. In the longer term, it aims at building up the necessary rationale, momentum and resources for the definition, deployment and operation of the next generation of European operational satellites.

This strategy calls, in the short term, for the complete overhaul of current policies and the introduction of advanced technologies for distributing Earth Observation data from the existing space infrastructure. We believe that the fostering of operational services requires the development of an integrated, transparent and user-friendly infrastructure to access information from Earth Observation missions in Europe. In this new paradigm, easy and inexpensive access to Earth Observation data is seen as the critical element and should be granted to any partner willing and capable of developing new applications and services. This strategy is perceived as an enabling mechanism to allow the development of a powerful

Earth Observation

A mosaic of satellite images from Envisat (MERIS) showing a cloud-free Europe © ESA 2003

service industry in Europe, which would facilitate and encourage future investments in Earth Observation satellites. It is also considered critical for the implementation of the Global Monitoring for Environment and Security (GMES) programme. Last but not least, the proposed approach is also intended to provide opportunities for turning one-off Earth Explorer missions into operational systems, and it responds to requirements expressed in the Living Planet Programme for long-term scientific observations.



The MSG-1 spacecraft shortly before launch

Earth Observation Today

Europe's successes

Europe has gained clear leadership in several critical technologies and in the scientific use of Earth Observation. The last 25 years have seen substantial, often unique, European contributions to such different sectors as operational meteorology, radar imaging, radar altimetry, oceanography, glaciology, radar interferometry, climatology, atmospheric chemistry, geodesy and others.

From the very beginning, the Meteosat series of satellites has put Europe at the forefront of operational meteorology. The recent launch of MSG provides the most advanced capability from geostationary orbit. The forthcoming EPS/MetOp will offer unique capabilities in advanced atmospheric sounding. Europe has gained undisputed worldwide leadership both in the technologies and applications of SAR (C-band in ESA and Canada, X-band in Germany and Italy). The best-known SAR applications include ocean and ice monitoring, and the most sensational results are associated with the use of interferometry. Displacements associated with earthquakes, inflation of volcanoes before eruption, subsiding areas in urban environments as a consequence of major works or water/oil/gas extractions - these are just a few examples of the extraordinary detection potential of SAR interferometry.

Europe is also at the forefront of Earth Observation from space in the optical/multispectral imaging domain, thanks to the Spot family of satellites. The MERIS instrument on Envisat is internationally recognized as providing unprecedented spectral resolution in support of land and ocean science and applications.

Ocean altimetry is another major European achievement thanks to Radar Altimeter instruments on ERS-1/2, Topex-Poseidon, Envisat, and Jason. The extraordinary accuracy achieved with this technique has been inherited from the expertise developed in geodesy/orbitography, which has also led to a number of advanced geodetic missions (Grace, Champ, GOCE).

Envisat is carrying the three most advanced instruments to date to study atmospheric chemistry (MIPAS/GOMOS/Sciamachy). The international Earth-science community will access the data from these instruments to better understand and model the complex processes taking place in the Earth's atmosphere, which are believed to be critical in understanding increases in the greenhouse effect.

It is also worth recalling that the ATSR instrument on ERS-1 and 2 and Envisat is the most accurate source of sea-surface temperature measurements from space, and the only one available that has the potential required to study long-term climate change by virtue of its accuracy and continuity over up to 18 years in orbit.

A new strategy should capitalize on available assets and maintain Europe's world-leading role in the development of operational environmental and security services based on Earth Observation.

Earth Observation business: a disappointment?

An Earth Observation service industry came into existence (thanks in particular to the efforts of the French company Spot Image) in the late 1980s and grew steadily in the 1990s, riding a wave of optimism resulting from the initial availability of data from the first commercial high-resolution satellites. The total annual revenue of the European Earth Observation industry at the end of 1997 was 207 MEuro, representing an annual growth of 6% over 1995-96. While the private market has been continuously strengthening, it remains much smaller than the public-sector market, mostly defence, which still represents 64% of the total market. The private-sector growth came mainly from the telecommunications sector (infrastructure deployment for cellular phones), followed by oil and gas exploration.

In 1998, the industry itself forecast that its revenues would rise to between 245 and 340 MEuro by 2000. In the event, the total European revenues had by then reached only 216 MEuro. This is equivalent to an annual growth of only 1.4% over 1998-2000, which represents a decline if annual inflation is taken into account. Revenues are coming from the sale of data and data rights (20%), sales of ground-segment equipment and software (26%) and sales of services and value-added products. It is estimated that over the period 1998-2000, public monies of the order of 25 MEuro/year was injected into the sector for the development of services and value-added products. All together, the value-adding industry has remained small, dispersed and fragile and heavily dependent on income from government programmes.

There may be several reasons for this disappointing performance. One is, possibly, the fact that space agencies worldwide have put their focus on the development of space hardware rather than the development of services. This lack of substantial public investment in the downstream sector was matched by industry, given the bleak perspective and the disappointing market pull by the user community. Indeed, users, customers and market owners have been reluctant to express requirements and to integrate Earth Observation information sources into their business practices. The validation of new information sources and of new services is not a one-off operation and needs to be supported over a sufficient term to encourage users to adopt new business practices. Finally, many potential users and customers of space information are simply not aware of the benefits they could accrue from using Earth Observation.

Facets of planet Earth to be addressed by the GOCE mission

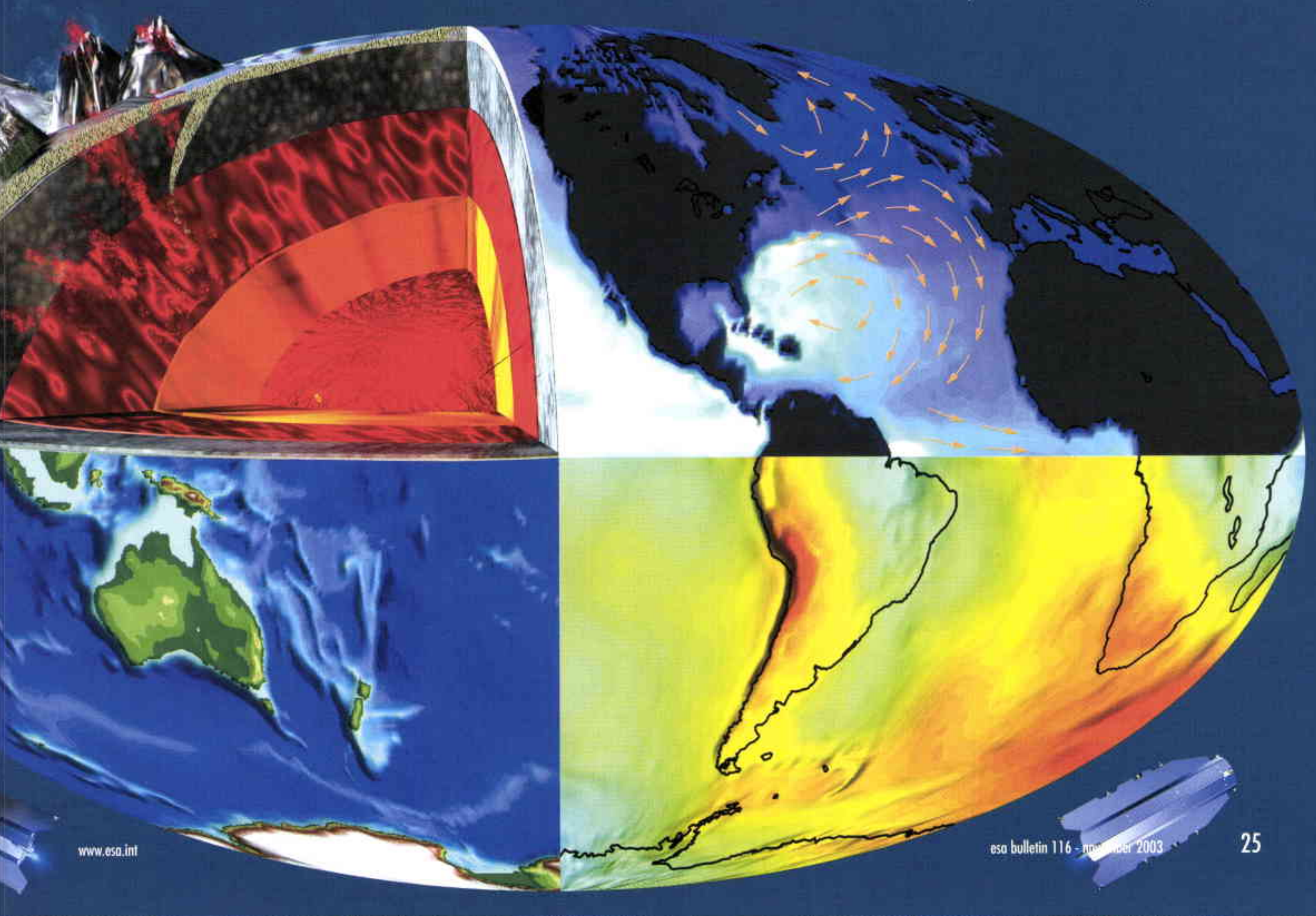


Image of the Iberian Peninsula acquired with Envisat's MERIS instrument. The instrument's 300 m imaging resolution and outstanding radiometric accuracy allow continuous monitoring of continental areas. Envisat can therefore help scientists and environmental agencies greatly in understanding the causes and consequences of soil erosion, river pollution, deforestation and other environmental threats

In this context, the two major causes that can be identified are the barrier of data cost and the hurdle of data access. We have daily reports of academic groups and small private service companies developing prototype applications using SAR and MERIS data. The validation at full scale of these services would require amounts of data that they just cannot afford under the current ESA data-policy conditions. These actors are left with the alternatives of either giving up their spin-off projects, or using US scientific data that are available free of charge. It should be recalled that GPS and Internet applications could be developed by millions from academic spin-offs and private initiatives because the system was freely and easily accessible. Inexpensive, or even free access to data is certainly a necessary, if not sufficient, condition for the development of a mature service industry.

A need for information and services, not for data

Services, whether commercial or public, are about the provision of the right information at the right moment to the proper person. High-level operational information services are needed, and not simply space data or satellite images. Scenarios, estimates of socio-economic impacts, quantitative statistics, trends and forecasts are demanded at various geographical and temporal scales in support of European policies, and this will be the purpose of GMES. Quantitative assessment and control are required in support of industrial and commercial activities (agriculture, insurance, construction, tourism).

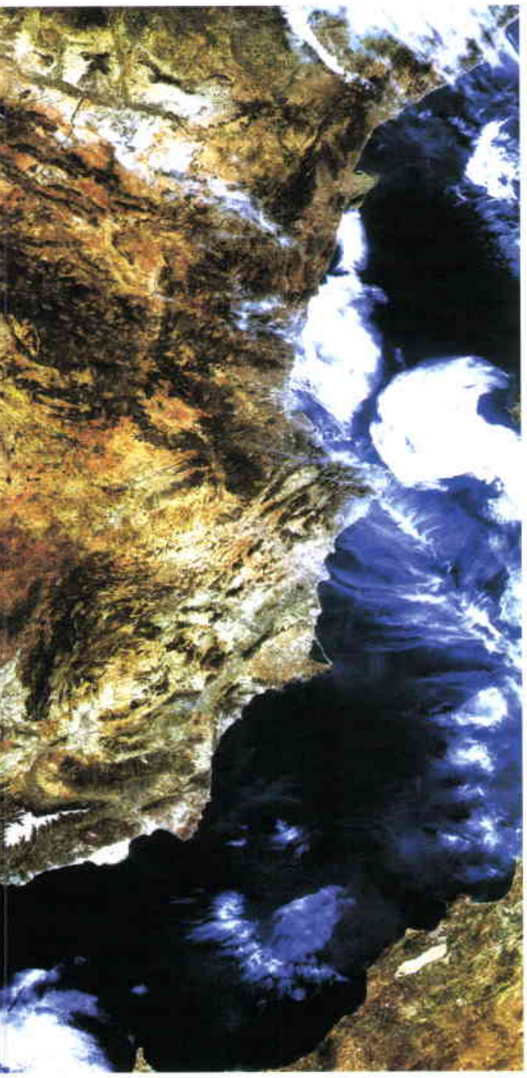
Future information services will be characterised by a stronger integration of space data with all kinds of other data and information, and they require a knowledge-based approach making full use of European expertise in Earth sciences, information technologies, economics and social sciences. The complexity of this next generation of integrated services may also require a network of partners who will contribute to the production of information services. This will also require that Earth Observation data reach out as far as possible away from the space community.

It is currently very difficult and expensive to access and integrate Earth Observation data from several different sources. It is therefore necessary to develop tools to allow operational data acquisition and handling in coherent formats and through a coordinated access chain.

The successful, mature uptake of Earth Observation will require the integration of European capabilities in modelling, data management and service delivery to describe the state of our environment and to predict responses to actual and potential change.

The potential for synergy of Earth Observation missions

Among the inadequacies of existing Earth Observation systems that are often cited, one of the most important is the lack of timeliness and the insufficient frequency of observations. For example, in order to provide useful information to support prevention, assessment and remedial actions in cases of natural disasters, frequent coverage and near-real-time

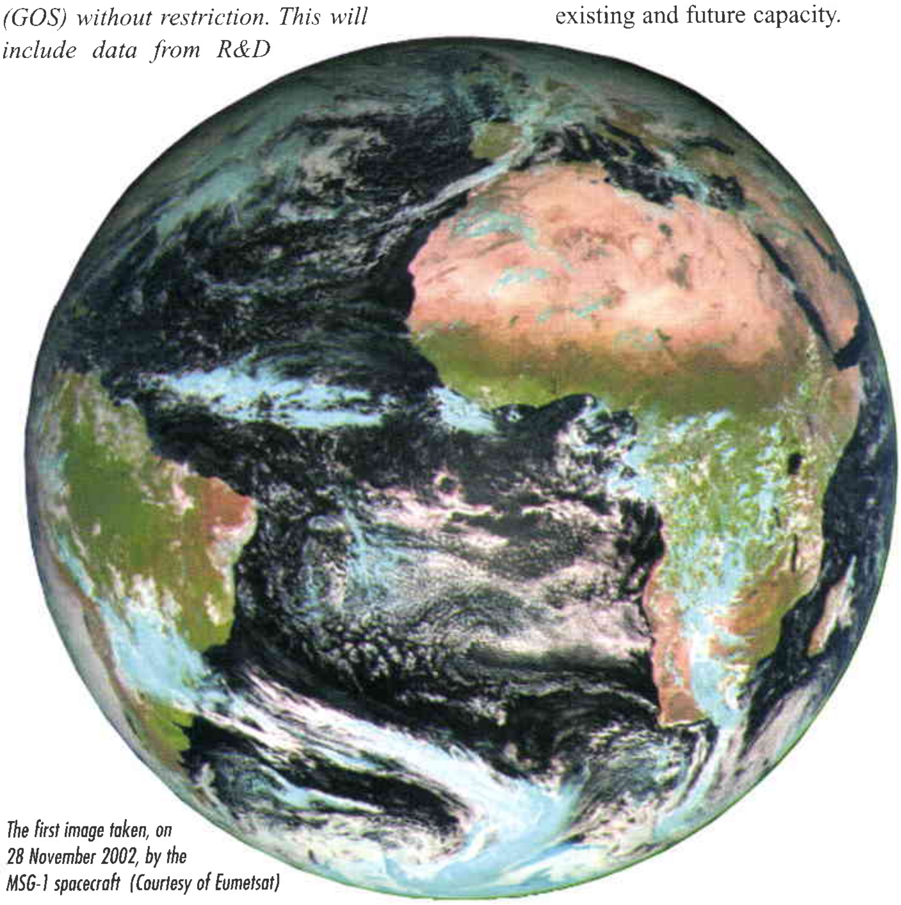


access to information, not data, are crucial requirements, indeed a must. Today, after thirty years, Earth Observation still remains largely an R&D tool. Despite the many Earth Observation satellites in orbit, it is not yet possible to get 'the right information at the right time'. When used separately, few if any of the current in-orbit systems can provide operational information to a wide community of users, whereas used in a cooperative way, as a single interoperable system, they could.

Therefore, without waiting for large dedicated satellite constellations, the situation can be improved significantly by better integrating existing satellite sources even of different resolutions, qualities, etc. Currently, more than 50 Earth Observation satellites are in orbit worldwide, carrying more than 150 instruments, of which approximately 20% are operated by European space agencies (ESA, Eumetsat, CNES, DLR, SNSB). Among those, there are about 15 civilian Earth Observation satellites available, which provide imaging data in the 3-30 metre resolution range using optical, infrared or radar sensors. Each of these instruments has its own specific purpose, but there is a clear lack of an integrated and synergistic approach to fully exploiting the very large volume of available measurements. The ESA Executive believes that there is a major opportunity within reach at this moment in time to overcome the individual shortcomings of each mission by jointly operating and exploiting this multitude and variety of instruments and thus easing the task of building and providing operational services.

This potential benefit has also been recognized by the World Meteorological Organization (WMO) community, which states that *"space agencies will continue to be encouraged to make their observations available to the Global Observing System (GOS) without restriction. This will include data from R&D satellites which are deemed to be relevant to the GOS"*, but should also include *"high-resolution optical and radar space imagery [for which] access to data remains an issue."*

"The aim is to bring about a very significant increase in the availability and utilisation of data, products and services, not only in terms of volume and variety, but also in the geographical spread of the users. The increases already promised by the upcoming satellite systems in terms, for example, of higher spatial resolution, more frequent observations and the availability of more spectral bands, are not simply minor improvements, but represent in many cases step changes. Making these significantly improved data, products and services available and at the same time aiming to increase the number and geographical spread of the users, will represent the major challenge for the WMO Space Programme in the next decade." The proposed new approach to ESA's Earth Watch programme should bring the necessary coordination of existing and future capacity.



The first image taken, on 28 November 2002, by the MSG-1 spacecraft (Courtesy of Eumetsat)

Duality is everywhere in Earth Observation

Use of civil space data and services by security/defence customers is common practice in Earth Observation. As an example, meteorology, which relies extensively on space assets and has a wide range of well-known civil applications, has been supported and used by the military sector in Europe from the very beginning in a wide range of applications, from air-traffic management to maritime navigation support, and even to forecast battlefield weather conditions. The United States is phasing out the dedicated civilian-only (POES) and military-only (DMSP) meteorological satellite systems, converging towards an integrated civil/dual-use system (NPOESS).

The same scheme existed for altimetric applications (Geosat), which is now being supported by civil sensors (Topex/Poseidon, Jason, ERS-1/2 RA and Envisat RA-2). Cartographic applications cover both civil and part of the military needs: the extensive use of Spot data during the 1991 Gulf crisis as well as the Afghanistan campaign are other well-documented examples.

The use of space-borne SAR to support navigation in ice-infested waters or to control maritime traffic in specific areas are additional examples of dual use. On the one hand, civil authorities want to control fishing activities in the European Economic Coastal Zone or illegal oil discharges at sea, while security authorities would use the same technique to monitor maritime traffic in strategic areas.

Derivation of Digital Elevation Models (DEM) from civil optical or SAR sensors is exploited for civil, but also security applications. The idea that defence customers should make use of civilian space Earth Observation data whenever available, while developing dedicated systems only where the requirement cannot be met by civilian systems, is becoming common practice and is presently being formalised as US policy.

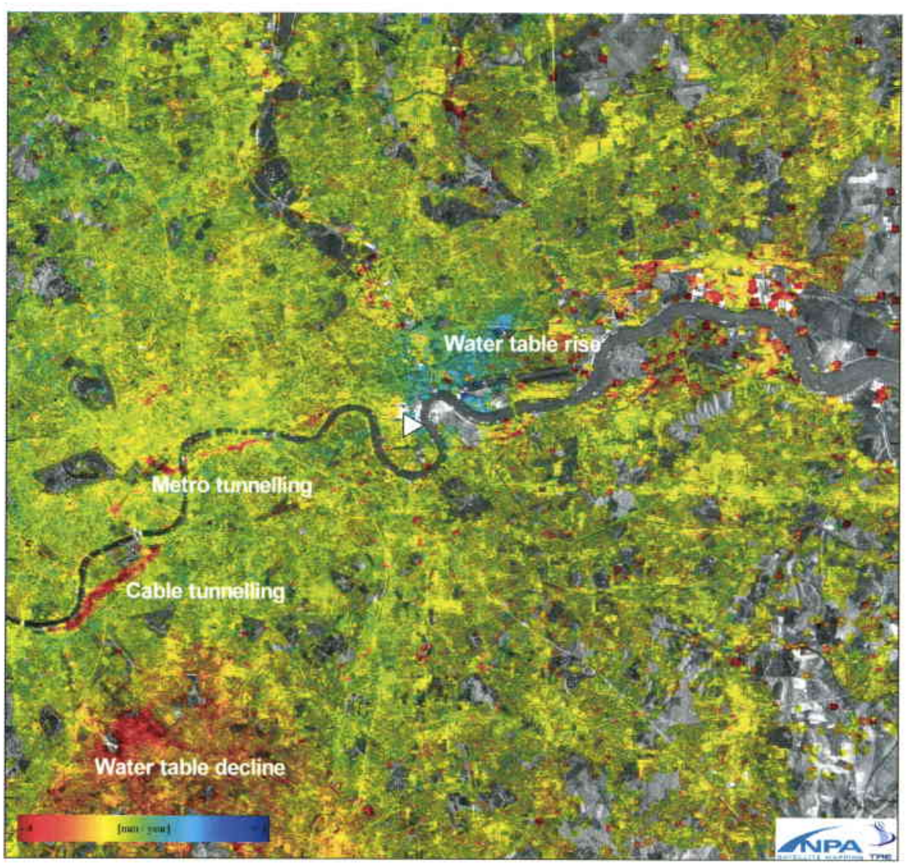
The United States has developed this approach to the extent that it has charged a military agency, the National Imagery Mapping Agency (NIMA), with providing anchor tenancy for a number of initiatives (Space Imaging, Digitalglobe, Orbview). This policy has not been sufficient to bring these initiatives to a sustainable level, and the recent Clearview contract demonstrates that, in the absence of a significant civilian service industry, the institutional role is essential for guaranteeing the availability of the infrastructure. A single, integrated, dual approach is practical and the only affordable solution to meet European needs.

Sustainability

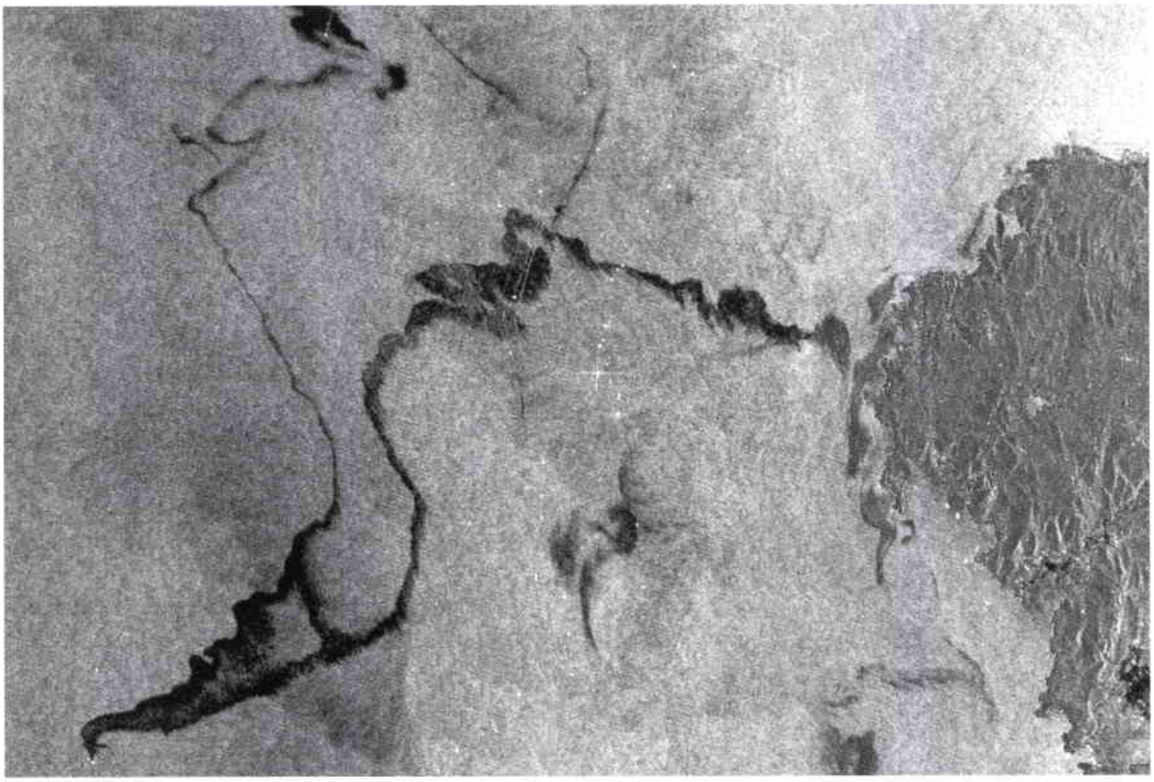
A need for long-term continuity

The UNFCCC (United Nations Framework Convention on Climate Change) Report on the Adequacy of Global Climate Observations, the GMES Forum and the WCRP (World Climate Research Programme) are all advocating the need for continuity of Earth Observation sensors for climate observations. Even short-term applications, such as disaster monitoring, require a long-term perspective of data provision to justify the adaptation of the institutional and technical infrastructure in favour of using space technology. For Earth Observation to be a viable information source for policy implementation, continuity should be guaranteed. But continuity cannot be guaranteed until a community of users has expressed a sustainable demand and a mechanism to support the provision of information. This chicken and egg situation has been solved in the cases of meteorology and defence. With a few exceptions, Earth Observation missions are one-time R&D missions with lifetimes of around 5 years.

For WCRP, the value of space missions comes mostly from their ability to produce globally integrated, high-quality and reliable climate data products, requiring the merged analysis of measurements from



Map of subsidence (annual rate) in Central London derived from ERS satellite altimeter data (Copyright NPA 2002)



An Envisat ASAR image, taken on 20 November 2002, clearly delineates the spread of the oil spill from the stricken tanker 'Prestige'

the whole constellation of operational and research/demonstration satellites.

The WRCP 'space strategy' relies upon the availability of long-term, stable and high-quality observations as currently provided by operational satellites (such as the meteorological series), complemented with innovative, process-oriented observations as provided by research satellites using new technologies.

Long-term continuity is linked with sustainability and requires the setting-up of institutional and/or commercial funding frameworks, transferring the maintenance of operational systems outside the R&D institutions and budget lines. This requires the extension of existing mandates of organisations, or the establishment of new ones. It also requires the introduction of new schemes for the relationships between institutions and industry (both manufacturing and service industry). Sustainability is a key issue in establishing operational services. It is recognized as such by the current Earth Watch Strategy and Earth Watch Declaration.

The following paragraphs provide a short analysis of the most popular models and schemes considered in the attempt to achieve sustainability. None of these models is the universal solution, and a suitable mix will have to be developed.

The 'Eumetsat' scheme

An Intergovernmental Conference in the early 1980s agreed to establish a new meteorological organisation. The Eumetsat Convention entered into force in 1986, with Eumetsat inheriting the Meteosat programme from ESA. In 1991, it initiated a new programme, the Meteosat Second Generation Programme, in order to ensure continuity of observations from geostationary orbit into the second decade of the 21st century. Within a decade, Eumetsat had become a mature organisation with direct responsibility for the operation of its satellites in orbit and with new programmes to ensure the continuity of observations.

In such a scheme, public funding comes from sources not necessarily of an R&D nature. The institutional users are the national meteorological offices, which fund the procurement of new fleets of satellites, tuned to respond to their specific needs, through an operating agency, Eumetsat. ESA, in agreement with Eumetsat, takes care of research and technology activities and is charged with the development of the spacecraft.

It should be investigated whether such a scheme can be extended to other major institutional users of space data, such as environmental or civil security agencies.

The 'Utilities' scheme

Earth Observation data are a necessary condition to the provision of a large number of information services that provide economic benefit.

The European Union and its member states have signed a large number of agreements, both at European and international level. Many of them address environmental topics, an area which Europe has identified as a policy priority among its global partners. Examples where monitoring of EC legislation is required are the Common Agricultural Policy, the environment and development policies, or specific legislation within these such as the Water Directive, the European Spatial Development Perspective, or the 6th Environmental Action Plan.

The space contribution varies from minor to essential, but there is no question about its added value, particularly in support of institutional and public-benefit uses. The information derived is addressing several areas of institutional responsibility, from weather forecasting to disaster monitoring and prevention, to aid to developing countries, to monitoring the implementation of treaties.

The satellites and the ground segments providing these data can be considered as essential infrastructures, like roads, motorways, electrical distribution networks, etc. Procurement and operation of these infrastructures is a public responsibility, better coordinated at European level, leaving to industry the role of developing and providing services and deriving commercial benefits.

Still a chance for PPP?

In Public-Private Partnership schemes, the business case becomes a critical element of the entire programme, including space segment, ground segment and service sector. Industry is committing itself to invest up-front in the programme, in anticipation of future revenues.

This was made possible in the United States because major institutional customers have been open to underwriting 'anchor tenancy' agreements with private-sector providers. This approach has not been very successful, as these entities (IKONOS, QuickBird, etc.) have failed to reach other customers. The recent Clearview contract, and the refusal of some of the private investors to support further development, is evidence of the inherent weakness of this scheme.

The lack of commitment of public authorities to rely upon information services that include Earth Observation data sources has not encouraged industry to engage in this process up to now. Industry will continue to be reluctant in the absence of reasonably guaranteed revenues in the short- to mid-term, and the role of the institutional sponsor/customer is central to this scheme, as in the previous ones.

It is worth noting that the successful development of new services would bring benefits to the service industry and to market owners. It is therefore this industry that should be targeted in the future for a PPP scheme, and not only the space manufacturing industry.

An end-to-end long-term strategy

The strategy presented here is intended to provide an alternative approach to developing the future Earth Observation operational infrastructure. While capitalizing on previous investments and successes, it should respond to the questions raised in the previous paragraphs regarding the sustainability of Earth Observation initiatives and overcome the current fragmented approach. The present lack of offers of operational services justifies the absence of long-term commitments from governments and private investors.

Over the long term, this strategy aims at the creation of a sustainable space infrastructure providing information in support of institutional and commercial services in Europe. This infrastructure should be tailored to the exploitation requirements expressed primarily by value-adding companies and service providers. Therefore, the preparation of a future operational infrastructure relies initially upon the successful exploitation of current missions.

The present strategy proposes to implement changes in the current management and exploitation of Earth Observation programmes in order to maximize the use of current and planned satellite capacity in orbit in the short- to medium-term, and to establish satisfactory operational services in a number of strategic sectors. It rests on three pillars, which should be built in parallel over the next three years.

Pillar 'S': Developing services

This phase was initiated after the Council at Ministerial Level in Edinburgh and covers the development of services and making them operational. It will be accelerated. A number of instruments have already been implemented following the decisions taken in Edinburgh, both within ESA and the European Commission: the GMES Service Element (GSE), Earth Observation Market Development (EOMD), Data User Element (DUE) and the EC 6th Framework Programme. The activities initiated through these instruments will receive increased support in order to generate rapidly representative forerunners of operational services. Access to new data sources will allow an improvement in the services provided and/or enable new services.

Pillar 'C': Providing access to current data sources

Information about Earth Observation services, data availability, project results and applications is currently accessible only in a very scattered way through different mission operators, scientific institutes, service companies, data catalogues, etc. Accordingly, only a limited community, knowing what to search for, is today in a position to collect and compile the necessary Earth Observation information. Easier and timely access to large quantities of primary data is a condition for delivering effective services.

The objective of this phase is therefore to offer European value-adding service industry straightforward, fast and economic access to data from the largest possible range of satellites. It is intended to primarily provide this service from ESA satellites and to progressively enlarge it to include other European satellites and, later on, non-European partners.

The current ground segment created for ERS, Envisat and the Multi-mission User Services will require upgrading and streamlining in order to offer users a single interface and a coherent environment for programming observations from several satellites and delivering combined products and organized data sets.

Access to non-ESA satellites will require the establishment of agreements with the respective satellite operators. They should be negotiated and implemented in order to preserve existing national and European capabilities and assets. In addition to ERS and Envisat, such a system could provide access to Spot, DMC and Radarsat imagery, to other European scientific missions, and possibly also to non-European scientific and operational satellites.

These activities are a natural extension of the mandate ESA has received through the Earthnet programme, the Envelope and the Earth Watch programmes. They will be implemented within already allocated funding, in the period 2003-2004. The deliverables from this activity will consist of an integrated interface to service providers and value adders for accessing satellite data and programming functions.

Pillar 'N': Integrating upcoming Earth Observation national projects in Europe

A set of Earth Observation missions are planned at European and national level in the next 2 to 8 years. Most of these missions provide high-resolution imaging data from radar and optical instruments, for civilian and defence applications: TerraSar X, Cosmo-Skymed and Pleiades. In addition, TerraSar L and, possibly, Rapid Eye will be considered.

The ground infrastructure introduced in pillar 'C' should be naturally extended to support these missions. Again, specific agreements will need to be set up with the relevant non-ESA programmes. The mission control and planning function will, for several reasons, remain specific to each mission or family of missions.

The resulting landscape, in the timeframe 2007-2008, should present the following picture:

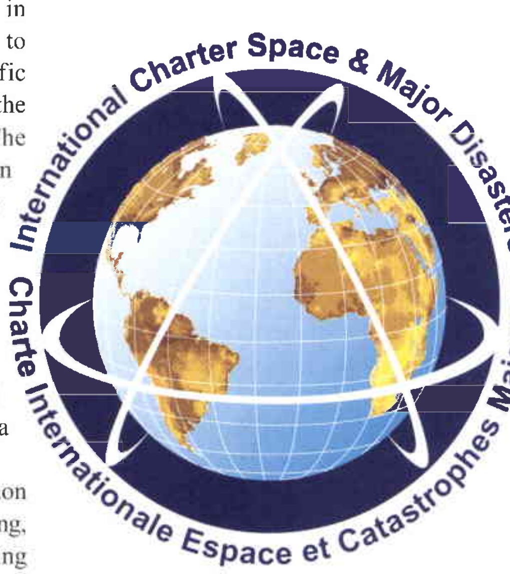
- A set of institutional and commercial services including, but not limited to, a response to GMES requirements.
- A data-distributio mechanism common to all these missions, including processing, archiving and distribution and allowing easy and coherent access to a wealth of inter-calibrated data sets.
- A complex constellation of satellites in orbit, resulting from a set of more-or-less independent initiatives.

The '0_2' generation

In parallel with the previous three phases, we will pursue the preliminary design of an Open and Operational system (the '0_2' generation), to be deployed as from 2010, comprising a space and ground infrastructure ensuring continuity with the capabilities of current systems, where appropriate and justified by the set of services made operational within pillar 'S'.

A Precedent: The International Charter on Space and Major Disasters

The International Charter on Space and Major Disasters is a first answer from the space community to facing some of these challenges. The Charter is working successfully and provides civil-protection agencies with access to data from a range of satellites. During 2002, for example, seven major disasters were covered by the Charter. This number was supplemented by another eight activations for minor disasters, out of the about 100 which occurred worldwide. In the case of the Prestige oil spill, where all countries concerned made extensive use of ERS, Envisat and Radarsat data, the first image was acquired after three days. Today ERS and Envisat follow the event at the rate of two images every three days. The mechanism of the Charter, although successful in giving access to data, suffers evident shortcomings owing to the lack of data integration and of association with an operational service provider.



Benefits and Challenges

The proposed initiative addresses directly the way in which information is elaborated and distributed in Europe. It needs to rely upon an efficient network for the circulation of data and information. It requires the development and improvement of information-processing technologies. It requires the education and training of adequate personnel for analysing data and interpreting results. It requires a drastic expansion in the use of models for interpretation and forecasting in several domains. The links between the operational users, the aerospace industry and the SME (Small and Medium-sized Enterprise) service-provider industry at large, and the science community will need to be reinforced. In short, when pursued in its entirety, the proposed initiative will have a substantial impact on the evolution of Europe as an information society.

The present strategy raises a number of significant challenges. The main ones are the design and implementation of the exploitation segment, the definition and the role of distributing entities, the creation of operational entities for the provision of institutional services, and the coordination of civilian and defence requirements.

Commercial and policy issues

Each operator and/or distributor will retain their own rights for exploitation but, by licensing to ESA the access to its services and data, will have access to a larger and integrated market. The development risk for new missions' ground segments will be reduced, and the synergy between the various missions will be enhanced. The definition and implementation of integrated multi-mission products will be encouraged and supported, financially and technically, reducing the final operations cost for all partners.

Clear rules for accessing data and services are a key issue for this approach to succeed. In pillar 'C' the individual policies of the various mission operators will obviously apply. They may be modified, at the user end, by financial or technical compensations negotiated by ESA with the operators. The forthcoming imaging missions, integrated in a European exploitation approach in the course of pillar 'N', should offer a coherent access policy, to be negotiated.

Technical challenges

The implementation of this programme will pose a number of technical challenges in terms of information access and presentation tools, archiving and distribution, information extraction, and mission planning.

An Earth Observation access portal linking information, service providers, data and results both on a global and regional scale will be set up. Previous experience (e.g. Infeo, CEOnet and EOSDIS) will be reviewed and developments will be enhanced.

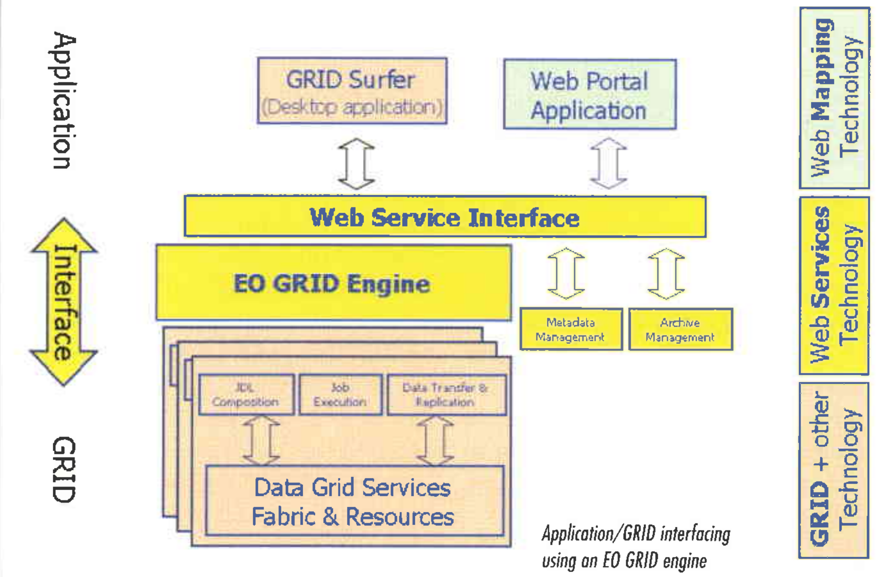
Traditional inventories and user catalogues, even multi-mission ones, provide information on availability and quality of data. Earth Observation data and other geographic information need to be presented to potential users in a complete, coherent and consistent form. Current and future GIS and web-mapping technology and interfaces can ensure immediate composition of different information layers (Earth Observation data sources, in-situ data, maps, results, meteorological data, etc.)

Maintenance of the rapidly increasing Earth Observation data archives is a technical challenge in itself. An even bigger challenge is the cost-efficient maintenance of a processing capability (hardware, operating system and adaptation of software to the modern languages) for these historical data. Data will have to be re-processed at regular intervals. GRID-based distributed processing technology can be applied for such individual, but resource-intensive, requirements.

An increasing amount of data is stored on-line and can be distributed via ground or satellite links. Network capacities are increasing and rapidly allowing the improvement of data-access methodologies.

Similar geophysical or environmental parameters are extracted from many different Earth Observation data sources. Initially comparable, later standardised methods, algorithms and even tools will improve and facilitate cross-calibration and long-term environmental trend monitoring. The development of multi-mission products as a basis for more reliable information will be supported and accelerated.

GMES, but also disaster management, requires immediate action from many different satellite and ground-segment operators. An initial coordination of this type has been established through the Charter activities. Such a process can be enhanced by the operational availability of coherent mission-planning tools, displaying for each mission operator the foreseen and later the actual acquisition plan of other missions.



Application/GRID interfacing using an EO GRID engine

Finally, service developers in many cases do not have the technical and financial resources to maintain their services operationally. A framework infrastructure for the support of developments and operations to service providers will facilitate the utilization of Earth Observation data and the acceptance by users of improved services.

The challenges and benefits for industry

This strategy and the resulting implementation approach should be beneficial to European industry in at least three domains: satellite manufacturing, ground-segment and data-processing software developments, and service provision.

This initiative will have a long-term impact on the satellite industry. The building and maintaining of a satellite infrastructure, with high technology content, will ensure the survival first and the technological progress later of European satellite industry. In the short term, this initiative will offer augmented justifications to currently weakening national initiatives, ensuring their implementation and continuity. The satellite industry relies heavily on these projects. If successful, such a long-term plan for operational Earth Observation will create the need for the replacement of at least one satellite per year. This will add to the workload already ensured by ESA with the Earth Explorers, and by Eumetsat with the operational meteorological satellites. The combined support of the current initiatives (GSE, EOMD, DUE, 6th Framework Programme) will provide European service industry with a level of funding never experienced before. More straightforward and cheaper access to basic data and products will help the industry to develop and provide more effective and economic services. An organized approach to exploitation, in particular in the interface to institutional users, will offer this industry an enlarged market and a better, less-fragmented, vision of the user requirements.

Benefits for national programmes

National initiatives will benefit from the proposed approach in a number of ways:

First of all, by saving in the deployment of the ground segment: the initiative proposed here offers to the national programmes the implementation of an integrated ground segment, with direct savings on the ground segments foreseen as part of each national programme, and more potential savings on the parts currently not envisaged, but necessary (data distribution, user services, long-term archiving, near-real-time services, etc.).

Secondly, by reduction of operation costs: it is not foreseen at this stage to integrate the individual mission-control facilities, but the common approach to ground-segment development and operations will result in substantial savings in the operating costs for the individual missions. An improved exploitation segment, with an augmented delivery of services, might, depending on the economic scheme selected, result in an improved economic return for satellite operators. This approach will also provide substantial support to exploitation: focusing the various missions on a common set of services will result in a more effective distribution of resources in support of the exploitation of the missions.

Finally, the proposed strategy will provide a major justification for the mission itself and for its continuity: the continuity of some of the national initiatives is in question, beyond the initial deployment(s). The creation of a unified approach to exploitation of these initiatives and the consequent development of long-term operational services will justify the continuity of the various data sources, if not of the individual missions.

Benefits for the scientific community

Some scientific issues require operational data series and are themselves a justification for operational satellites and operational information services. Anything that facilitates the generation and circulation of information will foster the development of Earth Sciences and the better understanding of Earth's phenomena. This will have an immediate impact on the development of services, since the scientific mastering of phenomena is a prerequisite to the development of reliable applications. Data from operational satellites should be made available to scientists.

Benefits for GMES and the ESA/EU relationship

Environmental monitoring, sustainable development and resource management are beginning to benefit from Earth Observation as an information source. The requirements in these domains emanate from a wide range of institutional entities at both national and European level.

With the GMES initiative, Europe is sending a strong signal that it has recognised the need for integrated operational information services to support European policies. These services will certainly benefit from smoother and more integrated access to data and programming functions for a wider range of satellite resources. The present strategic approach is essential for the proper implementation of GMES. GMES, in turn, will be instrumental to the identification of end-user institutional entities and to the development and the early delivery of services to such entities.

Consequences for defence and security

Defence authorities are intensive users of Earth Observation data and are currently the largest customers for commercial civilian imagery. Security also has a number of implications and constraints, including shutter control rules and restrictions on the timely diffusion of high-resolution data. Although it is not in the mandate of ESA to serve the defence community, we believe that the proposed approach should be designed to remain compatible with the requirements of the defence community and to accommodate the necessary constraints. The restrictions imposed for security reasons are well-known, have found solutions in the past with other satellite operators, and will be taken into account in the setting up of pillars 'C' and 'N' and in the deployment of the '0_2 generation'.

Conclusion

The strategy presented here should encourage a more effective use of information in many domains. It should favour the improvement in Europe of all technologies addressing the processing, management and circulation of information, regardless of origin. It should contribute to bringing together European capabilities in creating measurement instruments, generating data and information and delivering them. Synergy with European scientific teams will be fostered. The concept of a network of competences and the associated centres will be brought to reality. The approach set out here complements ongoing ESA Earth Observation programmes to ensure a comprehensive approach, including the understanding of Earth-system processes, relevant technology development, transition to a sustainable service implementation and subsequent long-term continuity of data availability.

The initiative proposed requires a high level of political support. It requires the recognition by Member States that independent and uncoordinated initiatives, in particular if targeting global issues and institutional services, lack justification and are doomed in the short- to mid-term. It requires the recognition that even current programmes and existing infrastructures need to come to a higher level of integration in terms of offerings (data, services) in order to exploit synergies and to meet the needs for effective information. It requires the recognition that the current business model has failed to deliver a dynamic industrial service sector, and that a different open-access approach provides a second chance for operational Earth Observation.

Political authorities should recognize that only an initiative of this size and scope can sustain European industry in both the manufacturing and service domains and transform the information and data handling industry in Europe.

Coherent and constant support from both Member States and the European Commission is required, as the initiative will take several years and is based as much on an integration of the offerings as on the coordination of the demand side: the requirements for information from institutional users across Europe! esa

Mapping Photosynthesis from Space

- a new vegetation-fluorescence technique

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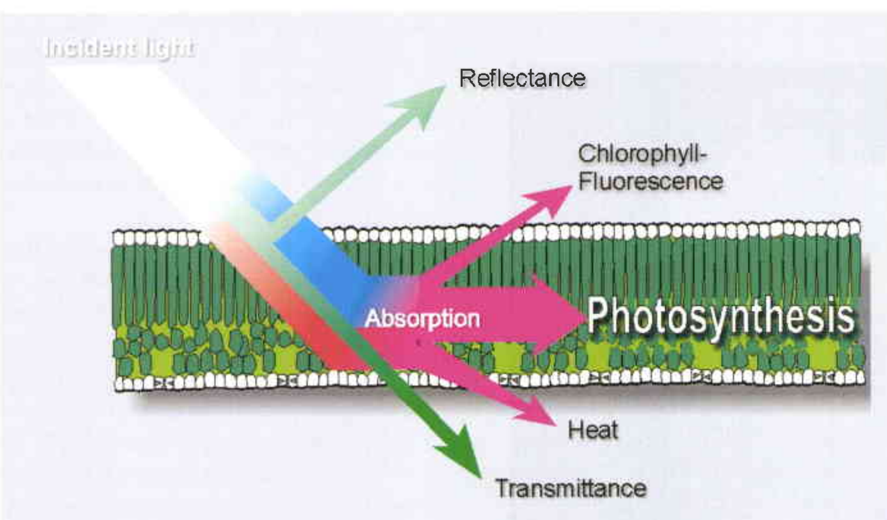
Most of the information that has been acquired so far by remote sensing of the Earth's surface has come from the analysis of reflectance data. Typically, the information provided by the sensors carried by satellites is embedded in either reflected sunlight, at optical and near- to mid-infrared wavelengths, in reflected radar pulses in the microwave domain, or in radiation emitted by the surface itself (thermal and passive microwave). There is, however, one additional source of information about the Earth in the optical and near-infrared wavelength range that has not yet been exploited by any satellite mission, namely 'vegetation fluorescence'.

Our interest in vegetation fluorescence in terms of observing the Earth stems from the fact that it provides unique information about the photosynthetic activity of the vegetation. Unlike conventional reflectance measurements, which are affected by numerous processes, fluorescence represents a specific observable of the fundamental physical processes occurring within the plant. Extensive experimental and theoretical studies have demonstrated that vegetation fluorescence serves as a proxy for the actual photosynthesis.

An Earth Observation mission based on fluorescence thus has the potential to provide valuable large-scale information about photosynthetic activity, which in turn would significantly improve estimates of carbon-dioxide uptake and provide a means for screening and monitoring vegetation vigour over large areas. This information would be complementary to that provide by current and planned optical remote-sensing satellites.

The topic of vegetation fluorescence is not new. The fluorescence signal has been studied for years and is routinely used in laboratories to study photosynthetic activity. The extension of passive fluorescence-measuring techniques to space, however, is highly innovative. Motivated by the potential of fluorescence to map photosynthetic activity at large scales, two experimental missions have been proposed in the past: Flex (ESA) in 1998 and Flexsat (NASA) in 1999. In terms of ESA programmes, the Fluorescence Explorer (Flex) was proposed within the framework of the First Announcement of Opportunity for Earth Explorer Opportunity missions. Although the proposal was not selected, it received a positive assessment and was on a short list of missions judged to have very high scientific merit. As a consequence, ESA's Earth Observation Science Advisory Committee (ESAC) recommended the initiation of scientific and technical studies furthering a satellite mission concept.

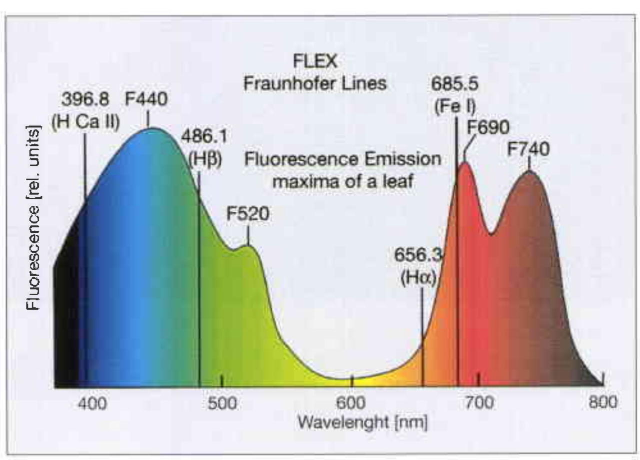
In response to this recommendation, ESA has initiated several activities over the last few years addressing key challenges in exploiting the fluorescence signal at satellite level. These include:
- an instrument feasibility study
- campaign activities
- scientific studies, and
- workshops.



How light energy falling on a leaf is partitioned. About 78% of the incident radiation is absorbed, while the rest is either transmitted or reflected at the leaf's surface. About 20% is dissipated through heat and only 2% emitted as fluorescence, as a by-product of photosynthetic reactions occurring within the leaf itself.

The main objectives of the Flex instrument-feasibility study were to refine the instrument concept for the detection of vegetation fluorescence from space, to identify potential bottlenecks, and to estimate the accuracy of the retrieval of the fluorescence signal from a spaceborne platform. The study was led by TNO-TPD, Delft (NL), with participation by the University Louis Pasteur (ULP), Strasbourg (F), the University of Karlsruhe, Karlsruhe (D) and York University, Toronto (Can.).

The Flex study addressed a critical technical challenge characteristic of vegetation fluorescence: the weakness of the fluorescence signal itself, whose level represents only a very small fraction of the total reflected visible light (less than 2% in most cases). This requires special observation methods based on measurements in very narrow spectral bands for which the reflected background signal is strongly depressed (the so-called 'Fraunhofer-line method'). The study examined various imaging concepts and performed extensive signal modelling to determine an acceptable sensor concept. One result of the study was to show that atmospheric effects on the signal could generally be corrected for through modeling, and that the retrieval of fluorescence radiance appears feasible from space with an overall accuracy of 10%. The study also identified the need to document the fluorescence signal over real vegetation canopies, as only a theoretical estimate could be used during the Flex study.



The fluorescence emission spectrum of a leaf as derived from laboratory measurements. The peaks in emission at 440, 520, 690 and 740 nanometres are clearly visible in spectrum.

The experimental setup during the ESA SIFLEX campaign which took place above the Arctic Circle, in Sodankyla, Finland. Observations of solar-induced fluorescence were made from the top of a 20 m tower overlooking the Boreal forest canopy.

To address these issues, an ESA field campaign known as SIFLEX (Solar Induced FLuorescence EXperiment) was initiated in 2002 in northern Finland. The aim was to establish and document fluorescence signal levels over Boreal forests, in specific bands of interest for spaceborne fluorescence sensors. The participating scientists collected 6 weeks worth of fluorescence data, covering the spring recovery of the forest from winter dormancy, through to its fully active summer state when photosynthesis was at its maximum. These measurements were made from an instrument, specially developed by the LURE photosynthesis and remote-sensing team in Paris, which was pointed at the forest canopy from the top of a 20 m tower erected especially for the campaign. Coinciding with the fluorescence data acquisition, a wide range of additional measurements were performed by the Finnish Meterological Institute, the University of Valencia, and York University. These included CO_2 flux measurements to establish a linkage between the fluorescence signal and the carbon cycle, and reflectance measurements and thermal measurements for canopy-modelling purposes.

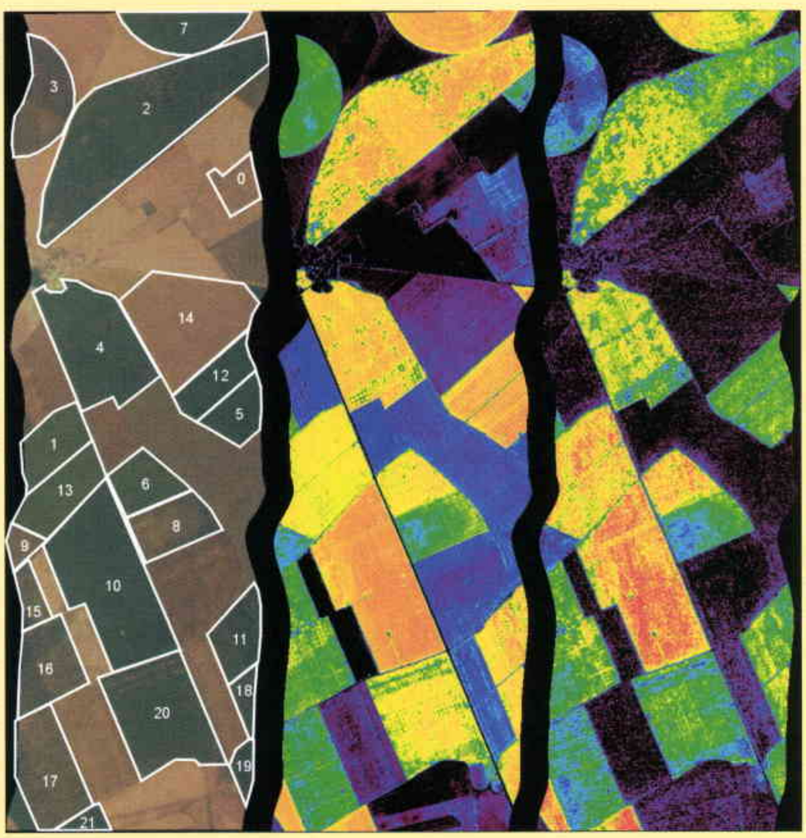
Overall the ESA SIFLEX campaign represented a significant step forward as, for first time, it was possible to detect and observe the chlorophyll fluorescence signal and its fluctuations in the natural environment over a long period of time. As a result, more realistic simulations can be made of the performance requirements for future spaceborne fluorescence sensors. Initial simulations based on campaign data show that the chlorophyll fluorescence signal is detectable by means of remote sensing even under the difficult low-light conditions that are typical in Arctic regions.

As part of the coordinated efforts, a study was also launched in 2002 by ESA to advance the underlying science of a possible future vegetation-fluorescence space mission through the development of integrated canopy-fluorescence models. The aim of this study is to incorporate the fluorescence signal into existing canopy models in order to simulate the total signal, consisting of both reflectance and fluorescence emission components. The final model will be validated using SIFLEX and other campaign data. In the future, it will serve as a basic tool with which to develop accurate quantitative approaches to extract information from fluorescence and reflectance data and form a basis for the development of retrieval algorithms.

In addition to existing activities, a number of future activities have been initiated to address the remaining open issues associated with an eventual space fluorescence mission. Of prime importance is the documentation of the fluorescence signal over different types of land-cover and under a variety of conditions. This follows a key recommendation made by the scientists attending the First FLEX Workshop help in June 2002 at ESTEC (NL). To meet this challenge, an airborne fluorescence instrument is currently under development. It will be flown next year over a test site in Spain during the 2003 ESA AIRFLEX (Airborne Fluorescence Experiment) campaign. This campaign is expected to provide important information about fluorescence signal sensitivity, spatial variability and scaling effects, and will complement the initial field activities initiated with SIFLEX.

Additional investigations are also currently underway based on airborne and spaceborne hyperspectral images. Recent results have shown that narrow imaging spectrometers are sensitive to the fluorescence signal in spectral bands where reflectance is strongly attenuated by atmospheric absorption. Different analysis methods based on hyperspectral data are under investigation.

It is interesting to note that, a quarter of a century after satellite detection of fluorescence was first envisaged, no operational system has yet been developed. For a long time, fluorescence studies have remained confined to the laboratory and have not attained the status of an operationally exploitable remote-sensing technique. A number of steps are required to transform the laboratory results into an operational space mission. The activities undertaken at present by ESA and other agencies have strongly contributed to this bridging phase. The feasibility of detecting fluorescence from space has been demonstrated through dedicated campaigns and instrument studies. The unknowns regarding the measurement, analysis and exploitation of the fluorescence signal are being addressed by the development of appropriate canopy radiative models and assessed using campaign measurements. Together these activities contribute to furthering the concept for a spaceborne fluorescence mission and open new ways for the global monitoring of vegetation, with improved estimates of vegetation photosynthetic activity and direct implications for carbon flux estimation.



The complementarity between indices derived from conventional reflectance measurements and from fluorescence. All images were derived from airborne hyperspectral data acquired with DLR's ROSIS sensor. The leftmost image represents a true colour image of the Barrax test site, near Albacete in Spain. The middle image represents an estimate of vegetation fluorescence derived using a novel technique applicable to hyperspectral data. The rightmost image represents the commonly used Green NDVI index, which is derived from reflectance data and generally provides information about greenness and vegetation vigour. The different spatial patterns and levels of the vegetation fluorescence image with respect to the NDVI image illustrate the additional information captured by fluorescence and the complementarity of reflectance and fluorescence measurements. (Courtesy of S. Maier, Satellite Remote Sensing Services, Australia)

Life in a Spin – What has been learnt from space

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Our Sense of Motion

During spaceflight, the linear acceleration due to gravity is reduced from 1-g on the Earth's surface to about 10^{-6}-g in Earth orbit, but the linear and angular accelerations associated with translation and turning are unaffected. Human adaptation to spaceflight therefore entails selective reorganization of the body's response to the relative absence of the linear acceleration due to gravity. Associated with this reorganization, astronauts experience nausea and disorientation during flight. After their flight, they experience walking and vision (gaze control) difficulties that could pose a serious problem if they had to function efficiently in a normal gravitational environment immediately after a long-duration spaceflight.

Although such difficulties have long been a source of concern, they are as still far from being fully understood. The otoliths, which are calcareous elements located in our inner ear that sense gravity and acceleration, act as linear accelerometers and drive various reflexes to maintain our gaze and posture when linear accelerations are acting on our bodies. This includes the linear acceleration due to gravity, the high-frequency linear acceleration associated with translation produced by forward/back, up/down or side-to-side movements, and the centripetal linear acceleration experienced when turning about a distant axis, such as when turning corners, driving or walking along a circular path.

The sum of these different linear accelerations is termed 'gravito-inertial acceleration', abbreviated to GIA. In the absence of translation and centripetal accelerations, gravity is the sole GIA. If the head is tilted with respect to gravity, or if the GIA is tilted with regard to the head, the otoliths sense the linear acceleration and orient the bodily posture or the eyes towards the GIA. In particular, the ocular counter-rolling (OCR) of the eyes tends to maintain the position of the retina with respect to the spatial vertical.

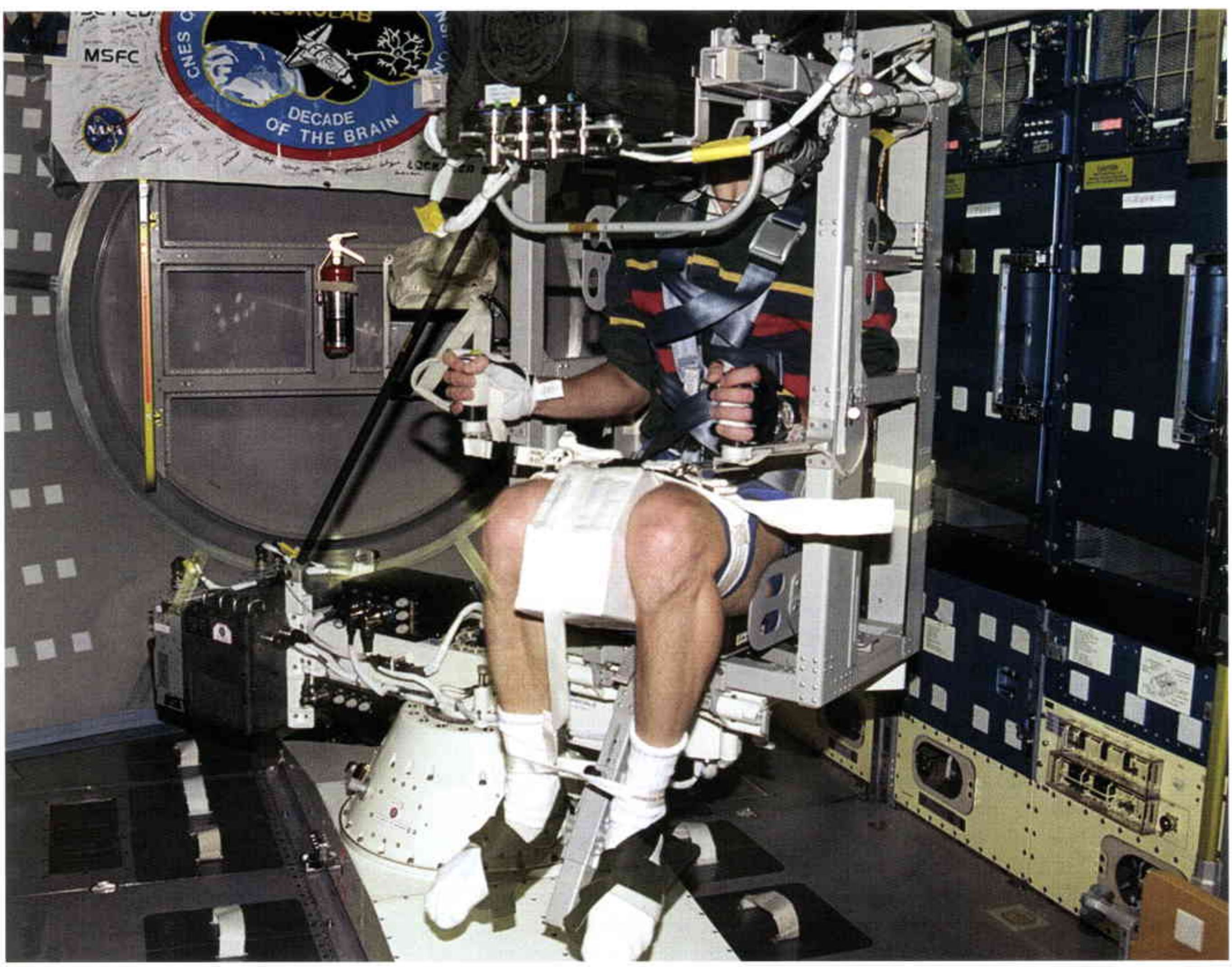
The VVIS Experiment on Neurolab

Although eye and perceptual responses to linear accelerations have been tested before and after spaceflight, the orientation of the eyes to the GIA had never been directly tested in space before the Neurolab mission in 1998. During that 16-day Shuttle mission, a series of investigations were carried out in the Spacelab module. One of the main items of equipment onboard was the ESA-developed Visual and Vestibular Investigation System (VVIS), designed to investigate the role of the inner ear in detecting changes in linear acceleration and hopefully provide a new approach to diagnosis back on Earth for disease or trauma in our inner-ear vestibular system.

One technique for generating GIA in space is to rotate the test subject about a distant axis in a centrifuge to generate centripetal linear acceleration. Until the Neurolab experiment, the human response to centrifugation had not been formally studied in space. One of the aims of the study was therefore to generate artificial gravity by centrifugation and examine whether low-frequency otolith function, as determined from OCR measurements during and after flight, is altered by the body's adaptation to microgravity.

Another measure of otolith function, albeit indirect, is our perception of the upright. During centrifugation on Earth, the sum of the gravitational and centripetal accelerations (i.e. the GIA vector) is perceived by the human body as the spatial vertical. Consequently, we experience a roll tilt of the body when we are upright

The Neurolab human centrifuge (VVIS) mounted in Spacelab's centre aisle generated linear accelerations of 0.5 g and 1.0 g along the astronauts' interaural axis for several minutes every other day.



When supine on the centrifuge arm, centrifugation was directed along the vertical axis of the astronauts' bodies. A linear acceleration of 1 g gave the astronauts the illusion of standing on their head.

during centrifugation. For example, test subjects in the left-ear-out position (see accompanying figure) who are exposed to 1-g of centripetal acceleration at the head during centrifugation on Earth will experience a GIA of magnitude 1.4-g tilted 45° towards the rotation axis with respect to the vertical. They perceive the GIA as the vertical and therefore feel tilted to their left in the roll plane by approximately 45°. Similarly, they sense a backward pitch of the body when they are supine with the head off-centre (see accompanying figure). This perception of tilt during centrifugation, which has been called the 'somatogravic illusion', is present in test subjects with an intact vestibular system. Whether the GIA is still perceived as the spatial vertical during in-flight centrifugation had never been tested and was the second major aim of the Neurolab experiment.

Since the otoliths are not activated during static pitch or roll tilts of the head or the body in space, but are still activated by high-frequency translational head movements, it has been proposed that adaptation to weightlessness entails a reinterpretation of the signals from the otolith organs, so that pitch or roll of the head with respect to the vertical would be sensed as fore-aft or left-right translation upon return to Earth. Maintenance of this so-called 'Otolith Tilt-Translation Reinterpretation' (OTTR) in the post-flight period has been believed to be responsible for the imbalance and gaze instability observed in returning astronauts. This reinterpretation was also believed to be responsible for the amelioration of space motion sickness, which afflicts roughly half of all space travellers during their first few days in orbit. A third aim of the VVIS experiment was to test this hypothesis by delivering sustained linear acceleration in microgravity. If OTTR had taken place, astronauts should incorrectly interpret the signals from the otoliths as translation, rather than correctly perceiving a static tilt.

Prior to the Neurolab experiments, the effects of artificial gravity on our body-orienting responses in space had only rarely been addressed. During the Gemini-11 flight in 1966, the spacecraft was tethered to an Agena target vehicle by a long Dacron line, causing the two vehicles to spin slowly around each other for several minutes. According to the Gemini commander, a TV camera fell 'down' in the direction of the centrifugal force, but the crew did not sense any changes at that moment. Subjects sitting on the ESA-built linear Sled flown during the Spacelab-D1 mission in 1985 perceived linear acceleration, but not tilt. Similarly, during off-axis rotation on the Spacelab IML-1 mission, the test subjects perceived only rotation, not tilt. In these experiments, however, the linear accelerations were less than 0.22-g, which ground-based studies have since shown to be insufficient to yield a perception of tilt.

The Results from Neurolab

There was found to be little difference between the eye responses to centrifugation in microgravity and on Earth. In both cases, the induced OCR was roughly proportional to the inter-aural linear acceleration being applied, with the OCR magnitude during 0.5-g centrifugation approximately 60% of that generated during 1-g centrifugation. The OCR magnitude in space was not significantly different from that induced by equivalent inter-aural linear acceleration during static tilt on Earth. In contrast to previous studies, there was no decrease in OCR gain post-flight. These findings raise the possibility that in-flight exposure to artificial gravity, in the form of intermittent 1-g and 0.5-g centripetal accelerations, may have acted as a countermeasure to the deconditioning of otolith-based orientation reflexes.

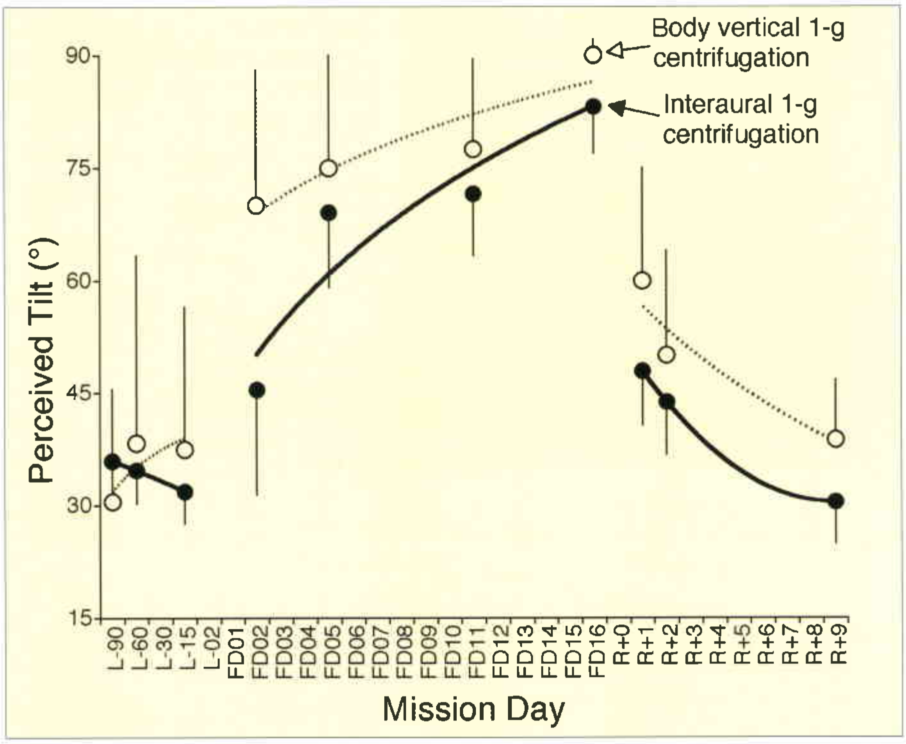
Before the Neurolab mission, astronauts had never been exposed to sustained linear accelerations of 0.5 and 1-g in space. The results showed that they perceived a body tilt relative to a perceived spatial vertical when exposed to 0.5 and 1-g, and that the magnitude of this tilt adapted throughout the mission. During their first test session, on flight day 2, the astronauts perceived a 45 deg roll tilt when subjected to a 1-g inter-aural linear acceleration. After two weeks in space, they perceived a tilt of almost 90°, which was essentially veridical in that it represented the actual level of linear acceleration experienced by the otoliths. This suggests that the otoliths were operating normally in space when exposed to sustained 0.5 and 1-g linear accelerations, after the initial period of adaptation.

The ESA Visual and Vestibular Investigation System (VVIS)

The VVIS, of which one flight and one training model were built by ESA, included a human-rated centrifuge, a visual display, and binocular video-oculography. The test subjects were seated with the body's vertical axis parallel to the axis of rotation at a radius of 0.5 m, either facing or with their back to the direction of motion, and either left-ear-out or right-ear-out. In this configuration, rotations at constant velocities of 254°/sec and 180°/sec provided centripetal accelerations of 1 and 0.5-g, respectively, directed along the test subject's interaural axis. They could also be positioned so that they lay supine along the centrifuge arm with their head 0.65 m from the axis of rotation. Centripetal acceleration was then directed along the body's vertical axis. A restraint system, consisting of a five-point harness, thigh, shoulder and neck pads, and a knee strap, held the body firmly in place. A custom-made facemask restrained the subject's head. A set of headphones provided a masking noise that eliminated external audio cues.

An LCD screen was mounted in a unit directly in front of the test subject's face on the centrifuge chair. Sequences of dots were displayed at known gaze angles to enable calibration of the eye movements. The display was also used to present optokinetic patterns (sequences of 5° stripes that moved horizontally, vertically and diagonally across the screen at 30°/sec) and smooth pursuit targets (small dots that moved horizontally and vertically across the screen). The pattern illumination was adjusted for each test subject for best viewing of the visual targets.

Binocular video recordings were obtained using two miniature video cameras mounted on the LCD visual display unit. Near-infrared LEDs attached to each camera were used to illuminate the test subject's eye. Images of the latter were directed into the video camera via a beam-splitter, which was transparent to light in the visible range and allowed the subject a clear view of the visual display. Two videotape recorders mounted at the opposite end of the rotator beam to the chair were used to store the images of the eyes, as well as centrifuge velocity and timing information.



Mean magnitudes of the tilts perceived by the four Neurolab crew members during interaural and body vertical 1-g centrifugation (L-: pre-flight; FD: flight day; R+: post-flight).

The finding that none of the astronauts felt translation instead of tilt in response to the constant 0.5 or 1-g linear accelerations in space indicates that the OTTR hypothesis is incorrect. Tilt is perceived as tilt, regardless of whether the test subjects are in microgravity or the 1-g environment of Earth, and is not sensed as translation. A model that references perception of tilt with regard to a weighted sum of all linear accelerations and body vertical as the perceived spatial vertical could explain these results. The underestimation of tilt on entry into microgravity suggests that the test subjects continue to weight their internal estimate of body vertical for computing the direction of the GIA. As flight progresses, the weight of this internal representation of body vertical would gradually decrease and the subjects finally adopt the centripetal acceleration as the new spatial vertical reference. This would carry over to the post-flight period and be responsible for a transient exaggerated sense of tilt on returning to Earth

Eye movements during centrifugation in darkness and during horizontal visual stimulation also shifted towards the centripetal acceleration in space, consistent with the perceptual data.

Lessons Learned

There were a number of innovations in the research equipment developed for the Neurolab flight. In addition to being the first use of binocular, three-dimensional, video-based, eye-movement recordings during controlled vestibular stimulation in space, it was also the first use of visual stimuli to study visual-vestibular interactions during centrifugation, either on Earth or in space.

The information from this research could be used to develop countermeasures to overcome lags in adaptation or the changes in gaze and balance that occur after astronauts return from space. Such countermeasures will be critical for the long-duration spaceflights associated with planetary exploration. When astronauts go to Mars, for example, they will have to fend for themselves immediately after landing on a planet with substantial gravitational force, although they will have been travelling in a microgravity environment for many months. Anything that could hasten their re-adaptation to a stronger gravitational environment will therefore be very valuable in overcoming gaze, posture, and walking difficulties.

One consequence of our findings is that if low-frequency linear acceleration is always perceived as tilt, whether we are in the weightlessness of space or on Earth, long-duration missions can proceed in the expectation that the astronauts will respond normally to artificial gravity or to the gravitational fields of other planets when they are encountered.

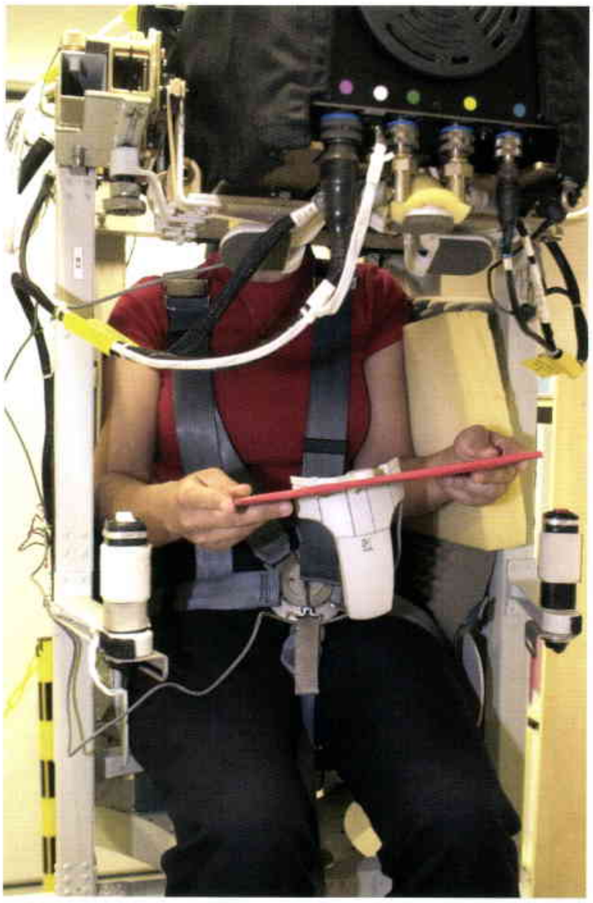
These experiments also have substantial clinical implications for those of us back on Earth. We still have little understanding of exactly which part of the human vestibular system is damaged or not operating correctly when we experience balance problems. We also do not yet understand why older people are so prone to falling. Alignment of the body axis to the GIA during walking or turning is likely to be an important factor in this imbalance. Consequently, evaluation of the perceived tilt during centrifugation might prove to be a useful test of the brain's ability to evaluate the direction of the GIA in a dynamic situation.

Ground-based Clinical Studies

After the Neurolab flight, the training model of the VVIS was moved to the MEDES Flight Clinic in Toulouse's Rangueil Hospital, where it has been used for several studies of patients with vestibular disorders.

A study performed at the MEDES clinic on 20 normal subjects allowed roll and pitch tilt perception during centrifugation at various g-levels to be characterized. It revealed an asymmetry in the perceptive roll response between acceleration and deceleration, and in the pitch response between forward or backward motion. These results were also used to confirm that the baseline data collected from the four Neurolab crew members were normal.

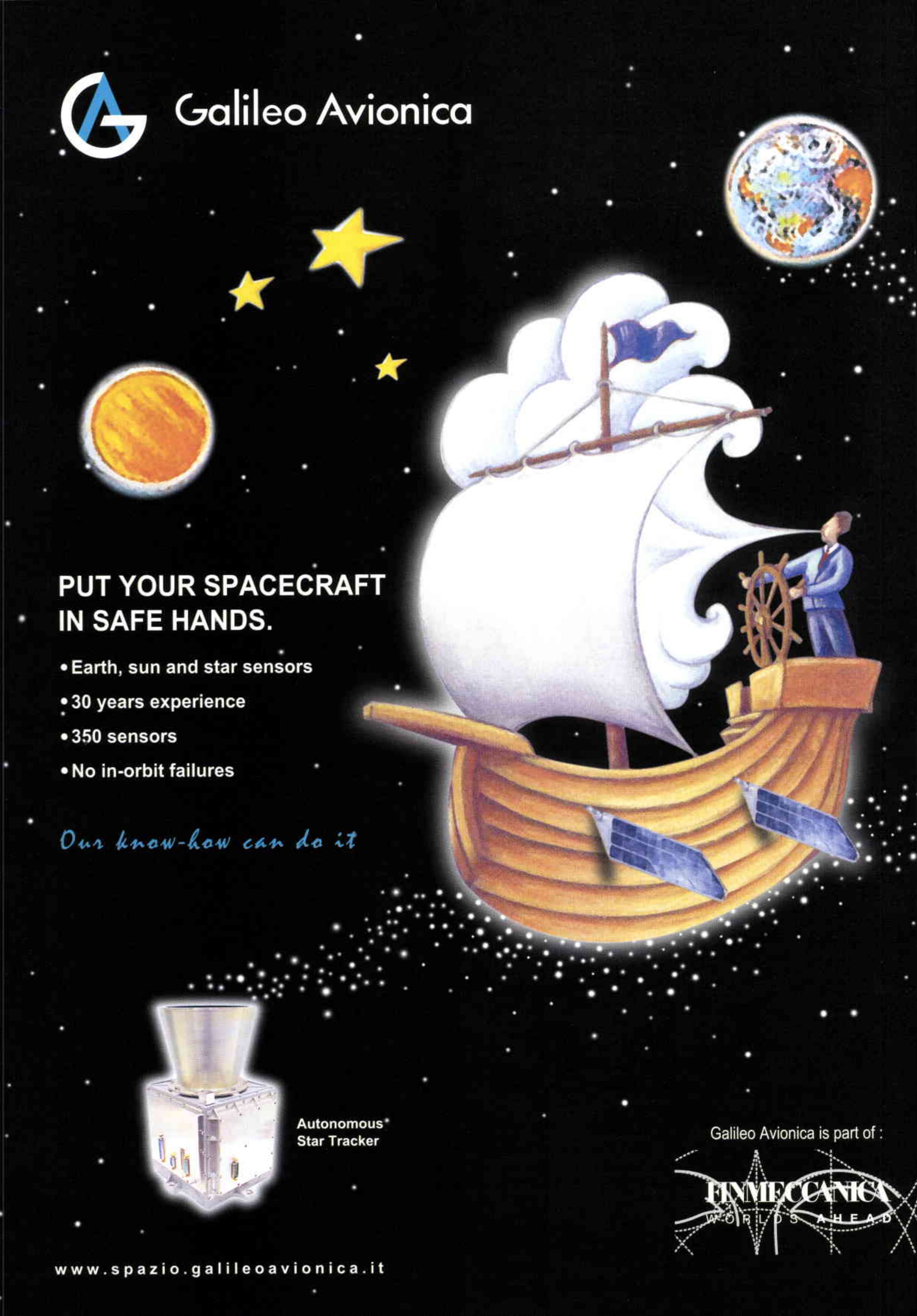
Another MEDES study has recently begun to study the tilt perception and OCR during centrifugation of 20 other patients with various vestibular problems. The causes for these deficiencies in some patients are already known (e.g. surgical lesions). For others, the 'classical' clinical vestibular evaluation methods show no abnormalities in recorded response, although the patients themselves still complain about vertigo and balance problems. Indeed, most clinical vestibular tests do not address the malfunctioning of the otolith organs per se. It is hoped that the perceptions and eye movements captured with the VVIS training model can be used for the diagnosis of disorders in the otolith organs. Programmes for 'vestibular rehabilitation' will also be tested using the VVIS centrifuge,



A test subject undergoing centrifugation, holding a plate in an orientation that she believes to be 'horizontal', i.e. perpendicular to gravito-inertial acceleration (GIA)

Conclusion

The human centrifuge experiments conducted in space during the Neurolab mission provided a unique opportunity to evaluate the adaptation of the human spatial orientation system to an unfamiliar environment. The fact that the astronauts perceived tilt rather than translation during centrifugation in space proved that the theory based on a reinterpretation of the otolith signals in microgravity is incorrect. Instead, the results showed that the otolith organs respond normally to a linear acceleration in space, and that both eye movements and perception align to the GIA both on Earth and in space. These findings have helped to identify new possibilities for the testing of the otolith function and the diagnosis of the causes of imbalance-related medical problems in patients here on Earth, and as well as for evaluating the efficacy of artificial gravity during long-duration space-flights to Mars and beyond.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The Future is our Business

- How ESA prepares its technology

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ESA Directorate for Industrial Matters and Technology Programmes, ESTEC, Noordwijk, The Netherlands

Introduction

Many people in all walks of life pay lip service to the fundamental importance of technology in our modern world, but few understand its true significance and role in our fast-evolving and ever-changing enviroment. For organisations such as ESA, however, which focus on Research and Development, it is an area of primary importance, a driving force that is at the very core of its existence.

To those on the outside, technology is often perceived as exciting, but mysterious – a stereotyping that is compounded by the jargon of technology, with words such as prototype and engineering model. In contrast, many working on the inside would describe technology and its associated disciplines as a vibrant and dynamic environment.

Another misconception about technology is that it only deals with the future. Any consideration of technology should look not only to the future, but also to the past. We must use the lessons that we have already learnt to stimulate our creativity and to develop new ideas.

Despite this, and underlying all the instrumentation and infrastructure, one vital element is often overlooked – the human element. People are ultimately what technology is about, and it is people that make the difference. This was explicitly acknowledged in the first ESA Technology Master Plan, in which it was stated that: *"...the ESA TMP shall make provisions to assure the motivation of staff for technology development"*. It is further acknowledged by the fact that the ESA Awards scheme, which relies on peer recommendation for choosing its winners, has technology teams and engineers as regular nominees.

What is Technology?

At this stage, it is worth differentiating between three closely related areas:

- Technology, which is the practical application of knowledge so that something entirely new can be done, or so that something can be done in a completely new way.
- Scientific research, which encompasses the discovery of new knowledge from which technologies can be derived.
- Engineering, which involves the use of technology to solve specific technical problems.

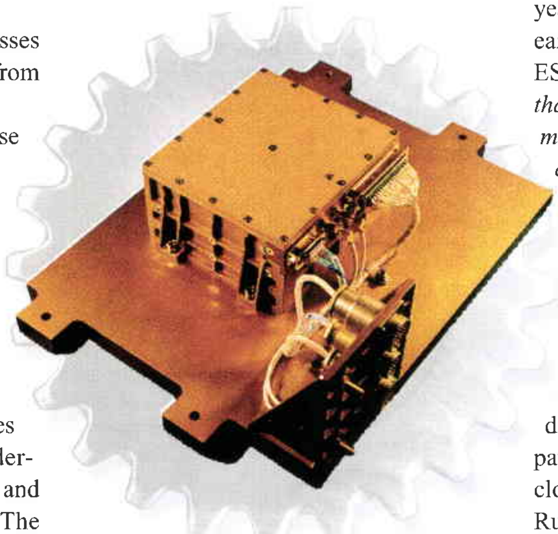
Because a scientific result or an engineer's idea can rarely be translated directly into an item or a product, the development of technology is a step-by-step process. The completion of each step validates the ideas, provides a greater understanding of the phenomena involved, and confronts the theory with reality. The experience thus gained allows people to move forward to the next stage with increased confidence. When put together, all of these steps form the development process – the 'D' in R&D.

Lower risk, higher cost

Technology effectively addresses a risk-reduction process, risk being understood here as the risks and uncertainties associated with performance, cost and schedule. What would be the likely consequences if a project were initiated without first ensuring that the technologies needed are available? Three of them are already well known, namely under-performance, schedule delays and cost overruns.

Throughout the development stage, one common truth persists: when investments are made in a particular technology, it begins to mature. The process of testing and analysing progressively reduces the risk involved in selecting that technology. At the same time, its readiness for use increases. 'Maturity' is reached when the level of confidence in the technology and the level of risk involved are deemed to have reached acceptable levels. The technology is then ready to be included in a product or a project, or to have something built around it.

As mentioned earlier, all technology starts with people – for instance, scientists making a discovery, or engineers having an idea. The first step is to check out and demonstrate the feasibility or validity of this idea. But to finally translate the idea into a product or project can take an enormous amount of time and effort. More people and materials will be needed as the development work progresses, as each step requires a greater effort for its completion. The closer you come to the final product, the more stringent are the requirements, the more accurate the manufacturing needs, the more realistic the tests – and ultimately, the greater the costs.



The first European Rubidium Ultra-Stable Oscillator for space application

In other words, the cost increases as the development cycle progresses, whilst at the same time, the level of risk involved decreases. Nevertheless, an increase in funding does not imply a proportional reduction in development time.

How does technology evolve and mature?

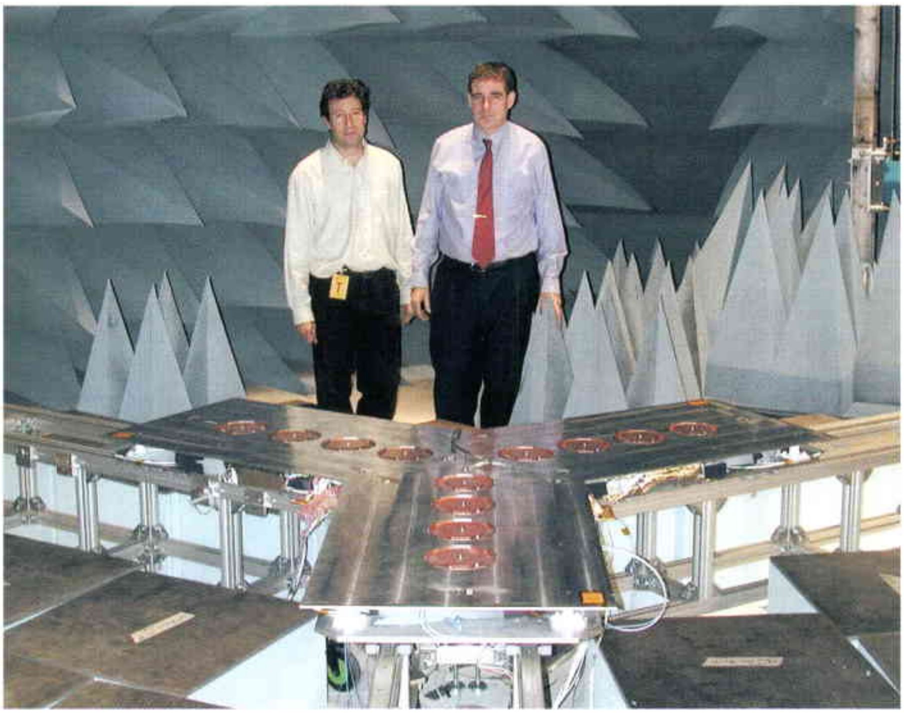
As we have seen, technology usually matures through a series of sequential steps, starting with the initial exploratory studies that support a pioneering idea. These are usually based on very broad views. In the case of space technology, the end result that is aimed at is usually a flight-qualified product that will be integrated onto a spacecraft.

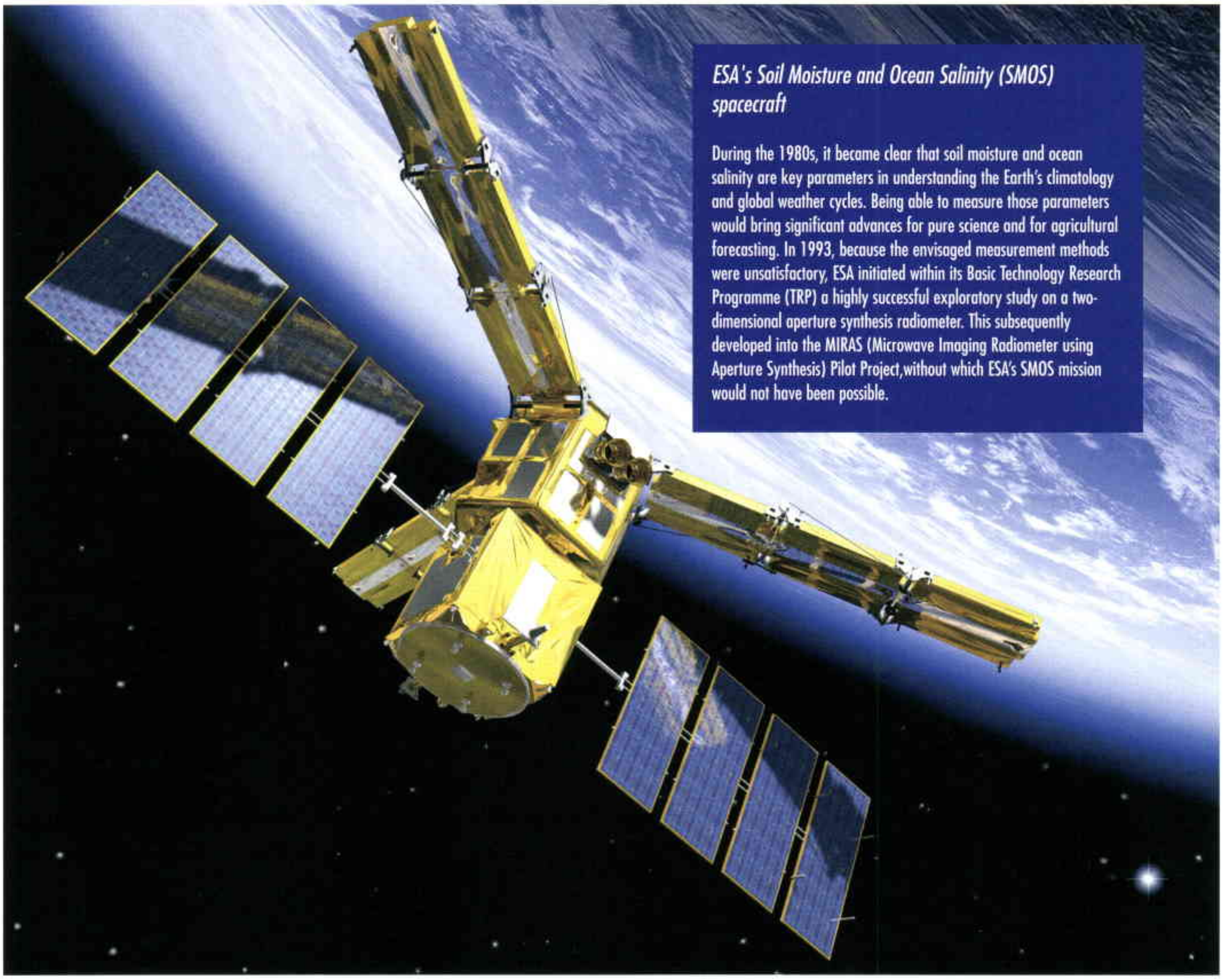
The process, however, is rarely that straightforward. It involves an enormous amount of both curiosity and foresight on the part of the people involved – factors that have been major driving forces for ESA's technology. For example, some 15 years ago, Stephen Feldham headed the early development of ultra-stable clocks at ESA. He says: *"Not only did we recognise that it would be fascinating to be able to measure time accurately, we also realised it could be a very important asset for Europe. We therefore tried to build clocks that were more accurate, smaller and lighter than any existing at that time."*

The result of this initial curiosity was technology that has since been developed into the European Galileo navigation system. However, technology development rarely follows a linear pattern and the first European rubidium clock for space was actually intended for a Russian radio-astronomy project.

Other factors that affect the way in which ideas develop include personal backgrounds and experience. These can help in the identification of the right problems for solution, and can also provide a considerable amount of motivation. Manuel Martin-Neira helped to conceive the MIRAS pilot project on which ESA's Soil Moisture and Ocean Salinity Mission (SMOS) is based. He recalls: *"My father and grandfather were forestry engineers, and I knew about the importance of measuring soil moisture for this community, and the problems involved in measuring it...I was fascinated by the idea of trying to apply radio-astronomical techniques (a field in which I had some experience) to problems here on Earth."*

MIRAS Pilot Project testing in progress





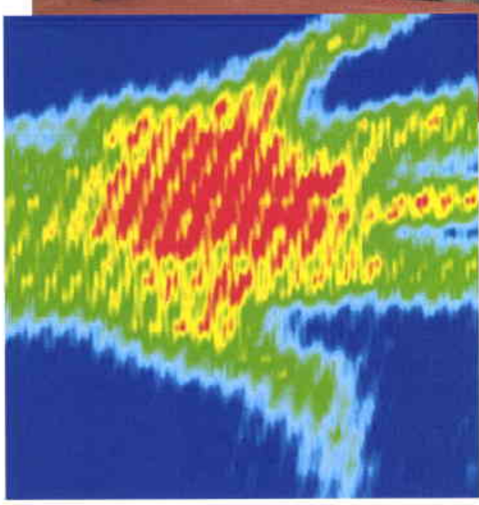
ESA's Soil Moisture and Ocean Salinity (SMOS) spacecraft

During the 1980s, it became clear that soil moisture and ocean salinity are key parameters in understanding the Earth's climatology and global weather cycles. Being able to measure those parameters would bring significant advances for pure science and for agricultural forecasting. In 1993, because the envisaged measurement methods were unsatisfactory, ESA initiated within its Basic Technology Research Programme (TRP) a highly successful exploratory study on a two-dimensional aperture synthesis radiometer. This subsequently developed into the MIRAS (Microwave Imaging Radiometer using Aperture Synthesis) Pilot Project,without which ESA's SMOS mission would not have been possible.

The StarTiger project

In a pilot project to test the StarTiger concept, 11 hand-picked scientists and engineers drawn from seven European countries spent four months in 2002 at Rutherford Appleton Laboratory (UK) developing a terahertz imager, a technology that did not exist but was regarded as highly desirable. The pilot project was successful, and in January 2003 was honoured with an ESA Award.

The world's first terahertz image of the human hand is shown below left



The intrinsic value of different people's experience was even more evident in the StarTiger initiative. Peter de Maagt, the originator of the concept, remarks: *"From my experience as a diving instructor, I know about the value of teamwork."*

Developing Technology for Space

For space programmes, the technology-development cycle tends to have a very long lead time, typically ten years. Consequently, a mission-development time frame is likely to be of similar duration (unless it relies totally on technologies that already exist, need a few incremental developments, or are being adapted from terrestrial applications). The time frame can sometimes be even longer, as demonstrated by the 30 years of development that has been needed before using electric propulsion operationally.

Primarily, space technologies exist to enable missions or applications, be they the result of planned developments or unexpected breakthroughs. The space-technology development process, from exploratory study to flight-qualified product, is driven by two key forces. The first is an identified need for an anticipated future mission, or 'mission pull', using technologies that are already within reach. The second is the advent of a new technology that promises advantages over other alternatives for future space projects, namely the 'technology push'.

PROBA, ESA's first small satellite mission for technology demonstration

In 1996, a small mission dedicated to in-orbit technology demonstration and Earth environment monitoring was proposed as part of ESA's GSTP-2 programme. PROBA (Project for On-Board Autonomy) is a small spacecraft equipped with a set of technologies that provide advanced on-board functions to support mission operations with minimum ground involvement. It proved so successful that the mission was extended to cover an official Earth Observation Campaign in 2003, and the PROBA team was proposed for an ESA Award in 2002.

Developing Technology within ESA

Technology is indispensable when it comes to building satellites and payloads, and sending them out into the inhospitable environment of space. It is therefore hardly surprising that 'technological research work' is a mandatory element within the ESA Convention.

Although technology lies at the heart of ESA's activities, it can be difficult to quantify what proportion of them directly involve technology. Some 90% of ESA's budget is spent on contracts with European industry and universities. Although this is for R&D in its widest sense, it also covers such aspects as systems studies and engineering, manufacturing, production, testing, launching, and mission operations. However, technology development can also be quantified in terms of its growing maturity, with each step in the development process being formalized in terms of a 'Technology Readiness Level' (TRL), with a scale of 1 to 8 reflecting the extent to which the technology has been proven in a realistic situation.

In this scenario, 'technology' within ESA is associated with activities from TRL levels 1 (technology concept and/or application formulated) to 4 (component or breadboard validation in the relevant environment). In exceptional cases, it will include TRL 5, based on a system/ subsystem model or prototype demonstration in a relevant environment – either on the ground or in space. In this case, the space environment is required to fully demonstrate readiness of the technology.

The introduction of ESA's R&D landscape and technology maturity scenario provides the possibility to cover the complete cycle of developments. *"We see it as a major achievement that it was possible to develop an integrated ESA-wide Technology R&D Programme in Support of Future Scientific Missions.... Initial technology developments, leading to an experimental feasibility verification, are pursued with funding from ESA's Basic Technological Research Programme (TRP). The Science Core Technology Programme (SCTP) focuses on reaching a higher level of technology maturity by developing engineering models, before the start of the definition phase of a scientific project"*, says Giorgio Bagnasco, the SCTP Coordinator.

The Future is Our Business

The future of technology development depends on its people, but the content of ESA's technology programmes must be in line with the Agency's future mission scenarios as well as the development of the commercial space segment. However, this is not an automatic or self-standing process – it requires active participation from people with both ideas and experience.

The new lightweight Inflatable Re-entry and Descent Technology (IRDT) demonstrator

The IRDT made its first test flight in February 2000, supported through ESA's Basic Technology Research Programme and the International Science and Technology Centre (ISTC). The technology is designed to reduce the mass and cost of future re-entry systems for visiting the planets and for returning to Earth. A second test-flight is planned for 2004.

Michael Eiden, Co-Chairman of the Working Group on Science relevant for the preparation of TRP 2004-2006 and GSTP-4, explains: *"One of the most important points is that everybody is able to express themselves and to confront and defend their ideas against those of others."* He adds: *"...Given all the new elements, the preparation of a new TRP Plan for Science is now more challenging than it was in 1985, when I first participated to such an exercise."*

The process of setting up new plans for the TRP and GSTP programme is based on the use of interdisciplinary Working Groups, composed of experts drawn from all ESA Directorates, covering the following themes: Earth Observation; Science/ Robotic Exploration Preparation; Human Spaceflight/Manned Exploration Preparation; Space Transportation/Re-entry Technologies; and Generic Technologies and Techniques. Their work is guided and reviewed by Advisory Panels at senior-management level, with the final endorsement being provided by an ESA-wide forum. The process is currently on-going, with new three-year plans for TRP 2004-2006 and GSTP-4 due to be published early in 2004.

Despite the complex process involved in establishing a new R&D plan, it has to be remembered that technology R&D for space applications has to progress quickly. Many fascinating problems remain to be tackled and the following are just a few examples of the challenging and very forward-looking technologies that are currently being explored:

- A wireless spacecraft, replacing complex cables and connectors, which represent a significant amount of dead weight on every spacecraft as well as being a potential source for failure. ESA is therefore currently investigating (within the TRP) a way of using either radio-frequency or optical devices to eliminate or substantially reduce the need for cabling.

- Wide band-gap semi-conductors, demonstrating the value of a completely new class of semi-conductor material that could overcome many of the limitations of today's silicon-based devices.
- Radically new ultra-light structures, looking at the feasibility of structural concepts based on inflatable devices.
- Active Intelligent Materials, exploring a new class of intelligent materials for space applications (e.g. artificial muscle).

It is worth remembering that, as with all R&D projects, there is always a chance of failure. However, the outcome of such investigations ultimately has the potential to shape the future face of space. esa

Technology Co-ordination in ESA

About 8% of ESA's annual budget is currently being spent on technology development, with a total of 250 million Euros spread over six Directorates. Technology planning is therefore well established within the Agency, which has published its 'Blue Book' on the ESA Technological Research & Development Programme on a regular basis since the late 70s.

However, the 1990s saw a need for revisiting the co-ordination effort, driven primarily by three factors:
- A change towards developing technology as a base for the selection of missions – i.e. missions driven by technology, such as in the Earth Observation Programme.
- The completion of many large programmes such as Artemis and Envisat and the preparation of follow-on programmes.
- Acquisition of the central role in the co-ordination of technologies in Europe.

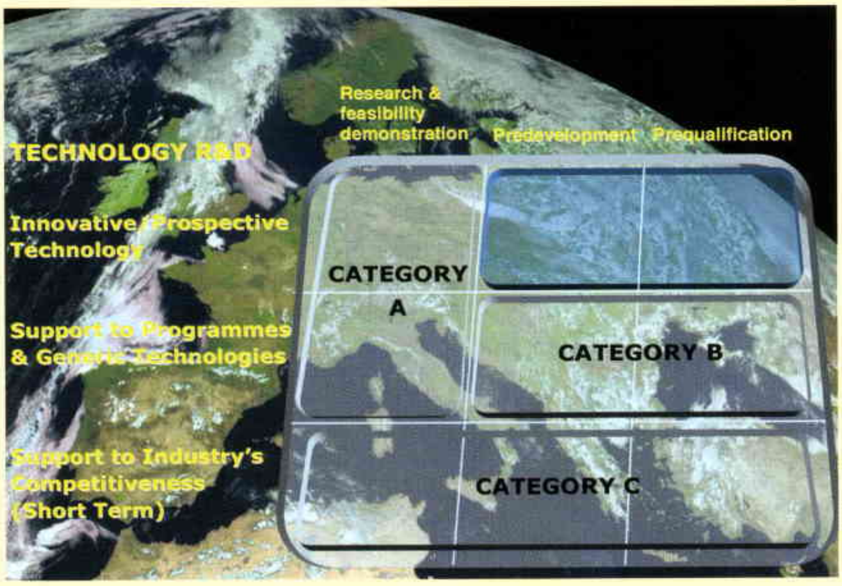
Within ESA, technologies serve three major aims, which are related to the short-, medium- and long-term needs, and are therefore strategically distinct:

- **Innovative/Prospective Technologies:** exploration of high-risk technologies and concepts to secure a leading position for the European space community in the long term.
- **Support to Programmes and Generic Technologies:** to support the technological aspects of every ESA projects, through the development of new products and processes.
- **Technologies that Support Industry Competitiveness:** to enhance existing products and processes, allowing rapid responses to European demands for global competitiveness.

ESA has built an R&D landscape that combines these different aims with the prevailing level of technological maturity:

Technology falling into Category B is embedded in the mission-orientated, preparatory programmes (e.g. for Science, Earth Observation and Human Spaceflight), while those primarily occupying Category C are conducted through application-specific industry-oriented programmes (such as ARTES for Telecommunications).

A strong bridging component is assured by the mandatory Basic Technology Research Programme (TRP), which covers exclusively Category A and addresses the emerging stages for the whole spectrum of space technology. The optional General Support Technology Programme (GSTP) complements the technologies developed in the preparatory programmes and responds to industrial demands for focused support.



Nuna II Breaks All Records to Win the World Solar Challenge!

Eric Trottemant
Education Office, ESA Directorate of Administration, ESTEC, Noordwijk, The Netherlands

The Dutch solar car 'Nuna II', using ESA space technology, again finished first in the 2003 World Solar Challenge, a 3010 km race from north to south across Australia for cars powered only by solar energy. Having set off from Darwin on Sunday 19 October, Nuna II crossed the finishing line in Adelaide on Wednesday 22 October in a new record-breaking time of 30 hours 54 minutes, 1 hour and 43 minutes ahead of its nearest rival and beating the previous record of 32 hours 39 minutes set by its predecessor Nuna in 2001.

The average speed of Nuna II, nick-named the 'Flying Dutchman' by the Australian press, was 97 km/h, also an improvement on the previous record of 91.8 km/h set by Nuna in 2001. Despite two quickly changed flat tyres, Nuna II travelled 828 km on the third day of racing – never before has such a distance been accomplished on one day by a solar-powered vehicle. On the fourth and final day, Nuna II again pushed the envelope by driving at a top speed of 110 km per hour, a new World record.

The space-age Nuna II was already in the lead by the end of the first day, having started from 10th position. Before the race began, it was already tipped as a hot favourite because of its use – like its forerunner Nuna in 2001 – of advanced space technology provided to the team via ESA's Technology Transfer Programme, which gives the car a theoretical top speed of 170 km per hour.

The aerodynamically optimised outer shell consists of space-age plastics to keep it light and strong. The main body is made from carbon fibre, reinforced on the upper side and on the wheels' mudguards with aramide, better known under the trade name of Twaron. The latter is used in satellites as protection against micro-meteorite impacts, and nowadays also in high-performance protective clothing like bulletproof vests.

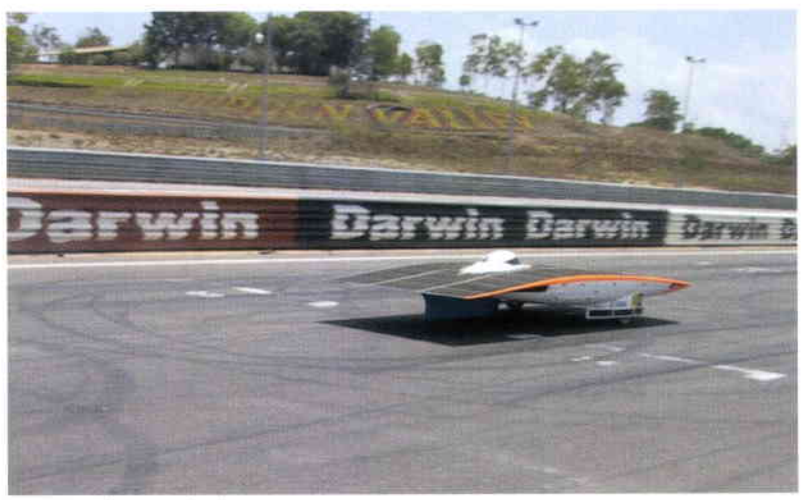
The car's shell is covered with the best triple-junction gallium-arsenide solar cells, developed for satellites. These cells harvest 10% more energy from the Sun than those used on Nuna for the 2001 race. Only weeks before this year's race, ESA had launched its first satellite to use these cells, the SMART-1 high-technology demonstration mission to the Moon.

Nuna II also carries Maximum Power Point Trackers, small devices that guarantee an optimal balance between the power drawn from the battery and that being generated by the solar cells, particularly under less favorable situations like shade and cloud. Many satellites now carry these devices, including ESA's Rosetta scientific mission to comet Churyumov-Gerasimenko, due for launch in February 2004.

Nuna II was built by a 12-strong team of students from the Universities of Delft and Rotterdam, strongly supported by a number of sponsors, including Nuon the Dutch energy company. ESA not only provided the team with engineering support via its Technology Transfer Programme, but also with general support via the ESA Education Office, previously headed by former astronaut Wubbo Ockels, who was an adviser to the team and also guided the first Nuna solar car to victory in 2001.

Pre-race preparations

Nuna II speeding across the Australian outback



Pre-race qualification speed trials

The winning team, in Adelaide

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The 'Nuna' Solar Car's European Tour

Corinne Flandy
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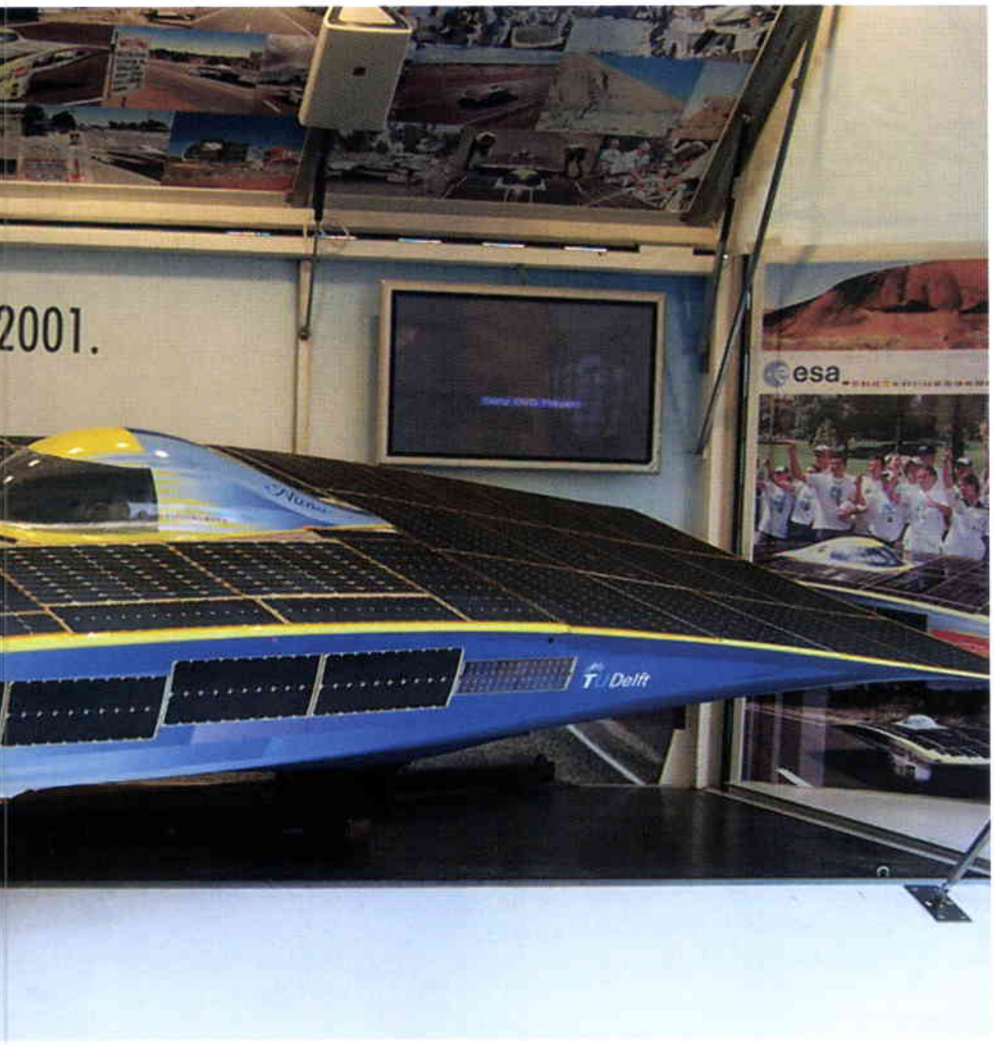
Following the victory of the ESA-sponsored Dutch solar car 'Nuna' in the World Solar Challenge 2001, the 3010 km race across Australia for cars powered only by solar energy, the Agency decided to give schools and museums throughout Europe the opportunity to put the spectacular vehicle on show. The objective of the tour was to give youngsters, students and teachers the opportunity to examine the space technology that had given Nuna its winning edge in 2001, and to raise general awareness of renewable energies.

The tour started on 4 November 2002 with a first exhibition at the Vetenskapens Hus (House of Science) in Stockholm. Thereafter Nuna continued its travels through 12 ESA Member States, visiting 36 schools and museums and finishing its journey in France, at the Collège la Côte Radieuse school in Canet en Roussillon. The enthusiasm shown by the youngsters and their teachers at every stop, and the coverage received in the local press, clearly demonstrated the success of the tour.

A Unique Opportunity for European Schools and Museums

Two months after having won the World Solar Challenge 2001 with a record time, ESA officially announced its decision to send Nuna on a European tour to help demonstrate the practical applications of space technology here on Earth. The announcement was sent out to all teachers who had participated in the TeachSpace Workshop (26-28 October 2001) and the Physics on Stage 2 Festival (2-6 April 2002). In addition, the tour was advertised in the second issue of the EDUnews newsletter, published in March 2002 and on the Education Office website. Teachers were invited to send an e-mail if they were interested in organising a one-day exhibition at their school. The ESA Education Office's mailbox was flooded with requests, proving straightaway that the project was very attractive.



The response was in fact so large that it would clearly not be possible to meet the demand, and it was therefore decided to contact all of the teachers who had expressed interest and ask them to submit a summary of the type of activities and events that they would propose to organise to raise the youngsters' interest in solar cars and renewable energy sources if Nuna would visit their school. An important aspect of the selection criteria was also the teacher's commitment to ensuring local media coverage of Nuna's visit. By the end of August 2002, thirty-six schools and museums with great ideas for putting Nuna in the limelight and involving as many youngsters as possible, had been selected. In the meantime, the ESA Education Office had been working hard on the project's logistical aspects.

Organising the Tour

After many discussions, there was a general consensus that it would be nice to create a sort of 'travelling museum', and so a special display trailer with opening front and side panels was designed to house Nuna during its travels.

To set the scene, the interior of the trailer was decorated with an Australian landscape and a patchwork of pictures of Nuna and the winning team. To provide the viewing public with more information about ESA and its activities, seven panels carrying more general information were also designed. To give the youngsters a flavour of the race itself, audio and video equipment was installed in the trailer and a DVD showing the Nuna adventure was produced. Thousands of A3 format posters of Nuna were printed for distribution to the youngsters as a souvenir of the solar car's visit to their school. By the end of August 2002, the small 'mobile museum' was ready to hit the road.

Taking to the Road

The Agency had decided that the tour would be more beneficial for the youngsters if two members of the Nuna Alpha Centauri race team could be present at each school visited to make a short presentation about the race, the car and renewable energy sources, and to respond to the many questions that the youngsters would certainly be asking.

Indeed, the Alpha Centauri team members were heartily welcomed at every stop, with teachers and pupils both enthusiastic about and highly interested in the presentations that they made. It was a chance for the youngsters to learn that the World Solar Challenge event was initially conceived and organised by Hans Tholstrup, a Danish adventurer, who first proved the feasibility of solar-powered transport by crossing Australia from west to east in 1982 in his solar car 'Quiet Achiever'. In the first World Solar Challenge competition in 1987, twenty-three solar cars participated and the race was won by the General Motors 'Sunracer' at an average speed of 67 km/h. The fact that Nuna won in 2001 with a record-breaking average of almost 92 km/h added to the interest in learning more about the car. The DVD was a perfect complement to the presentation in that respect.

After the film, it was time for the children to hear more about the technology used to build Nuna, the importance of aerodynamics, the special solar cells, the special tyres to reduce rolling resistance, and the race strategy applied. The youngsters therefore learnt, for instance, that Nuna's solar cells (triple- and double-junction gallium-arsenide type) had been developed for use in space and had a far higher efficiency than those currently found on the roofs of houses. They also learnt how the team managed to build such a light body for the car, by employing the 'Kevlar' material first used in space.

Teachers in the secondary schools that were visited exploited the Nuna presentation by linking it to their mathematics and physics lessons and encouraging the pupils to work on practical examples. In one primary school, a teacher demonstrated the concept of solar energy by showing the output from a small solar cell graphically on a computer screen.

The Alpha Centauri team members reported that it was amazing how many interesting workshops, drawing competitions and courses had been developed in the schools that they visited to make it an exciting and useful educational event. Many of the schools had also gone to great lengths to involve other schools in their area and to ensure extensive local press coverage.

Conclusion

The Nuna tour certainly proved to be a very successful initiative, giving thousands of youngsters an opportunity to learn more about the solar car's design and technologies and about the renewable energy sources that will more and more become a part of their daily lives. With Nuna II having just won the World Solar Challenge 2003, there will hopefully be the possibility to organise another such series of event to stimulate the interest of youngsters in science, space, and alternative sources of energy.

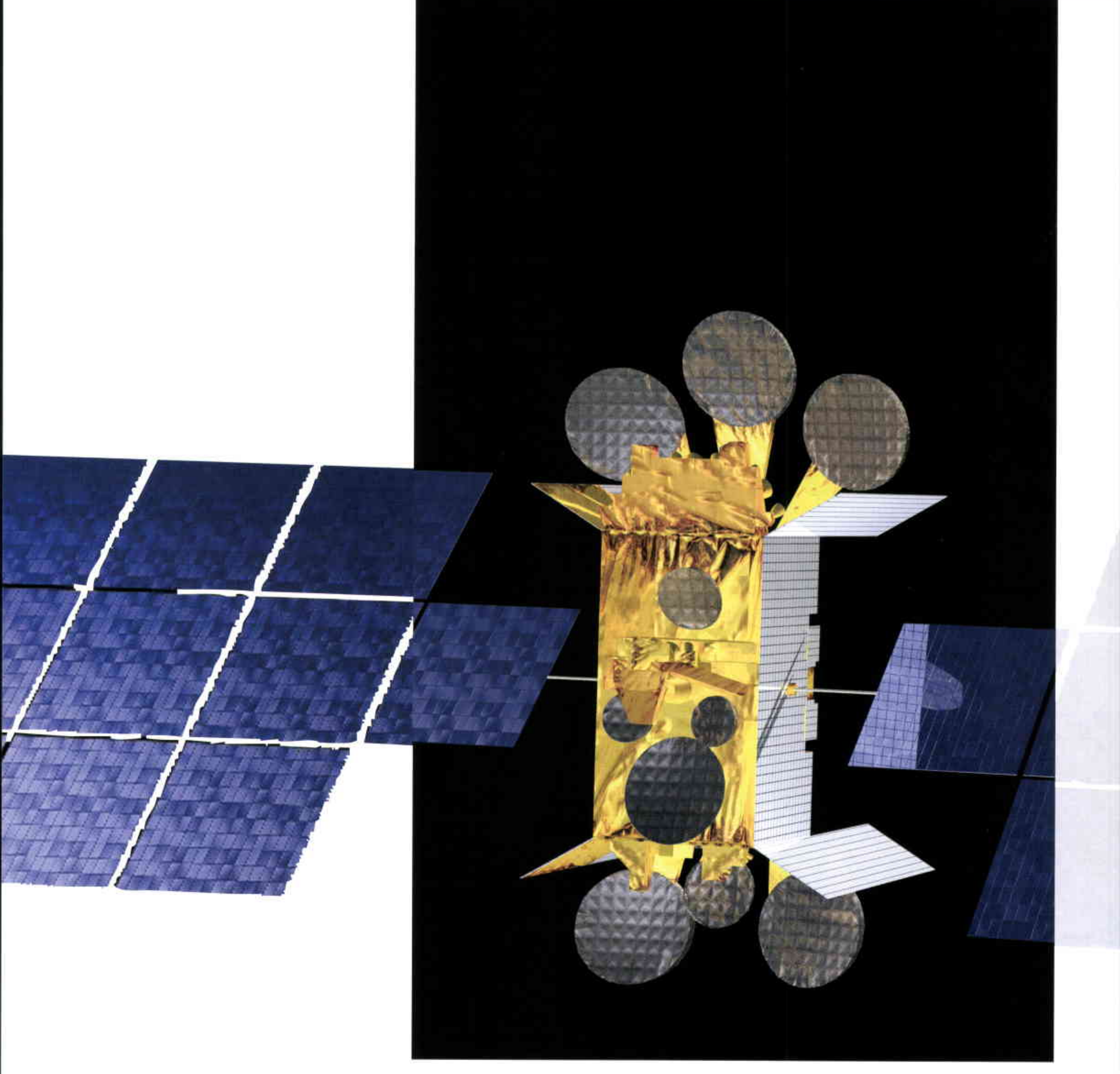
Acknowledgments

The author would like to thank the following teachers, whose contributions made the tour such a success: Adolfo Vázquez, Alistair Crawford, Ana Lúcia Oliveira, Angus Gregson, Antonio Violini, Bernadette Anbergen, Bernard Taylor, Björn Lingons, David Lomer, David Smith, David Woolhouse, Francisca Wheeler, Francisco Da'Costa, Georges-Marie Quesada, Jess Cooke, Ken Zetie, Line Rasmussen, Lisbeth Frantzen, Marc Beddegenoodts, Marco Martucci, Marco Nicolini, Marian Bakker, Michael Brookman, Paul Nugent, Per-Olof Nilsson, Pilar Jarque, Ralf Giesse, Sue McGrath, Thomas Schmidt, Wendy Swarbrick and Werner Warland.

ITINERARY FOR THE SOLAR CAR'S EUROPEAN TOUR - November 2002 - January 2003

Date	Country	City	Name of School
November			
04/11/2002	Sweden	Stockholm	Vetenskapens Hus
06/11/2002	Sweden	Gothenburg	Chalmers University of Technology
07/11/2002	Denmark	Copenhagen	Tycho Brahe Planetarium and Omnimaxteater
08/11/2002	The Netherlands	Groningen	Faculteit Techniek
12/11/2002	The Netherlands	Heerhugowaard	Montessorischool
13/11/2002	Belgium	Châtelet	Athénée Royal Pierre Paulus
14/11/2002	Belgium	Aarschot	Koninklijk Atheneum
16/11/2002	Belgium	Charleroi	Athénée Royal E. Solvay
18/11/2002	Germany	Dusseldorf	Schlossgymnasium Benrath
19/11/2002	Germany	Daun	Geschwister - Scholl - Gymnasium
20/11/2002	Germany	Darmstadt	Lichtenbergschule - Gymnasium
22/11/2002	Switzerland	Barbengo	Scuola Media
26/11/2002	Italy	Modena	ATCM
27/11/2002	Italy	Milan	Museo Nazionale della Scienza e della Tecnologia "Leonardo da Vinci"
December			
03/12/2002	England	York	Ampleforth College
04/12/2002	England	Bedford	Mark Rutherford Upper School and Community College
05/12/2002	England	Chislehurst	Farringtons and Stratford House
06/12/2002	England	London	St. Paul's School
09/12/2002	England	London	Highgate School
10/12/2002	England	Steyning	Steyning Grammar School
11/12/2002	England	Marlborough	St. John's School and Community College
12/12/2002	England	Bristol	Sir Bernard Lovell School
13/12/2002	Wales	Llanelli	Morfa Junior School
16/12/2002	England	Leicester	Wyggeston and Queen Elizabeth I College
17/12/2002	England	Tamworth	Wilnecote High School
18/12/2002	England	Burntwood	Fulfen Primary School
January			
08/01/2003	Scotland	Lenzie	Lenzie Academy
09/01/2003	Northern Ireland	Belfast	Queens University Belfast
10/01/2003	Northern Ireland	Belfast	Science Centre WhoWhatWhereWhenWhy
11/01/2003	Ireland	Dublin	Royal Dublin Society RDS
13/01/2003	Ireland	Dublin	Dublin City University
14/01/2003	Ireland	Galway	Galway Mayo Institute of Technology
20/01/2003	Portugal	Porto	Escola Secundária de Fontes Pereira de Melo
22/01/2003	Spain	Madrid	Universidad Complutense de Madrid
24/01/2003	Spain	Alicante	IES Haygon
27/01/2003	France	Canet en Roussillon	Collège la Côte Radieuse

AlphaBus



– Europe's contender in the large satcom market

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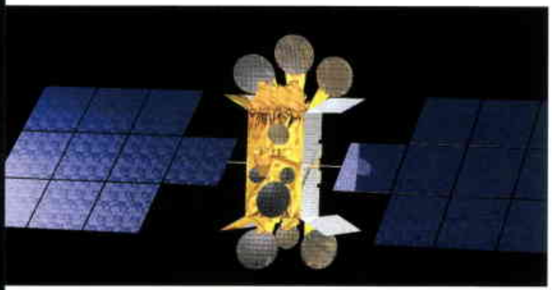
Project Managers, Joint Industrial Project Team,
Toulouse, France

The Stakes

There is a considerable risk that today's downturn in global markets may annihilate Europe's heavily contested share of commercial satellite sales, and this in turn may destabilise the core manufacturing capabilities of European satellite industry. A concentrated European institutional research and development effort is therefore required to sustain industrial capabilities during the downturn and to reinforce Europe's commercial product line for future growth markets.

The best of Europe's satellite manufacturing industry is therefore currently involved in an institutional programme known as 'AlphaBus', designed to create a new competitive product for the global commercial satcom market. In shaping a new European perspective for large communication satellites, AlphaBus combines the business know-how of EADS Astrium and Alcatel Space with the institutional strengths of ESA and CNES. Together they will select state-of-the-art European equipment providers to complete the industrial consortium for this unique European communications platform, complementing the top-end range of both Alcatel's Spacebus and Astrium's Eurostar products. The selected suppliers will be engaged in long-term agreements with the prime contractors, leading to a stable industrial structure for the operational life and future improvement of the product.

This initiative differs from ESA's more classical stand-alone developments, being motivated by the acquisition of leading-edge technology and the aim of establishing a competitive European product to satisfy recurring market opportunities. This market-oriented approach is a key element of the AlphaBus programmatic setup, and fierce global competition will be a fact of life. The benchmark for AlphaBus is the recurrent cost of today's large telecommunication platforms. The Member States participating in the AlphaBus programme will be requested to fund it in relation to the capabilities of their national industries to provide state-of-the-art technology at competitive prices. In other words, the AlphaBus R&D funds will not be dispersed throughout Europe unless national industries are competitive or provide a unique source for enabling technology otherwise not available in Europe.



To stimulate the Europeanisation of AlphaBus, ESA has already begun an ambitious programme of pre-developments for the enabling technology. These contracts open the way for individual European equipment providers with unique expertise to be selected for the AlphaBus industrial team.

Having realised what was at stake for Europe in terms of the global satellite communications market, ESA and CNES elaborated a cooperation agreement in 2002 to create a common institutional framework for AlphaBus. The two agencies have already provided the preparatory funding envelope and initiated contracts with a joint industrial project team set up by EADS-Astrium and Alcatel Space to execute the early design effort for the AlphaBus production line. Likewise, ESA and CNES have also formed a joint AlphaBus project team, based in Toulouse (F). With CNES having secured the programme at national level in France, it is now up to the other ESA Member States to fund their appropriate share of the AlphaBus development programme within ESA.

A successful AlphaBus development programme will contribute to a sound structure for the European satellite manufacturing industry, avoid fragmentation of available institutional R&D funds, close the technology gap with US competitors, and provide a unique contender for acquiring an appropriate share of the global market for large telecommunication satellites.

The Market

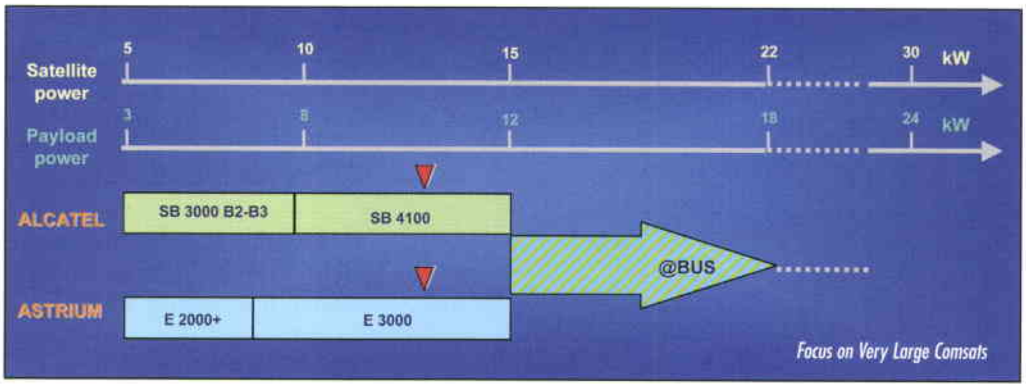
The AlphaBus initiative will result in a production line for a new platform that will be used by both EADS-Astrium and Alcatel Space - Europe's main competitors in today's volatile global market for commercial telecommunications satellites - to build communication satellites for the high-power payload market. In June 2003, the two companies made an unprecedented move at Le Bourget by publicly announcing a joint marketing strategy for AlphaBus. This commercial agreement covers the terms and conditions for a common marketing of the AlphaBus product, avoids mutual competition by recognising AlphaBus as the exclusive European response in the top-end sector of the market.

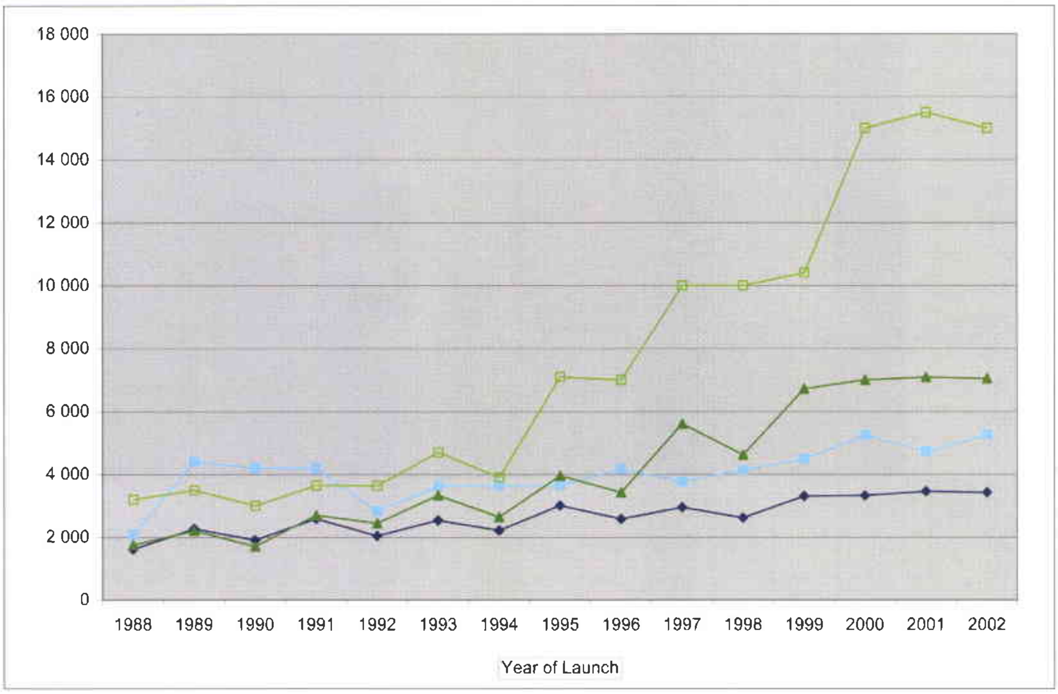
Before the market collapse in 2002, US companies such as Boeing, Lockheed Martin and Loral dominated the large-satellite sector of the telecommunications market. Only about one in twenty of the very large commercial telecommunications satellites launched in the boom period between 1999 and the end of 2002 was based on a European platform.

One way of categorizing the size of a platform is by the power-handling capability of its payload. US companies have enabling technologies for payloads with powers of up to 18 kW, whilst today's European platforms have payload powers of up to only 10 kW. This technology gap has given US products a competitive edge in the large satellite sector. Ultimately the physical dimensions of the platforms will limit the growth potential of the existing Spacebus and Eurostar product lines to about 12 kW. The AlphaBus provides the quantum leap needed to close the technology gap, to accommodate the higher payload power range, and to compete successfully on the global stage.

Intermediate market projections based on the replenishment of existing in-orbit infrastructure and growth potential in the new multimedia and mobile markets forecast a recovery to 2001 levels from 2008 onwards. Today, commercial initiatives like iPSTAR-1 and Wildblue-1 are already beginning to cater for these future markets. These high-powered telecommunications satellites based on US platforms will provide direct-to-desktop broadband access, making advanced Internet services - IP voice telephone, video-conferencing – and multimedia applications like video-on-demand and interactive television, readily available in the 2003/2004 time frame. Consequently, European satellite manufacturers cannot afford to wait for a full market recovery before developing a new platform to compete with their US rivals. Operators require a rapid response to new market opportunities and are already contesting today's 30-month turn-around-times between satellite contract award dates and flight-readiness!

The AlphaBus development programme therefore needs to start today in order to allow the first commercial bids on the global satellite market towards 2005/2006. Decision makers need to be aware that the AlphaBus product line will have a life cycle covering the next twenty years. History proves that sole reliance on the capabilities of existing satellite product lines has never proved a reliable strategy for meeting future needs.

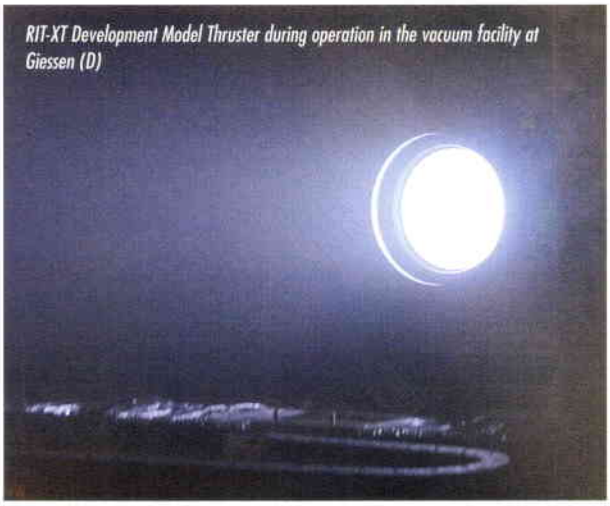




Evolution with time of mass (in kg) and power (in W) of comsat platforms (1988-2002) (Courtesy of Eurospace)

EADS ST (D) - Liquid Apogee Motor undergoing sea level testing

EADS ST (D) - RIT XT Ion Engine



RIT-XT Development Model Thruster during operation in the vacuum facility at Giessen (D)

Saft Li-Ion G5 battery cell

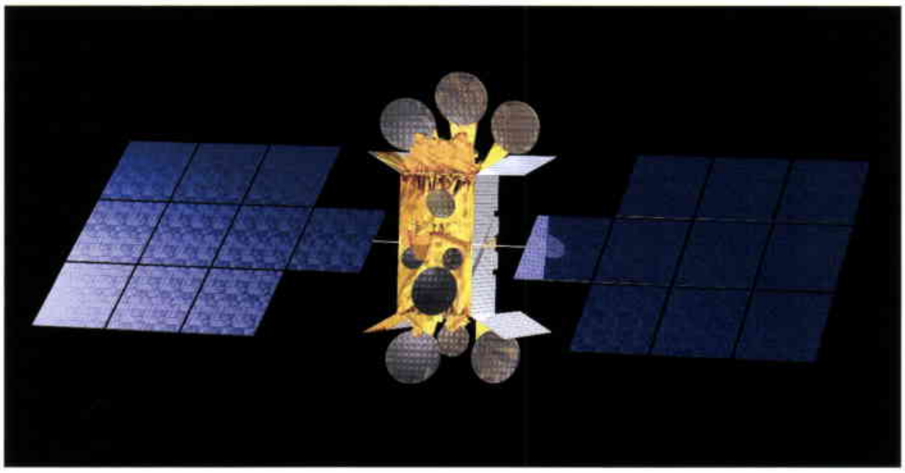
The Platform

The AlphaBus payload power range of 12 to 18 kW, corresponding to a solar array power of between 15 and 25 kW, positions it squarely in the attractive market niche for large satellites dominated by today's US products. The platform's physical dimensions, with a width of 3 m and height of 7 to 8 m, mean that it can derive maximum benefit from powerful launchers in the Ariane-5 category with their 5 m fairings and the economies of scale being offered. Its launch mass will vary from 5.5 to 8 metric tons. Ariane-5 compatibility is seen as a sound policy given that more than 90% of Ariane-4's launches were devoted to telecommunications satellites.

Adapted to handle antenna farms of up to 10 to 12 transmit and receive antennas, the platform can easily accommodate from 100 to 250 transponders. It can also handle high-power mobile missions servicing, for instance, future 3G-type handsets from geostationary orbit and requiring antennas of up to 7.5 m diameter.

This new generation of geostationary telecommunications platform will require a number of specific technology improvements. The ESA-funded pre-development contracts mentioned above cover such items as novel electric-propulsion technology based on plasma and ion thrusters, deployable radiator panels, active fluid loops and heat pipes for heat dissipation, new solar-array technology, a more powerful apogee boost motor, new lithium-ion batteries, fibre-optic gyroscopes, RF sensing technology, accelerometers and a new generation of star trackers. These developments will give AlphaBus growth potential beyond 20 kW payload powers.

The designs for the first commercial AlphaBus missions will stay close to their Eurostar and Spacebus heritage. This is normal commercial practice in order to increase customer confidence in a new product and to maintain target price levels. The new enabling technologies will be steadily introduced into the AlphaBus product line in accordance with the type of mission being supported, the payload power needed, and last but not least the requirements of the commercial customer.



The ESA-CNES R&D programme will help to establish the industrial production line for Alphabus, and ESA will also serve as a 'first customer' in procuring the protoflight model.

The Next Steps

2004 will be a key year for concluding the legal and programmatic framework between ESA, CNES and Industry. The ESA programme is covered by the ARTES-8 element of the Programme Declaration for Advanced Research in Telecommunications Systems (ARTES), as agreed at the Edinburgh Ministerial Council in November 2001. ARTES-8 covers the large-platform mission element, and its implementation has today been phased into two main streams.

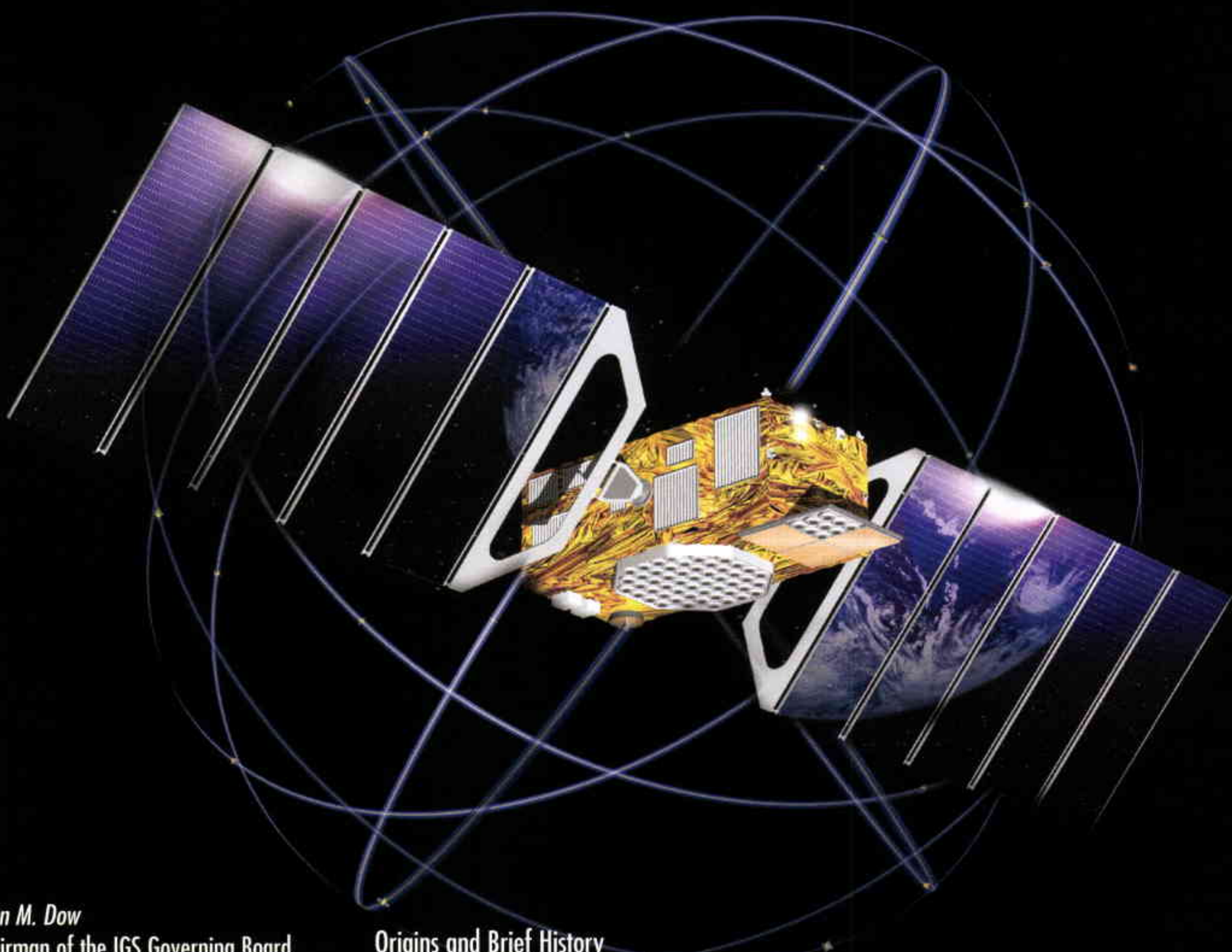
A first step in 2003 will enable the development of the AlphaBus production line, including the procurement of the protoflight model. The availability of a protoflight model of AlphaBus will ensure a rapid response to a mission opportunity arising either through an institutional roadmap emanating from the next Ministerial Council planned in 2004-2005 or through a commercial flight opportunity.

The AlphaBus preparatory phase will be completed in mid-2004. The main development phase needs to start in 2004 to align the first commercial bids with the expected market recovery. The selection process for equipment providers to be included in the industrial consortium for the AlphaBus development phase will start at the beginning of next year.

The Europeanisation of AlphaBus is a key objective and ESA is actively promoting the programme to all Member States. The national industries selected to participate will not only benefit from institutional R&D funding, but will also have access to long-term agreements for recurring commercial flights. Those States that decide to participate will enjoy fair access for their industries to the equipment competitions, the evaluation of which will be overseen by ESA, together with the industrial prime contractors and CNES.

If everything goes according to plan, the AlphaBus Programme will unite European industrial prime contractors and suppliers in an industrial consortium capable of becoming a European leader on the world market for large, high-power telecommunications satellites.

IGS The International GPS Service – for Leading-Edge Space Missions



John M. Dow
Chairman of the IGS Governing Board
ESA Directorate of Technical and Operational Support, ESOC, Darmstadt, Germany

Origins and Brief History

Global Navigation Satellite Systems (GNSS) are gradually becoming part of our daily lives. Their uses for aircraft navigation and more and more in our private cars are especially well-known. The general concept involves measuring distances from the user to several satellites and thereby obtaining an almost instantaneous determination of one's current position. The user systems are passive in that only the satellites transmit signals, and are based on the time differences between the transmission and reception of the signals. Two essential elements of the system are therefore a highly stable oscillator in the user receiver and an algorithm that determines the offset between the GNSS system time and the user's clock, as well as his or her position.

The classical type of GNSS is the US Global Positioning System (GPS), which has been developed and refined over the past 30 years and was declared fully operational in 1995. The system consists of at least 24 satellites orbiting in six evenly distributed planes inclined at 55 degrees to the Earth's equator, at about 20 000 km altitude. There are currently 27 usable GPS satellites in orbit. A similar Russian system (GLONASS) briefly achieved an operational constellation of 24 spacecraft in the mid-1990s, but at present only 10 are active.

After a number of years of preparatory studies, Europe is now well on the way to developing its own system, Galileo, joint funded initially by the European Union and ESA and later, it is planned, by private investment. Galileo will comprise 30 satellites in three inclined orbital planes, a few thousand kilometres higher than the GPS and GLONASS satellites in order to minimise the number of correction manoeuvres needed during the system's 20-year lifetime.

During the 1980's, as the first GPS satellites went into orbit, it became clear that the system had great potential for scientific applications requiring positioning accuracies much beyond those specified by the system owner (the US Department of Defense). At a meeting held in 1989 during the Assembly of the International Association of Geodesy (IAG) in Edinburgh (UK), it was proposed to set up a network of GPS receivers for this purpose. In 1991 a Campaign Organising Committee was appointed by the IAG and, following a Call for Proposals, 45 agencies and institutions joined forces to carry out a three-month test campaign, from June to August 1992, involving tracking the GPS satellites from about 30 stations, centralising the data rapidly through the (then just emerging) Internet for processing. With a few weeks' time lag, the analysis centres began to produce orbital solutions for the whole constellation which were about two orders of magnitude more accurate than the orbital data broadcast to users by the satellites themselves.

This campaign was such a success that the participants decided to continue operations without interruption. The 'International GPS Service for Geodynamics (IGS)' was officially launched as an IAG service in January 1994. The name clearly indicated the scope of the new service, which in particular was supporting research on plate motions and earthquake movements. A central task was to maintain an accurate Terrestrial Reference Frame, through determinations of Earth orientation parameters (rotation and polar motion) and a grid of globally distributed ground reference points. As the service developed, more and more applications were investigated, and in 1998 the name was shortened to 'International GPS Service'.

ESA, at its European Space Operations Centre (ESOC) establishment in Darmstadt, has been actively involved in the IGS from the outset, as a station operator and operational data centre (currently running GPS at 8 sites world-wide) and as an analysis centre, and has played an active role in a number of Working Groups and on the international Governing Board.

The GPS equipment at ESA's New Norcia ground station in Western Australia

Organisation and Available Products

The IGS routinely provides:
- high-quality orbits for all GPS satellites: accuracy is better than 5 cm, while real-time predictions are better than 25 cm at any time (the satellites broadcast orbits with accuracies of ca. 3 m)
- satellite and ground receiver clock correction with sub-nanosecond accuracy
- Earth orientation parameters (rotation, polar motion)
- tracking-site coordinates and velocities in the International Terrestrial Reference Frame, currently ITRF 2000
- pseudo-range and phase measurements, in daily and/or hourly files.

Over 200 institutions in more than 75 countries now participate in the IGS, providing data from more than 350 sites. Day-to-day management of the operations is conducted by a Central Bureau, located at the Jet Propulsion Laboratory in Pasadena (USA) and by the Analysis Centre Coordinator (ACC). The ACC function rotates between the different Analysis Centres: so far, Natural Resources Canada (Ottawa), the University of Bern (Switzerland), and (currently) the Geo-ForschungsZentrum Potsdam (Germany) have performed this task.

The basic products are classified according to their latency (time elapsed since the last measurement data included in the solution). At present, IGS 'Final' orbit and clock products are available within 11 days, 'Rapid' products within 17 hours, and 'Ultra-rapid' products within 3 hours. The latter are currently generated twice per day and include 24 hours of prediction, thus ensuring the availability of real-time orbit and clock products. No restrictions have been placed on user access to products.

Examples of the use of IGS products in place of GPS broadcast messages include 'precise point positioning' using GPS data from a user receiver and IGS orbit and clock solutions with centimetre accuracy, provided a few modelled corrections are taken into account (mainly tides and antenna offsets).

Special Projects of the IGS

Over the years a number of special activities have developed within the IGS. These have generally been organised in the form of Working Groups or Pilot Projects. In some cases they are of a fundamental nature (e.g. timing or reference frame) affecting all the basic products, in others they may be considered to be 'nuisance parameters' that need to be modelled or estimated within the basic algorithms (e.g. atmospheric products - troposphere and ionosphere).

The IGS global tracking network in 2003

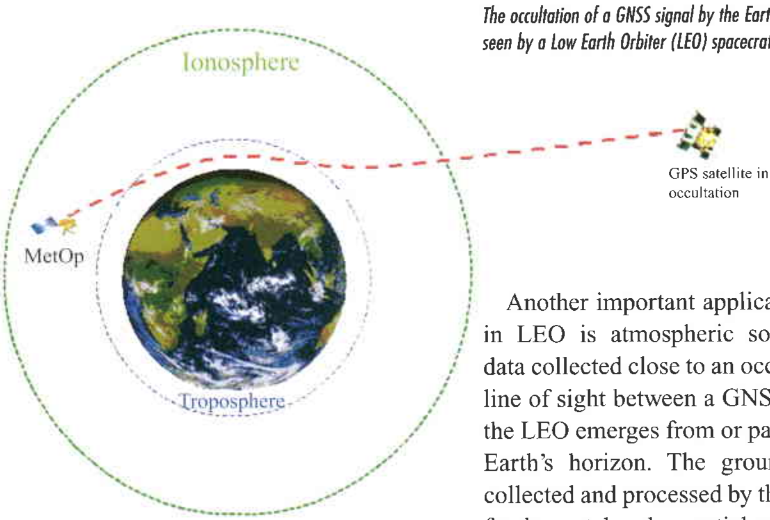
Reference Frame
The IGS Reference Frame (RF) Coordinator has responsibility for the coordination of IGS inputs to the International Terrestrial Reference Frame (ITRF). The ITRF is maintained by the International Earth Rotation and Reference Frame Service (IERS – name slightly modified since January 2003). GPS plays a major role in the ITRF, due to the large number of well-distributed, very well determined sites which it contributes (typical accuracies are 3 mm horizontally and 6 mm vertically, worldwide). The RF Coordinator is assisted by a Working Group consisting of representatives of the Analysis Centres and the IERS. The principal inputs from the Analysis Centres are weekly updates for the station positions and velocities and the Earth-orientation parameters, in a format known as SINEX (Software/Solution Independent Exchange Format), which includes information on the accuracy of the parameters determined (covariance matrix).

Timing Products
A very successful Time Transfer Pilot Project was operated from 1999 to 2002 by the IGS in conjunction with the Bureau International des Poids et Mesures (BIPM), Paris. The latter is responsible for the definition and maintenance of the UTC and TAI time scales, which provide the basis for civil time worldwide. GPS has long provided an important link between national time laboratories and BIPM, and the objective was to better link the laboratories with the IGS references (ITRF and GPS system time, both as realised by IGS). Important aspects were those of setting up GPS receivers close to the hydrogen masers of the laboratories, and investigating critical variations in cables due to thermal and other effects. This project now runs as a Working Group with a Coordinator, whose main task is to establish and make available an IGS time scale with more stability than is available from the satellites themselves, taking advantage of the presence of very stable hydrogen masers in the IGS ground network.

Low Earth Orbiters
GNSS receivers carried on spacecraft in Low Earth Orbit (LEO orbits have heights varying from just a few hundred to a few thousand kilometres) are very effective tools for rapidly and accurately determining the spacecraft's orbit. Due to the large number of satellites in the GNSS constellation, the coverage is redundant and continuous, so that it almost becomes possible to determine the orbit in a kinematic (geometric) way, minimising the

dependence on dynamic models of the motion.

The number of satellites in orbit with high-quality, two-frequency receivers has grown rapidly since mid-2000 with the launches of CHAMP, Jason-1, GRACE, Icesat and others. The ESA GOCE (Gravity Field and Steady-State Ocean Circulation Explorer) and the ESA/Eumetsat MetOp-1 spacecraft will join this group by 2006. Very impressive advances are already being made by processing of the GPS and other data from CHAMP and GRACE (CHAMP has accelerometer data, GRACE has very precise inter-satellite range-difference measurements between the two GRACE spacecraft). These efforts are leading to the best models currently available for the Earth's gravity field.

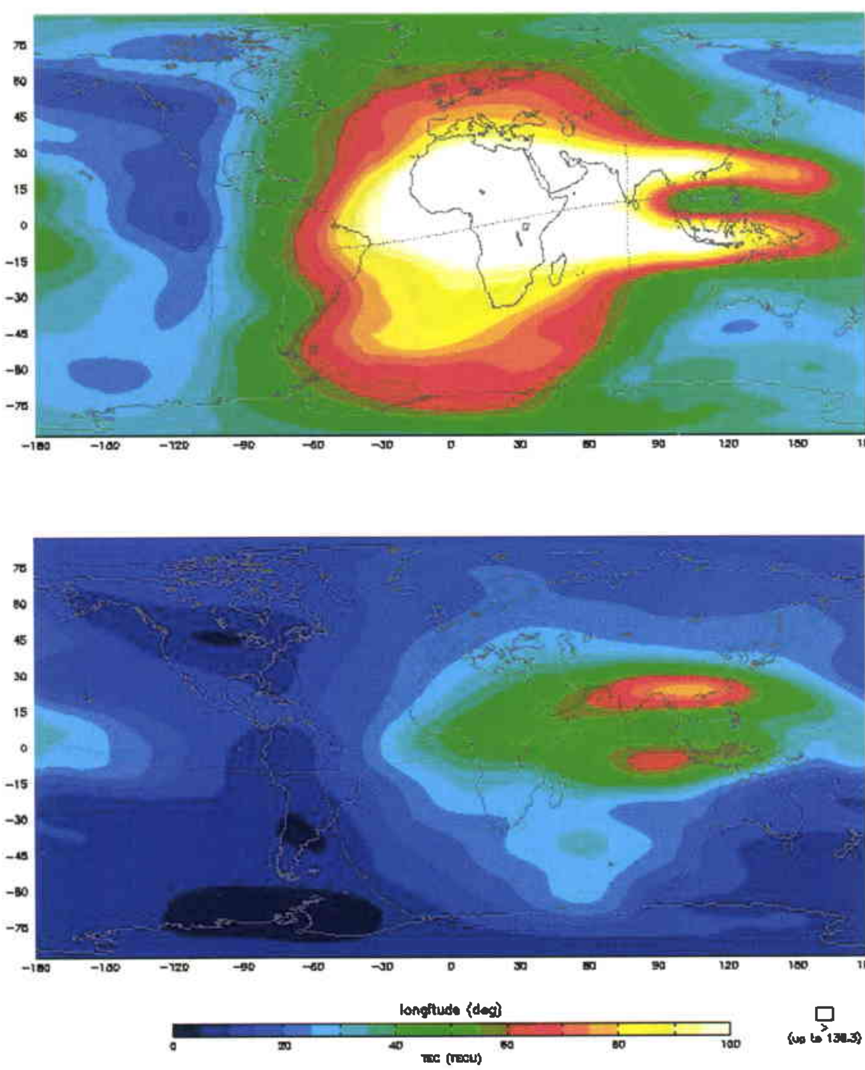


The occultation of a GNSS signal by the Earth's atmosphere as seen by a Low Earth Orbiter (LEO) spacecraft

Another important application of GNSS in LEO is atmospheric sounding, using data collected close to an occultation as the line of sight between a GNSS satellite and the LEO emerges from or passes below the Earth's horizon. The ground-based data collected and processed by the IGS provide fundamental and essential support to these LEO missions. The LEO Pilot Project (coordinated by ESOC) focuses the efforts of interested analysis centres on improved data processing for these orbiting receivers.

Atmosphere

Due to the multi-frequency nature of GNSS (at least two frequencies are needed in order to remove large measurement errors, which would otherwise be caused during propagation of the signals through the Earth's ionosphere), a well-distributed network of GNSS stations allows global mapping of the distribution of free electrons in the ionosphere with unprecedented spatial and temporal resolution. (In effect, each two-frequency measurement of pseudo-range or phase from every ground station, or LEO satellite, to every GNSS satellite provides a measure of the electron density, integrated along the line of sight). Five IGS Associate Analysis Centres produce global ionospheric maps with resolutions of 2.5 deg in latitude, 5 deg in longitude and 2 hours in time. The delay in delivery is currently about 5 days, but efforts are being made to reduce this. Regional solutions can be generated much faster. Heightened solar activity is being observed by the IGS through its effects on the Earth's atmosphere.

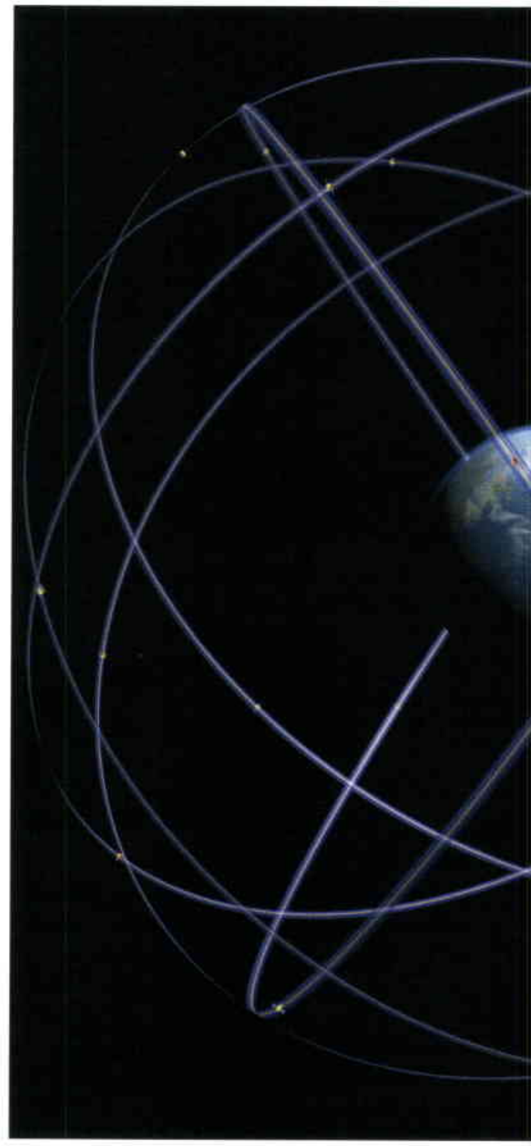


IGS Global Ionospheric Maps for high and medium solar activity, generated by combining the inputs from five Associate Analysis Centres

The magnitude of the tropospheric delay at each station, normalised to the zenith direction, is determined routinely by all IGS Analysis Centres and a combined product is generated by the Troposphere WG Coordinator. The physical parameter involved is the humidity content of the air in the lowest few kilometres of the atmosphere. Of course, unlike the case of the ionosphere, only isolated point values can be provided by GNSS, or at best regional maps where particularly dense station networks are located (e.g. Europe, Southern California). These values are being assimilated by meteorological institutes into both their weather forecasting (IGS ultra-rapid prediction values) and climate studies (values based on IGS final products).

Real-Time
The trend in navigation and other applications of GNSS is towards real-time data delivery and processing. Many IGS stations changed some years ago from delivering daily data files to delivering hourly files, with typical latencies of a few minutes. With the new generation of LEO satellites carrying GPS receivers, near-real-time delivery with a higher sampling rate (in some cases one measurement epoch every second, instead of every 30 seconds) is being requested. This can be done in 15-minute batches or as a real-time data stream. The IGS agencies are establishing protocols and procedures for handling this.

Tide-Gauge Benchmark Monitoring Project (TIGA)
Tide-gauge measurements made at widely separated sites have traditionally been difficult to relate to each other. By locating a GPS system close to a tide gauge, the height of the reference point on the tide gauge can be determined in the ITRF, and global and regional changes in sea level can then be monitored more reliably. Local crustal movements affecting long-term tide-gauge records can also be better characterised. The main objective of the TIGA project is to assist in the establishment of a significant number of permanent GPS measurement facilities at tide-gauge sites, and to process multi-year data sets including all or many such sites. This is a globalisation of some local/regional campaigns made with GPS to support the early calibration of altimeter instruments, e.g. on ERS-1, Topex/Poseidon, Envisat and Jason-1.

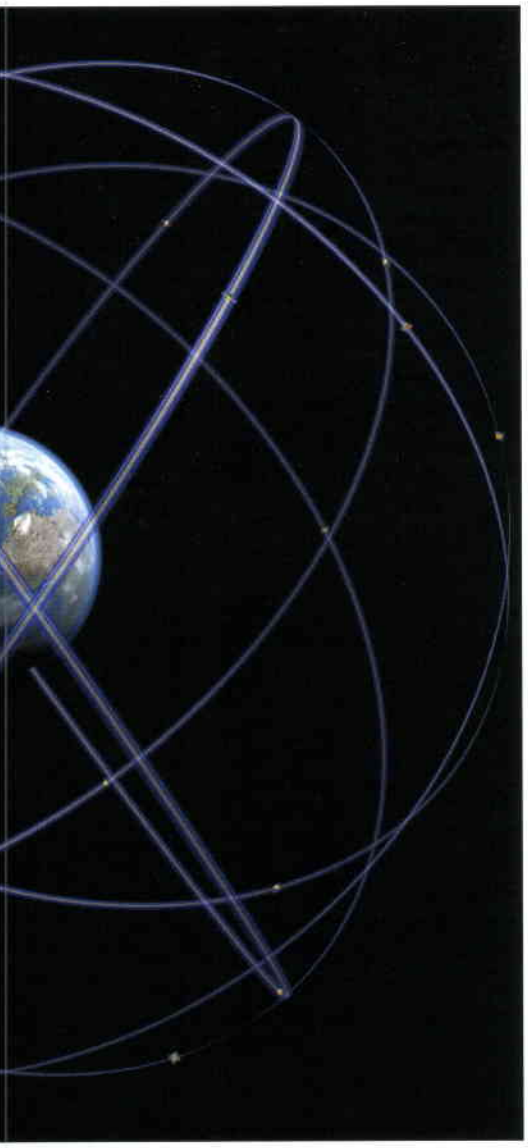


The Galileo satellite constellation. The 30 satellites (27 operational plus three in-orbit spares) will orbit the Earth at an altitude of 24 000 km, in three equally spaced planes inclined at 56 degrees to the Equator

International GLONASS Service (IGLOS)
The International GLONASS Experiment IGEX was designed as a three-month test campaign by the IGS in 1998 to verify for the first time the feasibility of setting up a global network of GLONASS tracking receivers and processing the data for improved orbit, clock and ground position determination. IGLOS has evolved from this effort as a project within the IGS, and has been operational since 2000, unfortunately with a reduced space segment due to the long times between GLONASS replenishment launches. The standard IGS infrastructure (stations, data centres, analysis centres, data products) has been adapted in such a way that GLONASS data can be handled like GPS data. Currently, advances are being made at the IGLOS analysis centres to integrate GLONASS and GPS computations into a single process. This is exactly the approach that will be needed to support Galileo in-orbit validation for the first test satellites (Galileo System Test Bed V2) and the first operational satellites.

Galileo/GNSS Working Group
The IGS has built up a reputation for providing the best available products for GPS applications, where the criteria for 'best' include timeliness and accuracy. Many of the concepts that are now standard in the GPS community have been developed within the IGS. GPS itself is being further developed, with the introduction of additional civil signals on the L2 (GPS Block IIR-M, from 2004) and L5 (GPS Block IIF, from about 2005) frequencies, while some studies have already been carried out for a next-generation GPS III, which would however not be fully operational before about 2015.

There is a strong interest in the IGS community in ensuring that the Galileo system is able to make a major contribution to scientific and other applications requiring very high positioning accuracy, as GPS has done. Inter-operability between GPS and Galileo is seen as a key requirement. While it is clear that IGS has had an exemplary function in some aspects of the early design and testing concepts for Galileo, notably in the Galileo System Test Bed GSTB V1, this community and its members, both European and non-



European, are well prepared to contribute their experience to the definition and validation of the Galileo system. A Galileo/GNSS Working Group was set up at the December 2002 Governing Board Meeting in San Francisco, with approved Terms of Reference that had been coordinated with ESA's Galileo project team.

Strategic Planning

The IGS is a self-governing, voluntary organisation with no central source of funding; it operates through the contributions of its component parts. Nevertheless, it has succeeded in carrying out long-term projects which no one of its members could have achieved alone. The IGS is directed by its international Governing Board, the composition of which is defined in the IGS Terms of Reference. Representatives of the IGS components (Analysis Centres, Data Centres, Networks) are elected by the IGS Associates, while representatives of related external bodies such as the IERS and IAG are appointed by those bodies. Working Group chairs are non-voting members of the Board. Following a significant preparatory effort, a two-day retreat of the Board in December 1999 resulted in a Strategic Plan for the years 2002-2007.

The IGS is committed to providing the highest-quality data and products as a standard for global navigation satellite systems in support of Earth-science research, multi-disciplinary applications and education. These activities aim to advance scientific understanding of the Earth-system components and their interactions, as well as to facilitate other applications benefiting society. As long-term goals the IGS aims to:

- provide GNSS data and products of the highest quality and reliability, making them openly and readily available to all user communities
- promote universal acceptance of IGS products and conventions as a World standard
- continuously innovate by attracting leading-edge expertise and pursuing challenging projects and ideas
- seek and implement new growth opportunities while responding to changing user needs
- sustain and nurture the IGS culture of collegiality, openness and cooperation
- maintain a voluntary organisation with effective leadership, governance and management.

Key areas of IGS activities in the next few years will be in the fields of GNSS on Low Earth Orbiters, real-time data availability and product generation, and new GNSS developments (Galileo; GPS IIR-M, GPS IIF, GPS III).

Outlook

The International GPS Service is about to celebrate - with a Workshop and Symposium to be held in Bern in March 2004 - its 10th Anniversary as an IAG service, though as I have explained the IGS as such is a few years older than this. The recently approved new IAG structure gives added status and roles to the services - others are the International Earth Rotation and Reference Frame Service (IERS), the International Laser Ranging Service (ILRS), the International VLBI Service (IVS) and the newly formed International Doris Service (IDS). The IAG's flagship project, the International Geodetic Global Observing System (IGGOS), will rely heavily on these services and on good collaboration between them.

The IGS has developed a great deal from the simple organisation that it was during the campaign of 1992, but the basic concept has been validated constantly over the years. A wide spectrum of projects and GNSS applications have been successfully integrated into its structure. Continuing improvement in the quality and reliability of the global network and data interfaces is critical to this success, as is the dedication of the data analysts. The IGS and its members continue to provide fundamental support to a range of scientific and applications space missions, and ESA's GOCE, MetOp and Galileo missions will benefit greatly from this.

Acknowledgment

The IGS operates through the combined efforts and enthusiasm of its more than 200 contributing organisations. Further information about the service and its products can be found on the IGS Central Bureau web site at:
http://igscb.jpl.nasa.gov.

esa

SSETI and ESEO

– Launching the dream!

Lierni Arana
Education Office, ESA Directorate of Administration, ESTEC, Noordwijk, The Netherlands

The ESA Education Office started the Student Space Exploration and Technology Initiative (SSETI) in 2000. The Initiative's main objective is to create a network of students, educational institutions and organisations on the Internet, which together will have the means to design, build and launch micro-satellites. It also aims to increase knowledge about space among the European youth of today through hands-on experience. Students have the opportunity to put their theoretical skills acquired at university into practice, to design, develop and launch micro-satellites, and much more.

In order to achieve these objectives, the infrastructure and the means of communication for the more than 800 students interested in the project had to be put in place. In addition to tools such as E-mail, a Bulletin Board and a Participants database, a web site (http://www.sseti.org) has been designed and implemented by the students themselves, allowing the SSETI community to easily communicate, interact and work together remotely. ESA's role includes the provision of communications, guidance, verification and testing support, as well as facilitating the launch arrangements.

Since SSETI's first steps back in October 2000, around 20 different universities throughout Europe have become involved in the very first SSETI micro-satellite project, known as the 'European Student Earth Orbiter (ESEO)'. The ESEO spacecraft is due to be launched on an Ariane-5 in late-2004.

Getting Organised

SSETI consists of two distinct elements:
- A centrally focussed organisation, led by the Education Office, whose tasks include the organisation, management and guidance of the project. This central organisation will provide the necessary Agency support in terms of expertise and testing and, ultimately, in negotiating the launch opportunity.
- A web-based organisation via which all of the parties involved can interact, communicate and meet in order to fulfil the goals.

The web site
www.sseti.org is the main point of reference for the SSETI project, where users can find all of the project-related information. It meets two important objectives: on the one hand it is the 'working place' for the SSETI community, and on the other it provides anyone who is interested with information about the project and its objectives, its current status, how to join, etc. Each registered user has a log-in and password affording full access to the information.

The web database
This database, developed by some of the SSETI students, is a part of the web site. Here one can find all the information related to the participants, addresses, universities, working groups, subsystems, profiles, etc. All SSETI project members must be registered in this database.

Chat sessions
Owing to the geographically distributed nature of the project, it is difficult for participants to meet physically at a given location. Internet-based 'chat sessions' allow them to conduct the meetings and reviews necessary for the day-to-day running of the project. Three weekly chat sessions are officially scheduled: two for the system-engineering team, and a general one for all the teams involved in the project.

E-mail messaging
E-mail is used extensively in SSETI, but there is no decision-making via e-mail. It is SSETI policy that all queries must be publicly addressed and discussed via a web-based User Bulletin Board (UBB). There are e-mail lists in place to facilitate such communication.

Requests for information
RFI is a particular way of addressing e-mails, in which the subject of the e-mail consists of the letters RFI followed by the reason for e-mailing and the deadline by which the question needs answering. If the e-mail is not answered before the deadline, the sender's own assumed answer, which has to be specified in the body of the initial e-mail, becomes the official answer to the question posed.

File transfer
This is an easy and effective tool for uploading/downloading documents to/from the server. It is an essential means for sharing all of the project documentation.

Workshops
These usually take place twice a year at ESTEC in Noordwijk (NL) and last one week. Two people per team are normally invited and the main goal is to exchange data and discuss project issues. The time is usually divided between lectures from experts on different space-related topics, presentations, and teamwork in the ESTEC Concurrent Design Facility (CDF).

Being physically all together in one place not only helps teams to get to know each other and exchange and share ideas, but also serves as a valuable period in which much of the work is carried out and where they have ESA experts on hand to answer any queries.

The Workshops are also essential for making sure that the project is following a consistent and coherent path.

How to Join

To participate in SSETI, students can either join an existing team (usually the case when the project is in its development phase) or form a new team (usually the case at the beginning of the project). Each team has a subsystem assigned to it, for which it is then responsible (including the financing).

Each team usually has at least four different 'coordinators': a main coordinator, a data coordinator, a communications coordinator, and a helping professor/teacher. The main coordinator is responsible for task distribution within his/her team and for solving the daily problems that arise. He/she also acts as the main point of contact for the team, and is responsible for the continuity of the Initiative at their institution. The data coordinator is responsible for the technical data and the subsystem sheets in the SSETI Design Model (SDM). The communications coordinator is responsible for publishing a weekly update on the Ultimate Bulletin Board (UBB), keeping the participant database current, and answering questions from other teams. The helping professors/teachers are dedicated university staff with significant technical knowledge, able to help students with technical questions.

A SSETI Workshop in progress in the Concurrent Design Facility at ESTEC in Noordwijk (NL)

CURRENT SSETI PARTICIPANTS

There are currently around 20 major European universities involved in the first SSETI project, namely the European Student Earth Orbiter (ESEO) micro-satellite. The following countries are part of ESEO: Switzerland, Spain, France, Italy, England, Ireland, Portugal, Sweden, Poland and Germany. The division of responsibilities across the various universities is as follows:

Subsystem	University	Country
Structures & Configuration	University of Porto University of Bilbao	Portugal Spain
Power	Naples University	Italy
Attitude Determination & Control	Instituto Superior Técnico	Portugal
Onboard Data-Handling System	Lulea University Newcastle University Ollscoil Atha Cliath	Sweden United Kingdom Ireland
Thermal Control System	Manchester University	United Kingdom
Propulsion	Stuttgart University	Germany
Communications System	Wroclaw University of Technology University of Calabria	Poland Italy
Mechanisms	Swiss Federal Institute of Technology	Switzerland
RadFET	Lulea University	Sweden
Narrow-Angle Camera	Umea University	Sweden
Ground Segment	Instituto Superior Técnico Wroclaw University of Technology Universidad Complutense de Madrid Universidad Politécnica de Madrid	Portugal Poland Spain Spain
Simulations	Escuela Técnica Superior de Ingenieros Aeronauticos	Spain
Mission Analysis	University of Zaragoza	Spain
Risk Assessment	University of Pisa	Italy
Public Relations	Hochschule für Druck und Medien	Germany
SSETI Design Model	Swiss Federal Institute of Technology	Switzerland
Legal Matters	University of Paris	Paris

ESEO

The European Student Earth Orbiter is currently in the design and development phase (so-called 'Phase-B'). When launched at the end of 2004, it will be operated from a ground station in Portugal. The mission objectives are to:
- take images of Earth and the Moon to stimulate space education in Europe
- test and qualify a propulsion system for future lunar missions
- test and qualify a star tracker developed from a commercial device
- measure radiation onboard the spacecraft.

Thermal testing of ESEO spacecraft components in ESA's ESTEC facilities

The benefits that are accruing to the participating students include:
- gaining hands-on experience in designing and developing spacecraft
- learning how a space project is carried out, what standards are applied and how ESA works
- participating in an international and interdisciplinary venture
- experiencing international and interdisciplinary teamwork with people from all over Europe
- interacting with ESA and industrial experts, and
- making several visits to ESTEC,

all of which contribute to making them better prepared engineers and scientists, who will hopefully continue to work in the European space environment in the future.

To the Moon and Beyond ....

SSETI is a unique platform for students in that it is extremely rare for young people to be given the responsibility for putting their theoretical expertise to use in a project where the outcome is a fully operational spacecraft. It provides them with the skills needed to cope successfully with the international and interdisciplinary approaches that are common in the European workplaces of today and tomorrow. It allows them to familiarise themselves with the European standards currently in place and the way in which a space project is carried out in industry. They are also faced with the task of writing high-quality documentation. Not least, all of the above needs to be done in parallel with their regular studies, teaching them to plan and prioritise.

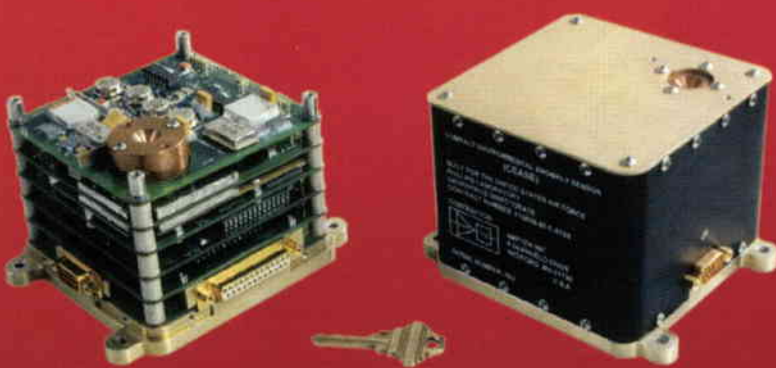
The work so far completed on ESEO shows that, given the proper support, coordination and advice, the project will be a success, and most importantly a good example of what the European students of today can achieve through teamwork, and a combination of enthusiasm, motivation and hard work.

The goals for SSETI are not focused only on Earth-orbiting satellites, however, and there are already thoughts about student missions to the Moon and even beyond...... Let's launch the dream! esa

Space Radiation Alarm

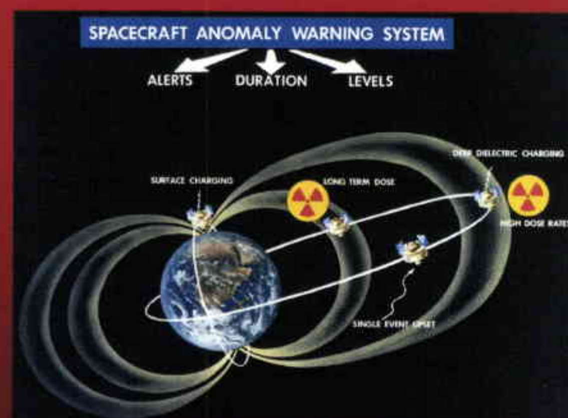
"CEASE"

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.

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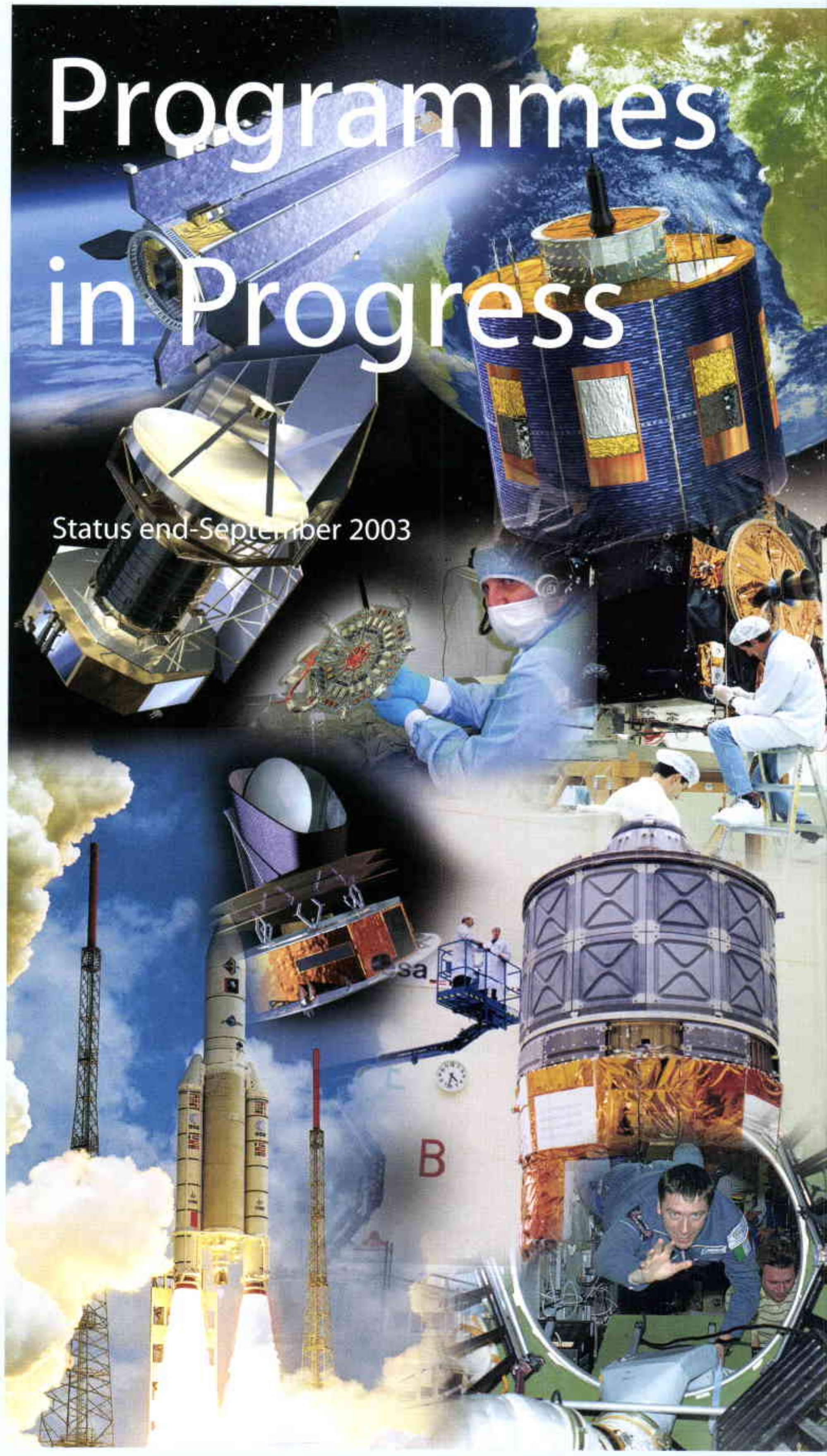


Programmes in Progress
Status end-September 2003

In Orbit

	PROJECT	COMMENTS
SCIENTIFIC PROGRAMME	SPACE TELESCOPE	LAUNCHED APRIL 1990
	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
	MARS EXPRESS	LAUNCHED JUNE 2003
	SMART-1	LAUNCHED SEPTEMBER 2003
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
	VENUS EXPRESS	LAUNCH NOVEMBER 2005
	HERSCHEL/PLANCK	LAUNCH FEBRUARY 2007
	EDDINGTON	LAUNCH EARLY 2008
	DOUBLE STAR (DSP-E)	LAUNCH DECEMBER 2003
	DOUBLE STAR (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 SEPT. 2004/ GOCE FEB.2006 SMOS FEB. 2007/ADM-AEOLUS OCT. 2007
	METOP-2	LAUNCH OCT. – DEC. 2005
	MSG-2/3/4	LAUNCH MSG-2 JAN. 2005 LAUNCH MSG-3 2006 MSG-4 STOR. 2007
HUMAN SPACEFLIGHT PROGRAMME	COLUMBUS	LAUNCH OCTOBER 2004 (UNDER REVIEW)
	ATV	FIRST LAUNCH SEPT. 2004
	NODE-2 & -3	LAUNCHES FEB. 2004 & NOV. 2006 (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	
	MFC	BIO, FSL, EPM, with COLUMBUS
LAUNCHER PROGRAMME	ARIANE-5 DEVELOP.	OPERATIONAL
	ARIANE-5 PLUS	AR5-ECA QUALIF. LAUNCH MARCH 2004
	VEGA	FIRST LAUNCH JULY 2006

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

OPERATIONS · ADDITIONAL LIFE POSSIBLE · RETRIEVAL · STORAGE

ISO

The Infrared Space Observatory Data Archive is being enhanced with new Highly Processed Data Products, including catalogues and atlases. Several of the ongoing projects focusing on reducing data from selected observing modes have been completed. A new interoperability mechanism, fully compliant with the Virtual Observatories standards, was demonstrated at the ADASS XIII Conference in Strasbourg (F) from 2 to 15 October.

ISO continues to have a significant presence in the refereed literature, with more than 1000 papers drawing upon ISO data and covering all areas of astronomy having appeared since late 1996.

Recent highlights include:
- The deepest survey by ISO: The bulk of the extragalactic diffuse light at 6.7 microns can be explained as the sum of the light emitted by many evolving galaxies. The deepest observation by ISO has resolved 65 sources in the SSA13 field, down to 6 μJy.
- The first detection of a purely rotational transition of ^{17}OH in the Interstellar Medium: Two resolved components of this transition appear in absorption towards the giant molecular cloud Sagittarius B2, which was observed at a spectral resolution of 33 km/s using the Fabry-Pérot mode of ISO's Long-Wavelength Spectrometer.

Ulysses

On 6 October, Ulysses completed its 13th highly successful year in orbit. The spacecraft and all of its scientific instruments continue to operate well, with data recovery levels consistently in excess of 97%.

For the first time since 1992, Jupiter is starting to feature strongly in the scientific activities of the Ulysses investigator teams. On 5 February 2004, the spacecraft will encounter the giant planet for the second time. Unlike the 1992 fly-by, however, this will be a distant encounter (closest approach will be at 1684 Jovian radii, or 120 million km, from the planet's centre, compared with 6 Jovian radii in 1992), and the spacecraft's orbit will therefore be unaffected.

Another difference between the two fly-bys is that this time the spacecraft will approach the planet from high northern latitudes. This is scientifically very interesting because Ulysses will be very well placed (75° north of the planet's equator in November/December) to detect radio emission from Jupiter's auroral regions.

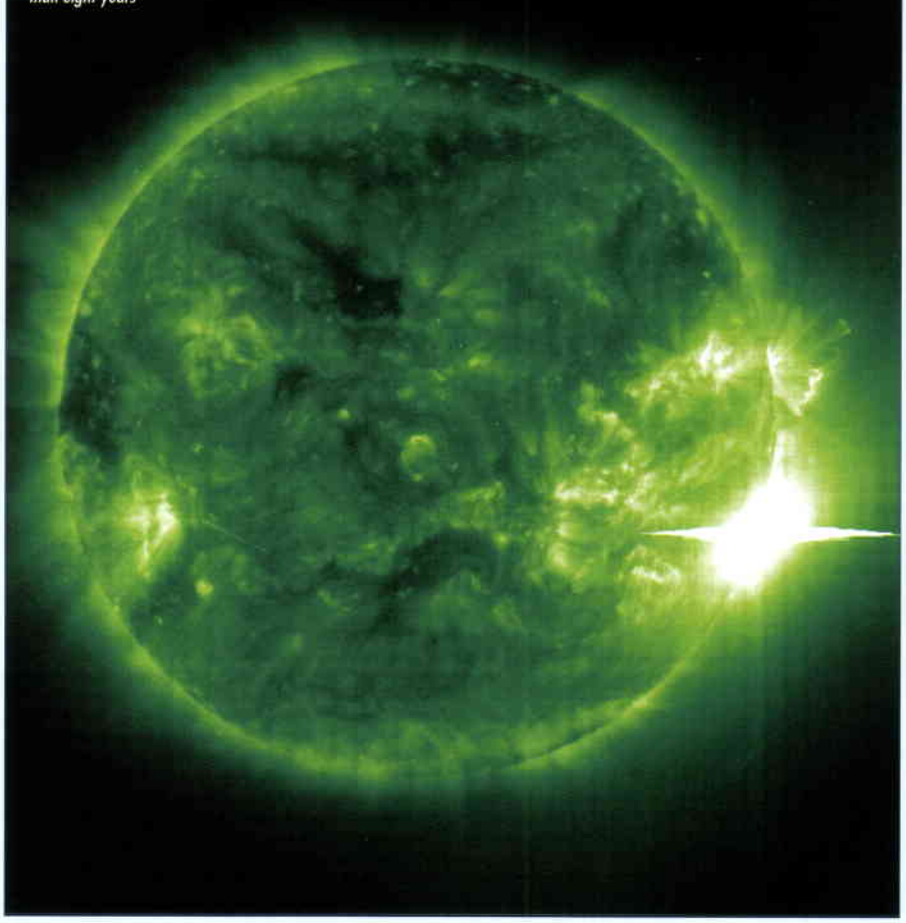
Recent findings by the Ulysses DUST team, showing that a steady increase in the flux of interstellar dust in the inner heliosphere is likely to occur as a result of the recent reversal of the Sun's magnetic polarity, have attracted significant media attention. Interstellar dust, which enters the heliosphere with the same velocity as neutral interstellar gas, was first detected by Ulysses.

SOHO

SOHO was recently awarded the Laurels for Team Achievement Award of the International Academy of Astronautics (IAA). This award recognises both the outstanding achievements in designing, building and operating the mission, as well as the science it has performed. It is a tribute to all of the engineers and scientists who have contributed to one of the most successful space science missions in history.

Since showing the first signs of degradation in early May, SOHO's High-Gain Antenna z-axis mechanism has become unusable in nominal mode, but can still be moved if necessary using double motor windings (prime and redundant). After careful analysis of all options, the team therefore decided to park the antenna in an 'ideal' position, where data

The huge solar flare that occurred on the solar limb on 4 November was the most powerful ever seen. This image was captured by the Extreme Ultraviolet Imaging Telescope on the SOHO spacecraft, which has been observing the Sun continuously for more than eight years



losses can be minimised by rotating the spacecraft 180 degrees once every three months. The result is 'keyhole' periods, alternating between 18 and 25 days every three months, allowing data downlinking using the regular 26 m DSN stations, with larger 34 or 70 m stations being required to fill the gaps.

The 13th SOHO Workshop, on 'Waves, Oscillations and Small-Scale Transient Events in the Solar Atmosphere', took place in Majorca (E) at the end of September and was attended by almost 100 scientists. The Proceedings will be published shortly by ESA Publications Division.

Huygens

On 15 October Cassini-Huygens completed six years in space and is still functioning very well. The 12th in-flight checkout of the Huygens Probe was successfully conducted on 18 September and an in-flight engineering demonstration of the Saturn Orbiter Insertion (SOI) manoeuvre was successfully completed in August. All SOI activities, except main-engine firing, were tested. A week-long engineering demonstration of the Probe Relay Mission will be conducted in early March 2004.

SOI itself will take place on 1 July 2004, and Huygens will be released on Christmas Day 2004 for an entry into Titan's atmosphere on 14 January 2005. A major engineering effort is being devoted to re-validating the entry scenario and the parachute-deployment sequence, taking into account the latest atmospheric models (Yelle Model including atmospheric gravity waves). An Agency-level mission review (delta Flight Acceptance Review) will be conducted in the period December 2003 - February 2004.

XMM-Newton

XMM-Newton operations continue to run smoothly, and the autumn eclipse season passed without incident. An effort is being made to model the satellite's radiation environment, with the goals of achieving a higher fraction of successful observations, and of slightly increasing the amount of available science time. Over 2800 observation sequences have now been executed and the data for all but 100 of them has already been shipped.

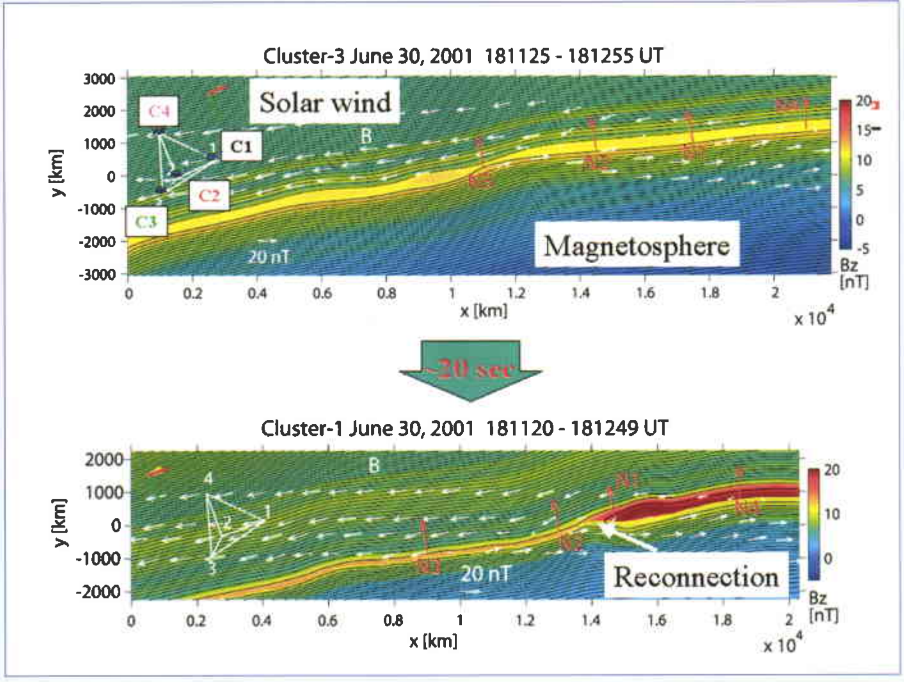
The work on upgrading the overall ground segment (to SCOS-2000) is progressing according to plan, and should be completed towards the end of 2004.

By the 30 April deadline for submissions in response to the latest XMM-Newton observing programme Announcement of Opportunity (AO-3), a total of 692 valid proposals had been received from 468 different Principal Investigators in 24 countries. These proposals requested almost 27 500 hours of science time, which is about 10% more than was requested in response to AO-2. In the subsequent evaluation process, involving 70 scientists from 16 countries, a total of 948 observations were selected for AO-3. Following the approval of the recommended observing programme by ESA's Director of Science, proposers were notified of the results in early July, thereby completing the process in record time. AO-4 is currently foreseen for release in September 2004.

A paper published in Nature on 12 June reported the first direct measurement of a neutron star's magnetic field using XMM-Newton, through the discovery of cyclotron resonant absorption dips in the star's X-ray spectrum. By mid-October, some 380 papers based on XMM-Newton data had been published in, or submitted to, the refereed literature.

Cluster

The four Cluster spacecraft continue to perform well, returning more than 99% of the data expected from the Master Science Plan. After exploring the day-side and night-side boundaries of geospace with various spatial resolutions, using different configurations of the four satellites, they are now configured 200 km apart to study fine details and measure currents in the Earth's magnetotail.



The onset of magnetic reconnection observed by the Cluster spacecraft. The upper panel shows the solar wind and the magnetic field of the Earth's magnetosphere reconstituted from the observations made by Cluster-1. The lower panel shows them as observed by Cluster-3. The reconnection process had started between the passages of the two spacecraft, which were separated by 20 secs in time, as evidenced by the large bulge in the magnetic field (Courtesy of Hasegawa & Sonnerup)

Recent science highlights is Cluster's observation of magnetic reconnection in progress in the polar cusp, the region above the pole where solar-wind particles enter directly into the magnetosphere and reach the Earth's atmosphere. The reconnection process accelerates ions, which can then produce a bright spot in the aurora. By chance, NASA's IMAGE spacecraft was in a position to observe the proton aurora at the same time and detected such a bright spot. Serendiptous coordinated observations like this one are equivalent to winning a lottery, as they are just as unlikely and scientifically just as rewarding! This is the first time that the reconnection process has been observed at high altitude and its direct effect in the ionosphere recorded.

In other instances, the Cluster spacecraft have been able to measure the exact curvature of the magnetic field in the Earth's magnetosphere, and its gradual change with ongoing reconnection, which is a unique but essential measurement for understanding energy storage and release in the magnetic field of near-Earth space.

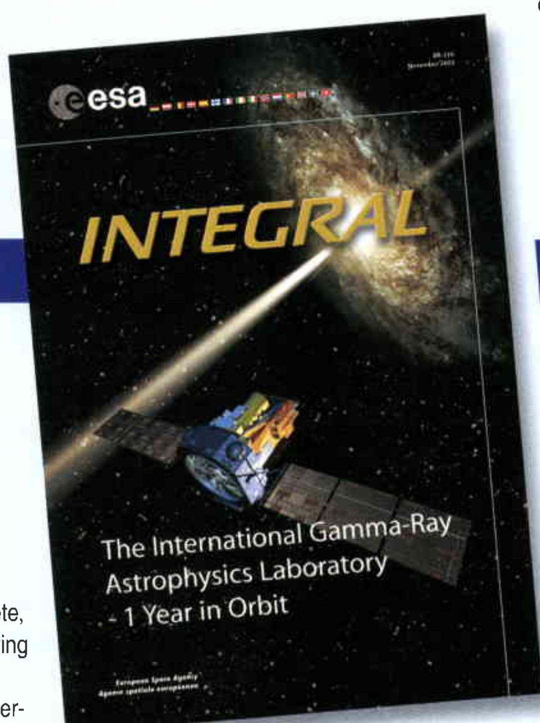
The 6th Cluster Workshop took place during the first week of October, reviewing the latest discoveries made by the mission and addressing, inter alia, the effects that solar activity has on the Earth's magnetosphere, the bow shock, the magnetopause, the polar cusp, and their spatio-temporal fluctuations.

Integral

Integral routine operations are proceeding smoothly with no major anomalies or interruptions to the observing programme. It is expected that most of the high-priority targets in the first year's observing programme will have been observed by the end of December, as anticipated. The process of selecting the targets for the second year's programme is nearly complete, with the Announcement of Opportunity having closed on 5 September. A total of 142 proposals were received, resulting in an over-subscription by around a factor of 8.

Approximately half the proposals are for compact galactic sources, one quarter for extra-galactic objects, and the remainder for nucleosynthesis studies and miscellaneous objects. The results of the selection process should be communicated to the astronomical community in November, with the requested observations taking place from mid-December onwards.

After the closure of the spring galactic-centre visibility window, Integral went on to observe a wide range of astronomical sources, including clusters of galaxies, interacting binaries, stellar associations, accreting binaries, active galactic nuclei and an unidentified gamma-ray source. Target of Opportunity observations were made of a relatively nearby Type-Ia supernova and a soft gamma-ray repeater that went into outburst. The galactic-centre region became visible again in August and Integral performed its deepest look ever (2 million seconds) searching for new sources, studying the enigmatic source close the middle of the galactic centre itself, and mapping the surrounding diffuse emission that results from the creation of new atoms and the annihilation of electrons and positrons.



PROBA

Operated from ESA's Redu station in Belgium, PROBA has been providing Earth-observation data to the CHRIS/PROBA scientific community as well as images for educational and public-relations purposes. About 50 sequences of five different multispectral images are produced monthly and 70 sites are being imaged with the High-Resolution Camera.

The space environment monitoring payload (SREM and DEBIE instruments) has continued to provide good data. These instruments are currently in use only half of the time, however, as priority is being given to Earth observation, as a precautionary measure to limit battery usage. This strategy will be reviewed for the winter season.

With a view to the further extension of the mission, a review of the spacecraft's health has been performed. It has been concluded that there is nothing to preclude another year of operations, as all onboard units are still performing satisfactorily and no significant degradation has been observed. The orbit, with a decay of 16 km since launch and a drift of 8 minutes, remains adequate for good-quality Earth imaging. However, some necessary upgrades to the ground segment have been identified, as several items have reached or are quickly approaching their end-of-life.

Rosetta

Since the postponement of the Rosetta launch in January, the flight spacecraft has remained in Kourou. The fuel has been off-loaded and various maintenance activities have been performed on critical units, especially mechanisms. Minor refurbishment/maintenance work on some payload units has also taken place.

The new flight software, which takes into account the new mission target and also some anomaly fixes, has

The cities of Santee and Poway to the north of San Diego, California, can be seen in this image of the area known as 'Sycamore Canyon Open Space Preserve', which has been ravaged by fires in recent weeks. The image was taken on 5 November by the CHRIS instrument onboard ESA's PROBA-1 spacecraft

been thoroughly tested on the spacecraft engineering qualification model at ESOC in Darmstadt (D), culminating in comprehensive system functional tests on the flight model, including commanding tests from ESOC. This exercise went off extremely smoothly, providing high confidence in the latest flight software.

A Launch Preparation Readiness Review has taken place, addressing all system aspects of the new mission, all activities on the flight hardware since the launch postponement, and any anomalies encountered during early Mars Express operations that might be relevant to Rosetta. No major discrepancies were identified and the green light was given to start the new launch campaign at the end of October.

For the lander, the main concern since the choice of the new mission scenario has been the larger size of the target comet, which could significantly increase the landing velocity. Various tests have therefore been performed on the landing gear to further assess its strength and damping characteristics. The results are very positive, showing that the lander can touch down successfully on the larger comet even if it has a higher density. A small hardware modification has been implemented to limit the tilting of the lander body and avoid toppling if the surface slope is high.

The launcher-qualification issue is being re-addressed to confirm the ability to launch Rosetta using the Ariane-G5+ version. A qualification review will take place at the end of November.

Ground-segment preparation is continuing according to plan, with confidence buoyed by the excellent performance of the new antenna in New Norcia (Aus.) during Mars Express operations. The new mission has a launch window that opens on 26 February 2004 and all systems are on track for this date.

Mars Express

After a highly successful launch on 2 June, the spacecraft was injected very precisely by the Fregat upper stage onto its interplanetary transfer trajectory. The subsequent post-launch checkout of the spacecraft, initial testing of the scientific instruments, and Beagle 2 commissioning activities have been successfully completed.

An identified shortfall in output from the power subsystem means that only about 70% of the expected power will be available during the mission. A comprehensive analysis has therefore been carried out to identify the cause and to minimise its impact on the science mission. That evaluation is nearly complete and it appears that nominal payload operations can be executed for more than 85% of the orbits, while the remaining 15% will require only some fine-tuning of power consumptions.

In July, the scientific community recommended a change to the orbit around Mars, in order to provide more daylight coverage for the optical instruments in the earliest mission phases. Although no final conclusions have been reached, all current studies indicate that the change is feasible.

Venus Express

The flight-model spacecraft structure has been delivered on time by Contraves (CH) to Astrium Ltd. (UK) for installation of the propulsion system, which is also proceeding according to plan.

All of the payload engineering models have been delivered to Astrium SAS (F) for installation on the test bench. Initial testing of the interfaces between payload and spacecraft subsystems has started and installation of the first version of the flight software is imminent.

Starsem has initiated all of the necessary analysis and study activities for the Soyuz launch, leading up to a preliminary mission-analysis review in mid-2004.

SMART-1

SMART-1 was successfully launched by an Ariane-5 vehicle (V162), which lifted off from Kourou, French Guiana, on 27 September at 23:14:39 UTC. The launch was perfect in terms of trajectory and spacecraft deployment, despite the complex triple-launch configuration (the other two passengers being Eutelsat's E-Bird and the Indian INSAT-3E, both telecommunications satellites).

SMART-1 was the last to be deployed into Geostationary Transfer Orbit (GTO) and telemetry contact was immediately established from the ESA ground station in Perth, W. Australia. The automatic activation sequence worked flawlessly as SMART-1 deployed its solar arrays, released the launch lock on the electric-propulsion orientation mechanism and configured itself into a safe mode, exactly as planned. The ESOC Flight Control Team, supported by Industry and ESTEC, then began the subsystem commissioning phase, which lasted about four days. All subsystems were found to work as expected.

On 30 September, the electric-propulsion system was successfully fired for the first time, and has since been thrusting regularly, increasing the semi-major axis by about 50 km per orbit. The goal is to apply thrusting as quickly as possible to escape from the Earth's hazardous radiation belts.

In the meantime, all 7 payload instruments have been successfully pre-commissioned (i.e. electrically and functionally verified), leading to the possibility of taking the first images with the SMART-1 instruments in late October.


The launch of SMART-1 on 27 September from Europe's launch base in Kourou, French Guiana

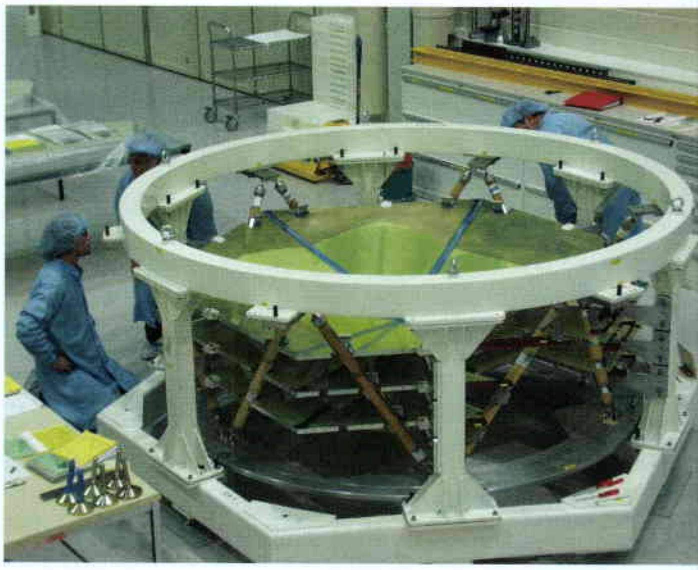
Herschel/Planck/ Eddington

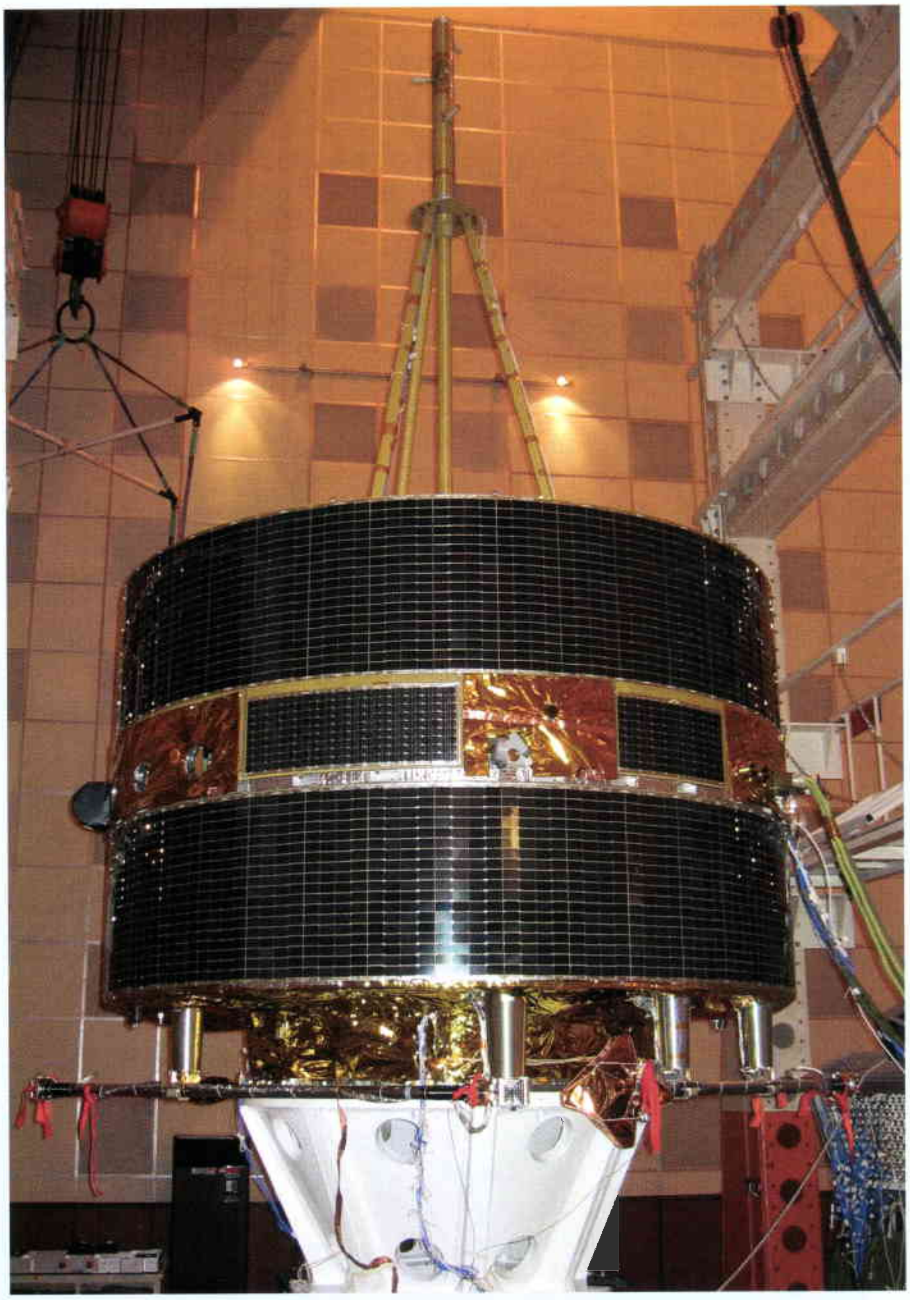
Overall technical progress in the development of the Herschel and Planck spacecraft has continued according to plan, with several major subsystem reviews successfully completed during the reporting period, e.g. for the Planck Payload Module structure, with the go-ahead given to complete qualification-model manufacture. Similarly, hardware manufacture for the Herschel Cryostat and Service Module structures is in full swing, but with completion now expected somewhat later than previously anticipated.

Development of the qualification models of the scientific instruments is making significant progress within the Instrument Consortia. Delays due to some development problems have been accommodated within the spacecraft development scheme and schedule.

With respect to the telescopes for both spacecraft, a second brazing of the twelve petals of the 3.5 m Herschel telescope primary mirror is to be performed in October. The reflectors for Planck are making good progress and the qualification model of the secondary

The qualification-model telescope structure for Planck (courtesy of Contraves)





The Double Star TC-1 satellite during mechanical testing

mirror has been completed and is now being tested. The primary mirror is now at the assembly stage.

Finally, there is also significant progress to report on the Eddington mission, with the first phases of the two parallel definition studies having been finalised by the industrial teams, resulting in two similar designs that fulfil the scientific requirements. The Eddington Payload Consortium proposal describing the intended support by European institutes participating in the mission has been received and is currently being evaluated.

Double Star

Following the integration of six European scientific instruments in July on the first Double Star satellite (TC-1, equatorial), a complete suite of functional tests was performed, which confirmed the compatibility of the Chinese spacecraft system with the Cluster-based payload.

The environmental testing phase commenced in August and the two main elements, the thermal-balance/thermal-vacuum and vibration tests, have been successfully completed. The latter in particular allowed some open issues relating to differences between the Double Star and Cluster environmental test specifications to be resolved. An EMC test has demonstrated a low noise environment for the scientific instruments, and the remaining radiated-EMC and magnetic-cleanliness tests will be completed by the end of October.

The launch campaign for TC-1 will commence at Xichang in China by 25 November, with lift-off of the Long March 2C vehicle foreseen for end-December.

Payload procurement for the second Double Star satellite (TC-2, polar) is progressing, with delivery to China foreseen before the end of the year, which is compatible with the planned mid-2004 launch from Tai Yuan.

CryoSat

Development of the CryoSat spacecraft is progressing well, with more proto-flight model equipment (S- and X-band transmission systems, on-board computer, three star trackers, etc.) having been delivered to the prime contractor. Mechanical integration on the spacecraft structure has started at the EADS Astrium GmbH facility in Friedrichshafen (D).

On the payload side, development of the SIRAL altimeter is also progressing, a major milestone having been reached with the delivery by Saab (S) of the twin antennas.

Ground-segment-related activities are progressing according to plan, with factory acceptance of the second version of the Payload Data Segment successfully completed at ACS (I) at the end of September. It is planned to ship the hardware to the Kiruna station after the acceptance of the Instrument Processing Facility.

GOCE

As completion of the detailed consolidation of the satellite design approaches, the sequence of Preliminary Design Reviews (PDRs) for spacecraft and payload elements is gradually being superseded by a sequence of Critical Design Reviews (CDRs), with those for the battery, the first version of the platform software, and the primary structure having already been initiated.

Following the problems encountered during the lifetime testing of the Micro-Propulsion Assembly (MPA) emitters reported in the last ESA Bulletin, it has been decided to remove the entire assembly and to use existing magneto-torquers to compensate for torques due to air drag (mainly) and radiation pressure. In addition, a simplified cold-gas system has been introduced to support in-orbit calibration of the gradiometer instrument. With these design changes, the accuracy of the retrieved gravity-field products should remain around 1 mGal for anomalies on the Earth's surface.

Manufacture of the structural model of the gradiometer instrument has recently started, and that of the Accelerometer Sensor Head (ASH) Demonstration Model (DM) is progressing. The first electrical tests on this model, including levitation of the proof-mass under 1-g conditions, are expected to commence shortly.

Problems have been encountered by the substrate supplier for the solar generator while testing samples to validate the manufacturing process. Manufacturing activities have therefore been halted while a failure investigation is carried out.

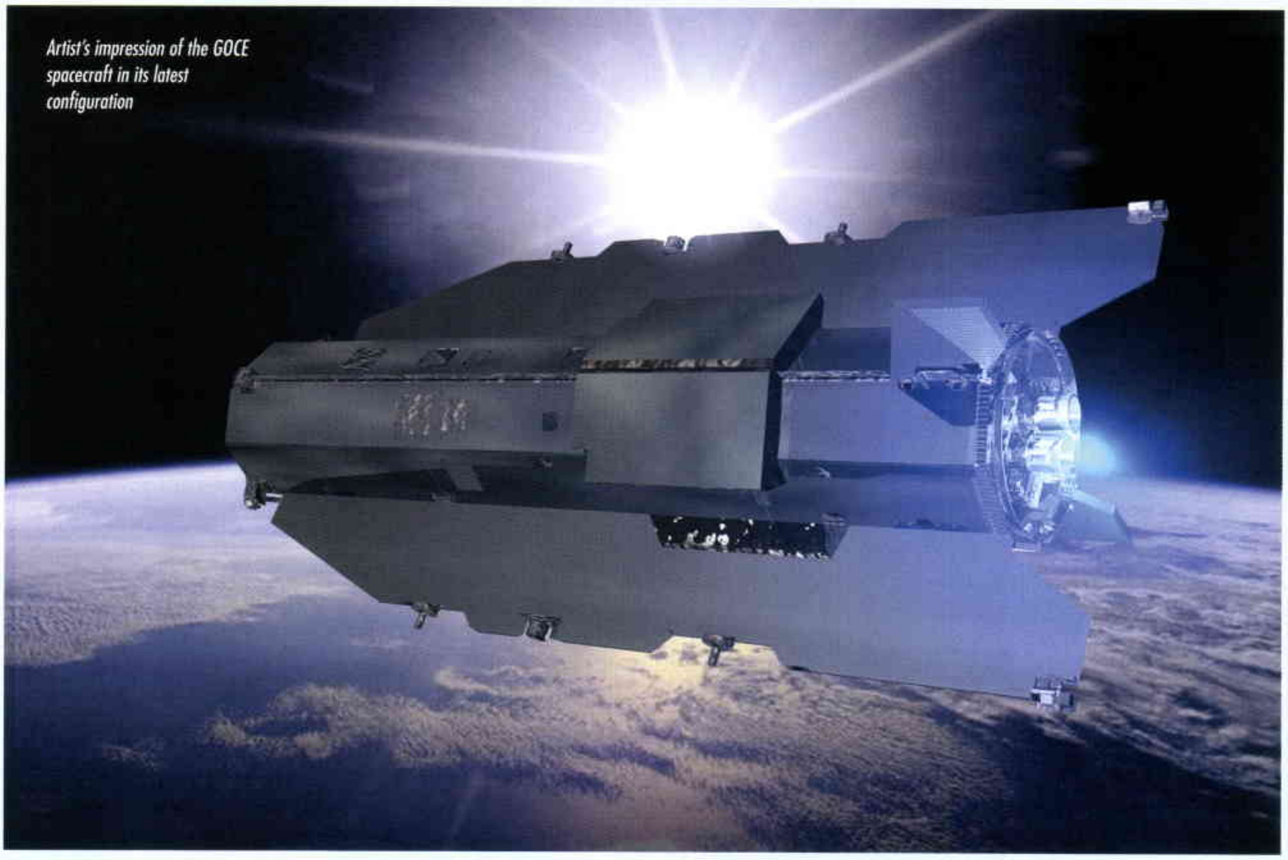
On the ground-segment side, the industrial consortium responsible for the Payload Data Segment, including all scientific data processing up to and including Level-1B, began work in September. Evaluation of the proposals received in response to the Announcement of Opportunity (AO) for the calibration and validation of those same Level-1B products has led to the selection of one comprehensive proposal. The contractor responsible for the Calibration and Monitoring Facility has completed the functionality definition activity and will release a detailed report before the end of the year.

The Tender Evaluation Board for the procurement of the launch services recently concluded that the Eurockot proposal is acceptable and subsequently recommended the placing of a contract, subject to satisfactory negotiations.

SMOS

In September, the Earth Observation Programme Board (PB-EO) unanimously approved the full implementation of the SMOS programme, whilst both CNES and CDTI confirmed their commitments for their parts of the programme.

An offer for the main development phase (Phase-C/D) for the payload, which is the major part of ESA's share in the programme,



Artist's impression of the GOCE spacecraft in its latest configuration is being evaluated. If it proves acceptable, a contract proposal will be submitted to the Agency's Industrial Policy Committee (IPC) in November, to enable a kick-off meeting with EADS CASA (E) and subcontractors before the end of 2003. The technical baseline for the contract will be the configuration resulting from the Payload Preliminary Design Review, scheduled to take place in October/November.

ADM-Aeolus

The Preliminary Design Review (PDR) package was successfully completed by the Board on 22 September. There are three main issues:

- Aeolus will include the first European high-power solid-state laser in space. There is very little such experience worldwide. Development work on the laser has shown that adequate output power and lifetime is achievable, but risks remain in these areas. The project will continue to pay close attention to the technological development work in this area.

- There is concern over the pressurisation conditions most appropriate for in-orbit operation of the laser. This appears to be the most significant risk facing the project, and the project will therefore agree a risk-mitigation plan with Astrium.

- The Vega launcher is the design driver for most of the mechanical environment and its latest fairing design presents some accommodation difficulties. Specified Vega insertion dispersions also lead to a marginal propellant budget for a worst-case launch date.

The PDR also concluded that the definition of the flight-operations concept is good, and that the design will meet the Agency's demanding, low-cost operation objectives. This includes satisfying the requirement for five days of autonomous operation in the case of a single-point failure.

Support contracts have been concluded with the three candidate launch providers: Eurockot, Dnepr and Arianespace (for Vega).

MetOp-1 in the anechoic chamber at Intespace (F)

All three have reviewed the PDR package and provided useful feedback to ensure continuing triple compatibility.

The majority of the subcontractors have been selected, although negotiations are continuing with most of them. Only ten items remain to be allocated at the time of writing, and the procurement packages for six of them have been issued.

The contract proposal for continuation of the industrial contract into Phases C, D and E1 was unanimously approved by the Agency's Industrial Policy Committee (IPC) on 25 September. As a result, signature of the contract is expected in October.

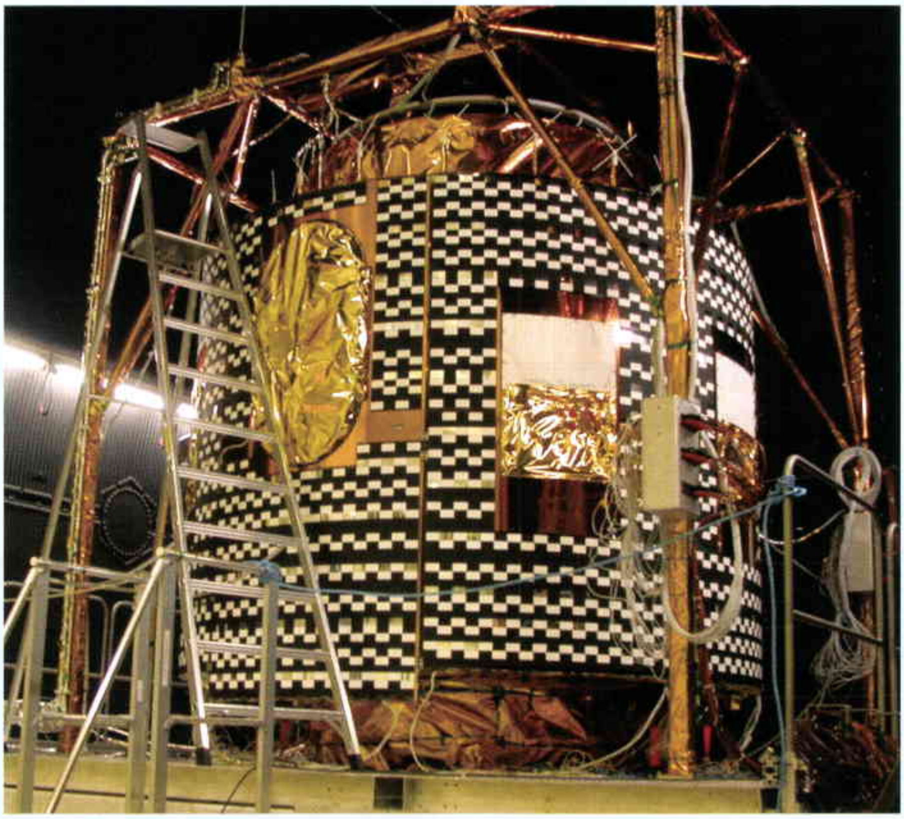
MetOp

Good progress continues to be made on the integration of the proto-flight satellite, MetOp-1, with the successful completion of the radiated tests (radio-frequency emissions and autocompatibility) in the anechoic chamber at Intespace in Toulouse (F). A number of minor issues were identified, but the spacecraft's design has been fully verified.

Preparations are now underway for the mechanical testing (vibration, acoustic, shock), which will take place in December/January, also at the Intespace facilities.

Work is also progressing on the Payload Module and the Service Module of MetOp-2, which will be the first satellite to fly at the end of 2005, with preparations underway for thermal-vacuum testing of the two modules, in the Large Space Simulator (LSS) at ESTEC in Noordwijk (NL) and at Intespace, respectively. These tests will start in the first quarter of 2004.

As far as the instruments are concerned, the electrical integration of the first IASI flight



The MSG-3 spacecraft being prepared for thermal testing at Alcatel Space in Cannes (F)

model has been proceeding smoothly, and the preparation of the complex test jig needed for instrument testing during the Payload Module thermal-vacuum test is well advanced.

The GOME-2 Qualification Results Review has also been held, and a solution to the grating efficiency problem has been identified and is being validated.

Meteosat Second Generation (MSG)

MSG-1

The commissioning phase for the MSG space segment was finalised in June and confirmed the satellite to be good health, with excellent instrument performances. The GEOSAR (Geo-Stationary Search And Rescue) mission is in the last phase of its commissioning, which is organised by COSPAS-SARSAT, but it has already been declared 'pre-operational'. The commissioning of the ground segment is still in progress and should be completed by the end of the year, after which the MSG-1 Routine Operations phase will start.

MSG-2

The MSG-2 spacecraft is still in its storage configuration, with a confirmed launch window of January-June 2005. De-storage and preparation for launch activities will resume in spring 2004.

MSG-3

This third satellite in the MSG family has now been integrated and is currently undergoing its environmental testing. It will be put into storage in spring 2004.

MSG-4

The industrial activities were kicked off in April and most unit and subsystem Baseline System Reviews have been successfully completed in the meantime.

Artemis

Artemis has continued to provide operational services for L-band mobile, data-relay and navigation users, all of whom have expressed their satisfaction with its performance and plan to make increasing use of the services in the future. The L-band payload (LLM) has been used continuously for European Mobile System (EMS) services under the contract with Telespazio. The spare capacity has been used to demonstrate advanced systems under development by ESA, including a Wideband Mobile Demonstration (S-UMTS), an Aeronautical Communication Demonstrator (SDLS), and an advanced modem for satellite communications. Other potential users of the LLM payload have been requested to confirm their financial offers and capacity requirements and draft contracts have been issued. Further meetings have also taken place with the two potential future data-relay application users: Liason Optique Laser Aeroporté (LOLA) and the Unmanned Space Vehicle (USV).

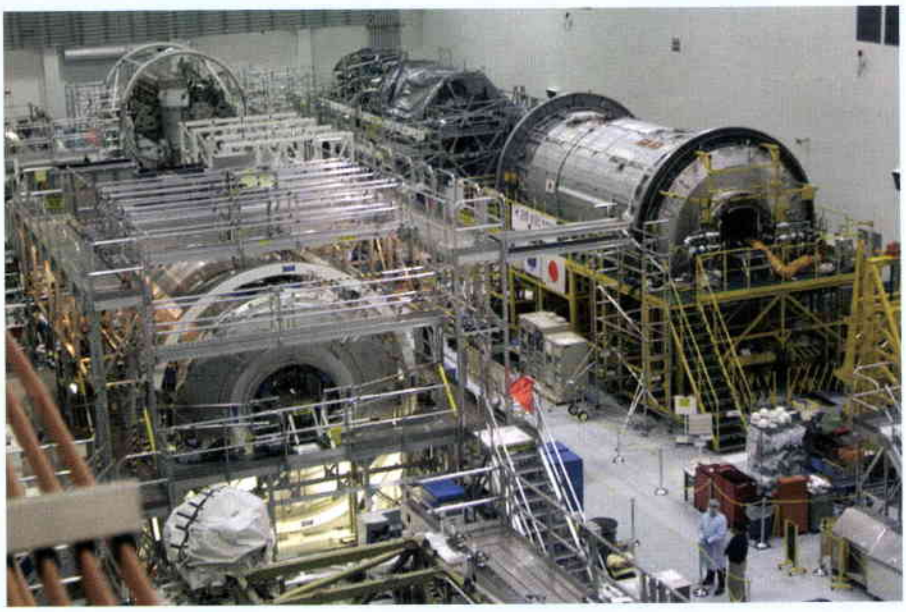
Artemis has also continued to provide an operational data-relay service to Envisat and SPOT-4. Reviews have been held with both customers to evaluate service and link performance to date, and to decide on the frequency of usage in the near-term. Envisat will continue to use 5 Ka-band links per day for ASAR and MERIS background mission data reception. SPOT-4 will continue to use one optical link per day for image data reception, and Artemis data will now be included in the Spot Image commercial process

The Optical Ground Station (OGS) on Tenerife, operated by Instituto de Astrifisica de Canarias (IAC, Spain), has continued to use optical links with Artemis for atmospheric measurements. For two weeks in September, the LUCE engineering model of the optical terminal on JAXA's OICETS spacecraft successfully completed a series of link tests to Artemis from the OGS, confirming its compatibility and overall acquisition and tracking capability.

By the end of September more than 500 radio-frequency links had been provided to Envisat, and 180 optical links to SPOT-4, with another 80 optical links to the OGS. The payloads work very well and the link quality is excellent. The few service outages have been the result of spurious disturbances resulting in platform anomalies, which are currently under investigation.

The navigation payload has been used for further performance characterisation tests in preparation for integration with the EGNOS pre-operational test bed in November.

All DRTM Participating States have now agreed the revised Resolution on Artemis Operational continuation, which is therefore adopted, allowing the implementation of funding arrangements to proceed and the renewals of contracts for extended operations to be initiated.



The Space Station Processing Facility at Kennedy Space Centre, with Node-2 on the left and JEM on the right

International Space station

Highlights

NASA's 'Return to Flight' plan for the Space Shuttle has been published and the approved planning window for the next launch is 'no earlier than 12 September–10 October 2004'.

At a Heads of Agency meeting in July, it was agreed to review and update the ISS Programme Action Plan adopted in December 2002. At the same time, the International Partners declared their solidarity and continuing determination regarding the programme. The 1000th day of permanent human presence on-board the ISS was achieved during the Heads of Agency meeting, on 29 July.

Progress flight 12P - a nominal refuelling and logistics mission - was launched on 29 August, docking with the ISS on 31 August.

Space infrastructure development

The Columbus Qualification Review 2 and Safety Review 3 have been successfully completed. The electrical test model qualification was on-hold due to the interface testing of the European Physiology Module and the Fluid Science Laboratory. Multiple-element integrated testing of Node 2 and the Japanese Experiment Module (JEM) have been completed at Kennedy Space Center (KSC). The Russian docking and refuelling systems have been mounted into the Integrated Cargo Carrier of the first Automated Transfer Vehicle (ATV) 'Jules Verne'. Tests on the Avionics Bay Proto-Flight Module have shown failures, which are being investigated, delaying delivery to end-October.

The ATV Cargo Integration contract was kicked-off on 28 July and the first cargo-manifest cycle has been completed. Manufacturing and procurement activities have already started. The ATV Production Readiness Review was completed successfully in mid-September, and the Exploitation Programme Tender Evaluation Board approved the ATV production proposal from industry on 26 September.

Regression testing is continuing on the Mission Preparation and Training Equipment

Work in progress on the Integrated Cargo Carrier 'Jules Verne'

ESA astronaut Pedro Duque (back right) during training in the Zvezda Simulator at the Gagarin Cosmonaut Training Centre

for the European Robotic Arm (ERA) to incorporate the actions identified during the equipment's System Qualification Review and Acceptance Review.

The first flight unit of the –80 degC Freezer (MELFI) was de-integrated from the Multi-Purpose Logistics Module (MPLM) in July and stored in the Space Station Processing Facility at KSC. The second flight unit has been integrated and the Test Readiness Review was held at the end of September. Final testing of the Hexapod is in progress.

The System Preliminary Design Review for the CRYOS cryogenic freezer is planned to start in November and end in March 2004. Negotiations for the freezer's main development phase (Phase-C/D) will commence in January for a planned start in April 2004.

The Cupola flight unit's acceptance testing is planned to start in October.

Operations and related ground segments
The Preliminary Design Review for the Columbus Control Centre was held on 18 July and a number of open issues were carried forward to the System Design Review on 9 September.

The ATV Control Centre System Integration Readiness Review was successfully completed on 13 August and the Critical Design Review was kicked-off on 9 September. The Operations Implementation Review, kicked-off in early July, was completed at the end of September.

In September, the flight model of the Microgravity Science Glovebox was successfully used for NASA experiments.

The Data Management System for the Russian Service Module (DMS-R) continues to operate problem-free.

Utilisation planning, payload developments and preparatory missions
Six Microgravity Applications Promotion (MAP) continuation proposals received in early July were evaluated by the Expert Panel on 8 August. Four of them were recommended for continuation, and in one case a resubmission was requested. A further four continuation proposals received in September - three life sciences and one physical sciences - will be reviewed by the Expert Panel on 20 October.

The Critical Design Review for SOLAR was held on 11 July and will be closed-out in October. The Flight Safety Review Phase 2 was completed on 18 September. The manufacture of engineering structural-thermal model and flight-model components has begun.

The structural/thermal analyses for EXPOSE have been completed and Investigators have agreed to the new location on EuTEF, which calls for reduced Sun-pointing of the EXPOSE experiment specimen. The CDR and safety reviews for EuTEF have been successfully completed and flight-model parts procurement and hardware manufacture have started.

The Atomic Clock Ensemble in Space (ACES) Phase-C/D contract was signed on 11 July and the PDR for the ACES payload took place at the end of September.

A number of experiments to be performed during the 'Cervantes' Spanish Soyuz Mission in October were transported to the ISS on 31 August by a Progress logistics flight (12P). Preparation of the remaining experiments, to be launched together with ESA astronaut Pedro Duque on the Soyuz vehicle, progressed and the logistics for access and operations as well as retrieval at the landing site were being defined.

Interface testing of Biolab using the Columbus Rack-Level Test Facility (RTLF) was concluded on 6 July. Interface testing of the EPM flight model, interface compatibility testing of the EPM with Cardiolab, and the EPM-Cardiolab Flight Safety Review were all completed successfully.

The System Test Campaign on the baseline configuration for the Fluid Science Laboratory without the Microgravity Vibration Isolation System was completed on 8 August, and interface testing using the RLTF was successfully completed at the end of September. The Flight Safety Review Phase 3 was also completed.

NASA's Human Research Facility that includes the ESA Pulmonary Function System is awaiting the next launch opportunity. The environmental test campaign on the flight model of European Modular Cultivation System in the US-Lab was completed in September.

Engineering-model testing of the Protein Crystallisation Diagnostics Facility is in progress and flight-model assembly has started.

The engineering model of the Materials Science Laboratory was shipped to Marshall Space Flight Center in mid-September.

ISS education
The ISS Education Fund held its inaugural Board Meeting at the European Astronaut Centre in Cologne (D) on 28 August, in conjunction with the SUCCESS prize-giving for

three students who had proposed experiments for the ISS. The ISS Education Kit in English is currently being updated by ESA Publications Division and will also be produced in several other languages.

Commercial activities
Contacts with major European corporations are continuing for Prime and Mission sponsorship. The marketing material for the ISS Business Club has been finalised. The RapidEye desig phase is progressing on schedule.

Astronaut activities
Training for the 'Cervantes' mission, to be launched on 18 October with Pedro Duque (André Kuipers as backup) on board, has been concluded successfully at Gagarin Cosmonaut Training Centre and the ESA Medical Board has approved the experiments that are to be conducted (see the 'In Brief' section of this Bulleti for latest news).

The first ATV crew-training dry run was successfully completed at the European Astronaut Centre (EAC) from 15 to 19 July. The first Payload Training Model (Biolab) was delivered to EAC on 16 September. A test run for a Commercial Training programme for six non-space-related customers was successfully completed at EAC on 16/17 September.

Vega

Progress has been made in terms of agreements with subsystem contractors under the main Vega development contract. In particular, a technical and programmatic agreement has been established in the thrust vector control (Sabca) and guidance, navigation and control (EADS) areas, for which kick-off meetings are scheduled in late October.

The start of the System Design Review was delayed until the end of October, partly in order to include a maximum of subcontractors' data and partly due to the need to introduce the actions agreed at the Avionics Preliminary Design Review held in July.

All P80 subcontracts have been signed by Europropulsion. The contract between ESA and CNES for the P80 contribution to the refurbishment of the firing test stand in Kourou has also been signed.

A number of machines needed to manufacture the large filament wound case of the P80 motor have begun to arrive in the purpose-built building in Colleferro (I).

Evaluation of the proposals received in response to the four Invitations to Tender issued by ESA has been the main focus of activities in terms of the ground segment. The standard Tender Evaluation Board (TEB) and Panels procedure is close to conclusion, with the TEB's final recommendation expected in the second half of October.

Aurora

Unanimously approved at the ESA Council at Ministerial Level in Edinburgh in 2001, the Aurora Programme will first define and later implement the European strategy for the robotic and human exploration of the Solar System, and particularly those planets holding the promise of harboring life. Based on a wide survey of the scientific and industrial communities prior to submission of the programme proposal, Aurora is currently in the preparatory phase, funded by 10 ESA Member States, including Canada. Due to be completed by end-2004, this phase will result in an updated Programme Proposal and a long-term strategy document 'The European Framework for Exploration'.

The Programme is run through a Board of Delegates from the Participating Countries (ABP) supported by an advisory body, the Exploration Programme Advisory Committee (EPAC), which has equal participation by scientists and technologists and an astronaut representative.

Aurora will feature robotic missions both to the Moon and Mars in preparation for human missions to both planets. The final goal is to enable European astronauts to go to Mars as part of an international endeavour by 2040, with Aurora providing the basis for a conscious decision on European participation, giving due consideration to strategic industrial, scientific and technological interest. Technology developments aimed at enabling interplanetary missions and exploration, as well as life sustainability and in-situ resource utilisation, are also a key element of the Programme.

Aurora missions will be categorised into two classes: 'Flagship' and 'Arrow'. The former are major missions serving as milestones on the road to Mars, building up the knowledge and capabilities needed to achieve the final goal, whilst offering important opportunities to a wide range of scientific disciplines. The latter are smaller missions, technology-driven and with shorter development times, mostly in support of Flagship missions.

Two Flagship missions have already been approved by the ABP:
- ExoMars, featuring an orbiter and a large rover carrying a 40 kg exobiology payload, due to be launched in 2009
- Mars Sample Return, featuring an orbiter, descent and ascent modules and an Earth re-entry module, which will bring a sample of Martian soil back to Earth.

In the Arrow class, two technology-demonstrator missions have been approved:
- a Re-entry Vehicle Demonstrator
- an Aero-capture Demonstrator.

Following pre-Phase-A studies conducted in the ESA Concurrent Design Facility at ESTEC (NL), three industrial consortia, led by Alenia Spazio (I), EADS Astrium (F) and Alcatel Space (F), have been awarded contracts to carry out a Phase-A study of the ExoMars mission. Two industrial teams, led by EADS LV (F) and SSTL (UK), have been engaged for the pre-development-phase study of the Re-entry Vehicle Demonstrator. The industrial proposals for the Phase-A study of the Mars Sample Return mission are currently being evaluated and contracts will be awarded very soon. The contracts for the design of the ExoMars rover and the Pasteur exobiology payload are expected to be awarded in the coming months.

In Brief

ESA and the EU: the start of a new partnership

Negotiations on a Framework Agreement for structured cooperation between ESA and the European Community have been concluded. On 12 November the ESA Council adopted the Agreement, which had already been endorsed by the EU Council on 20 October.

The ESA/EC Agreement marks a milestone in their relationship, emphasising that both partners have specific complementary and mutually reinforcing strengths, and commits them to working together while avoiding unnecessary duplication of effort.

The Framework Agreement has two main aims. The first is the coherent and progressive development of a European Space Policy to link demand for services and applications using ESA space systems and infrastructures in support of EU policies. The second aim of the Agreement is to establish a common basis and appropriate practical arrangements for efficient and mutually beneficial cooperation between ESA and the European Union.

"This Agreement will facilitate the setting up of new joint projects and provide a stable framework for ESA-EU cooperation, and that will benefit the European citizens", said ESA Director General Jean-Jacques Dordain. The Agreement also opens up new possibilities for cooperation, such as EU participation in ESA optional programmes, or ESA management of EU space-related activities.

The European Commission also adopted its White Paper on space, drafted with the support of ESA. It presents an action plan for implementing an enlarged European space policy, including proposals for joint ESA-EU space programmes that will take the Framework Agreement as their basis.

Critical decisions on 'Cosmic Vision'

At its 105th meeting, on 5/6 November, ESA's Science Programme Committee (SPC) decided to cancel the Eddington mission and rescope the BepiColombo mission due to the current financial exigencies and no prospect of a budget increase or other financial relief.

Eddington was supposed to look for Earth-like planets outside our solar system – one of the key goals in the search to understand how life came to be in the Universe. At the same time it was going to follow the path that the ESA-NASA mission SOHO had taken with the Sun of using astroseismology to look 'inside' stars.

The loss of the BepiColombo lander is also hard to take scientifically. ESA, in conjunction with the Japanese space agency, JAXA, will still put two orbiters around Mercury, but the ground data provided by the lander is a big loss.

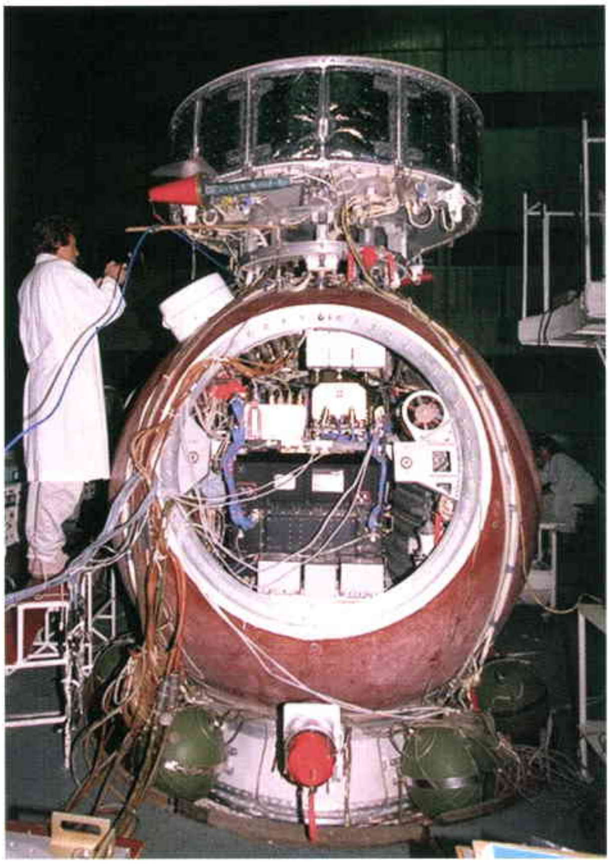
The origins of the problems were recognised at the ESA Council meeting held in June. Several sudden demands on finance occurred in the spring, the most obvious being the unforeseen Ariane-5 grounding in January, delaying the launches of Rosetta and SMART-1. A temporary loan of 100 million Euros was granted, but must be paid back out of present resources by the end of 2006.

With these decisions, the SPC has brought the scope of the Cosmic Vision programme down to a level that necessarily reflects the financial conditions rather than the ambitions of the scientific community.

A long and painful discussion during the SPC meeting resulted in the conclusion that only one new mission can be started at this time, namely LISA Pathfinder, the technical precursor to the world's first gravitational-wave astronomical observatory, LISA. The LISA mission, to be carried out in cooperation with the United States, is scheduled for launch in 2012.

Artist's impression of the LISA mission

ESA and Rosaviakosmos sign up for two Foton flights



Two Foton spacecraft will carry 660 kg of European payload

After a year of extensive negotiations, a new procurement order for two unmanned Foton capsule flights was signed on 21 October between ESA and the Russian Space Agency Rosaviakosmos. This order covers the Foton-M2 and -M3 missions, which will have 660 kg of ESA-supplied scientific payloads onboard.

The order binds ESA, Rosaviakosmos and two Russian partner companies (KBOM in Moscow and TsSKB-Progress in Samara) for at least the next three years, with a first launch scheduled for May 2005 and the second for autumn 2006. This will provide reflight opportunities for almost the entire experiment programme originally assigned to Foton-M1 but lost when that launch failed on 15 October 2002. It will also reinstate a substantial part of ESA's scientific objectives for the STS-107 mission, unfulfilled following the Columbia Shuttle accident in February with the tragic loss of its crew, experiment samples and science/technology experiments.

Foton capsules, which first flew in 1985, are based on the design of the Russian Vostok capsule, in which Yuri Gagarin was put into orbit in 1961. But whereas the original Vostok design has been developed for manned missions into the Soyuz spacecraft, it has been very largely maintained for the unmanned Foton, which is primarily used for physics and materials science experimentation. The typical length of a Foton mission is 15 days. The recoverable capsule is launched on a Soyuz-U and returned to Earth at the end of its mission, landing with the aid of a parachute system.

The Foton-M2 payload will include experiments in fluid physics (FluidPac, SCCO), exobiology (Biopan), five material science experiments to be processed in Russia's Polizon automatic furnace and further such experiments in the DLR Agat furnace, a technology experiment (Favorite) and the Autonomous experiments (Photo-li, Biofilter). Two further experiments will be embedded in the spacecraft's heat shield, one concerning re-entry technology (Keramik), the other meteoritic science (Stone).

The preliminary Foton-M3 payload definition is planned to include various experiments in biology (Biobox, Kubik, Eristo/Osteo), exobiology (Biopan), fluid physics (SCCO, Gradflex), protein crystallisation, material science (Polizon), new re-entry technology (YES-2), plus other Autonomous experiments. esa

Prestigious award for SOHO

The international SOHO team has been presented with the prestigious Laurels for Team Achievement Award of the International Academy of Astronautics (IAA).

The award recognises both the outstanding achievements in designing, building and operating the mission, as well as the science it has performed. It is a tribute to a team that has contributed to one of the most successful space missions in history.

The International Academy of Astronautics presents this award in recognition of extraordinary performance and achievement by teams of scientists, engineers and managers in the field of astronautics. This honour has been awarded only twice before – to the Russian Mir Space Station Team and the US Space Shuttle Team. Now the SOHO team joins this select group.

Throughout the mission, the team has continued to produce excellent science, and SOHO has revolutionised the way scientists think about the Sun and how it might affect the Earth's environment. More than 1500 papers, representing the work of more than 1500 scientists, have been published based on SOHO data. With SOHO still going strong, the success story is set to continue. esa

Pedro Duque safely back on Earth

Cervantes mission concludes with Soyuz TMA-2 landing

Spanish ESA astronaut Pedro Duque landed in the command module of the Soyuz TMA-2 spacecraft near the town of Arkalyk in Kazakhstan at 03:40 Central European Time (CET) on 28 October, thus concluding the successful 10-day Cervantes mission to the International Space Station (ISS).

The mission proceeded flawlessly with the completion of the experiment programme, the changeover of ISS Expedition crews and the exchange of the Space Station's Soyuz TMA lifeboat.

The Soyuz TMA-2 spacecraft undocked from the ISS with Duque as Flight Engineer, Yuri Malenchenko (Rosaviakosmos) as Commander and Edward Lu (NASA) as 2nd Flight Engineer.

During his 8-day stay on the ISS, Pedro Duque had carried out an extensive programme of scientific, technological and educational experiments as part of the Cervantes mission, the majority of which were sponsored by the Spanish Ministry of Science and Technology.

"The experiment programme has been a complete success", said ESA Mission Manager, Aldo Petrivelli, *"and results have been obtained for all 22 experiments. These included two physical science experiments, which utilised the European-built Microgravity Science Glovebox on the ISS, four biological experiments, four human physiology experiments and a number of educational experiments and technology demonstrations."*

During the Cervantes mission Pedro Duque had numerous contacts with the media from Spain and Germany. He talked via amateur radio with primary schoolchildren, winners of the Habla ISS competition.

In addition to the experiment programme, the Cervantes mission served to relieve the ISS Expedition 7 crew. Yuri Malenchenko and Edward Lu had been stationed on the ISS since 28 April 2003. They have now been replaced by the ISS Expedition 8 crew, Michael Foale (NASA) and Alexander Kaleri (Rosaviakosmos), who arrived with Pedro Duque at the ISS in the Soyuz TMA-3 spacecraft on 20 October and are scheduled to return next April with Dutch ESA astronaut André Kuipers. The Soyuz TMA spacecraft are being used as crew changeover vehicles due to the grounding of the Shuttle fleet following the Columbia accident in February.

This was Duque's second spaceflight, as he was a Mission Specialist on the Space Shuttle Discovery, STS-95 mission (29 October to 7 November 1998).

Pedro Duque conducting the Cardiocog experiment during the Cervantes Mission

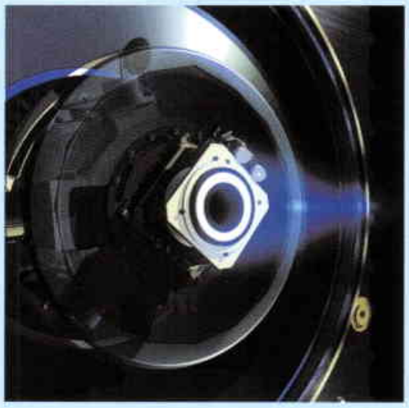
SMART-1 ion engine fired successfully

After a flawless launch during the night of 27/28 September on an Ariane-5, SMART-1's revolutionary propulsion system was successfully fired at 12:25 UT on 30 September 2003, in orbit around the Earth.

Engineers at ESOC, the European Space Agency's control centre in Darmstadt, Germany, sent a command to begin the firing test, which lasted for one hour. In space and in a true vacuum, the ion engine actually worked better than in pre-launch testing on the ground. Engineers will now analyse the data to see exactly how much acceleration was achieved and how smoothly the spacecraft travelled.

This is the first time that Europe has flown an electric primary propulsion in space, and also the first European use of this particular type of ion engine, called a 'Hall-effect' thruster.

The Solar Electric Primary Propulsion consists of a single ion engine fuelled by xenon gas and powered by solar energy. The ion engine will accelerate SMART-1 very gradually to cause the spacecraft to travel in a series of spiralling orbits – each revolution slightly further away from the Earth – towards the Moon. Once captured by lunar gravity, SMART-1 will move into ever-closer orbits of the Moon.



Close-up view of SMART-1's plasma thruster

Envisat radar altimetry tracks river levels worldwide

ESA has unvailed a new product range called River and Lake Level from Altimetry that provides previously inaccessible information on the water levels of major lakes and rivers across the Earth's surface, derived from Envisat and ERS radar-altimeter measurements.

For over a decade ESA has used satellites to bounce radar pulses off the Earth and precisely measure the height of ocean and land surfaces. But inland lakes and rivers have been effective blind spots for radar altimetry – at least until now.

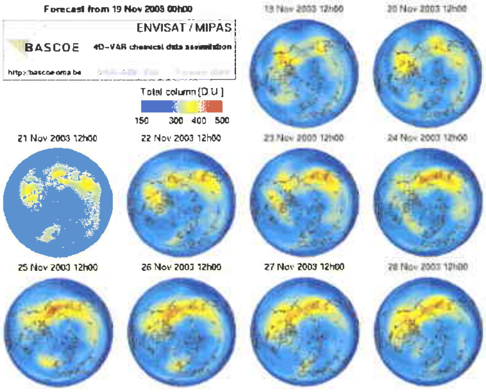
Hydrologists can use this new data to monitor river heights around the planet, assess the impact of global warming and help with water resource management. Inland water bodies are important as key sources of both water and food for the people living round them. They are also often regions of maximum biodiversity and represent early indicators of regional climate change.

The Radar Altimeter 2 (RA-2) flown aboard ESA's Envisat environmental satellite is the improved follow-on to earlier radar altimeters on the ERS-1 and ERS-2 spacecraft. From its 800 km-high polar orbit it sends 1800 separate radar pulses down to Earth every second and then records how long their echoes take to return, timing their journey with nano-second accuracy to calculate the exact distance to the planet below.

A team from the UK's De Montfort University team developed the river and lake monitoring software by painstakingly combing through many gigabytes of raw data acquired over rivers and lakes, taking note of the type of echo shapes that occurred. They sorted different echo shapes into distinct categories, then created an automated process to recognise these shapes within 'wet' signals and eventually extract usable data from them.

The plan is that global altimeter data for the last 12 years will be reprocessed to provide hydrologists with historical information, invaluable for assessing long-term trends. ESA also intends to install operational software in its ground segment so eventually the product can be delivered to users in near-real time, within three hours or less of its acquisition from space.

esa



In another application, a sophisticated software model of stratospheric chemistry that assimilates data from Envisat, BASCOE (Belgian Assimilation System of Chemical Observations from Envisat) forecasts global concentrations of ozone for ten days ahead.

New China-Europe Global Navigation Satellite System Technical Training and Cooperation Centre (CENC)

The European Commission, the European Space Agency and the Chinese Ministry of Science and Technology have decided to establish a training, cooperation and information centre for satellite navigation in China at the renowned Beijing University. The centre will be staffed initially by one or two experts supported by two administrative and technical assistants.

Europe and China share a common interest in cooperating to bring the benefits of satellite navigation, and Galileo in particular, to transport, science, land management, disaster prevention and other user sectors.

esa

Hubble assists Rosetta comet mission

Data from the NASA/ESA Hubble Space Telescope have played a major role in preparing ESA's ambitious Rosetta mission for its new target, comet 67P/Churyumov-Gerasimenko.

Hubble has been used to make precise measurements of the size, shape and rotational period of the comet. This information is essential if Rosetta is to rendezvous with the comet and then release a probe. Observations made by Hubble in March this year revealed that comet 67P/Churyumov-Gerasimenko (67P/C-G) is approximately five by three kilometres in size and shaped like a rugby ball. ESA mission scientists were concerned about the exact size of the solid nucleus, knowledge that is needed to adapt the mission to the comet's gravity.

"Although 67P/C-G is roughly three times larger than the original Rosetta target, its highly elongated shape should make landing on its nucleus feasible, now that measures are in place to adapt the lander package to the new scenario," says Dr Philippe Lamy of the Laboratoire d'Astronomie Spatiale in France.

Mission scientists began looking for an alternative target when the Rosetta mission's launch date was postponed. The delay meant that the original target comet, 46P/Wirtanen, was no longer easily reachable. But scientists did not have enough information on the back-up comet, 67P/C-G, and sought data from the largest telescopes.

Rosetta's launch is currently planned for February 2004, with a rendezvous with the comet about 10 years later.

esa

First Aurora mission design contracts awarded

The winners of competitive contracts for two of the ESA Aurora Programme's key robotic missions – ExoMars and the Earth re-entry vehicle demonstrator – have been selected. This marks a major milestone in this long-term programme for Solar System exploration. Alenia Spazio (Italy), Alcatel Space (France) and EADS Astrium (France) are to head the three industrial teams selected to carry out a full mission design for ExoMars, the Aurora exobiology mission to Mars.

Similarly, two industrial teams, headed by EADS Launch Vehicles of France and Surrey Satellite Technology Limited (SSTL) of the United Kingdom, respectively, have been selected for the pre-development phase of the EVD mission.

ExoMars

The ExoMars mission, to be launched in 2009, is the first of the major Flagship missions in the Aurora Programme. It includes an orbiter and a descent module that will land a large (200 kg), high-mobility rover on the surface of Mars. After delivery of the lander/rover, the ExoMars orbiter will also operate as a data-relay satellite between the Earth and the vehicle on the Martian surface.

The primary objective of the ExoMars rover will be to search for signs of past or present life on the Red Planet. Additional measurements will be made to identify potential surface hazards for future human missions, to determine the distribution of water on Mars and to measure the chemical composition of the surface rocks.

The contracts cover the design of the entire ExoMars mission, from launch, through the long interplanetary voyage, to the landing of the rover on the planet's surface.

Earth re-entry vehicle demonstrator

The second Aurora Flagship mission is a Mars Sample Return mission planned for 2011. Its main goal will be the retrieval of rock samples from the Martian surface and subsurface for subsequent analysis in laboratories on Earth.

In order to ensure the success of this challenging mission, a number of new technologies will have to be developed and tested. Conceived as a small technology-driven mission, the Earth re-entry vehicle demonstrator will be used to validate the design of the small Mars sample-return capsule that will bring back the precious samples of Martian soil.

The Earth re-entry vehicle demonstrator is expected to be launched in 2007. The baseline mission foresees the insertion into a highly elliptical Earth orbit of a small spacecraft carrying a re-entry capsule. In order to reproduce the final phase of a typical Mars return mission, the capsule will then carry out a ballistic re-entry into the Earth's atmosphere at speeds of up to 45,000 km/h.

Two industrial teams have been selected for the parallel Earth re-entry vehicle demonstrator mission studies. The concept presented by the industrial team, under the leadership of EADS LV (France) with the participation of OHB System (Germany) and Plansee (Austria) is solidly based on the experience of past projects.

The industrial team led by SSTL (UK) has devised an innovative concept well adapted for a small technology mission. The participation of highly specialised companies, Fluid Gravity Engineering (UK), Kayser Threde GmbH (D) and Vorticity Ltd. (UK) ensures excellent coverage of the mission's most critical technologies.

The next Aurora contract for Phase-A studies will concern the Mars Sample Return mission. esa

First Space Medicine Workshop at EAC

The first Space Medicine Educational Workshop took place at the European Astronaut Centre (EAC) in Cologne, Germany, in October. It allowed 44 European students, researchers and young professionals to get to know each other and learn more about human spaceflight and medicine.

The Workshop was split into presentations of project proposals by the attendees and lectures by experts. The week began with an opening ceremony during which participants witnessed the docking and hatch opening of the Soyuz TMA - Cervantes Mission via live links to Mission Control in Moscow and Houston.

In order to participate in the Workshop each student had to present an idea or concept in the field of space medicine, endorsed by a Professor, which had applicability both in space and on the ground. Student presentations ranged from an exoskeleton suit that just needs to be worn in order to have an exercise effect, to using remote-sensing data and specially designed low-cost sensors to predict malaria risk based on rainfall temperature and the wing-beat frequency of the mosquito.

The list of experts and guests included Jeff Davis (Director of Space & Life Sciences, NASA JSC), Martina Heer (Aerospace Medicine Institute, DLR), Marco Cardinale (University of Aberdeen), Beth Shephered (Responsible for exercise and countermeasures, NASA), Dietrich Manzey (University of Berlin), Ernst Messerschmid (Head of EAC and former astronaut), Vincenzo Costigliola (President of the European Medical Association), Michel Tognini (Head of the ESA Astronaut Division), Ulf Merbold (ESA astronaut), Loredana Bessone (ESA/EAC), Oliver Angerer (ESA/ESTEC), Rupert Gerzer (Director of the Aerospace Medicine Institute, DLR), David Raitt and Niels Eldering (ESA Technology Transfer Office).

Each morning, a representative of the Crew Medical Support Office gave the students an update on the status of the Cervantes mission and the role of the European medical doctor supporting the Mission. In the evening, groups were given accompanied tours of the actual medical console facilities used for mission support.

As an immediate outcome and on their own initiative, the participants have started a web-based forum to provide a focal point for both the educational and professional communities, at: www.spacesurgeons.com .

The Space Medicine Workshop was part of a new ESA initiative, "The Health Care Network", aimed at increasing its role in educational activities, by supporting other educational offices in ESA and external partners such as the DLR School Lab in Cologne.

Participants in the Space Medicine Workshop at EAC

Mei Ling Doery's project won the second prize

Parabolic flight veterans

On normal aeroplanes that get you from city A to city B, you earn frequent flyer miles. On the A300 Zero-G Airbus the number of parabolas you fly is counted, and the real parabolic flight veterans earn medals! Sixteen of those – three gold, eight silver and five bronze – were handed out during the 35th ESA parabolic flight campaign on 13 October. Parabola champion is Marcel Thierot with 4242. Other gold medals went to Philippe Fourcade (3608 parabolas) and Christophe Mora (3022 parabolas). Silver medal winners were Gilles Le Barzic (2351), Pierre Vaïda (2323), Charles Dupart (2320), Thierry Gharib (2136), Pierre Bencheik (1424), Roland Dairiam (1350), Vladimir Pletser (1284) and Anneke van der Geest (1107). Süzel Bussieres (882), Frédéric Gai (863), Jean-Pierre Fouquet (822), Jean-Charles De Longueville (498) and Maurice Hinsenkamp (467) were awarded bronze medals.

ZARM Drop Tower becomes an ESA External Facility

ESA has declared the ZARM Drop Tower, a 146-metre high landmark on the campus of Bremen University, Germany, an 'ESA External Facility'. The 'Zentrum für Angewandte Raumfahrt Microgravitation' Tower offers 4.47 seconds of weightlessness up to three times per day.

The Tower, which is unique in Europe and regularly used by ESA, offers the capability of conducting extensive research in microgravity, and it is an essential test bench for projects about to become operational. For both applications, ZARM has provided years of invaluable access to reduced gravity conditions for thousands of experiments, in many of which ESA has been involved.

The introduction of a catapult, planned for this year, will double the time available in reduced gravity conditions, opening broader research possibilities in good time for the International Space Station exploitation phase, and for microgravity applications in particular.

The contract was signed on 2 October by the Mayor of Bremen and President of the City Senate Dr Henning Scherf, Prof. Dr Hans J. Rath, ZARM Director General, Dr Hans Kappler, ESA Director of Industrial Matters and Technology Programmes, and Mr Gaele Winters, ESA Director of Technical and Operational Support. It was 'sealed' with a ceremonial drop in the Tower.

Hoisting the ESA flag: Bremen's Mayor Henning Scherf

ESA Payload Safety Review Panel certified "Cervantes" payload

The ESA Payload Safety Review Panel, established in cooperation with NASA in 2002, met in September at ESTEC for a Training Workshop. October's "Cervantes" mission was the first to carry ESA-certified payloads to the ISS.

Physics on Stage 3 – a great success for physics teaching

More than 400 participants from 22 European countries – most of them teachers – made the Physics on Stage 3 festival a roaring success. After a year of activities in each of the participating countries, delegates selected for their outstanding and innovative teaching projects came to ESTEC, in the Netherlands, from 8 to 15 November, to exchange ideas and methods and find ways of making science teaching attractive again. Physics on Stage is organised by members of the EIROforum and was co-funded by the European Commission as part of the European Science and Technology Week 2003.

His Royal Highness Prince Johan Friso of the Netherlands and Mrs van der Hoeven, Dutch minister of Education, Culture and Science, guided here by Wubbo Ockels, chairman of Physics on Stage 3, attended the Opening Ceremony

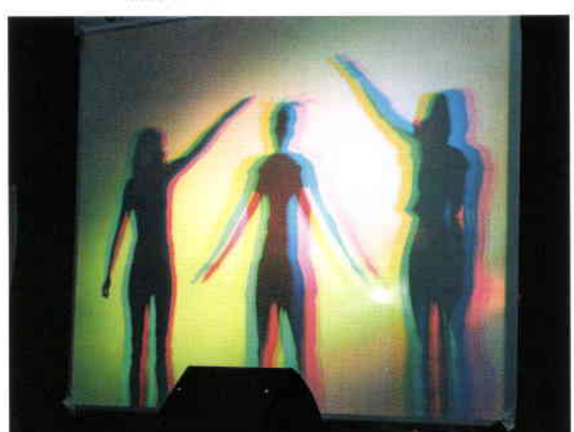
A team from Belgium presents "Playful Physics"

Liftoff for the third edition of the Physics on Stage science teaching festival! His Royal Highness Prince Johan Friso of the Netherlands launches a water rocket as the opening act

As a special treat, an Italian chef prepared a meal "cooked with physics" – ice-cream made with liquid nitrogen, for example (left)

Two participants from Poland and Belgium exchange teaching ideas at the fair

The most innovative and inspiring projects received the "EIROforum Teaching Awards". Rudolf Ziegelbecker from Austria and his two students won the second prize for their "cat gymnasts"



The Austrian performance "Eye Like Physics"

European Image Information Mining Coordination Group Gets to Work

The European Image Information Mining Coordination Group (IIMCG) was officially created on 26 May 2003 by its funding members: ASI, CNES, CNR, DLR, EC-IST, ESA, ETHZ, and EUSC.

At its first meeting, the IIMCG defined the IIM focus and areas of interest, as well as its own Terms of Reference.

IIM Focus and Areas of Interest

IIM focus is on research and technological activities for automated and user-centred extraction of information from Earth Observation images and image archives in support of content understanding. The main areas of concern are:

- Information modelling and processing for very large and heterogeneous image sets
- Mediating systems (e.g. learning, adapting themselves to user conjecture, suggesting solutions, etc.)
- Knowledge discovery concepts (including auxiliary data)
- Communicable information and knowledge
- Opportunities (e.g. usage scenarios, test cases, business models, technology transfer, etc.)
- Evaluation methods
- Related standards also for interfaces.

The IIM research and technological axes are:

- Automated and semi-automated processing
- Advanced archiving/computing
- Scalable systems
- Advanced user interfaces
- Content-aware networks
- Data-fusion/assimilation
- Soft-computing
- GRID techniques.

IIMCG Terms of Reference

Charter

For Image Information Mining (IIM) applied to Earth Observation images, the IIMCG shall:

- Promote European research and development of IIM techniques
- Interface with European and National programmes in the field, like the O_2 (Open and Operational) ESA initiative, the EC FP6 activities, etc.
- Foster, within the members, the possibility to:
  - Share scientific and technical experience, data, information and applications
  - Identify relevant scientific and technical issues
  - Suggest technical directions
  - Suggest solutions for funding and coordination of activities
- Provide a forum where interested bodies may:
  - Constantly be kept updated on ongoing activities in the field and on relevant scientific and technical issues
  - Exchange information (including gathering of suggestions and requirements)
  - Be informed about available demonstrators, prototypes, products, etc.
- Identify and suggest/promote appropriate standards
- Facilitate and promote the use of resulting products.

Mandate

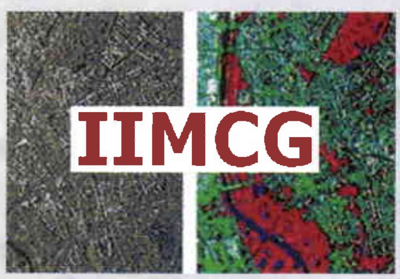
For IIM applied to EO, the IIMCG shall:

- Establish and maintain liaison with other interested bodies and with new sensors' research and design (in particular for the identification of short / medium / long term needs)
- Identify research and technological issues
- Define possible strategies and solutions
- Suggest activities and coordination methods
- Suggest standards and interfaces for possible technologies.

Modus operandi

For IIM the IIMCG shall:

- Prepare periodical plans and reports for internal and European distribution
- Define methods for ensuring maximum participation from European partners (e.g.: define rules for enlarging participation to the WG, foster the creation of Interest Groups or national contacts, gather input from research, institutions, industry, etc.)
- Meet at least twice per year
- Organise the Knowledge Based IIM Workshop once per year
- Establish as necessary internal Task Forces for specific areas
- Provide feedback to the IIMCG members from participation to other events
- Identify information for IIMCG internal use only or for free circulation
- Address and suggest approaches related to potential IPR issues
- Keep an updated list of related events
- Organise and update related Internet pages.



The necessary resources for participation in IIMCG activities will be provided by the respective parent organisations.

Coming Event

The IIMCG is currently organising the ESA-EUSC 2004 Conference on 'Theory and Applications of Knowledge driven Image Information Mining, with focus on Earth Observation' The event is the second in the series jointly organised by ESA and EUSC (the first was held in December 2002 at ESRIN), and is merged with the 2nd Image Information Mining Workshop (the first one took place in September 2002 in Zurich). The 2004 Conference will take place on 17/18 March, at the Torrejon de Ardoz Air Base in Madrid.
Visit http://earth.esa.int/rtd/Events/ESA-EUSC_2004 for further information and registration details.

Further Information

Further information about IIMCG projects, articles, documents, events, etc. can also be obtained via the Internet, by visiting http://earth.esa.int/rtd/IIMCG , or from the following Contact Points:

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Sergio D'Elia, ESA/ESRIN

ESA-EUSC 2004 Conference

Theory and Applications of Knowledge-driven Image Information Mining, with focus on Earth Observation

17 – 18 March 2004
Torrejon de Ardoz Air Base, Madrid, Spain

Organised by:
The Image Information Mining Coordination Group (IIMCG)

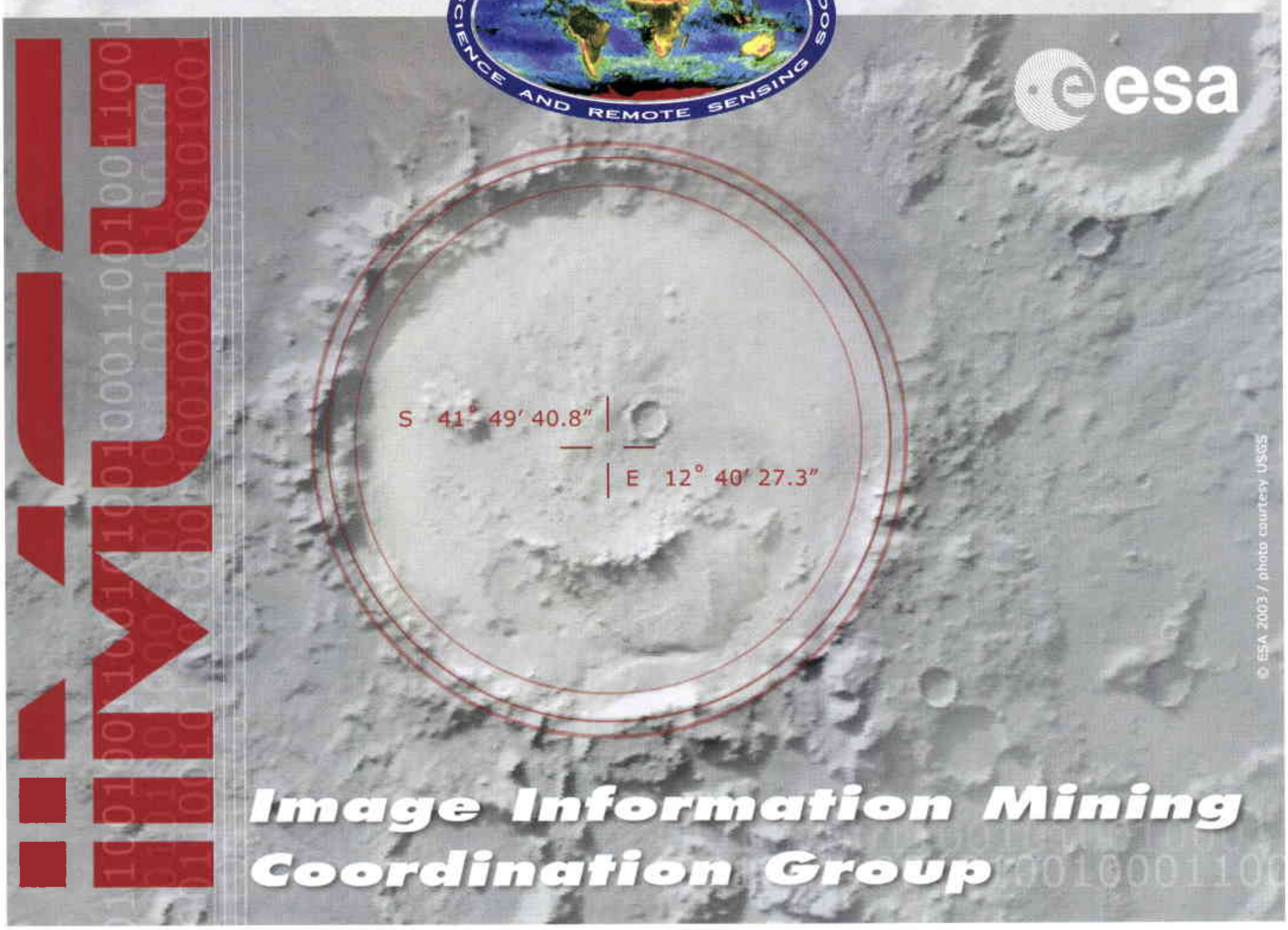
Objectives:
To review the state of the art and identify R&D requirements in the following fields of Earth Observation and other domains:
- Theoretical foundation of information retrieval from very large image data sets
- Image syntax and image semantics
- Knowledge-driven image information mining
- Knowledge sharing and management
- Multi-domain, multi-dimensional semantic information indexing and retrieval
- Multidimensional database systems
- Exploratory image information extraction
- Modelling user conjecture and human/machine interaction.

Sponsored by:
IEEE Geoscience and Remote Sensing Society

The main target audience includes the European space agencies and organisations, aerospace industry and research centres, and research and academic institutions involved in one or more of the above areas.

Registration:
The deadline for registration (no fee) for the Conference is ***16 February 2004.***

Further information can be found by visiting:
http://earth.esa.int/rtd/Events/ESA-EUSC_2004.



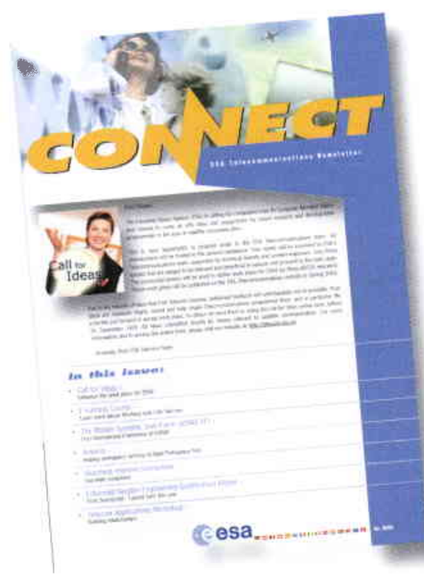
Publications

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 Newsletters

ON STATION NO. 14 (SEPTEMBER 2003)
NEWSLETTER OF ESA'S DIRECTORATE OF HUMAN SPACEFLIGHT
WILSON A. (ED.)
NO CHARGE

CONNECT NO. 03/03 (OCTOBER 2003)
NEWSLETTER OF ESA'S DIRECTORATE OF APPLICATIONS
MENNING N. & BATTRICK B. (EDS.)
NO CHARGE



ESA Brochures

VILSPA – THE ESA GROUND STATION IN SPAIN (SEPTEMBER 2003)
BATTRICK B. (ED.)
ESA BR-207 // 8 PAGES
NO CHARGE

GREEN PAPER ON EUROPEAN SPACE POLICY – REPORT ON THE CONSULTATION PROCESS (OCTOBER 2003)
EC/ESA JOINT TASK FORCE SECRETARIAT (ED. B. BATTRICK)
ESA BR-208 // 28 PAGES + CD-ROM
PRICE: 10 EURO

GOCE – ESA'S GRAVITY MISSION (OCTOBER 2003)
RIDER H., RAST M. & BATTRICK B. (EDS.)
ESA BR-209 // 16 PAGES
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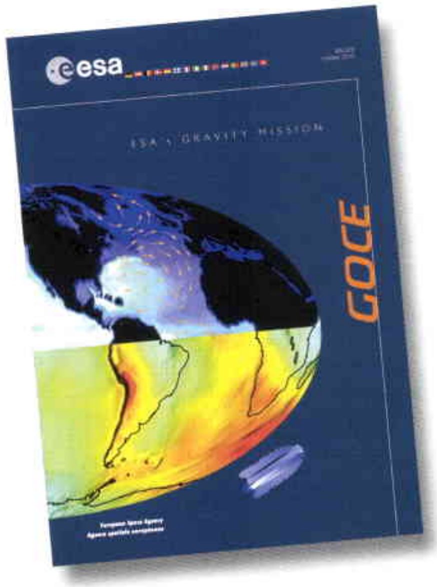

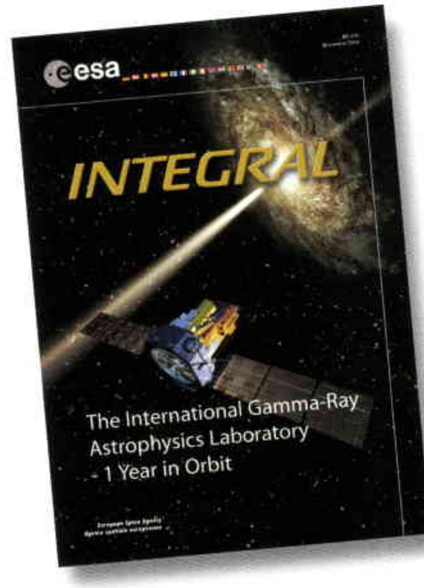

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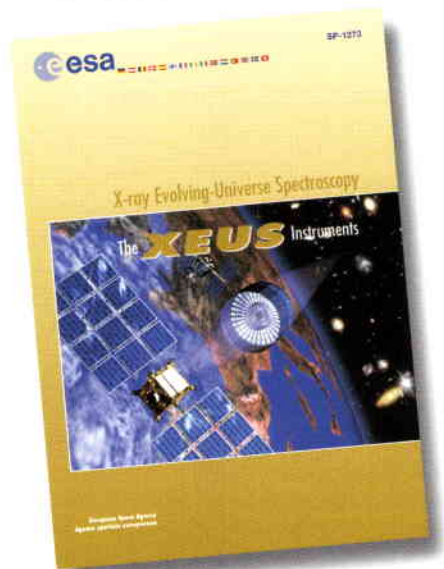

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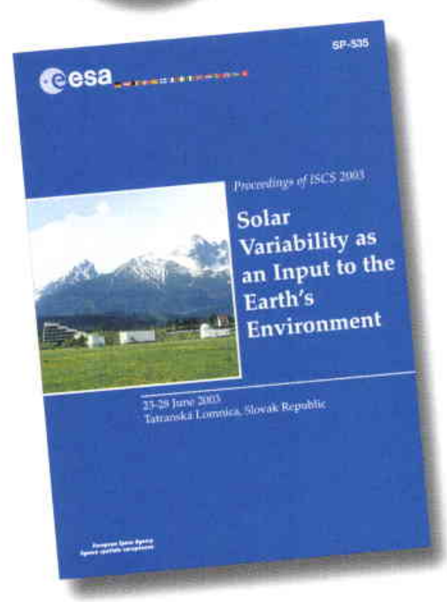

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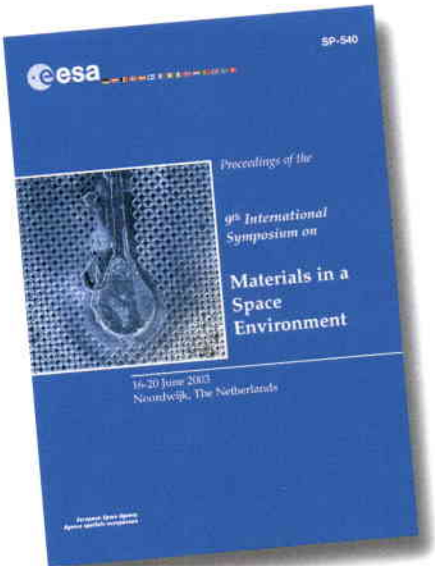

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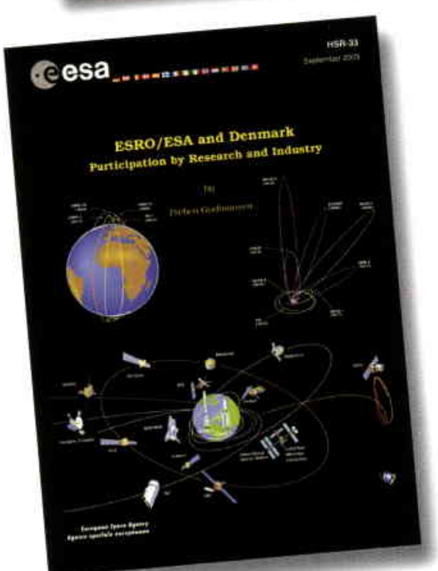

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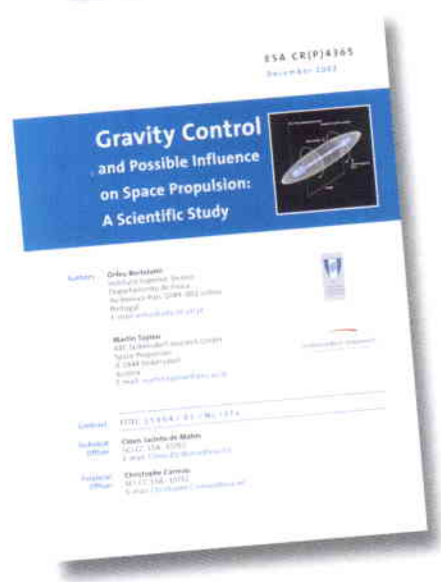

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