esa bulletin

number 96 - november 1998

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, Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom. Canada is a Cooperating State.

In the words of the 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 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: H. Parr

Director General: A. Rodotà.

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 Royaume-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.

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Le SIEGE de l'Agence est à Paris.

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

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

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European Space Agency
Agence spatiale européenne

Ariane-5 Completes Flawless Third Test Flight

A launch-readiness review conducted on Friday 16 and Monday 19 October had given the go-ahead for the final countdown for a launch just two days later within a 90-minute launch window between 13:00 to 14:30 Kourou time. The launcher's roll-out from the Final Assembly Building to the Launch Zone was therefore scheduled for Tuesday 20 October at 09:30 Kourou time.

On 21 October, Europe reconfirmed its lead in providing space transportation systems for the 21st Century. Ariane-5, on its third qualification flight, left no doubts as to its ability to deliver payloads reliably and accurately to Geostationary Transfer Orbit (GTO). The new heavy-lift launcher lifted off in glorious sunshine from the Guiana Space Centre, Europe's spaceport in Kourou, French Guiana, at 13:37:21 local time (16:37:21 UT).

This third Ariane-5 test flight was intended primarily to qualify Europe's new launcher for satellite injection into GTO, but also carried the Atmospheric Reentry Demonstrator (ARD) capsule, packed with the most advanced equipment to test and qualify new European technologies and flight-control capabilities for atmospheric reentry and landing. Flight 503 was the final qualification flight carried out under ESA responsibility prior to the launcher entering commercial service with Arianespace.

The launch, delayed twice from 13:00 by minor problems, was flawless. The solid-propellant boosters separated as planned at an altitude of about 62 km, 2 min 16 sec into the flight. The fairing was jettisoned after 3 min 6 sec, followed by separation of the cryogenic main stage after 9 min 52 sec at an altitude of 168 km. The Atmospheric Reentry Demonstrator was released approximately 2 min later, at an altitude of 216 km, and 3 min 14 sec thereafter the storable-propellant upper stage began to propel the stage assembly and Maqsat-3, built by Kayser-Threde, Germany, as a representative mock-up of a commercial satellite, towards its injection point. Almost exactly 33 min after lift-off, the upper-stage engine shut down and Maqsat-3 was successfully injected into GTO. The orbital parameters at that point were:

Perigee: 1027 km, compared with the 1028 ± 3 km predicted
Apogee: 35 863 km, compared with the 35 898 ± 200 km predicted
Inclination: 6.999 deg, compared with the 6.998 ± 0.05 deg predicted.

Speaking in Kourou immediately after the flight, Fredrik Engström, ESA's Director of Launchers and the Ariane-503 Flight Director, confirmed that: *"The third Ariane-5 flight has been a complete success. It qualifies Europe's new heavy-lift launcher and vindicates the technological options chosen by the European Space Agency."*

ESA's Director General, Antonio Rodotà, speaking at the European Press Centre at Evry near Paris, drew the media's attention to the fact that : *"The European Space Agency is already working to meet the challenges of the 21st Century with increasingly powerful and versatile launchers designed to handle the widest possible range of space missions."*

This sentiment was echoed by Alain Bensoussan, Chairman of CNES (to which ESA has delegated prime contractor responsibility for the new launcher), who commented that: *"France is proud to have helped make this ambitious European programme a success. The Ariane programme, consolidating as it does Europe's standing in the world space community, is an outstanding illustration of Europe's capacity to pool its best scientific and industrial teams in pursuit of a common goal."*

With the highly successful release, reentry and subsequent recovery of the automatic Atmospheric Reentry Demonstrator capsule (built for ESA by the French company Aérospatiale), Europe has moved a step closer to flying its own complete space missions. Engineers analysing real-time telemetry data from its suborbital flight reported that all of the capsule's systems had performed well and according to expectations. The ARD's telemetry systems and reception stations all functioned well, with more than 200 critical parameters for analysis of the flight and the behaviour of onboard equipment being recorded and transmitted to ground during the flight. The onboard GPS receiver also worked satisfactorily throughout the flight, except (as was expected) during the black-out period during reentry.

The ARD reached an altitude of 830 km before splashing down within 4.9 km of its target point in the Pacific Ocean between the Marquises and Hawaii, after 1 hour and 41 minutes. Having been recovered from the ocean just a few hours later, the capsule is now undergoing detailed technical analysis back in Europe. During the reentry, the ARD's heat-shield temperature reached 900°C, but the cone and thermal protection were found to be in perfect condition after retrieval, with the capsule having remained perfectly airtight throughout the mission.

Although not strictly a prototype of a possible future European Crew Transport Vehicle, which could fly to and from the International Space Station, the ARD represents a major step towards providing greater confidence in Europe's capabilities in reentry technologies for use not only in the framework of crew and equipment transport to and from space, but also for future reusable launchers. esa

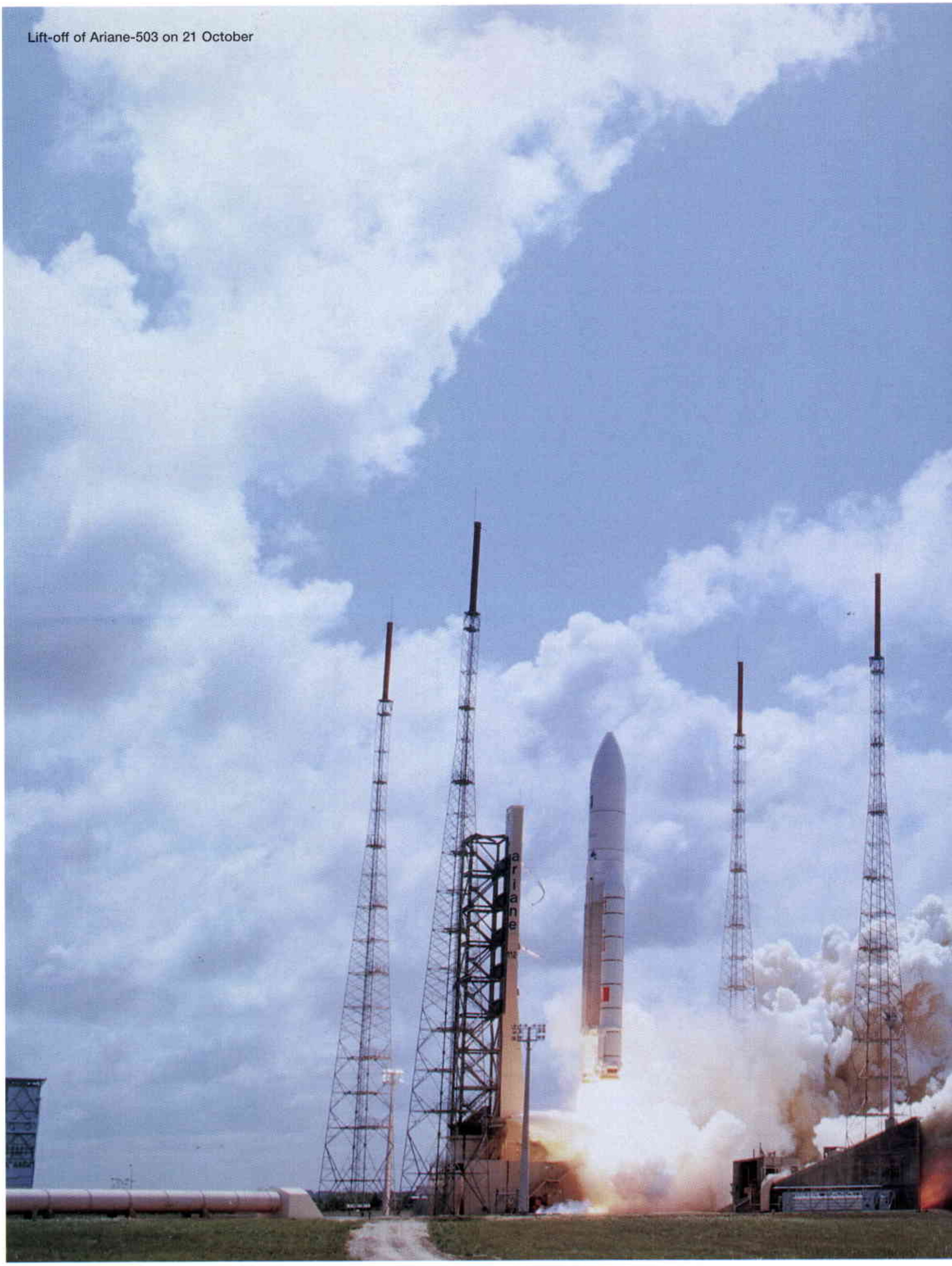
Transfer of the Ariane-503 lower composite from the Launcher Integration Building to the Final Assembly Building on 3 October

Mating of the lower payload, Maqsat-3, with its flight adaptor, in the Final Assembly Building

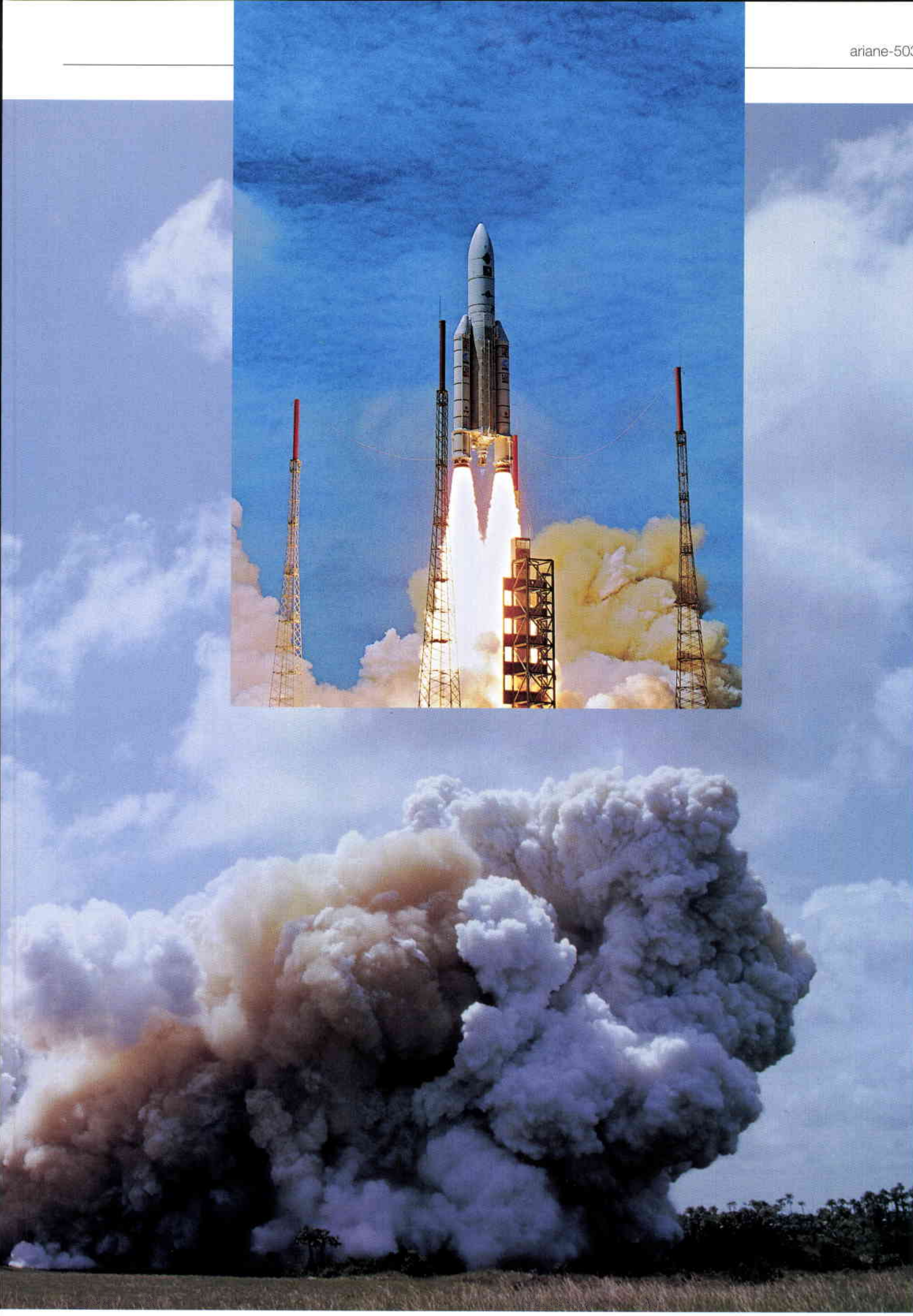
Mating of the upper payload, the Atmospheric Reentry Demonstrator (ARD), and its flight adaptor, in the Final Assembly Building

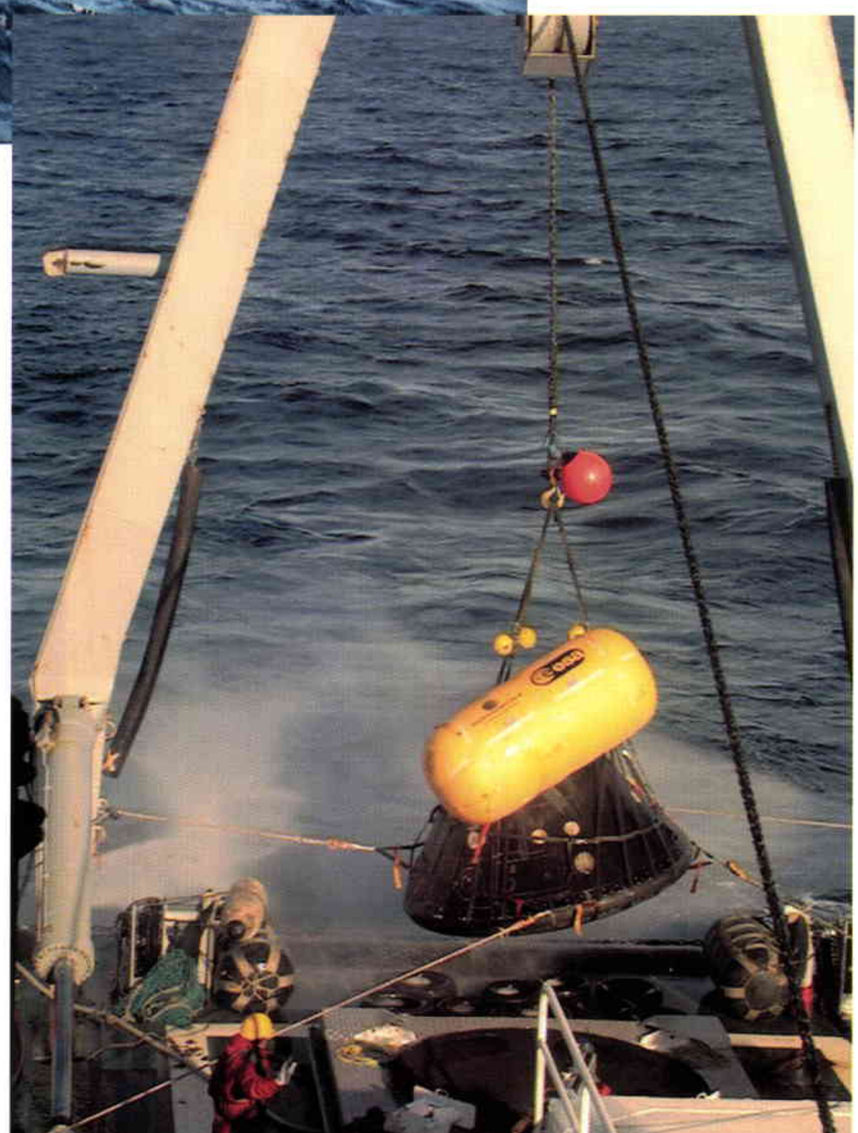
Installation of the fairing, in the Final Assembly Building

Transfer of the launcher from the Final Assembly Building to the Launch Zone on 20 October



Lift-off of Ariane-503 on 21 October





Recovery of the Atmospheric Reentry Demonstrator (ARD) capsule from the Pacific Ocean

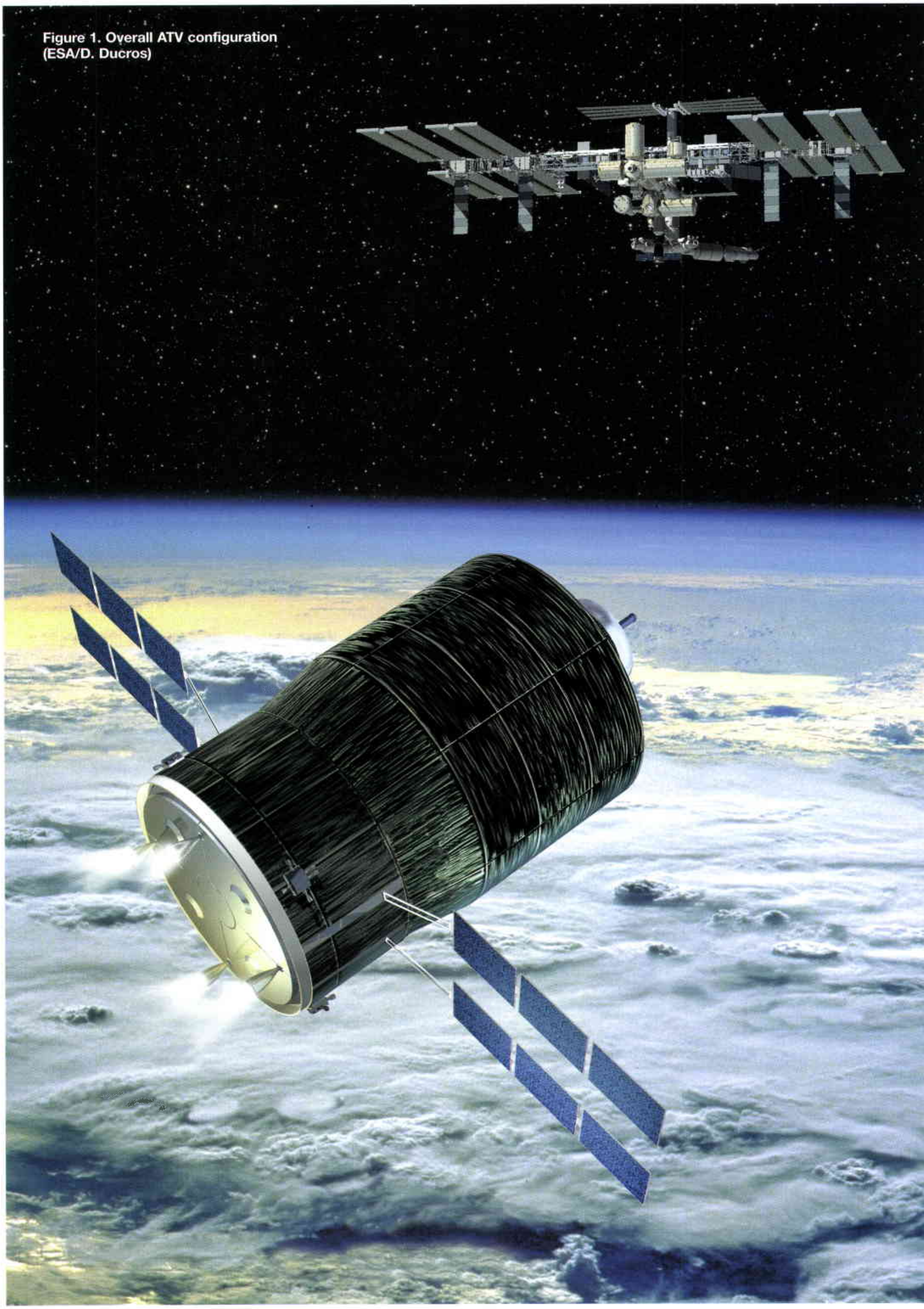


Figure 1. Overall ATV configuration (ESA/D. Ducros)

The Automated Transfer Vehicle

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J.Y. Heloret
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The development of the Automated Transfer Vehicle (ATV) was confirmed at the October 1995 ESA Ministerial Council meeting in Toulouse by the ESA Member States as part of the programme for European participation in the International Space Station. The ATV will be a servicing and logistics vehicle for periodically resupplying the Station. It will be operational from early 2003, flying servicing missions about eight times until 2013 or more, depending on the Station's lifetime extension. ATV will be the tool to pay in kind for Europe's share of Station common operations costs.

Introduction

As prime contractor for the Automated Transfer Vehicle (ATV) under an ESA contract, Aerospatiale's Les Mureaux establishment is responsible for overall management, system and vehicle engineering; vehicle testing, software development and overall verification of the vehicle and support to the Agency for external interfaces requirements establishment and negotiations.

DaimlerChrysler Aerospace Bremen is the prime contractor for ATV production. The production phase will probably begin in 2000, subject to timely approval by ESA Member States of the International Space Station Exploitation Programme.

Ground processing will take place in Europe and at the launch site in Kourou, French Guiana. Flight operations will be controlled from the ATV Control Centre in Europe during the free-flight phase and taken over by either the Russian Control Centre in Moscow and/or by the Space Station Control Center in Houston when approaching the Station and until docking.

Development status

Since the start of Phase-B2 with Aerospatiale in July 1996, complex negotiations have taken place between ESA and industry on this challenging programme. As a result of several proposal submission cycles supported by a recovery phase in early 1998, an updated Aerospatiale proposal was finally accepted by the ESA Tender Evaluation Board in early June 1998 and the associated contract proposal was approved at the end-June 1998 meeting of ESA's Industrial Policy Committee. Contract negotiations were finalised in July 1998; the contract was signed 25 November 1998.

The mission

ATV will be launched by Ariane-5E (E=Evolution) for the first time in late March 2003. This maiden launch will include specific mission demonstration objectives for final qualification of the ATV mission.

The ATV will provide the following services to the International Space Station:
- Delivery of dry and liquid cargoes to the Station, such as experiments, food, compressed air and water.
- Refuelling of the Station, i.e. the transfer of propellant to the Zarya (FGB) module, built by the Russian company Khrunichev under Boeing contract.
- Reboost and attitude control during reboost of the whole Station, i.e. orbit corrections using the ATV propulsion system to compensate for the continuous loss of altitude by the Station.
- Removal of waste from the Station followed by controlled destructive reentry of the ATV.

Payload capability

The ATV carries, in the same mission, both dry and liquid cargoes. It has an upload capability of up to 7.5 t and a download capability of up to 6.5 t, for a 400 km, 51.6° orbit.

The upload cargo can consist of:
- up to 5500 kg of dry cargo carried in a pressurised environment
- up to 840 kg of water

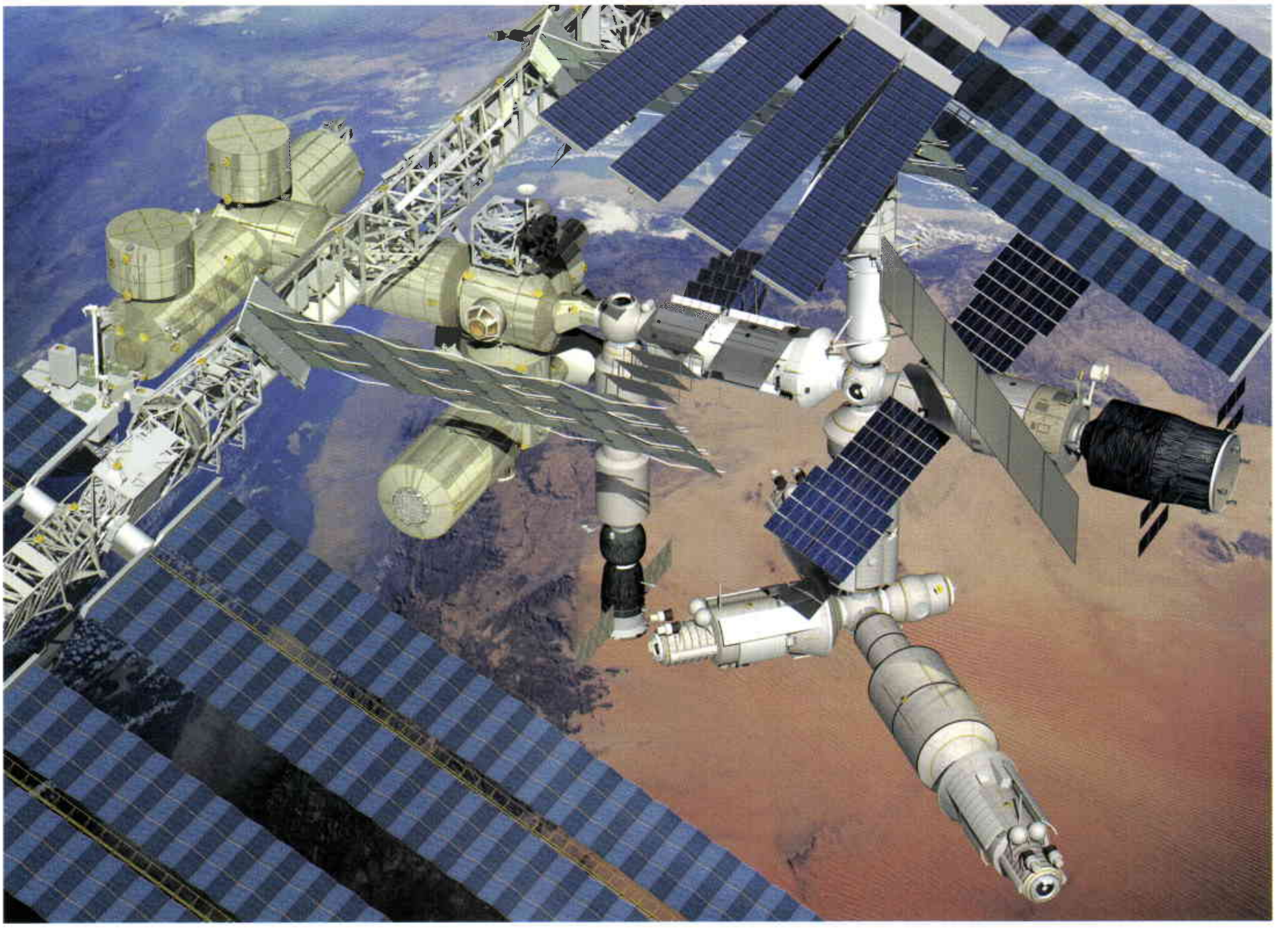


Figure 2. Docked to the Russian Service Module, the ATV is capable of reboosting the ISS into a higher orbit (ESA/D. Ducros)

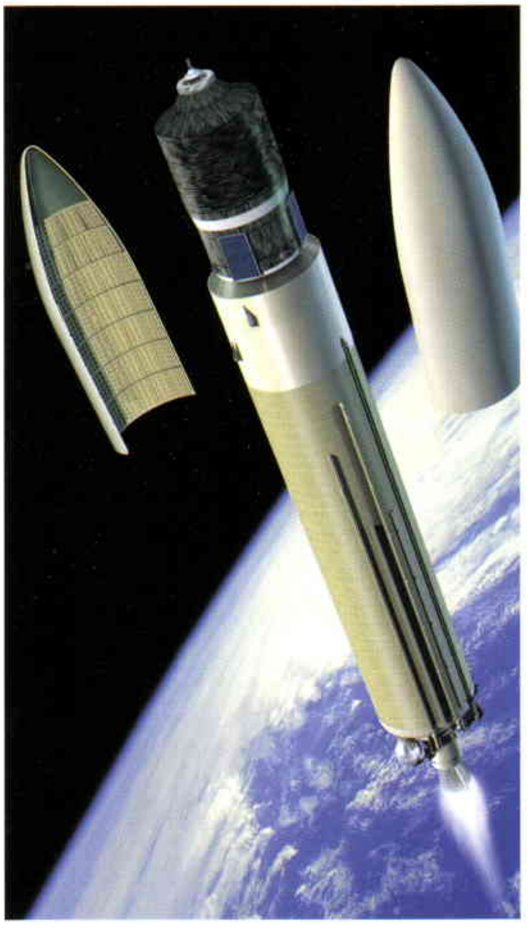


Figure 3. Ariane-5 core stage carrying the ATV with the fairing jettisoned (ESA/D. Ducros)

- up to 100 kg of air, oxygen or nitrogen
- up to 860 kg of propellant (306 kg of fuel and 554 kg of oxidiser) for Station refuelling
- up to 4000 kg for reboost and attitude control of the Station.

Mission profile

Ariane-5E injects the ATV into a 30x300 km, 51.6° transfer path. The circularisation and phasing operations are performed by the ATV after injection and last about 50 h. At the first apogee, after separation from the launcher, the ATV raises perigee to 400 km to stabilise the orbit. Onboard navigation is initialised by an activation order delivered by Ariane-5E at separation. All ATV operations are monitored from the ATV Control Centre in Europe via NASA's Tracking & Data Relay Satellite (TDRS) system.

Following the perigee-raising manoeuvre, a series of reconfiguration and check-out operations is performed, notably solar array deployment.

A series of phasing manoeuvres is then performed to bring the ATV to the Station altitude of 350-460 km. About 90 min before the ATV enters the approach ellipsoid, integrated operations begin and mission authority is transferred to the Mission Control Center in Houston or in Moscow.

Beginning 30 km from the Station, the ATV performs final approach and docking manoeuvres automatically over a period of 5 h, with either automatic or manual capability from the Station crew to trigger a collision avoidance manoeuvre should any problem occur at ATV or Station level. Upon detection of the first contact between the ATV docking system and the Russian Service Module, the ATV thrusts to ensure its capture and then triggers the automatic sequence of docking operations.

The attached phase lasts up to 6 months. During this phase, the ATV's hatch remains open unless it is closed to minimise the power required from the Station. The crew manually unloads cargo through a pressurised passageway while the ATV is in the dormant mode. Dry cargo of up to 5500 kg is located in a pressurised environment in the secondary structure of the Cargo Carrier. ATV can also carry up to 840 kg of water and up to 100 kg of air, oxygen or nitrogen.

Station refuelling operations are powered and controlled by the Station via specific hardware interfaces in sequence: integrity checks, line venting, fluid transfer and line purging. Propellant tanks in the external module of the Cargo Carrier carry up to 306 kg of fuel and 554 kg of oxidiser. Refuelling may be carried out in several increments.

The ATV is reactivated during the attitude control and reboost operations. These operations can employ the four 490 N thrusters of the main propulsion system, or the twenty 220 N thrusters of the attitude control system.

After departure from the Station, the ATV automatically performs manoeuvres for deorbiting and controlled reentry in the Earth's atmosphere. Carrying up to 5.5 t of waste from the Station, the ATV will be safely consumed during reentry.

Vehicle description

The ATV has a modular architecture. It is composed of the ATV Spacecraft itself and an Integrated Cargo Carrier.

The ATV Spacecraft includes:

- the separation and distancing module that ensures ATV separation from Ariane-5E

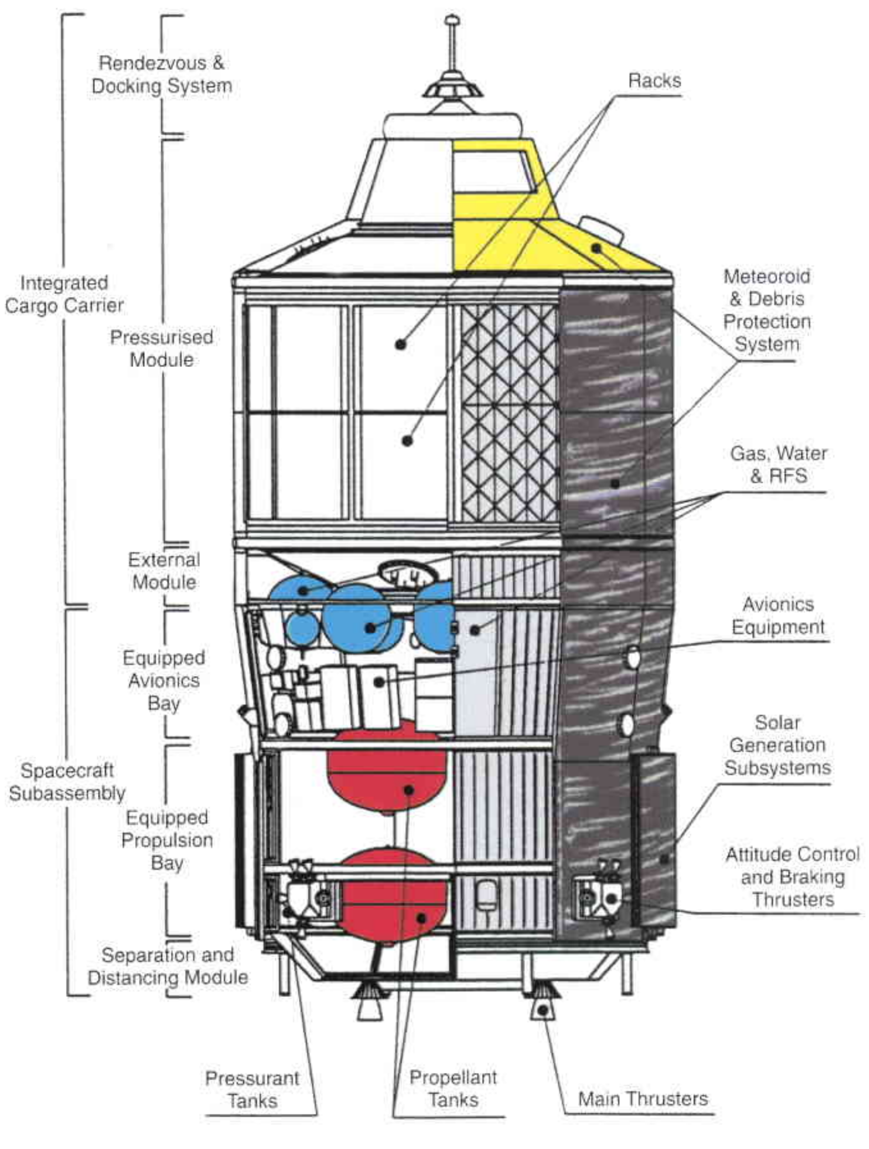
Figure 4. The Automated Transfer Vehicle approaching the International Space Station (ESA/D. Ducros)

- the propulsion bay accommodating the Propulsion and Reboost Subsystem
- the avionics bay housing the data management system, the guidance, navigation and control system, communications and thermal control
- the solar arrays.

The Integrated Cargo Carrier accommodates all cargo except for the reboost propellant, which is carried in the Spacecraft. It consists of:

- a cargo carrier with an equipped pressurised module for dry cargoes and an external bay for water and gas tanks and interfaces with the Spacecraft
- the active part of the Russian docking system
- avionics equipment such as rendezvous sensors and proximity link antennas.

Figure 5. ATV principal elements



ATV subsystems

The Russian Docking System

The Russian Docking System is based on the probe and drogue system used for many years by Russia for docking the Progress and Soyuz vehicles. It provides the ATV with the capture and release functions necessary for docking with and departure from the Station. The system is built in Russia and provided under ESA responsibility through an interagency barter agreement in exchange for ESA providing the Data Management System to the Russian Service Module.

Avionics equipment chains

The ATV avionics architecture centres around the Fault Tolerant Computer, composed of four data processing units. These are synchronised, executing functions determined by the software. This software is in charge of overall ATV management during the free-flying phases, from injection by Ariane-5E to ISS docking and from undocking to final destruction at reentry.

Guidance, Navigation and Control

Guidance, Navigation and Control calculations are based on two Global Positioning Satellite (GPS) receivers for position estimation, on four gyros and two Earth sensors for attitude estimation, and on two rendezvous sensors for final approach and docking. The system is in charge of the closed-loop ATV motion control, in particular to bring the vehicle to the specified conditions (position, velocity, attitude and angular rate) for docking with the Station and to the proper position and conditions for reentry to ensure safe debris fall-out.

Communications

Communications with the ATV are provided by two S-band systems: a TDRS link for communications with the ground and a proximity link for communications with the Station. Both systems are completely redundant.

Power generation and storage

The ATV power resources are based on solar arrays and batteries. Four deployable arrays generate power when exposed to the Sun. Rechargeable batteries are used to cover eclipse periods and to directly power the equipment. Non-rechargeable batteries are also used during certain flight phases. During the attached phase, the ATV in dormant mode requires up to about 600 W from the Station. Power is generated, stored, distributed and controlled under the supervision of the ATV mission and vehicle management avionics.

Solar arrays

The solar array subsystem consists of four wings with three panels each. Both gallium arsenide and high-efficiency silicon cells are used. Power at beginning-of-life is up to

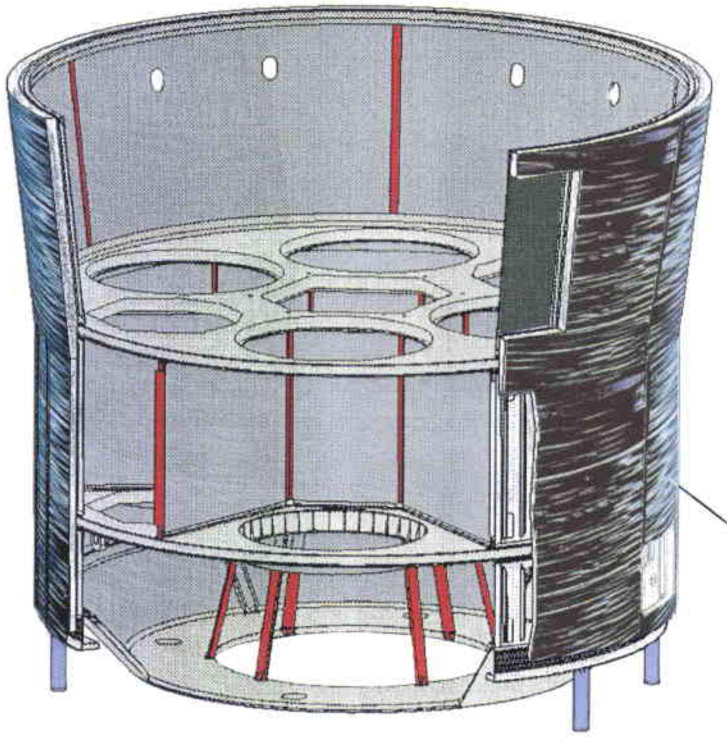


Figure 6. ATV Spacecraft structures

3860 W in Sun-pointing mode; the end-of-life (up to 6 months) output is 3800 W.

Thermal control
The ATV thermal control system is based on a semi-passive concept typical for satellites. Protection against the space environment is provided by multi-layer insulation covering the vehicle. External radiative coatings (aluminised secondary surface mirror coating or absorptive black paint) are optimised locally. Passive radiators and 100 active heaters are also used where necessary, particularly during the attached phase.

Spacecraft structures
Spacecraft structures comprise a Propulsion Module, an Avionics Module, and a Separation and Distancing Module, all of aluminium alloy. They are protected by a Meteoroid and Debris Protection System mounted on the primary structure.

Propulsion and Reboost Subsystem
The bipropellant Propulsion and Reboost Subsystem uses mixed oxides of nitrogen (MON, oxidiser) and monomethyl hydrazine (MMH, fuel) stored in eight identical 1 m-diameter titanium tanks. Tanks are pressurised with helium stored in two high-pressure tanks regulated to 20 bar. Tanks can accommodate up to 6760 kg of propellant for main navigation and reboost requirements. The same tanks are used for ATV propulsion and Station reboost. The system comprises four main engines of 490 N each with a specific impulse of more than 310 s, and 20 attitude control thrusters of 220 N each and a minimum impulse bit of less than 5 Ns.

Major ATV characteristics

The ATV will be launched by the Ariane-5 Evolution version, without the upper storable propellant stage, allowing injection of 20.5 t into a 30x300 km, 51.6° transfer path.
Length: 10.1 m
Maximum diameter: 4.5 m
Span with solar arrays deployed: 18.3 m
Power supply: 3800 W after 6 months
Spacecraft dry mass: 4.6 t
Cargo Carrier dry mass: 3.9 t
Net cargo mass: up to 7.5 t
Total ATV maximum mass at launch: 20.5 t

Industrial organisation

The industrial organisation follows the agreement reached during the October 1995 Ministerial Conference in Toulouse, with Aerospatiale Les Mureaux in charge of development and DaimlerChrysler Aerospace Bremen in charge of production, subject to approval by Europe of the International Space Station Exploitation Programme. An Inter-Prime agreement has been reached between Aerospatiale and DaimlerChrysler Aerospace.

The industrial structure planned for the development phase is as follows:

Aerospatiale in Les Mureaux (France) is the prime contractor for development and is in charge of:
- System engineering
- Vehicle engineering
- Flight software
- Vehicle testing

Alenia Spazio (Italy)
- Cargo Carrier development
- Thermal control studies

DaimlerChrysler Aerospace (Germany)
- Propulsion and Reboost Subsystem
- Spacecraft integration

Matra Marconi Space (France)
- Avionics equipment development
- Avionics Bay integration
- Guidance, Navigation and Control algorithms and software for rendezvous

Oerlikon Contraves (Switzerland)
- Spacecraft structure subsystem
- Dynamic models

Alcatel Bell Telephon (Belgium)
- Electrical Ground Support Equipment

Development plan

The ATV development logic requires three system models: a structural test model, an electrical test model and a protoflight model.

Structural Test Model
- early mechanical tests such as shock and dynamic tests to acquire a better knowledge of the environment and of the structural behaviour of the ATV
- early acoustic tests for validation of equipment's environmental requirements
- structural static tests
- thermal balance tests to validate the thermal mathematical model and the thermal control passive design
- solar generator system deployment test.

Electrical Test Model
- early environmental validation of the avionics subsystem, from the fault-tolerant computer pool and its basic software, up to the whole system by gradually adding the different assemblies and redundancies
- most of the functional qualification of the ATV with the Functional Simulation Facility, which is a ground support element offering simulators for missing equipment (if any), ATV kinematics and simulation of the external environment.

Protoflight Model, for final ATV qualification
- Acoustic tests
- Electromagnetic compatibility tests
- Release tests for the solar generator system
- Thermal balance test
- Complementary functional qualification on the Functional Simulation Facility (hardware and software). esa

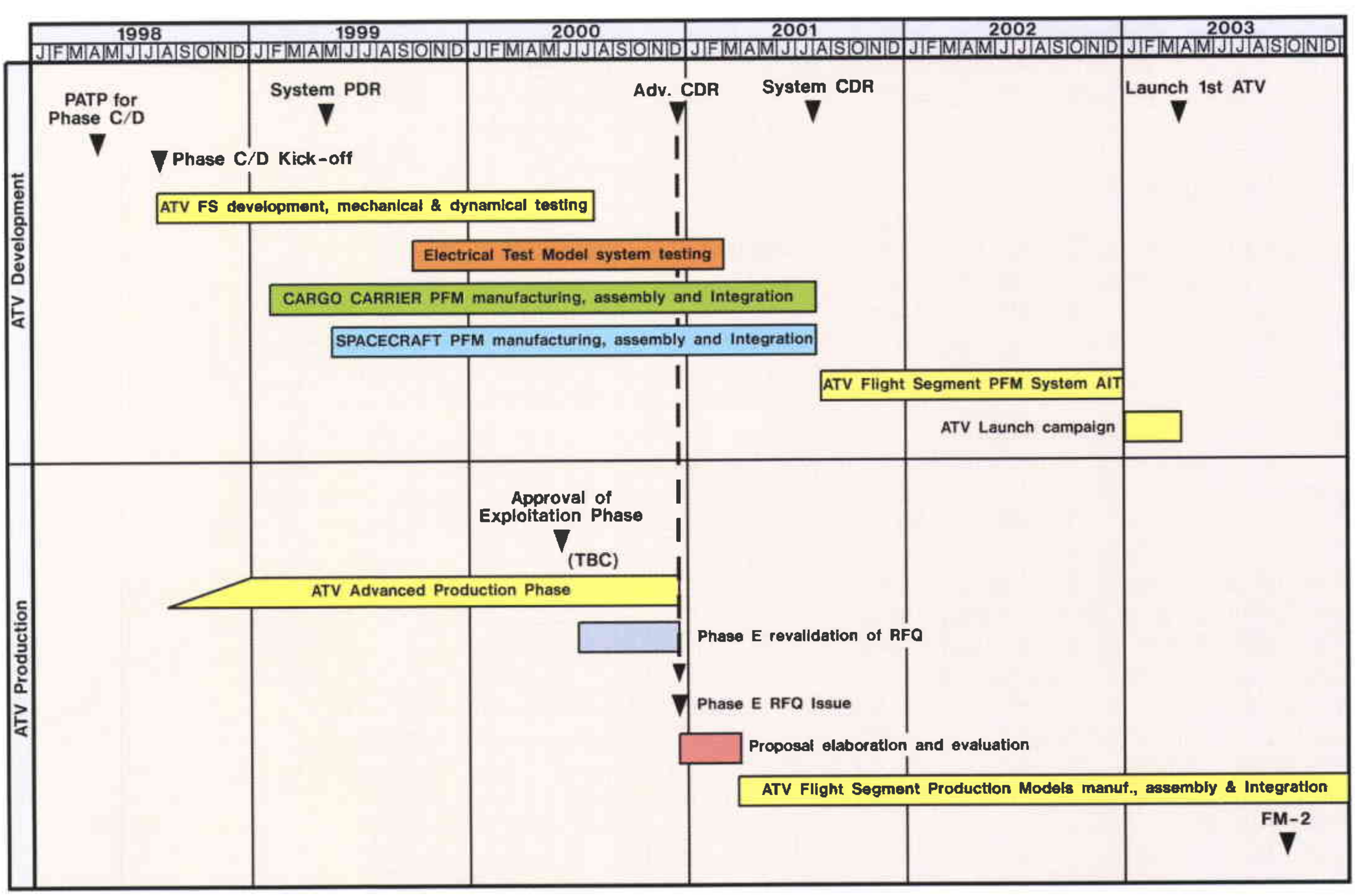


Figure 7. The overall ATV development schedule and transition to the exploitation phase

Aerothermodynamics for Space Vehicles – ESA's Activities and the Challenges

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In August 1988, ESA implemented a specialist section for aerothermodynamics within the Propulsion and Aerothermodynamics Division at ESTEC in the Netherlands. This capability was created to provide a competence in ESA for a new generation of space vehicles requiring aerothermodynamics expertise to enable their design: the Hermes Space Plane, planetary missions within the Agency's Space Science Programme and the Ariane-5 launcher. The Section was to be the focal point for this new discipline within ESA in addition to coordinating European activities in aerothermodynamics and providing technical support to the Agency's programmes. The Aerothermodynamics Section is now exactly 10 years old, making it timely to review the achievements, to elaborate on the importance of aerothermodynamics for space vehicles, and to present the challenges for current and future ESA space vehicles.

Introduction

Aerothermodynamics for space vehicles embraces the science and technology of classical aerodynamics extended to cover hypersonic speeds, and includes the physics and chemistry of chemically reacting and dissociated flows. The field covers external flows around aerospace vehicles and internal flows through vehicle propulsion systems. The activities cover theoretical aerothermodynamics, including computational fluid dynamics (CFD), experimental aerothermodynamics, flight testing and operations.

Over this ten-year period, as the technical capabilities of the Section have increased, more demanding space missions have inevitably emerged comprising launchers, reentry vehicles, planetary landers, and space station crew transfer and rescue vehicles. These new missions have imposed demanding aerothermodynamic requirements and challenges, which are reviewed in this article.

Aerothermodynamics at ESTEC has now evolved into a wide field of applications encompassing all of the major fluid dynamic aspects:

- External aerodynamics of aerospace vehicles covering their complete flight regime: subsonic, transonic, supersonic and hypersonic speed. The outputs of this work are aerodynamic loads and kinetic heating rates, used for the structural, thermal and flight-control design of the vehicles.
- External aerodynamics of aerospace vehicles to cover the transition from high-altitude free molecular flow to continuum flow as vehicles enter planetary atmospheres. Flight control of vehicles during this phase requires a combination of reaction control from small rocket engines and aerodynamic control from vehicle control surfaces.
- Aerodynamics of parachute and parafoil landing systems.
- Internal aerodynamics of aerospace vehicles covering the design of propulsion engine inlets, propulsive exhaust nozzles, engine flow control valves, manifolds and vents.
- Micro-aerodynamics which encompasses the assessment of local flow effects in gaps between thermal-protection tiles, and at steps between structural elements and at corners, such as those occurring at aerodynamic control surface hinges.
- Unsteady flow effects due to aerodynamic buffeting and flutter of structural elements.
- Chemically-reacting flows in combustion chambers and in the shock layer of aerospace vehicles during entry into planetary atmospheres.
- Two- and three-phase flows in non-equilibium, chemically frozen or equilibrium conditions where contamination or debris are concerns.
- Rocket-engine exhaust-plume flow impingement effects on spacecraft surfaces: forces moments, heating and contamination.
- Flow analysis of liquid-in-tube nutation dampers.

Aerothermodynamic facilities and tools for design

The means to address aerodynamic design issues, to quantify their effects and to qualify

the vehicle are:
- ground-based facilities such as classical wind tunnels, shock tunnels, plasma facilities and their instrumentation

- numerical analysis codes, ranging from simple and fast engineering tools to complex CFD codes combined with their pre- and post-processing routines. CFD is essential in the design process for the definition of the experiments, the interpretation of data, the validation of the physical modelling (for example, for transition and turbulence) and the subsequent extrapolation to flight conditions

- flight testing, ranging from simple generic configurations such as capsules, to complex vehicles for design validation and technology qualification in realistic environments, including their associated flight measurement techniques and air data systems.

To strengthen European capabilities for the design and qualification of space vehicles, the improvement of the three interdependent tools – wind tunnels, CFD and flight testing – has received top priority in ESA's Technology Research Programme (TRP) and General Support Technology Programme (GSTP). Furthermore, numerous workshops and symposia have been organised by the Aerothermodynamics Section to promote cooperation and interaction between universities, research establishments and industry.

The Manned Spaceflight Programme
Over the last ten years, this programme has been the main initiator and stimulus for a large number of aerothermodynamic activities. Its needs have resulted in the current high level of European technical expertise in experimental facilities and techniques, and CFD codes for space vehicle design. The current programmes are:

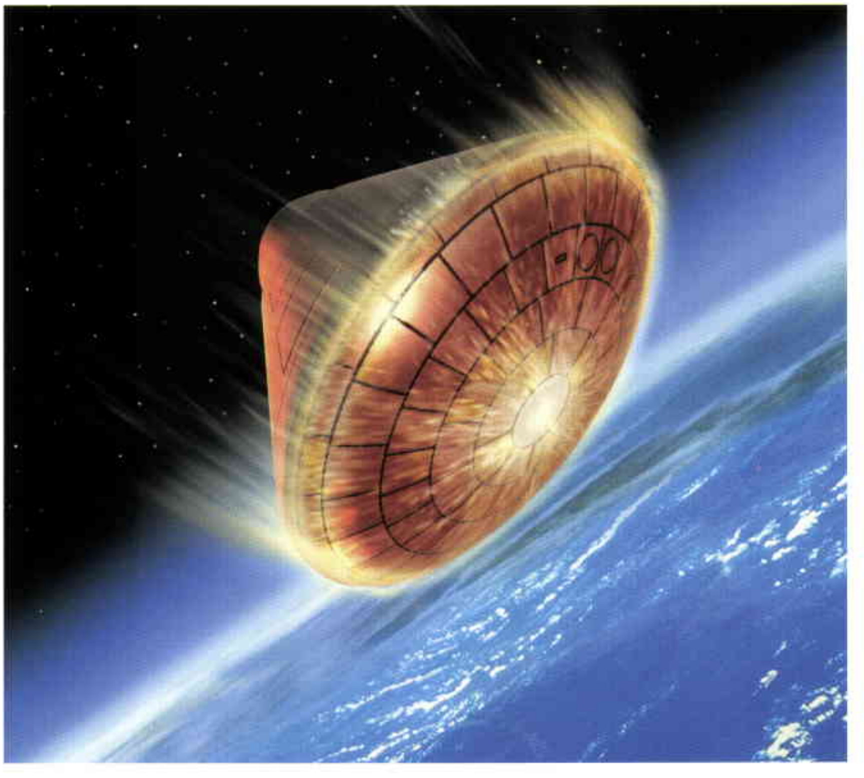
ARD
The Atmospheric Reentry Demonstrator (ARD) is a guided reentry vehicle of the Apollo type, (Fig. 1) which was launched on the third Ariane-5 test flight in October 1998. This mission was a major achievement for Europe as the ARD was the first ESA vehicle to perform a complete reentry. Throughout its reentry and descent, flight measurements were taken to evaluate heating, transition, reaction control system interaction, ionisation (black out) and parachute deployment. The post-flight analysis will give industry invaluable experience, allowing them to validate and improve their design tools.

XCRV
The Experimental Crew Rescue Vehicle (XCRV), also called the X38, is being designed as an experimental vehicle for the emergency return of crew from the International Space Station (ISS). It is a joint ESA/NASA project scheduled to have its maiden flight in late 2000. Europe plays an important role in the aerodynamic design of this vehicle. The aerothermodynamic challenges are:
- control and stability of the vehicle throughout its complete reentry flight regime
- efficiency estimates of the body flap and rudder effects of boundary-layer transition
- micro-aerothermodynamic effects like local heating in hinges and gaps
- heating rates on the nose and heating effects of windward boundary-layer transition
- integration of flight instrumentation into the vehicle in a non-obtrusive manner.

Figures 2 to 5 show some models of the XCRV vehicle and example CFD calculation results using Navier-Stokes codes.

ATV
The Automated Transfer Vehicle (ATV) is an expendable supply vehicle for the transport of equipment and propellant to the ISS. During rendezvous and docking operations using small rocket engines on the vehicle, exhaust-plume interaction effects will arise. These must be well understood and quantified during the design of the vehicle. The ATV must be destroyed during reentry. Aerothermodynamic calculations must guarantee that the burn-up of the vehicle in the atmosphere takes place

Figure 1. Artist's impression of the Atmospheric Reentry Demonstrator (ARD)



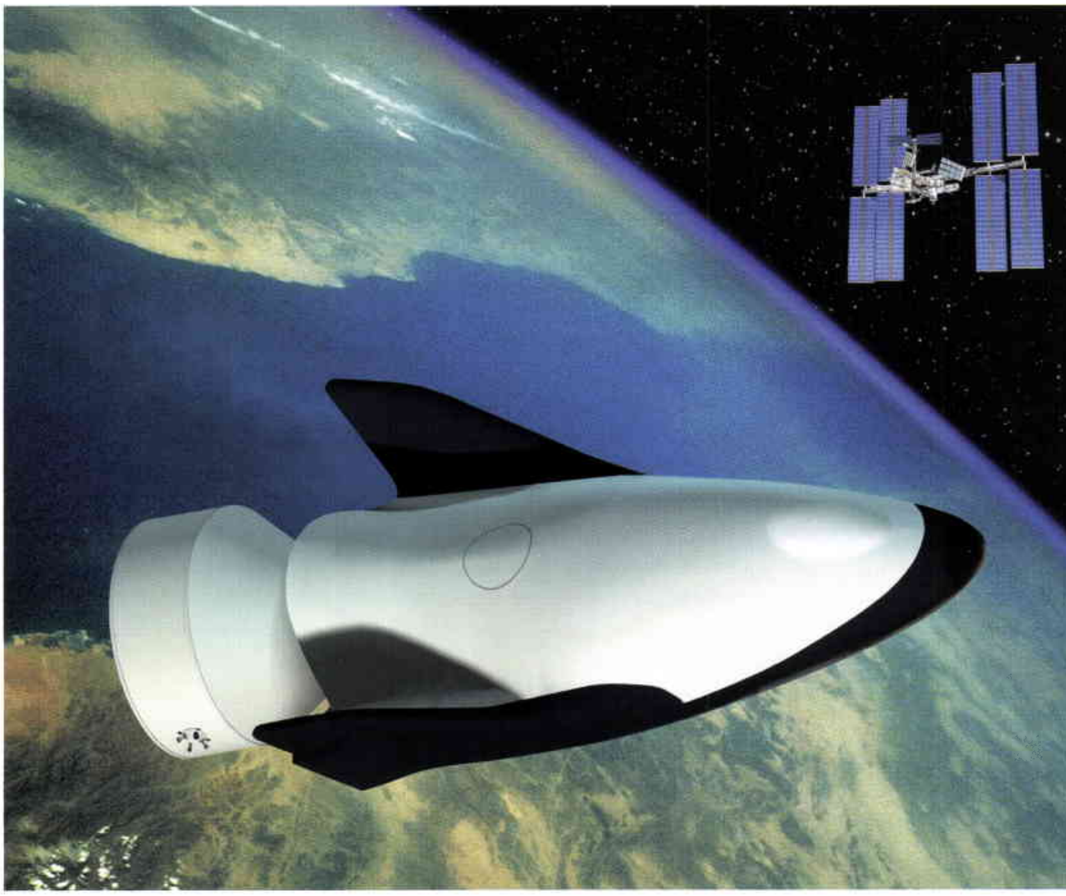


Figure 2. Artist's impression of the ESA/NASA X38 Crew Rescue Vehicle (CRV)

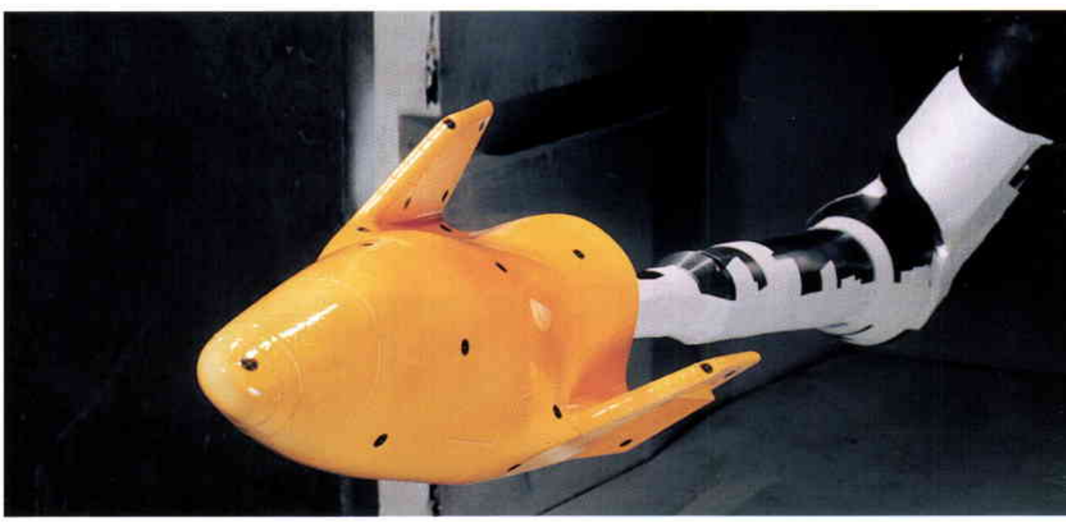


Figure 3. Aerodynamic tests of an X38 model at FFA in Sweden

Figure 4. Schlieren photograph of an X38 flow field during testing at FFA in Sweden

completely so that no parts of this large vehicle fall to Earth.

MSTP Technology Programme

The Manned Space Technology Programme was created to continue the development of technologies in reentry aerothermodynamics after the cancellation of the Hermes Space Plane Programme. The emphasis was on ground test facilities, reentry capsule critical issues, industrial CFD code improvements including code validation workshops, a parafoil technology programme and the creation of an engineering database for design. This work was completed by the end of 1997 when the programme was terminated. Figure 6 shows the test cases for CFD validation used for the aerothermodynamic workshops and the extrapolation-to-flight approach used for design.

Plasmatron

An induction heated plasma facility (plasmatron), was designed and developed at the Von Karman Institute (VKI) in Belgium, for the study of gas surface interactions such as catalycity and ablation in a contaminant-free environment.

Scirocco

The 70 MW Scirocco arc-heated plasma facility is under design and construction at CIRA in Capua, Italy. It will be used for materials testing under the high-temperature conditions experienced by reentry vehicles. It will be ready for operational use by the end of 1999.

The Science Programme

Spacecraft for science programmes have to deal with plume impingement problems caused by the exhaust gases from attitude and orbit control rocket engines. Additionally, those spacecraft which must enter planetary atmospheres face critical aerothermodynamic problems.

Intermarsnet and Venus Return Mission

The ESA-NASA Intermarsnet mission will place three instrumentation stations on the surface of Mars and an Orbiter around Mars for data-relay purposes. The launch is scheduled for 2003 using an Ariane-5 launcher. The stack of three stations must perform a ballistic entry into the Martian atmosphere using a heat shield to progressively reduce the vehicle's speed by aerodynamic drag. A parachute landing system will then be used to place the vehicle on the Mars surface. The configuration of the vehicle is shown in Figure 7. The aerothermodynamic issues are entry heating and vehicle stability, heat-shield separation, and parachute deployment.

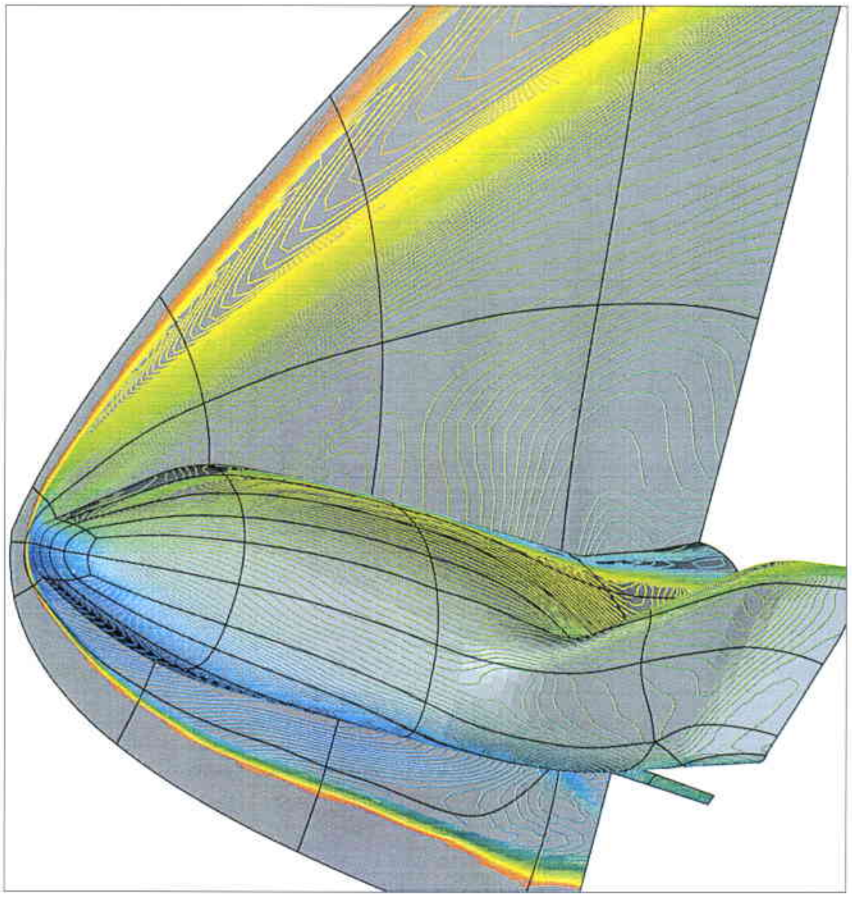


Figure 5. Mach number contours around the X38 (ESTEC)

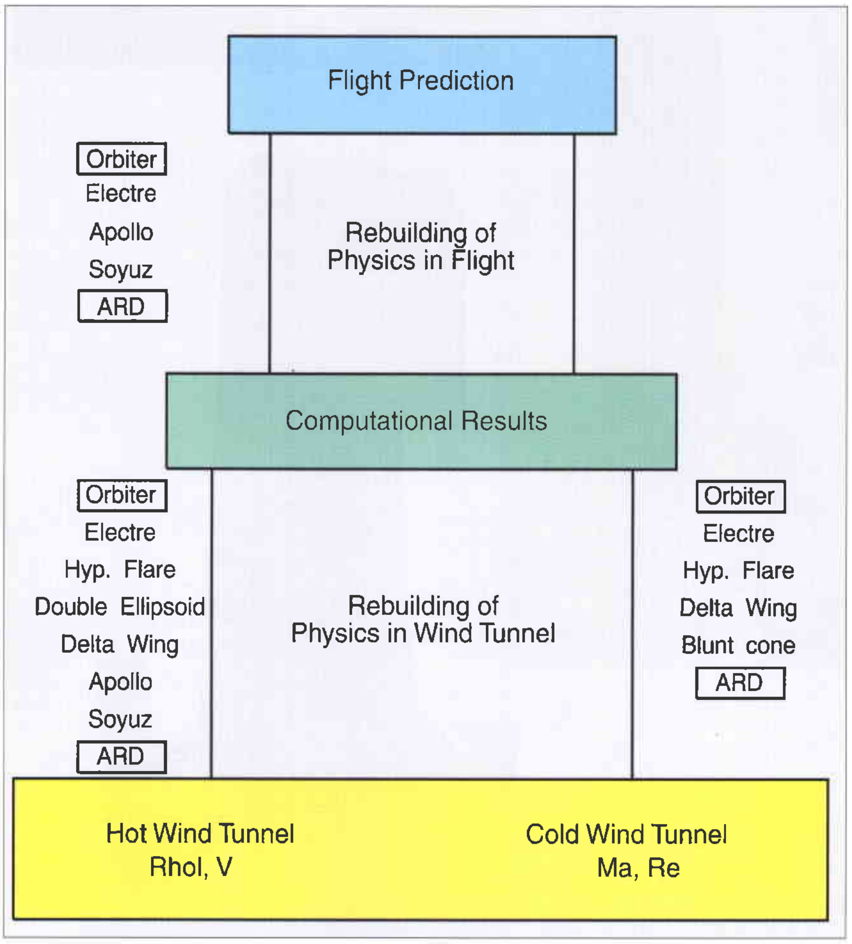


Figure 6. Test cases for CFD validation used in ESTEC workshops

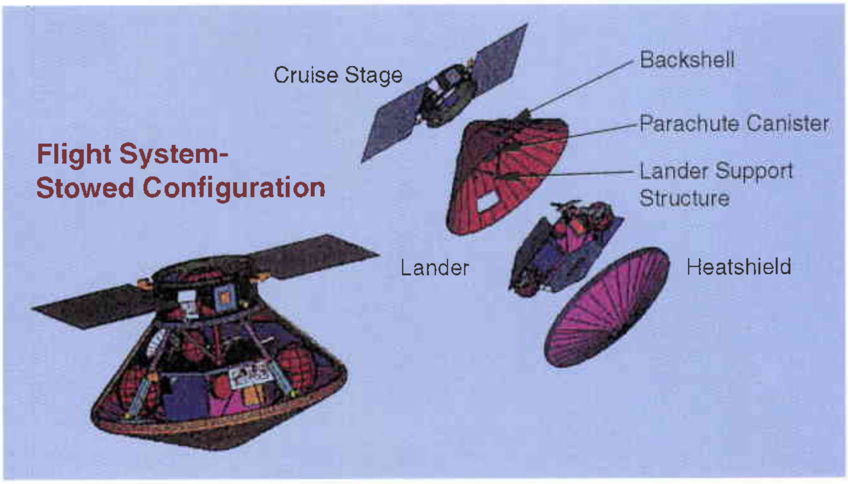
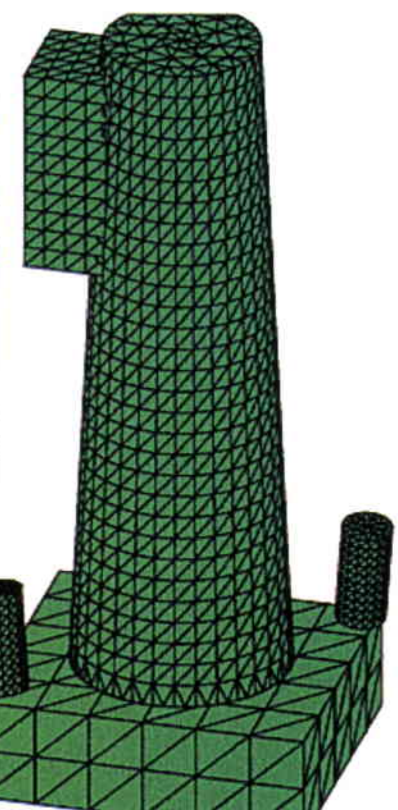
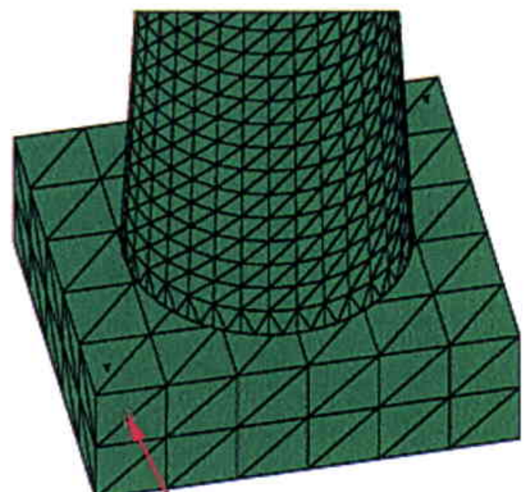


Figure 7. Intermarsnet vehicle configuration

One of the most challenging ESA scientific missions under study is the Venus Sample Return. It aims to return soil and atmospheric samples from Venus. Two Ariane-5 launchers will be required; one to launch an Orbiter composed of the Venus Orbital Module and Earth Return Module and the other to launch a Lander which will enter the Venusian atmosphere and descend using aerodynamic braking and parachute landing systems. For the return to Earth of rock and soil samples, the Lander will use a balloon to lift the vehicle off Venus' surface. A multistage solid-rocket system will then propel the vehicle to a Venus parking orbit to rendezvous and dock with the Orbiter vehicle. The Earth Return Module will then be propelled back to Earth and will enter the Earth's atmosphere and descend to a soft landing using aerobraking and parachute descent systems.





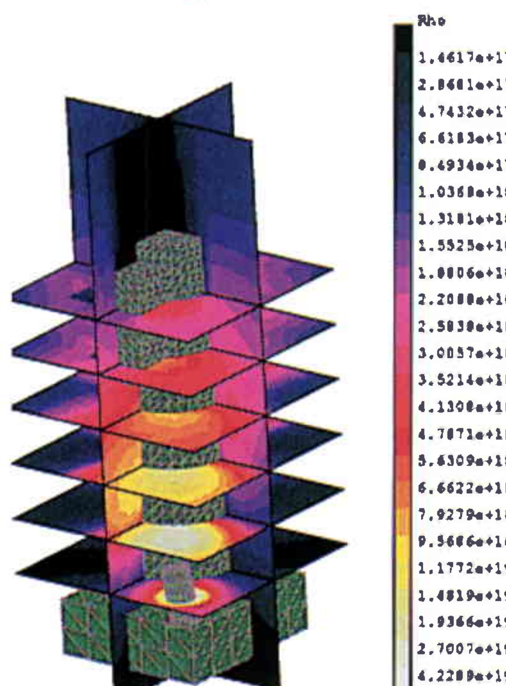


Figure 8. Plume interaction studies for XMM

The critical aerothermo-dynamics issues are:
- Venus aerocapture and aerobraking
- Venus and Earth atmospheric entry and descent
- ascent of the balloon
- ascent of the solid-rocket-propelled stage.

XMM
XMM is a large spacecraft, which makes plume-impingement effects from the attitude control rocket engines a critical issue. To illustrate the work that has been done to minimise such effects, Figure 8 shows the thruster nozzle pressure contours, the location of the thruster, the numerical calculation grids used and the resulting impinged gas pressure contours around the satellite. A combination of Navier-Stokes codes for the nozzle flow field calculation, with a Monte Carlo analysis for the plume near-field in combination with free molecular flow calculations for the thruster far field were used to address this problem.

The Telecommunications and Earth Observation Programmes
The major aerothermodynamic problem for these spacecraft is plume-impingement effects from rocket engines used for attitude and orbit control. The impingement effects from chemical rocket engines are now well understood and advanced analysis tools are available. Electric propulsion is now being introduced on these spacecraft for orbit-control purposes. This will pose a new problem of impingement of ionised propellant species, which is now being addressed at the level of the basic physics of the phenomena. An example is shown in Figure 9 for the Meteosat Second Generation (MSG) spacecraft. This shows the plume heating on the edge of the central plate of the structure caused by the exhaust plume from the 400N apogee engine. Navier-Stokes codes for nozzle flow calculations, in combination with Monte Carlo analysis, have been used to study this complex plume flow interaction.

The Launchers Programme
The aerothermodynamic challenges within the launcher Directorate are multiple and several types of support are therefore provided by the Aerothermodynamics Section.

Ariane-5
On behalf of CNES (the French Space Agency) and in close collaboration with industry, experimental and numerical studies have been carried out to assess the contamination from unused propellant as it is vented to space from the Second Stage Propulsion System (EPS) and the Attitude Control System (SCA). Another major activity was the design, construction and transonic wind-tunnel testing of the unsteady base flow buffeting loads on the Ariane-5 vehicle. Figure 10 show the details of an

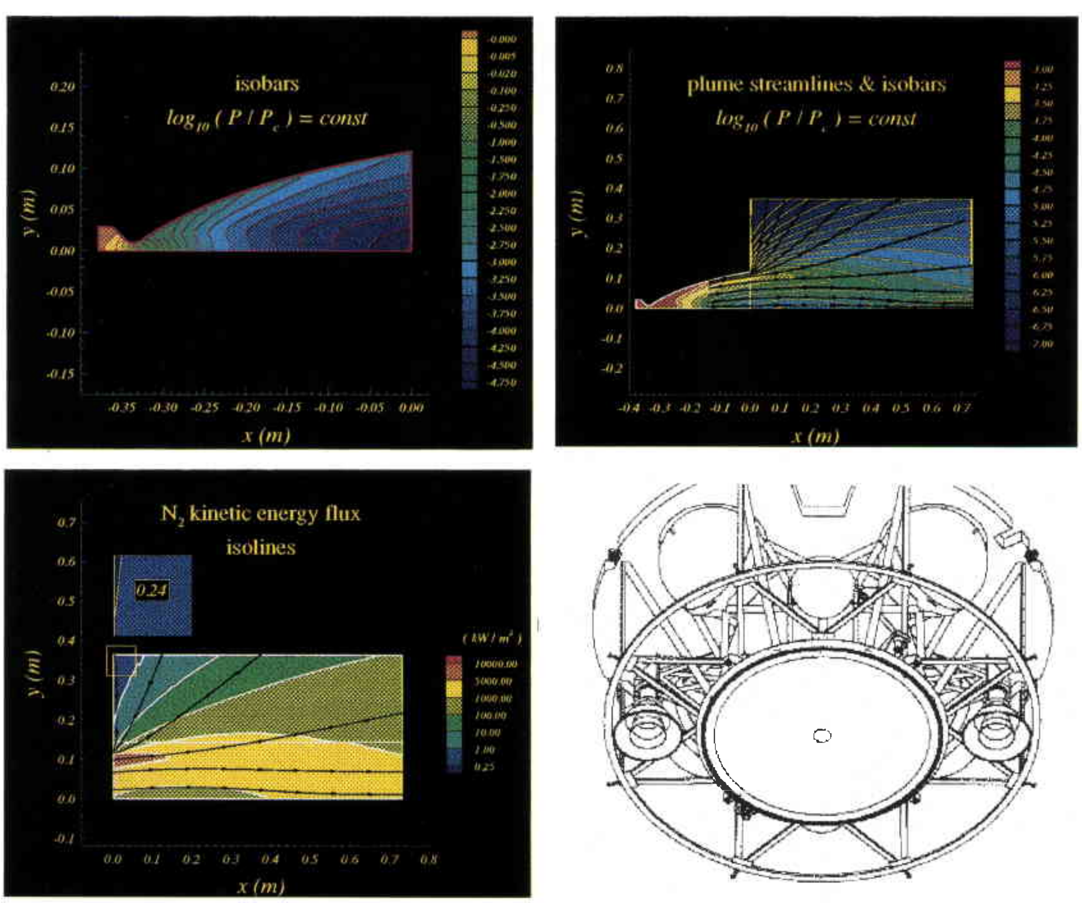


Figure 9. Plume interaction studies for MSG

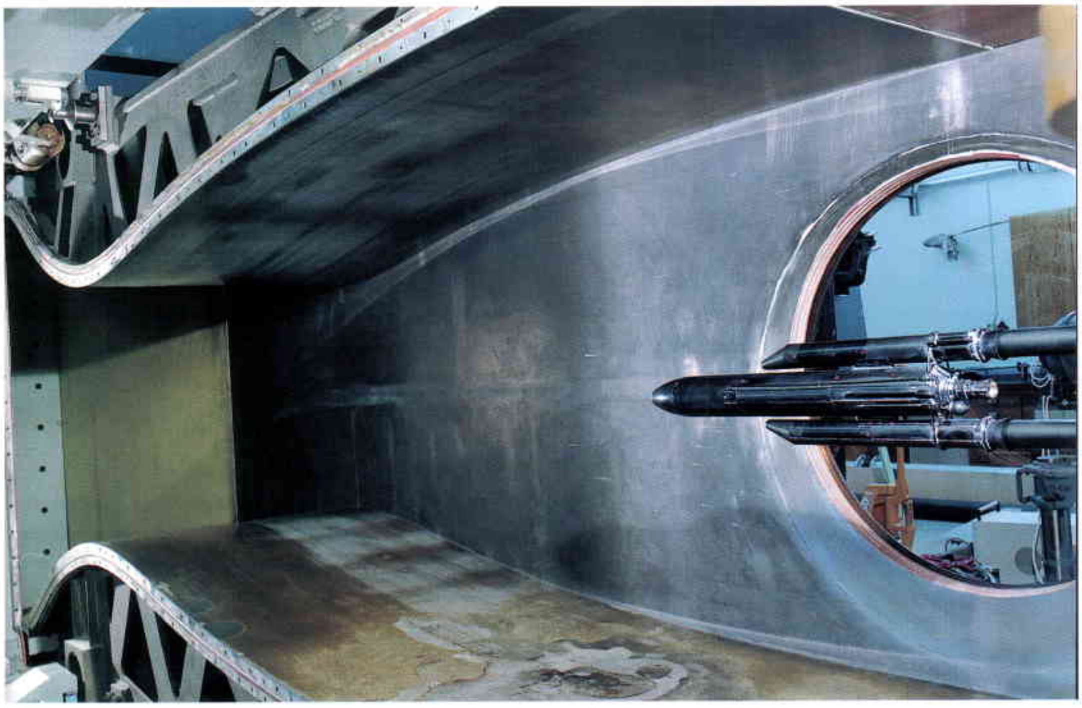


Figure 10. Ariane-5 model for buffeting studies at FFA in Sweden

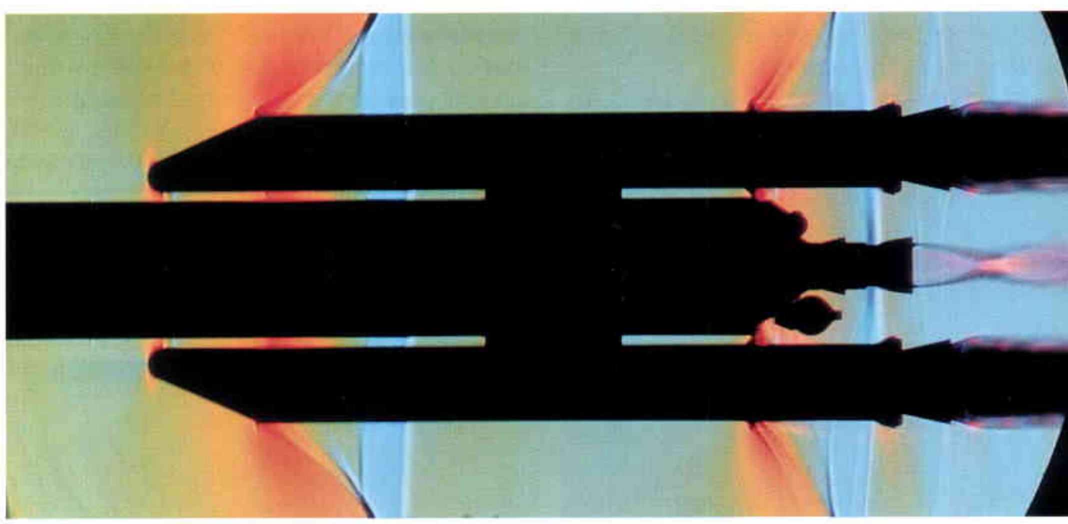


Figure 11. Schlieren photograph of an Ariane-5 flow field during testing at FFA in Sweden

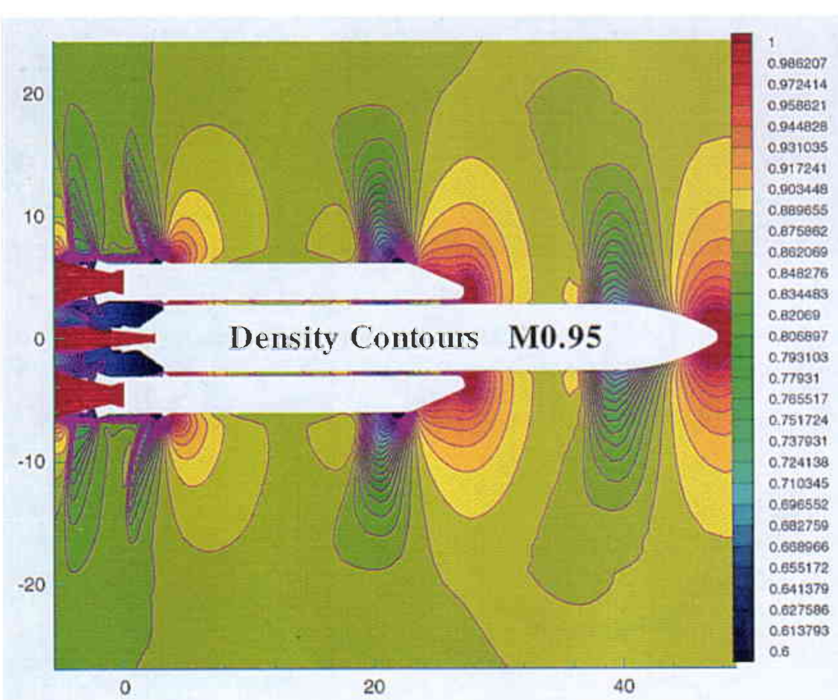


Figure 12. Density contours around the Ariane-5 launcher

Ariane-5 wind-tunnel model for the measurement of the unsteady buffeting loads using sensitive pressure transducers. The particularity of this model is that it also simulates the plume flow, using cold nitrogen gas, from the Vulcain main engine and from the Solid Rocket Boosters. Figure 11 shows a Schlieren photograph of the flow. The compression and expansion waves are clearly visible. Figure 12 shows three-dimensional Navier-Stokes unsteady flow computations at Mach 0.95.

FESTIP

ESA's Future Space Transportation Investigation Programme (FESTIP) has been implemented to examine future reusable launcher concepts that could be of interest for Europe. For FESTIP, aerodynamic activities were concentrated on generating aerodynamic and aerothermodynamic databases for each of the single-stage-to-orbit (SSTO) and two-

stage-to-orbit (TSTO) configurations and on the definition and follow up of the FESTIP technology programme in aerothermodynamics. The technology programme focussed mainly on the following critical points:
- roughness-induced boundary-layer transition
- turbulence modelling for shock-wave boundary-layer interactions
- flap efficiencies and heating
- base flow plume interaction
- flight measurement techniques
- air data systems.

As an example of this work, Figure 13 shows the computational grid of the FSS 5 configuration, which is an SSTO lifting body.

FLTP Programme
ESA's Future Launcher Technology Programme (FLTP) is now being prepared to continue the work undertaken within the FESTIP Technology Programme and is expected to start in 1999. Major aerothermodynamic activities which need to be pursued within the FLTP are:
- Improvement of measurement techniques such as:
  - pressure sensitive paint, infrared and phosphor paint techniques for heating analysis
  - stereo lithography for rapid model prototyping
  - standardised force balances for rapid testing in transonic, supersonic and hypersonic facilities.
- Simulation of hot plumes for base plume interaction for steady and unsteady loads.
- Stage separation loads, plume interaction loads, local micro-aerothermodynamic loads, buffeting on protuberances and base flows.
- Transition and turbulence modelling for shock/boundary-layer interactions.
- Interaction effects between aerothermodynamics, propulsion, structures and thermal protection.
- Propulsion system improvements: nozzle flow separation control, advanced nozzle concepts and integration.

During the FLTP it will be mandatory to maintain the following European aerothermodynamic facilities:
- the high enthalpy facilities: F4 at ONERA, HEG at DLR
- the plasma facilities: LBK at DLR, Simoun at Aerospatiale, Scirocco at CIRA, the plasmatron at VKI and the arc-heated facilities at IRS (Stuttgart University).

ESA's aerothermodynamic R&D activities
A series of TRP and GSTP activities have been initiated to prepare the technology needs for Europe's space programmes, including:
- Development and validation of three-dimensional nonequilibium Navier-Stokes codes combined with research on parallel processing to investigate the cost and time savings of executing aerodynamic codes on massively parallel computers.
- Validation experiments in hypersonic wind tunnels for the study of different types of boundary-layer transition mechanisms and turbulence modelling improvements for shock/boundary-layer interactions including the influence of hot wall effects.
- Scaling and extrapolation to flight conditions using NASA Shuttle Orbiter data for the study of the influence of real gas effects on trimming and flap efficiency. Testing in the F4 facility at ONERA and the shock tube HEG at DLR, to allow the comparison of wind-tunnel data with flight data using CFD.
- Testing instrumented tiles as flown on Japan's Hyflex reentry vehicle in the DLR plasma facilities for the study of micro-aero-thermodynamic phenomena such as tile gap filler heating and local boundary-layer transition.
- Improving Direct Simulation Monte Carlo codes for the study of satellite thruster plume interactions which cause forces, moments, heating and contamination.

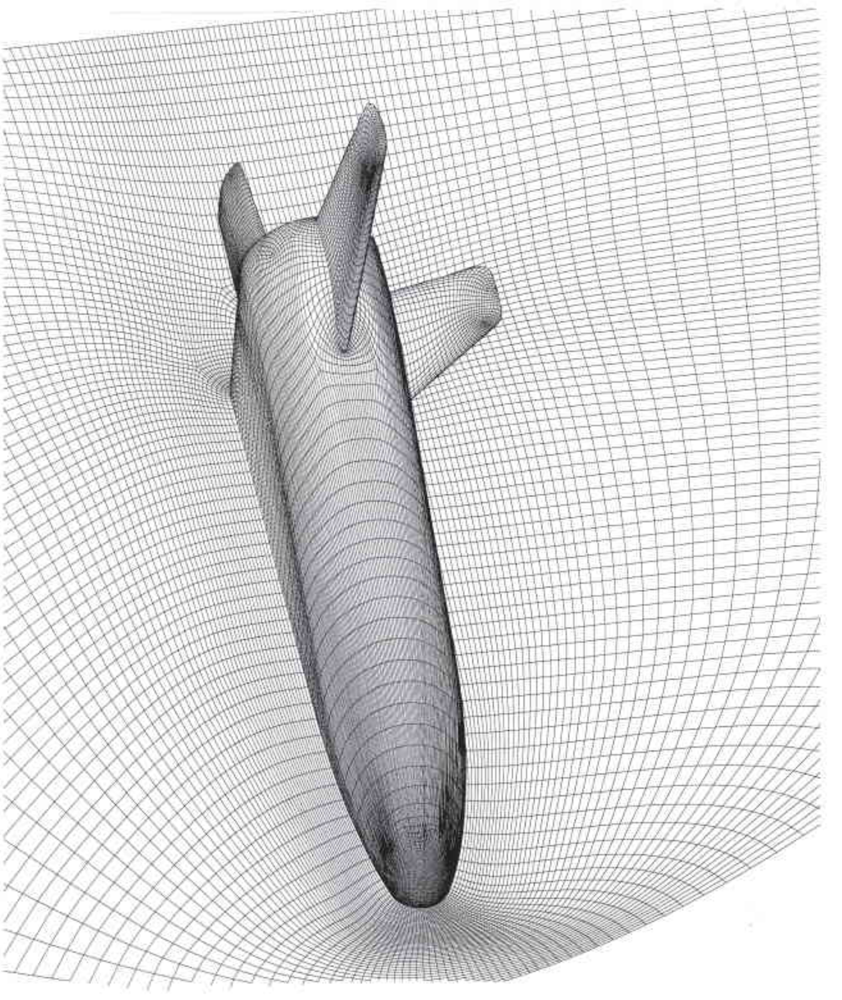


Fig. 13. Flow field computational surface grid around the FESTIP FSS 5 reusable launcher (ESTEC)

- Optimising force balances for dynamic-derivative testing using free and forced oscillation techniques for blunt body configurations such as the Huygens Probe, the ARD and the X38.
- Experimental study of base flow buffeting on simple and complex configurations such as the Ariane-5 launcher, including cold plume effects at transonic flow.
- Experimental and numerical studies of external expansion nozzles (plug nozzles) (Figs. 14, 15 & 16a,b) and nozzle flow separation control mechanisms for improved propulsion performance at sea level.
- Aero-thermochemistry database creation and standardisation including multi-phase flows.
- Aerodynamic analysis tool development for preliminary design.

International collaboration

Collaboration with partners outside Europe on specific items such as the Shuttle Orbiter and X38 with the USA, the Hyflex reentry vehicle with Japan and plasmatron test facilities with Russia have been very useful. An improved understanding has been obtained on critical hypersonic design problems such as the influence of real gas effects on vehicle pitch trim and flap efficiency, and tile gap heating and determination of the catalytic effects of thermal-protection-system tile coatings.

- In cooperation with the USA, NASA Shuttle Orbiter models were tested in the ONERA and DLR High Enthalpy facilities in exchange for NASA Langley wind-tunnel and flight data. This resulted in a good understanding of the use of these real gas facilities in the design process (Fig. 17).

- In cooperation with Japan – as part of an ESA/Japan Exchange Agreement – a combined experimental and numerical

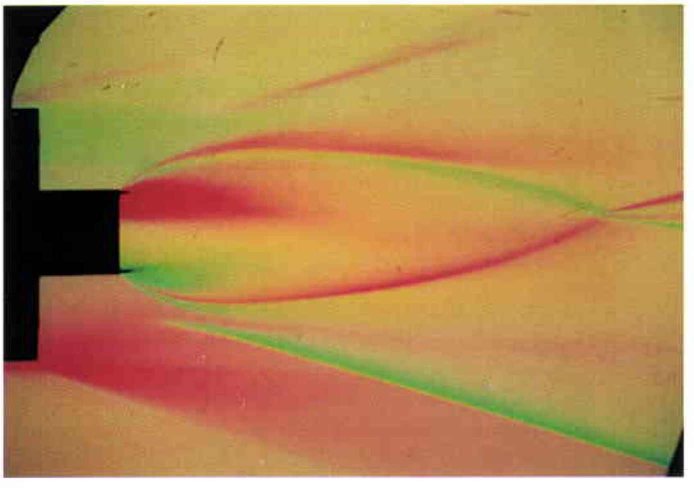


Figure 14. Schlieren photograph of the flow field from a plug nozzle (Technical University Delft)

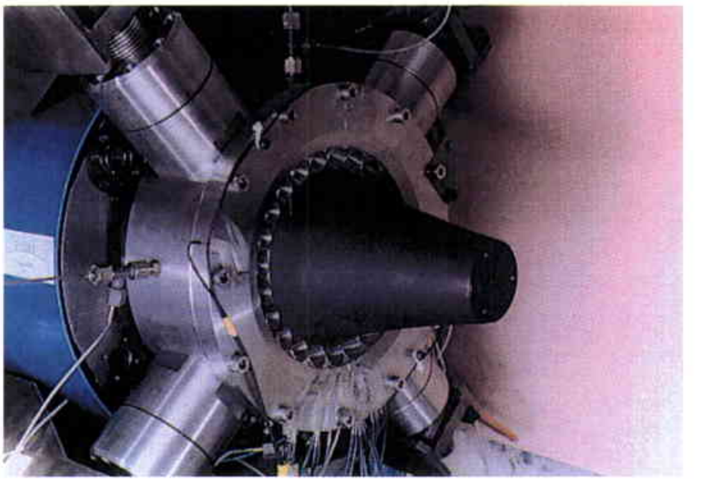


Figure 15. A clustered plug nozzle in the ONERA Ch4 test facility

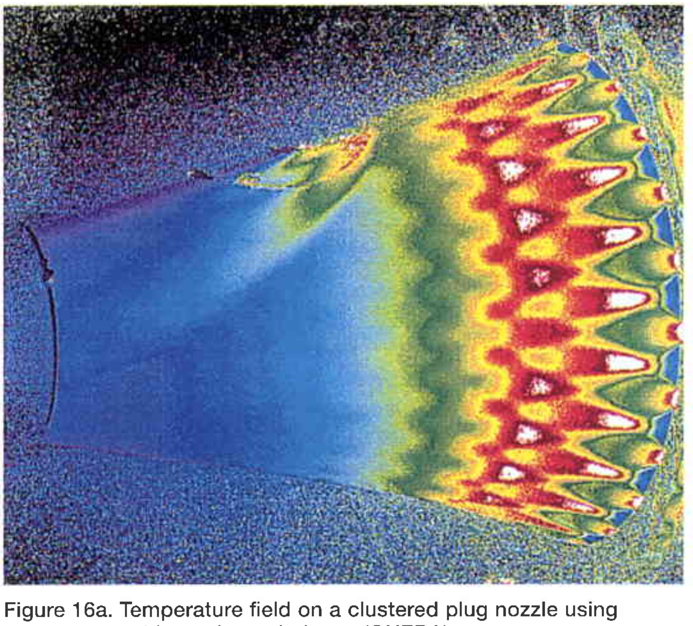


Figure 16a. Temperature field on a clustered plug nozzle using pressure-sensitive-paint techniques (ONERA)

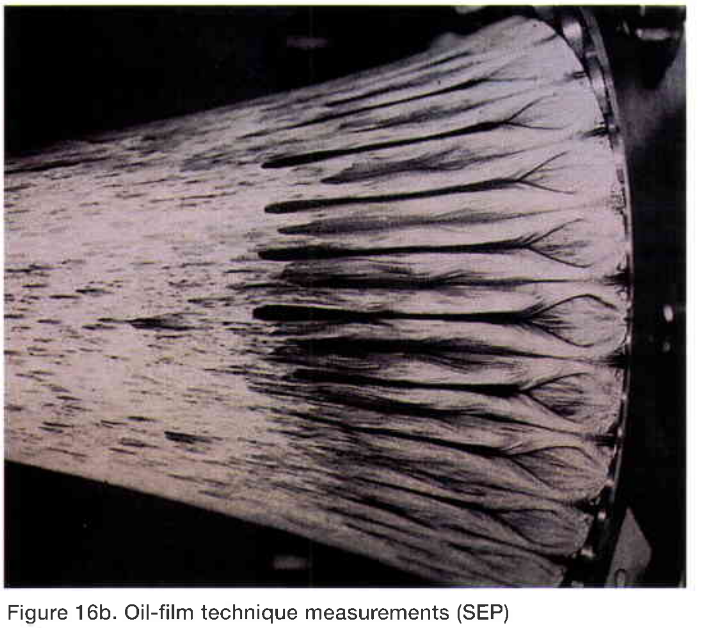


Figure 16b. Oil-film technique measurements (SEP)

activity is underway in the DLR LBK facility to study the heating between tiles flown on Japan's Hyflex reentry vehicle. The objective is to compare plasma wind-tunnel data with flight data and to analyse scaling and wind-tunnel-to-flight extrapolation issues. CFD plays an important role in these wind-tunnel and flight rebuilding activities (Fig. 18).

- In cooperation with Russia, a series of very useful activities have been performed including the examination of lessons learned from the Russian reentry vehicles Bor and Buran and the use of Russian facilities for database creation for validation, especially for thermal-protection-system testing. Of particular importance is the Russian expertise in plasmatron design, manufacture and testing for gas surface interaction effects: ablation, oxidation, ageing and coating catalytic behaviour. A strong collaboration has been embarked upon with VKI (B) for which the Agency has funded a completely new 2 MW plasmatron – the world's largest (Fig. 19).

Conclusion

This article has presented the wide scope of aerothermodynamics for aerospace vehicles and has traced ESA's activities in this field over the last 10 years – since August 1988 – when the Aerothermodynamics Section was first implemented at ESTEC. Aerothermodynamics has emerged as an important discipline, which is essential to enable the design of advanced launchers, reentry vehicles and advanced propulsion systems.

The Agency is sponsoring European industry and research laboratories in developing efficient numerical and improved experimental tools for aerothermodynamic design and verification. ESA's technology research programmes in aerothermodynamics have already helped European industry to increase its competence in this field. ESA has set up a coherent research programme to meet the needs of space projects. However, in order to maintain European expertise in CFD and experimental techniques, a continuing investment is essential. For the future, ESA will continue to pursue its objective of strengthening European aerothermodynamic capabilities by coordinating European efforts and by promoting close collaboration between universities, research establishments and industries. esa

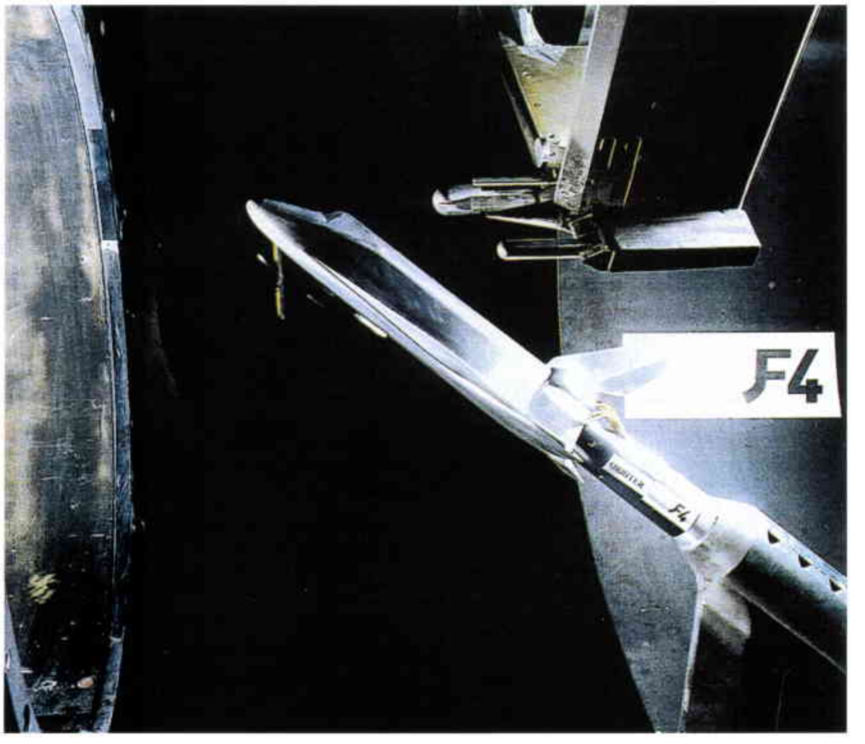


Figure 17. NASA orbiter model in the ONERA F4 High Enthalpy wind-tunnel

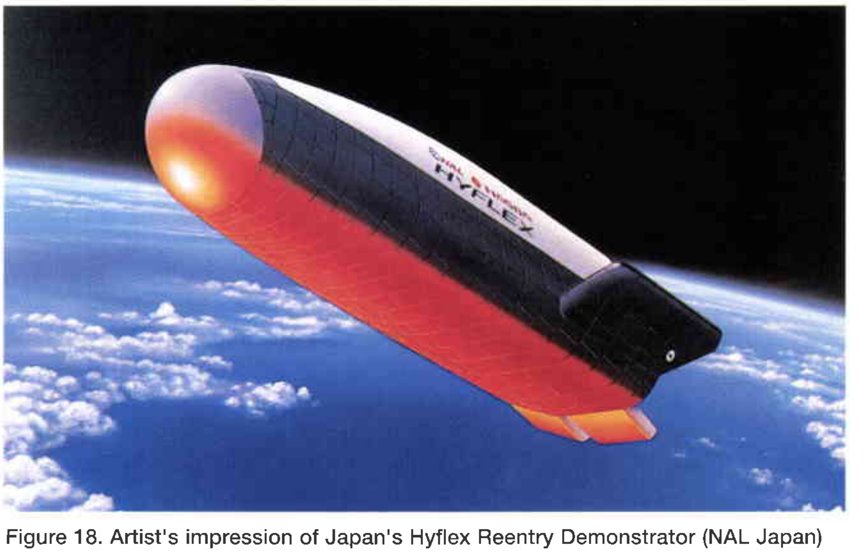


Figure 18. Artist's impression of Japan's Hyflex Reentry Demonstrator (NAL Japan)

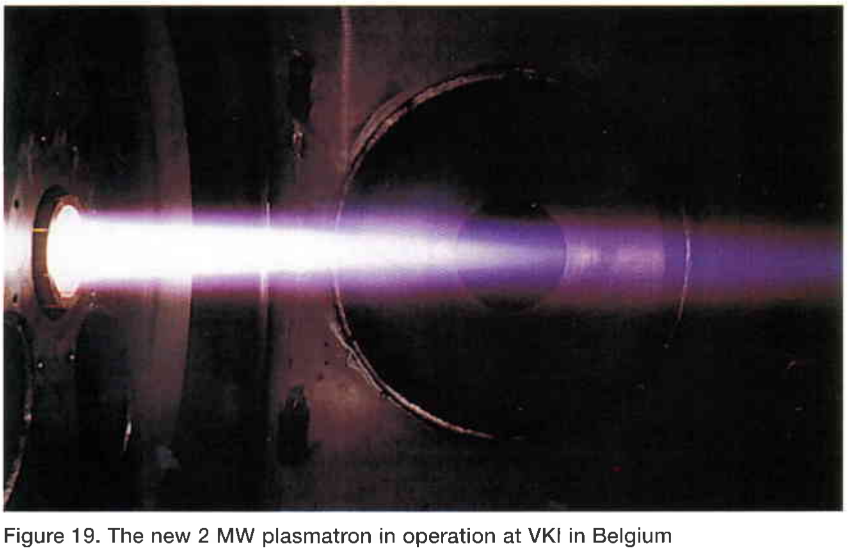


Figure 19. The new 2 MW plasmatron in operation at VKI in Belgium

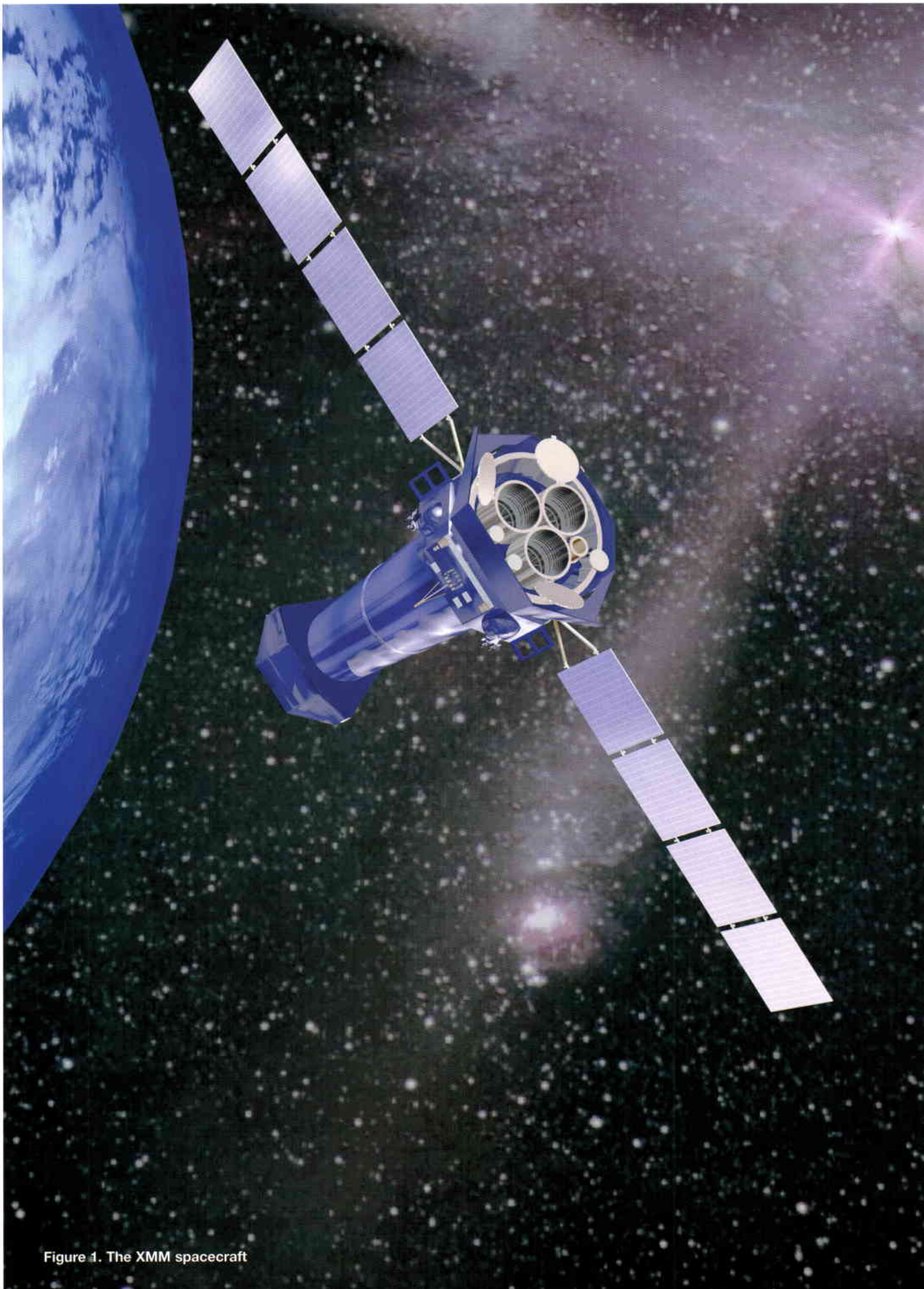


Figure 1. The XMM spacecraft

The XMM Simulator - The Technical Challenges

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The XMM satellite will be launched in August 1999 and a simulator has been developed to test and validate the supporting ground segment. Due to the very tight schedule and the high fidelity of the modelling required, this development effort has provided numerous unique challenges. This article details these challenges and the approaches that have been taken in meeting them, as well as the simulator's architecture and current status.

The XMM project

ESA's X-ray Multi-Mirror (XMM) observatory mission involves both a space segment and a ground segment. The former consists of the XMM satellite itself and the Ariane-5 launcher that will be used to put it into orbit. The ground segment consists of the Control Centres (MOC: Mission Operation Centre and SOC: Science Operations Centre), the ground facilities, the ground stations and the Science Survey Centre (SSC).

The XMM satellite (Fig. 1) is an observatory mission that will operate in the soft X-ray portion of the electromagnetic spectrum. The heart of the mission is therefore the X-ray telescope, which consists of three large mirror modules and associated focal-plane instrumentation, held together by the telescope central tube. Three scientific instruments have been selected, each of which is being developed by a separate multinational team. Each instrument team is headed by a Principal Investigator (PI) who has overall responsibility vis-a-vis ESA for the delivery of the working hardware and associated services. The three instruments that have been selected for flight are: the European Photon Imaging Camera (EPIC-MOS, EPIC-pn), the Reflection Grating Spectrometer (RGS) and the Optical Monitor (OM).

The XMM ground segment consists of the elements shown in Figure 2. The MOC will be located at ESOC in Darmstadt (D), the SOC at Villafranca near Madrid (E), and the SSC in Leicester (UK). Contact with the satellite will be maintained via the ESA ground stations in Kourou (French Guiana), Perth (W. Australia) and Villafranca during the mission's Launch and Early Orbit Phase (LEOP), and via the Kourou and Perth stations during the routine mission phase.

The MOC is responsible for mission operations planning and scheduling, execution of the schedule, satellite safety and recovery from satellite anomalies, maintenance of spacecraft-platform onboard software, and instrument-anomaly recovery in real-time liaison with the SOC. The SOC, in turn, is responsible for all science operations, including observation planning and monitoring, observation-proposal handling, payload software maintenance, and data distribution to the scientific community.

XMM simulator requirements

An XMM MOC simulator (MOCSIM) is required to test and validate the MOC data systems. It will be used to:

- test and validate the XMM Mission Control System (XMCS) and the Flight Dynamics System (FDS)
- validate the XMM MOC operational database
- test and validate the flight-operations procedures (both nominal and contingency) and the operations time line
- validate the procedures to support System Validation Tests (SVTs) and end-to-end tests
- train the Flight Operations Team.

The MOC simulator is also the data source for the simulation programme, which involves the complete mission-operations team both for the LEOP and routine mission phases.

Similarly, an XMM SOC simulator (SOCSIM) is required to test and validate the SOC data systems. It will be used to:

- test and validate the XMM Science Control System (XSCS)
- validate the XMM SOC operational database
- test and validate the instrument operation procedures (both nominal and contingency)
- validate the procedure to support System Validation Tests (SVTs) and end-to-end tests
- train the Science Operations Team.

The SOC simulator will be the data source for the SOC simulation programme.

The high-level requirements for MOCSIM are:
- accurate simulation of the XMM platform
- software emulation of CDMU (Control and Data Management Unit) and ACC (Attitude Control Computer) onboard processors to allow the actual onboard software to be executed at binary-code level
- functional modelling of the XMM instruments, with accurate modelling of the housekeeping instrument telemetry and dummy modelling of the science telemetry
- identical interface to the MOC as the actual ground-station equipment for telecommand uplinking (Telecommand Encoder: TCE) and telemetry downlinking (Telemetry Processor: TMP4)
- possibility to introduce simulated failures or special effects in all platform subsystems, and to a limited extent in the instruments, during the execution of a simulation run.

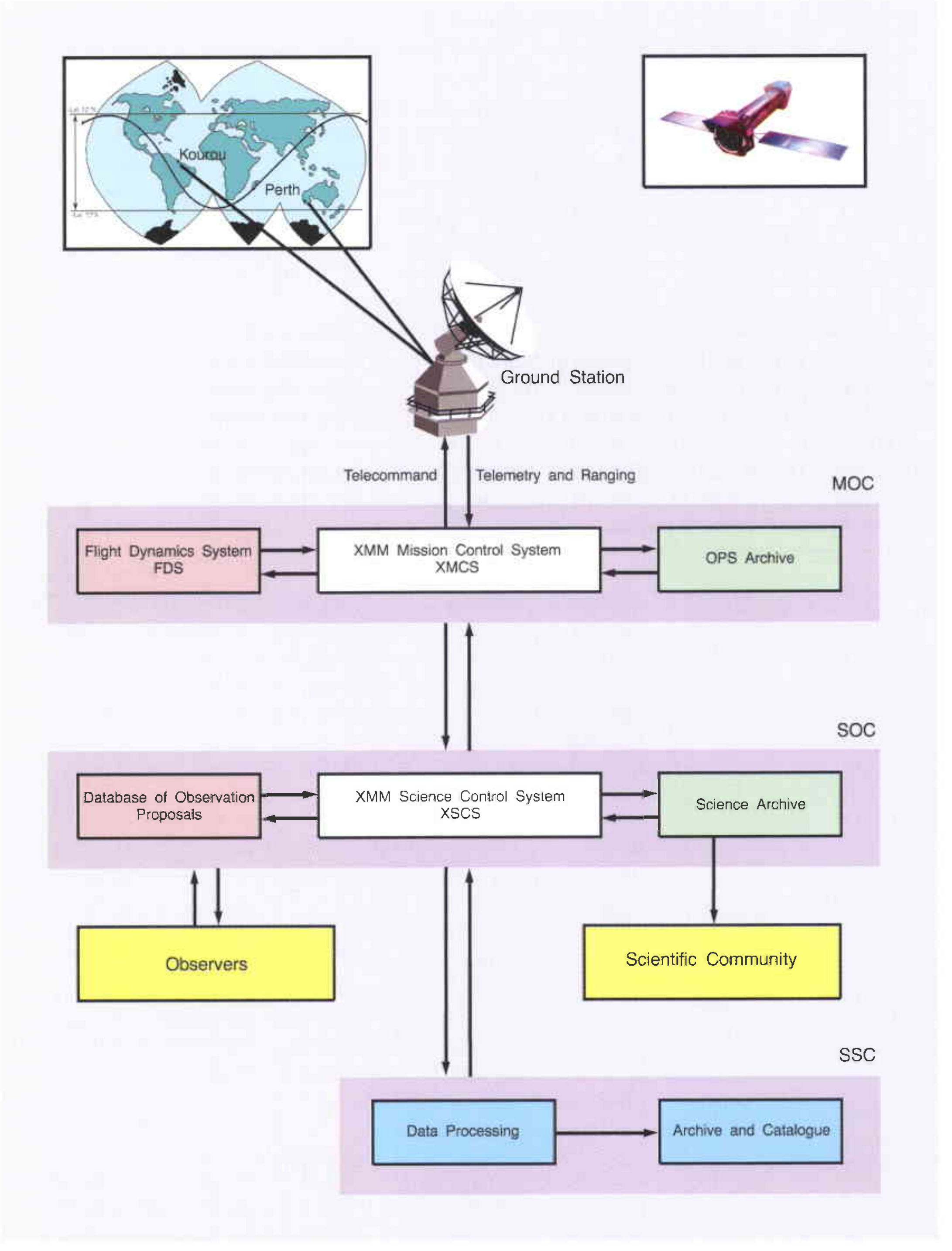

Figure 2. The XMM ground segment

The high-level requirements for SOCSIM are:
- accurate functional modelling of OBDH for all related instrument functions
- accurate modelling of instruments
- software emulation of the various instrument-controller processors to allow actual instrument software to be executed (only one instrument is required to be emulated at a time)
- accurate functional modelling of the instrument software of the processors that are not emulated
- playback of science data recorded with the actual instruments
- possibility to define at run-time which instrument is emulated
- possibility to introduce failures or special effects in all instruments.

Both MOCSIM and SOCSIM are real-time simulators, based on SIMSAT (Software Infrastructure for the Modelling of SATellite). SIMSAT is a standard ESOC infrastructure which provides the core functionality of any simulator: real-time kernel, event scheduling, public data management, logging, commanding, graphical user interface, modelling of such ground-station equipment as telecommand encoders and telemetry processors. Both simulators also make maximum use of standard ESOC generic models and have been developed in Ada to run on DEC-Alpha workstations.

The MOCSIM and SOCSIM modelling requirements are summarised in Table 1 on a subsystem-by-subsystem basis.

As can be seen from Table 1, the requirements for the two simulators are different, although similarity in some of the requirements suggests that a certain amount of synergy between MOCSIM and SOCSIM could be applied. Unfortunately, only 2.5 years were available for the complete development effort, from the review of user requirements to delivery of the

Table 1. MOCSIM and SOCSIM subsystem requirements

Subsystem	**MOC modelling**	**SOC modelling**
Radio Frequency	Accurate	Fixed (TM and TC flow only)
OBDH Bus	Accurate	Accurate
CDMU Processor and Software	Emulated	Functional
CDMU Hardware	Accurate	Realistic (to allow TC/TM flow)
ACC Processor and Software	Emulated	Not required
ACC Hardware	Accurate	Fixed
Attitude Sensors (Sun Sensors, Gyros)	Accurate	Not required
Actuators (Reaction Wheel, Thrusters)	Accurate	Not required
Star Tracker	Accurate	Not required
Orbit and Environment	Accurate	Not required
Dynamics	Accurate	Not required
Power Generation and Distribution	Accurate for platform and instruments	Fixed for platform, Realistic for instruments
Thermal	Accurate for platform and instruments	Fixed for platform, Realistic for instruments
RGS	Accurate for HK Fixed for science	Accurate for HK Accurate for science Science data file playback Emulated and functional IC
EPIC-MOS	Accurate for HK Fixed for science	Accurate for HK Accurate for science Science data file playback Emulated and functional IC
EPIC-pn	Accurate for HK Fixed for science	Accurate for HK Accurate for science Science data file playback Emulated and functional IC
OM	Accurate for HK Fixed for science	Accurate for HK Accurate for science Science data file playback Emulated and functional IC
EPIC Radiation Monitor	Accurate for HK Fixed for science	Accurate for HK Accurate for science Science data file playback
TCE	Realistic	Realistic
TMP4	Realistic	Realistic

Note: The following terminology is used: Accurate: modelling to a declared tolerance, Realistic: modelling such that parameter trends can be observed, Fixed: no dynamic modelling is applied.

complete system. Such a short time frame did not allow elements developed for one simulator (e.g. CDMU modelling of MOCSIM) to be reused as a baseline for the development of the other. It was therefore decided to merge the two sets of requirements and to develop a single simulator, the XMM simulator, which would meet both MOC and SOC requirements.

The implementation of the XMM simulator, as summarised in Table 2, reflects the merged MOCSIM and SOCSIM User Requirements. This table indicates the level of modelling (functional or software emulation) and whether or not a generic model is used.

The XMM simulator has been developed for ESOC by an industrial consortium led by Vega PLC, with Vitrociset as subcontractor. The user requirements and software requirements have been defined by ESA, with the involvement of the consortium during the software requirements phase. The architectural and detailed design phases have been performed by Vega/Vitrociset under firm fixed-price conditions, based on the XMM Simulator Software Requirements Document (SRD). The SIMSAT TCE and TMP4 ground models were developed in parallel by an industrial consortium led by TERMA, with SSL as subcontractor.

Challenges and solutions

The developers of the XMM simulator were confronted with two major challenges: the high fidelity of the modelling needed and the very tight schedule, which together have been the main drivers for the design and development approach adopted.

The high-fidelity modelling requirement resulted in numerous technical challenges, in particular:
- simulator design as close as possible to the satellite and instrument design
- high number of software emulators and its impact on the computer resources
- large number of possible configurations.

As for any major software development, the underlying software infrastructure and development environment were also key factors. Ultimately, all of these challenges had to be addressed and solutions found which would ensure the fidelity of the modelling without drastically impacting schedule and budget.

Schedule

The development schedule for the XMM simulator allows just 2.5 years from User Requirements Review to delivery of the complete simulator, which is a very tight schedule indeed for such a large software project. It is made even tougher by the need to incorporate spacecraft design changes arising during the development.

Incremental deliveries of the simulator have to be released at Launch–11 months (launch baselined for 2 August 1999), Launch–10 months, Launch–8 months and Launch–5 months to allow time for the validation of procedures and the simulation campaign. There is little flexibility within the schedule to allow for satellite design changes, major problems, etc.

The XMM simulator schedule (Fig. 3) is dependant on external information being provided to the development team as Customer Furnished Items (CFIs). A set of CFIs was identified for each simulator subsystem, with due dates 2 weeks prior to the start of work on the subsystem itself. This allowed the satellite design to be followed accurately and guaranteed that the most up-to-date data (documentation, database or software) would be used.

A major CFI for the simulator development is the Prime-Contractor-delivered Satellite Database (SDB). It is common to most of the work packages since it defines the telecommand and telemetry formats and contents. It is also used to generate the configuration files for the On-Board Data Handling (OBDH) model. Like the rest of the satellite design, the SDB is continually

Table 2. XMM simulator subsystems

Subsystem	Modelling	Generic Model
Radio Frequency	Functional	No
OBDH Bus	Functional	Yes
CDMU Processor and Software	Emulated	Yes
CDMU Hardware	Functional	Yes
ACC Processor and Software	Emulated	Yes
ACC Hardware	Functional	No
Attitude Sensors (Sun Sensors, Gyros)	Functional	Yes
Actuators (Reaction Wheel, Thrusters)	Functional	Yes
Star Tracker	Functional	No
Orbit and Environment	Functional	Yes
Dynamics	Functional	Yes
Power Generation and Distribution	Functional	Yes
Thermal	Functional	No
RGS	Functional and Emulated	Yes
EPIC-MOS	Functional and Emulated	Yes
EPIC-pn	Functional and Emulated	Yes
OM	Functional and Emulated	Yes
EPIC Radiation Monitor	Functional	
TCE	Functional	Yes
TMP4	Functional	Yes

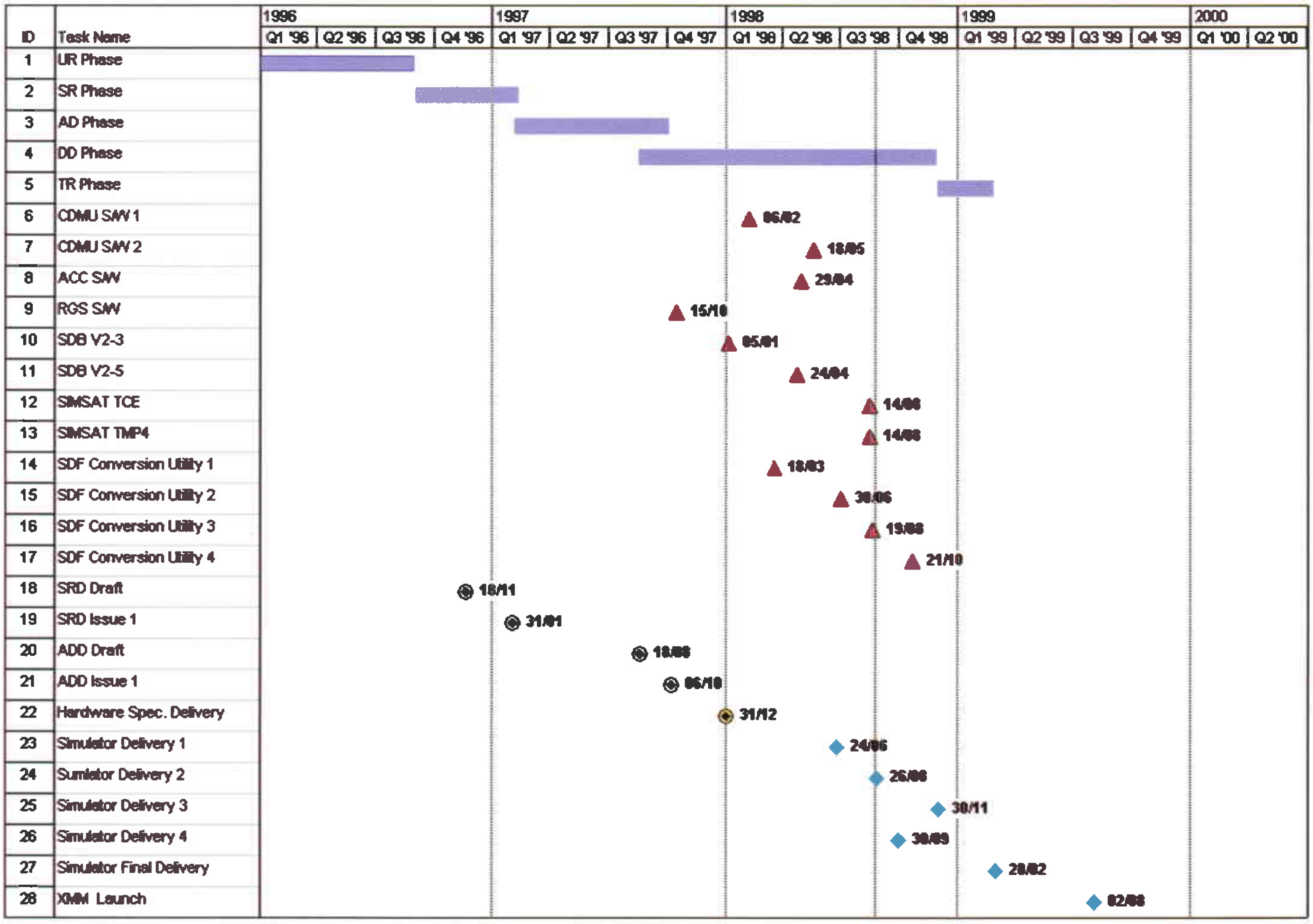

Figure 3. Schedule for the XMM simulator's development

changing, and will continue to do so up to and beyond the launch. The design approach, as presented later, has allowed the impact of these SDB changes on the design of the XMM simulator to be minimised.

Following the spacecraft design
Despite the fact that the XMM simulator was to be built under a firm fixed-price contract, its development had to be performed following a 'design-to-design' policy whereby the simulator had to shadow the 'evolving design' of the real XMM satellite. This meant no fixed baseline, which further increased the complexity of the development from both the technical and managerial viewpoints. The design baseline has been managed via a controlled set of satellite design information sources provided by ESOC as carefully selected and monitored CFIs. The Simulation Section at ESOC has been the focal point for the flow of information between the XMM Project and the XMM simulator development team. In order for the design-to-design policy to work, this information flow had to be maintained throughout the simulator and XMM satellite development efforts.

Payload modelling
The accurate modelling required for the XMM payload is a good example of the challenges implied by the above policy. The very complex XMM instruments are being developed by scientific institutes, under extreme time pressure. Consequently, immediate access to design information has not always been possible. The simulator development team has therefore had to make assumptions concerning the designs of the different instruments. Because of the latter's uniqueness, these assumptions have had to be carefully validated to ensure that the simulator design remained in line with that of the instruments. As it was not possible to overly divert the instrument Principal Investigators from their own critical development work, special Workshops were organised for each instrument, bringing together the scientists, XMM project staff and the simulator development team.

Science data files
The baseline for the XMM simulator was to play back science data recorded from the actual instruments. Early in 1997, however, it was recognised that science data covering all operational modes would not be available from ground testing. An alternative source of data had therefore to be identified. The Science Simulator (SciSIM) developed by ESA Space Science Department seemed a good

candidate, although the data (Observation Data File - ODF) that it generated would need to be modified for compatibility with the architecture and design baseline foreseen for the XMM simulator. An offline utility (XMM Science Data File Conversion Utility) was developed to convert ODF into Pre-IC data files usable by the XMM simulator. This task had to be performed in parallel with the development of the XMM simulator, and was defined to fit in with the various XMM simulator deliveries. The XMM simulator development team actively participated in the review and acceptance of the Science Data File conversion utility.

Emulation and computer resources
The XMM simulator has to cope with three software emulations of an MA31750 processor implementing the MIL1750A instruction-set standard. Software emulations had already been used in previous ESOC simulators, but XMM was the first simulator to require three emulators running in parallel (CDMU, ACC and one of the instruments). In any simulator, the most demanding computer resource by far is the emulator. Early indications based on previous projects showed that running three emulators could be feasible on a high-end DEC Alpha mono-processor workstation. Since there was a small risk involved with the approach, a detailed performance analysis was made during the architectural design phase.

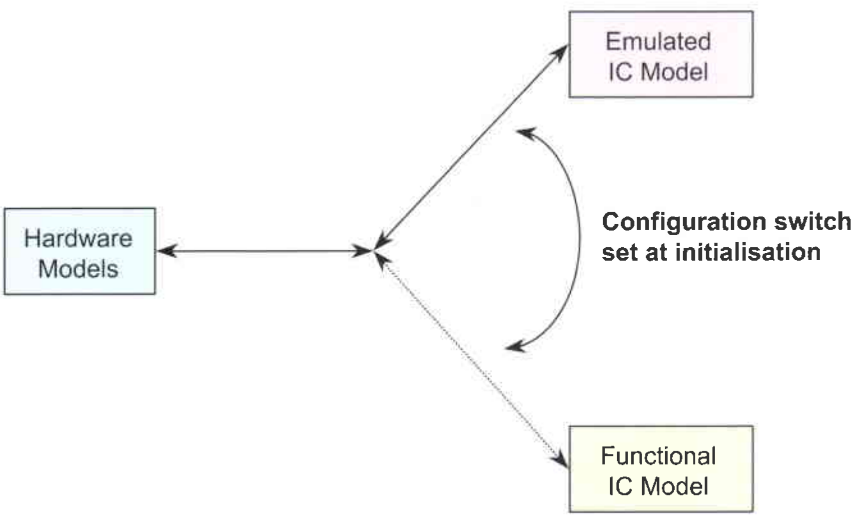

Figure 4. Instrument configuration selection

That performance analysis revealed that the MA31750 processor used by XMM was significantly more powerful and therefore more demanding in terms of computer resources than the 1750 and 31750 processors used on previous satellites. Computer resource projections were made for the different XMM onboard software items to be emulated, taking into account their characteristics (processors, clock speed, wait states), to obtain the projected CPU requirement of the XMM simulator. This showed that running three emulators would be extremely marginal on a mono-processor workstation. All of ESOC's earlier simulators had been targeted to mono-processor workstations and SIMSAT had never been used or tested in a multi-processor/multi-thread environment. An analysis carried out to identify potential problems, and to validate the core of the simulator architecture, concluded that a multi-thread/multi-processor architecture was indeed feasible and would not require any modifications to SIMSAT. The choice was therefore made to adopt this architecture and to run the XMM simulator on a DEC Alpha dual-processor workstation (DEC AXP 1200).

Simulator configurations
The simulator configurations define whether a functional or an emulated model is to be configured for each of the instruments. The XMM simulator has seven possible configurations, which can be conveniently selected using the SIMSAT MMI (man/machine interface). A configuration 'switch' in the instrument models is then used to select either the functional or emulated processor model (Fig. 4).

New ground and generic models
The XMM simulator is the first user of the new SIMSAT TCE and TMP4 ground models developed in parallel with the simulator. These are the first SIMSAT ground models to implement the ESA telemetry and telecommand packet standard. Due to their size and complexity, their delivery date was close to that of the XMM simulator, leaving very little time for integration and end-to-end testing. Fortunately, with SIMSAT the interface between spacecraft models and ground models is standardised. Moreover, the XMM development team was involved in the requirements reviews for these models, which helped to avoid incorrect assumptions being made on either side.

Architecture of the XMM simulator
The general architecture of the XMM simulator is shown in Figures 5 and 6. Its main characteristics are as follows:

- The breakdown into simulator subsystems reflects the satellite subsystems, for example RF, OBDH, power, thermal, etc. Interfaces between subsystems in the simulator then become identifiable against the actual satellite design, interface documents, etc.
- The interfaces between subsystems are minimised to aid design and ultimately simplify integration.
- Each subsystem can be viewed as a 'module'with an OBDH bus connection point, power network connection points, and thermal connection points. This is an

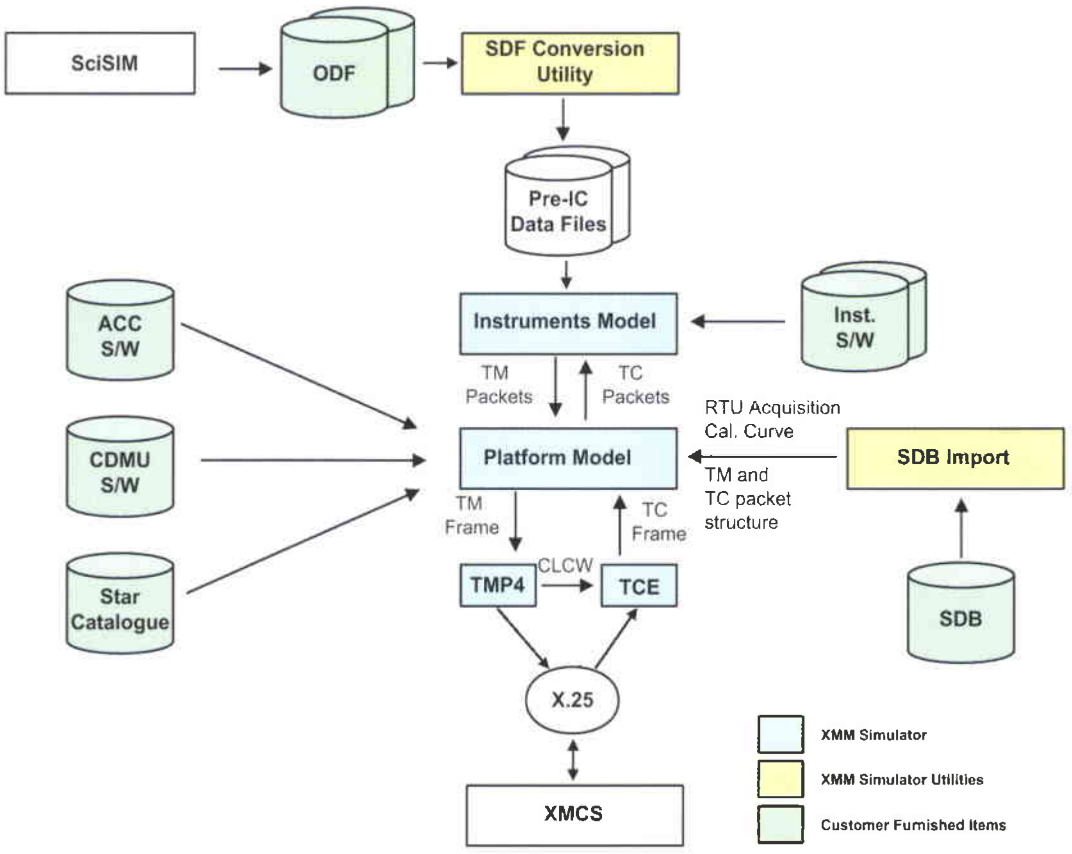

Figure 5. XMM simulator interfaces

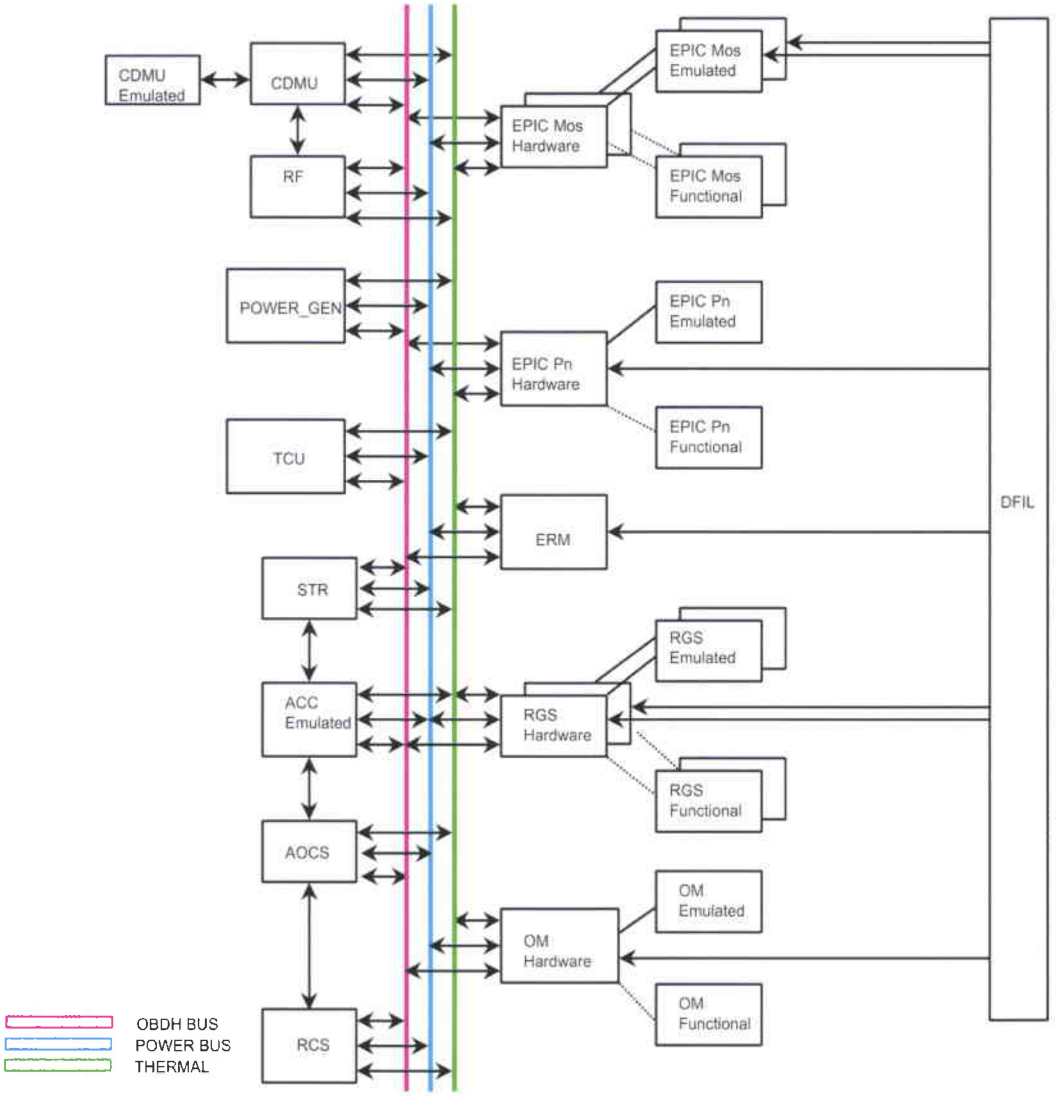

Figure 6. XMM simulator architecture

important feature since it allows for incremental deliveries of the simulator, each delivery adding new subsystems and functionality. Integrating a new subsystem into the simulator within the defined architecture 'only' involves connecting it to the OBDH bus, power network and thermal network.

- The instrument models are configurable as emulated or functional models. For commonality and efficiency reasons, both emulated and functional models use the same memory models, and access the hardware models through the same I/O interface models.
- The OBDH Remote Terminal Unit (RTU) model is initialised from files auto-generated from the Satellite Database (SDB). This file sets up the RTU commands, acquisitions and calibration curves used during analogue-to-digital conversions. This is an important feature since it minimises the impact of SDB changes on the OBDH models. Most changes in the contents of the SDB with respect to OBDH bus traffic only require the re-generation of the configuration files and then start up of the simulator. This has obvious time benefits not only during simulator development, but also for simulator maintenance.
- The XMM simulator has a telemetry decoder facility, which processes telemetry packets produced by the CDMU system. Analogue telemetry parameters are displayed in both engineering and raw format. The telemetry-decoder facility allows simulator operation without the XMM Control System, which is extremely useful during the simulator's system and acceptance testing. Like the OBDH RTU model, it uses configuration files auto-generated from the SDB, with the same benefits.

Current status

The first XMM simulator delivery was made at the end of June 1998, and the second at the end of August. The latter, which at the time of writing is still under acceptance testing, consists of a full platform model, including emulation of both the CDMU and ACC software. It currently runs on the target workstation in a mono-processor configuration. The third delivery, which will add one instrument, namely RGS, and implement the multi-processor architecture, is under final coding and testing and will be released at the end of September. The complete simulator will be released at the end of November 1998. A final delivery, incorporating corrections to any errors found during the user acceptance of the simulator, will take place at the end of February 1999.

Conclusion

The XMM simulator is an ambitious project due to the combination of the high fidelity of the modelling required and the very tight implementation schedule. To ensure that its design would closely mirror that of the satellite, the Customer Furnished Items that have been used in the simulator's development have been selected and monitored with considerable care. The simulator's architecture has been designed to take full advantage of the DEC Alpha multi-processor workstation in order to support the high number of configurations required. Maximum use was made of the ESOC infrastructure and expertise in order to cope with the strict schedule and budget constraints, and in seeking appropriate solutions to each of the challenges that would satisfy all parties. In the event, the very good co-operation between all parties involved - the XMM Project, Science and Operations Teams, the ESOC Simulation Section, and XMM Simulator Development Team - has been one of the key elements in this development project's success. esa

SILEX: The First European Optical Communication Terminal in Orbit

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Optical communication is presently in a rapid expansion phase, since it offers a considerable growth potential to the constantly increasing useful transmitted data rate demand. Planned constellations of communication satellites will benefit from the use of optical communication's ability to transmit the increasingly higher data rates with compact, low-mass terminals, while avoiding interference problems and radio frequency band saturation. In addition to semiconductor lasers and highly sensitive wide bandwidth optical communication sensors,optical communication implies utilisation of a wide range of leading-edge technologies, e.g. ultrastable structural materials, high-precision pointing mechanisms, large CCD matrices, fast digital signal processing, high precision optics, optical coatings with high reflectivity or narrow filter bandwidth and accurate thermal control.

In 1991 the development phase of an optical communication system, SILEX (Semi-Conductor Inter Satellite Link EXperiment) was started with MMS (F) as prime contractor leading a large European consortium.

The step from the optical bench in the laboratory to an optical terminal in orbit is enormous. This step was achieved when PASTEL (PASsager TELecom) on SPOT-4 was successfully launched on 22 March 1998.

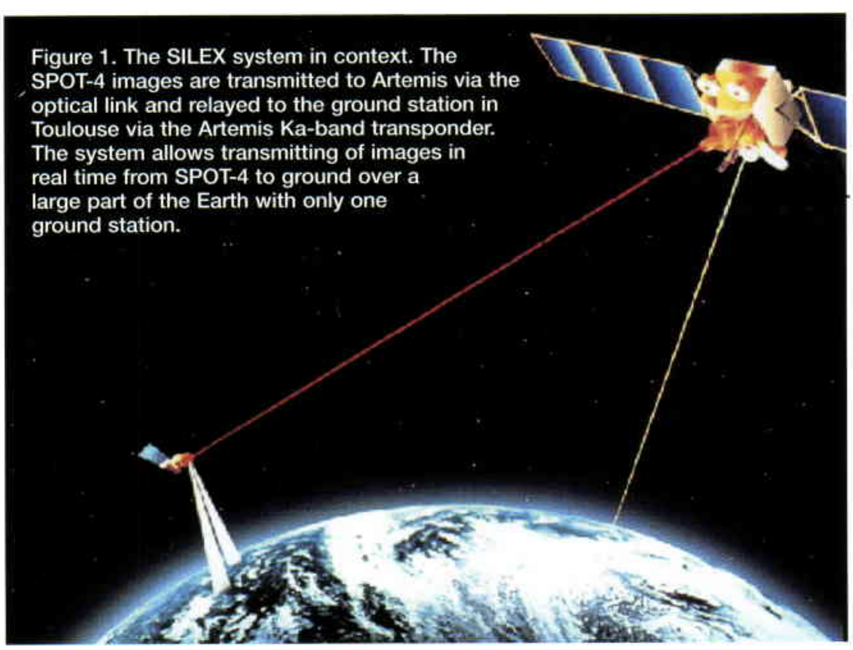


Figure 1. The SILEX system in context. The SPOT-4 images are transmitted to Artemis via the optical link and relayed to the ground station in Toulouse via the Artemis Ka-band transponder. The system allows transmitting of images in real time from SPOT-4 to ground over a large part of the Earth with only one ground station.

The SILEX mission

The SILEX system comprises two optical terminals: PASTEL on board the French earth observation satellite SPOT-4 and OPALE (Optical PAyload for Inter Satellite Link Experiment) to be embarked on the European communications satellite Artemis.

The objectives of SILEX are to perform optical communication link experimentation in orbit and to transmit SPOT-4 imagery to Artemis, which will relay it to the ground via its Ka-band payload. The use of the Artemis satellite in a high geostationary orbit allows communications to be achieved between SPOT-4 and its ground facilities in Europe over a much greater area of the globe than can be achieved directly (Fig. 2).

While SPOT-4 is already in orbit the full SILEX experiment cannot be carried out until Artemis is launched in early 2000. However, in spite of the missing partner, an in-orbit test programme has been undertaken, successfully performing all the internal calibrations, acquiring and tracking selected stars, and characterising the dynamic interaction between the host platform and the terminal.

PASTEL in-orbit performances

A particular problem to be overcome in the design and operation of optical links is that of signal acquisition and tracking. The divergence of the communication beam is only 8 µrad, which is several orders of magnitude lower than the open-loop pointing accuracy of a typical orbital platform. This is why a dedicated acquisition sequence must be undertaken where, while both terminals coarsely point to each other in open loop on the basis of spacecraft orbital models, OPALE on Artemis systematically scans a wide-angle (750 µrad) beacon beam in the direction of PASTEL on SPOT-4. When PASTEL is illuminated by the beacon beam, it rapidly corrects its line of sight and directs its narrow communication beam towards OPALE. Similarly OPALE detects the incoming PASTEL signal, aligns its line of sight, and transmits its narrow communication beam towards PASTEL. The two terminals then remain locked on each other in closed-loop tracking and the communication begins. Furthermore, due to the finite velocity of light

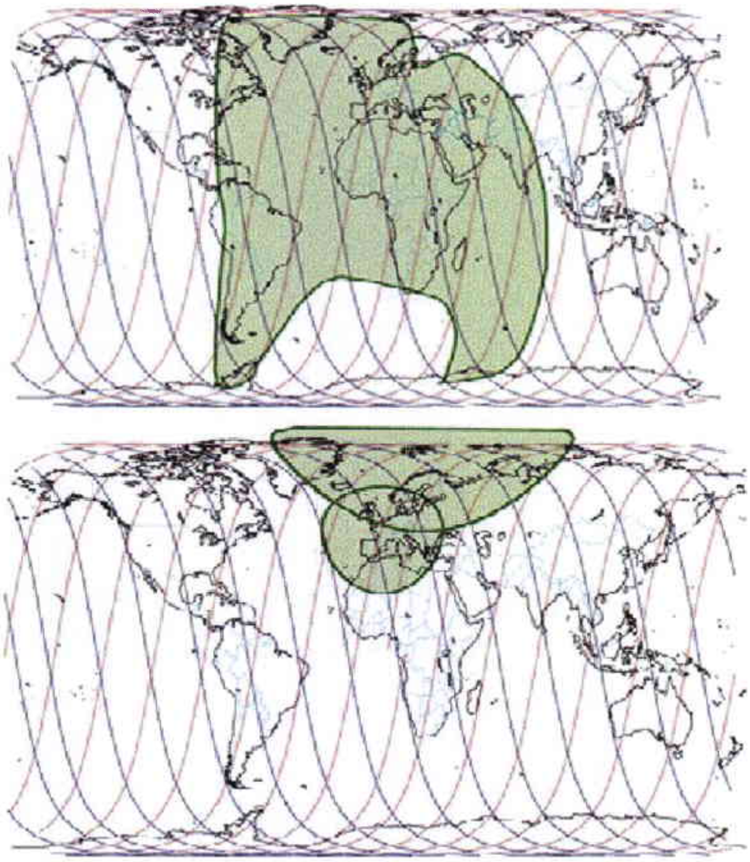


Figure 2. The ground coverage where real-time images can be relayed via Artemis to the ground stations in Toulouse (upper figure) compared to the coverage from the direct X-band link from SPOT-4 to the ground stations in Kiruna and Toulouse (courtesy CNES)

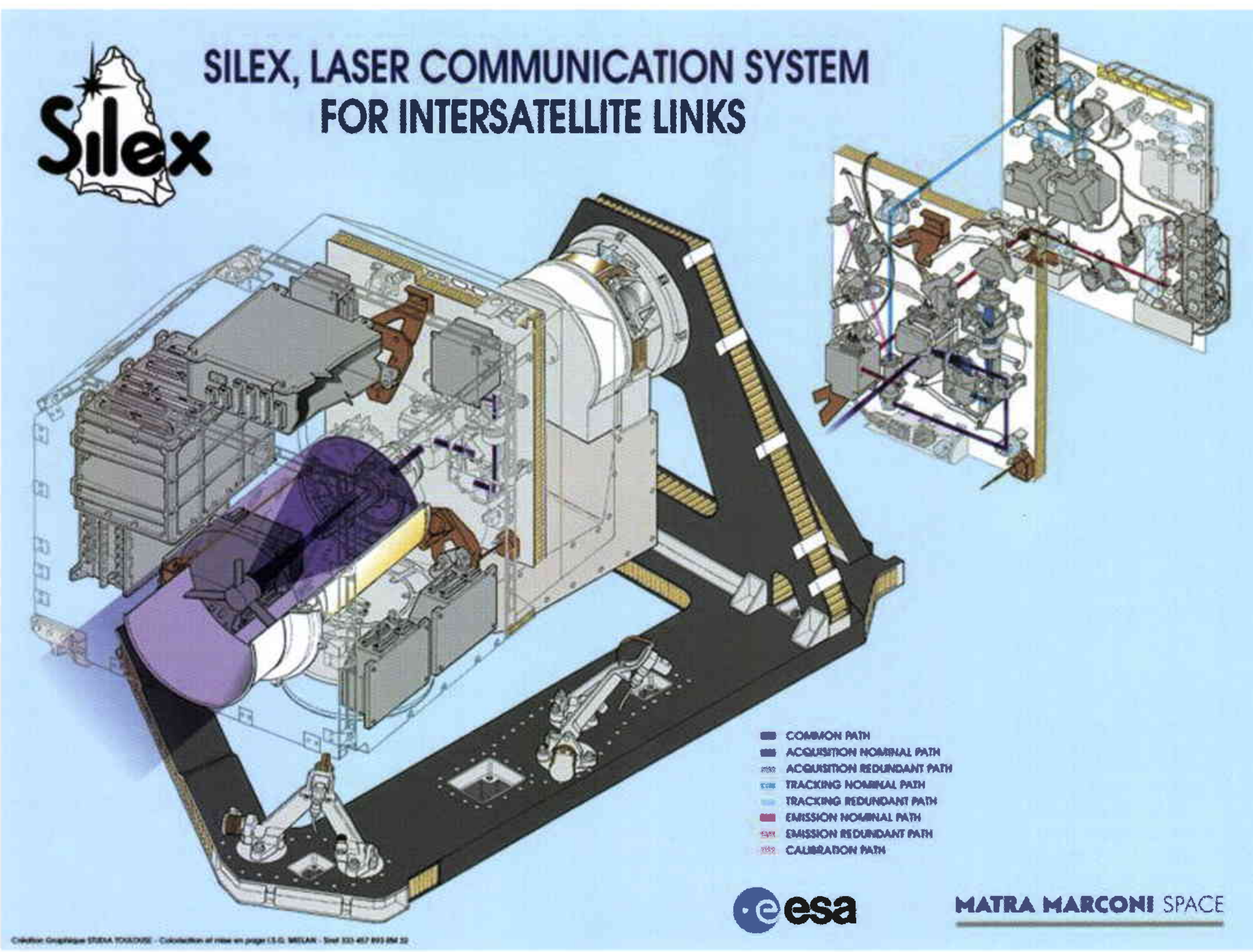


Figure 3. X-ray view of a SILEX terminal. The telescope and optical bench is located on the mobile part, which is mounted on a gimbal with a hemispherical pointing range. On the optical bench are located the acquisition and tracking sensors, the communication sensors, the laser diode transmitter packages, the fine pointing mechanism, the point-ahead mechanism, and all the necessary optical relays and filters.
The telescope mirrors and main structural elements are made of Zerodur. The acquisition and tracking sensors are based on CCD matrices, the laser diodes are of the GaAlAs type (0.8 µm), and the communication detectors are avalanche photo-diodes

Figure 4. The optical terminal PASTEL, located on the anti-Earth side of the SPOT-4 platform (photo courtesy CNES)

and the transverse velocity of the two host satellites, the transmitted beam must be offset with respect to the received beam direction by the so-called 'Point Ahead Angle'. This angle in the case of GEO-LEO communication is up to 70 µrad. The two terminals autonomously calculate the pointing directions based on orbital models of the two satellites. Because of the criticality of these operations it has been highly desirable to verify them as far as possible. In the absence of Artemis in orbit this has been achieved using a series of stars.

Arcturus, Betelgeuse and Sirius have each been successfully acquired and tracked several times, all at the first attempt. No acquisition failure has been observed, despite the fact that the irradiance from the stars is in some cases below the minimum beacon signal from OPALE and orders of magnitude below the telecom signal from OPALE. The terminal open-loop pointing error has also been demonstrated to be very small with respect to the acquisition field of view of 8000 µrad (Fig. 5).

Open loop error in µrad	x	y
Average	-333	251.5
Max from average	645	177.5

The time necessary to detect the incoming signal, correct the 'Line of Sight' and enter closed-loop tracking has been demonstrated to be only 90 ms.

The tracking error, which due to the very low incoming power level is dominated by quantification errors, has been shown to stay within the allocated budget with significant margins.

Tracking error		
1 σ µrad	Ex	Ey
Sirius	0.12	0.19
Arcturus	0.12	0.19
Betelgeuse	0.10	0.12

Internal calibrations allow measurement of the alignment stability between the reception optical path and the emission optical path. This stability over a typical communication session duration is as low as 0.1µrad in the worst case.

Calibrations of acquisition and tracking sensors and of laser diode transmitters have confirmed the good health of this essential equipment.

The temperature stability of the optical bench has been measured to be better than 0.2°C, which is promising for stable emission wavelength and alignment stability.

Conclusion

The conclusion of a detailed in-orbit test campaign is that PASTEL is in very good health and that the verified performances are excellent. Another important conclusion is that the ability to predict pre-flight the in-orbit performances, through a combination of both test and modelling, has now been validated.

Although the first optical intersatellite communication link will only be completed in early 2000 with the launch of OPALE, the present achievement of successful launch and demonstrated in-orbit test performances of PASTEL puts Europe a step ahead in the development of next-generation space telecommunication systems. esa

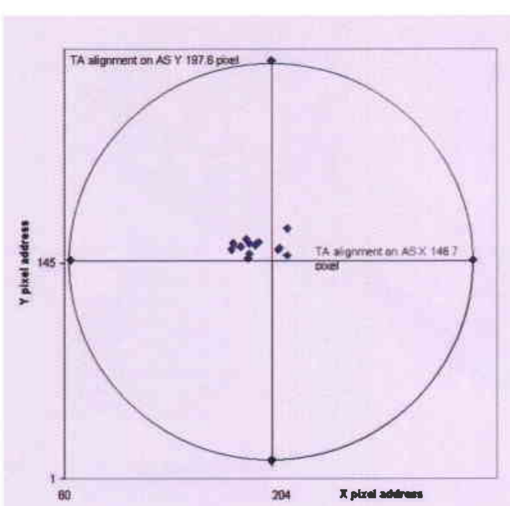
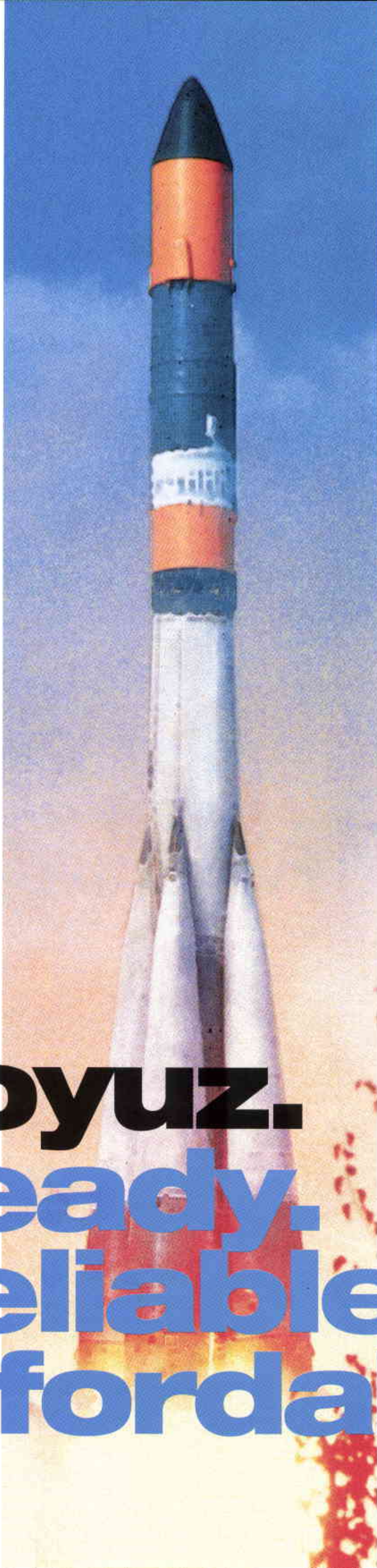


Figure 5. The open-loop pointing error of PASTEL compared to the acquisition field of view. The figure represents the first detected pixel position on the acquisition sensor during 12 star acquisitions performed over a period of one month. No in-orbit correction of alignments has been performed



Integrated Monitoring and Control: A New Approach

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This article presents the architecture of a new integrated monitoring and control system that has been implemented for several of the ground-segment subsystems involved in the processing and dissemination of the vast quantities of data produced by the Agency's ERS satellites.

Introduction

The System Monitoring market has evolved dramatically in recent years, due mainly to the need to guarantee the quality of a service to the users. Whilst in the early 1990s almost all system monitoring was performed using specially designed and proprietary software, with the evolution of networks and network-management tools industry has now developed a wide offering of Monitoring and Control (M&C) products and consolidated standards.

A series of technological and infrastructure projects run at ESRIN since 1995 have shown that the commercial network-management tools and standards fully satisfy not only the network-monitoring requirements, but also those related to the platform and higher level applications resources. This results from the commonality of requirements in the M&C area regardless the type of information handled.

Following this trend, some of the original M&C subsystems of the European Remote-Sensing Satellite (ERS) ground segment have been replaced with a new system called 'MIMS' (Multi-mission Integrated Monitoring System). MIMS monitors internal subsystems, the Internet servers of the Earth Observation User Services at ESRIN, and the outsourced commercial telecommunication links used in the ground-segment network. One of the applications monitored is the ESRIN Interface Sub-Set (ISS), an application whose main task is to provide data-exchange services (at file-transfer level) between the various ERS ground-segment entities (facilities).

Integrated monitoring and control in the exploitation of Earth-observation satellites

High-level indicators of Quality of Service (QoS) guide the exploitation of Earth-observation missions. The types of indicators used range from processed-data availability, to mission-planning performance. Their continuous monitoring and control is essential to guarantee the desired quality of service, provide early warnings of critical situations, prevent adverse impacts on the mission, and facilitate tight control over any anomalous situation that might arise.

The QoS indicators are used to monitor a series of heterogeneous systems, starting with the satellite and its payload and ending with the various ground-segment subsystems. A traditional M&C environment based on each subsystem's functionality allows only a scattered collection of information, which means that the synthesis of the overall QoS status remains difficult. Continuous monitoring of mission QoS can be only performed through an Integrated M&C environment, in which data is collected by a system with a specially conceived, and thereby unique architecture. Information can then be made available to operators and administrators directly involved in the maintenance of any ground-segment subsystem, as well as the managers of the overall exploitation activity.

In summary, the Integrated M&C system is essential for a complex ground segment in order to efficiently:
- highlight any anomaly for corrective action
- detect the cause of a problem, avoiding parallel investigation by different subsystem managers
- support the configuration-control and anomaly-handing tasks
- collect activity and status information to provide a graphical status representation and activity statistics.

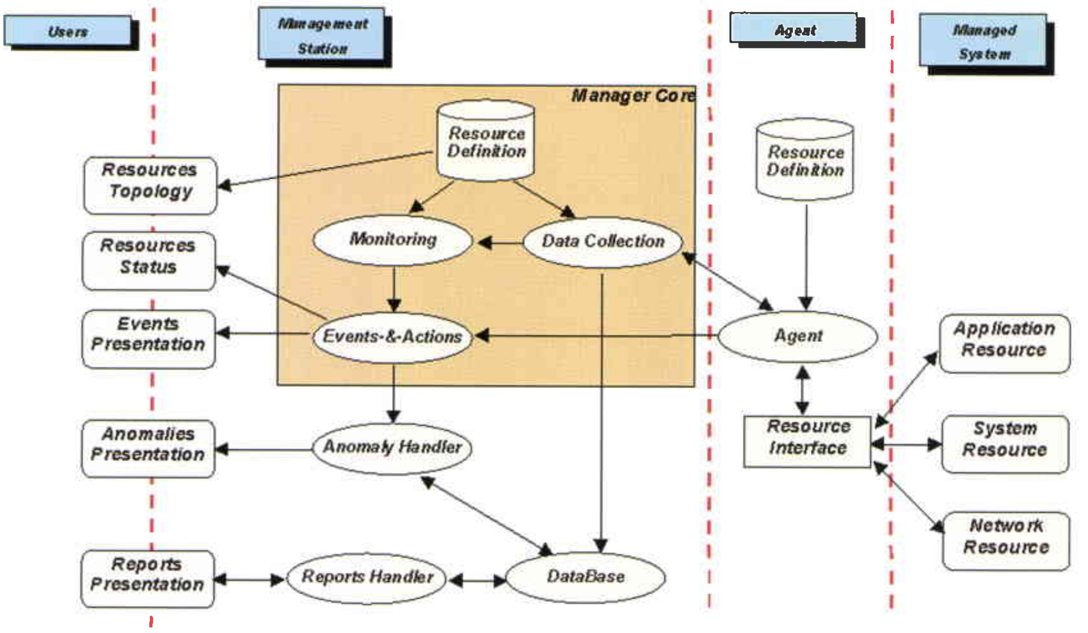


Figure 1. M&C functional model

The performance required of such a system and the complexity of the environment in which it must operate represented the main challenges during the MIMS development.

M&C functionality

MIMS is accessed and distributes information to users mainly via a World-Wide Web (WWW) interface which shows the topology of the ground-segment elements being managed and resource status as coloured icons. It also provides warning messages (e-mail, pop-up windows and event browser interface) to the operators to flag asynchronous events.

The key concept of MIMS is to gather together as much system status information as is required to furnish a reliable picture of the operational situation of the ground-system components. This information is collected from the managed systems through M&C 'agents' and stored in a database for further analysis and presentation.

The MIMS Manager is the set of components providing central system management functionality. Its main functions are to:
- provide the user interface
- host the Management Information Base (MIB)
- interface the agents in the managed systems
- collect and store managed object data from the agent
- handle and store the asynchronous events
- handle and store anomalies
- generate statistics.

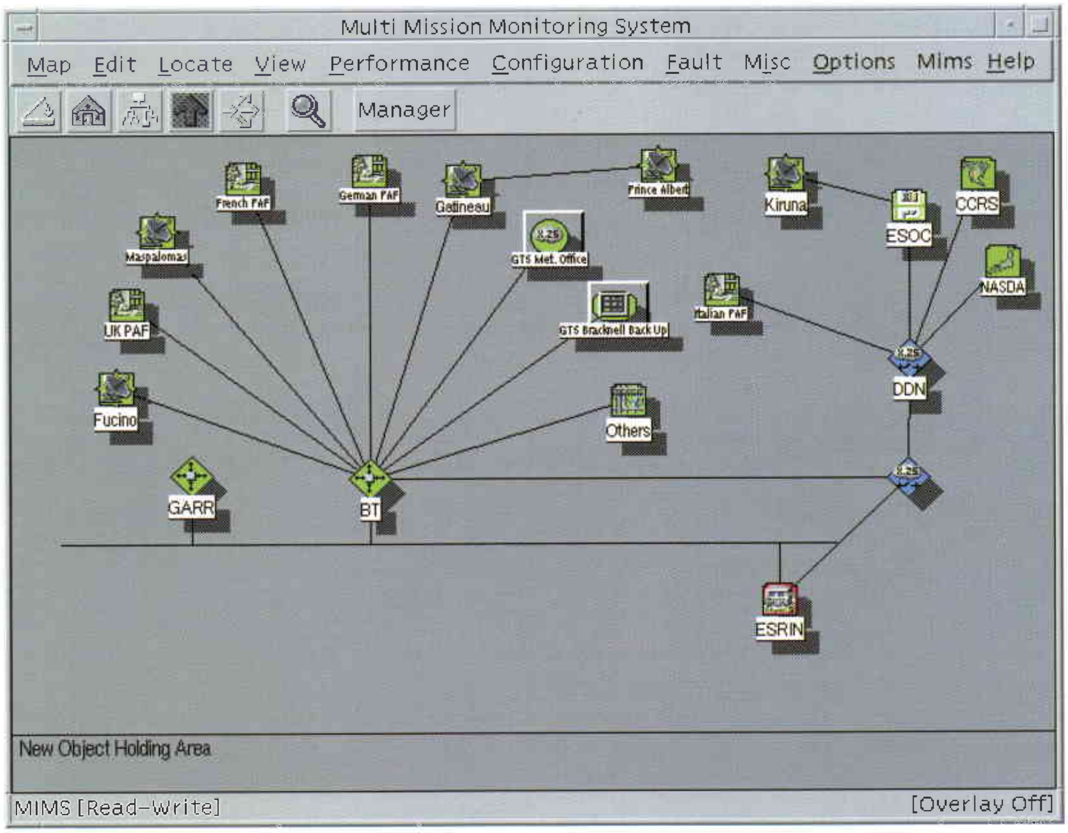
Object status definition and representation

Each monitored object has been represented by a set of maps and related sub-maps. The maps contain symbols (icons) that can be associated with a more detailed sub-map or an object resource (Fig. 2). This approach allows a hierarchical presentation of the managed objects, showing an increasing level of detail. Different maps can be used for defining different management regions, or for different presentations of the same management region. Multiple sub-maps can be displayed at any given time. The status of objects is represented by different colours with, for example, green showing good behaviour, meaning that all attribute values – disk mounted, occupation under a configured threshold, failures etc. – are nominal. An icon turning red indicates that an abnormal attribute value has been detected; double clicking on that icon will then show a dialogue box with the exact status of the item concerned.

Data collection and agent interface

The MIMS Manager and its agents support several protocols and interfaces. The standard interface is SNMP (Simple Network Monitoring Protocol) for IP networks, but the interface capability has been enlarged by a management link to CORBA (Common Object Request Broker Architecture) objects and integration of BMC's PATROL. The SNMP data collection is guided and controlled by the manager and it is intrinsically 'value-oriented': the manager system can obtain the value of a variable on the managed system and start configured actions depending on the sampled value. MIMS has implemented enhanced data-collection management, i.e. using logs, activity reporting, etc., and a collection database. SNMP's simplicity and minimal impact on the data transportation media makes it very useful for continuous monitoring, since the network is not loaded by the management traffic as it could be in the case of a CORBA-based monitoring, allowing a tight control on the application behaviour. SNMP is also useful for alarm-

Figure 2. MIMS user-interface sample: Map Browser for managed objects



sending in case of a resource crisis (disk full, network collapsing, etc.).

CORBA in the MIMS infrastructure
CORBA is an emerging standard for distributed infrastructure architectures, and as a consequence also in monitoring and control environments. CORBA and the CORBA collector are an experimental component within the MIMS monitoring architecture. CORBA agents can complement SNMP because they can be highly autonomous.

CORBA specifies a system, which provides interoperability between objects in a heterogeneous, distributed environment and in a way transparent to the programmer. Its design is based on the OMG Object Model. The latter defines common object semantics for specifying the externally visible characteristics of objects in a standard and implementation-independent way. In this model, clients request services from objects (which will also be called 'servers') through a well-defined interface. This interface is specified in OMG IDL (Interface Definition Language). A client accesses an object by issuing a request to the object. The request is an event, and it carries information including an operation, the object reference of the service provider, and actual parameters (if any). The object reference is an object name that defines that object unambiguously.

The ORB Core is the most crucial part of the Object Request Broker: it is responsible for the communication of requests. The basic functionality provided by the ORB consists of passing requests from clients to object implementations.

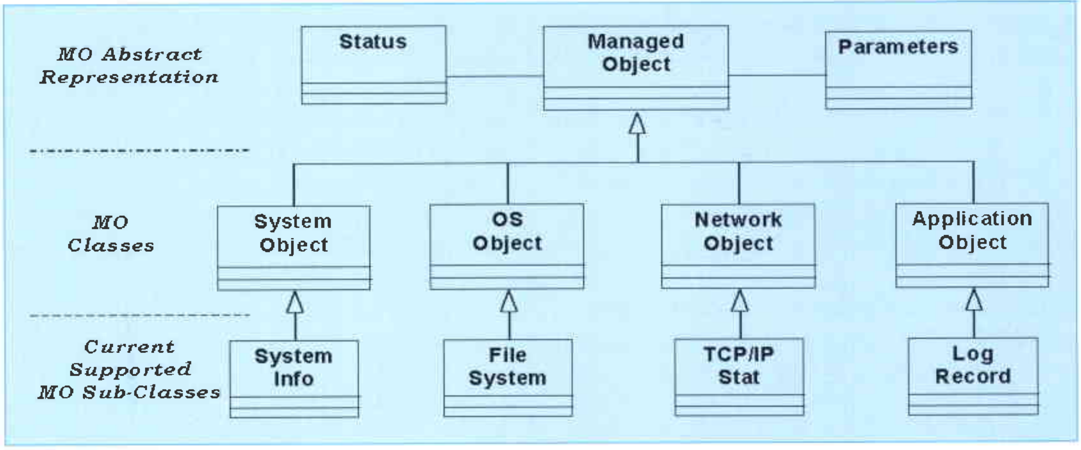


Figure 3. CORBA Managed Objects (MOs)

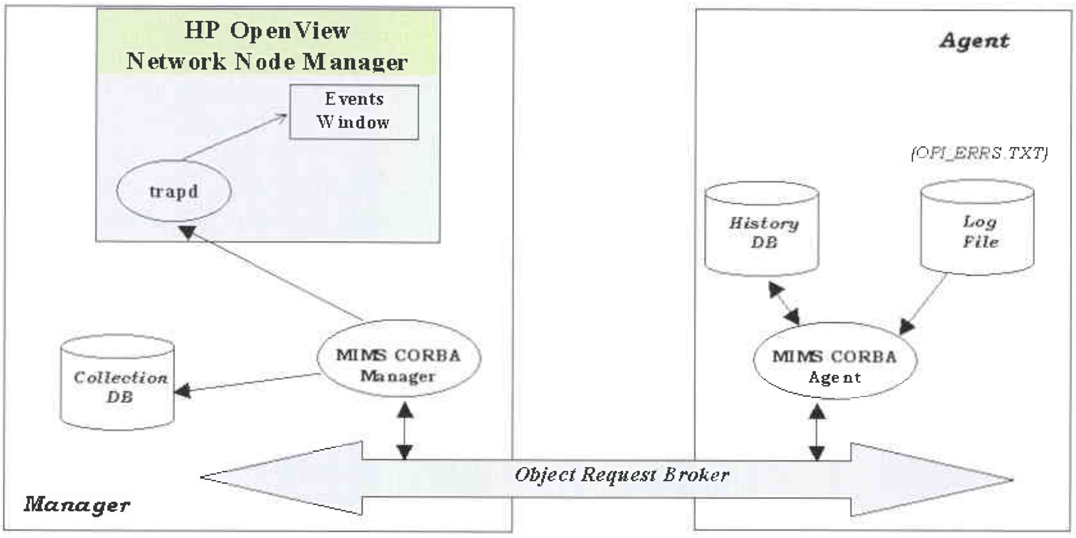


Figure 4. CORBA log-file manager-agent architecture

In the present MIMS CORBA Managed Object (MO) architecture (Fig. 3), any resource is represented by a general (abstract) object, i.e. an object of class MO (as reported in the model). Each of these objects has associated with it a number of parameters (depending on the type of resource) and an operational status.

While a MIMS CORBA-based agent needs to create the specific object type (FileSystem, LogRecord, etc.) in order to interface the resource (a file system, a log record, etc. – see Fig. 4), the manager only needs to have its abstract representation provided by an object of class MO. This approach allows the CORBA-based manager to have a common representation of all resources managed by the agents and the possibility to act on them in a consistent way.

CORBA's usage in MIMS is still considered an experimental infrastructure. The potential benefits of its distributed-object architecture within application-management systems are being evaluated and the correct engineering approach to the modelling of managed objects must be consolidated.

Event and anomaly handling

The SNMP Manager can also receive and processes asynchronous event messages as SNMP traps. The collector can also perform a threshold-based check on the collected data and internally generate an asynchronous event (Fig. 5). This will start user-defined actions if the received value is above a configured threshold, or if it returns below it. The M&C system is configurable to automatically insert an anomaly report into a database as soon as a certain abnormal situation is detected. The operator/manager should complete the report afterwards with remarks and solution proposals. The database contains an abstract and description of the problem, mission affected, downtime, related anomalies from other sources and more.

Statistics generation

The generation of exploitation activity statistics and reports for Management is an important task of the exploitation staff. The manual generation of such reports requires considerable effort. MIMS automates this task and efficiently produces high-impact reports based on templates and the collected data, every month, week, day or on request (Fig. 6).

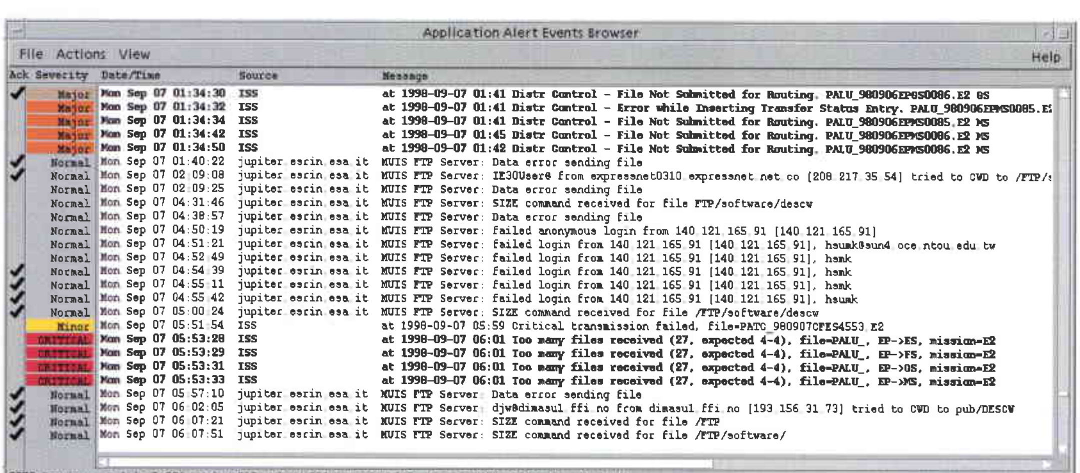


Figure 5. MIMS user-interface sample: Event Browser

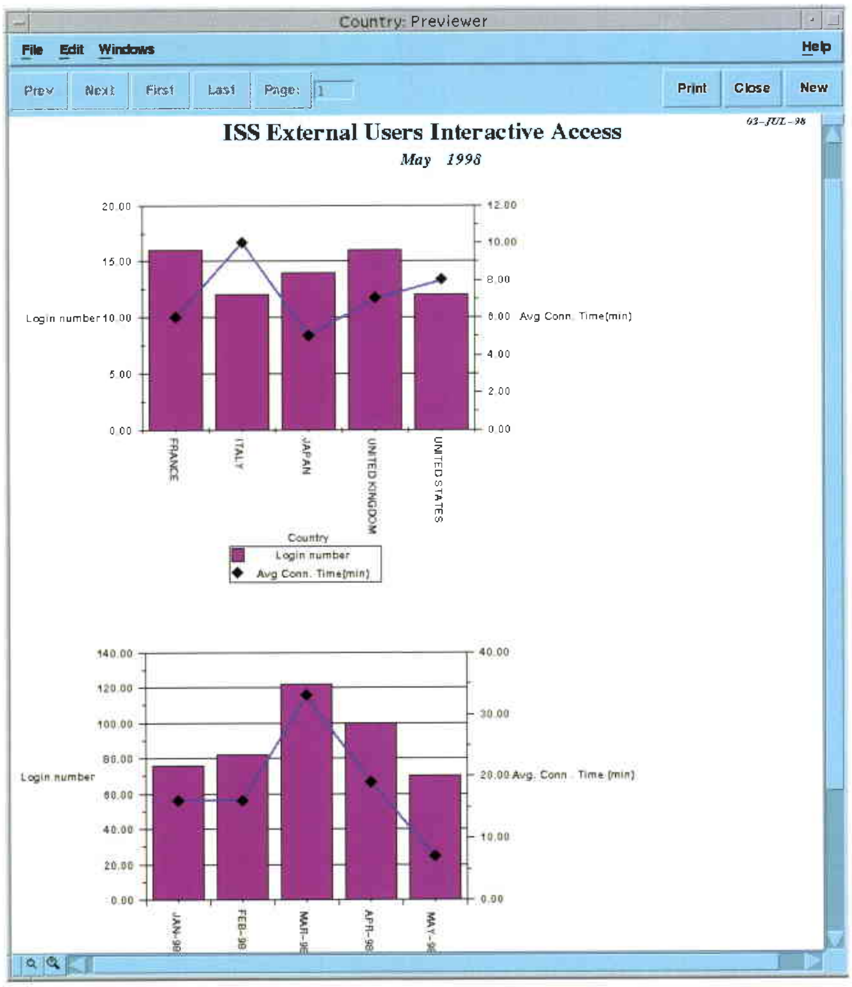


Figure 6. MIMS user-interface sample: Report Generator

Architecture

As noted in the introduction, an essential aspect of MIMS is the integration of commercial software packages. Figure 7 shows the various interacting components:

- HP OpenView Network Node Manager (basic MIMS basic management functionality set, such as IP network devices and interfaces discovery, SNMP protocol-management station, managed-objects representation through hierarchical configurable maps, event-handling infrastructure, SNMP data collection, simple collected data-analysis capability)
- HP OpenView SNMP Extensible Agent (SNMP agent for Sun/Solaris systems)
- DEC-OpenVms SNMP Extensible Agent
- BMC's PATROL Management Suite and PATROL View (integrated in the HP-OpenView NNM provides a number of user interfaces to the remote objects interfaced by the PATROL Agents/Knowledge Modules installed in remote systems)
- BMC's PATROL Agent/ORACLE Knowledge Module (together with the PATROL View installed in the MIMS management station, it provides the infrastructure to monitor the CUS Oracle instance)
- IONA's Orbix and OrbixTalk (IONA implementation of the CORBA 2.0 standard adopted by MIMS for interfacing the UK ERS Processing and Archiving Facility (PAF))
- ORACLE Server and ORACLE Reports (archive system for collected data and enhanced reporting capabilities)
- Remedy's Action Request (anomaly tracking functionality).

Core components

The network-management product HP-OpenView NNM has been put at the core of MIMS. The main characteristics are:

- MAP system: is the standard NNM view of the monitored object status.
- Data Collector: data is collected from the Agent systems via a SNMP Collector element. It polls, under user configuration (for each managed object from which data is to be retrieved), the Agent systems (get requests) and stores the returned managed

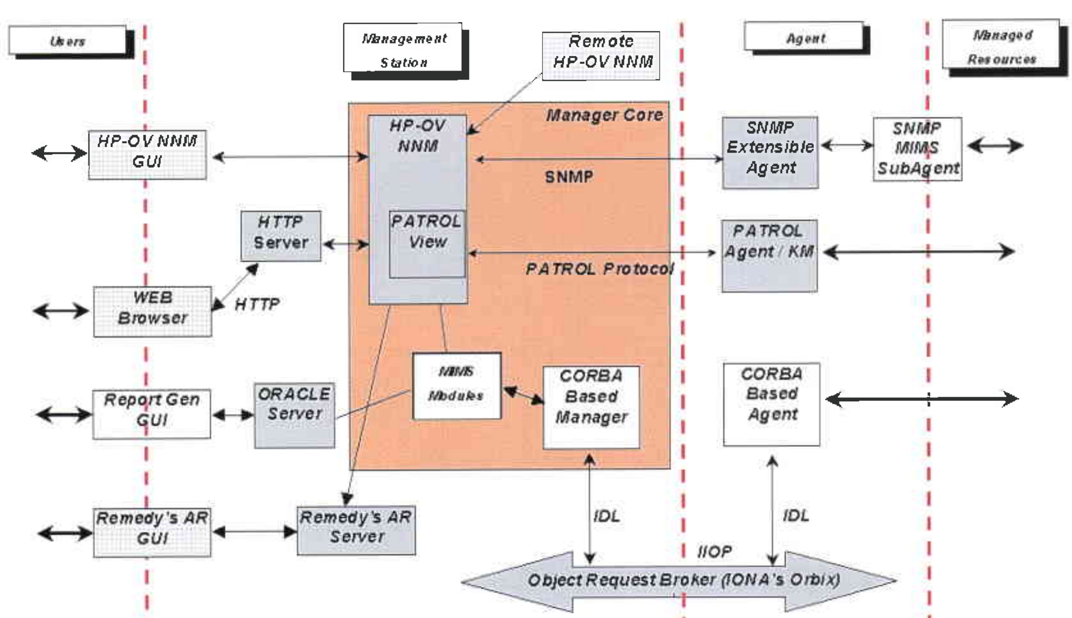


Figure 7. MIMS architecture

object value in a flat-file repository. Data collection presents the following functionality:

- frequency of the get requests
- thresholds can be set for the value of the retrieved data; if the value retrieved is not within the defined threshold, an event can be configured to which an action is associated, and the action can be an OpenView task (such as a change of the colour of a symbol in the MAP) or a user-defined action (such as to send an e-mail to a user list)
- user-defined algebraic (and hence if necessary also logical) expressions which provide a means of generating higher level parameters
- collected data-analysis tool: a graphical tool is provided with the standard HP-OpenView NNM, which allows one to display the collected data values over time
- SNMP browser: a user window interface through which it is possible to navigate on the loaded MIBs in order to get (or set on the write-access variables) managed systems SNMP MIB variables.

The design of the event-collection and storage sub-system is shown in Figure 8.

Extensible SNMP Agent

The HP-OpenView Extensible SNMP Agent software includes a master Emanate Agent and three subagents (HP-UNIX subagent, MIB-II subagent and the Extensible Agent subagent). The master agent implements the SNMP communications stack and protocol (SNMP manager-agent interface) and the interface mechanism with the subagents. The MIB-II subagent implements the SNMP MIB-II standard, which provides interfaces to system and network variables to be managed in the agent host. The HP-UNIX subagent provides system information such as the number of UNIX processes currently running, or the percentage utilisation of each file system. The third component (Extensible Agent) allows one to develop subagents for any resources.

Hierarchical manager- to-manager communication

The ERS ground system makes use of outsourced network services via the ESRIN network infrastructure support. A manager-to-manager communication, using the SNMP trap mechanism, was chosen to link MIMS to relevant status messages of the external commercial network services. This allows anticipation and detection of data-dissemination and connectivity problems.

Conclusions

The MIMS project has provided a practical demonstration that commercial network-management tools and standards can satisfy the stringent applications monitoring and control requirements of complex space projects. Several major achievements have been recorded:

- the high efficiency of the system development effort, achieved by the integration of commercial off-the-shelf tools, customisation and configuration for the ground-segment managed objects
- reduction of the efforts needed to add a new sub-system to the monitoring environment
- the high system modularity, allowing simplified replacement of any of its components.

Use of these new-generation network-management tools for the mission-critical tasks in the ERS satellite ground segment has been a positive experience. Currently, additional ERS ground-segment systems located at ESRIN are therefore being integrated into MIMS. esa

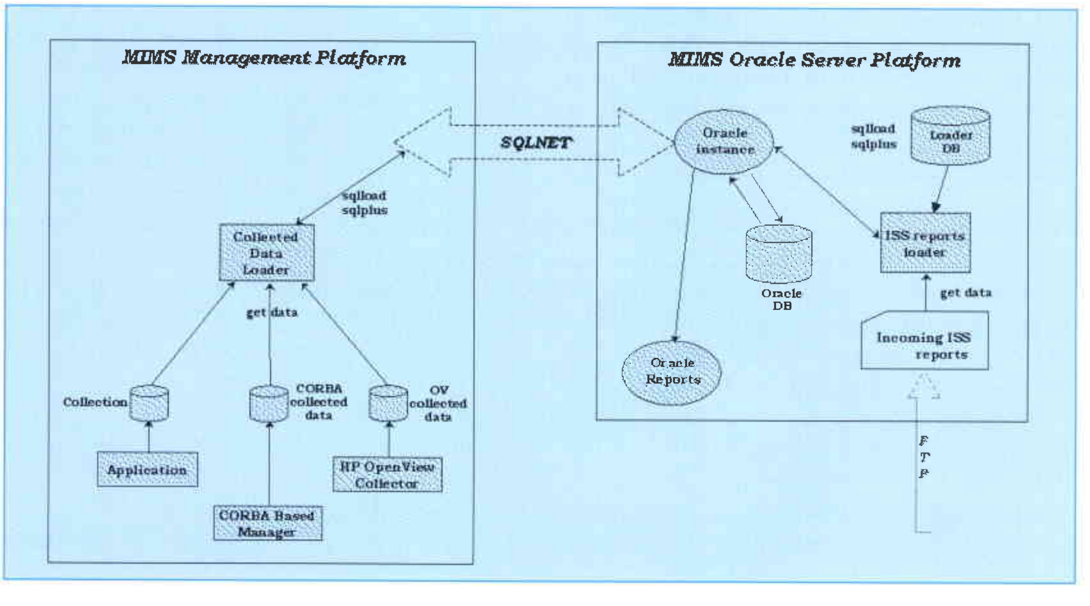


Figure 8. Event collection and storage sub-system

Modern Modal-Identification Analysis

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The ISSPA computer program allowing the modal identification of structures from sine-vibration-test data has been integrated into DynaWorks 4.0 and applied successfully for the characterisation of several space structures. Its integration into a system such as DynaWorks provides increased capabilities within the modal-identification process as well as greater flexibility and user-friendliness.

This article describes the user interface that was specifically developed to handle the ISSPA module in terms of data selection, management of identification sequences and all of the graphical displays which are so indispensable if one is to work efficiently on practical applications. A practical application of the new tool to a complete satellite, performed at ESTEC and Intespace in early 1997, is also reported.

Introduction

The identification of the modal properties of structures has gained significant importance in recent years because it constitutes an essential step in the updating and correlation of the mathematical models used for the design and verification of aerospace structures. For these activities, representative mathematical models are indispensable and modal identification is usually the first step in the updating procedure for such models. The possibility of performing modal identification using shaker-test results enables one to integrate this activity within a standard shaker sine qualification test with minimal impact on the project schedule.

Identification of Structural System Parameters (ISSPA) is a modal identification method that has been developed at the University of Kassel, in Germany. It is based on the identification of the physical and modal mass, stiffness and damping matrices of a structure in the case of an 'incomplete excitation'. The latter means that the number of excited modes is lower than the number of measurement degrees of freedom needed to describe the test item's structural dynamic behaviour in physical coordinates.

The previous software implementation of the original ISSPA method consists of various Fortran programs and was used for the characterisation of space structures such as the SUMER and SGSS instruments currently being flown on ESA's SOHO scientific satellite. The software's performance in terms of the quality of modal identification was excellent, but the handling of all of the data involved was cumbersome due to the 'old fashioned' nature of the user interface then available. The integration of ISSPA into DynaWorks has simultaneously enhanced DynaWorks with a modal identification capability and eased the task of the ISSPA user by providing a state-of the-art interface.

Tool description

As with the original ISSPA program, the task of modal identification consists of sessions corresponding to the processing of the results from one test with a specific excitation axis. Each session is composed of sequences of identification calculations for one or more frequency bands. The latter are user-selected sub-domains of the overall frequency range of the test responses. For each sequence, modal characteristics (e.g. frequency, modes and damping) are derived, as well as various physical matrices (e.g. inverse mass matrix, inverse stiffness matrix and damping matrix). Modal information from several sequences of a session can then be combined to form the modal base at session level. Synthesised responses can be calculated from the modal base of a sequence or a session of sequences.

The various stages of an identification sequence are as follows:
- initialisation
- curve-fitting and residual correction
- identification
- mode deletion and matrix assembly
- calculation of equivalent proportional damping

- combination of sequences
- response synthesis.

Modal identification steps

Selection of the ISSPA identification option opens a window listing the various stages of the identification procedure and the windows showing the available information.

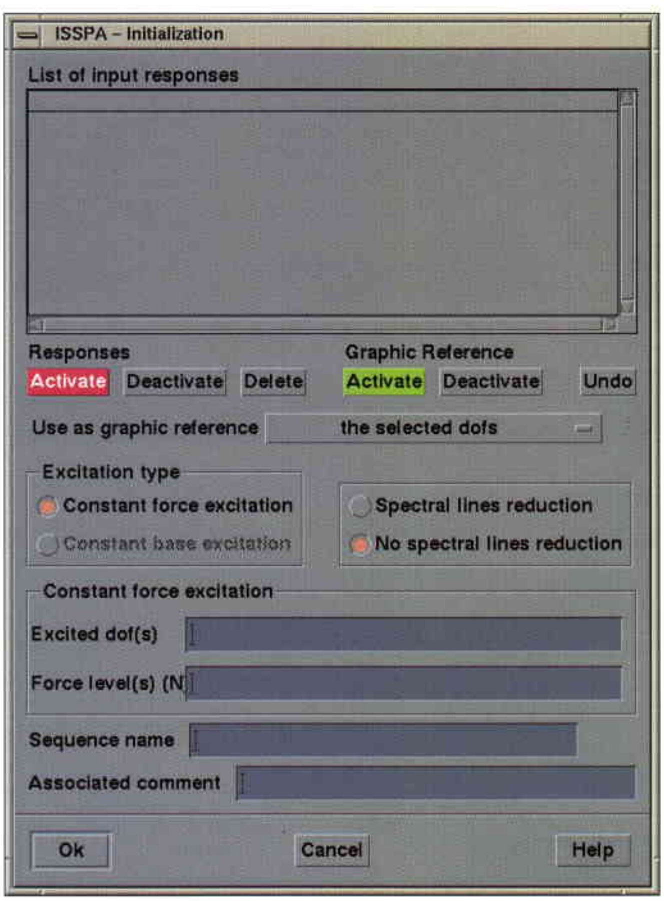
Initialisation

The initialisation is an important step in any identification sequence because it defines the main parameters of the process. The initialisation window presented in Figure 1 allows the definition of:

- The responses used in the identification: the selection is made in the first sequence and cannot be modified for subsequent sequences in the session.
- The graphical reference: this is the curve that will be plotted in the graphical windows for the selection of the frequency bands and response peaks, and three options are available:
  - selected response: particular responses selected by the user as graphical reference
  - envelope of all responses' imaginary parts used in the identification session
  - phase resonance criterion: curve derived from all responses used in the identification session that clearly show resonance peaks.
- The type of excitation and corresponding parameters:
  - constant-force excitation (i.e. modal-survey test results normalised to a constant excitation)
  - constant-base excitation (i.e. shaker test results normalised to a constant excitation); this option is currently not active, but shaker test results can be processed as modal-survey test results using the constant-force excitation option, provided the rigid-body movement imposed by the shaker is subtracted from the responses.
- Spectral line reduction: an option to reduce the number of frequency points of response curves with a minimal impact on identification quality; it is useful in cases where data is voluminous and/or computer resources are limited.

Last but not least, descriptive information facilitating the management of the identification sequences can be specified.

Once the initialisation window is defined, a graphical window presenting the graphical reference is opened. One or more frequency band(s) can be defined graphically by moving vertical cursors with the mouse, or typed explicitly in the columns located on the right-hand side of the window (Fig. 2). The identification process can now start for the selected frequency band(s).



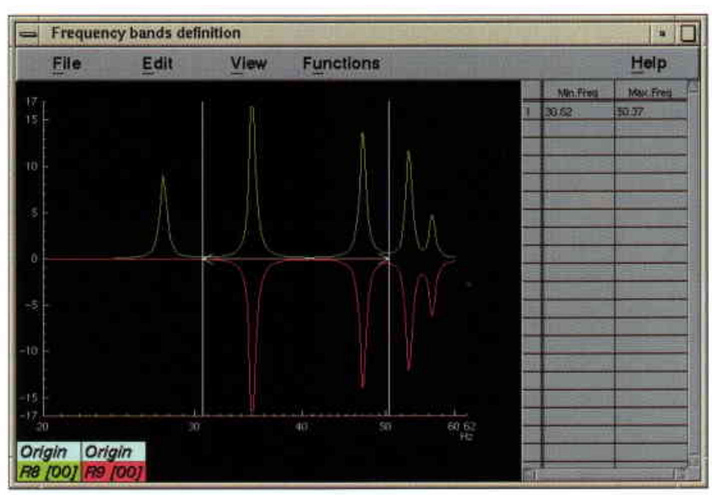


Figure 2. Frequency-band selection window

Figure 1. Initialisation window

Curve fitting and residual correction
The next step is a multiple degree of freedom (MDOF) curve-fit and a residual correction of the data to eliminate the effects of modes outside the selected frequency band.

The response peak frequencies are selected using the graphical reference in a similar manner to the frequency-band selection. At this stage, modal results such as frequency, mass, damping and mode shape are already available for modes within the frequency band(s).

The quality and validity of these intermediate results can be assessed by displaying two curves (Fig. 3):
- the Damping Iteration curve
- the Modal Mass Iteration curve.

The calculation of effective modal masses requires the vector of inertia forces as input. If not defined explicitly by the user, a unit vector is used. Of course, the modal masses are not then correct, but the convergence information can still be used. The number of curve pairs corresponds to the number of selected peaks.

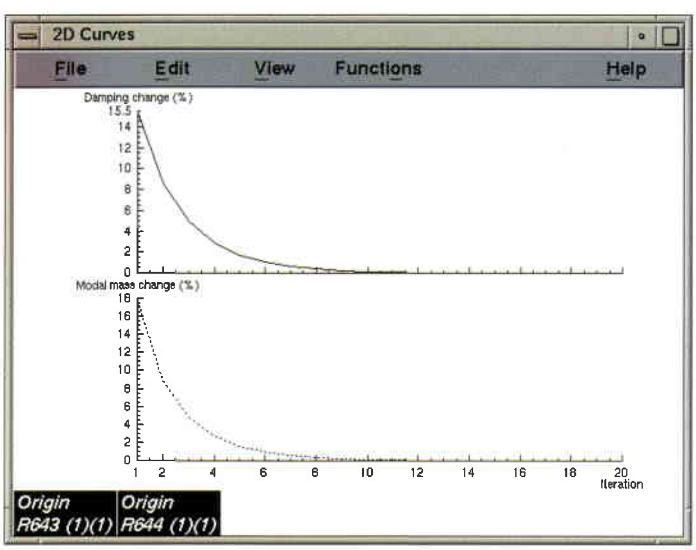
ISSPA identification
Once a satisfactory MDOF identification is achieved, the modal results can be refined using the ISSPA method itself. It allows the computation of:
- number of effective modes in the selected frequency band(s)
- modal parameters of these modes
- eigen-shapes of these modes
- contribution of these modes to the inverse mass, stiffness and damping matrices.

The effective number of modes corresponds to the number of modes effectively excited in the test within the selected frequency band(s) and is given by the number of non-negligible singular values.

At the end of the calculation, information about the identification accuracy within the frequency band(s) is displayed in terms of RMS errors (Fig. 4). In this message, the wording 'condensation of 2 effective dofs' actually means 'assembly of substitute measurement matrices from 2 effective vectors of the singular value decomposition'.

The number of effective modes within the frequency band(s) can be verified by inspecting the ratio of singular-value curves (Fig. 5).

The most suitable number of effective modes corresponds to the number of modes with non-negligible singular values for the real and imaginary parts (a recommended threshold value is 0.1). Selecting too few modes for the ISSPA identification results in large RMS errors, while selecting too many modes results in noise or numerical modes. At this stage, a good engineering judgement is necessary.



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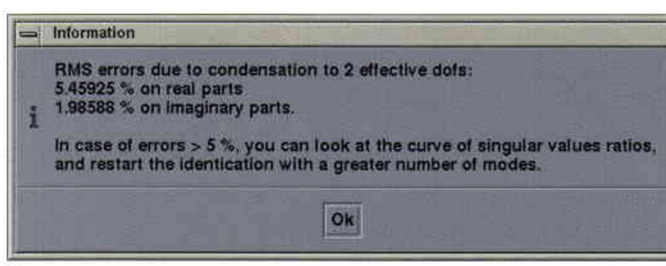

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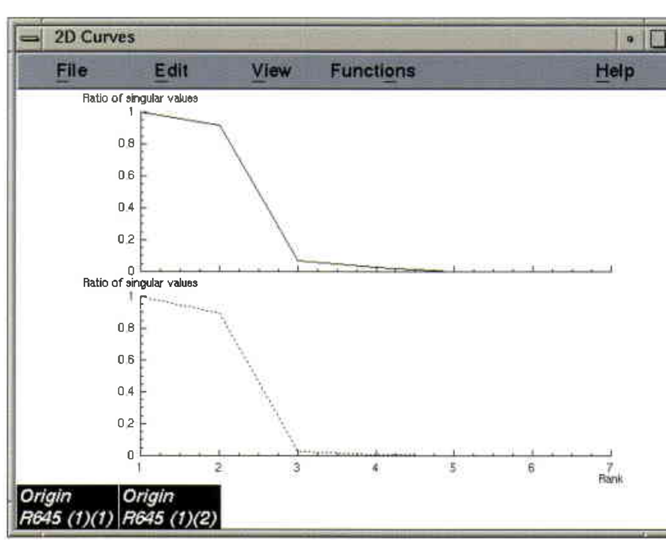

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Figure 3. Damping and modal mass iteration curves

Figure 4. Identification RMS errors

Figure 5. Ratio of singular values

Mode deletion and matrix assembly
This step is essential if the current sequence is to be combined with other sequences at a later stage. It allows the removal of unwanted modes and performs the assembly of physical matrices for the system corresponding to modes within the frequency band(s). Once again, the decision to keep or reject a mode in the modal base requires good engineering judgement.

Calculation of equivalent proportional damping
This step is only possible after matrix assembly. It enables a refinement of the estimate of the diagonal elements of the damping matrix by resolution of the system of equations of motion around the modal frequencies, since the damping values are the only unknowns of the system.

Combination of sequences
Further to the processing of a sequence, the above steps can be repeated for new sequences and other modes identified in other frequency band(s). Sequences can easily be combined just by specifying their names. To aid in this task, a control and a status window are available to help the user to remember the content of each sequence (Figs. 6 and 7).

The purpose of this step is to create a modal base containing all the retained modes from the different sequences of the session that the user wants to use for a subsequent response synthesis.

Response synthesis
The purpose of the response-synthesis step is to validate the computed modal characteristics by comparing the analytical responses computed using the identified modal parameters with the original test responses (Figs. 10 and 11). The response synthesis can be performed for the current sequence or for the modal base of the session resulting from the combination of sequences.

Additional related tools

Three tools in the DynaWorks system that are independent of the modal-identification module are also useful in a modal-identification exercise:

Display of mode shapes
If a computer model of the test specimen is available in the database, plots of the identified mode shape can be visualised. If needed, superimposition with analytical model mode shapes is possible for visual comparison (Figs. 8 and 9).

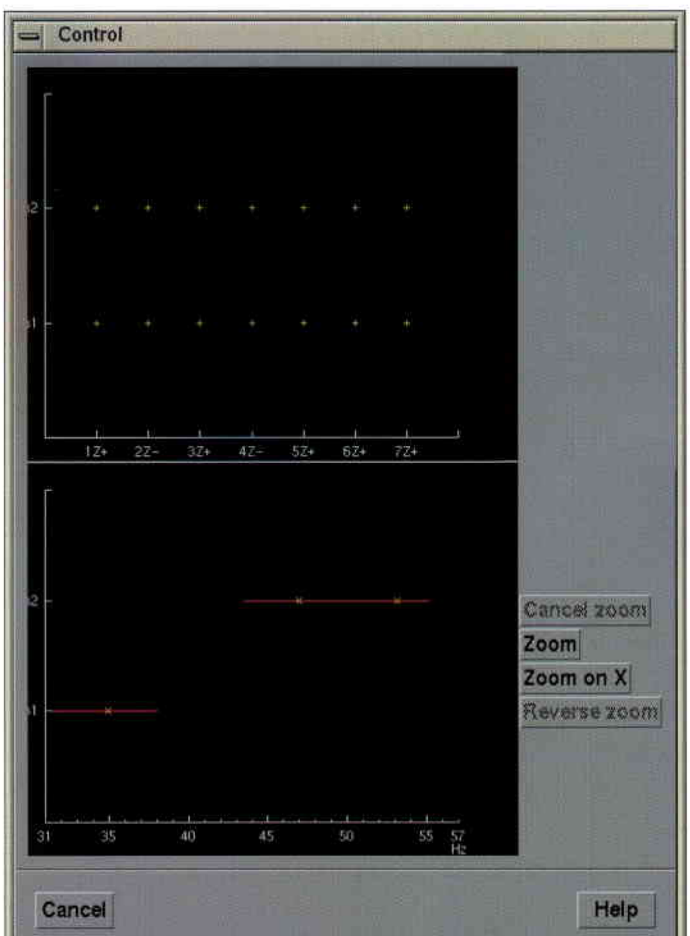


Figure 6. Control window

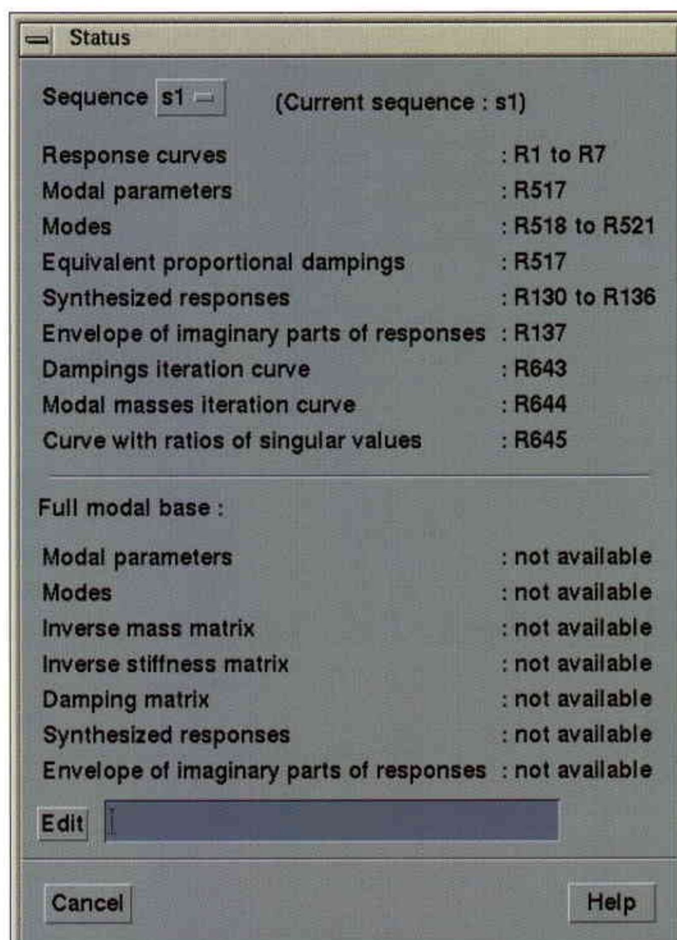
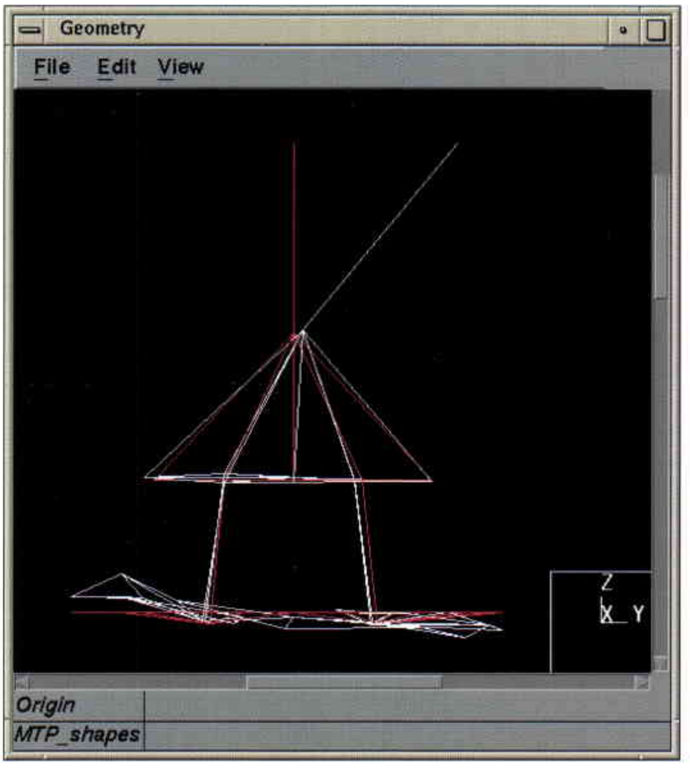


Figure 7. Status window



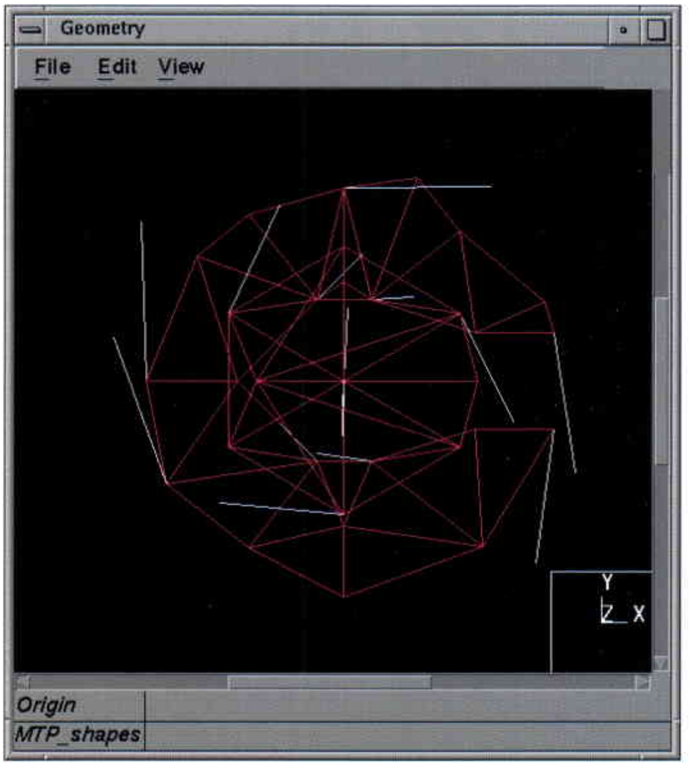


Figure 8. Antenna mode at 53 Hz

Figure 9. Torsion mode at 37 Hz

MAC calculation

The calculation of the MAC (Modal Assurance Criterion) is available as a DynaWorks stand-alone function. It uses a pairing table to allow computation of the MAC between modes of two different models. A specific tool is also available to create the pairing table in the most automated manner possible, but preserving user control over the pairings defined. The results of the MAC calculation can be displayed in a DynaWorks 3D window for a visual assessment of the quality of the correspondence between modes.

Test animation/mode animation

The test animation facility allows one to replay a vibration test on the screen using a topological model of the test item. Animated displacements are computed from measured experimental acceleration responses (harmonic or transfer functions). The real movement of the structure during the test, corresponding to the superposition of all individual modal responses of the specimen, is reproduced at each frequency.

The mode animation facility helps in understanding the various modes identified and their comparison with analytical modes.

Management of identification sessions

The current state of an identification session can be saved at any time, restored to continue working, modified and saved again. There is no limit to the number of sessions that can be saved, other than the available computer resources.

In addition, the main results such as modal parameters, matrices and synthesised responses can be saved selectively to the database for archiving or future use with other DynaWorks tools.

Practical application

A DynaWorks implementation of ISSPA has been used at ESTEC to perform a modal identification for ESA's MTP satellite (Meteosat Transition Programme) based on low-level sine tests performed at Aerospatiale in Cannes (F). This work was necessary to allow a good correlation and updating of the mathematical model of the spacecraft destined for a coupled load analysis by Arianespace.

Base excitation tests were performed in the three axes, delivering the Frequency Response Functions (FRFs) via about 32 accelerometers (60 DOFs). The FRFs were imported into DynaWorks, and the Elastic Transfer Functions (ETFs) required as input for the modal identification derived by removing the rigid-body movement imposed by the vibration table. This identification task constituted a challenging test for DynaWorks/ISSPA since the test responses were quite noisy and often represented degenerated modes.

Results

Three identification sessions – one for each excitation axis – were performed in the frequency range 5 to 65 Hz. For each session, DynaWorks delivered a modal base consisting of:

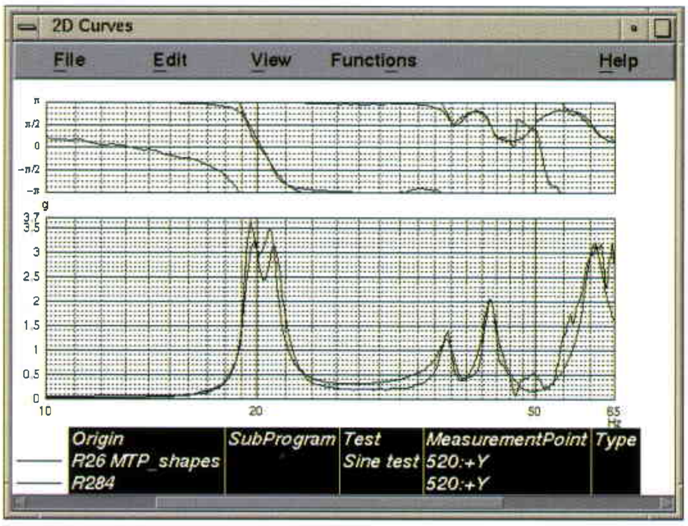


Figure 10. X-excitation, measurement point 520: +Y

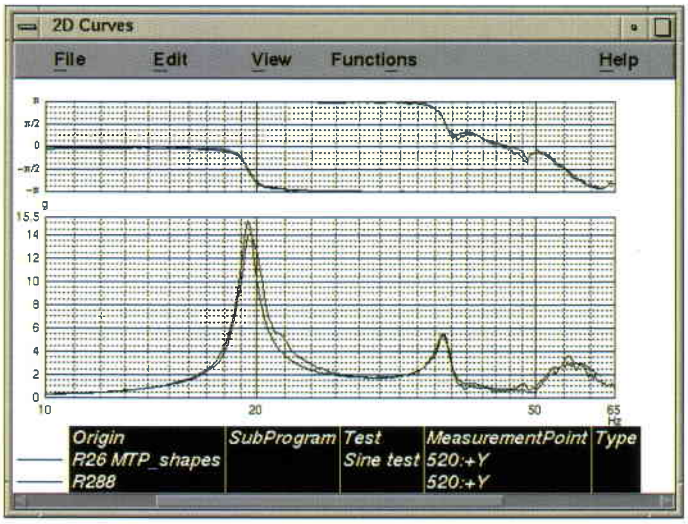


Figure 11. Y-excitation, measurement point 520:+Y

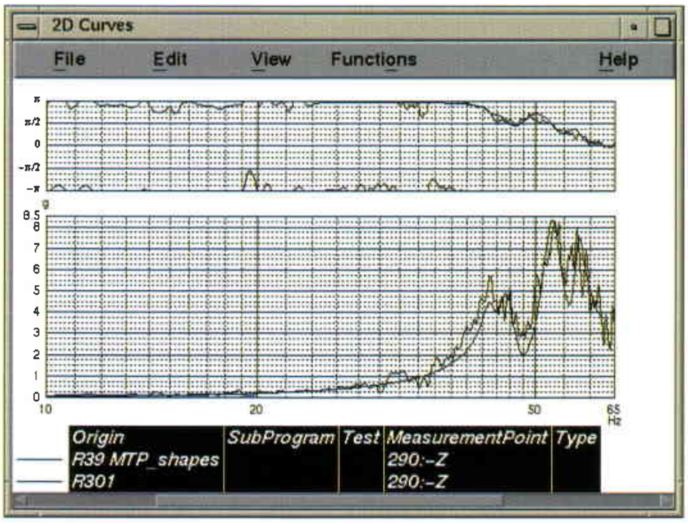


Figure 12. Z-excitation, measurement point 290:- Z

- mode shapes
- frequencies
- dampings.

An experimental model was used to plot each identified mode's shape for visual inspection and comparison with analytical mode shapes. Figure 8 is a superposition of deformed and undeformed shapes, whilst Figure 9 presents a torsion mode where displacements are shown as vectors. Damping values were obtained for each mode of each of the three modal bases.

Synthesised responses for each modal base and each measurement point were computed in the frequency range of interest and compared to test responses to assess the quality of the modal identification. Figures 10-12 present a comparison of original test and synthesised responses. Test animations were also performed to further assess the quality of the identification process.

Present limitations and on-going improvements

During the practical application described above, a number of potential further improvements were identified and the software is currently being updated in order to implement them.

One limitation that was noted was the impossibility of combining the modal bases of different sessions. Indeed, modes that are poorly excited in one direction are normally not found within the modal identification session corresponding to that direction. This mode can, however, be identified in another session corresponding to an axis in which the mode is properly excited. The possibility of combining modal bases of different sessions will allow more complete and meaningful checks. Indeed, modes that are weakly excited (i.e. lateral modes in an axial test) may be replaced by modes of another session corresponding to a test in which these modes are strongly excited. In this way, it will soon be possible to select the best set of modes for the calculation of the synthesised response of a given session.

esa

Navigating Through Earth Observation Knowledge

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Earth observation (EO) from space is a highly specialised technological domain where data and terminology need to be presented to users in an understandable language and customised to meet particular requirements. Most applications that use remote-sensing data require a high level of user expertise – the selection of EO products and their potential for specific applications is not always obvious. In addition, different EO user communities have varying requirements with respect to data, sources and other information when they access EO user services.

To ensure that the required information is obtained efficiently, yet with maximal flexibility, the interface between ESA's EO user services and the wide spectrum of users will have to incorporate some aspects of a knowledge-based system. Intelligence in user systems will be required for occasional users or where help concerning complex subjects is required for a time-efficient and successful session.

EO Knowledge Navigational System

The software system EO Knowledge Navigational System (EKNOS) has now been field-tested in the Remote Sensing Exploitation Department at ESRIN and offers an EO application-related knowledge-based system on the Internet. It includes various data such as descriptions for image products, algorithms, and instrument and ground facility references. The development, supported by the Earth Observation Preparatory Programme (EOPP), is novel to EO user services and reaches far beyond traditional thesaurus-based systems.

EKNOS has been implemented using leading-edge software and database technology. The long-term objective is to gradually build a complete stock of EO facts and relationships making image products and services fully accessible. In the medium-term, the chosen technology will be consolidated. The two essential functions of the system are:

- to enter free search terms with the support of a thesaurus and applying boolean operators
- to navigate within the knowledge base using the techniques of semantic networks.

EO knowledge model and information mining

Existing EO user systems furnish metadata, browse products and documents mostly with limited correlation. Users must make their own judgement about the applicability to a problem, often based on many factors (e.g. compound product characteristics, space/time requirements, accuracies, parameter types, etc.). The purpose of 'intelligent' guiding is to present users with a facility that reflects an intuitive understanding of the EO environment. An EO ontology has been elaborated in the course of this project, modelling the major EO science, engineering and user components. Figure 1 shows a three-plane graph representing the levels which are traversed during a search (by the software) or during navigation (by the user).

The first level contains the user concepts which comprise all the elements that belong to a thematic area – the term 'disaster management' is not typically found in remote sensing, but is linked to particular EO programmes, multi-date analysis and missions. The user concepts appear as free collections of objects that are prepared by an expert, and extracted from knowledge and analysis of past user interactions. The EKNOS system capitalises on previous work done for the CEOS Dossier (http://ceos.esrin.esa.it/) which focuses on application requirements and space capabilities. The term 'concept' means temporary associations which remain on a certain level until they are consolidated and added at the next update to the semantic network (see level 2). This eases the implementation of a scalable system and removes unnecessary system administrator work.

The second level addressed by user concepts in the graph is a conceptual knowledge model. It comprises the relevant object classes and associations. This model represents a picture

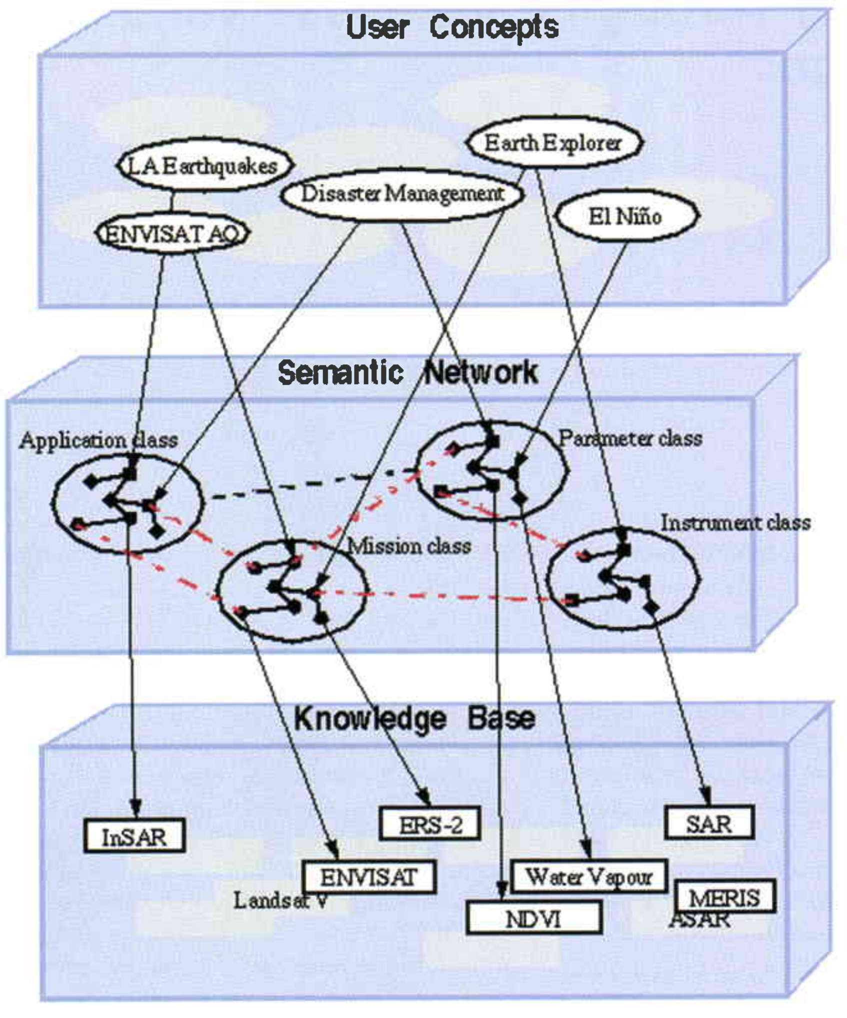


Figure 1. EKNOS three-level concept

of EO-typical objects and shows how they relate to each other. The object classes and associations form the semantic network and are implemented for long-term validity. In most cases, frequent modification of the model is not desirable since this would lead to an increase in system maintenance. (This drawback usually appears in implementations of object-oriented database systems where full advantage is taken of the object-oriented modelling power.) Since object-oriented models cannot be created perfectly, records of user interactions are used to optimise the model. The super-classes, such as 'instrument', contain sub-classes describing in more detail the composition of that class and also allow the introduction of taxonomies. Taxonomies represent structures (e.g. instrument poly-hierarchies as a classification of instruments under multiple criteria) that show how higher classes are specialised (e.g. synthetic- and real-aperture radar). The conceptual model links to the real objects at the instance level which is implemented according to the specific internal/physical model of the database system.

The third level (knowledge base) represents the implementation of instances of each class and taxonomies as defined by the second level. This level also incorporates the rules under which searches and navigation are executed by

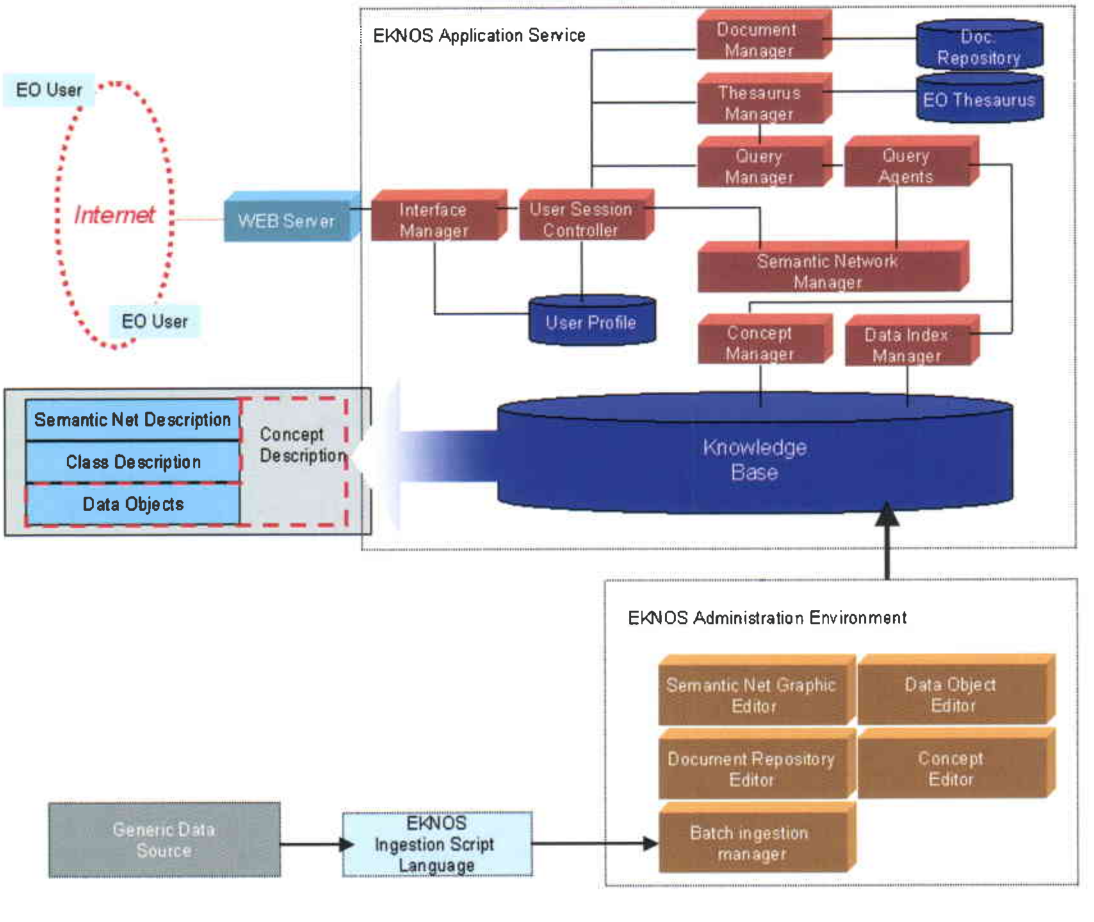


Figure 2. EKNOS architectural concept

assigning individual weights to the object relations. Individual weights can be recorded in multi-dimensional matrices for which the indices belong to classes, concepts, object instances and other criteria to be assigned. This technique can boost the precision and performance since it optimises the traversing of search and navigation paths.

The knowledge-based system concept

With the help of artificial-intelligence information technology, the EKNOS system integrates several elements that contribute to optimal response to a user query. The architecture (Fig. 2) takes advantage of object-oriented database capabilities insofar that they are a natural baseline for the implementation of semantic networks. Other elements are:

- search and inference mechanisms
- thesaurus
- dictionary
- direct link to core documentation management
- knowledge acquisition and maintenance mechanism.

In particular, the usage of a thesaurus and dictionary can help with the pre-processing of a user query through different levels of sophistication. Once a search is executed, the system trades off between the 'precision' of findings and the 'recall' of broader scopes (spreading of activation) based on the selected search strategy and control parameters. The search strategy is driven by user preferences of search depths, search algorithms and target classes. User domains are semi-automatically recognised by EKNOS and the resulting information items are bundled throughout a session and returned to the user. Figures 3 and 4 show examples of the EKNOS graphical user interface for entering queries and displaying the results, respectively.

Figure 3. EKNOS graphical user interface: example of query entry

Figure 4. EKNOS graphical user interface: example of instances

Conclusion

The intelligent guiding in EKNOS is achieved using a knowledge model for navigation and querying with the objective of successfully accessing EO data, information and end-user services. The EKNOS project has provided a robust knowledge-based system meeting two objectives for EO applications:

- reduced complexity in accessing EO-application domain information
- largely automated information retrieval.

Earlier implementations of knowledge-based and reasoning techniques had shown the feasibility and benefits of higher-system autonomy for EO user support, which the EKNOS system has now confirmed and demonstrated. It is hoped to complement the 'explicit knowledge' now supplied to EKNOS with the 'tacit knowledge' of experienced EO practitioners in the not too distant future esa

Just published:

Space Business in Europe

1999 Edition

(November 1998)

As we race toward the end of the century, the European space industry is preparing for the dawn of a new era: cyclical geostationery communications markets will bottom out in the early 2000's; satellite communications constellations are increasing in importance and the launch industry has undergone dramatic change. Moreover, as the consolidation process speeds up, this will undoubtedly lead to the creation of two powerful, world-class prime contractors in the near future.

To understand these and other crucial issues at play in the market today, it is vital to have the most up-to-date and pertinent information. **Space Business in Europe, 1999 Edition** is the only in-depth report on the European space business which provides the latest facts and figures along with an exhaustive analysis of the industrial, commercial and financial aspects of the industry.

Part 1 provides a detailed insight into space business in Western Europe in 1997-1998, comprising:

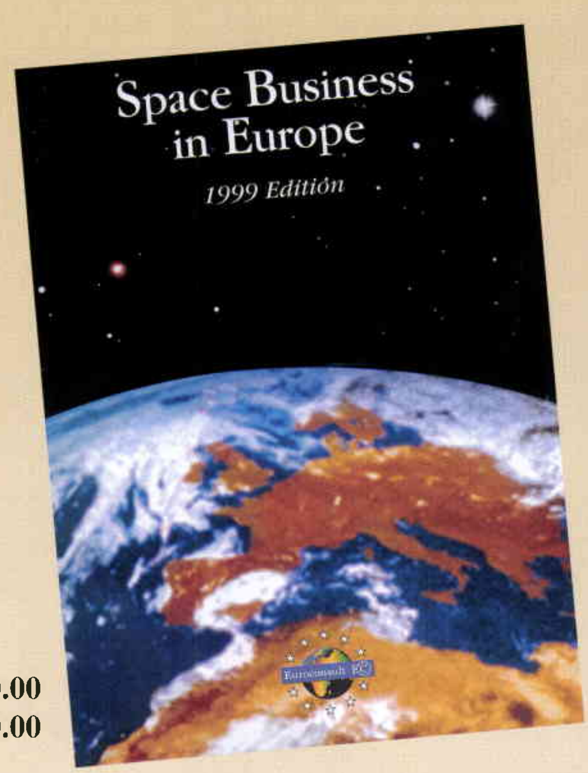
- *sales volumes, sales breakdown by application and market* (both domestic and export);
- *in-depth analyses of market shares and competitive/regional market positions* of the major players, complemented by an overview of space industry restructuring;
- a study of the *evolution of industry sales and employment* at both the European level and national level in France, Germany, Italy and the United Kingdom.

This section concludes with a brief overview of the relative positioning of the 21 leading European space companies.

Part 2 is a detailed industrial and financial analysis of the leading 21 European companies -each profile includes:

- *an in-depth analysis of the overall financial condition of the companies* over a ten-year period;
- *a round up of developments in all of their business areas*;
- analysis *of each company's space activity* and the resulting industrial and financial impact this has on overall operations;
- *an overview of the latest major space programmes* (national, European and/or international) in which they are involved.

This 240 page report, which consists of some 150 tables and graphs illustrating key variables, has become a highly regarded reference work for the European space industry. Financed on a multi-client basis, this study has been compiled by a team of world renowned experts in the field with over 15 years combined international experience of the space market.



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Multimedia Services for Interactive Space-Mission Telescience

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ESA is presently preparing the installation of a ground communications infrastructure to support telescience in the scope of the International Space Station (ISS) and the Columbus Orbital Facility (COF), representing the European contribution. Telescience – or remote science operations – is the remote operation of scientific payloads onboard space platforms. The provision of remote operations capabilities for an experiment platform or laboratory in space imposes high safety, reliability and security requirements on the supporting communications system. These requirements are met by the Interconnection Ground Subnetwork (IGS), an ESA-provided autonomous Intranet with gateways to the secure networks of other space agencies. The main objective is to provide scientists with a 'virtual presence' at the experiment workplace in space.

This article focuses on new technologies, which enable and license scientists with limited requirements (e.g. for data availability and access reliability) to operate an experiment in space at minimum communications costs. Additionally, the proposed architectural concept uncovers an access to real-time space events for everyone on the World Wide Web (WWW), which is a significant public relations amplifier. The article describes how multimedia technologies could, already now, support tele-operations of experiments in space and reports on the results of a study in this field conducted by ESA along with an industrial team. An outlook for future service and application developments is also given.

Multimedia profile for low cost science usage

In recent years, ESOC has supported scientists in preparing for future remote science operations in space in the scope of precursor missions with Spacelab, Spacehab and the Russian space station MIR. An important topic of the lessons learned became the awareness that communications carrier services are very expensive when compared to the cost for an experiment's development and operation. The operational scenarios and the applied technologies have been identified, including activities at ESOC to prepare for future high Quality of Service (QoS) communication implementations*. These services within a secure operational Intranet, are rather expensive and are not directly accessible by users with more modest availability and reliability requirements. To serve also these users, the global Internet provides an attractive low-cost alternative.

A study has been conducted together with an industrial team headed by DASA, and supported by ZARM-Fab, OHB-System, and CeBeNetwork all located in Bremen, Germany. The scope of the study was to investigate recent developments in the area of Internet Protocol (IP)-based technology for integrated multimedia networks and to demonstrate solutions suited to the ESA telescience applications. A prototype implementation on the basis of the ESOC communications testbed supported the demonstration. The results have been extrapolated to provide a vision of a future low-cost telescience scenario.

Global public Internet technology and services owe their widespread acceptance partly to the basically distance-insensitive flat-fee tariffing concept. Thus, the Internet appears as the straightforward low-cost solution to deliver experiment data and video streams, even simultaneously, to a very large user community. The limitations of the current IP technology, protocol suite and implementations are nevertheless not allowing true support of real-time multimedia applications over the global Internet as required for telescience. Currently, only a dedicated operational Intranet with guaranteed line capacities could achieve this, as is implemented in the IGS.

Operational scenario for multimedia-based science users

Figure 1 explains how a typical user workstation will be supported with the ESA-provided communications infrastructure for the ISS scenario, the Interconnection Ground Subnetwork (IGS). The figure shows the experiment and how it will be accommodated

* See 'Validating Future Operational Communications Techniques: The ATM Testbed', ESA Bulletin No. 92, November 1997.

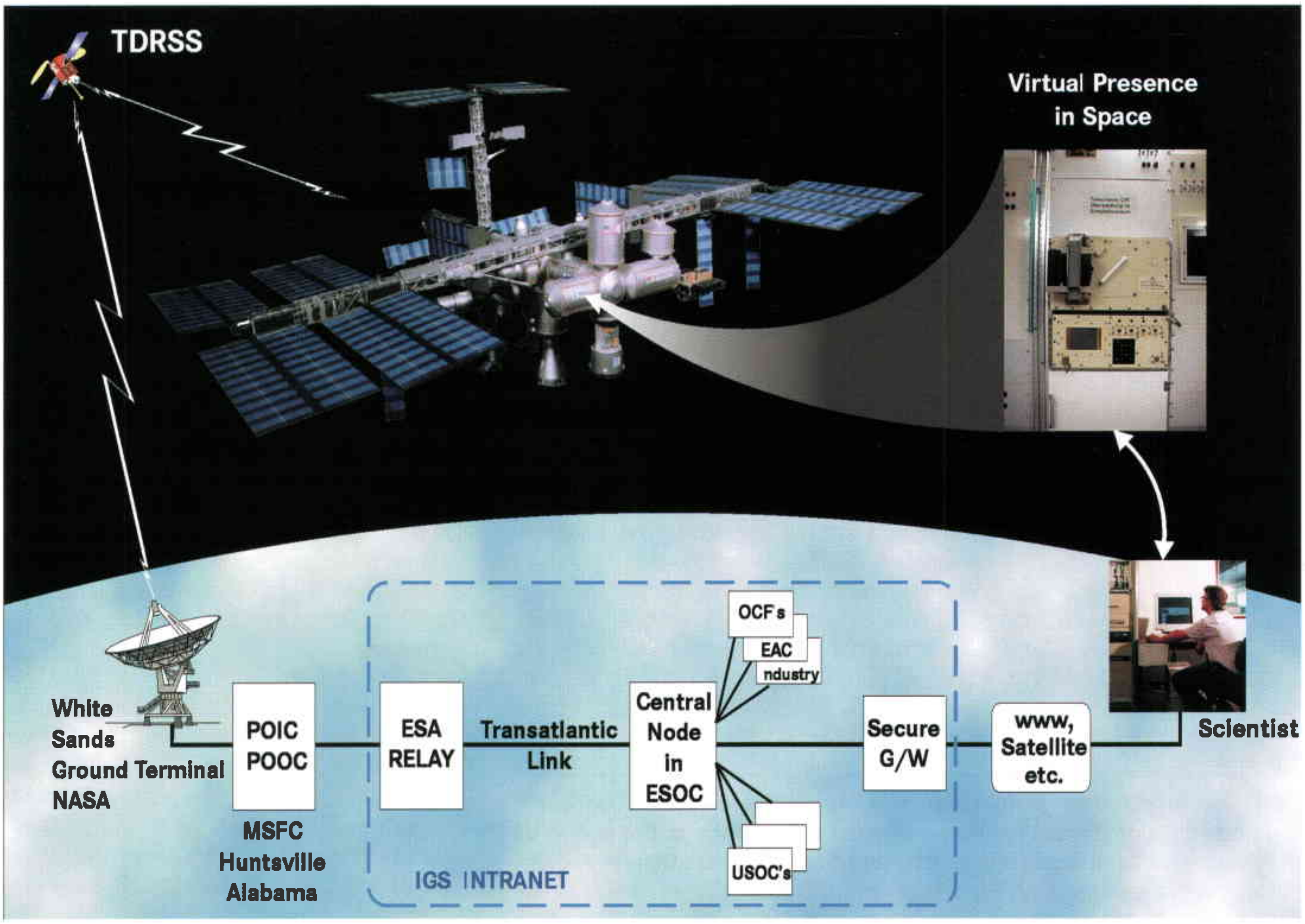


Figure 1. International Space Station scenario with integrated remote-user site

in the COF, the European part of the ISS. Telemetry data, i.e. scientific and housekeeping data and the video streams, will be transferred to ground via a network of geostationary Tracking and Data Relay Satellites (TDRS). The antennas of the NASA ground station in White Sands, New Mexico, will terminate the space-to-ground link. Via high-speed communication lines the data will then be propagated to the Marshall Space Flight Center in Huntsville, Alabama, where the Payload Operations and Integration Centre (POIC) and the Payload Data Service System (PDSS) are located.

Here the European science telemetry data will be transferred to the ESA relay and transported to the IGS central node at ESOC in Darmstadt, Germany, using a highly-reliable Asynchronous Transfer Mode (ATM) service* over a trans-Atlantic link. The IGS central node containing the major operational communications and network management infrastructure is at the centre of a star-like network, interconnecting all involved European operations entities. The entire IGS network is operated and maintained by an industrial control team located at ESOC. The central node services are extended to the global Internet by a secure gateway to protect the secure operational Intranet. Via this gateway, the home-based user can access telemetry data and video streams as standard IP services.

Understanding telescience operations requirements

In developing an experiment to be conducted in space, the dependency of the enhanced scientific return on a real-time interaction capability needs to be evaluated carefully, since the required communications support resources (line cost) can easily become a cost driver when higher data rates need to be supported.

The requirements for the interactive operation of science experiments in space are the following:

- Most users need to monitor their experiment by receiving the telemetry data. They need to display the received housekeeping and experimental data on a monitor, preferably at their home site. These data are numerical values, which provide information on temperatures, velocity, pressures or other measured parameters. In addition, graphical information like pictures or video streams may be of importance to evaluate the experiment's progress. Especially with respect to video streams, the quality requirements

* See 'Validating Future Operational Communications Techniques: The ATM Testbed', ESA Bulletin No. 92, November 1997.

for the communications services are steadily growing. For example, the Critical Point Facility (CPF), during its last mission on EuroMir 94, was supported on the ground by a video service data rate of 384 kbps. The planned Fluid Science Lab (FSL) for the COF with its two high-quality video cameras could even require a video bandwidth of up to 32 Mbps. However, the space-to-ground link resources are limited. In addition, an average of only 4 Mbps (with peak data rates up to 32 Mbps) is allocated to the European complement of the ISS. Also the cost of high-speed data transport on the ground is rather high. Therefore, use of the high-resolution mode for CPF video distribution will be extremely limited.

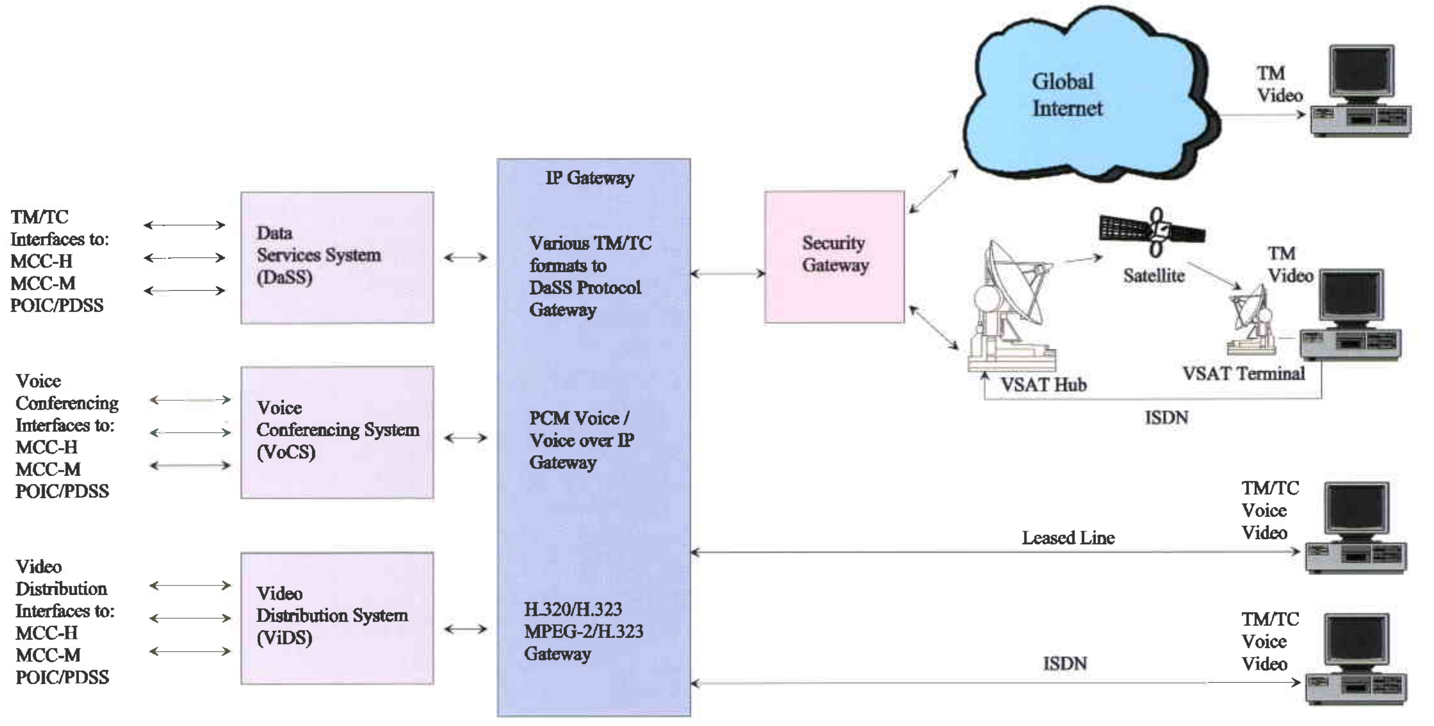
- The second requirement, the online availability of data, is decisive for interactive remote operations. Here a distinction is made between online and offline data distribution. Online implies receiving the data nearly in real time (i.e. within seconds up to a few minutes). Offline means distribution of collected science data with a significant time delay, e.g. overnight.
- To be in the position to react to unexpected experiment events, data must be delivered online, i.e. nearly in real time. The reaction of the experimenter on the ground could be a voice request to a crew member on board the spacecraft or to an experiment facility controller on the ground (requesting the transmission of a telecommand) or directly by a telecommand, sent by the experimenter himself.
- This leads to the third requirement, the experiment control. If the facility design provides this capability, the user should be able to control his experiment by himself. As he is most familiar with his experiment, he should be able to directly issue telecommands.
- As the user has to share the resources of the ISS and COF with other scientists, his experimental work needs close cooperation and coordination with several other operational entities on the ground: the facility responsible (if his experiment is run within a common facility on board the spacecraft), the flight element control centre, which is scheduling, for example, power and possibly the availability of crew time. Therefore, he needs additional communication media to support this coordination. The coordination tools are mainly voice conferencing and video conferencing with other partners and, when available, additional support for cooperative work including application sharing and whiteboards.
- The last requirement results from the considerably longer experiment operations phases within the ISS in comparison to Spacelab and Spacehab missions. In the past, a typical mission had a duration of a couple of days up to two weeks. On the ISS, a mission or increment can be three months or more. Under these extended mission conditions the user wants to stay at home. In the past, the user had to move with most of his ground support equipment to a NASA site to monitor his experiment. Now the user can operate his experiment from his institute, where he has his supporting science staff and all the necessary processing resources available.

All of these requirements need to be considered when designing a remote user environment. In addition, the communication cost must remain reasonable in relation to the overall cost of an experiment. The cheapest and most flexible solution which fulfils all of the above requirements with an acceptable service quality, would be the ultimate answer for the user.

IP gateway to operational services

In order to enable low-cost access at a central European site to the operational communication infrastructure of the ISS, it is first necessary to map all operational services (telemetry, telecommand, voice conferencing and video distribution) to the Internet Protocol (IP), which then allows one to easily map the IP service to the most appropriate and cost effective underlying carrier service. Figure 2 shows the IP Gateway Concept which is part of the IGS Central Node.

The data services for telemetry and telecommand are provided by the IGS Data Services System (DaSS), which interfaces with all partner control centres involved in ISS operations, i.e. the Mission Control Centre Houston (MCC-H), the Mission Control Centre Moscow (MCC-M), the Payload Operations Integration Centre (POIC) and the Payload Data Service System (PDSS). Together with the IP gateway, it accommodates all required TM/TC format conversions to provide a unique simple interface to the users via TCP/IP. Similarly, the interfacing for the voice conferencing services of partner control centres is provided by the IGS Voice Conferencing System (VoCS). An IP gateway function converts the pulse code modulated (PCM) voice signals into Voice over IP, requiring very low bandwidth. In the same manner, the interfacing for the video distribution services of partner control centres is provided by the IGS Video Distribution System (ViDS). An IP gateway function converts the H.320 or MPEG-2 coded video streams into low rate H.323 video signals.



Legend:
TM: Telemetry
TC: Telecommand
MCC-H: Mission Control Center Houston
MCC-M: Mission Control Center Moscow
POIC: Payload Operations Integration Center
PDSS: Payload Data Service System
PCM: Pulse Code Modulation
IP: Internet Protocol
MPEG: Motion Picture Export Group
ISDN: Integrated Services Digital Network
VSAT: Very Small Aperture Terminal

Figure 2. IGS Central Node - IP Gateway Concept

Once all services (data, voice and video) are converted to IP, it is easy to map the IP service to different carrier services depending on the user requirements. Via a security gateway, a multitude of users can be connected to the operational environment via the global Internet. Due to the current unreliable performance of the global Internet, it is envisaged to provide online/offline telemetry and video only. Via a security gateway to a VSAT system service, highly asymmetric and multicast traffic profiles can be supported in which a user community receives much more data than is sent back into the operational environment. This is typical for multi-user offline telemetry distribution for which the VSAT service represents a low-cost solution. Also, via a security gateway, a secure tunnel can be established over the global Internet, which has similar characteristics to a direct link. It is therefore assumed that the full range of operational services, i.e. telemetry, telecommand, voice conferencing and video distribution, is available over this type of setup with, however, fluctuating performance. Via leased lines or ISDN dial-up services, a user can be provided with the full range of operational services with guaranteed performance. ISDN only supports data rates up to 2 Mbps.

In the context of the study, various commercial off-the-shelf products for the IP gateway are being evaluated for the individual services:

1. Online telemetry distribution is available over TCP/IP, i.e. no gateway function is required.
2. Offline telemetry distribution uses the reliable Multicast File Transfer Protocol (MFTP) over IP multicast to transfer data to multiple users over different carrier services at the same time.
3. Voice conferencing is assumed to be partly covered by video conferencing, which always includes an audio channel.
4. Video distribution uses an H.320 to H.323 conversion, which implements the video gateway functionality; for onward distribution to multiple users IP multicast is employed based on the IP/TV and the reflector products.

Internet Service Providers (ISPs)

The global Internet is built by interconnection of Internet Service Provider (ISP) networks. The global Internet, and also private operational Intranets, are based on the current IP version 4 (IPv4), which does not allow bandwidth reservation on an application basis, rather the IP service is provided on a 'best effort basis'. Over the global Internet, low data rates – up to a few kbps – could be supported for science data transfer. It is, therefore, a good choice for monitoring low-rate telemetry, but it is definitely not adequate for telecommanding, where guaranteed data rates and minimum latency are mandatory. The problem of security and confidentiality of data can be solved by data encryption techniques. Video distribution/ conferencing and especially audio conferencing via the global Internet is also possible. However, the availability of bandwidth is unpredictable with high fluctuations depending on the entire traffic load. Only those tools that can also adapt to degraded modes can cope with these limitations. World-wide investments by terrestrial Telecoms and Internet Service Providers (ISPs) in new access technologies, e.g. Asymmetric Digital Subscriber Line (ADSL),

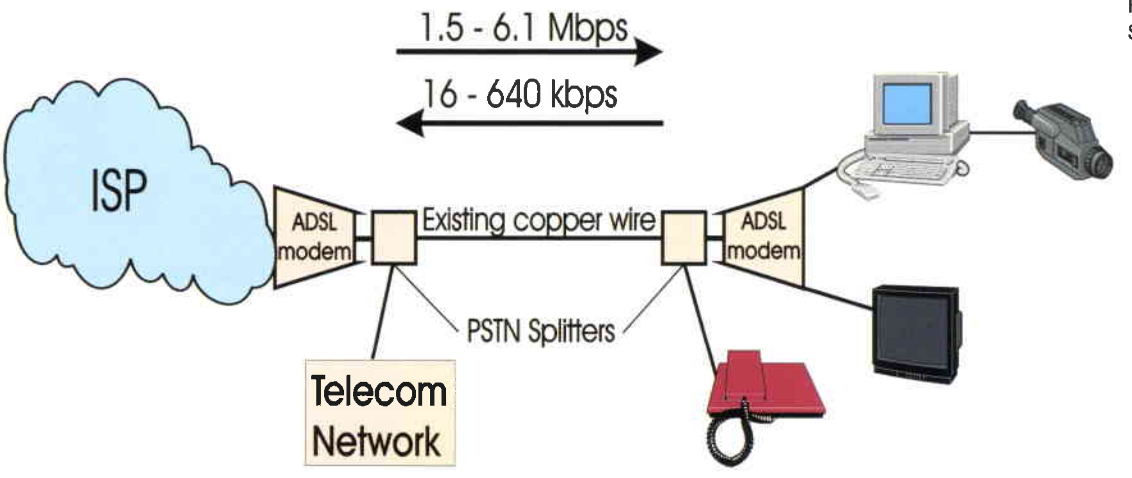


Figure 3. Asymmetric Digital Subscriber Line (ADSL)

and enhancements of their backbone networks with Asynchronous Transfer Mode (ATM) suggest that global Internet performance will increase rapidly in the next years.

ADSL is designed to improve the low bandwidth access connection between the terrestrial ISPs and the service users, which today access the ISP via telephone modem, ISDN or leased lines. The major advantage of ADSL is that it uses the existing copper wire infrastructure of the Public Switched Telephone Network (PSTN) and can operate seamlessly in parallel with the existing telephone service. Figure 3 shows how the user can reach his ISP and telephone provider over the same pair of copper wires (up to 8 km). The ADSL access is highly asymmetric, i.e. between 1.5 and 6.1 Mbps are possible in the ISP-to-user direction, but only 16 to 640 kbps are available in the reverse direction. This asymmetricity is adequate for a typical global Internet user.

Other ISPs do not use terrestrial access technologies but rather satellite-based ones. Figure 4 shows a Very Small Aperture Terminal (VSAT)-based system that can distribute up to 12 Mbps to a multitude of users. The main VSAT Hub (uplink) station is connected via dedicated connectivity to the IGS Central Node IP Gateway from where it receives the data (telemetry, video distribution) to be uplinked. The distribution is via geostationary satellite to the VSAT system users who interface from their PCs via a special PC-card and an outside antenna to the VSAT system. A low-rate return channel via telephone modem is normally provided via a terrestrial ISP through the global Internet to the VSAT provider to allow interactive applications. VSAT-based access technology provides a cost advantage when the same data needs to be multicasted to a large user community.

ISDN and leased lines

Dial-up ISDN lines can easily extend the full range of IGS operational services. Currently, dial-up ISDN lines are the best trade-off between cost effectiveness and secure connectivity, with minimal delay and a guaranteed bandwidth for short periods of time. A cost trade-off between leased lines and ISDN has to be made for each experiment mission profile. ISDN lines can be bundled in increments of 64 kbps to a single data link of up to 2 Mbps, allowing low- and medium-rate telemetry transfer and also telecommanding, due to its guaranteed bandwidth and high security. Additionally, audio and video conferencing is easily supported by this technology.

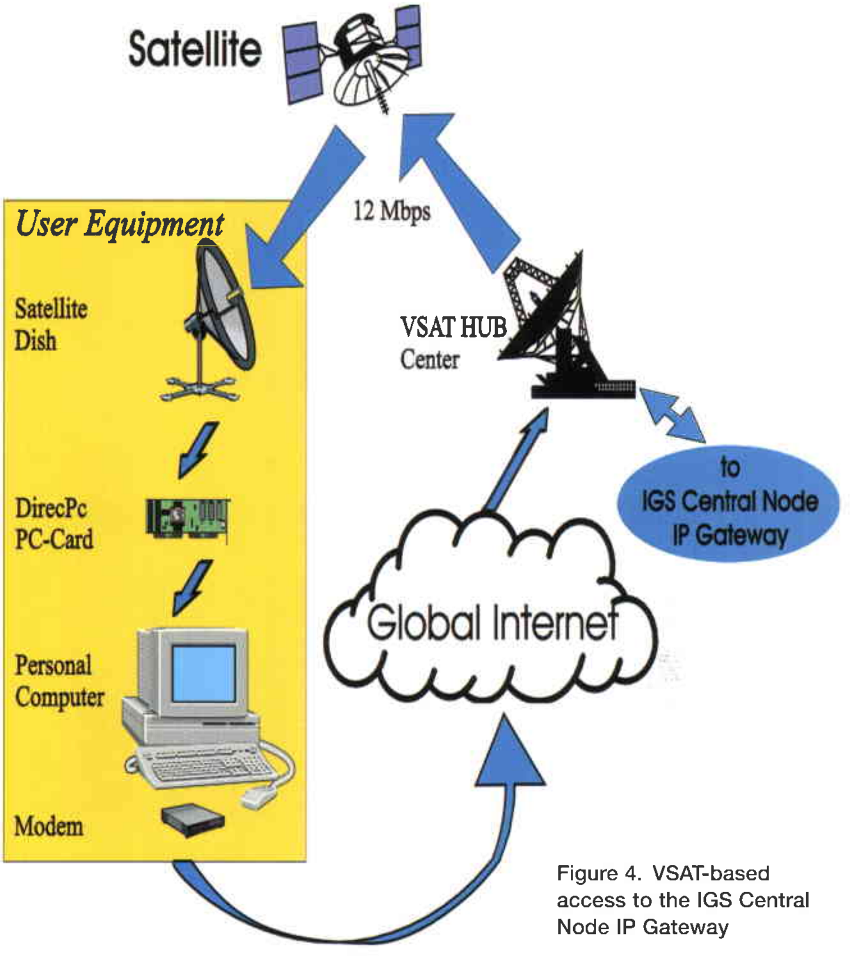


Figure 4. VSAT-based access to the IGS Central Node IP Gateway

IP version 6

The lack of adequate bandwidth for telecommanding is one of the major deficits of IP version 4. New bandwidth reservation schemes known as IP version 6 (IPv6) are being standardised. In the context of the study, the first beta version implementations of IPv6 are being tested. Although it is not expected that the global Internet will quickly move towards IPv6, it is predictable that this technology can be easily implemented in the private IGS Intranet, which would connect users via leased lines and ISDN directly into the operational communication environment. This would allow the telescience user to base himself on standard IP services with guaranteed bandwidth for each application in a low-cost telescience workstation.

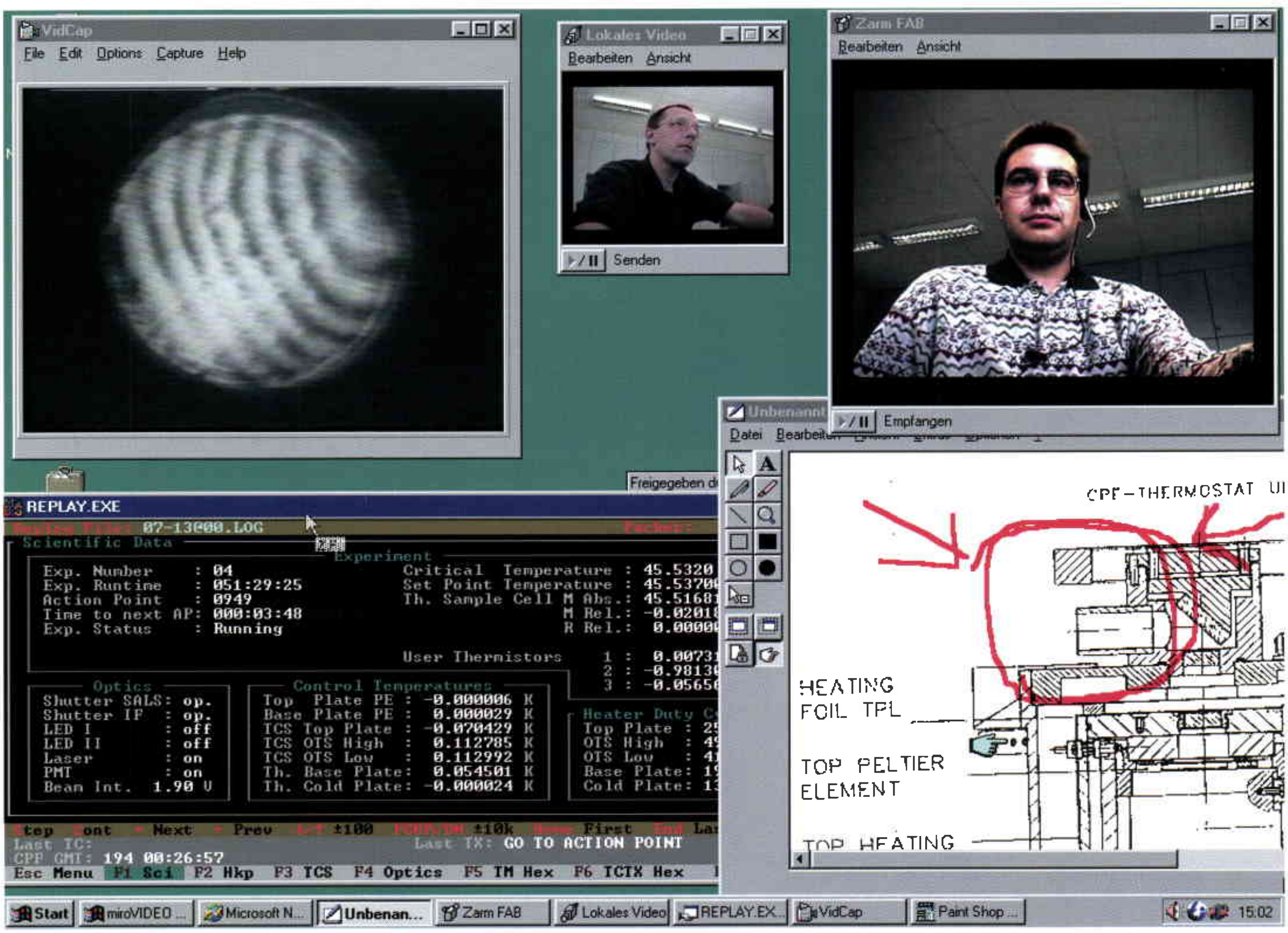
IP multicast

IP multicast is a technique to distribute the same data to multiple users of IP networks by minimising the network load. In the context of the study, this mechanism has been tested over terrestrial IP networks and VSAT-based IP networks. Within the IGS, this mechanism is interesting for online/offline telemetry distribution and video distribution. A reliable Multicast File Transfer operating over the IP multicast network service can implement offline telemetry distribution. Such a scenario will actually be demonstrated and evaluated based on the Multicast File Transfer Protocol, which allows, in particular, a wide variety of data rates between sender and receivers (few kbps to Mbps) in the same multicast tree.

Mapping space science operating requirements to the virtual workplace in space

In the following, an economic implementation of an experimenter workplace is described based on current multimedia technology. It is a demonstration build-up representing the user front-end for an experimenter who is working with the Critical Point Facility (CPF) used within the Bremen Engineering Operation Science (beos) as a demonstration facility. The demonstration is built up exclusively of existing ground S/W of the CPF facility augmented by commercial-off-the-shelf software and hardware integrated in a single PC. Figure 5 depicts how these tools could be combined for low-cost, interactive telescience. All communication tools are based on the Internet Protocol, which is the de-facto standard for data transport, thus providing the necessary

Figure 5. Screen dump of the user terminal demonstration



flexibility with respect to the transport media (carrier service).

The screen shown in Figure 5 accommodates several windows, which provide all the required functionality needed for this demonstration:

- *Monitoring and control*: In the lower left window of the screen, the typical display of a numerically-oriented payload front-end is shown which is a CPF-specific EGSE data display. In the COF scenario, these data will be based on a CCSDS/IP data stream provided by the Data Services System (DaSS). From this display, pre-validated telecommands could also be selected for transmission.
- *Monitoring of video*: The video stream from the on-board experiment facility is part of the down-link video and can be shown on the screen by a multimedia player (upper left window). The video service is provided by the Video Distribution System (ViDS) of the operational communications infrastructure.
- *Coordination*: For operational coordination, several PC tools can provide the necessary functionality. Audio and video conferencing between different partners is possible, and can be integrated with the Voice Conferencing System (VoCS) and Video Distribution System (ViDS), which are part of the ESA-provided operational communications infrastructure. Two parties are engaged in a conference as shown in the upper right part of the display. The smaller window shows a self-view of the participant; the other window presents the image of the counterpart. Below the video windows, a whiteboard has been opened which is being used for discussion of the CPF thermostat unit, and free-hand-drawn pointers and annotations are being used to help in the discussion. Also, any other application located in any of the participating PCs could be shared.
- *At the home site*: Everything the user needs is integrated in one low-cost workstation (PC) which can be located anywhere in the world where sufficient communication services are provided – but preferably in the experimenter's office or laboratory. This represents substantial savings in terms of cost and time (e.g. travel requirements are minimised).

Conclusion

The needs of experimenters for new technologies, services and applications – which demarcate today's multimedia solutions – at substantially reduced communication costs, provided the motivation to investigate alternatives for low-cost, interactive space telescience. These investigations focused on those implementations which are supported by access services to the global Internet since its communications costs are not distance-sensitive. The requirements for operating a spacecraft and experiments call for the proof of high reliability, availability and performance by the supporting communications infrastructure, resulting in significant carrier costs. For the COF scenario, a topology is proposed which provides a secure Internet-based access to the operational communications services.

Within the framework of an industrial study, various products have been evaluated which support data, voice, video and shared application services. The experience gained within the study attests that current services and applications based on the global Internet can provide adequate and inexpensive support for scientists in tele-operating their experiments in space. However, the underlying network resources have to be shared with other public users and the competition for bandwidth can result in severe communication service degradations, which some experiment scenarios may not tolerate. Even so, experimenters with less critical requirements will find Internet-based services the most economic.

The considerable development activities in communications technology and the continuous expansion of global Internet resources should result in significant performance improvements for Web-based services. Presently, major progress is reported in the fields of VSAT-based services, in bandwidth reservation techniques like IPv6, in ADSL modem technology and in the build-up of relevant support infrastructures. It is very likely that even within the initial International Space Station exploitation phase, the performance of the global Internet will grow from the currently low kbps data flow to a more reliable data service (even up to 6 Mbps).

Acknowledgements

Much of the data presented here is based on the work and contributions of Ms Raquel Barco Moreno (ESOC), and the industrial team represented by Mr Richard Sethmann (OHB-System), Mr Holger W. Oelze (ZARM-FAB), and Mr Frank Arnold (CeBeNetwork). The high motivation of the team facilitated the achievements described in this article.

esa

Canada and ESA: 20 Years of Cooperation

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This year marks the 20th Anniversary of the signing of the first Cooperation Agreement between Canada and the European Space Agency (ESA), which has resulted in numerous benefits on both sides of the Atlantic. These include the development of strategic technologies for Canadian and European space programmes, the creation of alliances between Canadian and European space companies, and a 'rapprochement' between Canada and Europe in space science and technology. The future therefore looks bright for continued cooperation between Canada and ESA.

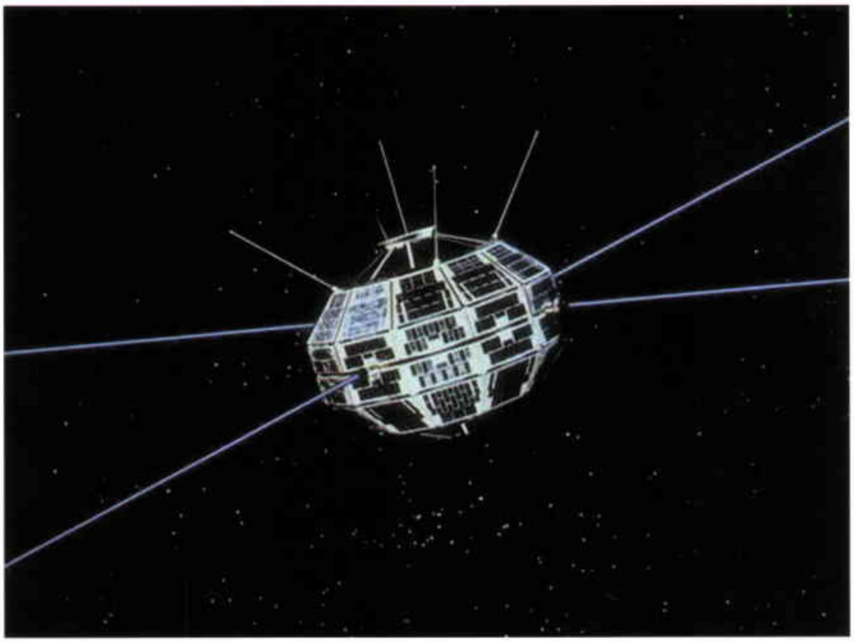

Figure 1. Alouette-1, Canada's first research satellite for the study of the ionosphere (photo courtesy of CSA)

Canadian space achievements and capabilities

Canada's total surface area is three times that of all ESA Member States taken together, but the population of Member States is twelve times that of Canada. Canada's unique geography and demography has inspired the rapid development and adaptation of space technology to meet national needs, particularly in the areas of telecommunications and earth observation. Today, Canada is one of the largest users of space systems and services in the world for communications, search and rescue, navigation, resource management, surveillance and environmental monitoring.

On 29 September 1962, Canada became the third nation after the USSR and the USA to enter the space age with its own satellite Alouette-1, which measured the electron density distribution in the ionosphere, a problem for radio communications at northern latitudes. Designed for a one-year lifetime, the spacecraft exceeded all expectations and was decommissioned on its tenth anniversary.

In 1972, Canada became the first country with a domestic commercial satellite communication system (Anik-A) and, later, the first to use direct-broadcast TV. From the experimental CTS-Hermes satellite in 1976 and the subsequent developments of the Anik satellites until today, advances have continued in the development of critical technologies and applications for future satellite communications systems, in concert with the private sector.

Remote sensing has been the other focal point for the development of the Canadian space programme from the very beginning. In 1972, Landsat-1, the first environment-monitoring satellite, was launched and its first image was received at the ground station in Prince Albert, Saskatchewan. Developed and operated by the Canadian Space Agency (CSA), Radarsat-1 is Canada's first earth-observation satellite and the world's first operational commercial Synthetic Aperture Radar (SAR) system. Launched in November 1995, it provides all-climate, day-and-night imagery for very fast delivery to customers around the world. Key applications include the monitoring of the global environment in areas of ice navigation, cartography, geological exploration, maritime surveillance, disaster relief operations and agriculture and forestry monitoring.

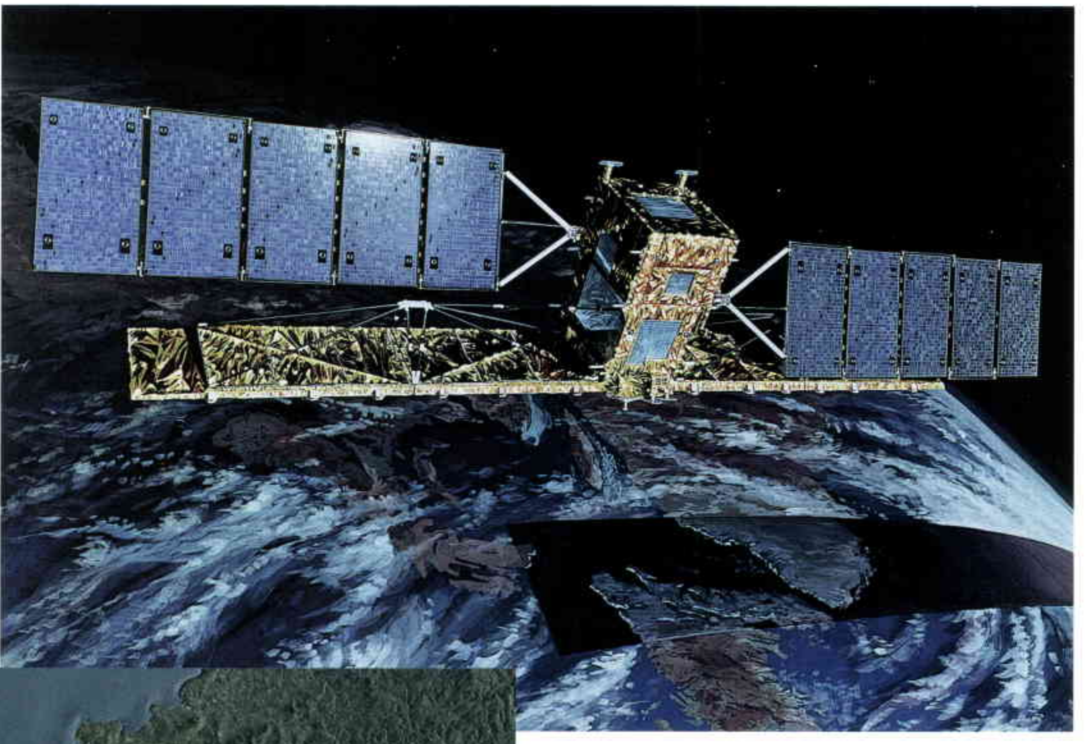

Figure 2. The Radarsat-1 spacecraft

Figure 3. Image taken by Radarsat-1

Radarsat-1 is the first space-borne radar that provides the opportunity to acquire images in variable modes of ground resolution, coverage swaths, and incident radar beam angles. Users have access to a variety of beam selections that can image a swath from 35 to 500 km with resolutions from 10 to 100 m, respectively. Incidence angles range from less than 20 deg to more than 50 deg.

Canada is now planning the follow-on Radarsat-2. Under a policy of partnership with the private sector, CSA will contribute approximately $225 million towards the construction and launch of the new satellite, with the private sector assuming the rest of the financial obligations, as well as the ownership of the system and the lead role in its operation and the marketing of the images. Following an international competition conducted by CSA, the industrial team led by the Canadian firm MacDonald Dettwiler and Associates (MDA) won the contract for Radarsat-2. MDA will build a lighter, cheaper, and considerably more capable satellite, providing the same type of data as Radarsat-1 as well as new capabilities including new modes, higher resolution, multi-polarisation, more frequent revisits and increased downlink margin, allowing the reception of data from lower cost receiving antenna systems.

In 1982, the Remote Manipulator System had its maiden flight on the US Space Shuttle, opening a new era for Canada's space industry in the area of space robotics and giving the world a symbol of Canada's technological prowess. ESA and Canada are also partners with the USA, Japan and Russia in the International Space Station Programme. Canada's contribution is the Mobile Servicing System, which will be essential for the assembly, maintenance and operation of the Station. The first element, the Space Station Remote Manipulator System, will be launched at the end of 1999. Canada also has an active astronaut programme, as well as long-standing activities in space science (atmospheric research, astronomy, solar-terrestrial relations and microgravity) and space-technology development.

By virtue of its national investment in space, Canada is the world's seventh space nation. In 1996, Canadian space industry generated $970 million in revenues, 30% of which was in the form of exports, and employed approximately 5000 people.

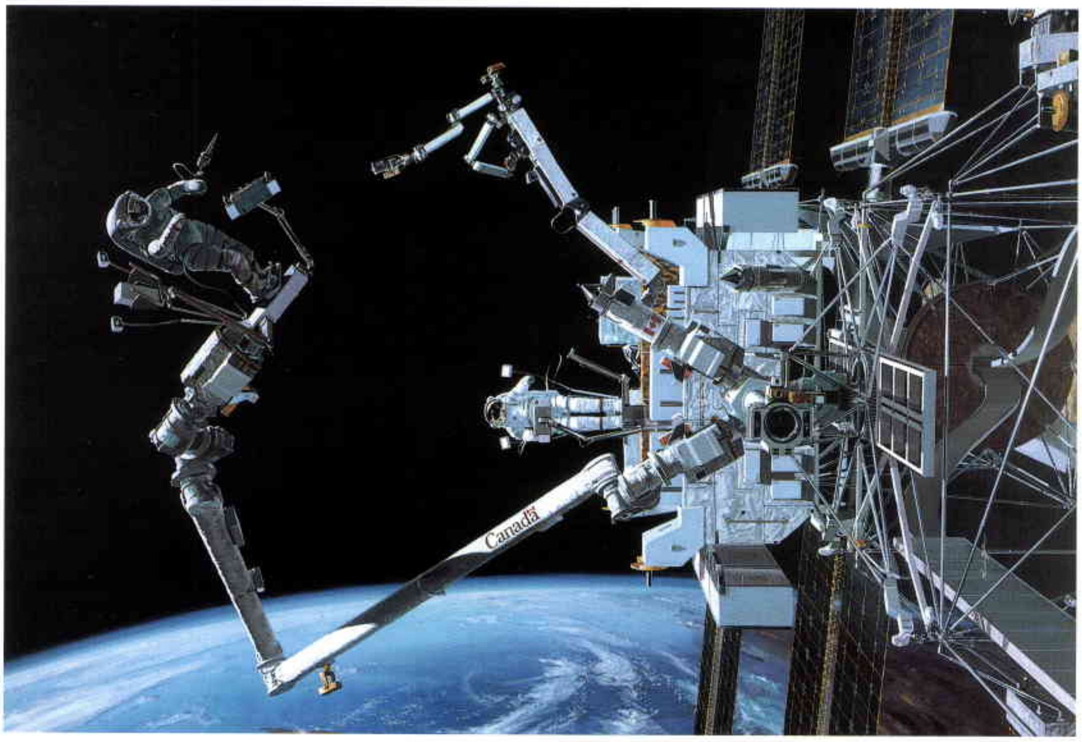

Figure 4. Canada's contribution to the International Space Station, the Mobile Servicing System that will be essential in the assembly, maintenance and servicing of the ISS (photo courtesy of CSA)

Canada is also the only non-European nation to be so closely associated with ESA. This is an essential component of the Canadian Space Agency's efforts to build a strong national programme, to work with like-minded partners, and to enhance industry's competitiveness.

History of Canada's cooperation with ESA

Cooperation between Canada and ESA's forerunner the European Space Research Organisation (ESRO) started in the early 1970s*, when ESRO provided critical elements (solar-cell panels, low-noise receiver and the 20 W Ku-band travelling wave tubes) for the Canadian Communications Technology Satellite (CTS), later renamed Hermes. This satellite was launched on 17 January 1976, and became the first one to operate in the Ku-band. The David Florida Laboratory (now part of CSA), located west of Ottawa, was built to integrate and test

* Cooperation between Canada and Europe in space existed before ESA and the Canadian Space Agency (CSA) were created. The Convention establishing ESA was signed on 30 May 1975 and ratified on 30 October 1980. The law creating the CSA was adopted on 15 December 1989.

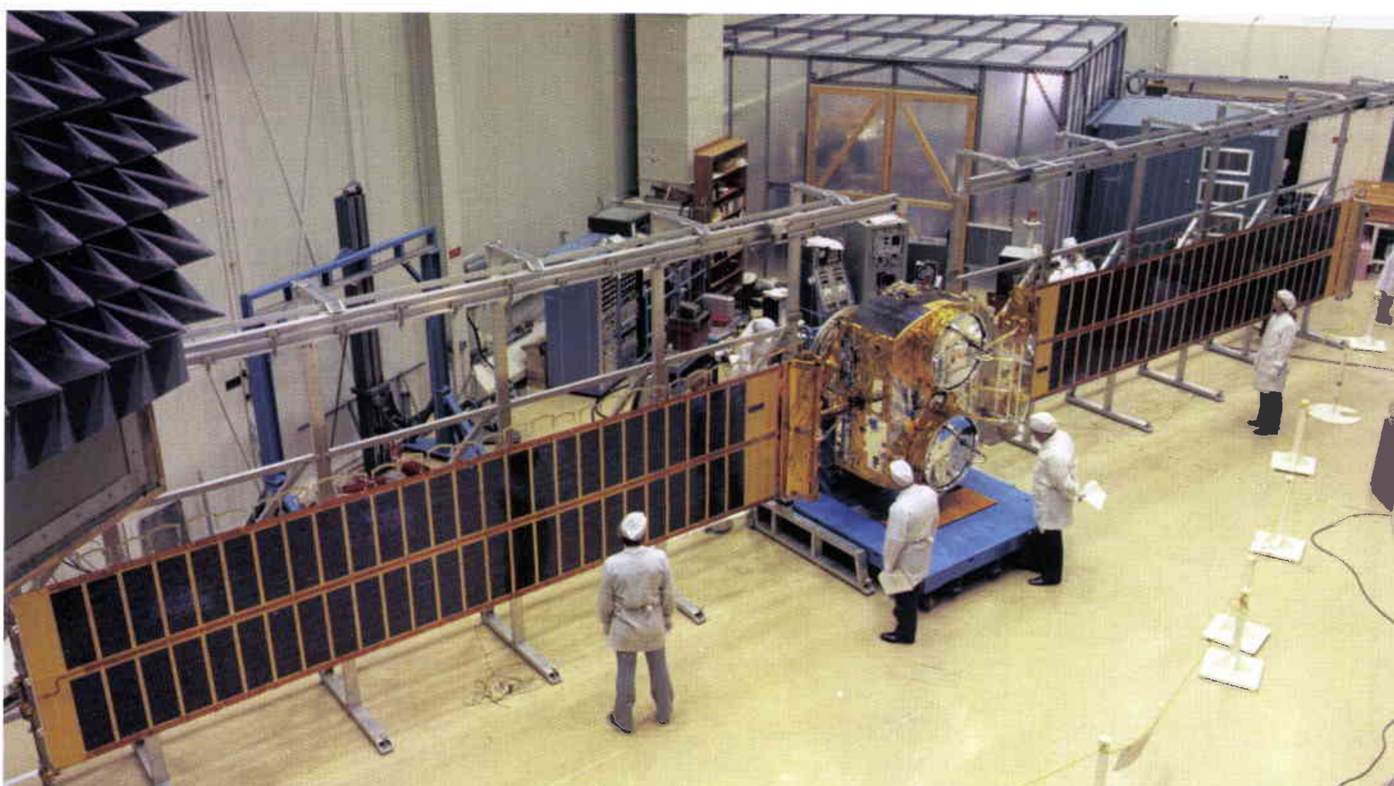

Figure 5. CTS-Hermes engineers monitoring solar-array deployment in the high bay of the David Florida Laboratory, near Ottawa (photo courtesy of Communications Research Centre)

the satellite. The CTS/Hermes satellite occupies an important place in the evolution towards high-power satellites because it permitted future communications systems to realise the small, low-cost ground stations and opened the way to a variety of direct-broadcasting applications. ESA's large solar panels provided 1200 W of power for CTS/ Hermes, making it the most powerful communications satellite of its time. During that period, Canada was also an observer at meetings of the European Space Conference.

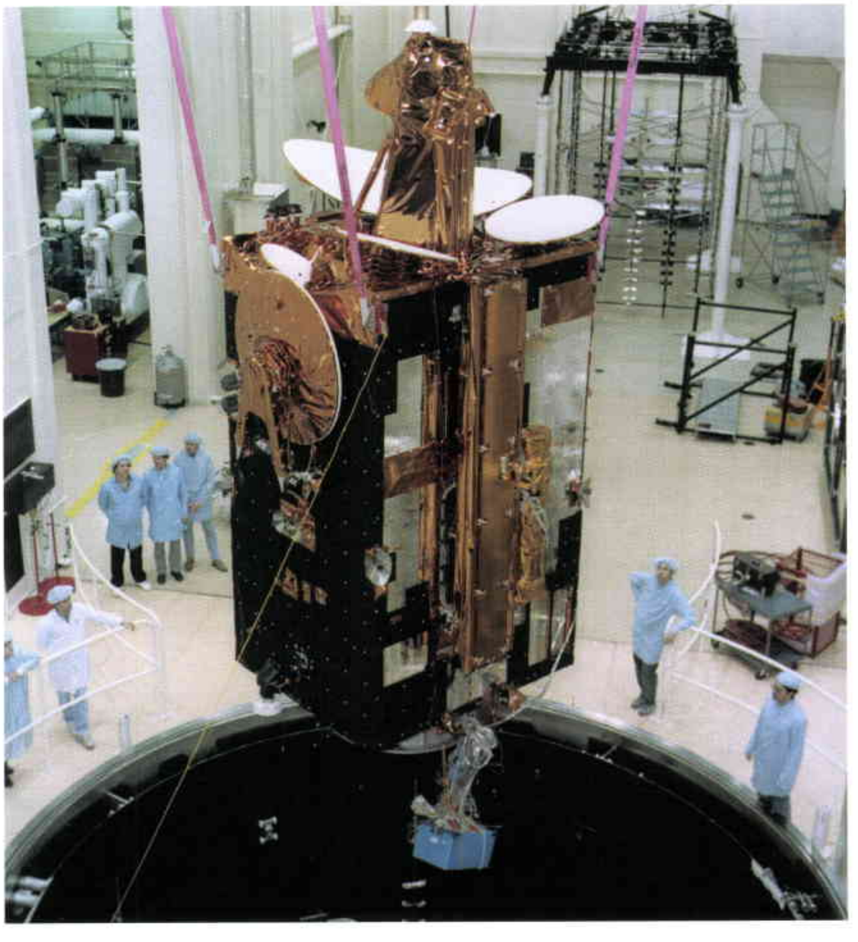

Figure 6. Olympus under test at the David Florida Laboratory in Ottawa (photo courtesy of Communications Research Centre)

Pursuant to Article XIV.1 of the ESA Convention, the first Agreement between the Government of Canada and ESA was signed on 9 December 1978, and entered into force on 1 January 1979. It was renewed in 1984 and again in 1989, the second time for a period of ten years, expiring on 31 December 1998. These Agreements, which were part of a broader strategy of the Canadian Government to strengthen cooperation with Europe in critical areas of science and technology, made it possible for Canada to participate directly in ESA programmes, activities and deliberations. Canadian industry has the ability to bid for, and receive, contracts for work in programmes of interest. Canada also obtained the right to participate in ESA's deliberative bodies, and to take part in decision making.

Programmes

Canada and Canadian space industry have actively participated in several ESA programmes, mostly in the areas of satellite communications, remote sensing and generic technology development. These programmes include ERS, EOPP and Envisat in remote sensing, Olympus, PSDE, ASTP, Artemis and ARTES in satellite communications, MSTP/ Hermes in manned space flight, and GSTP.

Olympus

The Olympus programme was initiated by ESA in 1978. For the scientists and engineers involved in space-based telecommunications in Canada, Olympus was a natural follow-on to technology demonstration and the experimentation associated with high-power satellites that had begun with CTS/Hermes and continued with Anik-B. Canada, the third largest participant in the programme, was involved in the solar-array subsystem, assembly integration and test support, payload amplifiers and microwave components. The final assembly, integration and testing were performed at the David Florida Laboratory in Ottawa, because at that time Europe did not possess the infrastructure necessary to test a satellite the size of Olympus.

ERS

The concept of a Synthetic Aperture Radar (SAR) was developed in Canada in the early 1970s and the first digital SAR image from space was produced in Canada in 1978. This demonstration that the processing of SAR data was possible convinced Canada to take an active role in ESA's first European Remote Sensing Satellite (ERS-1). The focus of the ERS mission on providing essential data addressing a wide range of environmental concerns paralleled Canada's increasing interest in using remote-sensing activities to monitor and protect our global environment.

Canada has been involved in the ERS programme since the beginning of the preparatory phase in 1980, and Canadian industry made a major contribution to the development of the ground segment and the microwave hardware. Canadian ground stations in Gatineau and Prince Albert receive and process the data from the ERS-1 and ERS-2 satellites. The expertise acquired from SAR technology and the experience gained in the reception, processing and use of ERS-1 and ERS-2 data have facilitated the development and operation of Radarsat-1.

The information provided by ERS and Radarsat has had a profound impact on our understanding of oceans and polar ice caps and an immediate benefit in many other areas such as ice-cover surveys, pollution and natural-disaster monitoring, ship-routing and offshore exploration, all of which are of prime importance for Canada.

Canada is now a participant in the Envisat-1 programme. The experience gained by Canadian industry on ERS was used on Radarsat-1, which in turn served the Envisat programme and so on with Radarsat-2 and future missions. The remarkable synergy that exists between the ESA and Canadian programmes is a prime example of the benefits of the cooperation.

Objectives of the cooperation with ESA

Canada's objectives fall into three categories: policy, programme and economic/industrial. From a policy point of view, the focus is on the diversification and reinforcement of Canada's posture as an international space partner and on fostering closer collaboration between Canada and Europe in science and technology research. Programmatically, Canada seeks to develop and demonstrate advanced systems and technologies by participating in large space projects on a cost-sharing basis, thereby supporting the implementation of the Canadian Space Programme. Canada also seeks to support the competitiveness of Canadian industry, through alliances with European firms, and to foster the two-way transfer of technologies between Europe and Canada.

Benefits of the cooperation

During 1996, CSA commissioned a complete external evaluation of Canada's cooperation with ESA since 1978. This study, completed in spring 1997, showed that Canada's overall objectives in its relationship with ESA have been achieved. Canadian investments in ESA have resulted in significant direct contracts to Canadian companies and follow-on spin-off sales, promoting the development of the industry as a whole. Several strategic alliances have been concluded, for the performance of ESA and other commercial programmes. Canadian space projects such as the Radarsat and Anik series of communications satellites have been facilitated by Canadian involvement in ESA activities. Moreover, Europe and Canada have developed a much closer working relationship in this critical area of international science and technology*. The evaluation also surveyed the views of Canada's European partners (at ESA, in Member States and their industries) and revealed their views that cooperation with Canada had also been very beneficial to Europe, for reasons similar to those above.

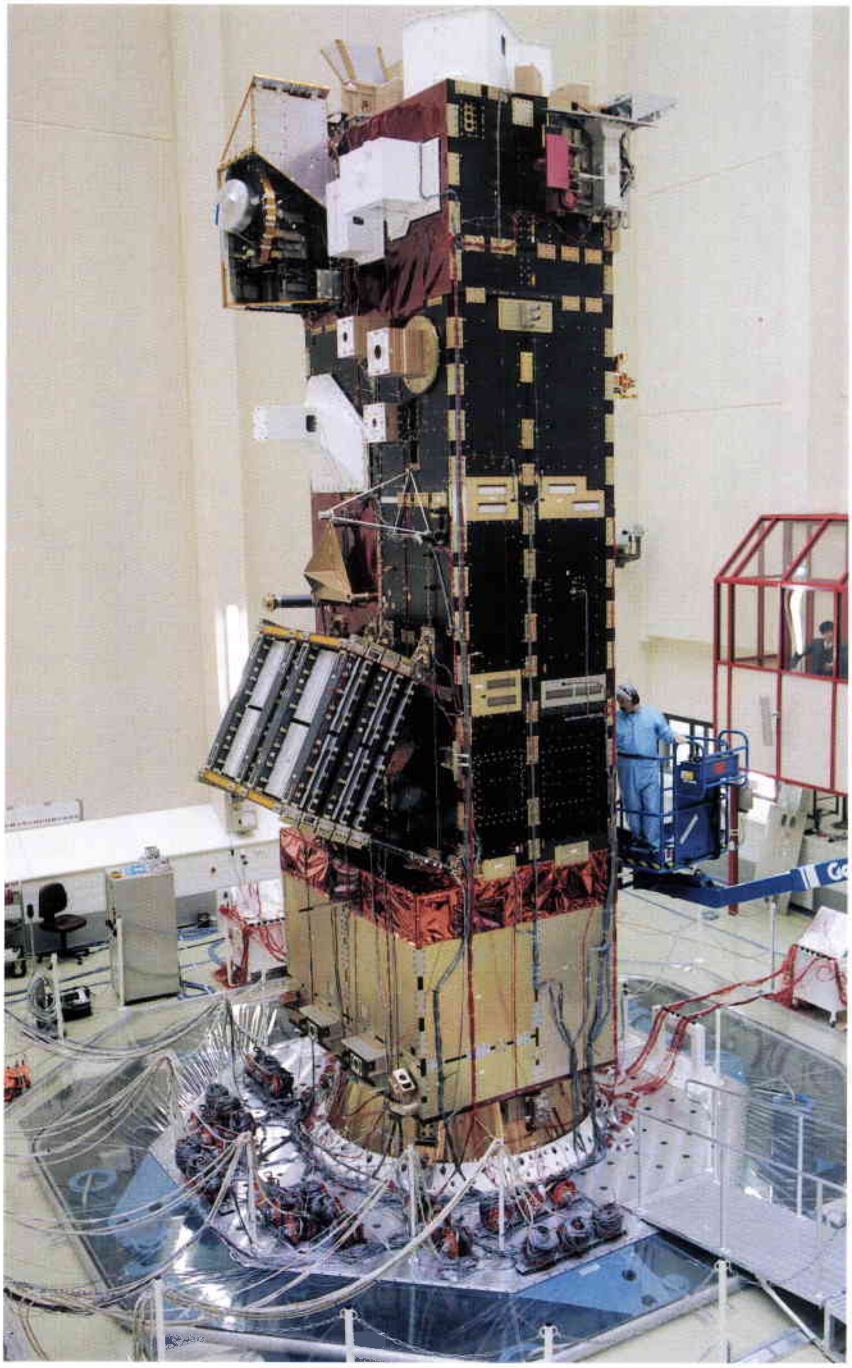

Figure 7. The Envisat spacecraft

In 1994, an economic study performed by the University Louis-Pasteur (Strasbourg) and the Ecole des Hautes Commerciales (Montreal) revealed that every ECU spent by ESA in Canada created 4.20 ECU of additional added value (indirect spin-offs) for the contracting firms and their Canadian suppliers. The ratio calculated in this study was significantly greater than that calculated in a similar study performed in 1989 (3.50).

There are a number of structural differences between Canada's relationship with ESA and that of its Member States: Canada's status as a Cooperating State; the geographical distance; and the specialisation of Canadian companies in technology niches. However, experience has

* Canada also has a science and technology cooperation agreement with the European Union (EU), which allows Canadian companies and organisations to partner with Europeans and participate in the EU's Research and Technology Development Framework Programme.

Figure 8. The Canadian flag, flying alongside those of some of its ESA Member State partners, at the European Space Research and Technology Centre (ESTEC), in the Netherlands

demonstrated that these differences can often be very constructive. Indeed, Canadian industry has developed a worldwide lead in some technologies, which can be of benefit to ESA. Also, since Canada's national space programme involves expenditures about ten times greater than its ESA contribution, the work performed by Canadian industry for ESA benefits from a strong technology base. In addition, Canadian and European companies, working side-by-side in ESA programmes, learn a lot about their respective management practices and business cultures.

Policy aspects

ESA and CSA objectives are almost identical. Both the Act that created the CSA and the ESA Convention refer to their mutual mission to promote the development of space science and technology for exclusively peaceful purposes. There is also a strong similarity between the visions of CSA and ESA. A primary focus of both agencies is to promote the competitiveness and success of their industries through technology development programmes and innovative and flexible funding mechanisms.

Conclusion

The space cooperation between Canada and ESA is unique. ESA is the only international space agency in the world and, to this day, Canada is the only non-European country to be so closely associated with ESA. In addition to ensuring substantial socio-economic benefits on both sides of the Atlantic, this collaboration has strengthened the bonds between Canada and Europe in critical areas of science and technology. Whereas twenty years ago the cooperation was primarily technology-driven, this is now complemented by a strong commercial element.

The next Canadian Long-Term Space Plan (LTSP-III), to be proposed to the Canadian Cabinet in early 1999, will include a recommendation for the continuation of Canada's cooperation with ESA. This recommendation will be based in part on consultations with all concerned stakeholders in Canada, and will set the stage for Canada-ESA relations to continue into the next millennium.

As we look to the future, we can be confident that space cooperation between Canada and ESA will be as mutually beneficial and fruitful as the past 20 years have been.

The MediaGlobe Concept
– Watch What You Want, Whenever You Want!

A. Mauroschat
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&
SpaceTech Participants

On 3 July 1998, the participants in the Second International SpaceTech* Space Systems Engineering Programme presented to an audience of European space professionals their proposal for an innovative multimedia broadcasting service based on a new information distribution concept. This 'MediaGlobe' concept is a user-oriented 'end-to-end system' that includes new approaches for doing business using the latest multimedia technology. It would facilitate the development of attractive new services and allow Europe to capitalise on its considerable expertise in satellite-related communication technologies. ESA is already involved in the development of high-performance multimedia communications through its ARTES (Advanced Research in Telecommunications Systems) programme, and pursuit of the MediaGlobe initiative would provide European industry with an excellent opportunity for active participation in this booming and highly competitive field.

Introduction
Television is today's single most important mass communication medium and has become an integral part of our society. There are more than a billion households with televisions world wide, but viewers are generally not satisfied with the programming on offer. Despite the ever-increasing number of channels available, there are inherent limitations in the way they are delivered. Television today means 'passive' consumption of real-time programming. The viewer is confronted with a multitude of simultaneously transmitted programmes, from which he or she may choose the one they fancy most at any given moment. The viewer has no further options, other than to use a video recorder. The MediaGlobe concept would revolutionise how we watch television in that it would allow viewers to see the programmes they want whenever they want, putting them in complete control.

All of the elements in the MediaGlobe end-to-end system have been analysed, including the mission architecture, the system verification and implementation plan, the business plan, and the marketing strategy. This analysis has shown that MediaGlobe represents a lucrative business opportunity for both broadcasters and investors.

Participants in SpaceTech 1997/98

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* SpaceTech is an international post-graduate programme run by Delft University of Technology, in The Netherlands. It leads to a Masters Degree in Space Systems Engineering, with a strong focus on market-oriented and cost-conscious end-to-end systems engineering. ESA is one of the organisations sponsoring and participating in the SpaceTech programme.

What is MediaGlobe?
MediaGlobe would be the first direct-to-home satellite broadcasting system to offer new digital TV and information broadcasting services where the home user has full control over the content. It would radically change the way in which the home user, equipped with a simple and compact dish-antenna terminal with high-volume data storage, would watch television in the future.

Which services?
MediaGlobe would offer its subscribers a personalised home videotheque and information store that is dynamically updated according to their specific profiles and wishes. At any point in time, viewers would be able to choose from hundreds of movies, live events, and thematic programmes stored on their own MediaGlobe terminal, somewhat akin to a huge video recorder.

The various TV services offered would differ in terms of content, delivery times and pricing. The latest movie, for example, might have a guaranteed delivery time of some 15 minutes, after being ordered from the MediaGlobe service centre via a telephone modem link and received via the next satellite download together with the authorisation code needed to view it.

MediaGlobe would also provide Intranet broadcasting services for direct-to-office and small-office/home-office users, typical applications being business information services, software distribution and catalogue updates to specialised user groups.

To whom is it devoted?
MediaGlobe would allow broadcasters and information service providers to expand their service offerings and thereby reach new customers. On behalf of its partners, MediaGlobe would offer 'television and information on-demand' services to millions of users in Western Europe, Eastern Asia and the Pacific, and Eastern North America.

How does it work?
MediaGlobe relies on three geostationary satellites, each of which would cover one of the three service areas (Fig. 1). Broadcasters and information providers send their contents to the respective MediaGlobe multiplex- and up-link stations, where the programme suite is assembled and up-linked to the satellite. Each MediaGlobe satellite then broadcasts thousands of video and information contents to millions of users in its particular service area. The video data is continuously received by the MediaGlobe terminal and, if there is a match with that user's personalised reception profile, stored for future viewing. The user, who then has full control over the stored contents of their terminal, would be charged per view and billed accordingly via toll-free terrestrial lines to the local MediaGlobe service centre.

An essential element in the MediaGlobe concept's success is the availability of high-volume digital storage capacity at an affordable price (Fig. 2). Fortunately, this capacity is continuously increasing, thereby enhancing the service's attractiveness and facilitating its future expansion to include memory-consuming applications like high-definition television (HDTV).

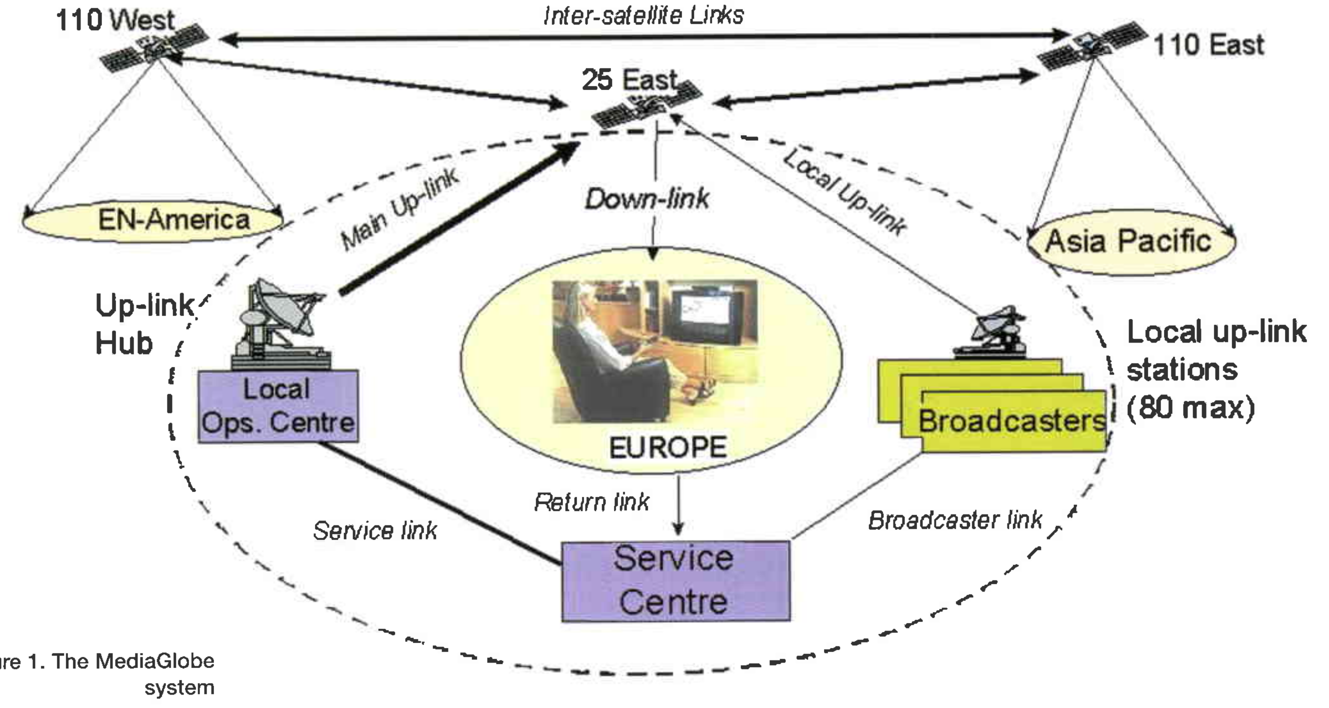


Figure 1. The MediaGlobe system

MediaGlobe would be the first space system to allow broadcasters direct access to the satellite and to provide service distribution to three different parts of the World simultaneously.

Local access
To achieve this, each satellite also has a number of onboard mutiplexers, which would allow small broadcasters to access the MediaGlobe satellites directly using small earth stations. Hence no dedicated communication links to an up-linking station are required, which allows significant cost savings and makes the MediaGlobe approach very attractive to its participating partners.

Global connectivity
The MediaGlobe satellites are interconnected via inter-satellite links in order to allow direct transmission of contents to users on all three continents without the need to organise dedicated point-to-point links on the ground, thereby allowing further cost savings.

Availability
MediaGlobe services could be introduced as early as 2002, when the necessary high-capacity data storage terminals will be readily available. MediaGlobe could be first to market with this new approach to television services, enabling it to capture an increased share of the emerging pay-TV market.

The market
MediaGlobe would target the lucrative digital direct-to-home pay-TV markets in Western Europe, Asia, the Pacific and North America. This market is expanding on a global basis with an annual subscriber growth rate of 37% (Fig. 3). By the year 2000, more than 30 million subscribers are predicted world-wide, with an ongoing transition from analogue to digital transmission, and annual revenues are expected to grow to $12 billion. In parallel, the cost of the equipment needed by the user will decrease, making these services globally available and affordable. This creates a high growth perspective for new multimedia applications like tele-banking, home-shopping and interactive television.

The most promising regions are Western Europe, Eastern North America and Asia Pacific, because of their predicted growth rates as well as their current gross domestic products and high-tech readiness. The Digital Video Broadcasting (DVB) market generates revenues via subscriptions, advertising and licence fees from public-service broadcasters. Of these, the subscription fee, at 64% of revenues, is the largest source of pay-TV income. Pay-TV applications are also the sector with the strongest growth expectations.

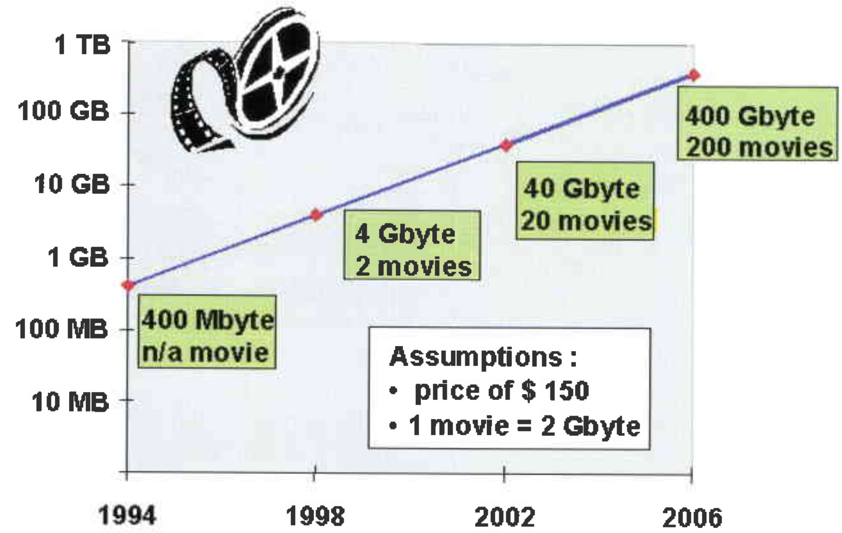


Figure 2. The key enabling technology: availability of digital storage capacity

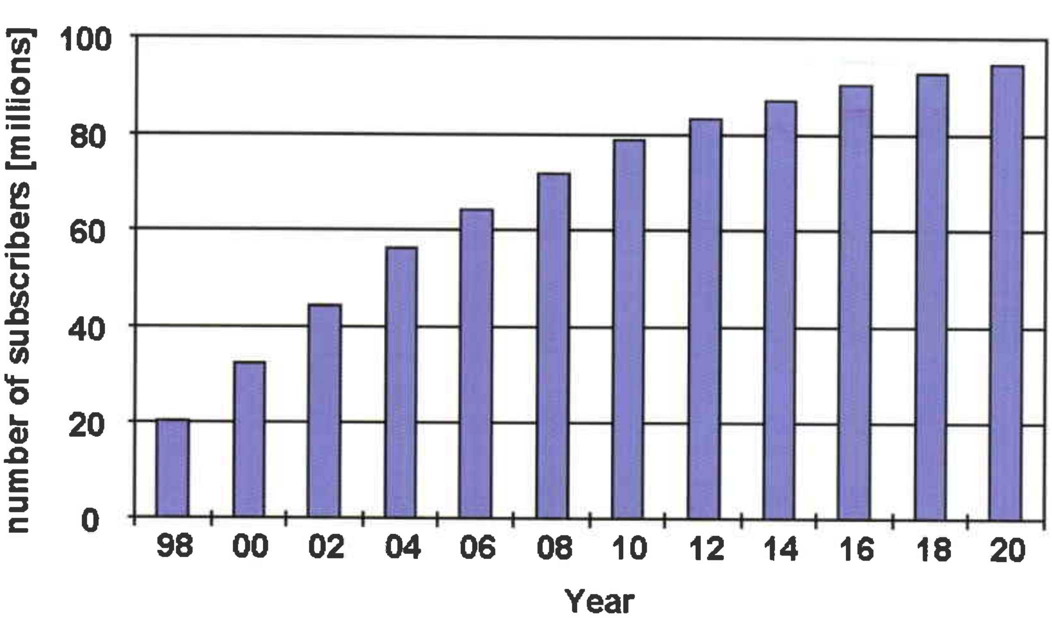


Figure 3. The world-wide digital pay-TV market

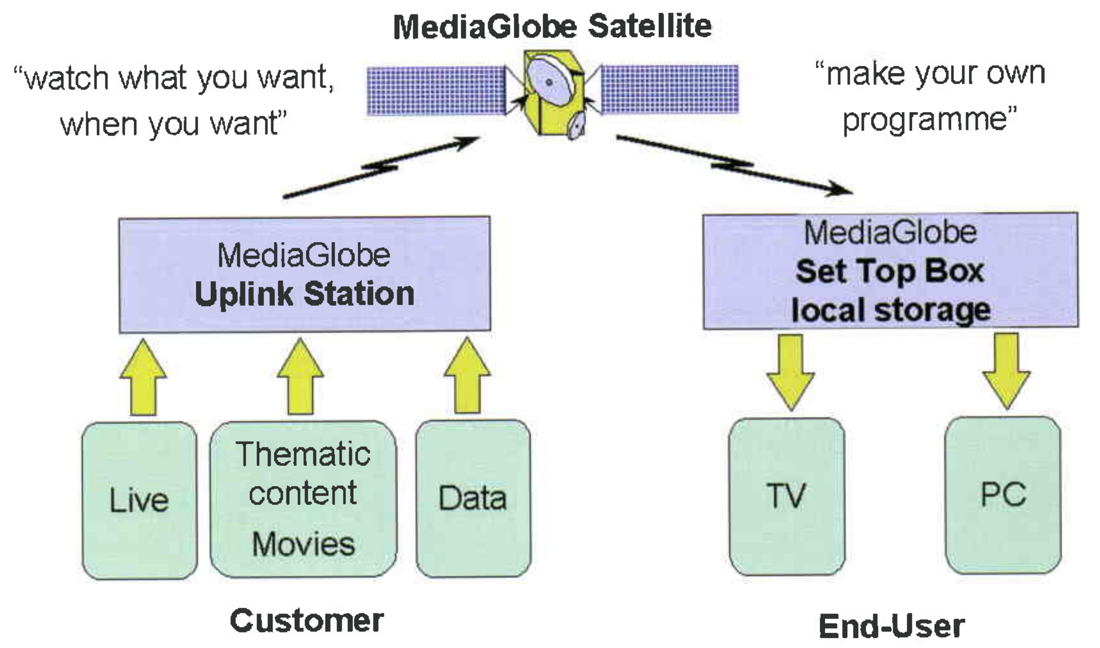


Figure 4. The MediaGlobe new service concept

Table 1. Movie transmissions per day depending on category, defined by user demand

	Europe	
Category	Number of movies	Repetition rate per day
Top seller	20	> 80
Best seller	160	18
Basic	1700	1

The services

TV-on-demand

This service would broadcast the most popular movies with better than VHS quality, and thematic television contents with subjects like nature, history, science, series, etc. in SDTV quality (Fig. 4). The movies would be divided into three categories, depending on user demand, with each category being transmitted several times per day (see Table 1).

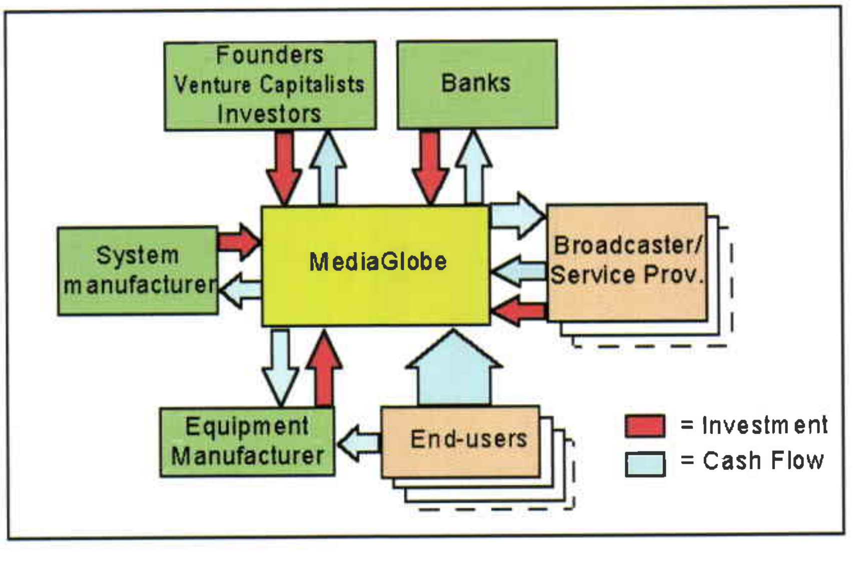


Figure 5. The strategic alliances and value chain

Live broadcasting

This service would include sets of programmes and events in Standard Digital TV (SDTV) that are interesting enough to be broadcast in real time. Examples are sports, popular shows, news and special events. The viewers could either watch these in real time as they do now, or programme their storage-and-ordering box to capture them for future viewing (even during transmission) much like today's video recorders.

Data

The broadcast data content would include software and software updates, databases, catalogues and their updates, games and Internet contents. Customers would include both business and private users. For example, software could be made available to a user for a specific (limited) period for a lower cost than purchasing the software outright. Private users might be expected to order computer games, catalogues and databases like phone books, whereas companies and smaller business users might be more interested in more specialised databases, business software and software updates.

A new approach to the value chain

Traditionally, satellite operators have provided bandwidth to broadcasters and service providers, who have then addressed the end user. MediaGlobe would provide TV and data services directly to end users, sharing this market sector with today's satellite operator's customers, namely the broadcasters (Fig. 5). This implies that the user would have only one interface for the MediaGlobe service, for central functions such as the updating of user profiles and billing. For the broadcasters, it means relinquishing their direct link to the end user, but in return they gain access to the new MediaGlobe approach to providing TV services, which means a high degree of flexibility and an overall increase in market volume.

MediaGlobe would be responsible for system procurement and mission operations. It would also be responsible for the service operations, which include contents processing, data encoding and up-linking, order processing, billing, networking and provision of the help-desk functions. This clearly distinguishes MediaGlobe from other satellite operators whose role has been limited, as noted above, to the provision of bandwidth to broadcasters.

All of the players in the MediaGlobe value chain are strategic partners who provide the equity and invest in the system. These partners would share in MediaGlobe's success and receive a proportion of the revenue. Success of the venture depends on the participation of broadcasters, contents providers and end-user equipment manufacturers. The latter need to be involved from the outset, as the timely development and availability of the MediaGlobe set-top storage-and-ordering box, including all of the specialised user interfaces and control functions, is critical.

Pricing and marketing

MediaGlobe foresees an approach leading to comparatively low charges for the three services offered, with pricing on a pay-per-view/pay-per-volume basis. There would be a monthly charge of, say, $9 per month for two years for the end-user equipment (dish antenna, storage-and-ordering box, integrated receiver and decoder). The charges for the movies would depend on the category; e.g. $2.5 for a top movie would compare favourably with pay-TV providers' rates and be comparable to normal video-store rental charges. Based on the average pay-TV viewing times in Europe, the price for the MediaGlobe live-broadcast service might be $8-10 per month, which would be highly competitive compared with any other pay-TV service concept. Data-push services would be offered to the end user for a charge of $0.1 per megabit, independent of the number of users.

As part of its new business approach, MediaGlobe would subsidise the transponder costs and charge broadcasters only a fraction of the market price for satellite capacity. In return, it would keep 20% of the end-user revenues, corresponding to its added value, namely the service provision to television viewers. This concept is very favourable and would allow new broadcasters and content providers to get to the market quickly.

For the TV-on-demand broadcast service, MediaGlobe proposes to charge only $1 million per transponder per year, which is considerably cheaper than the strongest competitors currently charge.

MediaGlobe charges to broadcasters for live services would be at least 25% lower than those of any competing satellite operator, and would be in the range of $200-450 per hour, depending on the region and time of transmission.

MediaGlobe targets a market share of 15% of the pay-TV market within three years of starting operation, and 20 to 30% in the longer term. In order to achieve that degree of market penetration, MediaGlobe's marketing campaign would include a demonstration service prior to full service launch, both to provide proof of concept and attract potential users. Heavily subsidising end-user equipment would help to penetrate the market quickly.

MediaGlobe does not aim at a new market, but at the existing and established direct-to-home market. This means that MediaGlobe users would be equipped with a dual-reception antenna, allowing them to receive the TV programmes of the already established satellite operators and the new MediaGlobe service offerings with a MediaGlobe TV receiver (equipped with the special storage-and-ordering box).

The technical solutions

The technical solutions address all of the space- and ground-based resources needed to implement the end-to-end MediaGlobe service concept, plus the infrastructure required to operate and maintain it (Fig. 6 and Table 2).

The different services provided by the broadcaster are up-linked to the satellite either via local up-link hub stations, or directly via a dedicated up-link station at the broadcaster's premises. The data contents are selected by the end users via their storage-and-ordering boxes, which are connected to the different MediaGlobe local service centres via low-data-rate terrestrial communications links (using the Public Switched Telephone Network) for ordering and billing purposes. The data stream is multiplexed either on the ground in the case of up-linking via the hub station, or onboard for the data that come from broadcasters using their own up-links. The MediaGlobe satellite constellation then provides access to the three coverage areas from a single point, since the data are relayed to the satellite covering the target area via the inter-satellite links.

Table 2. Primary characteristics of the MediaGlobe space and ground segments

Functional Requirements

Performance

- Number of transponders:	50 (+12 redundant)
- Transponder data rate:	38 Mbps
- Transponder bandwidth:	36 MHz
- Bit error rate (BER):	10^{-10}
- EIRP:	> 56 dBW peak
- Receiver G/T:	12 dB/K (standard 60 cm diam. dish)
- Storage device memory:	40 GB
- Equipment cost:	< $500

Coverage

Service regions (Fig. 7):

- Asia-Pacific region comprising Japan, northern coastal regions of China (from Beijing to Shanghai) and South Korea
- Western Europe in particular with Italy and Spain as well as the German-speaking countries, the Benelux and France
- The Eastern part of North America from Florida up to Newfoundland, and west to the Mississippi River

leading to the following orbital-slot requirements (Fig. 8):

- Asia-Pacific satellite:	110° East
- European satellite:	25° East
- American satellite:	110° West
- Beam coverage on surface:	4000 km x 2000 km
- Connectivity:	satellites interconnected via inter-satellite links
- ISL data rate:	200 Mbps
- System response time:	< 24 hours, depending on service

Operational Requirements

- Start of service:	2002
- Duration:	15 years
- Orbit:	GEO
- Availability:	99.5% during sunlight and eclipse
- Reliability:	0.68 at end-of-life for overall spacecraft bus, and 0.82 for payload
- Security:	To deny unauthorised access data encryption to data and command channels since services are commercial in a very attractive market
- Survivability:	Capability to survive natural / launcher induced environments No capability to survive external wartime threats
- Data content, form and format:	DVB standard ETS 300421, ETS 301192

Constraints

- Schedule:	Programme decision: end-1998 Order launches: mid-1999
- Set up industrial organisation and preliminary phase with partners by beginning of 1999	
- Development phase: early 1999 to early 2002 (= 3 years)	
- Regulatory issues:	1998
- Regulation:	Agreement with ITU & WARC for allocation of frequencies, bandwidth and orbital slots

Interfaces

- Data:	DVB
- Launcher:	Ariane-5: max. GTO mass 6800 kg, fairing 4.57 m x 10.35 m (single launch) Proton D1e: max. GTO mass 5500 kg, fairing 3.97 m x 7.3 m (single launch)

Development

- Development time:	< 3 years, with time-to-market as key driver

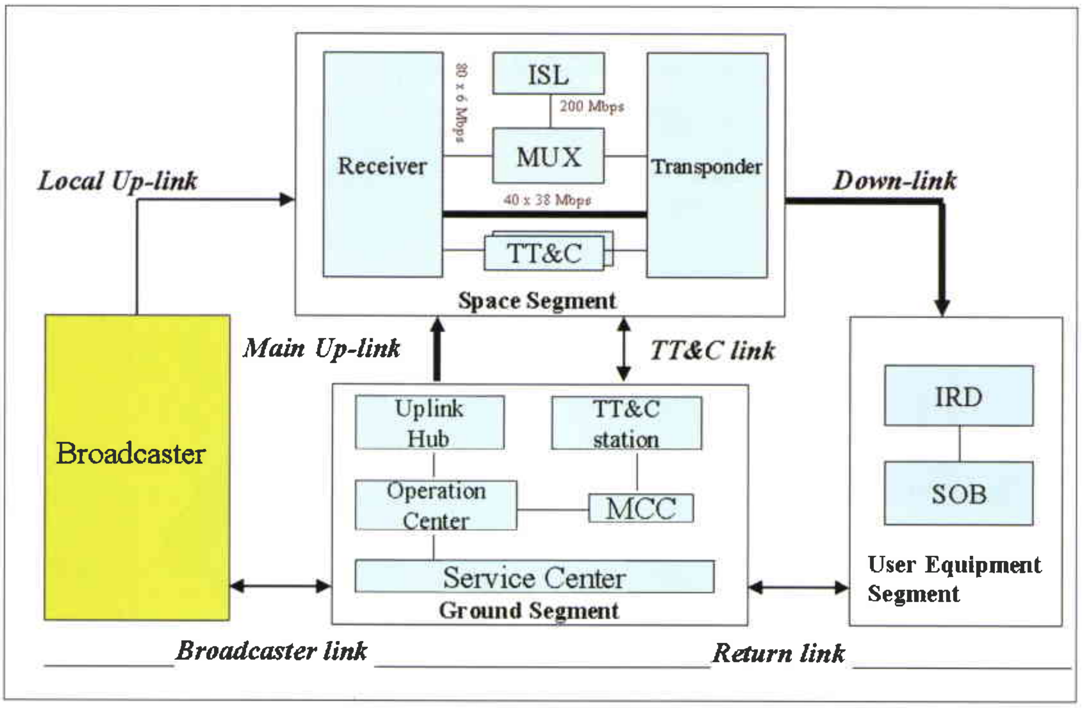


Figure 6. The space- and ground-segment architectures

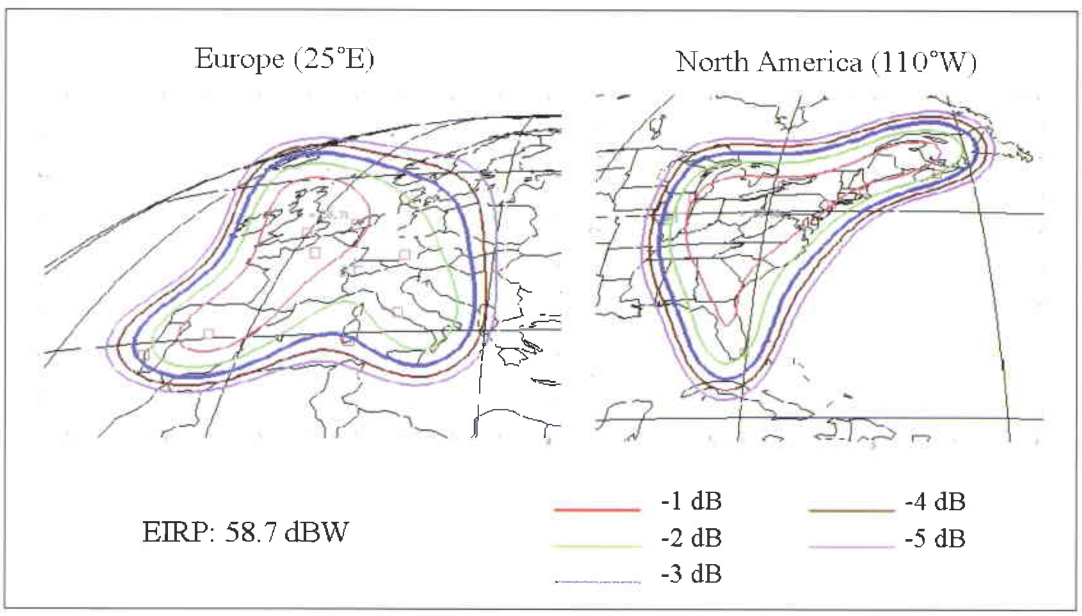


Figure 7. The Northern Hemisphere coverage areas

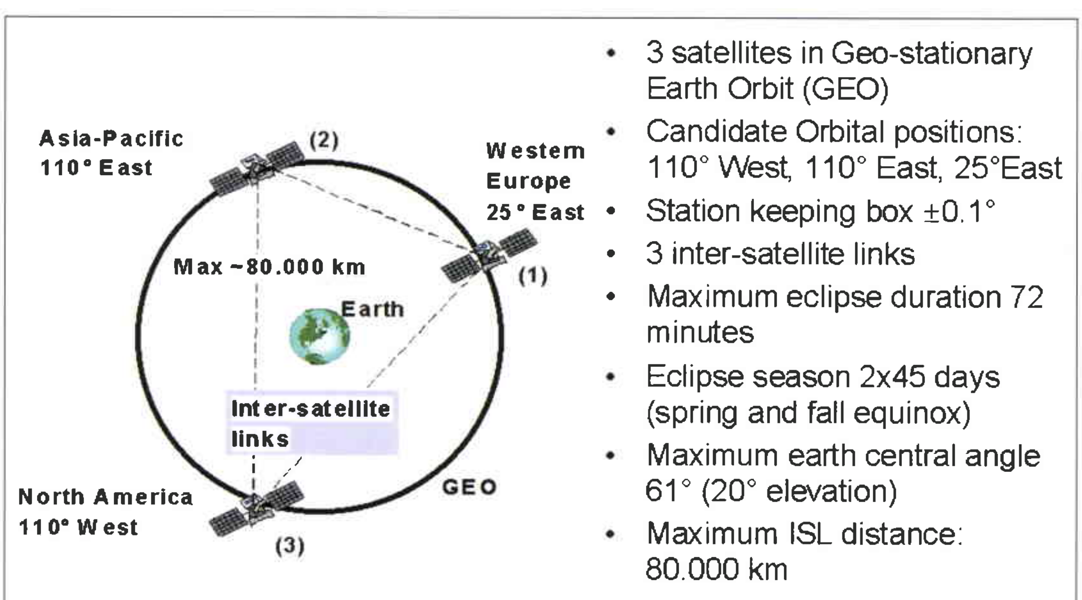


Figure 8. The MediaGlobe constellation

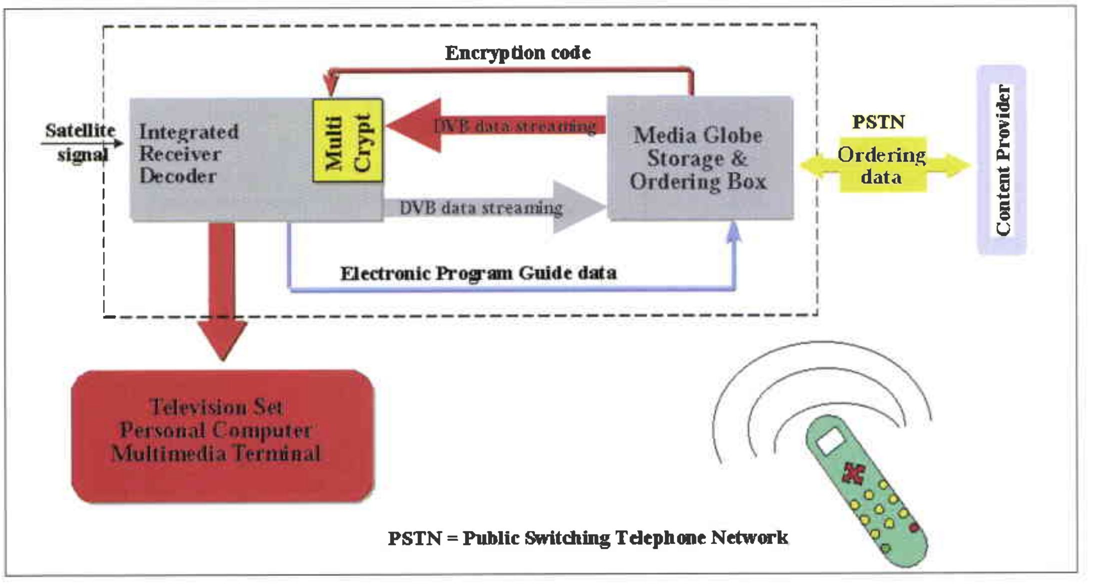


Figure 9. End-user equipment data flow

The data are received by the end users via standard satellite dishes (60 cm), possibly with a dual feed for reception from two satellites, and DVB-compatible Integrated Receiver Decoders. The end-user equipment requirements have been established on the basis of the market-analysis and the business-case study. The storage capacity of the end-user equipment is therefore sized according to the expected average use of the system based on the market study.

The MediaGlobe end-user equipment needs to be specially designed (Fig. 9). The broadcast signals are received and decoded by a standard DVB-compatible Integrated Receiver Decoder (IRD). The IRD has a DVB data streaming output for the video data to be stored in the Storage-and-Ordering Box (SOB) and an input for the data to be played back. The interface between the IRD and the SOB is a PCI-compatible Smart-Card. The main SOB sub-components are a microprocessor, a hard disk with controller and a modem for transmitting the ordering data, selected via the Electronic Programming Guide (EPG), to the billing centres and receiving the decryption code.

The three MediaGlobe geostationary spacecraft have to carry and support the communications payloads and provide all the necessary housekeeping functions. From the initial payload mass and power budgets, it is evident that high-end next-generation communications satellites will be needed:
- Accommodation of 450 kg payload and provision of 9.5 kW of payload power
- Payload Earth-pointing better than 0.1 deg in roll/pitch, 0.25 deg in yaw
- Support of mission operations, including data up-linking, broadcasting, ISLs
- Service provision 24 hours per day (daylight, eclipse) without interruption
- Operational in geostationary orbit (launcher type and environment)
- 15 year nominal design lifetime
- Spacecraft functions and subsystems fully controlled (autonomously/from ground).

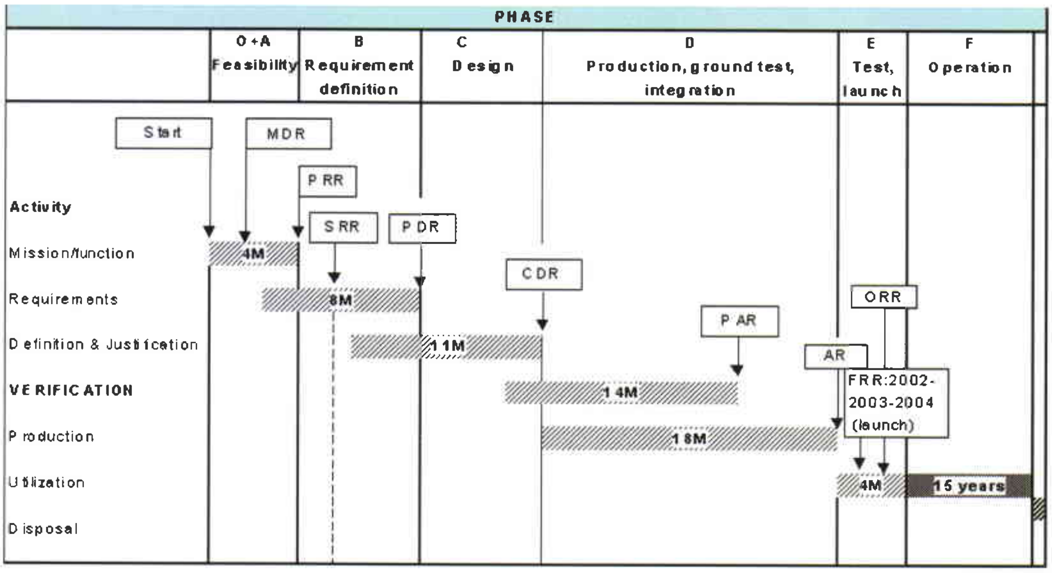
Implementation

The MediaGlobe schedule (Fig. 10) is based on a three-year implementation period, from system definition to operational qualification of the first MediaGlobe spacecraft (flight model 1), foreseen to be launched in 2002. The second and third flight models would be launched in consecutive years. The short time span requires that certain activities be conducted in parallel, particularly those relating to the early design and manufacture of the spacecraft and the co-ordination between the space- and ground segments needed to validate the complete system.

Due to the short schedule for the development, assembly and delivery of the MediaGlobe satellites, and in order to reduce the overall costs, the following approach is foreseen:
- maximum use of commercially available hardware (modified as necessary)
- use of the protoflight model philosophy at all levels, with engineering models only being used for newly developed equipment and equipment that has been drastically modified
- subcontracting of all development, test and verification activities

The characteristics of the proposed MediaGlobe space- and ground segments are shown in Figure 11.

Figure 12 shows the spacecraft bus, with its Ku-band antennas (1.5 m for transmission, 1.3 m for reception) and its optical inter-satellite terminals. The power subsystem is based on rigid fold-out, dual-junction, gallium-



CDR: Critical Design Review, FRR: Flight Readiness Review, AR: Acceptance Review, PAR: Preliminary Acceptance Review
ORR: Operational Readiness Review, SRR: System Requirements Review, PRR: Preliminary Requirements Review
MDR: Mission Definition Review

Figure 10. The implementation schedule

Space Segment

- GEO-satellite constellation: 3 spacecraft
- Lifetime: 15 years
- Data throughput: 1.9 Gbps
- Down-link EIRP: >56 dBW peak
- Transponders: 50+(12), with 10^{-10} BER (QPSK)
- Inter-satellite links: 1.046 microns, 200 Mbps (BPSK)
- Dry/wet mass: 2450/4600 kg
- Power (EOL): 16.0 kW

Ground Segment

Users
- Dual reception dish : 60 cm
- Integrated receiver decoder
- Storage and Order box: 40 Gbit
- TV and PC multimedia terminal

Control
- Mission Control Centre: 1
- Local Operation Centres: 3
- Local Service Centres: 3
- Broadcaster Uplink Stations: <80
- Telemetry, Tracking and Command (TTC) Stations: 3

Figure 11. MediaGlobe system summary

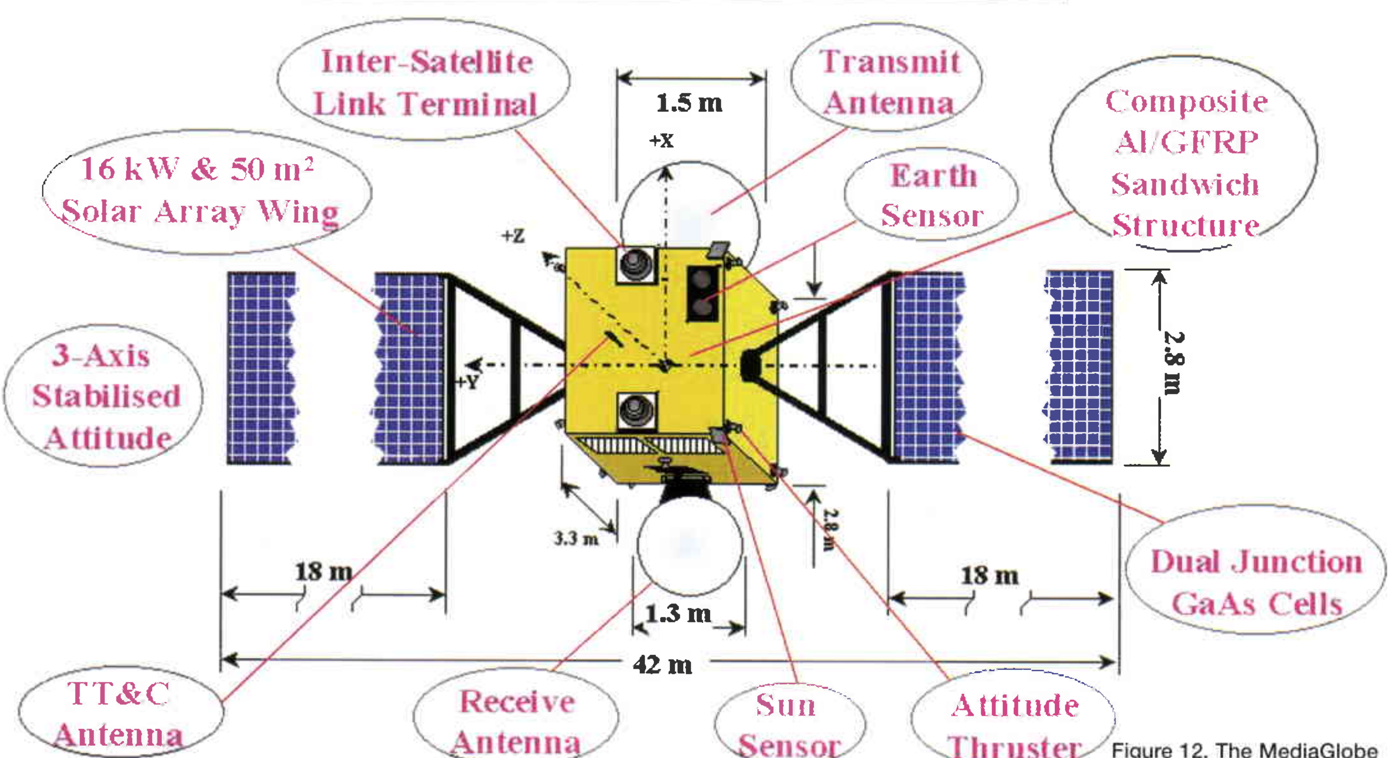


Figure 12. The MediaGlobe spacecraft

arsenide/germanium solar-panel arrays with nickel-hydrogen batteries. The solar-array performance is 16 kW at end-of-life and the battery capacity is 13 kWh. The spacecraft platform is three-axis-stabilised, with momentum wheels for pitch control and roll-yaw stiffness, reaction wheels for momentum storage, and reaction-control thrusters for momentum dumping and attitude manoeuvres.

The baselined propulsion subsystem is a liquid bi-propellant Unified Propulsion System (UPS) consisting of a liquid apogee motor and reaction-control thrusters, providing the required delta-V for orbit transfer, attitude-control manoeuvres and east-west station-keeping. Ion propulsion has been selected for north-south station-keeping, leading to a 33% net propellant-mass saving compared with chemical propulsion, at the expense of an increase in the overall power budget to accommodate the 870 W required to operate each ion thruster (for 2 h/orbit).

Table 3. Internal rates of return (IRRs) for less-than-optimum MediaGlobe scenarios

Business Case	IRR, %
Baseline	44.3
Number of users in all service regions 30% lower than expected	35.0
All launches delayed by 1 year	32.4
Interest rate increases by 30%	43.4
Movie prices drop by 30% in all regions	38.0
Cost of end-user equipment increases by 30%	37.5
Free-of -charge end-user equipment	26.8
Launch failure necessitates leasing alternative capacity for 1 year	36.7

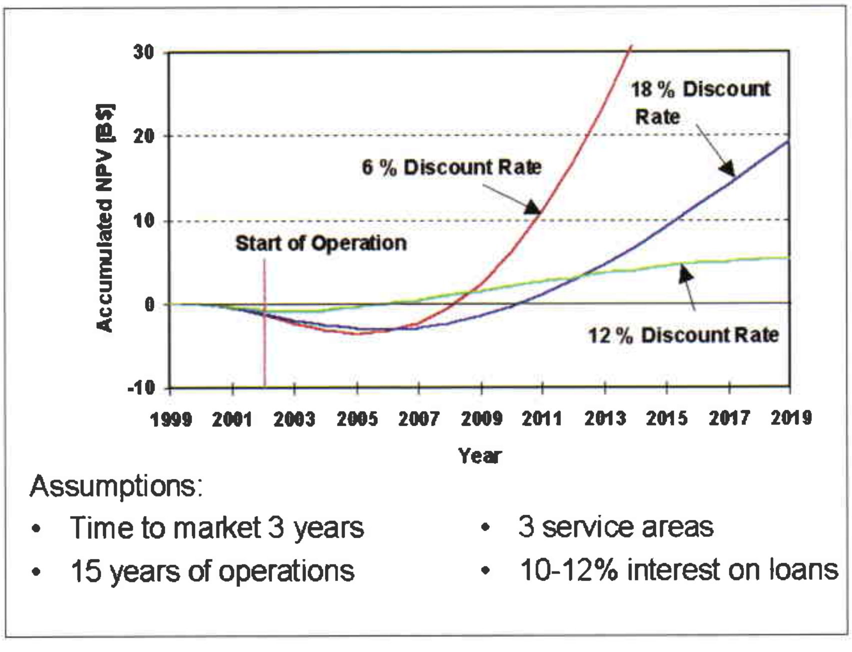


Figure 13. Financial-return projections

The mission-operations concept is based on a single Mission Control Centre (MCC) providing the functionality for spacecraft and ground-station monitoring and control, and offline mission planning, mission analysis and network monitoring activities.

MediaGlobe – A superior business opportunity

As the accompanying panel detailing the 'MediaGlobe Business Case' shows, MediaGlobe represents a unique business opportunity offering high rates of financial return. MediaGlobe is ready to offer potential investors a 7-year equity investment, with entry in 1999 and exit in 2006. Taking into account the predicted annual profit before tax of $900 Million averaged for the years 2007-2012, the valuation of MediaGlobe in 2006 should be some $4500 Million. With the overall investment equity set at $820 Million, the shareholders would get 5.6 times their invested capital back, corresponding to an Internal Rate of Return (IRR) of 45% per annum. From a company point of view, the IRR is a function of the investment period. Approximately 6 years after startup, MediaGlobe would have an IRR of about 13% per year, while in the longer term (>12 years) this should increase to more than 40%. Even factoring in the impact of a number of potential threats to MediaGlobe revenues (Table 3), the worst-case IRR would still exceed 25%. Considering the very conservative business assumptions that have been made throughout, MediaGlobe therefore constitutes an exceptionally attractive commercial multimedia business opportunity (Fig. 13). esa

The MediaGlobe Business Case

MediaGlobe's business case for the three proposed service regions depends strongly on the procurement schedule for the three spacecraft and the ground segment, which are coupled to the launch dates in 2002, 2003 and 2004.

The major milestones can be directly translated into the capital investments and expected revenues shown in Figure 14. The overall investment needed for MediaGlobe amounts to about $1.9 billion, peaking in 2002 with a total annual investment of $570 million and decreasing thereafter to a steady annual level of about $60 million from 2005 onwards (Fig. 15).

A substantial marketing effort will be necessary to secure rapid market entry and penetration. The MediaGlobe marketing plan therefore consists of three elements:
- general marketing costs in the pre-operational and operational phases, which form part of the MediGlobe operations costs
- subsidising of end-user equipment costs in the early operational phases, which form part of the MediaGlobe capital investment costs.

MediaGlobe's projected operations costs are $200-250 million annually. The marketing cost (46%) is also the largest element of the investment cost ($1.9 billion in total), corresponding to the end-user equipment subsidy, followed by the combined cost of the space and launch segments (44%).

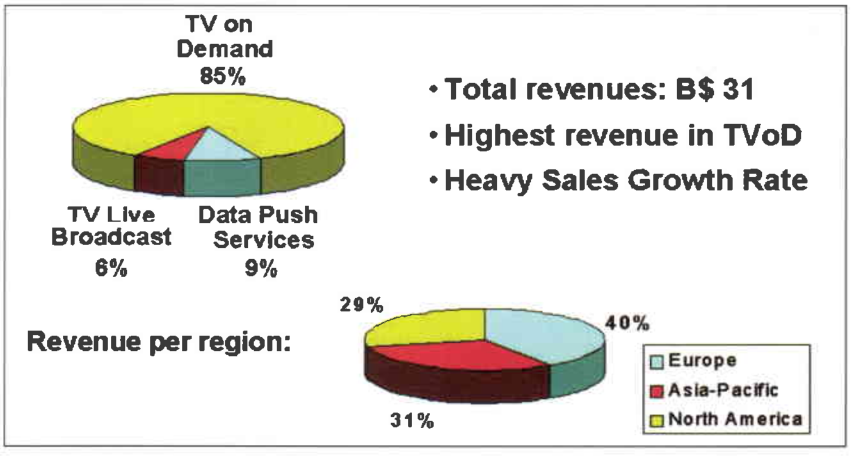
The MediaGlobe project would have three distinct phases: the foundation and development phase, the investment phase, and the operational phase. The investment phase, comprising the procurement of the three satellites and the ground segment, would end with the full deployment of the space segment and feed into the operational phase. As business develops and revenue streams and overall profitability burgeon, there could be an Initial Public Offering (IPO) of MediaGlobe shares in say 2006/2007.

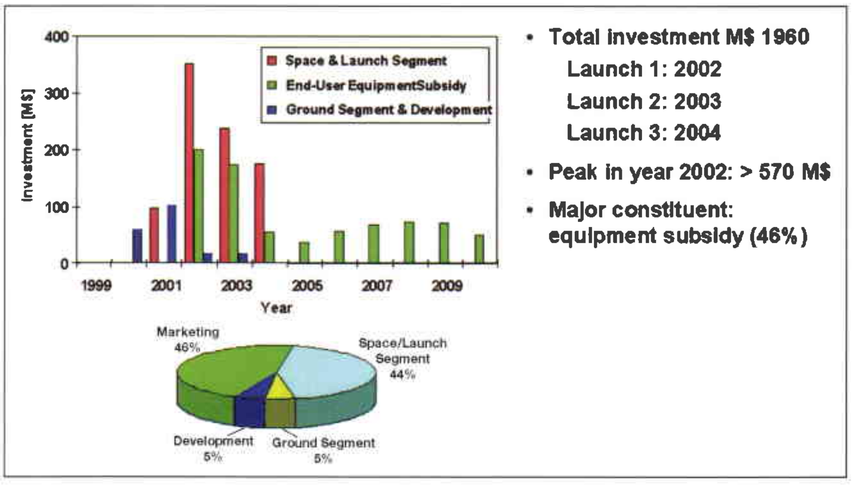
MediaGlobe would seek equity funding for about 67% of the total up-front investment to minimise capital borrowing costs (interest on bank loans). The initial start-up capital would be provided by Venture Capitalists and the Founding Partners. Broadcasters and service providers, as well as spacecraft and equipment manufacturers, would be invited to become shareholders and thereby participate in the success of the emerging business.

MediaGlobe's projected revenues from 2002 onwards show strong growth potential, with a six-fold increase projected over the total 15-year mission lifetime for all three service regions, leading to total revenues of $31.3 billion. This equates to revenues of $14 million per transponder per year, which is a factor of 3 to 7 higher than current returns.

Figure 14. Market-revenue breakdown

Figure 15. Capital investment breakdown

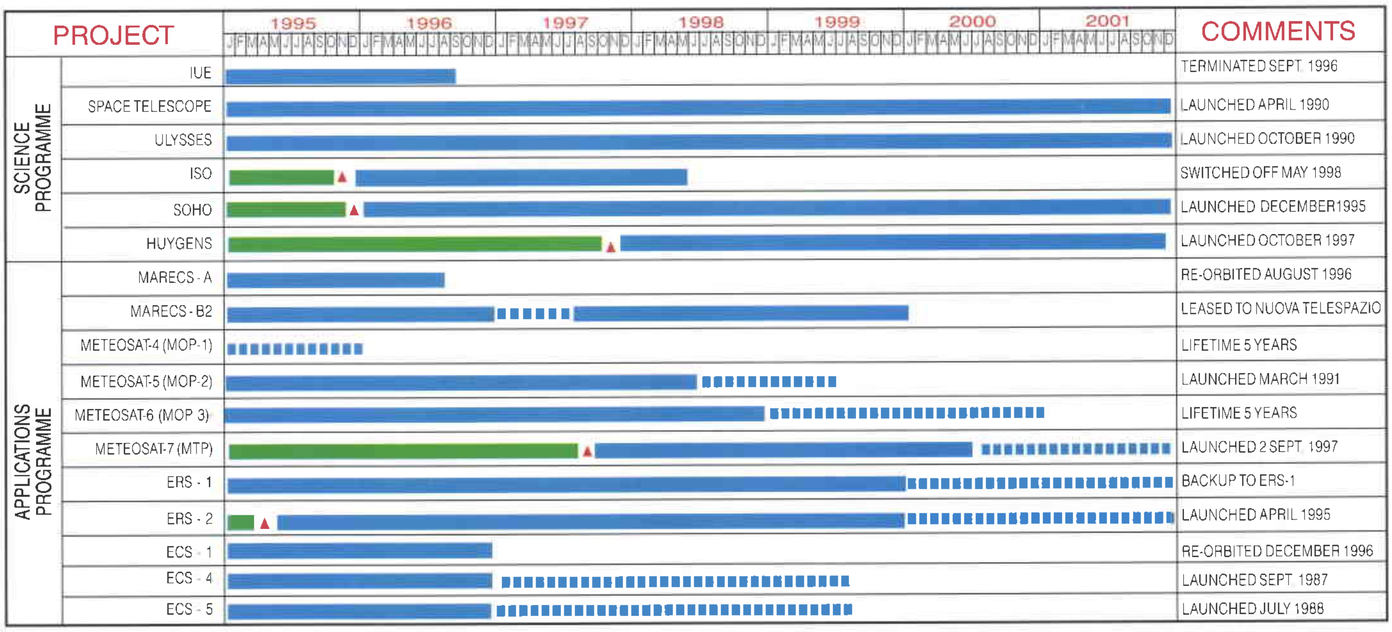




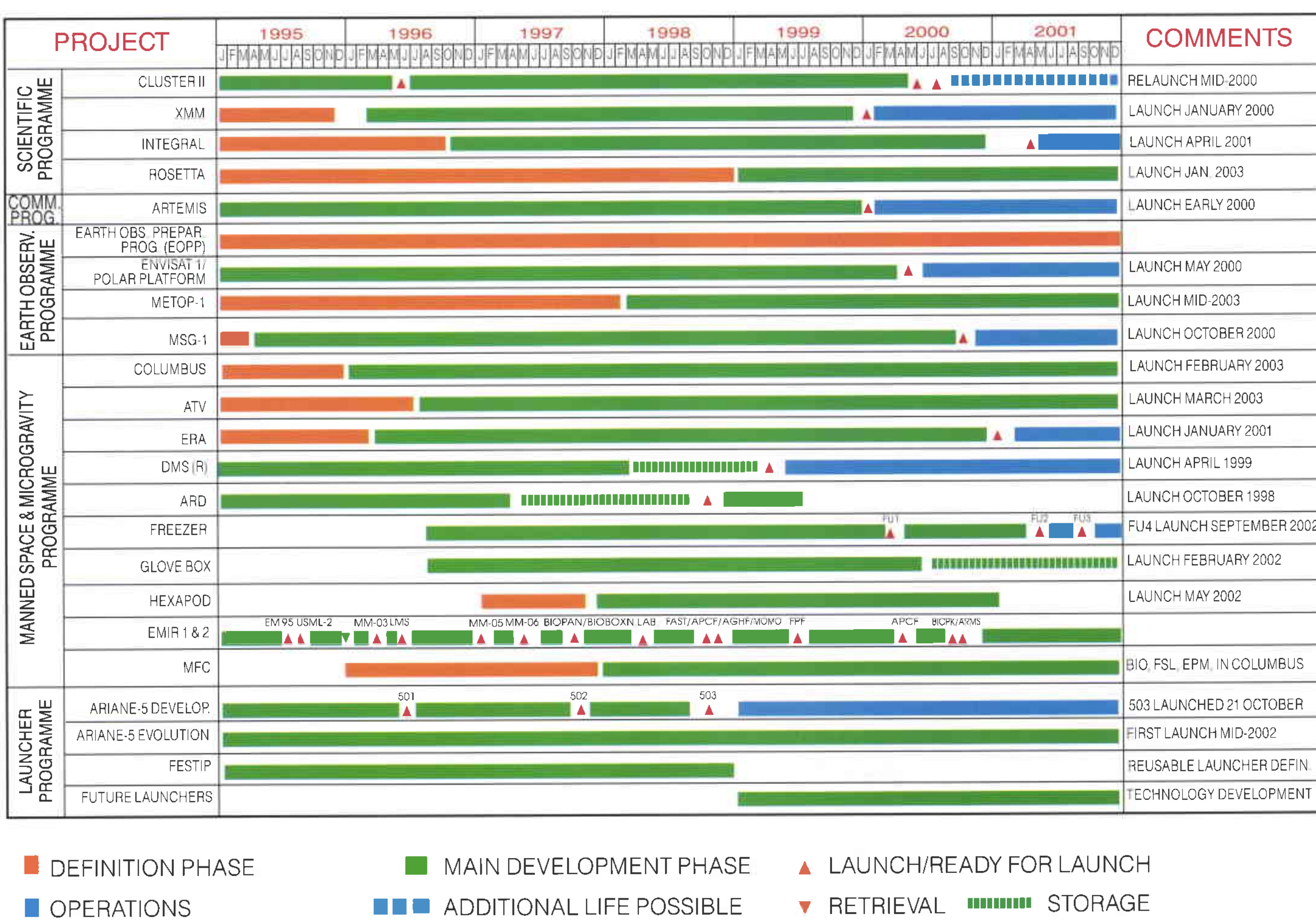
Programmes under Development and Operations
Programmes en cours de réalisation et d'exploitation

(status end September 1998)

In Orbit / En orbite



Under Development / En cours de réalisation



Ulysse

Situation de la mission et du satellite

Progressant vers le sud de l'équateur solaire, le satellite Ulysse a atteint sa distance maximale par rapport à la Terre à la fin du mois d'août (6,35 unités astronomiques, soit 951 millions de kilomètres). C'est la sixième fois au cours de la mission que le satellite, la Terre et le Soleil sont en conjonction, c'est-à-dire pratiquement alignés. L'angle Soleil-Ulysse-Terre étant faible (0,9 degré lors de cette dernière conjonction), il a fallu manoeuvrer très soigneusement le satellite afin de maintenir l'angle d'aspect solaire (l'angle entre l'axe de rotation et le vecteur satellite-Soleil) dans les limites opérationnelles prédéfinies. La collecte des données a subi un certain ralentissement au cours de la période de conjonction, en raison tout à la fois de la baisse de performance des liaisons descendantes, provoquée par la proximité de l'axe de visée et de la direction du Soleil, et par l'indisponibilité des stations sols chargées des opérations de récupération de SOHO. L'ensemble des sous-systèmes et des expériences du satellite continuent à fonctionner parfaitement.

Résultats scientifiques marquants

Le surcroît d'activité solaire constaté fin 1997 a été suivi d'une éruption prolongée en avril/mai de cette année. Comme précédemment, les effets de cette activité ont été très clairement observés à 1 UA et sur la position d'Ulysse, cinq fois plus éloignée. La comparaison des données obtenues par les instruments embarqués à bord d'Ulysse avec celles recueillies à 1 UA a constitué l'un des thèmes de l'atelier 'Aphélie d'Ulysse', qui devait se tenir fin octobre à Oxnard, en Californie. Cet atelier devait procéder également à un examen général des questions scientifiques abordées à l'occasion de la phase de maximum solaire de la mission et examiner en détail les nouvelles perspectives ouvertes par les observations d'Ulysse dans le domaine de la physique des chocs.

Comme les années précédentes, les résultats obtenus par Ulysse ont fortement retenu l'attention lors de la récente assemblée scientifique du COSPAR. Il a notamment été question d'une nouvelle évolution du modèle de champ magnétique héliosphérique, proposé à l'origine par Fisk pour expliquer la persistance d'augmentations récurrentes des flux de particules à grande énergie observées par Ulysse aux latitudes élevées de l'héliosphère. Des travaux récents ont montré que la reconnexion des lignes de forces des champs magnétiques dans la ceinture coronale d'émission de particules aux latitudes basses, élément constitutif du modèle de Fisk, pourraient expliquer l'ouverture naturelle des boucles fermées du champ magnétique, permettant aux éléments de la boucle de s'échapper dans l'héliosphère sous forme de vent solaire lent.

Le lent éloignement d'Ulysse des régions équatoriales, jusqu'à une distance radiale d'environ 5 AU à l'aphélie, couplée à la très faible activité solaire constatée pendant la majeure partie de l'année 1997, ont fourni une occasion unique de mesurer la variation radiale réelle de la composante anormale du rayonnement cosmique (ACR) décelée dans l'héliosphère interne, à l'abri d'effets latitudinaux. L'ACR est constituée de particules interstellaires neutres ionisées par le vent solaire et qui emmagasinent par la suite de l'énergie dans l'héliosphère lointaine pour s'intégrer au flux du rayonnement cosmique. Les mesures obtenues, réalisées en collaboration avec le programme SOHO et qui revêtent une grande importance pour les théories sur le transport du rayonnement cosmique, auraient été impossibles au moment où le satellite se trouvait sur le plan de l'écliptique (avant la rencontre avec Jupiter) en raison du haut niveau d'activité solaire masquant la composante ACR.

Archives

Les archives de l'ESA relatives à Ulysse sont accessibles sur le Web, à l'adresse suivante :

http://helio.estec.esa.nl/ulysses/archive/.

Les données concernant la rencontre entre Ulysse et Jupiter (février 1992) ont été archivées via le système de données planétaires de la NASA et sont désormais accessibles sur CD-ROM.

Télescope spatial Hubble

Le fonctionnement du HST se poursuit sans heurts et avec profit. Les propositions relatives au 8ème cycle d'observations du télescope devaient être adressées avant le 11 septembre. Elles seront examinées en novembre et décembre.

L'instrument NICMOS, dont la fin de vie est proche, a été très utilisé au cours de l'été. Le débit massique de cryogène dans le tube capillaire a fait l'objet d'une surveillance et s'est révélé constant. Le fluide devrait donc être épuisé comme prévu en décembre 98 ou au début de janvier 99. La date officielle de cessation de l'exploitation scientifique du NICMOS a cependant été fixée au 15 novembre 1998. Après cette date, on procédera à trois opérations d'étalonnage destinées à surveiller le comportement de l'instrument au cours de sa période de réchauffement.

Les préparatifs de la prochaine et délicate mission de maintenance et de réparation du télescope (M&R), prévue au printemps 2000, se poursuivent. La validation pour l'espace d'un certain nombre de sous-systèmes devait être réalisée dans l'installation d'essais des systèmes en orbite du télescope spatial (HOST), embarquée à bord de la Navette lors de la mission STS-95 du 7 novembre 1998. Parmi ceux-ci figurent un turbo-réfrigérateur à cycle de Brayton inversé, destiné au système de refroidissement du NICMOS. Ce dispositif, testé dans des conditions de gravité nulle, pourrait redonner vie à l'instrument. La possibilité d'installer ce cryorefroidisseur sera attentivement étudiée au cours des prochains mois, sur les plans technique et scientifique. Des représentants de l'ESA participeront à ce processus.

L'astronaute de l'ESA Claude Nicollier, qui avait participé à la première mission de ce type en décembre 1993, figure au sein de l'équipage désigné pour mener à bien cette prochaine mission de maintenance et de réparation du télescope.

Un 'Comité pour la deuxième décennie du HST' a été constitué avec la participation de l'ESA et s'est réuni pour la première fois cet été. Les avis qu'il fournira devraient permettre d'optimiser l'exploitation scientifique du télescope spatial au cours de sa deuxième décennie de fonctionnement, en tenant compte des interactions possibles avec d'autres projets (NGST, VLT, Keck, Gemini, etc....). Il se réunira pour la deuxième fois en novembre, au Centre européen de

Ulysses

Mission and spacecraft status

The Ulysses spacecraft, heading progressively further south of the Sun's equator, reached its maximum distance from Earth (6.35 astronomical units, or 951 million km) at the end of August. This also marked the sixth conjunction period of the mission, when the Earth, the Sun and Ulysses are in close alignment. Because the Sun-Ulysses-Earth angle becomes small (0.9 deg during this particular conjunction), careful spacecraft manoeuvring was needed to keep the Solar Aspect Angle (the angle between the spin axis and the spacecraft-Sun vector) within the predefined operational limits. Data recovery during the conjunction period has been somewhat reduced, both because of expected loss in performance of the downlink as a result of the proximity of the line-of-sight to the Sun, but also due to the non-availability of ground stations caused by the SOHO recovery operations. All spacecraft subsystems and experiments continue to perform well.

Science highlights

The surge of solar activity at the end of 1997 was followed by a more extended outburst in April and May of this year. As in the earlier case, the effects were clearly observed both at 1 AU and at the location of Ulysses, five times further away. A comparison of data obtained by the instruments onboard Ulysses and data acquired at 1 AU formed one of the themes of the Ulysses Aphelion Workshop, held at the end of October in Oxnard, California. Other topics included a general discussion of the scientific questions to be addressed by Ulysses during the solar-maximum phase of the mission, and a detailed examination of new insights gained into shock physics as a result of Ulysses' observations.

As in past years, Ulysses results featured prominently at the recent COSPAR Scientific Assembly. Highlights included further developments of the heliospheric magnetic-field model first proposed by Fisk to explain the persistence of recurrent increases in the flux of energetic particles at high heliographic latitudes observed by Ulysses. Recent work has shown that magnetic reconnection in the streamer belt at low latitudes, a necessary element of the Fisk model, could provide a natural way of opening up closed magnetic-field loops, thereby allowing loop material to flow out into the heliosphere as the slow solar wind.

Ulysses' slow transit of the equatorial regions at a radial distance of 5 AU around aphelion, coupled with the very quiet solar conditions existing during much of 1997, have provided a unique opportunity to measure the true radial variation of the anomalous cosmic-ray component in the inner heliosphere, free from latitudinal effects. ACRs are interstellar neutrals that become ionised in the solar wind, and subsequently gain energy in the distant heliosphere to become part of the cosmic-ray flux. This measurement, made in collaboration with SOHO and of importance for cosmic-ray transport theories, was not possible during the in-ecliptic phase of the mission (prior to Jupiter encounter) because of the high level of solar activity that masked the ACR component.

Archive

The ESA Ulysses archive is accessible via the World Wide Web at URL:

http://helio.estec.esa.nl/ulysses/archive/.

The data from the Ulysses Jupiter Encounter (February 1992) have been archived via the NASA Planetary Data System, and have recently been issued on CD-ROM.

Hubble Space Telescope

HST continues to operate very smoothly and successfully. The deadline for the 8th Cycle of HST observations expired on 11 September and the proposals received will be reviewed in November/December.

During the summer, the NICMOS instrument was heavily used in view of its approaching end-of-life. The mass flow of cryogen through the capillary tube has been monitored and found to remain constant. The exhaustion date prediction is therefore unchanged (December '98 / early January '99), but the formal end to science operations for NICMOS has been set at 15 November 1998. After that date, three calibration proposals will be run to monitor the instrument's behaviour during the warm-up period.

The preparatory work for the next complex Maintenance and Refurbishment Mission (Spring 2000) continues: a number of subsystems will be space-validated during the flight of the Hubble Space Telescope Orbiting Systems Test (HOST) platform aboard the STS-95 Shuttle mission, due to be launched on 7 November 1998. Of these, the NICMOS Cooling System will allow zero-g verification of a Reverse Turbo Brayton Cycle Cooler, which should give new life to NICMOS. The possible installation of the cryocooler will be critically reviewed, both scientifically and technically, in the following months. ESA representatives will participate in the review process.

The Shuttle Crew for the next Maintenance and Refurbishment Mission has been selected and includes ESA Astronaut Claude Nicollier, who participated in the first M&R Mission in December 1993.

A new 'HST 2nd Decade Committee' has been formed (with ESA participation) and met for the first time this summer: its charter is to provide indications for the best scientific exploitation of HST in the next second decade of operations, taking into account the interrelationship with other projects like NGST, VLT, Keck, Gemini, etc. The second meeting will take place at the Space Telescope European Coordination Facility (ST-ECF) next November.

The possibility of installing a redundant imaging capability during the last M&R Mission to HST is being studied by an ad hoc Committee (again with ESA participation).

A data set of WFPC2 images taken over the last 4 years are being analysed at the Space Telescope Science Institute (ST-ScI) with the aim of monitoring the camera's photometric stability.

Similarly, the entire data set of the FOS Instrument has been analysed by the ST-ECF in order to assess possible improvements in the calibration. It was found that a better correlation with the magnetometer readings can substantially improve the wavelength calibration, particularly for the red channel. The new calibration scheme has been agreed upon between the ST ScI and the ST-ECF and will be implemented within the frame-work of the new Memorandum of Understanding (MOU) agreement .

coordination du Télescope spatial (ST-ECF).

Un comité Ad Hoc, auquel participe également l'ESA, étudie actuellement la possibilité d'installer une capacité d'imagerie redondante au cours de l'ultime mission M&R vers le HST.

Un ensemble d'images prises au cours des quatre dernières années par la WFPC2 (caméra planétaire à grand champ) est actuellement analysé par les chercheurs de l'Institut scientifique du télescope spatial (ST-SCI) afin d'évaluer la stabilité photométrique de la caméra.

De la même manière, l'ensemble des données recueillies par l'instrument FOS ont été adressées pour analyse au ST-ECF afin d'étudier une éventuelle amélioration de l'étalonnage. On a ainsi découvert qu'on pourrait mieux étalonner les longueurs d'onde, notamment dans le rouge, en améliorant la corrélation avec les indications du magnétomètre. Le ST-SCI et le ST-ECF se sont mis d'accord sur le nouveau plan d'étalonnage qui sera mis en oeuvre dans le cadre du nouveau mémorandum d'accord (MOU).

Dans le cadre du même accord, le ST-ECF participe à la réalisation du deuxième Catalogue d'étoiles-guides, qui sera utilisé opérationnellement par de nouveaux instruments, tels que la caméra de technologie avancée pour observations astronomiques (ACS).

Ce nouveau concept d'étalonnage, mis en oeuvre avec succès depuis plus de deux ans au ST-ECF, pourrait être également adopté par le ST-SCI pour les archives.

Parmi les travaux scientifiques récents menés à bien grâce au HST figure notamment l'étude détaillée, conduite par un groupe d'astronomes européens, d'un amas dense d'étoiles jeunes situé dans le Petit nuage de Magellan. Cette étude fournit un aperçu de l'évolution des étoiles dans un environnement pauvre en métaux, similaire à celui qui prévalait aux premiers âges de l'Univers. Les résultats et les images de ces travaux peuvent être consultés sur le site :

http://ecf.hq.eso.org/stecfpubrel.html.

Huygens

Situation du véhicule spatial

L'ensemble Cassini/Huygens se dirige vers son but, son antenne à gain élevé (HGA) continuellement pointée vers le Soleil afin que ses principaux éléments, dont notamment la sonde Huygens, soient maintenus à l'ombre. Les activités en vols se poursuivent sans heurts.

Une manoeuvre visant à décaler l'axe de l'antenne de 12 degrés par rapport au Soleil a été réalisée le 28 mai afin de mener à bien certains essais particuliers sur Huygens (voir plus loin). L'antenne restera sinon pointée vers le Soleil jusqu'au 28 décembre. A partir du 9 janvier 1999, l'alignement de Cassini sur l'axe Soleil-Terre devrait permettre d'utiliser l'HGA aussi bien pour communiquer avec la Terre que pour servir de pare-soleil. Grâce à la possibilité qui lui est offerte de décaler son axe de 12 degrés par rapport à la direction du Soleil, l'HGA restera en fait dirigée vers la Terre entre le 28 décembre et le 21 janvier. Au cours de cette période, Huygens sera légèrement exposée au Soleil, mais les études détaillées qui ont été faites sur le plan thermique montrent que l'intérieur de la sonde demeurera bien en deçà des températures admissibles pour les batteries.

La transmission de données à haut débit de l'HGA permettra de procéder pendant un mois à un examen approfondi de la charge utile de l'orbiteur. Cette activité ne peut être menée à bien plus tôt en raison du faible débit de données imposé par l'antenne à faible gain (40 bit/s la plupart du temps).

Opérations scientifiques

En dépit d'un certain nombre de limitations sur le plan opérationnel, trois séries d'activités scientifiques et techniques ont été entreprises au cours du premier survol de Vénus par le véhicule spatial. Le détecteur d'ondes radio et d'ondes de plasma (RPWS) a guetté pendant plusieurs heures les ondes radio émises par les éclairs qui déchirent l'atmosphère vénusienne. Les résultats de ces observations se sont révélés peu concluants en première analyse, en raison notamment des limitations imposées par la retransmission de données et sous l'effet prédominant du plasma en dessous de 80 kHz. Un essai technique du radar a été réalisé au plus proche de la planète. Il a permis de vérifier le bon fonctionnement des éléments radiométriques de l'instrument. Une configuration défavorable n'a pas permis de recueillir le signal renvoyé par la surface de Vénus. Enfin, il a été possible d'obtenir des données atmosphériques par occultation lorsque le véhicule spatial s'est retrouvé derrière la planète par rapport à la Terre.

La programmation optimisée des observations scientifiques susceptibles d'être entreprises lors du survol de la Terre (18 juin 1999) et du second survol de Vénus (24 juin 1999) a débuté, en tenant compte des capacités opérationnelles restreintes dont disposera Cassini au cours de cette période.

Opérations en vol de Huygens

La deuxième vérification en vol de Huygens s'est déroulée le 27 mars 1998. Les six instruments de la charge utile ont affiché d'excellents résultats, de même que les sous-systèmes électriques de la sonde qui ont été testés. La variation du niveau du signal produit par la liaison radio ombilicale entre l'orbiteur et la sonde, déjà constatée au cours de la première vérification en vol, a de nouveau été perçue. On a émis l'hypothèse que cette variation pouvait avoir été provoquée par le bruit radioélectrique solaire capté par l'antenne HGA pointée vers le Soleil. Un essai spécifique a été réalisé le 28 mai, consistant, pendant un court moment, à décaler l'antenne de 12 degrés par rapport à l'axe du soleil. Les résultats de cet essai ont confirmé l'hypothèse du bruit solaire et permis de vérifier l'excellent fonctionnement des récepteurs radio de Huygens dans un environnement sans bruit.

La séquence de commande prévue pour la prochaine vérification est en cours de validation sur le modèle d'identification (EM), représentatif du modèle de vol, conservé à l'ESOC, à Darmstadt (D). Cette séquence de commande sera ensuite envoyée au JPL pour être téléchargée à bord du véhicule spatial. La prochaine vérification en vol de Huygens aura lieu le 22 décembre 1998. Ces essais seront réalisés quelques jours seulement avant l'utilisation prévue de l'antenne HGA mentionnée plus haut. Les données recueillies lors de la vérification seront retransmises le 28 décembre, premier jour de cette utilisation et cinq jours après avoir été enregistrées. Cela

As part of the same agreement, the ST-ECF is participating in the production of the Guide Star Catalogue II, which will be used operationally by new instruments such as the Advanced Camera for Surveys.

The concept of 'on-the-fly calibration', which has been successfully implemented and run at the ST-ECF for more than two years, is being considered for implementation in the ST-ScI Archive as well.

Recent scientific highlights include the detailed study by a European group of a dense cluster of young stars in the Small Magellanic Clouds. This study is providing insight into the stellar evolution in a metal-poor environment, similar to the one prevailing in the early cosmic ages. Results and pictures can be found at:

http://ecf.hq.eso.org/stecfpubrel.html.

Huygens

Spacecraft status
The Cassini/Huygens spacecraft flies with its High-Gain Antenna (HGA) continuously pointed at the Sun to shade the whole spacecraft, and the Huygens Probe in particular. The in-flight activities are proceeding very smoothly.

An off-Sun turn (by 12°) was executed on 28 May in order to perform a special Huygens test (see below).The spacecraft will remain in the HGA-to-Sun attitude until 28 December, whereafter the alignment of Cassini with the Sun-Earth line on 9 January 1999 will allow the HGA to be used to communicate with the Earth, in addition to still being used as a Sun shield. By allowing off-Sun pointing by up to 12°, the HGA will be kept pointing at Earth from 28 December to 21 January. During that period, Huygens will be slightly exposed to the Sun, but the detailed thermal predictions that have been made show that the interior of the Probe will remain well within acceptable temperatures for the batteries.

The high data rate that will be available through the use of the HGA will allow a thorough, month-long, in-orbit checkout of the Orbiter payload to be conducted. This activity could not be carried out before due to the limitations on the downlink data rate imposed by the Low Gain Antenna (40 bps most of the time).

Science operations
In spite of operational limitations, three engineering/science activities were carried out during the Venus-1 flyby. The Radio and Plasma Wave Science (RPWS) instrument conducted a several-hour-long search for radio signals caused by lightning in the Venusian atmosphere. A preliminary analysis indicates that, primarily because of the data-return limitation, the observations are inconclusive because strong plasma effects were predominant below 80 kHz. The Radar instrument conducted an engineering test near closest approach. It allowed the full functionality of the radiometric part of the instrument to be verified. The unfavourable geometry did not allow successful acquisition of a signal 'bounced' from Venus' surface. Finally, during the portion of flyby when the spacecraft flew behind Venus (as seen from the Earth), atmospheric occultation data were obtained.

Planning has started for conducting an optimised set of science observations during the Venus-2 encounter (24/06/99) and the Earth flyby (18/06/99), within the restricted operational capability of Cassini at that time.

Huygens flight operations
The second in-flight checkout of the Huygens Probe was conducted on 27 March 1998. All six payload instruments reported excellent results, as did all Probe electrical subsystems that were tested. The change in the signal level of the Probe-to-Orbiter umbilical radio link, which had already been observed during the first in-flight checkout, was again detected. It was hypothesised that this change was caused by solar radio noise picked up by the Sun-pointing HGA. A special off-Sun test, with the HGA de-pointed by 12° for a short period, was carried out on 28 May. The results of this test confirmed the solar-noise hypothesis, and allowed the excellent health of the Huygens radio receivers in a noise-free environment to be established.

Currently, the Probe command sequence to be used for the next checkout is being validated using the flight-representative Probe engineering model located at ESOC in Darmstadt (D). This command sequence will subsequently be sent to JPL for uploading to the spacecraft.

The next Huygens in-flight checkout will be carried out on 22 December 1998. This test is scheduled just a few days before the HGA opportunity (see above). The Huygens checkout data will be played back during the first day of the HGA opportunity on 28 December, i.e. five days after the checkout, to allow the Probe to cool down before it is exposed to the Sun.

Cluster-II

The Pre-Integration Review for the first new flight spacecraft (FM 6) has been successfully held. This releases the start of integration of the subsystems and payload. The structure has already been delivered and the harness integrated. The deliveries for the rest of the units are still going according to schedule. Some problems have occurred with respect to the manufacturing of the memory packages of the solid-state recorder. It is believed that these have now been resolved and work-around solutions for the integration and testing of the first unit, which is not completely flight standard, have been agreed.

Most of the first payload elements are now undergoing final calibration and will then be ready for integration into the spacecraft.

The contract between Starsem and ESA for the launch of the four Cluster-II spacecraft using two Soyuz launch vehicles has been signed. The two launches are planned to take place approximately one month apart in the middle of 2000.

Preparations are underway for moving the antenna originally foreseen for use with Cluster from Odenwald (D) to Villafranca (E), which will then be the primary ground station during the Cluster-II main operations phase.

XMM

Work on the flight satellite is progressing at Dornier (D). The service module of the *permettra à la sonde de se refroidir avant son exposition au Soleil.*

Cluster-II

La revue de pré-intégration du premier modèle de vol des nouveaux satellites (FM6) a été réalisée avec succès, permettant ainsi d'entamer l'intégration des sous-systèmes et de la charge utile. La structure a déjà été livrée et le câblage mis en place. La livraison des autres éléments se déroule conformément au calendrier prévu. La fabrication des blocs de mémoire de l'enregistreur à état solide a connu quelques problèmes. On estime que ces problèmes ont été résolus et l'on s'est mis d'accord sur des solutions de repli pour l'intégration et les essais de la première unité, qui n'est pas tout à fait aux normes de vol.

La plupart des éléments de la première charge utile subissent actuellement leurs derniers étalonnages et seront ensuite prêts à être intégrés au satellite. Le contrat prévoyant le lancement de quatre satellites Cluster-II à bord de deux Soyouz a été signé entre Starsem et l'ESA. Les deux lancements devraient avoir lieu à un mois d'intervalle, vers la mi-2000.

Les préparatifs visant à transférer d'Odenwald (D) à Villafranca (E) l'antenne prévue à l'origine pour le programme Cluster se poursuivent. Villafranca sera prête alors à jouer son rôle de station sol primaire lors de la phase d'exploitation principale de Cluster-II.

XMM

La préparation du modèle de vol du satellite se poursuit chez Dornier (D). L'intégration du module de service est terminée et celui-ci devait être livré à la mi-octobre à l'ESTEC pour y subir des essais. La livraison à l'ESTEC de l'ensemble plan focal, qui comprend l'instrumentation rayons-X, a été reportée à février 1999, après installation et essais des derniers instruments rayons-X.

Les spécialistes du Centre spatial de Liège (CSL) ont presque achevé les essais combinés du module miroir de secours avec le déflecteur rayons-X et la grille de réflexion associés. Les caractéristiques de l'ensemble du chemin optique en lumière parasite ont été validées, au moyen d'essais de lumière parasite sous angle élevé réalisés au cours de l'été chez DASA, à Munich. Ces essais ont donné d'excellents résultats.

L'activité dans le domaine des instruments scientifiques a surtout consisté, cet été, à tester et analyser le comportement des caméras. Un certain nombre de difficultés, longues à analyser, sont venues ralentir les efforts entrepris. Mais l'on sait désormais que ces instruments seront très performants. La date de leur livraison a été reportée au mois d'octobre 98. Cette nouvelle échéance et les modifications qu'il a fallu apporter en conséquence au calendrier d'assemblage, d'intégration et de vérification (AIV) ont fait reporter la date de la revue de recette pour le vol à octobre 1999. Le lancement aura lieu en janvier 2000.

La revue de mise en oeuvre du secteur sol a été réalisée et la documentation de référence est en cours de mise à jour. Pendant ce temps, la livraison des éléments de logiciel destinés au contrôle de la mission se poursuit comme prévu. Une première série d'essais combinés mettant en oeuvre le logiciel de contrôle de la mission et le satellite devaient être entrepris en octobre 1998.

Intégral

Après de nombreuses années consacrées aux travaux de planification, de conception et d'analyse, le projet Intégral est définitivement passé au stade du concret : le programme d'essais du modèle structurel et thermique (STM) est presque achevé et le programme portant sur le modèle d'identification a été lancé.

Le programme d'essais du STM a progressé selon les plans prévus. Le module de servitude, hérité du XMM après qualification mécanique et thermique, a dû subir un certain nombre de modifications prévues (portant notamment sur l'emplacement des propulseurs, le positionnement de l'antenne, les interfaces avec le module de charge utile (PLM), l'installation de différents sous-systèmes, la configuration des éléments de régulation thermique). Les instruments ont été intégrés pour la première fois sur le PLM, sans que cela pose de problème particulier.

The Integral Structural and Thermal Model (STM) in the Large Space Simulator at ESTEC (NL)

Modèle structurel/thermique d'Integral dans le grand Simulateur spatial de l'ESTEC (NL) satellite is fully integrated and will be delivered for testing at ESTEC by mid-October 1998. The focal-plane assembly which houses the X-ray instrumentation is re-scheduled to arrive at ESTEC in February 1999, after integration and testing of the remaining X-ray instruments.

At Centre Spatial de Liège (CSL), combined testing of the spare mirror module with the associated X-ray baffle and reflection grating is reaching completion. The validation of the stray-light behaviour of the complete optical path has been completed with wide-angle stray-light tests, conducted during the summer at DASA in Munich. These tests yielded excellent results.

During the summer, efforts on the scientific-instrument side were concentrated on testing and analysing the behaviour of the imaging cameras. This process has been slowed by a number of difficulties, which took time to analyse. The results of this work now show that these instruments will have very good performance. The deliveries of the instruments have been re-scheduled for October 1998. Based on these new dates and the ensuing re-arrangements of the assembly, integration and verification (AIV) schedule, the Flight Acceptance Review will now be held in October 1999. The launch will then take place in January 2000.

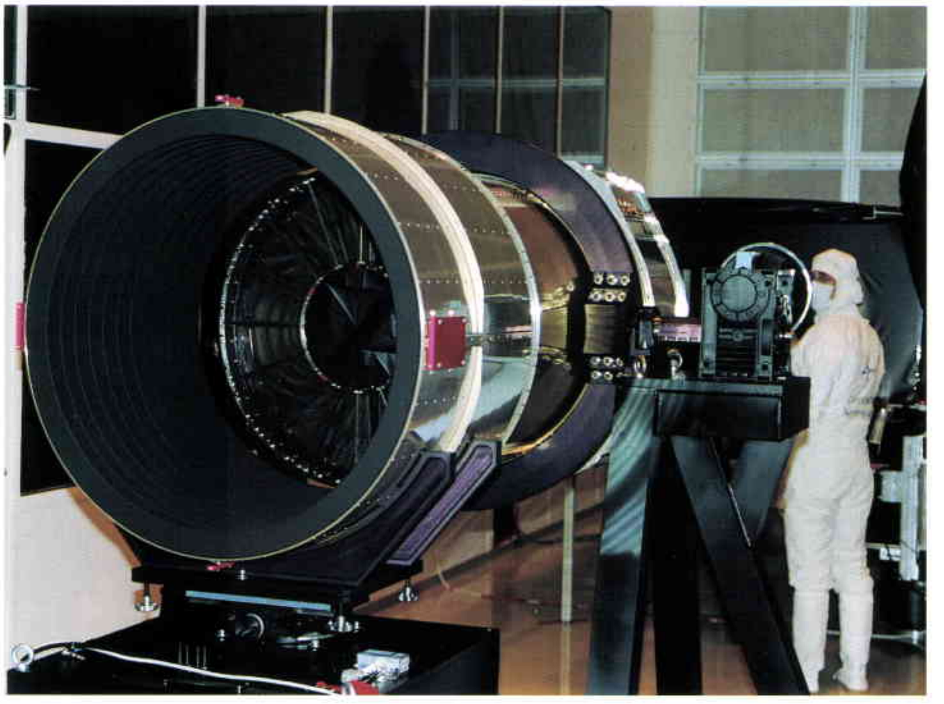
The ground-segment implementation review has been completed and the baseline documentation is being updated. In the meantime, the deliveries of mission-control software elements continue as planned. A first combined test linking the mission-control software and the spacecraft will be conducted in October.

Integral

After many years of planning, design and analyses, Integral is now definitively in the hardware phase: the testing programme for the Structural Thermal Model (STM) is nearing completion and the Engineering Model (EM) programme has started.

The STM test programme is proceeding according to plan. The Service Module, received from XMM after completion of their mechanical/thermal qualification, had to undergo a few planned modifications (i.e. thruster locations, antenna positioning, interface to Payload Module (PLM), various subsystem boxes, thermal hardware configuration). The instruments have been integrated for the first time on the PLM. No particular problems have been encountered.

As a result of a major effort by the industrial team, the crucial start date for the thermal-balance test was met. After successful completion of that test and the mass-properties measurements, the mechanical qualification tests (modal survey, acoustic and shock separation) have started. The STM programme is planned to end in October 1998 with the vibration test at IABG (D).



An XMM mirror assembly (flight model no. 3) on a test bench at DASA in Ottobrunn (D)

Ensemble du miroir d'XMM (modèle de vol no. 3) sur banc d'essai chez DASA à Ottobrunn (D)

Rosetta

The selection of equipment suppliers is nearly complete after a long evaluation process which has involved the assessment of more than one hundred proposals. The Rosetta industrial consortium, under the leadership of Dornier (D), is now well consolidated and good progress is being made on all technical aspects of the spacecraft design.

The spacecraft configuration has been frozen and work in industry is now focussed on detailed technical design and on finalising the first round of mechanical and thermal analysis in time for the System Design Review (SDR) planned for October-November 1998.

A severe mass-reduction exercise, which has affected both the spacecraft's and the instrument's design, is nearly complete. Together with the thermal design of the spacecraft, this remains one of the major concerns for the project and will require constant attention.

Design Reviews are also being implemented on the payload side at experiment level, and for the ground segment where the first Requirements Review is under way.

The contract for the procurement of the new 34 m antenna destined for the Perth (Aus.) ground station has been awarded to the Canadian company SED.

Artemis

The Artemis satellite arrived at ESTEC for its system-level test campaign on 30 June. After some final integration activities, it has been successfully subjected to a full series of electrical tests, including electromagnetic compatibility testing.

Grâce aux efforts de l'équipe industrielle, la date cruciale prévue pour le démarrage des essais de bilan thermique a été respectée, ce qui a permis – après leur achèvement et le calcul des caractéristiques de masse – d'entreprendre les essais de qualification mécanique (recherche de modes vibratoires, essais acoustiques et étude des effets du choc de séparation). Le programme d'essais du STM devait s'achever en octobre, avec les essais de vibrations menés à bien chez IABG (D).

Rosetta

La sélection des équipementiers est presque achevée, après un long processus d'évaluation portant sur plus d'une centaine de propositions. Le consortium industriel Rosetta est aujourd'hui bien consolidé sous la direction de Dornier (D), et la conception technique du satellite progresse de manière satisfaisante.

La configuration du véhicule spatial a été gelée et les travaux industriels sont maintenant axés sur la conception technique détaillée du satellite et sur l'achèvement du premier cycle d'analyses thermiques et mécaniques, dans des délais compatibles avec la tenue de la revue de conception système (SDR) prévue en octobre-novembre 1998. D'importants travaux ont également été entrepris pour diminuer tout à la fois la masse du satellite et des instruments. Ils sont pratiquement achevés. Ce problème, comme celui ayant trait à la conception thermique du satellite, reste l'un des plus importants à résoudre et réclame une attention constante.

Des revues de conception sont également en cours pour les expériences destinées à la charge utile. Pour sa part, le secteur sol fait l'objet d'un premier examen des impératifs.

Le contrat portant sur l'approvisionnement d'une nouvelle antenne de 34 m destinée à la station sol de Perth (Aus) a été attribué à la société canadienne SED.

Artémis

Le satellite Artémis est arrivé à l'ESTEC afin d'y subir, le 30 juin, une campagne d'essais au niveau système. Après parachèvement de son intégration, il a été soumis avec succès à une série complète d'essais électriques et de compatibilité électromagnétique.

Il subit aujourd'hui une série d'essais d'ambiance qui ont débuté par une phase de simulation solaire.

EOPP

Stratégie et programmes futurs

Le Conseil de l'ESA réuni au mois de juin a été le théâtre de deux développements majeurs pour la mise en oeuvre de la Stratégie de l'Agence dans le domaine de l'observation de la Terre, développements qui ont été rendus possibles par d'importants travaux préliminaires. Les délégations ont tout d'abord donné leur accord à une mise en oeuvre initiale du Programme-enveloppe d'observation de la Terre, dénommée 'Extension spéciale de l'EOPP', à titre de mesure transitoire avant le prochain Conseil ministériel. Au cours du même Conseil de juin, le niveau de participation et de souscription à la deuxième extension de l'EOPP a été porté à un seuil critique permettant de lancer les quatre première études de phase-A pour des missions de base d'exploration de la Terre.

Missions futures

Les études de phase-A de quatre propositions de missions de base d'exploration de la Terre ont été lancées au début du mois de juillet, dans le cadre de l'élément 'Exploration de la Terre' de la proposition de programme-enveloppe d'exploration de la Terre. Deux nouveaux séminaires, auxquels ont participé délégations, industriels et chercheurs, ont été organisés après celui consacré à la mission d'étude des processus à la surface du sol et de leurs interactions : l'un consacré à la mission sur le rayonnement terrestre et l'autre à la mission sur le champ de gravité et la circulation océanique en régime stable. L'appel à propositions pour la première mission de circonstance destiné aux chercheurs principaux a été lancé à la mi-juillet.

L'évaluation des projets reçus dans le cadre de 'l'appel à propositions d'esquisses de projets de surveillance de la Terre' a été achevée. Ses résultats

The satellite is now proceeding into the environmental test campaign, starting with a solar-simulation phase.

EOPP

Strategy and future programmes

Activities leading up to and at the June meeting of the ESA Council have resulted in two very significant developments in terms of the implementation of the ESA Earth Observation Strategy. Under the title of EOPP Special Extension, as a transitionary measure before the next Council Meeting at Ministerial level, Delegations have agreed to an initial implementation of the Earth Observation Envelope Programme. At the same Council, the subscription and participation to EOPP Extension 2 was raised to the critical level to allow the start of the first four Phase-A studies for the Earth Explorer Core Missions.

Future missions

In the context of the Earth Explorer element of the proposed Earth Observation Envelope Programme, the Phase-A studies for four candidate core missions were kicked-off in early July. Following the seminar on the Land Surface Processes and Interactions mission, two further seminars have been held in connection with the Earth Radiation mission and the Gravity Field and Steady State Circulation mission, with Delegate, scientist and industry participation. The Call for Proposals by lead investigators for the first opportunity mission was released by mid-July.

During this same period, the assessment of the Call for Outline Earth Watch Proposals was also completed. The results of this assessment will now be put forward for discussion with the Delegations, together with the initiation of parallel technical activities.

Campaigns

Preparations for the CLARE 98 (Cloud Lidar And Radar Experiment) have advanced through experimenter review and implementation preparations.
In August, a small-scale campaign in support of the Land Surface Processes and Interactions mission took place in Spain. This was a precursor to a possible large-scale campaign in 1999.

Envisat/Polar Platform

Envisat system

The Announcement of Opportunity (AO) for scientific data exploitation and pilot projects has attracted very high interest in the Earth Observation user community. The more than 700 proposals received are currently being evaluated and the results of the selection process will be published before the end of the year.

System activities are now focusing on the preparations for the system verification. A verification plan for the integrated ground segment has been defined and initial testing will start by the end of 1998. The major flight-model (FM) system tests are under definition, such as the FM Thermal Balance/Thermal Vacuum (TB/TV) test scheduled for March 1999 at ESTEC. A satellite-level qualification review is planned for the first half of 1999.

ENVISAT payload

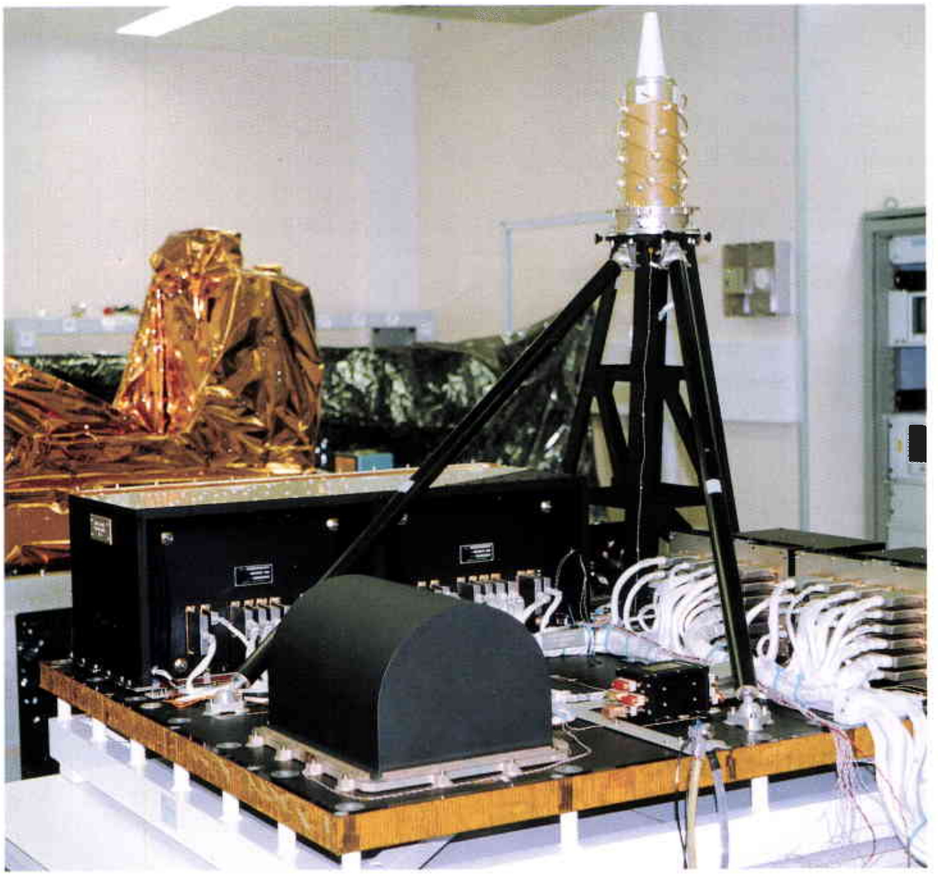
The ASAR engineering-model (EM) antenna has been delivered, thereby completing the delivery of the EM instruments. In accordance with the split-delivery approach, the EM ASAR is now under instrument-level testing on the Polar Platform at Matra Marconi Space in Bristol (UK). The FM ASAR antenna active tiles have started to be delivered for higher level integration and all show good performance.

The RA-2 FM testing is nearing completion. All tests performed so far (performance on one chain, EMC, I/Fs) have shown excellent results.

The Laser Retro Reflector FM has been accepted and is ready for shipment to Matra Marconi Space (UK). Testing of GOMOS has been completed at CSL (Liège) and preparatory work for delivery has been initiated.

Envisat/Polar Platform flight-model solar-array deployment during acceptance testing at Fokker Space (NL)

Déploiement du générateur solaire du modèle de vol de la Plate-forme polaire d'Envisat pendant les essais de recette chez Fokker Space (NL)



Flight model of the Envisat DORIS/MWR instrument composite undergoing final testing prior to delivery to Matra Marconi Space (B)

Modèle de vol du couple d'instruments DORIS/Radiomètre hyperfréquence d'Envisat pendant les derniers essais avant livraison à Matra Marconi Space (B)

doivent faire l'objet de discussions avec les délégations, conjointement au lancement d'activités techniques parallèles.

Campagnes

La préparation de la campagne CLARE 98 (Expérience de radar et de lidar de nébulosité) s'est poursuivie avec la revue des expérimentateurs et des préparatifs de mise en oeuvre.

Une campagne de soutien à petite échelle de la mission d'étude des processus à la surface du sol et de leurs interactions s'est déroulée en août en Espagne. Elle pourrait préfigurer une campagne plus importante, à organiser en 1999.

Envisat/Plate-forme polaire

Système Envisat

L'avis d'offre de participation (AO) à des projets pilotes et d'exploitation de données scientifiques a suscité un grand intérêt parmi les utilisateurs de données d'observation de la Terre. Plus de 700 propositions ont été reçues et font actuellement l'objet d'une évaluation. Les résultats de la procédure de sélection seront publiés avant la fin de l'année.

Les activités système se concentrent à présent sur la préparation de la vérification. Un plan de vérification du secteur sol intégré a été défini et les premiers essais débuteront d'ici la fin de l'année. Les principaux essais au niveau système du modèle de vol - comme par exemple les essais d'ambiance thermique sous vide et de bilan thermique prévus en mars 1999 à l'ESTEC - sont actuellement en cours de définition. Une revue de qualification au niveau du satellite devrait être réalisée au cours du premier semestre de 1999.

Charge utile Envisat

La livraison de l'antenne du modèle d'identification (EM) de l'ASAR a mis un terme à la fourniture de l'ensemble des instruments de l'appareil. Conformément à la démarche de livraison fractionnée adoptée, l'EM de l'ASAR se trouve actuellement chez Matra Marconi Space à Bristol (R-U) pour y subir des essais au niveau des instruments sur la plate forme polaire. La livraison des tuiles actives de l'antenne du modèle de vol de l'ASAR pour intégration au niveau supérieur a débuté. Tous ces éléments ont affiché de bonnes performances.

Les essais du modèle de vol du RA-2 sont presque achevés. L'ensemble des tests accomplis jusqu'à présent (performances sur une chaîne, CEM, interfaces) ont donné d'excellents résultats. Le modèle de vol du rétroréflecteur laser a été accepté et se trouve prêt à être expédié chez Matra Marconi Space (R-U). Les essais de l'instrument GOMOS se sont achevés au CSL (Liège) et les préparatifs en vue de sa livraison ont commencé.

Un problème de vibrations mécaniques internes a été constaté sur l'instrument AATSR et devrait être résolu par une modification de l'ensemble au plan focal. Cette solution doit encore être validée et mise en oeuvre sur le modèle de vol.

Activités relatives à la plate-forme polaire et au satellite

Le montage du modèle d'identification du satellite Envisat a progressé avec l'intégration de l'antenne ASAR. Cette opération parachève la configuration EM du module charge utile. L'assemblage de ce module avec le modèle de vol du module de servitude permettra de constituer le modèle d'identification complet du satellite, qui devra subir alors des essais au niveau système, et notamment des essais de compatibilité radioélectriques. L'édification, autour du satellite, de l'enceinte RF complète nécessaire à ces essais est aujourd'hui pratiquement achevée.

Le modèle de vol du module charge utile prend forme, avec l'intégration de l'ensemble des dispositifs électroniques de la case à équipement de la charge utile avec la structure et le câblage du porte-charge utile.

Le développement des unités de vol restantes a parallèlement progressé. Des problèmes survenus dans la fabrication de la mémoire de l'enregistreur à état solide devraient avoir des conséquences sur le calendrier de livraison de l'appareil.

An internal mechanical-vibration problem on the AATSR instrument has been identified and potentially resolved by a modification to the instrument's Focal-Plane Assembly. This solution still needs to be validated and implemented on the flight model.

Polar Platform and satellite activities

The Envisat satellite engineering-model programme has progressed with the completion of the EM ASAR antenna integration. This finalises the EM Payload Module configuration. This Module has then to be reassembled with the FM Service Module so as to constitute a complete EM satellite, which will then undergo system testing, and in particular the radio-frequency compatibility test. For this test, a complete RF enclosure must be built around the satellite, and this is now almost finished.

The flight-model Payload Module is taking shape with the integration of all the electronics of the payload equipment bay with the payload carrier structure and harness.

In parallel, the development of the remaining flight units has progressed. A memory manufacturing problem has occurred which will have an impact on the delivery of the solid-state recorder; workarounds are being investigated. The flight-model solar array is undergoing final acceptance tests (see accompanying picture).

The issue of shock compatibility with Ariane-5 has progressed with the proposal by ESA to implement a shock attenuator on the launcher. This solution still needs to be consolidated technically and programmatically.

Envisat ground segment

The Payload Data Segment (PDS) validation phase has started with the successful completion of the first Test Readiness Review (TRR). While integration of the PDS facilities is progressing well on the reference platform at Datamat (I), integration of the first equipment items is about to start.

The Flight Operation Segment (FOS) development and integration is progressing according to plan, the next major milestone being the Satellite Verification Test 1, planned for end-1998.

Meteosat

Meteosat operations

Meteosat-7 is operating nominally and should continue to function until the launch of the Meteosat Second Generation spacecraft, scheduled for October 2000.

Meteosat Second Generation

The satellite STM (Structural and Thermal Model) has now been prepared for mechanical testing. To this end the SEVIRI thermal dummy has been replaced by the actual SEVIRI STM. The accompanying picture shows the SEVIRI Engineering Model (EM), which is presently under integration at Matra Marconi Space (F) prior to being delivered to Alcatel Space in Cannes (formerly Aerospatiale) at the beginning of 1999 for integration into the EM satellite.

As in the previous phase, Critical Design Reviews (CDRs) at equipment and subsystem level are continuing with the aim of releasing flight-hardware manufacture. The System CDR is still planned for October 1998.

The development of the MSG-1 spacecraft and the procurement of MSG-2 and MSG-3 are on schedule, with engineering-model and some flight-model production in progress at equipment and

Integration of the engineering model of the SEVIRI instrument for Meteosat Second Generation (MSG) at Matra Marconi Space (F)

Intégration du modèle technologique de l'instrument SEVIRI destiné au Météosat de seconde génération (MSG) chez Matra Marconi Space (F)

On recherche actuellement des solutions de repli. Le modèle de vol du réseau solaire subit ses derniers essais de recette (voir illustration).

La proposition faite par l'ESA de placer un atténuateur de choc sur Ariane-5 devrait contribuer à résoudre la question de la compatibilité du satellite avec le choc au largage. Cette solution nécessite encore une consolidation sur les plans technique et programmatique.

Secteur sol Envisat

La phase de validation du système des données de charge utile (PDS) a débuté avec la réalisation d'une première revue d'aptitude aux essais (TRR). L'intégration des premiers équipements est sur le point de commencer, tandis que l'intégration des installations du PDS sur la plate-forme de référence se poursuit avec succès chez Datamat (I).

Le développement et l'intégration du secteur sol des opérations en vol (FOS) progresse selon le calendrier prévu. Les premiers essais de vérification du satellite, prévus à la fin de 1998, constitueront la prochaine étape importante du programme.

Météosat

Exploitation de Météosat

Météosat-7 fonctionne normalement et devrait demeurer opérationnel jusqu'au lancement du premier satellite Météosat de deuxième génération, prévu en octobre 2000.

Météosat de deuxième génération

Le modèle structurel et thermique du satellite (STM) est aujourd'hui prêt à subir des essais mécaniques. La maquette thermique du SEVIRI a été, pour ce faire, remplacée par le véritable STM de l'imageur. L'illustration ci-contre montre le modèle d'identification du SEVIRI, actuellement en cours d'intégration chez Matra Marconi Space (F) avant d'être livré début 1999 chez Alcatel Space, Cannes, (anciennement Aerospatiale) pour y être intégré au modèle d'identification du satellite.

Comme lors de la phase précédente, des revues critiques de conception (CDR) se déroulent actuellement au niveau des équipements et des sous-systèmes afin de permettre de lancer la fabrication du matériel de vol. La revue critique de conception au niveau système était prévue en octobre 1998.

Le développement du satellite MSG-1 et l'approvisionnement de MSG-2 et MSG-3 progressent selon le calendrier prévu, avec la réalisation en cours d'un certain nombre de modèles d'identification et de quelques modèles de vol au niveau des équipements et des sous-systèmes. La réalisation de l'instrument SEVIRI et du sous-système de communication mission pour le premier modèle de vol demeure sur le chemin critique.

Le lancement de MSG-1 reste programmé pour octobre 2000 et celui de MSG-2 en 2002. MSG-3 devrait être livré pour stockage en 2003.

Métop

La consolidation de la conception du satellite et le gel de sa configuration sont aujourd'hui pratiquement achevés. Certaines incertitudes demeurent cependant, notamment en ce qui concerne les instruments fournis par le client (CFI). La mise au point pratiquement achevée des interfaces d'instruments fournies par les américains a permis de progresser dans ce domaine. La conception d'ensemble des CFI les moins précisément définis (TASI, GOMB-2) est également arrêtée, et certaines itérations de détail encore prévisibles ne devraient pas avoir d'effet négatif sur le développement du satellite.

Le cycle des revues de définition préliminaires (PDR) a pu ainsi être lancé. Les PDR au niveau des unités sont en cours et devraient conduire à celles réalisées au niveau système du satellite, à la mi-1999. La conception des équipements est aujourd'hui presque gelée et l'approvisionnement des éléments à haute fiabilité est, par exemple, déjà en cours. Certaines activités de fabrication ont commencé.

Les différentes propositions concernant les instruments GOME-2 et GRAS ont été reçues. L'évaluation et la sélection des projets, ainsi que les négociations qui s'en suivront, devront être terminées suffisamment à temps pour permettre de lancer d'ici à la fin de l'année les activités de développement proprement dites de ces instruments (phase C/D).

Au cours d'une réunion spéciale, le Conseil d'Eumetsat a franchi une importante étape en autorisant le lancement du programme EPS et en s'engageant de manière formelle vis-à-vis du programme Métop-1 de l'ESA. La procédure d'approbation d'Eumetsat n'est toutefois pas formellement achevée. Quatorze États membres (assurant 83% du financement) ont pleinement adopté le programme, mais trois autres doivent encore faire entériner cette décision par une procédure nationale et n'ont émis qu'un vote 'ad referendum'.

Cette très importante décision autorise le lancement de l'ensemble des activités industrielles liées à Métop et devrait permettre la mise au point finale et la signature prochaine du contrat passé en commun par l'ESA et Eumetsat avec le maître d'oeuvre, Matra Marconi Space.

ERS

L'exploitation du système ERS se poursuit sans heurts, avec d'excellents résultats tant au sol que dans l'espace. La charge utile ERS-2 fournit des données d'excellente qualité, avec une grande disponibilité.

Après avoir subi une défaillance de gyroscope le 3 juin dernier, le système de pointage du satellite est aujourd'hui stable et fonctionne selon les spécifications requises. La surveillance des performances du système de contrôle d'attitude et d'orbite a été accrue et de nouveaux mécanismes permettant de renforcer le système sont en cours d'installation.

ERS-1 a été placé en hibernation, mais les vérifications périodiques qu'il subit montrent que le niveau de performance de la charge utile est préservé.

Le SAR d'ERS-1 est activé en mode image une fois par jour afin de préserver les performances des batteries. Cette opération de routine permet de programmer l'acquisition de paires d'images d'interférométrie SAR entre ERS-1 et ERS-2.

subsystem level. The SEVIRI instrument, together with the mission communication subsystem, remains on a critical path for the first flight model.

The launch of MSG-1 remains on schedule for October 2000, with MSG-2 to be launched in 2002 and MSG-3 to go into storage in 2003.

Metop

Design consolidation and the freezing of the satellite configuration has now been very largely achieved. Some uncertainties remain, especially in so far as the Customer Furnished Instruments (CFIs) are concerned. However, good progress has been made in this area also, with the US-supplied instruments' interfaces now essentially finalised. The design envelopes for the less well established CFIs (TASI, GOMB-2) are also in place and, although some detailed iteration has still to be expected, this should not adversely impact the satellite development.

The Preliminary Design Review (PDR) cycle is thus now underway, with unit-level PDRs being held, leading up to the satellite system PDR, which is scheduled for mid-1999. Equipment design is now substantially frozen and the hi-rel parts procurement, for example, is now well underway. Manufacturing has started in some areas.

The GOME-2 and GRAS proposals have been received, and evaluation, selection and negotiation should be completed in time to start the main development effort (Phase-C/D) for these instruments by the end of the year.

On the programmatic side, a major step forward has been achieved within Eumetsat, in that a special meeting of their Council has authorised the start of the EPS programme, including a full commitment to the ESA Metop-1 Programme. The Eumetsat approval process is not quite complete, however, in that 14 States (representing 83% of the required funding) have fully agreed to the programme, whilst 3 States have still to complete their national procedures and thereby lift their current 'ad referendum' votes.

This very positive step now permits the full release of the Metop industrial activities and should allow the finalisation and signature of the joint ESA/Eumetsat contract with the Prime Contractor (Matra Marconi Space) in the near future.

ERS

ERS system operations are continuing to run very smoothly, with excellent performances from both the space and ground segments. The ERS-2 payload is providing high-quality data with very good availability.

After the gyroscope failure on 3 June, satellite pointing is stable and within specification. The performance monitoring of the attitude and orbit control system has been increased and new mechanisms to reinforce this system are being set up.

ERS-1 is in hibernation, but the periodic checkouts show that the payload's performance level is being maintained.

To maintain the performance of ERS-1's batteries, the satellite's SAR image mode is activated once per day. This routine switch-on is being exploited to perform ERS-1/2 SAR interferometry by planning the acquisition of SAR image pairs.

In-orbit Technology Demonstration Programme

DDE
The Discharge Detector Experiment (DDE) will be delivered to NPO PM at the end of November 1999. There it will undergo the final test campaign and be integrated on the Espress-14 spacecraft. The software and electrical interfaces with the spacecraft were successfully tested at ESA's Moscow Office in May. The flight units for the experiment are presently being completed.

PROBA
The recent space-segment System Design Review showed that good progress has been with PROBA (Project for On-Board Autonomy). The structural model and mass dummies are being manufactured and assembled prior to mechanical and thermal qualification early in October. Hardware-unit manufacture has been released in order to have the data-handling engineering model ready by the end of the year for integration together with the other EM equipment due to arrive thereafter.

A new and more advanced type of solar cell has been selected, featuring 200 µm-thick, 4 cm x 4 cm gallium-arsenide cells on a germanium substrate with integrated diode (integral diode) protecting the cell against reverse breakdown under, for example, shadow conditions.

The SDR highlighted the criticality of the software development and it was decided to co-locate the software development team at ESTEC, thereby providing good facilities and easy access to in-house expertise. The Qualification Design Review (QDR) is planned for the second quarter of 1999, leading up to a mid-2000 launch.

FEEP
The payload-accommodation requirements for the FEEP (Field-Emission Electric Propulsion) system for using a Get-Away-Special (GAS) cannister on the Shuttle (G-752) have been forwarded to NASA, which is currently evaluating the request. The preliminary safety data package is in preparation. Models of the experiments are nearly complete and will allow modal analysis as well as dimensioning and positioning forecasts. FEEP thrusters have been assembled – two methods of nickel deposition have been used – and the test activities will begin soon.

All in all, the FEEP programme is proceeding according to plan.

International Space Station Programme

ISS overall assembly sequence
As a result of the worsening financial situation in Russia, the launch of the Service Module will have to be further delayed from April to June/July 1999. In addition, there is a clear indication that RSA will be financially unable to support the launch of the number of Soyuz/ Progress vehicles foreseen for 1999 in Revision D of the ISS Assembly Sequence. A series of meetings is scheduled for end-September to address the consequences

Programme de démonstration technologique en orbite

DDE
L'expérience de détecteur de décharge (DDE) sera livrée à NPO PM fin novembre 1999. Elle subira alors sa dernière campagne d'essais avant d'être intégrée sur Espress-14. Les logiciels et les interfaces électriques avec le véhicule spatial ont été essayés avec succès fin mai dans les locaux de l'ESA à Moscou. Les unités de vol destinées à l'expérience sont en cours d'achèvement.

PROBA
La récente revue de conception système (SDR) du secteur spatial a démontré la progression satisfaisante du projet PROBA (Projet d'autonomie de bord). Le modèle structurel et les masses fictives ont été fabriqués et assemblés, en vue de la qualification mécanique et thermique prévues début octobre. On a lancé la fabrication du matériel nécessaire à l'obtention d'ici à la fin de l'année du modèle d'identification du dispositif de traitement de données qui sera intégré aux modèles d'identification des autres équipements devant être fournis par la suite.

Un nouveau type de photopile, plus perfectionné, a été choisi. Il est composé de 200 éléments à l'arséniure de gallium, d'une épaisseur de l'ordre du micron et d'une surface de 4x4 cm, placés sur un substrat en germanium à diode intégrée, protégeant la cellule contre le claquage inverse, provoquée par exemple par un passage à l'ombre.

La SDR a permis de souligner la difficulté de réalisation du logiciel et il a été décidé d'en détacher l'équipe de développement à l'ESTEC, où elle disposera d'installations appropriées et d'un accès facile au savoir-faire du Centre. La revue de conception pour la qualification devrait se dérouler au cours du second trimestre 1999, avant le lancement prévu à la mi-2000.

FEEP
La demande d'utilisation d'un boîtier GAS (offre spéciale de vol) pour l'installation de la charge utile FEEP (système de propulsion électrique par émission de champ) sur la Navette spatiale (G-752) a été transmise à la NASA où elle est en cours d'examen. L'ensemble des données préliminaires de sécurité est en préparation. Les modèles des expériences sont presque achevés et doivent permettre de procéder à des analyses modales et de faire des prévisions sur le plan des dimensions et du positionnement. Les propulseurs FEEP ont été assemblés (on a utilisé deux méthodes de dépôt de nickel) et les essais devraient débuter prochainement.

Dans l'ensemble, le programme FEEP progresse conformément aux prévisions.

PROBA

Programme de Station spatiale internationale

Séquence d'assemblage de l'ISS
L'aggravation de la situation financière en Russie a eu pour conséquence de retarder une nouvelle fois le lancement du module de service russe, reporté d'avril à juin-juillet 1999. En outre, tout laisse présager que l'Agence spatiale russe ne sera pas en mesure de soutenir financièrement l'ensemble des lancements de véhicules Soyouz/Progress prévus en 1999 dans la Révision D de la séquence d'assemblage de la Station spatiale internationale (ISS). Une série de réunions devaient se dérouler fin septembre afin d'examiner les conséquences de cette situation sur la séquence d'assemblage de l'ISS, ainsi que les moyens de se prémunir contre tout nouveau problème surgissant du côté russe. Une réunion de la Commission de contrôle de la Station spatiale (SSCB) était également prévue début octobre.

Laboratoire Columbus (COF)
De nouvelles réunions ont eu lieu avec la NASA. Elles ont porté sur les projets d'accords bilatéraux ESA/NASA relatifs aux essais et vérifications, sur la vérification du logiciel de télécommande

on the overall ISS Assembly Sequence and potential actions to safeguard against further problems on the Russian side. A Space Station Control Board (SSCB) is scheduled for early October.

Columbus Laboratory (COF)
Further meetings with NASA have taken place addressing the proposed joint NASA/ESA bilateral test and verification agreements, the Command and Data Management software verification, the launch-to-activation timeline, agreement on the incorporation of the NASA PEHG (Payload Ethernet Hub/Gateway) in the Columbus module, the loan from NASA of an International Standard Payload Rack (ISPR) and secondary structures for test and launch purposes, and common display/graphics standards.

ESA and NASA have reviewed the implementation of the External Payload Facility (EPF) and the fire-suppression modifications. Discussions with NASA safety authorities indicated that they are satisfied with the principles of the Columbus revised approach to fire suppression. The initial design of the NASA Express Pallet has been simplified, thereby making it easier for ESA to maintain a degree of inter-changeability for the payloads.

The system Electrical Ground Support Equipment (EGSE) deliveries have started, and the system Electrical Test Model assembly has begun. Problems have occurred with the Data Management Software, and its delivery will be some months later than originally planned. Equipment-level qualification tests have started, and preparations are underway for the first integrated-subsystem-type tests.

COF launch barter
Design changes to Node 2, to accommodate crew quarters and revised internal configuration layouts, have been performed. As a result of these changes, a shift in the delivery date to NASA, from August to October 2000, has been agreed. The re-engineering principles for Node 3, to make it the crew accommodation quarters until the Habitation Laboratory is launched, were agreed with NASA and a Reference Design Review was conducted in July. Formal ASI/NASA agreement on the re-engineering has not yet been achieved. In the context of Software Deliveries/ DMS-R items / Associated Sustaining Engineering for NASA, final hardware deliveries have been completed to NASA and Software Verification Facility (SVF) support at Johnson Space Center continues.

The start of Phases-B,C,D for the Crew Refrigerator/Freezer Racks (CR/FR) has been delayed because NASA is reviewing where the CR/FR will be installed in the Station. Transhab has been suggested as a new location, but its utilisation has not yet been approved. An initial contract to study and breadboard critical design areas has been started with industry to ensure timely delivery of the system. Phase-A for the Cryogenic Freezer Racks was completed at the end of June and the release of the Invitation to Tender (ITT) for Phases-B/C/D/E is scheduled for end-October.

Cupola 1 and 2
Following intensive technical discussions with NASA on the implementation of the Barter Arrangement (under which ESA will supply two Cupolas for the ISS), ESA is now responsible for the overall Cupola Segment and its verification. This led to modifications to the ITT that was subsequently released. Industrial proposals are due at the end of September.

Automated Transfer Vehicle (ATV)
A dedicated working group supported by ESA, NASA and Aerospatiale has been investigating a possible back-up scenario with the ATV being berthed on the Node 3 nadir port (on the US Segment) of the Space Station. This scenario is considered technically and operationally feasible and a decision on whether to chose this option is expected in September.

Following an ESA/RSA Level-1 meeting in July at which RSA stated that they were not ready to barter RSA/RSC-Energia activities required for integrating the ATV with the Russian Segment against long-term DMS-R support needed from ESA, it was decided to provide RSA with the ESA financial targets for the ATV integration work, as well as the targets for the procurement of Russian hardware needed for the ATV.

At the Level-1 meeting, ESA informed RSA about the parallel activities being undertaken with NASA to investigate an alternative scenario under which the ATV would berth to the US Segment. RSA provided an initial letter of response to the ESA targets in mid-August, and further negotiations are planned for early-September to try and reach a firm agreement on all technical, programmatic and contractual aspects.

Negotiations of the Phase-C/D contract were concluded in July. However, taking into account the uncertainty regarding the ATV location at the Station, a Preliminary Authorisation to Proceed (PATP), covering the period until end-September, was signed at the end of July. Signature of the contract is now expected at the end of September.

Negotiations with Arianespace have started to establish a frame contract for the procurement of Ariane-5 launch vehicles for ATV flights. It is worth mentioning that the missions covered by the ISS Exploitation Programme represent Europe's prime means to trade-off its share of the ISS Common Operations Costs.

Crew Transfer Vehicle and CRV/X-38 co-operation
All of the 13 ESA subsystems/major elements of the X-38 V-201 spacecraft are now in the detailed design, development and manufacturing phase.

Discussions on the current X-38 co-operation, on ESA's future involvement in the CRV programme, and on ESA's early commitment for ESA-furnished essential elements of the operational CRV (Crew Rescue Vehicles based on the X-38 concept) have led to a good understanding between NASA and ESA. A corresponding Protocol concerning the formal CRV/X-38 co-operation has been established for signature in September.

In August, the Request for Quotation (RFQ) for the new ART (Applied Re-entry Technology) programme was issued, and a proposal from industry was received and evaluated. Assuming that the Agency's Industrial Policy Committee (IPC) approves the contract proposal in September, it is planned to award the contract in early October.

Atmospheric Re-entry Demonstrator (ARD)
Since June, the ARD itself has been stored at CSG (Centre Spatial Guyanais) in Kourou. The final mission-analysis and flight-readiness review for Ariane-503 and its payload, including the ARD, took place

et de gestion des données, sur le déroulement de la séquence allant du lancement à l'activation, sur l'accord relatif à l'intégration de la charge utile PEHG de la NASA dans le module Columbus, sur le prêt par la NASA d'un ISPR (bâti international de charge utile normalisé) et de structures secondaires à des fins d'essais et de lancement, et sur les normes graphiques et d'affichage communes.

L'ESA et la NASA se sont penchées sur la mise en oeuvre de l'installation de charges utiles externes et sur les modifications des procédures de lutte contre les incendies. Les discussions entreprises avec les responsables des problèmes de sécurité de la NASA ont montré que ceux-ci étaient satisfaits de la nouvelle procédure anti-incendies adoptée pour Columbus. La conception initiale de la Palette express de la NASA a été simplifiée, facilitant ainsi l'interchangeabilité des charges utiles de l'ESA.

La livraison des équipements de soutien sol électriques (EGSE) et l'assemblage du modèle d'essais électriques du système ont débuté. La mise au point du logiciel de gestion des données a rencontré certains problèmes, retardant sa livraison de quelques mois. Les essais de qualification au niveau des équipements ont débuté, ainsi que la préparation des premiers essais du type sous-systèmes intégrés.

Compensation du lancement du COF

La conception de l'élément de jonction n° 2 a été modifiée afin de permettre l'aménagement de quartiers pour l'équipage et de tenir compte de la nouvelle configuration interne. En fonction de ces modifications, la date de livraison à la NASA a été repoussée d'un commun accord d'août à octobre 2000. L'ESA et la NASA se sont également mises d'accord sur les principes présidant au réaménagement de l'élément de jonction n° 3 en quartiers pour l'équipage, en attendant le lancement du laboratoire d'habitation. Une revue de la conception de référence a été réalisée en juillet. L'accord ASI/NASA relatif à cette reconfiguration n'a pas encore été formalisé. La livraison à l'agence américaine des derniers éléments entrant dans le cadre de la fourniture de logiciels, d'éléments DMS-R et d'ingénierie de soutien associée a été achevée. L'équipe de l'ESA présente au Centre spatial Johnson continue également d'apporter son assistance à l'installation de vérification de logiciels (SVF).

La NASA examine actuellement les lieux d'implantation possibles des bâtis réfrigérateurs/congélateurs destinés à l'équipage de la station (CR/FR), ce qui a retardé le lancement des phases de développement B, C et D de ces éléments. On a avancé l'hypothèse du Transhab, mais l'utilisation de celui-ci n'a pas encore été approuvée. Un contrat préliminaire passé avec l'industrie doit permettre d'étudier les éléments critiques du système et d'en réaliser des maquettes, afin d'en garantir la livraison en temps voulu. La phase A du développement des bâtis congélateurs cryogéniques (CRYOS) a été achevée fin juin et le lancement de l'appel d'offres relatif aux phases B/C/D/E était prévu pour la fin octobre.

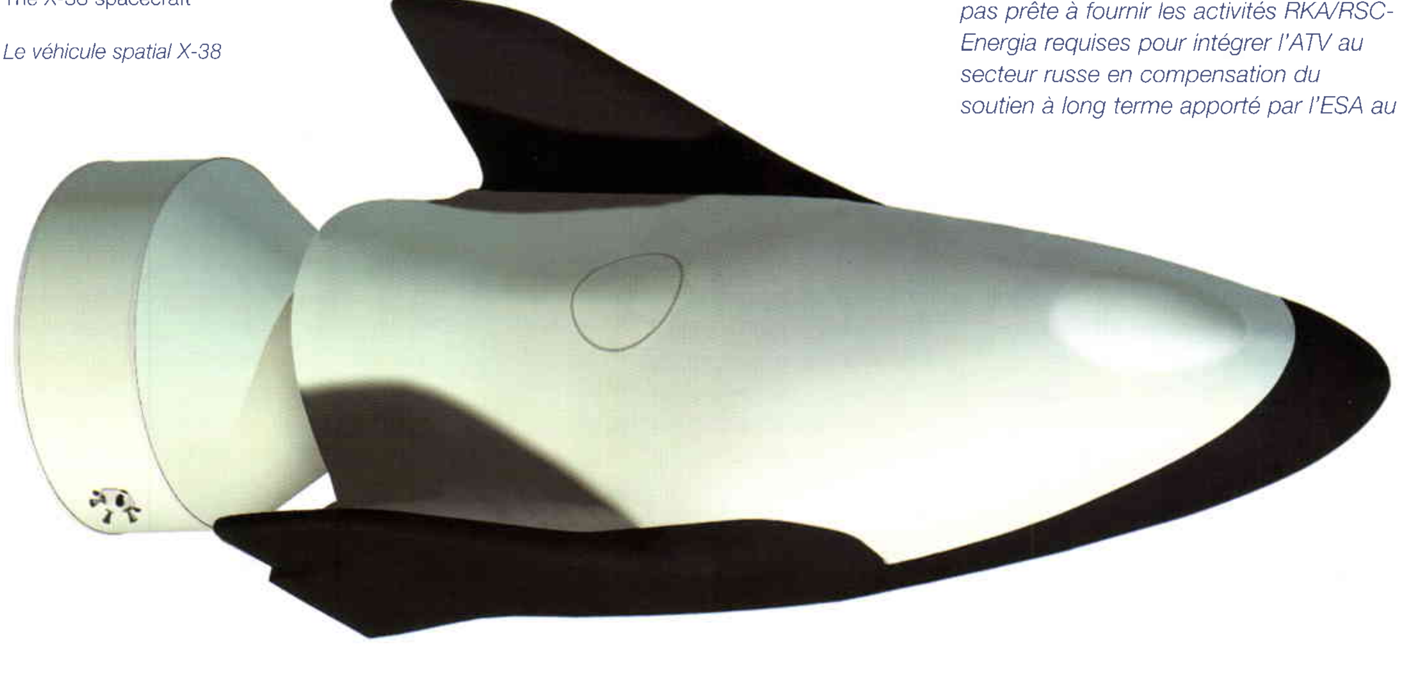
Coupoles 1 et 2

Après des discussions techniques approfondies avec la NASA sur la mise en oeuvre de l'arrangement de compensation (aux termes duquel l'ESA fournira deux coupoles à l'ISS), il a été décidé que l'agence européenne serait responsable de l'ensemble des coupoles et de leur vérification. Cette décision a entraîné une modification de l'appel d'offres lancé par la suite. Les propositions industrielles devaient être déposées avant la fin septembre.

Véhicule de transfert automatique (ATV)

Un groupe de travail spécialisé, réuni par l'ESA, la NASA et Aerospatiale, a étudié un scénario de remplacement possible, consistant à amarrer l'ATV au point d'accès côté nadir de l'élément de jonction n° 3, dans le secteur américain de la Station spatiale. Ce scénario est considéré comme techniquement et opérationnellement réalisable, et une décision relative à la concrétisation de cette option devait intervenir en septembre.

A la suite d'une réunion ESA/RKA organisée en juillet au niveau 1, l'agence spatiale russe a annoncé qu'elle n'était pas prête à fournir les activités RKA/RSC-Energia requises pour intégrer l'ATV au secteur russe en compensation du soutien à long terme apporté par l'ESA au



The X-38 spacecraft

Le véhicule spatial X-38

successfully during July and August. The validation of the communications links between CSG, the Libreville station, the Toulouse Control Centre, the ARIA aircraft and NASA Goddard Space Flight Center (GSFC) was also successfully completed.

Ground-segment development and operations preparation

With respect to the Control Centres, the study with CNES/DLR to define the facilities at DLR in Oberpfaffenhofen (D) and CNES in Toulouse (F) for controlling the Columbus Laboratory and the ATV has been extended. In parallel, definition studies of the Columbus Laboratory control centre, the ATV control centre and a combined control centre at ESOC are being conducted.

Comments on the ESA/NASA/RSA Trilateral ATV Demonstration and Nominal Operations Flight Plan were received from RSC-Energia at the end of July. The RSC-Energia-proposed changes to the ESA/NASA operations concept are under review. The latest version of the NASA Display and Graphics Commonality Standard (DGCS) has been reviewed and requires further clarification.

With regard to the COF/ATV Operations Support Functions and Facilities, the ASI-study addressing the centralised implementation of the operations-support functions at ALTEC has not produced a result acceptable to the principal contractors involved. An ESA proposal to break the deadlock by assigning major roles to both Italian industry and the ALTEC facility has been submitted to ASI for further consideration.

Utilisation

Promotion

A Working Group has been set up with Eurospace to elaborate schemes for increasing the support and engagement of industry in Utilisation Promotion.

Preparation

The kick-off meeting on the forest-fire detection payload FOCUS took place in August. This is a partnership project for Phase-A funding between ESA, DLR and industry. Concerning the Cupola barter with NASA for the offsetting of launch costs for ESA external payloads, NASA has indicated informally its preference for FOCUS and TEF (Technology Exposure Facility) as the payloads for ESA/NASA co-operation.

The Invitation to Tender (ITT) for the Technology Exposure Facility (TEF) has been released and proposals are due in early October. The ITT for the COF launch payload integration has been issued and proposals are due in mid-October.

Hardware development

The contract for Phases-B/C/D of the European Drawer Rack (EDR) and European Storage Rack (ESR) for COF was placed with a consortium led by Alenia. The Critical Design Review of the Standard Payload Computer (SPLC) has been successfully concluded and the recurring production initiated.

Astronaut activities

In accordance with the Council decision in March 1998 to create a single European Astronaut Corps, ASI performed a pre-selection of Italian astronaut candidates and presented – after formal acceptance by ESA – Paolo Nespoli and Roberto Vittori on 31 July 1998 as new members for the European Astronaut Corps. The former national astronauts Jean-Pierre Haigneré (CNES), Léopold Eyharts (CNES), Umberto Guidoni (ASI), Hans Schlegel (DLR) and Gerhard Thiele (DLR) have also been integrated into the European Astronaut Corps.

In order to provide the appropriate coverage for the new members, a further interim 'Shuttle Mission Specialist Training Agreement' has been concluded. This agreement will be incorporated shortly into a single comprehensive Agreement covering the Shuttle-related training arrangements for all members of the European Astronaut Corps residing at NASA/Johnson Space Center.

A new COF training catalogue has been published in the Astronauts Training Database (ATD) and is currently available via the EAC web-based training pages.

Early deliveries

Data Management System for the Russian Service Module (DMS-R)

After successful completion of testing, the Fault Tolerant Computer (FTC) delta software has been delivered to RSC-Energia for installation in the Service Module. Further software changes have to be approved by the joint software control board and will become a formal change to the baseline.

The schedule for all outstanding DMS-R hardware and software deliveries has been agreed with RSC-E and is compatible with the current Service Module schedule. ESA has taken the appropriate measures to ensure the procurement of additional spares. This is necessary to fulfil ESA's obligations for repair or replacement of failed computers during the engineering-support period. A binding agreement between RSA and RSC-E on the long-term sustaining engineering support and spares requirements is pending.

MPLM ECLSS Environmental Control and Life Support Subsystem

Design modifications for the Duct Smoke Detector are under discussion, and those for the Line Shut-off Valves are under way. As a result of these two items, the finalisation of qualification of the overall MPLM/ECLS will be delayed until early next year. The flight hardware, which is installed in the MPLM flight model 'Leonardo', already delivered to NASA/Kennedy Space Center, will have to be removed and replaced with upgraded items (they are readily accessible).

Due to the open qualification items, the closure of acceptance of the hardware cannot be completed yet by ESA. However, ASI have assumed custodian-ship of all delivered items in the meantime. Flight Unit 2 equipment has been delivered to the MPLM Prime Contractor, as have almost all items for Flight Unit 3.

European Robotic Arm (ERA)

RSA has been requested to accept a six-month delay in the delivery of ERA (and the training equipment), in-line with the revised SPP launch date (Assembly Sequence Revision D). If ratified, this will result in a need date for delivery of January 2000.

As the current subsystem delivery schedules result in delivery of the ERA flight model in mid-December 1999, and problems exist with two of the contractors, the ERA schedule is critical. It is now expected that the ERA Critical Design Review will have to be rescheduled for January 1999, with the final Board meeting in February. The EQM model of the On-Board Computer (OBC) and the first EQM End-Effector have been shipped to Fokker (NL), as have the EQM

DMS-R. Il a été décidé en conséquence de communiquer à la RKA les objectifs de prix fixés par l'ESA pour les activités d'intégration de l'ATV et pour l'approvisionnement du matériel russe nécessaire au véhicule. Au cours de la réunion au niveau 1, l'ESA a également informé l'agence russe des contacts pris avec la NASA pour examiner le scénario de remplacement consistant à amarrer l'ATV au secteur américain de l'ISS. La RKA a adressé, à la mi-août, une première réponse à l'ESA concernant les objectifs de prix. De nouvelles négociations étaient prévues début septembre pour tenter de parvenir à un accord définitif sur l'ensemble des aspects techniques, programmatiques et contractuels de ce dossier.

Les négociations relatives au contrat de phase C/D ont été conclues en juillet. En raison toutefois des incertitudes concernant l'emplacement de l'ATV sur la station, il n'a été délivré à la fin juillet qu'une autorisation préliminaire d'engagement des travaux (PATP) jusqu'à la fin septembre. La signature définitive du contrat devait intervenir à la fin du mois de septembre.

Des négociations visant à élaborer un contrat cadre de fourniture de lanceurs Ariane-5 pour l'emport de l'ATV ont été entamées avec Arianespace. Il convient de rappeler que les missions de l'ATV prévues dans le cadre du programme d'exploitation de l'ISS constituent le principal moyen pour l'Europe de couvrir sa part des coûts d'exploitation communs de la station spatiale.

Coopération relative au véhicule de transfert d'équipages/X-38

Les phases de conception détaillée, de développement et de fabrication de l'ensemble des 13 éléments majeurs et sous-systèmes du véhicule spatial X-38/V-201 à fournir par l'ESA sont aujourd'hui lancées.

Les discussions NASA/ESA sur la coopération actuelle dans le domaine du X-38, sur la participation future de l'ESA au programme CRV et sur l'engagement préliminaire de l'Agence de fournir des éléments essentiels du CRV opérationnel (véhicule de secours des équipages, basé sur le concept X-38) ont permis de renforcer l'entente entre les deux agences. Elles ont abouti à l'adoption d'un protocole officiel relatif à la coopération ESA/NASA dans les domaines du CRV et du X-38, qui devait être signé en septembre.

La demande de prix (RFQ) relative au nouveau programme ART (programme d'application des technologies de rentrée) a été adressée en août. Une proposition émanant de l'industrie a été reçue et soumise à évaluation. Le contrat devait normalement être attribué en octobre, après avoir été approuvé en septembre par le Comité de la politique industrielle de l'Agence.

Démonstrateur de rentrée atmosphérique (ARD)

L'ARD a été stocké au mois de juin au CSG (Centre spatial guyanais) à Kourou. L'analyse finale en vue de la mission et la revue d'aptitude au vol d'Ariane-503 et de sa charge utile – comprenant l'ARD – ont été réalisées en juillet et en août. La validation des liaisons de télécommunications entre le CSG, la station de Libreville, le Centre de contrôle de Toulouse, l'avion ARIA et le Centre spatial Goddard de la NASA (GSFC) a également eu lieu avec succès.

Développement du secteur sol et préparation des opérations

Les études entreprises avec le CNES et le DLR sur une implantation des installations de contrôle du laboratoire Columbus et de l'ATV à Oberpfaffenhofen (D) pour le DLR et à Toulouse (F) pour le CNES, vont être poursuivies. D'autres études de définition sur l'implantation du centre de contrôle du laboratoire Columbus, du centre de contrôle de l'ATV et d'un centre de contrôle commun à l'ESOC se poursuivent parallèlement.

RSC-Energia a adressé au mois de juillet un certain nombre de remarques relatives au plan de vol de démonstration et d'opérations nominales trilatéral ESA/NASA/RKA de l'ATV. Elle a proposé d'apporter certaines modifications au concept d'exploitation ESA/NASA actuellement examiné. La dernière version de la norme sur les communités entre les affichages et les graphiques (DGCS) de la NASA a été examinée et requiert de nouveaux éclaircissements.

Les conclusions de l'étude relative à l'implantation centralisée des fonctions d'exploitation et de soutien chez ALTEC, réalisée par l'ASI dans le cadre de la définition des installations et des fonctions de soutien des opérations de l'ensemble COF/ATV, ne sont pas considérées comme acceptables par les principaux contractants concernés. Pour sortir de l'impasse, L'ESA a adressé une proposition à l'ASI, suggérant d'assigner des rôles importants tout à la fois à l'industrie italienne et à ALTEC. Cette proposition est en cours d'examen.

Utilisation

Promotion

Un groupe de travail a été constitué avec Eurospace afin de proposer des solutions permettant d'accroître le soutien et l'engagement de l'industrie dans la promotion de l'utilisation de la Station.

Préparation

La réunion de lancement du projet de charge utile FOCUS (détection des incendies de forêts) s'est déroulée en août. Il s'agit là d'un projet en partenariat dont la phase A est financée par l'ESA, le DLR, et l'industrie. La NASA a marqué officieusement sa préférence pour FOCUS et TEF (Installation d'exposition au milieu spatial pour les recherches technologiques), en tant que charges utiles choisies dans le cadre de l'accord de compensation ESA/NASA Coupoles/emport de charges utiles externes de l'ESA.

Les appels d'offres (ITT) relatifs au TEF et à l'intégration des charges utiles pour le lancement du COF ont été diffusés et les propositions devaient parvenir respectivement au début et à la mi-octobre.

Réalisation des matériels

Les contrats de phases B/C/D du bâti à tiroirs européens (EDR) et du bâti de stockage européen (ESR) pour le COF ont été attribués à un consortium conduit par Alenia. La revue critique de conception (CDR) du calculateur standard pour charges utiles (SPLC) a été positive, ce qui a permis de lancer la production de l'appareil.

Activités des astronautes

Conformément à la décision prise en mars 1998 par le Conseil de créer un corps unique d'astronautes européens, l'ASI a procédé à la préselection de candidats astronautes italiens et a choisi le 31 juillet 1998 – après approbation officielle de l'ESA – Paolo Nespoli et Roberto Vittori pour faire partie de ce corps. Les anciens astronautes nationaux

Manipulator Limb System (MLS) and the Camera and Lighting Units (CLUs). This enables the initiation of the System EQM AIT (Assembly, Integration and Test) programme with the commencement of the Electrical Bench testing.

Microgravity

EMIR-1 and EMIR-2

The ESA Advanced Gradient Heating Facility (AGHF), Advanced Protein Crystallisation Facility (APCF), Facility for Adsorption and Surface Tension (FAST) and Morphological Studies on Model Systems (MOMO) payload facilities are scheduled for launch in the Spacehab module on Shuttle flight STS-95 on 29 October. APCF, Biobox and FAST will be delivered only days before the launch for last-minute installation in Spacehab on the launch pad, in order to be able to prepare and install sensitive samples as late as possible.

After installation of the AGHF rack into the Spacehab module at the end of July, the facility successfully passed the final Integrated Verification Test (IVT) and is now ready for launch.

The refurbishment work on both APCF flight models is nearing completion and day-by-day planning for the protein filling in Europe, hardware transport to the Spacehab Payload Processing Facility (SPPF), final integration and test work at the SPPF and late installation in Spacehab are being performed.

Refurbishment activities on Biobox are underway, including both hardware and software modifications to improve performance and to adapt to Spacehab interfaces. Final assembly of the flight model and closure of all verification items with Spacehab is planned for early-September.

The Interface and Verification Testing of FAST with Spacehab has been successfully completed. The facility controller and both experiment cells are now integrated and all software has been verified and tested. A key milestone will be the scientific verification during a long experiment functional test in September.

The Morphological Transitions in a Model Substance (MOMO) refurbishment has been completed, including the improvement and full validation of the MOMO control software. MOMO has been shipped to Cape Canaveral (USA), where it was tested before hand-over and then integrated into the Spacehab.

Microgravity Facilities for Columbus (MFC)

The Biolab Prime Contractor started conducting subcontractor Preliminary Design Reviews (PDRs) in June. The system PDR will start in October and should be completed in January 1999. It is planned to release the ITT for the Experiment Preparation Unit (EPU) for Phases-B/C/D in October 1998.

The Fluid Science Laboratory (FSL) consortium is working to schedule and breadboarding activities are currently in progress. Subcontractor PDRs will start in the last quarter of 1998. Technical exchanges are continuing with the Canadian Space Agency (CSA) to investigate the possibility of introducing their Microgravity Vibration Isolation Mount (MIM) system inside the Fluid Science Laboratory (FSL) in order to improve the microgravity environment for the experiments. A decision will be taken by end-1998.

The Preliminary Authorisation to Proceed (PATP) for the Phase-C/D contract for the Material Science Laboratory (MSL) in the US module has been extended to 30 November. The RFQ for the complete Phase-C/D was sent out to industry in mid-July and the contract is expected to be awarded in November. Co-operation with NASA concerning the Material Science Laboratory (MSL), which will be accommodated in the US Lab, is ongoing.

Two parallel Phase-A study contracts for the European Physiology Module (EPM) are In progress and the final presentations will be held in September. The ITT for the Phases-B/C/D procurement will be released by end-1998. Discussions with NASA concerning the joint operation and co-location of the EPM with the Human Research Facilities are progressing. A final agreement should be reached by end-1998.

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Jean-Pierre Haigneré (CNES), Léopold Eyharts (CNES), Umberto Guidoni (ASI), Hans Schlegel (DLR) et Gerhard Thiele (DLR) y ont également été intégrés.

Un nouvel accord intérimaire de formation des spécialistes mission de la Navette spatiale américaine a été conclu afin de tenir compte de la désignation des nouveaux astronautes. Il sera intégré prochainement à un accord global regroupants les différents arrangements relatifs à la formation pour la Navette de l'ensemble des membres du Corps des astronautes européens en poste au Centre spatial Johnson de la NASA.

Un nouveau guide de formation pour le COF a été intégré à la Base de données de formation des astronautes (ADT). Il est disponible via les pages de formation sur le Web du Centre de formation des astronautes (EAC).

Livraisons à court terme

Système de gestion de données pour le module de service russe (DMS-R)

Après avoir été testé avec succès, le logiciel delta destiné à l'ordinateur à tolérance de panne (FTC) a été livré à RSC-Energia pour être installé à bord du module de service. Les nouvelles modification apportées au logiciel devront être approuvées par la commission conjointe de contrôle des logiciels avant d'être officiellement incluses dans la base de référence.

On s'est mis d'accord avec RSC-E sur le calendrier de livraison de l'ensemble des matériels et logiciels restants destinés au DMS-R, qui est conforme au calendrier actuel du module de service. L'ESA a pris les dispositions nécessaires pour assurer l'approvisionnement des pièces de rechange supplémentaires. Ces mesures permettront à l'Agence de remplir ses obligations de réparation ou de remplacement des ordinateurs défaillant pendant la période convenue de soutien technique. Un accord portant sur l'assistance technique à long terme et la fourniture de pièces de rechange est en cours de négociation entre la RKA et RSC-E.

Sous-système de contrôle de l'environnement et de soutien-vie (ECLSS) du MPLM

Les modifications envisagées pour le détecteur de fumée sont en cours d'examen et celles prévues pour les vannes d'isolement des conduites sont en cours. Les problèmes posés par ces deux éléments ont retardé jusqu'au début de l'année prochaine la qualification définitive de l'ensemble MPLM/ECLS. Le matériel de vol déjà installé sur le modèle de vol 'Leonardo' du MPLM livré au Centre spatial Kennedy de la NASA devra être démonté et remplacé par des éléments améliorés (d'ores et déjà disponibles). L'ESA ne peut clore la procédure de recette tant que la qualification des différents éléments n'est pas achevée. L'ASI assure pendant ce temps le stockage des éléments livrés. Les équipements de la deuxième unité de vol, et la plus grande partie de ceux de la troisième unité de vol, ont été livrés au maître d'oeuvre du MPLM.

Bras télémanipulateur européen (ERA)

Suite à la modification de la révision de la date de lancement de la Plate-forme science et énergie (SPP) (révision D de la séquence d'assemblage), il a été demandé à la RKA d'accepter un report de six mois de la date de livraison de l'ERA (et de ses équipements d'entraînement). En cas d'accord, une nouvelle date de livraison de l'ERA devra être fixée.

Le calendrier de livraison actuel des sous-systèmes prévoit la livraison du modèle de vol de l'ERA à la mi-décembre 1999, ce qui le rend critique en raison des problèmes rencontrés par deux contractants. On estime à présent que la revue de conception critique de l'ERA devra être reportée à janvier 1999, la réunion finale de la commission étant fixée au mois de février. Les modèles de qualification et d'identification (EQM) de l'ordinateur de bord, du premier organe terminal de l'ERA, de l'élément articulé, ainsi que les unités caméra et éclairage ont été livrés chez Fokker (NL). Cela doit permettre de lancer le programme d'assemblage, d'intégration et d'essais du modèle de qualification au niveau système, qui commencera avec le début des essais électriques au banc.

Microgravité

EMIR-1 et EMIR-2

Le vol STS-95 de la Navette spatiale, lancé le 29 octobre 1998, a permis d'emporter dans l'espace plusieurs charges utiles de l'ESA, logées dans le module Spacehab. Il s'agit du Four à gradient de haute technologie (AGHF), de l'Installation de cristallisation des protéines de pointe (APCF), de l'Installation d'études de l'adsorption et de la tension de surface (FAST) et de l'Installation d'études morphologiques sur des substances modèles (MOMO). Les installations APCF, Biobox et FAST n'ont été livrées à la NASA que quelques jours avant le lancement, pour être placées à la dernière minute dans le Spacehab, sur le pas de tir lui-même, afin de permettre de préparer et d'installer aussi tard que possible un certain nombre d'échantillons sensibles.

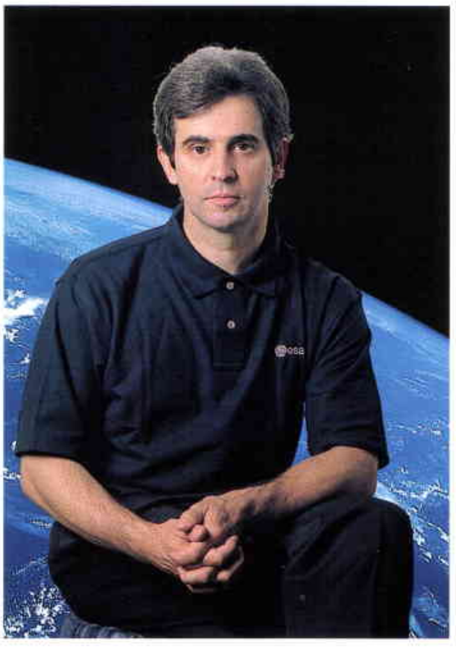
Le bâti de l'AGHF a été installé dans le Spacehab à la fin du mois de juillet, avant que l'installation ne subisse avec succès les derniers essais de vérification intégrés (IVT) et soit déclarée prête pour le vol.

La remise en état des deux modèles de vol de l'APCF a pu être achevée à temps et il a fallu organiser au jour le jour le chargement des protéines en Europe, le transport du matériel vers l'installation de préparation des charges utiles du Spacehab (SPPF), les derniers essais et travaux d'intégration dans la SPPF et enfin l'installation finale dans le Spacehab.

La Biobox a également été remise en état. Il a notamment fallu apporter des modifications tant au plan des matériels que des logiciels afin d'en améliorer les performances et les adapter aux interfaces du Spacehab. L'assemblage final du modèle de vol et les dernières vérifications relatives au Spacehab ont eu lieu en septembre.

Les essais de vérification des interfaces de FAST avec le Spacehab se sont également bien passés. Le dispositif de contrôle et les deux cellules à expériences ont été intégrées et l'ensemble des logiciels ont été vérifiés et testés. Un test de longue durée, réalisé en septembre, a marqué une étape importante dans la vérification scientifique des expériences.

In Brief



Four European Astronauts Begin Training in Houston

Four European astronauts have joined 14 others from the United States, Canada and Brazil in the Astronaut Class of 1998, which began Mission Specialist training at NASA's Johnson Space Center in Houston, Texas, on 24 August. After successful completion of the 12-month basic training programme, they will be eligible for assignment to future missions on the US Space Shuttle and the International Space Station.

The four astronauts – Léopold Eyharts (F), Hans Schlegel (D), Paolo Nespoli (I) and Roberto Vittori (I) – will take part in courses ranging from an in-depth study of the Shuttle and Space Station systems to survival training in remote areas.

The astronauts joined ESA during the summer in the first phase of the creation of a single European Astronaut Corps. Existing astronaut programmes in individual European countries are being merged into a single one under ESA management in order to allow Europe to respond in a cost-effective manner to the mission opportunities that will become available to ESA as the European partner in the International Space Station (ISS).

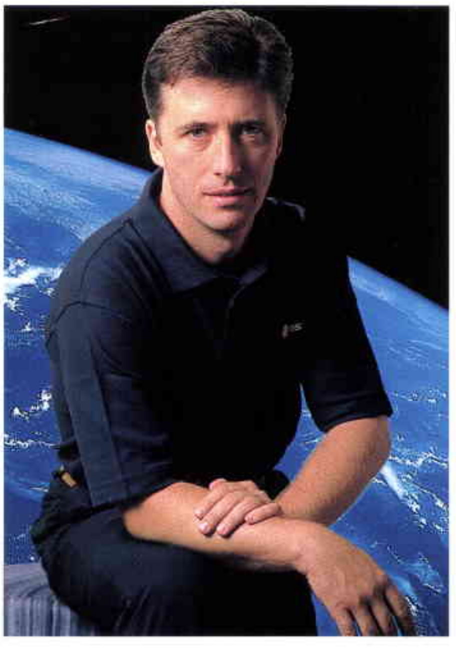
Léopold Eyharts is the European astronaut who has most recently spent time in space. He represented the French National Space Agency, CNES, on the French-Russian Pégase mission aboard the Russian space station Mir for three weeks in February 1998.

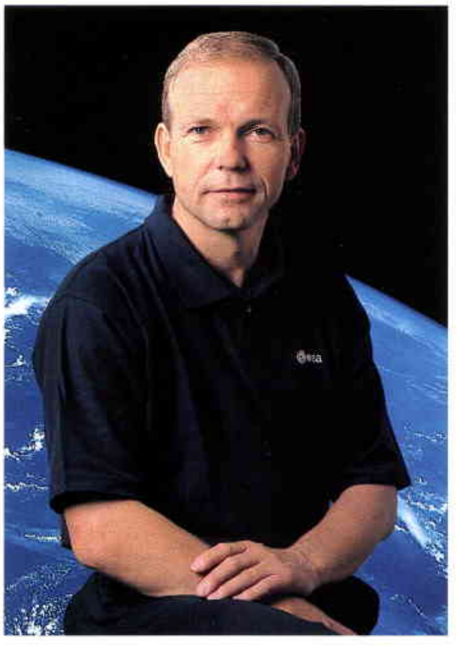
Hans Schlegel flew aboard the Space Shuttle's STS-55/D-2 mission in April-May 1993 as an astronaut of the German Aerospace Centre, DLR, and since then has trained extensively at Star City, in Russia.

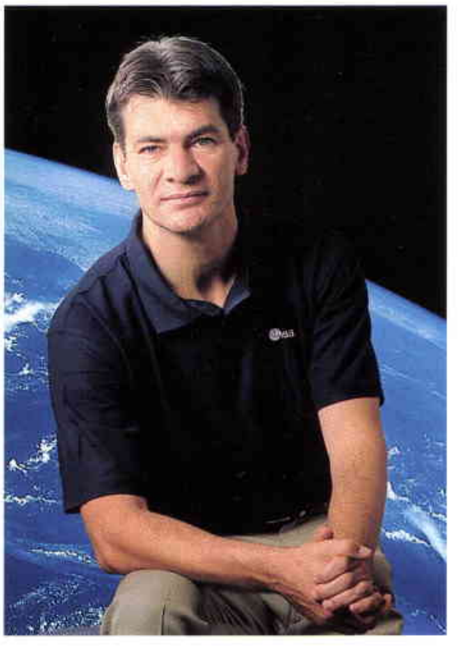
Paolo Nespoli and Roberto Vittori are both astronaut candidates selected in July by the Italian Space Agency, ASI, in cooperation with ESA. Paolo Nespoli was previously an astronaut training engineer with ESA and prepared training for the ISS, while Roberto Vittori is a major in the Italian Air Force and is specialised as a test pilot.

The first element of the ISS was launched into orbit on 20 November (see page 123 of this Bulletin). The first astronauts will move into the Station about six months after its construction begins. European astronauts will begin living and working on the Station shortly thereafter.

Left: Léopold Eyharts
Below, left to right: Roberto Vittori, Hans Schlegel and Paolo Nespoli







ESA Recruits Two New European Astronauts

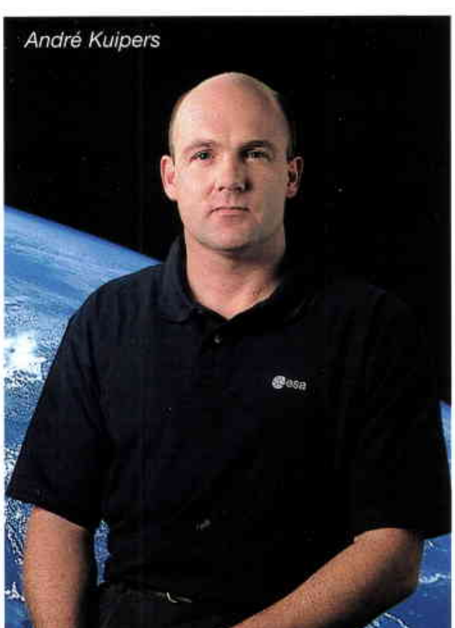
On 5 October, at Space Expo in Noordwijk (NL), ESA's Director General Antonio Rodotà, together with the Dutch Minister for Foreign Trade, Gerrit Ybema, announced the appointment of André Kuipers (NL) to the European Astronaut Corps.

On 19 October, during the opening of the Association of Space Explorers Congress, Mr Rodotà, together with the Belgian Minister for Science Policy, Yvan Ylieff, announced the appointment of Frank De Winne (B) to the Corps.

André Kuipers (aged 40), a medical doctor from Amsterdam and Frank De Winne (aged 37), a senior test pilot in the Belgian Air Force, will begin training, around mid-1999, in order to qualify for future missions aboard the International Space Station.

Kuipers is a specialist in space-related medical research. Since 1991, at ESTEC, he has participated in the preparation, data collection and ground control of physiological experiments developed by ESA for flight on the US Space Shuttle, the Russian Mir space station and, in the future, on the International Space Station. He also coordinates the life-science experiments for ESA's parabolic-flight campaigns and participates as an experimenter, test subject and flight surgeon.

Kuipers is the second Dutch astronaut. The first, Wubbo Ockels, was recruited in 1977 and flew on the Spacelab D-1 mission in 1985 on the US Space Shuttle.



André Kuipers

Frank De Winne

De Winne, a Major with 12 years of flying experience and a special interest in man-machine interfaces, has logged 2300 hours of flying time on various types of high-performance aircraft. He is currently the squadron commander of the 349th Fighter Squadron stationed at the Kleine Brogel Airbase in Belgium.

De Winne is the second Belgian astronaut. The first, Dirk Frimout, flew on the Space Shuttle's Atlas-1 (STS-45) mission in 1992.

With these nominations, ESA has completed the first phase of its creation of a single European Astronaut Corps by merging existing national astronaut programmes with the ESA programme (see ESA Bulletin 95, pages 47-53). The goal is to have a total of 16 astronauts by mid-2000 in order to meet the demand for European astronauts as the International Space Station is assembled and onboard research begins. The European Corps currently comprises 12 astronauts: Jean-François Clervoy, Léopold Eyharts, Jean-Pierre Haigneré (France); Thomas Reiter, Hans Schlegel, Gerhard Thiele (Germany); Umberto Guidoni, Paolo Nespoli, Roberto Vittori (Italy); Pedro Duque (Spain); Christer Fuglesang (Sweden); and Claude Nicollier (Switzerland). Their home base is the European Astronaut Centre in Cologne, Germany.

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113-112-111-110-109....Lift-off

Four more successful Ariane-4 launches have taken place from the ESA launch site in Kourou (French Guiana) – on 25 August (V109), 16 September (V110), 5 October (V111) and 28 October (V113) – placing six more satellites into geostationary orbit as follows:

- V109: ST-1, the first telecommunications satellite operated by Chunghwa Telecom of Taiwan and Singapore Telecom
- V110: PAS-7, an international telecommunications satellite operated by PanAmSat Corp. (US)
- V111: W2 for Eutelsat and Sinus-3 for NASB (S)
- V113: Ge-5, a US television satellite and AfriStar, a direct radio broadcast satellite for the African continent.

Flight V112 corresponds to A503, the third flight of Ariane-5 which took place on 21 October (see page 4 of this Bulletin).

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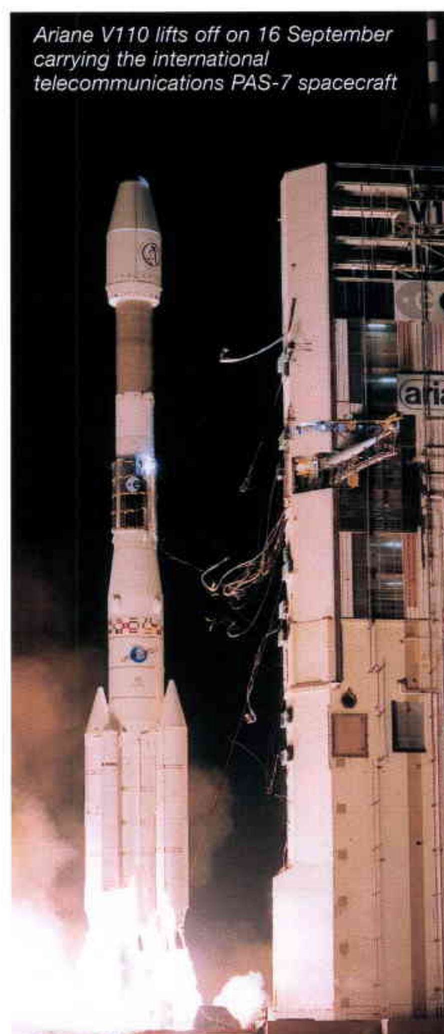
Ariane V110 lifts off on 16 September carrying the international telecommunications PAS-7 spacecraft



ESA Astronaut Awarded 'Soyuz Return Commander' Certificate

On 2 October, ESA astronaut Christer Fuglesang was awarded the 'Soyuz Return Commander' certificate at the Yuri Gagarin Cosmonaut Training Centre in Zvyozdny Gorodok (Star City), near Moscow, qualifying him to be the commander of a three-person Soyuz capsule during its return from space.

He is the second non-Russian to have earned this certificate (fellow ESA astronaut Thomas Reiter was the first, in July 1997). Moreover, Fuglesang will become the first European astronaut trained as a NASA Mission Specialist who is also able to command the Russian vehicle.

The Soyuz is used to transport astronauts to and from the Russian space station Mir. When the International Space Station (ISS) gets underway, the Soyuz will be one of two vehicles used by Station astronauts; the other is the US Space Shuttle. The Soyuz will also be the main vehicle that the astronauts onboard the ISS will use in the event on an emergency – at least one Soyuz will remain docked at all times to the Station as a 'lifeboat' in the initial years of operation.

Christer Fuglesang, of Swedish nationality, joined the European Astronaut Corps in 1992. After introductory training at ESA's European Astronaut Centre (EAC) in Cologne, Germany, and two years of intensive training in Russia, he was the "Board Engineer 2" remaining on stand-by for the joint European-Russian Euromir 95 mission.

In April 1998, he completed a two-year Mission Specialist course at NASA's Johnson Space Center, qualifying him for future Space Shuttle flights. He resumed training at the Yuri Gagarin Training Centre in Russia in June 1998 and since then has undergone some 500 additional training hours for the Soyuz Commander certificate.

New ESA Director of Application Programmes

At its 137th meeting held at ESA HQ in Paris on 21 and 22 October, the ESA Council appointed Mr Claudio Mastracci (I) as Director of Application Programmes.

Born on 30 March 1940, Mr Mastracci graduated with a degree in electronic engineering from the University of Rome in 1964. He subsequently completed a postgraduate degree in telecommunications.

In 1966 he joined Selenia (I) as a radio frequency designer in the Communication Division. In 1984 he was appointed Central Technical Director, a position he maintained when Selenia Spazio merged with Aeritalia GSS in 1990.

In 1994 he became Deputy General Manager of Alenia Aerospazio and then First Vice President of Operations in 1997.

Claudio Mastracci is presently Senior Vice President and a Member of the Management Board of the Space Division of Alenia Aerospazio, where he is in charge of strategic alliances and international cooperation, with particular regard to new initiatives, product strategy and research & development.

Mr Mastracci is expected to take up duty at ESA by 1 December 1998.

ESA at Farnborough International '98

The Agency's presence at this year's Farnborough International air and space show, from 7 to13 September, included a high-fidelity full-scale model of the Envisat environmental monitoring spacecraft, to be launched in the year 2000. The 24.8 m high, 8200 kg spacecraft is the largest environmental satellite ever built.

Once in orbit, Envisat will constantly monitor the Earth's environment, its sophisticated sensors observing the atmosphere, oceans, land surfaces, ice cover, etc., with unprecedented accuracy. In addition to helping us to achieve a much better understanding of the processes of change that are affecting on our planet, Envisat will hopefully also guide us in how we might repair some of the long-term damage already being done to our planet and how we might be able to forestall major environmental catastrophes in the future.

The importance of Earth observation from space, and of the role of ESA's Envisat mission, were highlighted in a speech made by Lord Sainsbury, the newly appointed UK Minister for Science, at the Farnborough '98 Press Conference. Extracts from Lord Sainsbury's speech are reproduced in the accompanying panel.

Earth observation was also the main topic at ESA's own Press Conference at Farnborough, on 8 September. With the theme 'Envisat and Beyond: Making the Planet a Better Place to Live', several ESA specialists gave presentations both on this programme (G. Duchossois and S. Bruzzi) and the Agency's new Living Planet Programme (D. Southwood) for the next millennium.

Right: ESA Director General, Antonio Rodotà, and Lord Sainsburry, in front of Envisat

Below, from left to right: Antonio Rodotà, Derek Davis, Director of the British National Space Centre (BNSC) and David Southwood, ESA's Head of Earth Observation Strategy

This is the first opportunity I have had to make a statement on space policy. I am very pleased to have the responsibility within Government for this important subject, which brings together research and industry. The sector is at the cutting edge of developing new technology and its uses. Even so, there is a healthy commercial market. The BNSC's survey shows UK industry turnover of £800 million and employment of 6500 people in high-grade jobs.

So, from origins in science-oriented research, space has developed into a multi-billion dollar industry. It is a truly global market in every sense. To stay in that market, British and European industry must remain competitive. The European Space Agency (ESA) has an outstanding record in establishing the industry and a European presence in space...............

I am delighted that Antonio Rodotà, the Director General of ESA, is present today to hear what I have to say. Mr Rodotà came to ESA from a career in the space industry. He therefore recognises the importance of pursuing the major business opportunities in a fast-growing market, of developing new commercial space applications to generate wealth, and of the need to be industrially competitive.

Mr Rodotà is overseeing the development of a new management approach in ESA. He will shortly be proposing a new system for Member States to monitor the Agency through performance measures. More importantly, I expect him to propose specific targets which it will be his objective to achieve against each of those measures. Coming from a commercial background myself, I find this approach perfectly natural. But I recognise that for an International Organisation to be managed on this basis is radical, and all the more welcome for that.

.........However, I do want to emphasise the positive initial steps which the Agency has (already) taken and respond to them by announcing the UK's commitment to two of the new ESA programmes to which I just referred. These are in the fields of navigation and Earth observation.

On navigation, the UK is now committing £5 million to take a 25 percent share of a programme to prepare for the next generation global satellite navigation system. ESA is working closely with the European Commission. This programme has been designed to support the Commission's negotiations at a political level with the US and with other operators of first-generation systems. It is a practical application of the EU-ESA co-operation we have sought. The UK will be equal largest contributor to this programme, along with France and Germany.

.........In the second area, Earth observation, the UK is committing £4 million and taking 20 percent of the first phase of the Living Planet programme in ESA. This programme has three main objectives: developing our knowledge of the Earth, preserving the Earth and its environment, and managing life on Earth in a more efficient way...... .The UK will be the second largest contributor to this phase of the programme, ahead of France and all other Member States apart from Germany.

In addition to these direct investments in ESA programmes, I am also announcing today a £1.65 million investment to be made here at Farnborough in a Processing and Archiving Centre, or 'PAC', to handle data from the ESA satellite Envisat. Yesterday, Mr Rodotà opened the ESA/BNSC stand, which features a full-scale model of Envisat, the environmental monitoring satellite. I hope you will take time to see it. The PAC will convert satellite data into usable form for potential customers and researchers. They in turn will process it into information and develop knowledge which will have scientific and, in many cases, commercial value...........

..... I would like to close by emphasising that space is an example of what the Government aims to achieve in its science policy generally: it creates a flow of world-class scientists and engineers; brings innovation into industry; boosts competitiveness; and leads to the development of new companies on the back of research departments.........

Lord Sainsbury
UK Minister for Science

'International Organisations and Space Law: Their Role and Contributions' – An International Colloquium

ESA and the European Centre for Space Law (ECSL) are in the process of organising the Third ECSL International Colloquium, which will be devoted to the above topic. The meeting, co-organised with the University of Perugia and the Italian National Research Council (CNR), will take place at the Palazzo Cesaroni in Perugia, Italy on 6 and 7 May 1999.

To be seen as a precursor to the UNISPACE III Conference in Vienna in July 1999, this Third ECSL International Colloquium will focus on the growing problems and policy issues faced by International Organisations involved in conducting and regulating activities in space. All of the major European players are expected to participate, including the European Union, Eumetsat, Eutelsat, Intersputnik and Eurocontrol, as well as many of the UN family of organisations, Inmarsat, Intelsat, ITU, ICAO and WIPO.

Day 1 of this unique Colloquium will cover the implementation of Space Law in the context of International Organisations, including the problems arising from the privatisation of international space organisations. Day 2 will focus on the contributions that the International Organisations themselves can make to the future development of Space Law, for example through the concluding of international Treaties and Agreements. Acknowledged experts and practitioners in Space Law will address the latest developments in the field and ample opportunity for discussion will be scheduled after each session.

Further information regarding the final programme and eventual participation in the Colloquium can be obtained from:

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8-10 rue Mario Nikis
75738 Paris Cedex 15

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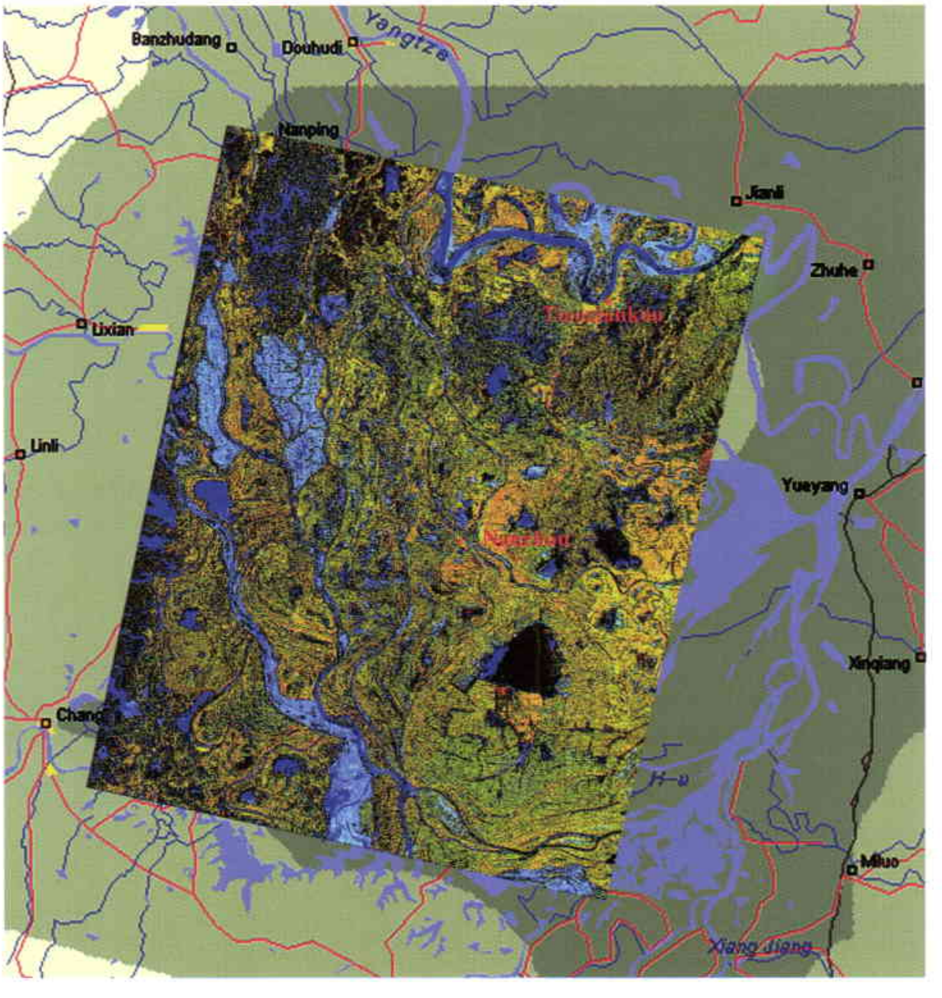
The Proceedings of the Colloquium will be published in June 1999 as ESA Special Publication SP-442, and will be available from ESA Publications Division.

Flood Monitoring in China

The quick and accurate identification and monitoring of inundated areas during severe floods is of critical importance for the minimisation of risk to human life, for the mounting of rescue operations, and for damage assessment and limitation.

ESA's Earth-observation satellites, ERS-1 and ERS-2, orbiting the Earth at an altitude of 780 km once every 100 minutes, monitor our planet day and night in all weather conditions. Their radar imagery provides invaluable help in forestalling and coping with environmental threats, as well as helping us to achieve a much better understanding of our planet as a living system.

The accompanying image shows an area located about 200 km southwest of Wuhan, one of the cities most damaged by the floods along the Yangtze River in China. The image was obtained by geocoding and superimposing an ERS SAR multi-temporal data set (processed by DLR) onto a topographic map of the area. The ERS data used for the multi-temporal image were acquired by Ulan Bator ground station on 9 June 1993 (reference frame) and 1 August 1998 (during the flood event). Flooded zones are shown in light blue tones. Areas normally covered by water such as lakes, artificial basins and swamps are visible in dark blue or black.



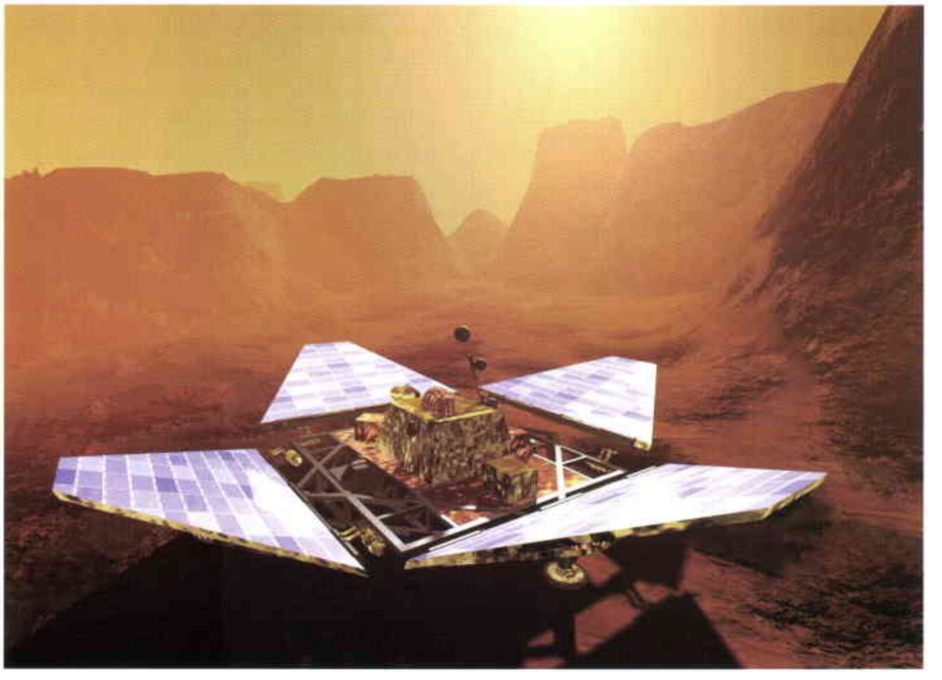
ERS-2 multi-temporal image showing extensive flooding along the Yangtze River in China (ESA image processed by DLR)

'Mars Express' Wins Unanimous Support

All fourteen national delegations in ESA's Science Programme Committee have backed the project to send a spacecraft to Mars in 2003. Support for Mars Express, as this exciting mission is called, is qualified by concern about the long-term budget of ESA's Science Programme. At its meeting in Paris on 2 and 3 November, the Science Programme Committee made its approval of the implementation of Mars Express conditional on sufficient funding for the Science Programme and no impact on previously approved projects.

"*The green light for Mars Express shows that Europe is perfectly capable of seizing special chances in exploring space,*" said Roger Bonnet, ESA's Director of Science. "*At a cost to ESA of 150 million ECU, Mars Express is the cheapest Mars mission ever, yet its importance and originality are far greater than the price tag suggests.*"

Roger Bonnet continued, "*Mars Express has been advertised by the Science Programme Committee as a test case for new approaches in procuring and managing future science projects, with a view to achieving major savings. In the international arena, Mars Express will confirm Europe's interest in a major target for space research in the new century, when we make our forceful debut at the Red Planet. In fact, Mars Express is designed to be a pivotal element of an international multi-mission, global effort for the exploration of Mars.*"



Development of the spacecraft will now proceed swiftly, to meet the deadline of an exceptionally favourable launch window early in June 2003. Mars Express will go into orbit around Mars at Christmas 2003.

Seven scientific instruments on board will include a high-resolution camera, a range of spectrometers, and a radar to penetrate the Martian surface. For the first time in the history of the exploration of the Red Planet, scientists can hope to detect sub-surface water, whether it exists in the form of underground rivers, pools, glaciers or permafrost.

Signs of life on Mars, whether extinct or continuing today, may reveal themselves to a lander carried by Mars Express. This is Beagle 2, a project led by the Open University in the United Kingdom, with contributions from many other European countries. The lander also promises invaluable information about the chemistry of the Martian surface and atmosphere. Beagle 2 is to be independently funded. Some of the necessary funds have already been raised and ESA has agreed with the principal investigator to keep a place for Beagle 2 aboard Mars Express. The financial situation will be verified at a date to be agreed with the mission's prime contractor.

For more details about the mission visit the Mars Express web site at: http://sci.esa.int/marsexpress/ esa

SOHO Gets Back to Work!

Brilliant new pictures of the Sun from ESA's Solar and Heliospheric Observatory (SOHO) show that its ordeal since contact was lost in June has come to a happy ending. The last of the 12 scientific instruments once again began routinely sending back data in November, completing the long saga of recovery.

Roger Bonnet, ESA's Director of Science commented, "*Scientists on both sides of the Atlantic have waited anxiously for the recovery of SOHO. Thanks to the extraordinary determination and skill of ESA and NASA personnel, with industrial contractors and scientific teams also playing their part, the world has recovered its chief watchdog on the Sun. SOHO is needed more than ever, because the Sun is rapidly becoming stormier with a mounting count of sunspots.*"

Following launch on 2 December 1995, SOHO revolutionised solar science by its special ability to observe simultaneously the interior and atmosphere of the Sun, and particles in the solar wind and the Sun's outer atmosphere. It had returned about two million images when, on 25 June 1998, during routine maintenance operations, ground controllers at NASA Goddard Space Flight Center in Maryland, USA lost contact and the spacecraft went into Emergency Sun Reacquisition mode.

The immediate efforts to re-establish nominal operations did not succeed and telemetry was lost. A joint team was formed at NASA Goddard under the direction of ESA's Francis Vandenbussche, the ex-SOHO System Engineering Manager. The team comprised ESA, Matra Marconi Space (spacecraft prime contractor), NASA and Allied Signal staff.

Bistatic radar measurements by the 300 m Arecibo antenna and a 70 m dish of NASA's Deep Space Network (DSN) on 23 July found that SOHO was still in its nominal halo orbit, near the L1 Lagrangian point, and turning at roughly one revolution per minute.

Contact was re-established with SOHO on 3 August following 6 weeks of silence. Signals sent through the DSN station at Canberra, Australia, were answered at 22:51 UT in the form of bursts of carrier signal lasting from 2 s to 10 s. These signals were recorded both by the NASA station and the ESA Perth station.

Command sequences were uplinked to divert the available solar array power into a partial charging of one of the onboard batteries. After 10 h of charging, the telemetry was commanded on and seven full sets of telemetry frames giving the spacecraft's status were received on 8 August at 23:15 UT. Further onboard information was obtained the following day in two subsequent telemetry acquisitions lasting 4 min and 5 min. Data gathered included information on the temperature of the scientific instruments.

After both batteries were fully charged, thawing of the hydrazine fuel in the tank was started on 12 August at 22:39 UT. It was interrupted several times during the week in order to recharge the batteries, necessary because the power data revealed a slightly negative power balance.

Thawing of the hydrazine in the tank was completed on 28 August after 275 h of heating. After 36 h of recharging the batteries, heating of the first of four fuel pipe sections connecting the tank to the thrusters began at 12:30 UT on 30 August.

On 31 August, the SOHO Mission Interruption Joint ESA/NASA Investigation Board released its final report (http://sohowww.estec. esa.nl/ whatsnew/SOHO_final_report.html). It concluded that the chain of events leading to the loss of contact described in its preliminary report was correct, and it recommended, in order to prevent similar mishaps in the future, that ESA and NASA review and correct the spacecraft ground procedures, the procedure implementation, the management structure and process, and the ground systems. No fault on the spacecraft contributed to the mishap.

As the fuel pipes were slowly thawing, attitude recovery was planned beginning in early September. Owing to the precarious power balance, it took until 10 September to thaw one of the two redundant branches of the fuel pipes. After this, the batteries were recharged and the propulsion system temperature was maintained in preparation for the attitude recovery manoeuvre.

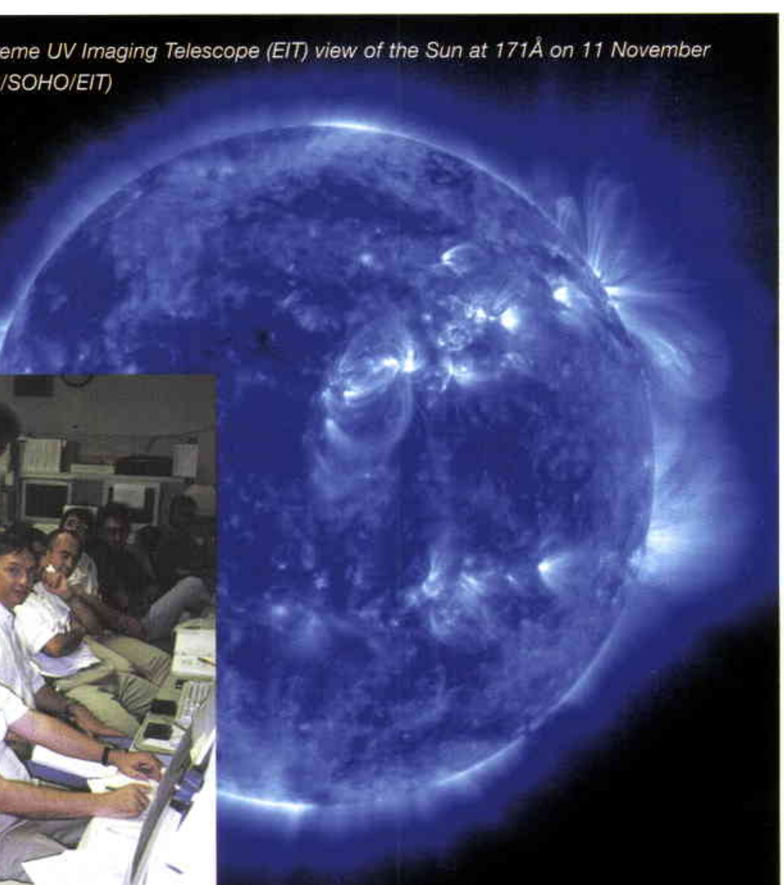
The verification of the procedures for attitude recovery was completed on 14 September and a rehearsal of the attitude recovery manoeuvre was carried out the next day.

Finally, on 16 September, the first but important step in the full recovery of SOHO was successfully completed. Sun pointing (without roll control) was achieved at 18:30 UT, after a gradual despin of the spacecraft followed by a planned Emergency Sun Reacquisition. All operations went according to plan. The experiment substitution heaters were switched on 42 min after the ESR was triggered.

After a busy week of recommissioning activities for the various spacecraft subsystems and an orbit correction manoeuvre, SOHO was finally brought back to normal mode on 25 September at 19:52:58 UT.

Instrument switch-on began on 5 October 1998 with the SUMER instrument, followed by VIRGO on 6 October, GOLF on 7 October, COSTEP and ERNE on 9 October, UVCS on 10 October, MDI on 12 October, LASCO and EIT on 13 October, CDS on 17 October, SWAN on 18 October and CELIAS on 24 October. No signs of damage due to thermal stress during the deep freeze were detected. With SUMER completing its recommissioning on 4 November, all 12 science instruments were back to normal. A diary account of the recovery can be found at:
http://sohowww.nascom.nasa.gov/ operations/Recovery/updates.html

Further SOHO information, including links to the latest images, can be found at:
http://sci.esa.int/missions/soho/ esa



SOHO Extreme UV Imaging Telescope (EIT) view of the Sun at 171Å on 11 November 1998. (ESA/SOHO/EIT)

SOHO ground controllers work towards regaining Sun pointing on 16 September. Recovery team leader Francis Vandenbussche is seated second from the left

Integral Space Observatory Presented to the Media

On 22 September, media representatives were given a unique opportunity to inspect the full-size Structural Thermal Model of ESA's International Gamma-Ray Astrophysics Laboratory (Integral), in the Agency's Test Centre at ESTEC in Noordwijk (NL). Journalists, photographers and television crews were invited by the Agency to view the 5 m-high spacecraft, which weighs more than 4 tons. To be launched from Baikonur in 2001 on a Russian Proton vehicle, Integral has been designed to help scientists to decipher the processes of the Universe's alchemy which fabricate the elements of stars and galaxies, as well as the end points of stellar life.

The industrial Prime Contractor for the Integral spacecraft is Italy's Alenia Aerospazio in Turin. The Principal Investigators responsible for the provision of the scientific instruments to be flown and for the scientific data's pre-processing and distribution are listed below (box).

Why gamma-ray astronomy from space?

Being a million times more energetic than visible light, gamma-rays are the most powerful form of electromagnetic radiation known. Consequently, gamma-ray astronomy can be used to explore the most energetic phenomena occurring in nature and to address some of the most fundamental problems in physics. It can provide us with novel information about the stupendous physical events that made the Universe habitable. We now know, for instance, that most of the chemical elements in our bodies come from long-dead stars, but how were these elements formed?

However, gamma-rays cannot be detected from the ground because the Earth's atmosphere shields us from such high-energy radiation. Space technology provides the answer by allowing observatories like Integral to operate from outside the Earth's radiation belts, at an orbital altitude of more than 40 000 km.

One of the Integral mission's most important scientific objectives will be to study such compact objects as neutron stars or black holes. Besides stellar black holes, there may exist much bigger specimens of these extremely dense objects. Most astronomers believe that in the heart of our Milky Way, as in the centres of other galaxies, there may lurk giant black holes. Integral should be able to find evidence of these exotic objects.

Even stranger than the energetic radiation coming from the centres of distant galaxies are flashes of extremely powerful radiation that suddenly appear somewhere in the gamma-sky and disappear again a short time later. These gamma-bursts seem to be the biggest observed explosions in the Universe, but nobody yet knows their source. Integral will help to solve this long-standing mystery also.

ESA, the pioneer in gamma-ray astronomy

ESA pioneered gamma-ray astronomy in space with its Cos-B satellite, launched in 1975. Both Russia and the United States subsequently followed ESA's lead, with the Soviet's Granat (in 1989) and NASA's Compton GRO (in 1991), respectively. Integral will keep Europe in the forefront of this exciting area of science.

Integral carries two primary scientific instruments: an Imager, which will provide the sharpest gamma-ray images yet of distant objects by exploiting so-called 'coded-mask' technology, and a Spectrometer, which will be able to gauge gamma-ray energies extremely precisely. The latter, designed to operate at a temperature of -188°C, will be 100 times more sensitive than the previous highest-spectral-resolution space instrument.

These two primary instruments will be supported by two monitoring instruments that will play a crucial role in the detection and identification of the gamma-ray sources. An X-Ray Monitor will observe X-rays, which are still extremely powerful but less energetic than gamma-rays, while an Optical Monitoring Camera (telescope) will observe the visible light emitted by the various energetic objects.

The Integral Science Data Centre, which will pre-process and distribute the scientific data from this unique mission, will be sited in Switzerland.

Imager	P. Ubertini (IAS, Frascati, Italy)
Spectrometer:	G. Vedrenne (CESR, Toulouse, France)
	V. Schoenfelder (MPE, Garching, Germany)
X-Ray Monitor:	N. Lund (DSRI, Copenhagen, Denmark)
Optical Monitoring Camera:	A. Gimenez (INTA, Madrid, Spain)
Integral Science Data Centre:	T. Courvoisier (Genova Observatory, Switzerland).

Research Using Earth Observation in the 21st Century – A New Report

A newly issued Agency publication, ESA SP-1227, entitled *'Earth Explorers - The Science and Research Elements of ESA's Living Planet Programme'*, presents the plans for the Earth Explorer element of the European Space Agency's new *'Living Planet'* Programme for Earth Observation. *Living Planet* marks a new era for European Earth Observation based on smaller, more focussed missions and a programme that will be user-driven. The users envisaged for the Earth Explorer spacecraft are the Earth Science community in Europe, a community that has cut its teeth on the big multi-user spacecraft ERS-1 and ERS-2 and now looks forward to Envisat's launch in 2000. This community will now be able to look forward to a programme of more frequent, but smaller and more focussed missions directed at the fundamental problems of Earth system science.

The research objectives for the Earth Explorer missions (Part A of SP-1227) have been drafted by the ESA Earth Science Advisory Committee (ESAC), chaired by Prof. G. Mégie, supported by members of the ESA Executive. The programme grows out of European scientific heritage in Earth Observation, as exemplified by the Meteosat, Spot and ERS satellites. All of these, in their different ways, were trail blazers and have established European competence. The tradition continues with the missions currently under construction, namely Meteosat Second Generation, Metop and Envisat.

Part B of SP-1227 describes the implementational and financial aspects of the Earth Explorer missions.

The Agency's overall strategy for Earth Observation in the coming decade was endorsed by the ESA Council in March 1998. The *Living Planet Programme* follows on from Envisat, which is to be launched early in 2000. It is intended to cover the whole spectrum of user interests, ranging from scientific research through to applications. The research-driven Earth Explorer missions will be paralleled by applications-driven Earth Watch missions, designed to focus on specific Earth Observation applications and service provision.

In the long run, Earth Watches are expected to become free-standing services outside the Agency. The *Living Planet Programme* also covers exploitation and technological development elements whose purpose is to underpin market development and ensure cost-efficient implementation both of Earth Explorer and Earth Watch spacecraft.

The plan described in SP-1227 has been drawn up following extensive consultation with the Earth Observation community in the ESA Member States (as well as Canada, which has long closely co-operated with ESA in Earth Observation). It is intended to reflect not only their ideas and aspirations but also to be a response to concerns about climate change and man's impact on it. Many of the areas identified in the programme directly relate to the work of the Intergovernmental Panel on Climate Change (IPCC) which was established, under the auspices of the United Nations, to advise governments on the state of knowledge of climate change and its implications.

Furthermore, the proposed work has to be seen as underpinning European interests in monitoring the Earth and its environment. This reflects not only Europe's role in defining, monitoring and verifying international conventions made in response to global concerns, but also its role in providing the information needed to better understand and manage the environment at the regional and European level. In this regard the Agency has remained in close touch with both the European Commission (EC) and the European Organisation for the Exploitation of Meteorological Satellites (Eumetsat) in all its planning for the new programme.

Copies of ESA SP-1227 are available (price 50 DFl) from the ESA Publications Division Bookshop:

Tel. (31) 71 5653405
Fax. (31) 71 5655433
E-mail: fdezwaan@estec.esa.nl

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First Spanish Astronaut Rides into Orbit

The Space Shuttle Discovery performed a perfect lift-off on Thursday 29 October, carrying ESA astronaut Pedro Duque among its international 7-member crew, including space pioneer John Glenn who made his return to space 36 years after he became the first American to orbit the Earth.

Glenn is not the only member of this crew to go into the record books. Duque does too, as the first Spaniard to travel into space. Born in March 1963, over a year after John Glenn's epic flight, he was also the youngest member of the crew.

"For me it is a great honour not only to represent my own nation and the rest of Europe, but also to have the privilege of working alongside John Glenn."

"I'm looking forward to the flight itself, experiencing life in microgravity and being able to look down on the Earth. It is a great adventure but it will also be a time of intense hard work and activity," said Duque during a pre-launch interview.

"We're learning a lot about international cooperation and this will be a final check for some of the ESA science facilities to make sure they and the ground teams will work efficiently on the International Space Station," he added.

Duque was cheered on his way by thousands of spectators at the launch site, including his wife and three young children.

Astronauts Pedro Duque (left) and Steven W. Lindsey take a break from busy experimentation onboard the Space Shuttle Discovery during Flight Day 7.

During the launch phase, Duque monitored the overall performance of Discovery and its systems, looking out for any anomalies or malfunctions. On reaching orbit, his responsibilities included working with the team that deployed the communications antennas and opened Discovery's payload bay doors to let surplus heat out of the Shuttle into space.

Duque's tasks during the nine-day flight included supervising five advanced scientific experiment facilities installed in the Spacehab module, located in the payload bay. Scientists from eight European countries – Belgium, France, Germany, Italy, Spain, Sweden, Switzerland and the United Kingdom – had experiments on the flight to study the effects of weightlessness on various materials and substances.

"The ESA facilities are advanced and largely automatic, so it was more a question of periodic checks and ensuring that data was routed to the correct place," said Duque. *"This kind of operation is typical of what work will be like on the International Space Station, where crew time will be at a premium."*

Duque was also the mission's laptop troubleshooter. He looked after a record number of 19 laptop computers being carried by Discovery to help run the Shuttle's systems and the experiments.

The day after the international crew's safe landing at the KSC Shuttle Landing Facility on 7 November, Flight Commander Curtis L. Brown Jr. told press that Pedro Duque had done an excellent job during the mission and that he was a 'natural' in adapting to Shuttle working and living conditions.

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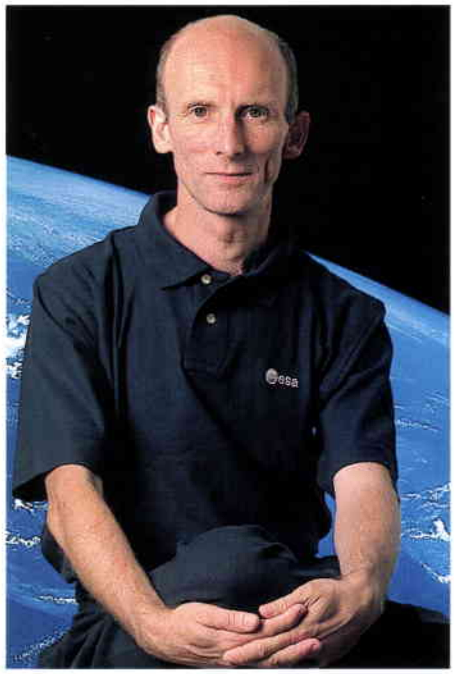
The international Shuttle crew takes a break from its training schedule to pose for the STS-95 pre-flight portrait. Seated are astronauts Curtis L. Brown Jr. (right), mission commander; and Steven W. Lindsey, pilot. Standing, from the left, are Scott F. Parazynski and Stephen K. Robinson, mission specialists; Chiaki Mukai, payload specialist representing Japan's National Space Development Agency (NASDA); Pedro Duque, mission specialist representing ESA; and US Sen. John H. Glenn Jr., payload specialist.

European Astronaut Assigned First Shuttle Flight

ESA and the German Aerospace Centre (DLR) have announced the assignment of Gerhard Thiele (D), as Mission Specialist on Shuttle flight STS-99. The Shuttle Radar Topography Mission (X-SAR/ SRTM), dedicated to the ecological mapping of the Earth's surface, is scheduled for September 1999.

Gerhard Thiele, a physicist, was trained as a Payload Specialist by DLR and was a member of the German D-2 flight back-up crew, in which he was responsible for communications between the astronauts onboard the Space Shuttle Columbia and the scientists in the Control Centre at Oberpfaffenhofen, Germany. He has since started Mission Specialist training at NASA-JSC to qualify him for missions on the Space Shuttle and the International Space Station. This will be his first Shuttle flight.

For the SRTM mission, the Shuttle will have a complex arrangement of radar systems onboard, including a high-tech instrument made in Germany. The mission's objective is to create a three-dimensional image of the Earth. For the first time, the planet's surface will be simultaneously scanned from two different perspectives. Opening the cargo bay will bring the planet into the sights of a 12-metre radar antenna and a second system, mounted on a 60-metre telescopic arm. With this configuration, a great technological challenge, the Earth will be viewed by two "radar eyes" simultaneously. Both radar systems can receive the returning signal in more or less "stereo" mode, which is the mission's prime innovation.



Gerhard Thiele has been selected as Mission Specialist on STS-99 due to be launched in September 1999

Topographic surveying of the Earth supplies crucial basic data to solve many problems in the areas of geoscience and environmental protection. Radar is ideally suited for remote sensing, with two decisive advantages over conventional optical procedures: radar can "see" both at night and through cloud cover, so that a complete survey of the Earth's surface can be made in just a few days.

Topographic data and digital surface models obtained from the Shuttle Radar Topography Mission will pave the way for a wealth of applications. Digital altitude records will serve to improve processed products based on data delivered by other European environmental monitoring satellites and are a prerequisite for extremely precise cartographic products. Records of this kind can also be helpful in the extension of cellular telephone networks, above all in identifying optimum locations for transmitting masts.

Finally, disaster control management (e.g. in the case of flooding) also depends on such data for information on the situation in the areas affected. Weather forecasting and climate modelling will also benefit from exact topographic data.

The six astronauts onboard the Shuttle will have the difficult task of precisely extending the telescopic mast and aligning it with the antenna. They will also control the data recordings, a volume of almost 3000 Gb, that will provide an almost complete survey of the Earth's surface.

SRTM is a joint project of NASA, NIMA (National Image and Mapping Agency), DLR (German Aerospace Centre) and ASI (Italian Space Agency). NASA's Jet Propulsion Laboratory (JPL) is responsible for the development of the C-Band Radar Interferometer System, DLR for development of the X-Band Radar System. Dornier Satellite System, a subsidiary of Daimler-Benz Aerospace (Dasa, Munich), is the main industrial contractor for development of the X-SAR radar system. esa

A New Look for ESA's Space Science Web Site

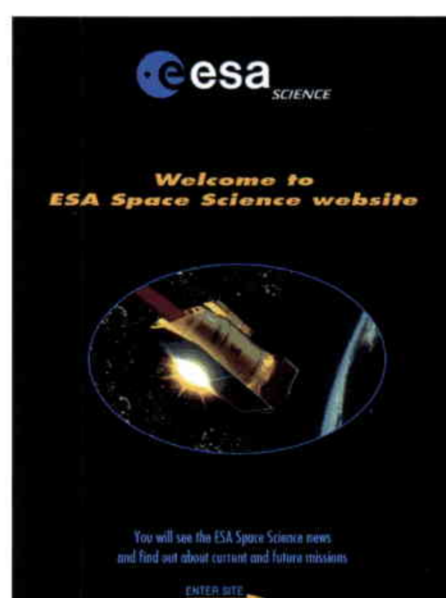
http://sci.esa.int/

This web site is a key part of the ESA Science Directorate's outreach policy. The role of the site is to promote ESA's space science missions, their scientific benefits and latest findings. It also aims to encourage interest and participation from scientists, industry, the media and the public. During the coming months, the look and tone of the site is set to change and what you see now is just the start of this transformation.

Part of the task is to make the site easier for people to use, helping them to learn more about ESA's work. The news and images are presented in a fresh, bold and consistent style, giving even the most unscientific of users a feel for the latest discoveries in space science.

From this web site, you can obtain information on:

- satellites in orbit: Hubble Space Telescope (HST), Ulysses, Infrared Space Observatory (ISO), Solar and Heliospheric Observatory (SOHO), Cassini/Huygens
- satellites under development: XMM, Cluster-II, Integral, Rosetta, First/Planck
- future Cornerstone studies: GAIA, IRSI, Lisa, Mercury Orbiter. esa



The History of the European Space Agency – An International Symposium

This Symposium, which was co-organised by ESA and the Science Museum in London (11-13 November), brought together some of the leading personalities from European governments, industry and the academic world who have made significant contributions over the years to the development of the European space programme. Many of the speakers addressed the context in which the key developments took place and all of the major policies and programmes undertaken by the Agency and its predecessors (ESRO and ELDO) since the sixties. Speakers included former Government Ministers such as Mr Michael Heseltine of the United Kingdom, Mr Hubert Curien of France, and Mr Antonio Ruberti of Italy.

Speaking at the Science Museum during the opening of the Symposium, UK Science Minister Lord Sainsbury of Turville noted that *"a sense of history is important for any organisation: it both binds members together and helps to identify where we are heading.... The key role that ESA has played since its inception in 1975, and above all its ability to adapt to changing circumstances, stand the Agency in good stead to play a key role in this future".*

ESA's Director General, Antonio Rodotà, pointed out that historically European space cooperation had often been accompanied by uncertainty, yet Europe's space programme continued to be pursued with a large measure of success. *"Projects such as Ariane have come to symbolise the value of excellence and of true European collaboration in high technology. The latest example is the flawless final qualification flight of Ariane-5 on 21 October,"* he said. Mr Rodotà also made the point that the European space programme can make a major contribution to improving Europe's competitiveness and economic performance on the world stage, whilst also contributing to British Prime Minister Tony Blair's vision of a 'people's Europe'. *"We need to convince Europeans that they have reason to be proud of themselves and of what they can achieve through the pooling of their talents and resources"*, Mr Rodotà said.

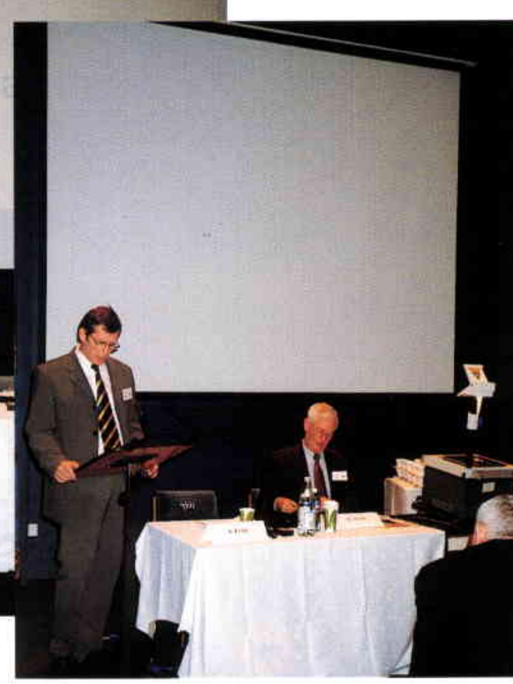
Also speaking during the Symposium's Opening Session, Sir Neil Cossons, Director of the Science Museum, spoke of the importance of space both to the Museum's visitors and to its research community. *"Space is the most popular topic of science amongst our visitors"*, he said, and *"Understanding the history of the European Space Programme is vital to our presentation of achievements and aspirations in space exploration".*

During an enthusiastically received after-dinner speech during the Symposium,

Mr Karl-Egon Reuter, ESA's Head of Cabinet and organiser of the Symposium, giving his introduction

Mr Michael Heseltine, former UK Government Minister

Mr Peter Creola, Head of the Swiss Delegation to ESA and Chairman of ESA's Long-Term Space Policy Committee (LSPC)



Mr John Krige, leader of the ESA History Project, and Dr Hermann Strub (seated) former ESA Council Delegate one of Europe's foremost space advocates and pioneers Sir Hermann Bondi, Director General of ESRO from 1967 to 1971, also emphasised the importance of communication as a key to successful cooperative endeavours in space, or indeed in any other major undertaking.

The London Symposium represented the culmination of the ESA History Project, which has for the past eight years researched the history of European space initiatives between 1964 and 1987. The Symposium Proceedings will be published at the end of the year by ESA Publications Division, as ESA Special Publication SP-436. The history of ESA and its numerous programmes and projects is documented in a series of 23 individual History Reports (two more are currently in preparation) produced by the ESA History Team (John Krige, Arturo Russo and Lorenza Sebesta), which have also been published by and are available from ESA Publications Division. There is also a hard-bound monograph available which documents the earliest history of European endeavours in space, titled 'Europe in Space, 1960 – 1973' (ESA SP-1172). esa

Reports in the ESA History Series

HSR-#	Date	Title	Author
1	July 1992	The Prehistory of ESRO 1959/60	J. Krige
2	October 1992	ESRO's First Scientific Satellite Programme 1961-1966	A. Russo
3	November 1992	Choosing ESRO's First Scientific Satellites	A. Russo
4	January 1993	The Early Activities of the COPERS and the Drafting of the ESRO Convention (1961/62)	J. Krige
5	March 1993	Europe in Space: Edoardo Amaldi and the Inception of ESRO	M. de Maria
6	March 1993	The Definition of a Scientific Policy: ESRO's Satellite Programme in 1969 – 1973	A. Russo
7	March 1993	The Launch of ELDO	J. Krige
8	May 1993	Europe into Space: The Auger Years (1959 - 1967)	J. Krige
9	May 1993	The Early Development of the Telecommunications Satellite Programme in ESRO (1965 - 1971)	A. Russo
10	September 1993	The History of ELDO Part 1: 1961 - 1964	M. de Maria
11	January 1994	Reflections on Europe in Space	J. Krige & A. Russo
12	January 1994	The Origins of the Federal Republic of Germany's Space Policy 1959 - 1965 — European and National Dimensions	P. Fischer
13	February 1994	ESRO's Telecommunications Programme and the OTS Project (1970 - 1974)	A. Russo
14	July 1994	United States - European Cooperation in Space During the Sixties	L. Sebesta
15	February 1995	United States - European Cooperation in the Post-Apollo Programme	L. Sebesta
16	February 1995	The Scientific Programme Between ESRO and ESA: Choosing New Projects (1973 - 1977)	A. Russo
17	February 1996	The Aeronautical Satellite System: An Example of International Bargaining	L. Sebesta
18	September 1996	The Availability of European Launchers and Europe's Decision 'To Go It Alone'	L. Sebesta
19	August 1997	Big Technology, Little Science The European Use of Spacelab	A. Russo
20	September 1997	The Definition of ESA's Scientific Programme for the 1980's	A. Russo
21	October 1997	Spacelab in Context	L. Sebesta
22	March 1998	The European Meteorological Satellite Programme	J. Krige
23	September 1998	The Third Phase of the Telecommunications Programme ECS, Marecs and Olympus	A. Russo

Dawn of the International Space Station

The first module for the new International Space Station was successfully launched at 06:40 UT on 20 November aboard a Russian Proton rocket from the Baikonur Cosmodrome in Kazakhstan. The rocket blasted off under overcast skies and strong winds, and disappeared behind the clouds within 40 seconds.

The 12 m-long Zarya module reached orbit less than 10 minutes after liftoff. It will provide propulsion, power and communications during the early stages of station assembly. When completed in 2004, the complex will be the largest-ever structure in space, stretching over 100 m and spanning an area the size of a football field.

ESA Director-General Antonio Rodotà, who watched the launch at Baikonur, said, *"This is the largest technological project to be undertaken jointly by the nations of the world in the history of mankind. For Europe, it is the start of an exciting new era in space exploration."*

The International Space Station will serve as an orbital home for astronauts and cosmonauts for at least 15 years. As one of five international partners (together with the United States, Russia, Japan and Canada), ESA is contributing two major elements: the Columbus laboratory and the Automated Transfer Vehicle.

Europe will take part in 19 of the 45 flights planned during the 5-year assembly phase and is also supplying scientific and technical equipment to NASA and the Russian Space Agency. Once the Station is in operation, European astronauts will be regular visitors.

At the time of going to press, NASA's Space Shuttle was planned for launch on 3 December carrying the Station's second element: the 'Unity' Node-1. Attached to Zarya, this will serve as the central building block for the Station.

On the day of Zarya's launch, ESA announced that it has begun soliciting microgravity research proposals in physical sciences and biotechnology to be conducted on the Station.

"The foundation stone for this unique international research and test centre in space has been laid today. Now it is important that Europe's best scientists and engineers make good use of it," declared ESA Director of Manned Spaceflight and Microgravity, Jörg Feustel-Büechl. He explained that, *"besides fundamental research, scientists are encouraged to consider projects that have industrial applications perspectives, and researchers from European industry are particularly welcome to apply."*

The new Announcement of Opportunity for Microgravity Research Programmes and related Applications in Physical Sciences and Biotechnology is available on the Internet at :

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Zarya's launch has inaugurated the 5-year construction phase of the International Space Station (ESA/D. Ducros)

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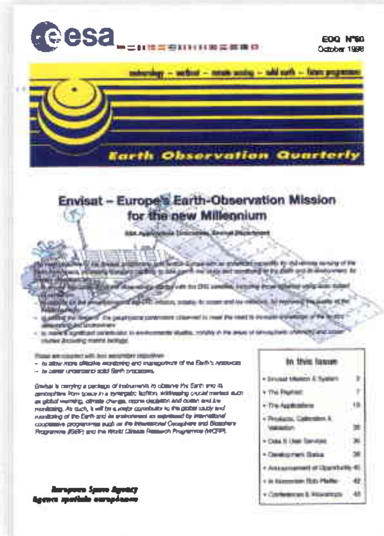

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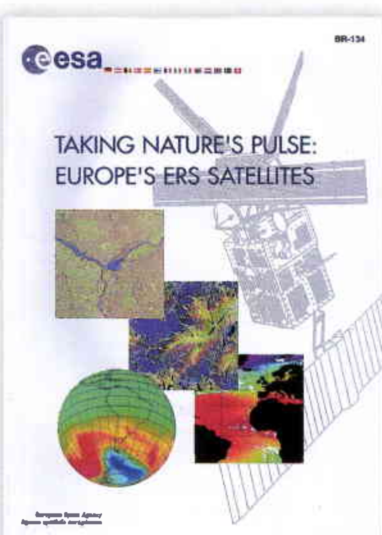

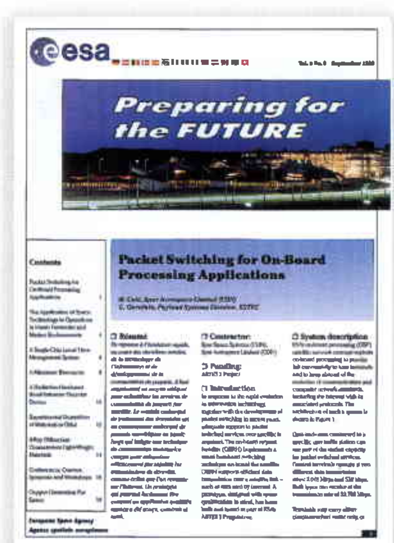

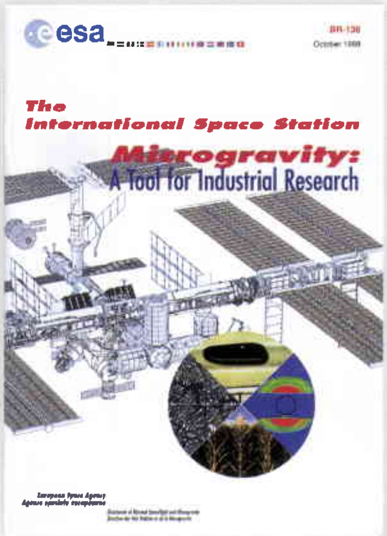

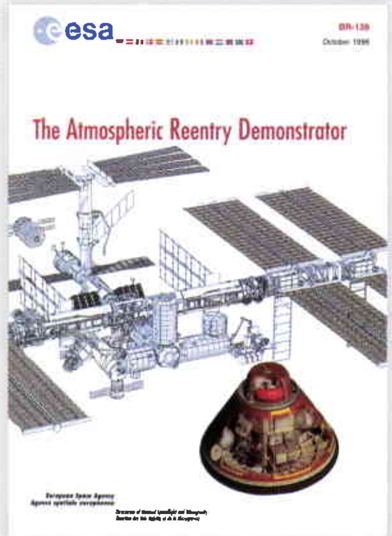

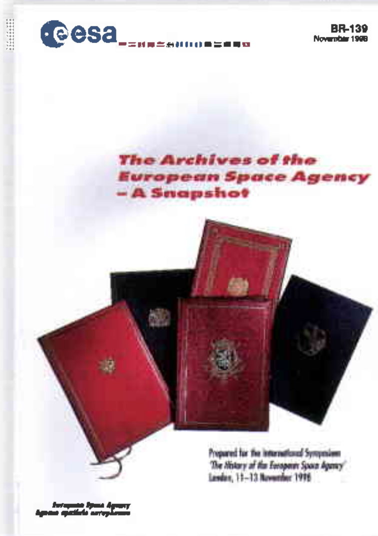

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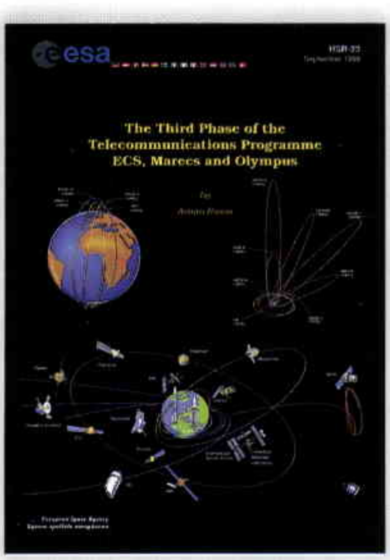

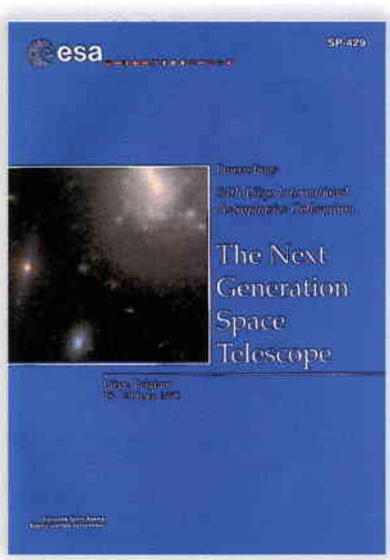

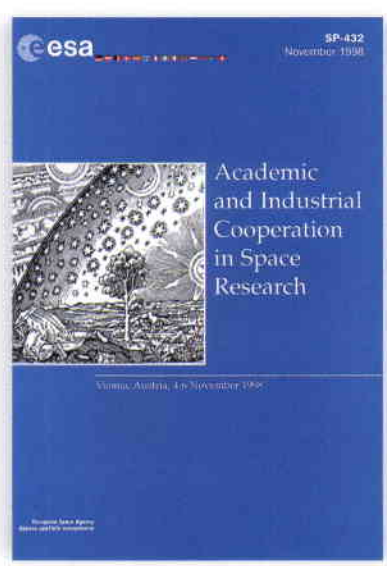

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