esa

number 17, august 2004

on station

The Newsletter of the Directorate of Human Spaceflight http://www.esa.int/spaceflight

in this issue

European Space Agency
Agence spatiale européenne

Directorate of Human Spaceflight
Direction des Vols Habité

ESTEC Hosts ISS Heads of Agencies

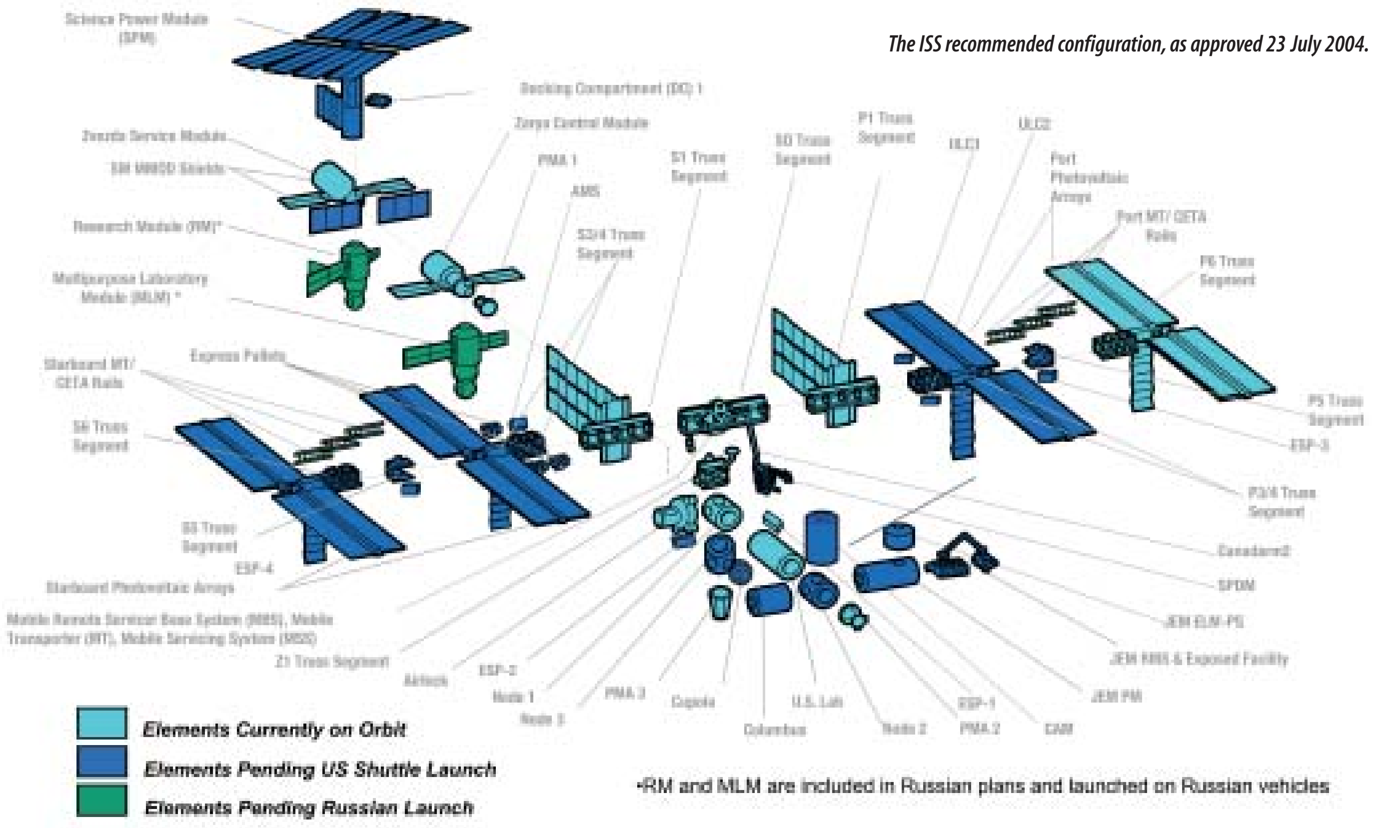
Jörg Feustel-Büechl
ESA Director of Human Spaceflight

On 23 July, just days before this issue of *On Station* went to press, an ISS Heads of Agencies meeting was held at ESTEC to discuss important Station issues. These included the Space Shuttle's Return to Flight, the overall situation of the Station, the positions of the individual Partner programmes and, finally, the latest report of the Multilateral Control Board (MCB). ESA was represented by Jean-Jacques Dordain, NASA by Sean O'Keefe, the Canadian Space Agency by Marc Garneau, the Russian Federal Space Agency by Anatolii Perminov and Japan's JAXA by Kaoru Mamiya.

The Heads of Agencies received a very thorough briefing from all five ISS Partners. NASA is making a major effort this year – reflected in the budget of around $4 billion, and approximately the same next year – in getting the Shuttle back into service. Of the 15 actions recommended by the independent *Columbia* investigation team and the 10 self-imposed actions, most are well underway and some have been completed, while the most difficult, on-orbit inspection tools, are still being worked on.

NASA currently plans for the Shuttle to return to flight in March 2005, but with a possibility of a 1-2 week delay. We are very satisfied with this progress, which allows us to continue the planning for our own Station elements.

The Heads of Agencies received an update on ISS operations and were pleased to see that, despite the Station crewing limitation of only two astronauts, there are no major onboard problems. Quite the opposite, in fact: all the critical consumables are in good condition, all critical systems are performing normally and the logistics requirements are being staisfied with two Soyuz and four Progress flights per year. We recently saw an EVA having to be abandoned soon after it began, but it was recently successfully completed, and further spacewalks are planned in August and September. All in all,



The ISS recommended configuration, as approved 23 July 2004.

the Station is in good shape despite the circumstances under which it is being assembled.

MCB Report

The most important part of the Heads of Agencies meeting was the review and agreement on the MCB report. This summarised the proposed Station final configuration as well as proposing a Program Action Plan (PAP). The PAP was essentially placed on hold following the *Columbia* accident in February 2003. The Heads of Agencies endorsed the Station final configuration and approved the PAP. The diagram above shows this configuration.

The configuration is essentially as planned before the Shuttle tragedy. On the NASA side, the US Habitation Module and the Crew Return Vehicle (CRV) have been deleted. For the Russians, two Soyuz taxi and rescue spacecraft will be attached to the Station. Pleasingly, Russia has reintroduced two modules – the Research Module (RM) and the Multipurpose Laboratory Module (MLM). These additions may provide an opportunity for ESA's European Robotic Arm (ERA) from around 2007. As a consequence of adding these two modules, Russia foresees reducing its 2005 logistics resupply flights by half in order to support module development. The effect upon ESA's utilisation planning remains to be assessed.

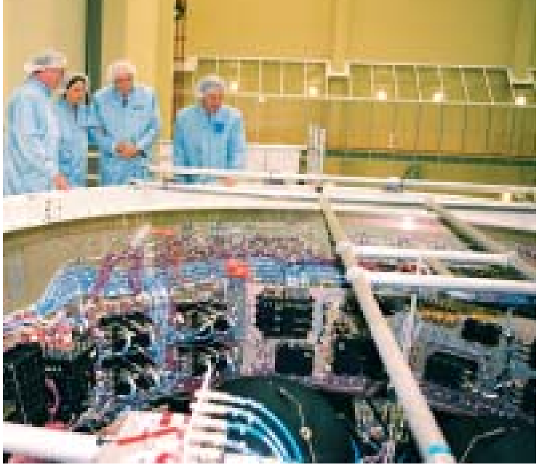
The PAP now has to be executed, requiring concrete plans to be presented to the MCB and the Heads of Agencies in December 2004/January 2005. These plans should detail how each Partner will support development of the agreed configuration, and will entail considerable negotiations between Partners. The MCB will control this process and then reconvene to approve the recommended configuration.

As regards our European effort, ESA's Programme Board of participating Member States last February accepted a revised Refined Scenario #3. This was a follow-up to December 2003's Council decision to add a bridging phase for extending the Columbus schedule, as well as providing additional support for the Automated Transfer Vehicle (ATV) and the interim Station utilisation programme.

Additionally, we in ESA are taking some extra internal measures for identifying and implementing the most prudent industrial contractual approach in order to provide only that industrial support which is absolutely necessary to cover this difficult period.

Columbus Preparation

With respect to our Columbus core element, we are now in the final stages of assembly at prime contractor EADS-ST in Bremen (D). The infrastructure is ready and individual research facilities (Biolab, Fluid Science Laboratory, European Physiology Modules, and European Drawer Rack) have completed their individual testing as well as the integrated sequence testing with Columbus. The following articles in this issue describe this work. Following this, the first System Validation Test (SVT) has been successful – an end-to-end test of the Columbus infrastructure and its payloads, plus some of the ground elements that monitor and control the flight equipment. Further SVTs will progress towards ultimately checking the end-to-end operations that include the Columbus Control Centre (Oberpfaffenhofen, D), the European User Support and Operations Centres and the NASA Johnson Space Center. Completion of these SVT tests will mark the end of the development of Columbus. Following any updates to the documentation to reflect the 'as-is' status, Columbus will then be placed in hibernation in the Bremen integration hall. During hibernation, occasional work may include limited improvements. In any case, Columbus will be ready at short notice to restart ground processing once a firm launch date has been agreed by the ISS Partnership. Based upon this Heads of Agencies meeting, we still expect to see Columbus being launched at the end of 2006 or, at the latest, in early 2007.



The Heads of Agencies delegations visit ATV 'Jules Verne' in the ESTEC Test Centre.

ATV Nearing Flight

On 12 May, we concluded a contract with EADS-ST for the revised ATV development contract; this is now a Firm Fixed Price. The goal of this contract is the launch of the first ATV, 'Jules Verne', in October 2005. The ATV production contract and the initial operator contract were signed on 13 July with EADS-ST, including Alenia Spazio as a major partner.

ATV Jules Verne is now in ESTEC and being prepared for environmental testing: thermal, vacuum, electromagnetic and acoustic.

Interim Utilisation Programme

The agreed interim utilisation programme now allows us to bridge the gap between the previously planned Columbus launch date of October 2004 and the current late 2006. For our Users, this means the possibility of using drop towers, parabolic flights, sounding rockets and Russian Foton flights. The programme also includes onboard use of the ISS via Soyuz, Progress and Shuttle flights to the greatest extent possible. We are also finalising an Italian Soyuz flight for April 2005, and are still negotiating a long-duration flight beginning in October 2005. ■

Columbus Completes Development

The Mission Manager's Perspective

Bernardo Patti
Columbus Mission Manager, Development Department,
D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Bernardo.Patti@esa.int

Introduction

Europe's key research contribution to the ISS is the Columbus laboratory module, planned for launch with its payload aboard Shuttle assembly Flight 1E in late 2006. Getting ready for 1E involves preparing four major elements:

– the Flight Segment of the module and its payloads;
– the Ground Segment of the Columbus Control Centre (COL-CC) and the User Support Operations Centres (USOCs);
– the operations procedures and products;
– the crew training.

The tragic loss of Shuttle *Columbia* in February 2003 caused shockwaves throughout the Shuttle and Station schedules, and Columbus has been severely affected.

For the first time, all the elements of Columbus are together for combined testing ...

Readiness of the Flight 1E Elements

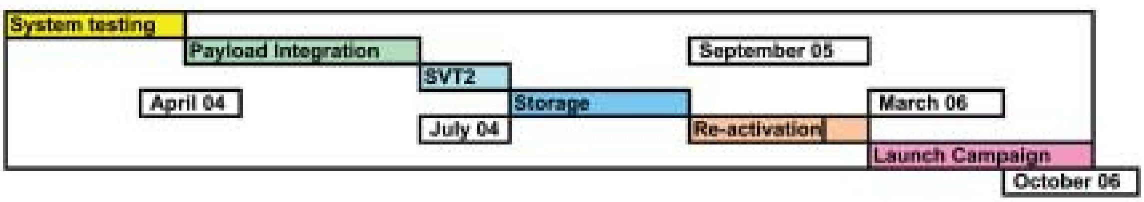
The Columbus module, under the prime contractorship of EADS-ST in Bremen (D), has passed its Qualification Review 1 (QR1) and is now finishing its test campaign to support the Final Qualification Review in September-October. At launch, Columbus will be carrying four research rack facilities inside: Biolab, the European Physiology Modules (EPM), the Fluid Science Laboratory (FSL) and the European Drawer Rack (EDR); plus two external payloads: the European Technology Exposure Facility (EuTEF) and the SOLAR observatory. The Shuttle will carry the last two in its cargo bay for installation by EVA on Columbus once at the Station.

The Columbus Control Centre, being built under DLR prime contractorship in Oberpfaffenhofen, has passed its System Design Review 2, and the Qualification Review is planned for September.

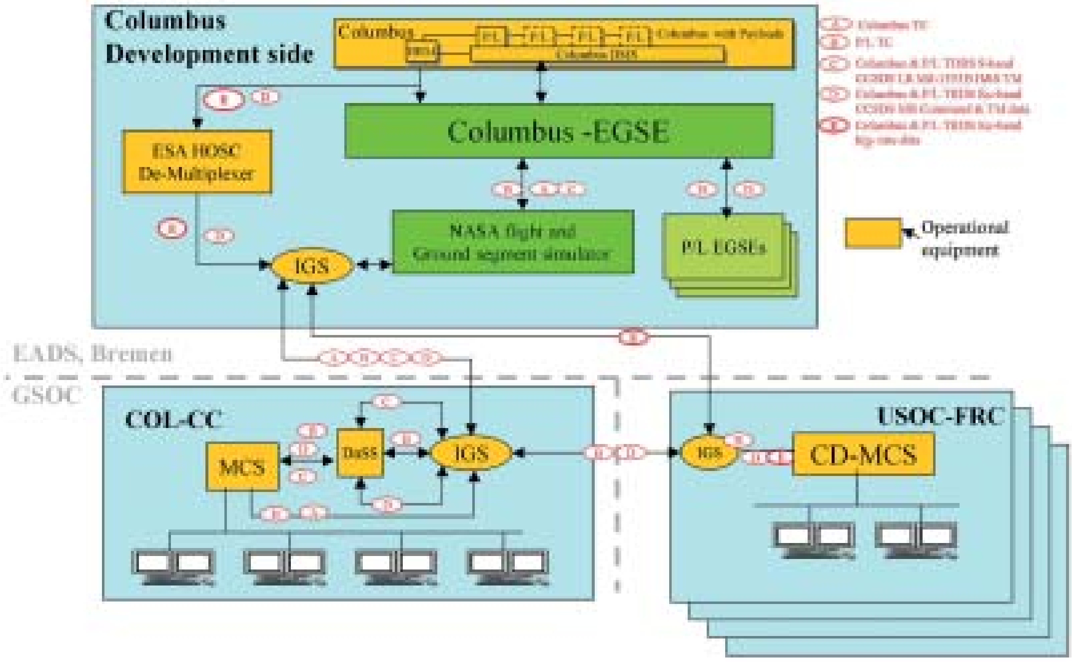
The USOCs are a set of decentralised centres that will each operate an individual rack in Columbus. The initial four will grow to five when Columbus is fully operational. Their development recently began under ESA contracts with the host national agencies.

Preparing for 1E flight operations is the responsibility of DLR at Oberpfaffenhofen, including control procedures, displays, handbook flight rules, training operators and conducting simulations.

Columbus crew training is led by the European Astronaut Centre in Cologne (D), in conjunction with prime contractor EADS-ST (Bremen). The work



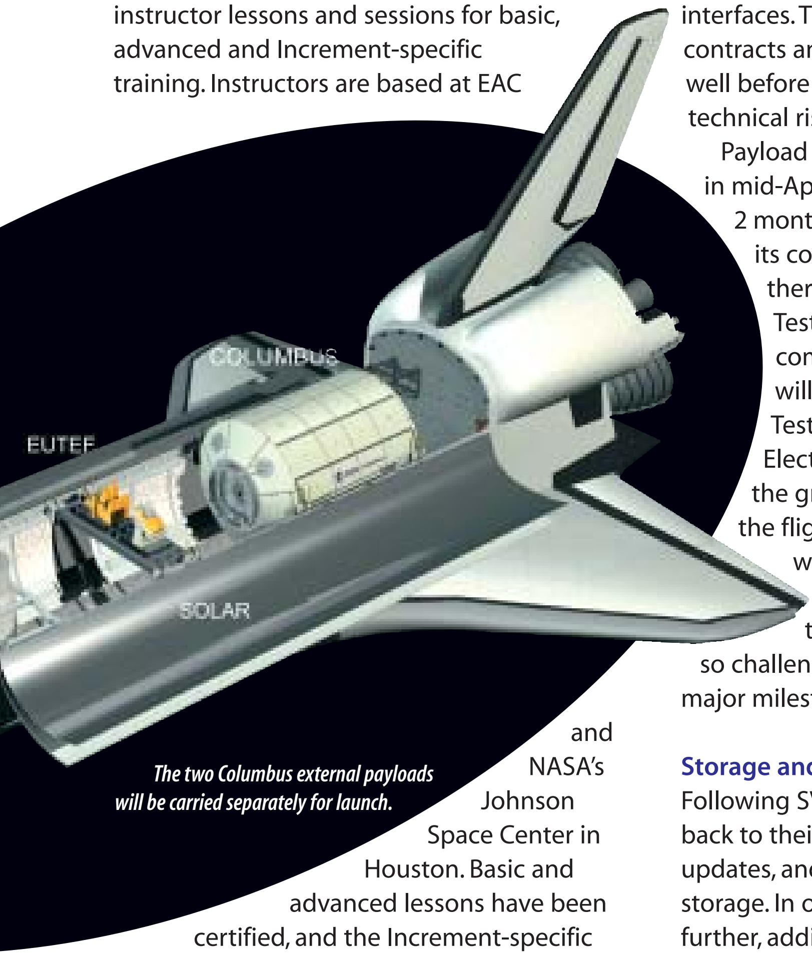
The latest Columbus schedule.



The second System Validation Test will bring all the elements of Columbus together for the first time.

CD-MCS: Columbus Distributed Monitor & Control System
DaSS: Data Services Subsystem
EGSE: electrical ground support equipment
FRC: Facility-Responsible Centre
GSOC: German Space Operations Centre
HOSC: Huntsville Operations Support Center
HRM: High Rate Multiplexer
IGS: Interconnection Ground Subnetwork
MCS: Monitor & Control System
P/L: payload
USOC: User Support Operations Centre

covers the creation of training material, instructor lessons and sessions for basic, advanced and Increment-specific training. Instructors are based at EAC and NASA's Johnson Space Center in Houston. Basic and advanced lessons have been certified, and the Increment-specific curriculum is in the certification process.



The two Columbus external payloads will be carried separately for launch.

Flight 1E Integration

The 2-year delay for Columbus caused by the Shuttle's grounding has forced considerable replanning by ESA. However, instead of slowing development, ESA has decided to complete the flight and ground segments, and to verify their interfaces. This minimises the impact on contracts and could identify interface issues well before the new launch date, thus reducing technical risks in the programme.

Payload integration with Columbus began in mid-April and is expected to take 2 months. Each of the four racks will prove its compatibility with Columbus before there is an overall Integrated System Test. Once payload integration is completed, the space-ground interface will be verified by System Validation Tests. SVT1 will use the Columbus Electrical Test Model working through the ground segment, while SVT2 will see the flight Columbus and its research racks working with the Control Centre and the USOCs. SVT2 is the first test on the assembled major elements. It is so challenging that its achievement will be a major milestone.

Storage and Reactivation

Following SVT2, the four racks will be shipped back to their contractors for refurbishment and updates, and Columbus will be readied for storage. In order to reduce the risks even further, additional work could include end-to-end testing of the external payloads and extended software endurance testing.

Thirteen months before launch, the module and its payload will begin a second round of integration and testing to prepare for shipping to the Kennedy Space Center and the 7-month launch campaign.

Ready for Orbit

Microgravity Facilities for Columbus (MFC)

Giuseppe Reibaldi
Head of Microgravity Facilities for Columbus and External Payloads Division (MSM-GF), D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: giuseppe.reibaldi@esa.int

Introduction

The Microgravity Facilities for Columbus (MFC) Programme was approved in 1995 at the Ministerial Council in Toulouse, together with other elements of ESA's participation in the International Space Station (ISS). MFC includes the development of several complex multi-user facilities: Biolab; the Fluid Science Laboratory (FSL) and the European Physiology Modules (EPM) for Columbus, and the Materials Science Laboratory (MSL) and the Pulmonary Function System (PFS) for the US Destiny module. Developing the experiment hardware and preparing to improve the facilities' subsystems are also part of MFC.

The most productive research facilities yet built for the ISS are almost ready to fly ...

Status

The Phase-C/Ds of the facilities began in 1997-1999 in a staggered way, depending on the level of maturity reached during the definition phases. The industrial contracts were awarded to all the major European prime contractors, such as EADS-ST (D) for MSL, EADS-Astrium (F) for Biolab, Alenia (I) for FSL, OHB (D) for EPM and Damec (formerly Innovison; DK) for PFS.

PFS (circled) integrated in HRF-2 inside MPLM.

EPM (left) and Biolab installed in Columbus ready for IST.

Biolab, FSL and EPM
The Flight Models (FMs) completed verification of their Columbus interfaces using the Rack Level Test Facility (RLTF) at EADS-ST in Bremen (D) in 2003. They ended their qualification in April with their delivery for the Integrated System Test (IST) and the end-to-end System Verification Test (SVT) inside the Columbus FM module at Bremen.

The Training Models have been delivered to the European Astronaut Centre in Cologne (D), while the Engineering Models (EMs) will not be delivered until early 2005, in order to retrofit the late changes introduced in the FM models as a result of the scientifically required upgrades.

Materials Science Laboratory (MSL)
MSL, a cooperation with NASA, will be integrated in the US Materials Science Research Rack (MSRR-1) for launch in mid-2006. The EM has been delivered to NASA Marshall Space Flight Center, while the FM and Training Model will be delivered in the second half of 2004.

Pulmonary Function System (PFS)
PFS is a cooperative project with NASA that

allows ESA to have a flight opportunity before the Columbus launch. All models have been delivered to NASA and the FM is integrated in the US Human Research Facility-2 (HRF-2) for launch aboard the next Shuttle mission, LF-1, in 2005.

User support activities
The hardware for the first year of experiments in orbit is being built: Experiment Containers for FSL and Biolab, and cartridges for MSL. No new major development is required yet for EPM and PFS.

Challenges

Developing these facilities met several major challenges. They had to comply with very challenging scientific requirements established by the science teams. Each facility has about 1000 requirements – similar in quantity for the whole of Columbus. They include the highest degree of automation possible (Biolab's 7-degree-of-freedom robotic arm) in order to minimise crew involvement. Telescience operation from the ground allows scientists to interact with their experiments in space. The high level of modularity means that the facilities can be refurbished in orbit.

The facilities exploit developments funded by the Agency's technology programmes, and close cooperation with the Technical Directorate has been set up to define the required upgrades and the potential for evolution.

Satisfying the scientific requirements was constrained by the mass limit for each facility launched in Columbus: 500 kg. Similar and less complex NASA facilities are allowed up to 800 kg when carried by the Multi-Purpose Logistics Module (MPLM).

The MSL Engineering Model. MSL will be installed in NASA's Destiny module.

The overall engineering approach to the facilities' development was centralised within the HME-GF Division, allowing technical standards to be created that ensured a continuous learning process with limited staff. This approach was extended to the external payloads, with similar successful results.

Cooperative agreements have added to the programme the Microgravity Vibration Isolation System (MVIS), developed by the Canadian Space Agency for FSL, and Cardiolab, developed by CNES and DLR, for EPM. MVIS will greatly enhance FSL, providing good isolation for experiments from the Station's microgravity disturbances. Cardiolab offers a wide set of physiology instruments for cardiovascular studies in space.

The FSL FM ready for IST.

The MFC facilities were developed within very tight financial budgets set by ESA. This forced a rigid financial discipline upon the prime contractors, which has allowed MFC to continue within those fixed resources longer than planned and with greater scope. The programme has awarded contracts totalling more than 50% of its budget to several small- & medium-sized enterprises (SMEs), developing skills in these companies that will be exploited in future programmes.

MFC is also working on behalf of ESA's ISS Exploitation Programme to procure spares and prepare procedures for a smooth transition to the operational phase in orbit.

Outlook

At the end of the Columbus IST and SVT in August 2004, the EPM, Biolab and FSL FMs will be returned to their prime contractors for upgrading and robustness testing aimed at improving their performance and reducing the risk of on-orbit failures. This work will be completed 13 months before the launch date of Columbus, now planned for late 2006.

Conclusion

The MFC Programme is nearing conclusion; it has delivered the planned facilities, meeting or exceeding challenging technical requirements and the very tight financial constraints. These ESA facilities incorporate state-of-the-art technology with an optimum blend of automation and human intervention. They are the most complex and productive facilities yet built for the ISS, giving Europe the lead in exploiting the Station. This was achieved through the expertise and close cooperation of the ESA and Industry teams. ■

A Testing Time

Columbus Payload Testing in the RLTF

Volker Koehne & Horst Koenig
Payload Engineering Integration, Operations Department, D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Volker.Koehne@esa.int; Horst.Koenig@esa.int

Introduction

ESA's Biolab, Fluid Science Laboratory (FSL), European Drawer Rack (EDR) and European Physiology Modules (EPM) racks will be launched inside Columbus on Mission 1E, together with the EuTEF and SOLAR external payload platforms. These complex internal payloads have completed their thorough testing in the Rack Level Test Facility (RLTF), so that can now become part of Columbus, where another campaign will soon begin to show that the module works as a whole.

The Columbus payload facilities have successfully completed a major part of their testing ...

The experiments inside Columbus are accommodated in International Standard Payload Racks (ISPRs). In the RLTF, the ISPRs were supplied with the same resources they can expect in orbit: power, data (low, medium and high rate), video, water cooling, nitrogen gas and vacuum/venting. The external experiments are housed on standardised Columbus External Payload Adapters (CEPAs). In the RLTF, these CEPA payloads are provided with the power and data interfaces they will have in space.

In order to provide maximum confidence that the Columbus payloads will work properly in orbit, their integration and test programme is divided into two phases in a classical test approach: the RLTF acted as the Columbus Engineering Model before the payloads are tested in the Columbus Flight Model. In both test phases, the payload Flight Models are used.

During the second phase, the RLTF itself has to show compatibility with the data/video interfaces of the Columbus FM. Once Columbus is in orbit, the RLTF will be used as the Columbus reference model for integrating future payloads.

The Fluid Science Laboratory undergoes testing in the RLTF.

EADS Space Transportation in Bremen (D), with subcontractor Alenia (I), is the Columbus Payload Integrator (CPI) and thus responsible for conducting both test phases. This article covers the first test phase; the four racks are now being integrated into Columbus for the second phase.

Test Objectives

Experience shows that verifying the operational procedures and the software interfaces (telemetry packets and telecommands) between the racks and Columbus is the most time-consuming and complex part of the tests. Testing the hardware interfaces is limited to verifying the connections.

Payload telemetry and telecommands are divided into two groups: system-level parameters and commands that have to be available to Columbus and its control centre, and payload-specific parameters and commands of interest to the experimenters in the User Support Operations Centres (USOCs) or astronauts operating the payload. In the RLTF, the Columbus electrical ground support equipment (EGSE) plays the role of the control centre, while the payload EGSE represents the USOC.

The RLTF verified that data packets are forwarded to their correct destinations, and that parameters and commands unique to a payload are correct and satisfy the system requirements. This has verified all the software elements – the Mission Database (containing all packet definitions and routing information), the payload software and the payload EGSE database. Discrepancies were resolved by modifying the software.

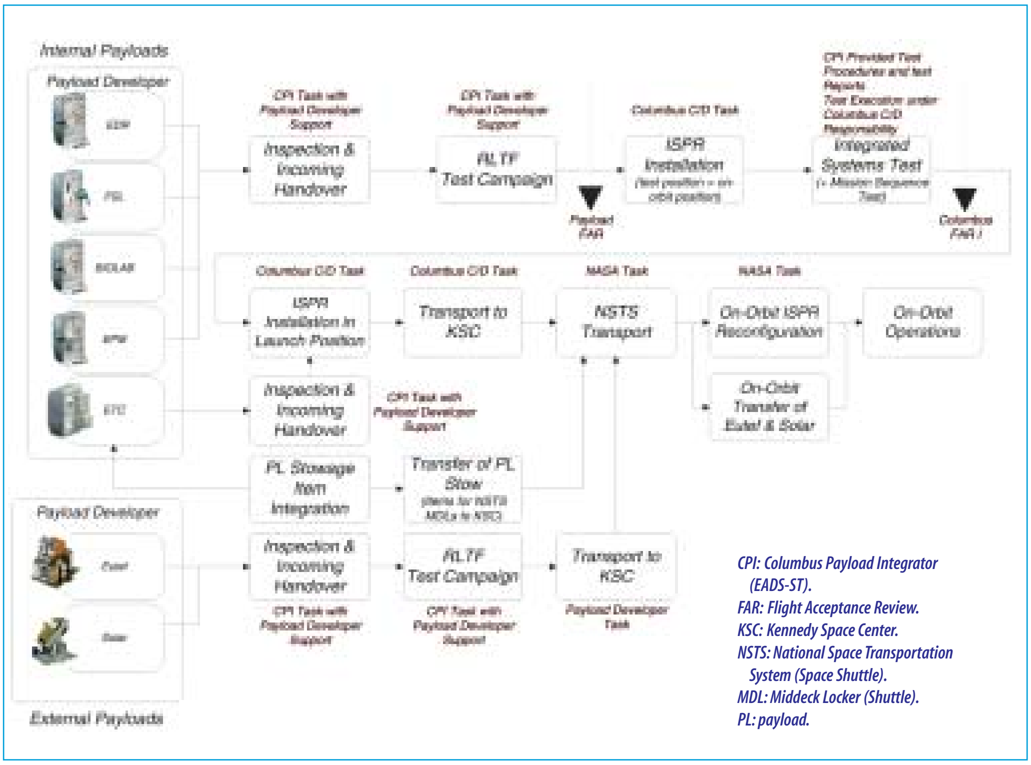
RLTF Capabilities

The RLTF was conceived as a faithful representation of the Columbus interfaces without the actual module. It has three major elements: Electrical Test Model (ETM) with payload power and data interfaces; ETM EGSE with payload EGSE interfaces; payload adapters with utility interface panel connector, water services, vacuum and nitrogen gas connections.

The ETM provides power to the payloads via the Power Distribution Unit, it reads caution and warning signals from payloads and provides them to the Vital Telemetry and Command Controller, it sends and receives low-rate data on the MIL-STD-1553 bus through the Payload Control Unit, it sends and receives medium-rate data of up to 10 Mbit/s on the Ethernet LAN, and it receives and processes high-rate data and video images through a serial line at up to 30 Mbit/s. It can also receive and process video from an NTSC analogue video line.

The ETM is functionally identical to the Columbus module. The Columbus avionics are represented by their engineering models. Power comes from commercial supplies configured to match the power characteristics of Columbus. Payload simulators generate a realistic scenario for the rack under test.

The software running on the ETM Data Management System (DMS) is identical to the software on the Columbus DMS. The same is true for the Video/Data Processing Unit. The Mission Database (MDB) that contains the telemetry/telecommand definitions for the entire Columbus system (including all payloads and other software) is also identical to that used on the Columbus flight model.



The Columbus payload integration flow for the 1E mission. A fifth ESA rack, the European Transport Carrier (ETC), will also be launched inside Columbus, but it is a passive carrier and did not need RLTF testing.

Payload Test Experience

So far, all four active payload racks (Biolab, EPM, FSL, EDR) have been successfully tested on the RLTF (see box). The EuTEF and SOLAR external platforms will follow by the end of 2004.

Time constraints during development meant that the payloads entered RLTF testing without completing their Preliminary Acceptance Reviews (PARs) at their contractors, which would have been standard procedure. This was allowed assuming that they completed RLTF testing showing full conformance with the Columbus interfaces. This approach initially caused additional work for EADS but ultimately proved successful and time-saving.

Some software discrepancies were found (and corrected) on the payloads and the MDB. For the hardware, interface problems included payload LAN connector wiring. The high-rate demultiplexer in the Columbus EGSE did not behave as expected by the payload contractors. Instead of a continuous stream, it sends out data in short bursts of 100 Mbit/s, which cannot be processed by the payload EGSEs. Since the demultiplexer is a commercial product that cannot be modified, the problem had to be solved by adding a converter to smooth the bursts into a continuous bit-stream of 30 Mbit/s.

Conclusions and Lessons Learned

Testing the four payload racks in the RLTF before moving into Columbus itself now was clearly the correct choice. Having standard equipment such as the ISPR, Standard Payload Computer (SPLC), Remote Power Distribution Assembly and Avionics Air Assembly in the racks proved to be an advantage. It should be emphasised that all the Columbus and payload software protocols (as part of SPLC) worked flawlessly. The cycle for updating software in the Mission Data Base needs to be shortened from the current months to weeks.

Completed RLTF Testing

Biolab
TRR: 14 May 2003
RLTF Test:15-28 May
PTR: 6 Jun

EPM
TRR: 8 Jul 2003
RLTF Test: 11-31 Jul
PTR: 28 Aug

FSL
TRR: 12 Sep 2003
RLTF Test: 18 Sep - 2 Oct
PTR: 17 Oct

EDR
TRR: 6 Feb 2004
RLTF Test: 10-27 Feb
PTR: 11 Mar

PTR: Post Test Review
TRR: Test Readiness Review

Watching the Sun

The SOLAR Payload for the ISS

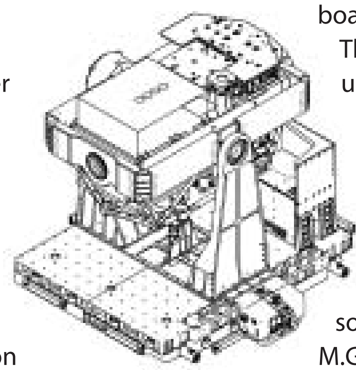
Piero Galeone[1], Leticia Péres Cuevas[2] & Giacinto Gianfiglio[3]
[1]SOLAR Payload Manager; [2]SOLAR Payload System Support Engineer, [3]Head, ISS External Payload Section, Utilisation Department, D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Piero.Galeone@esa.int; Leticia.Perez.Cuevas@esa.int; Giacinto.Gianfiglio@esa.int

Introduction

Europe's Columbus laboratory offers the opportunity to mount payloads outside the International Space Station on its External Payload Facility (EPF). One of these external payloads, SOLAR, will study the Sun across most of its spectral range for 18 months, extendible to 3 years, from the EPF zenith position. Its three complementary solar science instruments – SOVIM, SOLSPEC and SolACES – were selected in 1997 via an Announcement of Opportunity issued by the Directorate of Human Spaceflight (MSM), ESA's Directorate of Scientific Programmes (SCI) supported instrument selection.

Columbus will host an important solar observatory ...

The instruments are carried on a Coarse Pointing Device (CPD) that points at the Sun by compensating for the Station's orbital movement. The overall payload is integrated on a NASA-provided Columbus External Payload Adapter (CEPA), developed by Boeing (USA) in tight coordination with MSM's External Payloads Section. SOLAR development and integration with the science instruments and CEPA are the responsibility of Alenia Spazio (Turin, I). Carlo Gavazzi Space (Milan, I) and Oerlikon Contraves Italiana (Rome, I) are subcontractors respectively for the CPD control unit and the CPD pointing mechanism. SOLAR is planned to be launched on an Integrated Cargo Carrier-Lite in the Space Shuttle cargo bay in 2006 (see the other Columbus articles in this issue).



The SOLAR Science Instruments

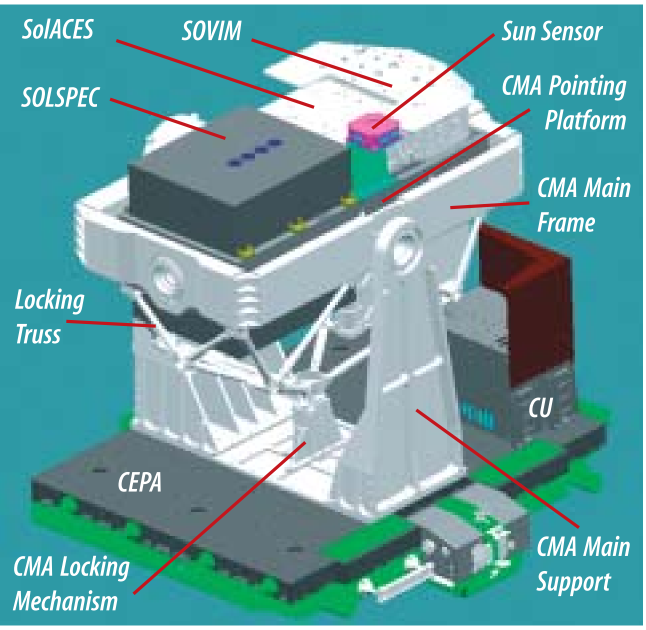
SOVIM (Solar Variability and Irradiance Monitor) will measure the solar spectral irradiance via filter-radiometers in the near-UV (402 nm), visible (500 nm) and near-IR (862 nm) regions, together with the total solar irradiance using two types of radiometers covering the range from 200 nm to 100 µm. The Principal Investigator (PI) is C. Fröhlich at the Physikalisch-Meteorologisches Observatorium Davos / World Radiation Center (PMOD/WRC, Davos, CH), under Swiss national funding. Most of the industrial effort is subcontracted to Oerlikon Contraves (Zurich, CH). SOVIM relies on a contribution from the Institut Royal Météorologique de Belgique (IRMB, Bruxelles, B), responsible for the development of the DIARAD radiometer, and on support from ESA's SCI, via the PRODEX programme.

The instrument concept is based on upgrading the SOVA instrument that flew on Eureca; indeed, it is reusing electronics boards retrieved from that mission. The Flight Model is currently undergoing verification testing.

SOLSPEC (SOLar SPECtral irradiance measurements) will operate in the range 180-3000 nm, with an accuracy of 2% in UV and 1% in visible and IR, and will study solar variability. The PI is M.G. Thuillier at the Centre National de la Recherche Scientifique (CNRS), Service d'Aeronomie (Verrières le Buisson, F), with French national funding from CNES. SOLSPEC relies on partnership contributions from the Belgian Institute for Space Aeronomy (IASB/BIRA, B) and Landessternwarte (LSW, Heidelberg, D). Through the Belgian partnership, SOLSPEC can access expertise from ESA's SCI via PRODEX. The instrument concept upgrades the Eureca SOSP instrument.

The FM is completing integration and testing.

SolACES (Solar Auto-Calibrating EUV/UV Spectrophotometers) will measure the spectral irradiance in the UV and Extreme-UV regions (16-220 nm). The PI is G. Schmidtke at the Fraunhofer-Institut für Physikalische Messtechnik (IPM, Freiburg, D), with German national funding from DLR. MSM supports them with a contract to provide industrial human spaceflight expertise from EADS-ST (Friedrichshafen, D). In addition, they can also rely on support from SCI, for contamination expertise. The FM is planned to be ready by end-September 2004.



The Coarse Pointing Device (CPD)

CPD consists of a Control Unit (CU), CPD Mechanical Assembly (CMA) and Sun Sensor. It tracks the Sun in two axes with an accuracy of 1° and a stability of 0.3° (over 10 s). It provides pointing ranges of ±40° along the primary rotational axis, and ±25° along the secondary axis. The CU integrates the data handling, control and communication functions into a single box. It uses ESA's Standard Payload Computer board, and its design is partly based on the Remote Power Distribution Assembly.

The major constituents of the CMA are:

– two main lateral supports hosting the two bearings, brushless DC motor and optical encoder, to drive and control rotation around the main axis;
– the rectangular main frame, suspended between the main lateral supports along the main rotation axis; it hosts the two bearings, brushless DC motor and optical encoder, to drive and control rotation around the secondary axis at 90° to the main axis;
– the smaller rectangular frame (CMA pointing platform) hosting the science instruments and the Sun Sensor, and suspended from the main frame along the secondary axis;
– the locking mechanism, to hold the CMA pointing platform during launch, on-orbit installation and return to Earth;
– a bottom baseplate, hosting the whole CMA, and interfacing with the CEPA.

The CPD locking truss.

The digital Smart Sun Sensor from Galileo Avionica provides 2-axis fine detection of the Sun with an accuracy of 0.02°.

SOLAR Payload Challenges and Status

The development of SOLAR called for innovative design solutions for the CPD and the science instruments. CPD's structural design was particularly challenging because of the combination of mechanical and structural requirements (loads, mass, pointing requirements, return to Earth after a 3-year mission). The design involves use of composite materials, supported by campaigns to characterise the materials and processes (including the molybdenum-coating hardening process for the bearing bushes, used for the first time on a space mission). When recovered after its 18-36 month mission, SOLAR is expected to be Europe's record-holder for the longest exposure to space before return to Earth; Eureca was in orbit for about 9 months before recovery.

A campaign of integrated software tests using the software simulators of the three science instruments with the CPD CU Engineering Model was completed in February 2004. The SOLAR Engineering/Structural Thermal Model, used for CMA environmental qualification and CU functional verification, without instruments, will be completed in July. A fit-check of the CEPA FM with its Flight Releasable Attachment Mechanism counterpart on the Columbus EPF has been completed. Integration of the SOLAR Proto-Flight Model will be completed by the end of the year. Integration with the ICC-L launch carrier will begin at Cape Canaveral about 5-6 months before launch. ■

Exercising Control

49 months of DMS-R Operations

Claus Reimers[1] & Daniel Guyomard[2]
[1]Head of Future Activities Office, Development Department,
[2]ATV Follow-On Procurement Engineer,Operations Department,
D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Claus.Reimers@esa.int; Daniel.Guyomard@esa.int

Introduction

The 'Data Management System for the Russian Segment of the ISS' – more succintly known as 'DMS-R' – was launched in 2000 as a core part of Russia's Zvezda module, the first habitation element of the International Space Station. Provided by ESA, DMS-R manages the Russian portion of the ISS, and handles Guidance, Navigation & Control for the entire Station. In parallel, ESA benefits by using this computer family for its own Columbus and Automated Transfer Vehicles (ATVs).

The ISS control system provided by ESA has now been operating sucessfully in orbit for 4 years ...

Zvezda carries two Fault Tolerant Computers (FTCs) for critical system and mission control tasks, plus two Control Post (CP) Computers for crew interfaces and experiment control. The computer infrastructure connects to the Station's Russian and US segment via an extended system of MIL-1553B data busses.

Each FTC consists of three interconnected identical processing units working in parallel redundancy and providing advanced fault-masking by majority voting. Tasks include interaction with the ATV, both during the approach and docked phases.

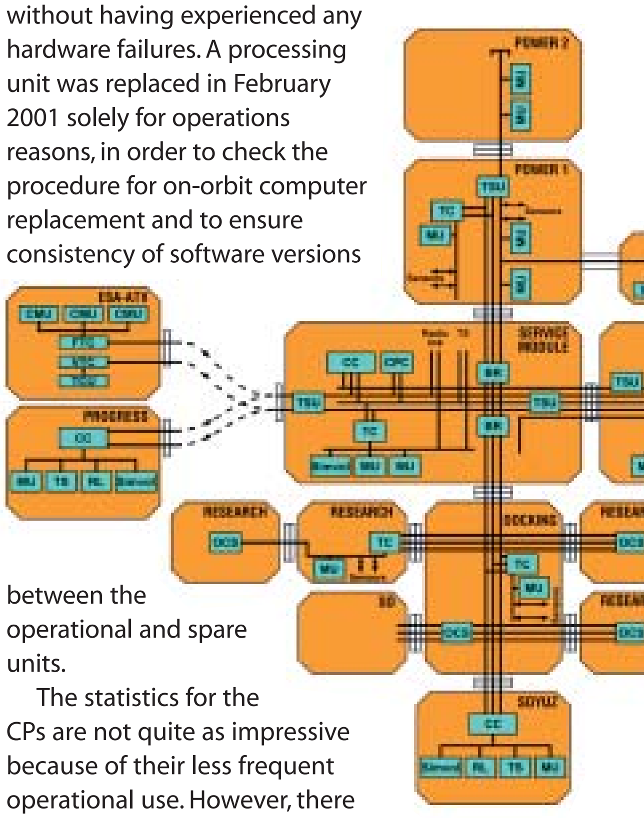
The CP Computers are based on the same basic processing unit but without the advanced fault-tolerance. However, they have a mass memory unit, LAN interfaces and dedicated connections to two standard ISS laptops used for crew interfacing, including control of the European Robotic Arm.

While all the hardware, system software and ground system were developed by ESA and its contractors, the application software was provided by Zvezda prime contractor RSC-Energia.

Hardware Performance

After the launch of Zvezda on 12 July 2000 carrying two FTCs, a seventh processing unit was delivered by Progress-1P as an onboard spare in August 2000. That ferry also brought the first CP, for installation by the Expedition-1 crew in November 2000. The second CP followed aboard Shuttle 5A and was installed in February 2001.

By early March 2004, the FTC processing units had accumulated more than 36 000 h of operating time (more than 40 000 h with ground testing before launch). The system of these six units is therefore exceeding its calculated theoretical mean-time-between-failure of 45 000 h by almost a factor of six without having experienced any hardware failures. A processing unit was replaced in February 2001 solely for operations reasons, in order to check the procedure for on-orbit computer replacement and to ensure consistency of software versions between the operational and spare units.



The statistics for the CPs are not quite as impressive because of their less frequent operational use. However, there

Yuri Gidzenko working with the Control Post laptops.

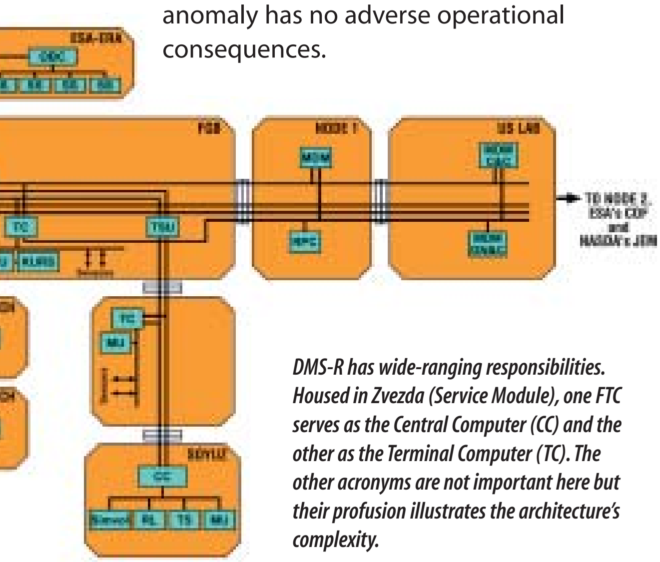
have been no hardware failures so far, although some problems seen recently with the mass memory unit have yet to be evaluated.

Based on this excellent performance, RSC-Energia has decided for the moment not to order additional spares beyond the initial set agreed shortly after the development programme.

Operational Experience

While the CP Computer has seen one 'warm' restart owing to perturbations on its power supply line, no other problems have been reported. With the FTC, a phenomenon was observed soon after launch that has still not been fully explained and resolved. Although an anomaly, it has never degraded operations thanks to the computer's inherent fault-tolerant design, which masks such faults. The issue is the occasional reset and automatic restart of an FTC processing unit. Evolution to the fourth application software version – required mainly to handle the growing Station, but also offering improved telemetry for software analysis – has reduced the frequency of these events. However, the ultimate origin of this anomaly has not yet been identified and the restarts still happen about every 3 months.

Part of the problem is the difficulty in tracing such a rare event because the diagnostic information in the reset processing unit is lost after the warm restart erases its entire volatile memory. Current software modifications therefore focus on improving the diagnostic possibilities but they are being pursued with modest priority because the anomaly has no adverse operational consequences.



DMS-R has wide-ranging responsibilities. Housed in Zvezda (Service Module), one FTC serves as the Central Computer (CC) and the other as the Terminal Computer (TC). The other acronyms are not important here but their profusion illustrates the architecture's complexity.

A more spectacular event alerted the world's press on 4 February 2002 when the Station lost its nominal attitude control for several hours and transitioned into a survival mode. Although the DMS-R is basically responsible for Station GNC, the Russian Segment depends in some situations on extensive data and information from the US Segment. These include desaturation of the US Control Moment Gyros, when Zvezda's thrusters have to take over ISS attitude control. The communication between DMS-R and its NASA counterpart collapsed owing to a number of coincidences and could not be reestablished by a warm restart because of the lack of valid context data. After several unsuccessful attempts, the data exchange was finally reinitiated via a cold start (power off/on) of DMS-R. This brought the Station back into a normal operational mode.

Following an investigation of this event, the Russian application software was modified to provide a more robust context management.

The two FTCs installed in Zvezda are literally black boxes.

Applications Beyond the Russian Segment

From the beginning, DMS-R's development not only targeted the Station's Russian Segment but also ESA's own space elements. Derivatives of the FTC and CP Computers are now being used successfully as Data Management Systems for ATV and Columbus, respectively.

Summary

RSC Energia and ESA are highly satisfied by the excellent performance of the DMS-R system. Its 49 months of onboard operations feature no hardware failures and minimum effort for solving software and operational problems. DMS-R is clearly a very successful programme both for the Agency and for Industry.

Further information on DMS-R can be found at:
esapub.esrin.esa.it/onstation/onstation5.htm

IMPRESS

New Industrial Materials with the Help of Space Research

David Jarvis[1] & Olivier Minster[2]
[1]IMPRESS Project Coordinator; [2]Head of Unit for Physical Sciences, D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: david.john.jarvis@esa.int; olivier.minster@esa.int

ESA is leading a research project into the materials of the future ...

Introduction

The ESA-led IMPRESS (Intermetallic Materials Processing in Relation to Earth and Space Solidification) project was recently selected by the European Commission as a 'flagship project' in materials science and applications. It comprises a large multidisciplinary consortium of 43 research groups and companies, with a total budget of €40 million from the EC, ESA, industry and others.

By combining the industrial and academic expertise of more than 200 leading scientists from 15 countries, IMPRESS now has the potential to make Europe a world-leader in this strategically important area of materials science over the next 5 years.

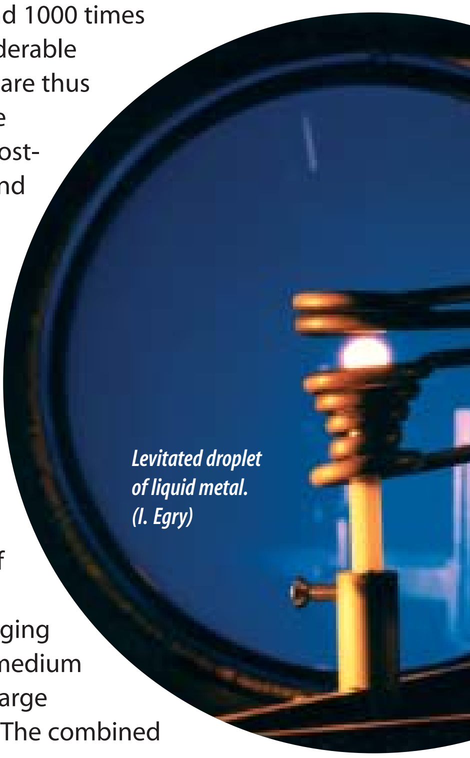
Project Objectives

The scientific objective of the project is to study the relationship between the processing, structure and properties of intermetallic alloys. These special crystalline alloys are the materials of the future, with many different applications ranging from aerospace components to power generation systems. Titanium aluminides, for example, have remarkable mechanical and physical properties at temperatures up to 800ºC. It is the combination of high melting point, high strength and low density that make them ideal for high-performance gas turbine blades. These blades, produced by advanced casting techniques, will be used in the next generation of turbines for modern power stations and aero-engines. Using titanium aluminide would result in a 50% weight reduction of turbine components, possibly leading to improved thrust-to-weight ratios of aero-engines, higher efficiency, reduced fuel consumption and lower exhaust emissions.

Intermetallic alloys are equally important for advanced catalytic powders. Catalysts speed up chemical reactions, thereby saving considerable time and energy. There are many uses of catalysts in, for instance, the pharmaceutical, food and energy industries. In IMPRESS, scientists will investigate catalytic powders made from nickel and cobalt aluminides.

Rapidly-solidified, nano-structured particles will be produced by gas atomisation and, after some further processing, will be used by industry to speed up hydrogenation reactions, which are vital for the production of certain chemicals and plastics.

Companies developing and using hydrogen fuel cells will also benefit greatly from this research, since catalytic electrodes based on nickel and cobalt powders are effective alternatives to conventional platinum electrodes – and 1000 times cheaper. Considerable improvements are thus expected in the performance, cost-effectiveness and sales potential of these pollution-free power-generation systems.



Levitated droplet of liquid metal. (I. Egry)

Industry

IMPRESS has the active participation of 14 European companies, ranging from small-to-medium enterprises to large multinationals. The combined

IMPRESS Project Participants

ESA (Project Coordinator)
Max-Planck Institut für Eisenforschung GmbH (D)
University of Birmingham (UK)
Institut National Polytechnique de Toulouse (F)
Helsinki University of Technology (FIN)
Kungl Tekniska Högskolan (S)
Slovak Academy of Science (SK)
Research Institute for Solid State Physics and Optics (HUN)
Centro National de Investigaciones Metalurgicas (E)
Deutsches Zentrum für Luft- und Raumfahrt (D)
British Ceramic Research Ltd. (UK)
University of Wales Swansea (UK)
Turbocoating S.p.A. (I)
University of Leeds (UK)
University of Greenwich (UK)
Magnitec Oy. (FIN)
Calcom ESI S.A. (CH)
National University of Ireland (IRL)
ACCESS e.V. (D)
Leibniz-Institut für Festkörper- und Werkstoffforschung (D)
Ecole Polytechnique Fédéral de Lausanne (CH)
Centre National de la Recherche Scientifique – Grenoble (F)
Institute of Structural and Macrokinetics & Materials Science (RUS)
CNR-IENI Milan (I)
Tylite International Oy. (FIN)
Hydrocell Ltd. (FIN)
Krakow Univ. of Mining and Metallurgy (POL)
University of Cambridge (UK)
Tratamientos Superficiales Iontech S.A. (E)
Qinetiq Nanomaterials Ltd. (UK)
Ufa State Aviation Technical University (RUS)
Fraunhofer Gesellschaft e.V. (D)
Institut National Polytechnique de Lorraine (F)
Katholieke Universiteit Leuven (B)
CNR-IENI Genoa (I)
INASMET Foundation Ltd. (E)
NPL Management Ltd. (UK)
Universiteit Leiden (NL)
Universität Ulm (D)
Institute of Chemical Problems for Microelectronics (RUS)
Rolls-Royce plc. (UK)
ALD-Vacuum Technologies AG (D)
Tital GmbH (D)

annual turnover of these companies is of the order €9 billion. They have diverse interests in IMPRESS, notably in aerospace propulsion, power generation, hydrogen fuel cells, software development, coating technology, casting and powder production – not to mention space hardware development. Other companies have expressed a strong interest in joining as the project evolves. One of the gratifying aspects of IMPRESS is the fact that industry has been energetically involved from the outset and has defined the measurable targets of the project. These companies will now have direct exposure to the new knowledge and will be first in line for licensing and patenting.

International Space Station (ISS)

The ISS, as well as other microgravity platforms, will be used extensively to perform benchmark experiments on these intermetallic alloys. The unique data will make a vital contribution to the project, by generating fresh knowledge, confirming theories, validating computer models and optimising industrial processes.

The ISS facilities that will be used by the IMPRESS team include:

- the Materials Science Laboratory (MSL), which will permit solidification experiments of high-temperature intermetallic alloy samples;
- the Electromagnetic Levitator (EML), which will allow containerless melt processing and non-contact measurement of thermo-physical properties;
- the IMPACT facility, which will permit well-defined experiments in nano-particle formation and agglomeration.

Research activities have already begun in these areas and numerous precursor experiments on parabolic flights and sounding rockets have been defined and secured.

Impact of IMPRESS

The impact of IMPRESS will be felt on many different levels. Firstly, it has the potential to give European industry a world-leading position in turbine production and fuel cell development. The economic significance of this should certainly not be underestimated because these two sectors are steadily growing; conservative market projections suggest that global demand could reach at least €45 billion by 2011.

Not only will IMPRESS greatly strengthen the global competitiveness of the European industries involved, but it will also lead to major environmental and energy-efficiency benefits. It is hoped that the results of the project will make a valuable contribution to the Kyoto Protocol on Climate Change.

On a regional level, many educational and training activities are foreseen to promote industrial research and inspire a new generation of young scientists. Dissemination via museum and trade exhibitions, TV reports, interviews and newspaper articles will also bring the new knowledge to a wider audience and, in particular, to the general public.

Not least, a number of scientific research groups from newly-acceded EU countries of Slovakia, Poland and Hungary, plus Russia, are involved and significant efforts will be made to ensure their full and active participation.

Conclusion

By integrating ground-based and space resources over the next 5 years, it is believed that IMPRESS will greatly contribute to the fabric of European research. Furthermore, it will combine the promise of great economic opportunities with environmental benefits.

ESA, as coordinator, is now in the final stage of contract preparation; the start date is expected to be July 2004. Once off the ground, IMPRESS will undoubtedly become a shining example of trans-national cooperation in materials science, with many applications that could support future space programmes. ■

Expert Return

The Expert Reentry Testbed

Marco Caporicci
Reentry and Human Transportation Division, Development Departmen
D/HME, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Marco.Caporicci@esa.int

Introduction

ESA has worked since the early 1990s to gain flight experience of atmospheric reentry in order to design crew vehicles, reusable transportation systems, planetary probes and sample return missions. In 1998, the Atmospheric Reentry Demonstrator (ARD) was successful as ESA's first end-to-end mission: launch, suborbital flight, reentry, splashdown and recovery. The results from its material samples and instrumentation meant that measurements could be compared with computer predictions. National capsules such as Express and Mirka have also flown, with various levels of success. All were characterised by relatively simple or well-tested shapes, and the thermal protection consisted mainly or exclusively of ablative materials. The European Experimental Reentry Testbed (Expert) is taking the work to the next level.

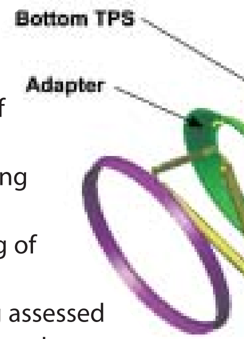
Expert, with a first launch in 2006, will help Europe to design future reentry vehicles ...

The Need for Expert

Previous work in Europe on Hermes, crew capsules and the X-38 lifting body highlighted the need for hypersonic and atmospheric entry flight data in order to benchmark the aerothermodynamic computer predictions and design tools. These consist of computational fluid dynamic analyses, wind tunnel experiments and ground-to-flight extrapolation. We still need to collect more data on a number of aerothermodynamic phenomena:

– flap efficiency and heating;
– shock wave/boundary layer interactions;
– boundary layer transition from laminar to turbulent;
– high-temperature and gas chemistry effects;
– gas-surface interaction effects (catalysis, oxidation).

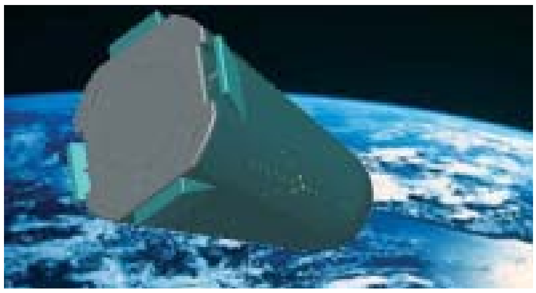
Expert is shaped to address these phenomena via dedicated measurements. A major consequence is the use of non-ablative thermal protection, so that the flow boundary layer is not contaminated by chemical species and solid particles. Of course, this makes these materials candidates for future reusable vehicles, although a single flight will not generate data on extended usability.



Also, special care has to taken with the positioning and number of sensors, the recording of the free stream parameters during entry using by the air data system, and in the storage and telemetry downloading of the data. Innovative and promising measurement techniques are being assessed carefully because they might improve the quality of the flight database.

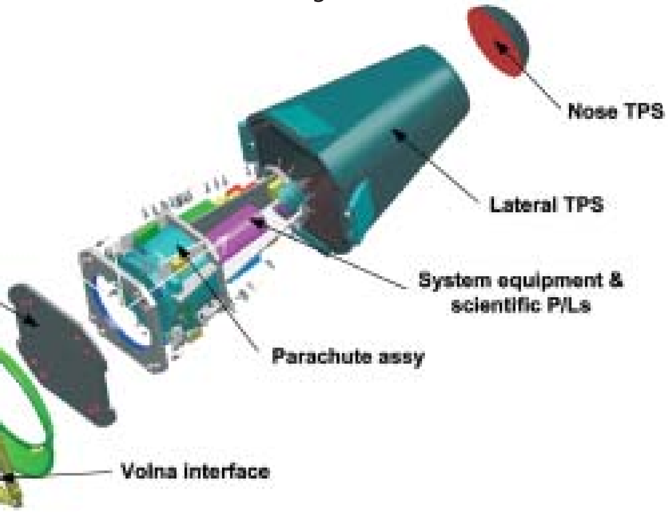
The Expert Project

A feasibility study under ESA's General Study Programme in 2001 analysed and traded-off various candidate shapes. An initial assessment of the mission, layout and subsystems provided confidence about its feasibility. The result was a



low-cost conical capsule with a blunt nose, lofted by the Russian submarine-based Volna launcher. Expert is designed for suborbital flights within a reentry speed range of 5-7 km/s. The recovery site is the Russian military base on the Kamchatka peninsula.

Expert's development was approved at the Ministerial Council in November 2001 as part of of the Interim Technology Phase for Reusable Transportation and Atmospheric Reentry. ESA then refined the vehicle shape and identified a set of experiments. By 2003, subscriptions by Member States allowed development of the first flight unit to begin. The Phase-B contract, with Alenia Spazio as prime and CIRA as the scientific payload coordinator, will take the Expert system up to the Preliminary Design Review, for Phase-C/D to begin in early 2005. At least three flights using dedicated flight units are planned for different reentry conditions, starting in 2006.



The Expert Design

Expert's shape is composed of simple geometrical elements: an ellipsoidal blunt nose, a conical body, a clothoid ellipse/cone junction, and four flat sides with four fixed flaps (two open and two closed). At launch, it is suspended nose-down on the third stage of Volna via an interface adapter. The parachute bay is in the central cylindrical area. The nose, external shield and the four ramps will carry the aerodynamic drag. The external shield consists of four curved corner panels and four triangular panels. Their junctions, and those with the internal structure, will move to cope with the thermal gradients.

The parachute bay cover will jettison to trigger the sequence of mortars for canopy deployment. Expert will impact the ground nose-first so it will probably not be reusable but the structure should allow recovery of the

stored data and as much as possible of the avionic equipment.

There are three main areas of thermal protection: the carbon/silicon carbide nose cap; metallic surfaces (PM1000, Gamma-TiAl) on the conical sides and base; and ceramic flaps, which host several experiments.

The avionics architecture is as simple as possible, making major use of commercial off-the-shelf equipment. Modular software for system application and flight control will be developed. The mission application software includes spacecraft separation monitoring, polling of the onboard units and activating experiments, formatting and storing gathered data, managing transmitted telemetry, and controlling the parachute opening process. The flight control software includes attitude control loops (GPS, accelerometers), thruster valve activation and valve monitoring and redundancy management. A guidance system based on cold-gas thrusters will be used typically for nutation damping.

All the data will be stored in a dedicated mass-memory unit. Some will also be transmitted to ground during specific portions of the mission.

A set of experiments is being defined together with the measurement techniques. These include an air data system; pressure, force and heat flux measurement; catalytic gauges; electron beam fluorescence for measuring the concentrations of chemical species; Langmuir probes and reflectometers.

Conclusion

Expert will help to mature our understanding of reentry requirements for future manned missions as the focus shifts from commercial reusable launch vehicles to Space Station cargo transportation and future human exploration missions. ■

What is MSM-M?

The Development Department of MSM

Alan Thirkettle
Head of Development Department (MSM-M),
D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Alan.Thirkettle@esa.int

Introduction

The core responsibility of MSM-M is the development of the infrastructure items being delivered by ESA to the International Space Station: the Columbus module, the first Autmoated Transfer Vehicle (ATV; Jules Verne), the Cupola, Nodes-2 and -3 and the European Robotoic Arm (ERA). We have already delivered the environmental control and life-support (ECLS) elements for the three Multi-Purpose Logistics Modules (MPLMs) of the Italian Space Agency (ASI), all of which have flown, and all the European contributions to the prototype Crew Return Vehicle, the X-38, unfortunately cancelled by NASA. The department provides ESA's representative on the Station's top technical forum, the Space Station Control Board (SSCB). We are also responsible for developing the family of building blocks, in the form of studies, technologies and pre-developments, for the Directorate's future activities in Exploration and Station enhancements.

MSM's Development Department is building ESA's main contributions to the ISS...

To carry out this work, there are:

- four main development project divisions;
- a Future Activities Office;
- a Product Assurance and Safety Manager (who is both the ESA interface to NASA for PA/S matters at the infrastructure level and the ESA representative on the independent ISS Safety Review Panel);
- a Systems Support Office and the ESA Houston Office, both of which serve not only all MSM-M projects but also all other ISS activities of the Directorate.

In total, we are 52 staff and 16 support contractors, located in ESTEC, Les Mureaux (F), CNES Toulouse (F) and Houston, and we are backed up by some 25 man-years of functional support from our colleagues in the Technical Directorate.

Columbus Project Division

MSM-MC, managed by Bernardo Patti, is responsible for developing the Columbus module. It also has the mission management responsibility for Flight 1E to ensure that all elements for the successful launch of Columbus, including its payload rack facilities, external payloads and carrier, ground segment, launcher interfaces, operational support products and crew readiness, are ready. Columbus is well advanced: it has completed its qualification and acceptance programme at the module level. This spring will see a series of end-to-end tests involving the module, its payloads and the ground segment, including the NASA side of the loop. Columbus was on track for launch in October 2004 until the tragedy of *Columbia* last year, and now faces the prospect of going into storage later this year, until a few months before its revised launch date of late 2006.

ATV Project Division

MSM-MA, led by Robert Lainé and sited at the Les Mureaux facility of prime contractor EADS-ST, is responsible for the development of ATV. It has the mission management responsibility to ensure that all elements for launching the first ATV are ready, including its pressurised cargo, propellants, water and gases, ground segment, launcher interfaces, operational support products and crew readiness. ATV has had a difficult development ride, unsurprisingly for such a complex vehicle, but it is now in the final stages of system functional and physical integration and test.

The main hardware elements are at the integration site in Bremen (D), and this summer will see the complete Flight Model shipped to ESTEC for environmental tests before delivery to the Kourou launch site early in 2005. Meanwhile, the system software is being tested; its various versions with different levels of functionality and complexity are being evaluated.

Human Spaceflight Systems & Robotics Division

MSM-MR, headed by Rainer Steinmeyer, has the job of completing ERA, managing the coordinated robotics activities agreed with the Technical Directorates, and leading the human systems future activities of the department. ERA has been through its qualification and acceptance programme, and the flight hardware is being prepared for storage. Its original launch and operational scenario, as part of Russia's Science & Power Platform, has been in jeopardy for several years because of the financial problems of the Russian space agency. An alternative scenario is again this year being seriously sought, as part of the overall ISS Programme Action Plan.

With respect to future activities, the devlopment of closed-loop ECLS systems is well advanced, with integrated demonstrators under ground test and preparation for flight test of an electrolyser (the only part that is gravity-sensitive) under way. Studies of inflatable modules and their associated ergonomics are being made. All of these activities are also supported by the Columbus division.

Reentry and Human Transport Division

Marco Caporicci leads MSM-MX, which is responsible for all transportation activities other than launcher development. Created to manage the X-38/CRV projects, which were cancelled by NASA as part of their cost-reduction exercise in 2001-2002, the division is now responsible for running the Interim Technology Programme for reentry and reusable launch systems, managing coordinated activities agreed with the Technical Directorate, and leading the study activities for future cargo and human transportation elements that support the Exploration and ISS enhancement activities.

The Expert aerothermodynamic flight testbed is being built to validate the computer-model and wind tunnel data for designing reentry vehicles (see the article on Expert in this issue). Derivatives of the ATV as a platform for scientific payload download and cargo up/down logistics are being studied. Development of the International Berthing and Docking Mechanism, initiated as part of ESA's CRV contribution, continues, and ideas for a flight demonstration are being generated.

Nodes/Cupola Office

Philippe Deloo *is* the MSM-MN office! The Cupola is one of the barter elements from ESA in exchange for 'goods and services' from NASA instead of paying hard currency. It is almost complete: the Structural Test Model has been delivered to Houston and the Flight Model will arrive at the Kennedy Space Center this summer. Until about a year ago, we were only observers in the Nodes project, since the technical, programmatic and contractual management was delegated to ASI. However, there has been a rapid enlargement of ESA's role over the last year following the revelation of significant cost overruns under the ASI contract. It is not yet decided if there will be a change in management responsibility for the remaining work; if so, ESA staff involvement will have to grow quickly!

Future Activities Office

MSM-MF, under Claus Reimers, coordinates all the future activities work in the various divisions, whether robotic, habitation or transportation and whether funded by the STEP, General Studies or ISS Development Programmes. Dietrich Vennemann has worked full-time on the Aurora programme for its first 3 years. The office's main activity has been studies into a small cargo-return system based on Russian inflatable heat shield technology, and the associated flight demonstration using a Volnya launcher later this year. In addition, the office carries the burden of coordinating the Directorate's interface to ESA's Technology Research Programme (TRP), General Support & Technology Programme (GSTP) and General Studies programme, and representing us on a number of the steering boards.

System Support Office

MSM-MS, headed by Arie Bossche, has a truly horizontal function within the department. With the support of the Houston Office, they analyse the multitude of proposed Station changes issued by NASA, determine whether they are applicable and then follow up with the relevant project teams via the department's Engineering Board to ensure a minimum impact on ESA. They are also responsible for maintaining the Department's technical system and system support requirements (i.e. the Agency's baselines) and the verification control methodology and documents. They are the custodians of the Bilateral Verification, Hardware/Software Exchange and Documentation Exchange books that are agreed with our ISS Partners. This office, in the person of Pia Mitschdoerfer, is also responsible for internal departmental communication and reporting, without which we would soon cease to function effectively.

ESA Houston Office

On the fifth floor of Building 4S at NASA's Johnson Space Center, one finds the ESA Houston Office, MSM-MH, managed by Dave Wyn Roberts. This office is the eyes, ears and mouthpiece of ESA within the NASA ISS Program Office. As such, they represent the Directorate's technical departments (development, operations and utilisation), and administratively support the local ESA astronauts and their direct support staff. In addition to the Station, Dave and his team keep up with the Shuttle programme and the various technology efforts that go on within the confines of JSC, to ensure that we all have the latest reliable information.

Summary

So that is the MSM-M Department. Like all the others, we rely on the full-time support of team members from other Departments and Directorates. We have our Project Controllers (Klaus Schmidt and Andrea Amaldi), our Configuration Managers (Bram Bekooy and Rob Meijer) and our Contracts Officers (Patrizio Graziano, Emilio Cerou and Franck Germes), without whom we could not function as ... MSM-M.

Young Engineers' Satellite

Educational Demonstration of SpaceMail

Philippe Willekens[1], Alexander van Dijk[2], Michiel Kruijff[2], Erik van der Heide[2], YES2 Team
[1]ESA Education Office; [2]Delta-Utec SRC, Leiden, The Netherlands
Email: Philippe.Willekens@esa.int; delta-utec@delta-utec.com

The AIR capsule begins deployment on the 30 km-long tether from Foton-M3.

Introduction

In April 2002, the ESA Education Office and the Dutch company Delta-Utec SRC began the development of 'YES2 SpaceMail', the second Young Engineers' Satellite. This first-ever student-built reentry capsule has two prime objectives:

European students are developing innovative tethered and reentry concepts for flight in 2006 ...

– provide European students with spectacular and motivating hands-on experience;
– demonstrate the SpaceMail concept of returning a small capsule from space. This will use two new technologies: a tether rather than a conventional rocket engine for deorbiting, and a capsule that will land in Russia using innovative methods of deceleration and thermal protection.

The YES2 mission is supported by ESA's Human Spaceflight Directorate, and is envisaged to be launched in 2006 as an educational payload attached externally to the Russian unmanned Foton-M3 spacecraft. After 2 weeks in orbit, YES2 will deploy the small reentry capsule on a 30 km-long, 0.5 mm-diameter tether and 'swing' it back to Earth, landing it safely and accurately. Largely developed and built by students and young engineers, YES2 will demonstrate the SpaceMail concept as an innovative route for returning small payloads from low Earth orbit.

SpaceMail Concept

SpaceMail involves a tether system on a spacecraft swinging a capsule into a reentry trajectory, providing flexibility in payload return. This concept could deliver experiment data and other products in small packages like a postal service. Accurate landing can be achieved through the low-complexity, low-cost and lightweight tether deployment hardware in combination with a robust deployment control strategy.

The YES2 team has been designing, developing and testing inflatable technology as one of the reentry options, guided by the principle of 'inherent safety'. The capsule is inflated in space, during a specific phase in the tether deployment, and all in one go. The capsule will function as its own parachute, without the need to change configuration, both in the hypersonic (entry) and subsonic (landing) regimes. With this approach, there is no need for a second-stage inflation or actual parachute to guarantee a soft landing. The overall system is therefore considerably simpler and the number of failure modes is reduced.

Massimo Busetto (Univ. Padova) integrates the YES2 onboard computer as part of the tether test set-up at the Center of YES2 Expertise Krefeld.

Tethers in Space

The use of tethers in space is not new. They have been studied for many years and several applications are being considered. Apart from momentum-transfer for sample return (SpaceMail) or orbital transfer, applications include rotating tether systems for inducing artificial gravity on the way to Mars, and electrodynamic tethers as propellantless thrusters for satellite deorbiting or drag compensation. Since 1966, about 15 generally successful experimental tether missions have flown in space, demonstrating the various principles. The YES2 SpaceMail demonstration is the logical next step (most notably to SEDS1 and SEDS2 of 1993 and 1994, respectively) in the development of tether applications. It will be the first European-built tether system to operate in orbit and will also be the first to demonstrate accurate orbit insertion. Following a successful demonstration, the tether system could be used as is with almost any current reentry capsule design.

How Does it Work?

Returning to Earth from a circular orbit at 400 km altitude requires a deceleration of about 120 m/s. A tether can provide this through two effects: the gravity gradient (80 m/s) and the swing of the tether (40 m/s).

During tether deployment, the capsule and spacecraft are forced by their mechanical connection to orbit the Earth with the same period – that of their centre of mass. Gravity is stronger closer to Earth, so the capsule at the lower end of the tether needs a higher speed to remain in a circular orbit. However, while connected to the tether, the capsule is kept artificially below that speed. If the tether is cut, this restriction disappears and the capsule will drop into a new orbit matching its speed. The perigee is lowered by up to 13 times the tether length.

The tether is deployed downwards at a large forward angle with respect to the vertical owing to a combination of inertia, coriolis and gravity-gradient forces. When deployment is completed, gravity-gradient forces will pull it back to the vertical, causing it to swing. So cutting the tether near to the vertical means the backward swing adds another 40 m/s of deceleration to the capsule.

The current layout of YES2 on the Foton battery pack. The canister (red) holds the tether, which is connected to the MASS cylinder (Mechanical and Data Acquisition Support System) via the 'barberpole' tether breaking system (yellow). The MASS cylinder interfaces with the inflatable AIR capsule (not shown) and is mounted on an ejection system derived from a Swedish Space Corp. design. The Fotino capsule is on top of the MASS cylinder.

YES2

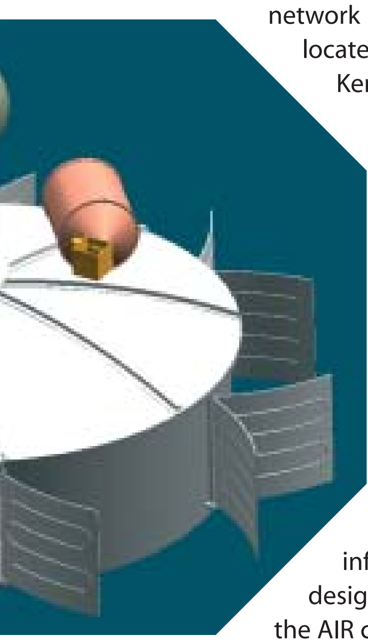
YES2 has its origins in the TeamSat cooperative venture between Delta-Utec SRC and ESA's Education Office, in which the Dutch company was responsible for the first educational YES satellite aboard the Ariane-502 test flight in 1997.

The YES2 mission is being developed by students from Europe, Russia and Canada with support from ESA. The project started in May 2002 (Phase I), with a focus of involving students from all over Europe in setting up a network of participating universities. Some 400 students from 25 universities were involved at this stage in studying the technical feasibility of the mission and coming up with concepts for inherently safe capsules. Many hands-on projects were initiated, such as a tether-deployment test rig, parabolic aircraft flight deployment testing, capsule mock-ups and drop tests, flexible heatshield development and high-temperature inflatable manufacturing technology. At the end of Phase I, a winning concept for the 'AIR' (*A*n *I*nherently-safe *R*eentry) capsule based on inflatable technology was chosen from a wide variety of

Early samples of the inflatable beams for the AIR capsule were made by YES2 student Matteo Benetti at the Italian company Aerosekur. The high-temperature beams consist of an inner layer of Kapton (transparent beam at left) with a high-strength Zylon outer layer.

innovative and interesting concepts. The phase was officially closed with a successful YES2 Preliminary Design Review at ESA/ESTEC in December 2003.

During Phase II, recently started, the detailed design of the satellite systems and the manufacturing and testing of the components are under way. For this purpose, five YES2 Centres of Expertise (CoE) have been set up with the support of the Education Office. They have been chosen from the established network in Phase I and are located at five universities: Kent (UK), Krefeld (Germany), Patras (Greece), Reggio Emilia (Italy) and Samara (Russia).



As a baseline, the YES2 mission currently involves the simplified 40 cm-diameter, 1.5 kg spherical 'Fotino' capsule to demonstrate the flexible heatshield developed for the AIR inflatable capsule. The design and development of the AIR capsule itself continues under supervision of the CoEs, who are seeking active support from European industry to have the fully-fledged inflatable capsule included on the YES2 mission. Last April, the YES2 students made a successful Critical Design Review presentation to ESA experts at ESTEC. It was the conclusion of an intense workshop in which students exchanged their design work and interacted with experts from the different ESTEC departments.

In early 2003, the YES2 team at Reggio Emillia performed drop tests of the inflatable 'GARLIC' capsule mock-up from a 100 m cliff near Reggio, Italy. Similar tests were performed with the 'LEPTON' capsule mock-up.

Russian and European students gathered in Russia for the Summer Space School Samara 2003 where YES2 was a major theme. Teams from Toulouse, Munich, Cranfield and Reggio brought mock-ups of their inflatable capsule designs for subsonic windtunnel tests (the LEPTON capsule can be seen).

Conclusion

The 'YES2 SpaceMail' project is providing an exciting opportunity for students to participate in the design, construction and flight of an actual space experiment. The tether and reentry technologies being developed are highly innovative and of broad interest to the space community. In parallel, the project has created a network of European universities where students can participate in real space projects. Some 400 students were involved during the initial phases, whereas some 30 students are now actively engaged in the detailed design and manufacture of the flight hardware. The eventual success of the mission could give a boost to tether applications in general and would show that the tethered reentry system is a viable technology for a future LEO payload-return system. It also shows that young people can be challenged with daring questions, have an innovative approach, and can provide Europe with a talented workforce for the future. ■

YES2 students tested their tether test-rig design in 2003 during an ESA parabolic flight campaign.

On Station
ISSN 1562-8019

The Newsletter of ESA's Directorate of Human Spaceflight

This newsletter is published by ESA Publications Division. It is free to all readers interested in ESA's manned spaceflight and microgravity activities. It can also be seen via the website at http://esapub.esrin.esa.it/

For a free subscription or change of address, please send an email to esapub@esa.int

ESA Publications Division / EXR-CP
ESTEC, Postbus 299, 2200 AG Noordwijk, The Netherlands
Fax: +31 71 565-5433

Editor: Andrew Wilson (Andrew.Wilson@esa.int)
Contributing Writer: Graham T. Biddis
Layout: Eva Ekstrand

ISS Education Fund

SPACE FOR LEARNING

The **ISS Education Fund** – supporting an understanding of science.
Be a part of it today

ESA is offering you the opportunity to join with leading organisations and individuals across Europe in supporting the ISS Education Programme. The Programme seeks to provide teachers in every school with a unique range of learning resources that use the magic of space to stimulate and capture the interest of young people. Paper-based education kits, DVDs, PC-based learning tools and interactive online education resources for use in the classroom are all being produced and disseminated free of charge to teachers.

The Programme is supported by the new **ISS Education Fund**. Members of the Fund enjoy a wide range of benefits, including marketing and PR, networking opportunities and enhanced access to the facilities and people of the European Space Agency. More importantly, their contribution helps to make a difference to Europe's young people and to build an understanding of science.

The **ISS Education Fund** – supporting the education programme, helping teachers, stimulating young people.

Join the ISS Education Fund

You might not be able to become an astronaut – but now you can join them and make a difference to Europe's young people

The European Astronaut Corps joins the Education Fund.

Current members include:
- European Astronaut Corps
- UNESCO
- Dutch Space
- Ogilvy Public Relations
- Armagh Planetarium

and many more – see **www.esa.int/issef**

It's your opportunity – be part of it
ISS Education Fund Membership
- Find out about joining
- Discover the benefits
- See how you can make a difference.

Contact:
Fiona Wilson
+31 71 565-6042
Fiona.Wilson@esa.int