Columbus: Ready for the International Space Station

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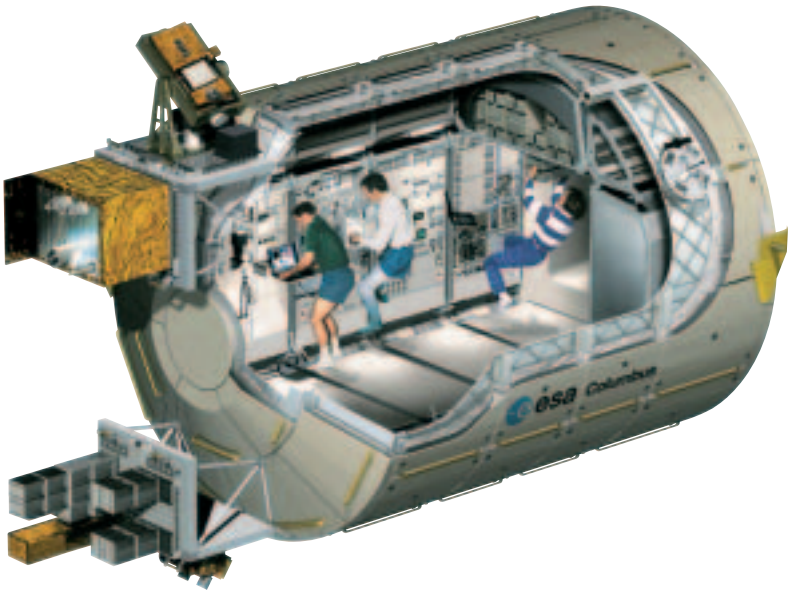
One of the key contributions to the development and operation of the International Space Station (ISS) is ESA's Columbus Laboratory Module. It will be transported to the ISS, together with its payload complement, on Space Shuttle Assembly Flight 1E in 2006. Columbus's readiness for launch requires the availability not only of the Module itself, but also three other major elements being provided by ESA, namely: the Ground Segment, consisting of the Columbus Control Centre and the User Support and Operations Centres (USOCs), the Operations products, and the Crew Training.

Status of the Four ESA Elements

The ESA-provided elements required for Flight 1E readiness fall into four categories:

The Flight Segment

The flight segment consists of the Columbus Laboratory Module and its associated Payload Complement. The Laboratory Module has been developed for ESA under the Prime Contractorship of EADS-ST in Bremen, Germany, with a major contribution from Alenia Spazio of Turin, Italy. The Module has already successfully completed its Qualification Reviews 1 and 2, and is currently undergoing testing to support the Review 2 close-out activities, which are planned to be completed in March 2005.



The Columbus Laboratory Module

The Columbus Payload Complement is composed of four pressurised payload racks (so-called 'ISPRs'), namely: the Biolab, the European Physiology Module (EPM), the Fluid-Science Laboratory (FLS), the European Drawer Rack (EDR), and two unpressurised external payloads, EuTEF and SOLAR. While the four pressurised payload racks will already be integrated into the Columbus Laboratory Module prior to launch, the unpressurised external payloads will be accommodated on a dedicated cargo carrier provided by NASA.

The Ground Segment

The Ground Segment is made up of two distinct elements, the Columbus Control Centre and the User Support and Operation Centres (USOCs).

The Columbus Control Centre, developed under the Prime Contractorship of DLR in Oberpfaffenhofen (D), was inaugurated in October 2004 and is already supporting mission preparation and mission simulations from its control rooms.

The European USOCs will carry out the majority of tasks related to the preparation for flight and in-flight operation of the Columbus payloads. Based at existing national centres specifically equipped by ESA for ISS activities, these USOCs will act as the link between the user community and ESA's ISS utilisation organisation. They will interact with the scientists at their User Home Bases by disseminating experiment data to them, and receiving and processing requests for experiment scheduling.

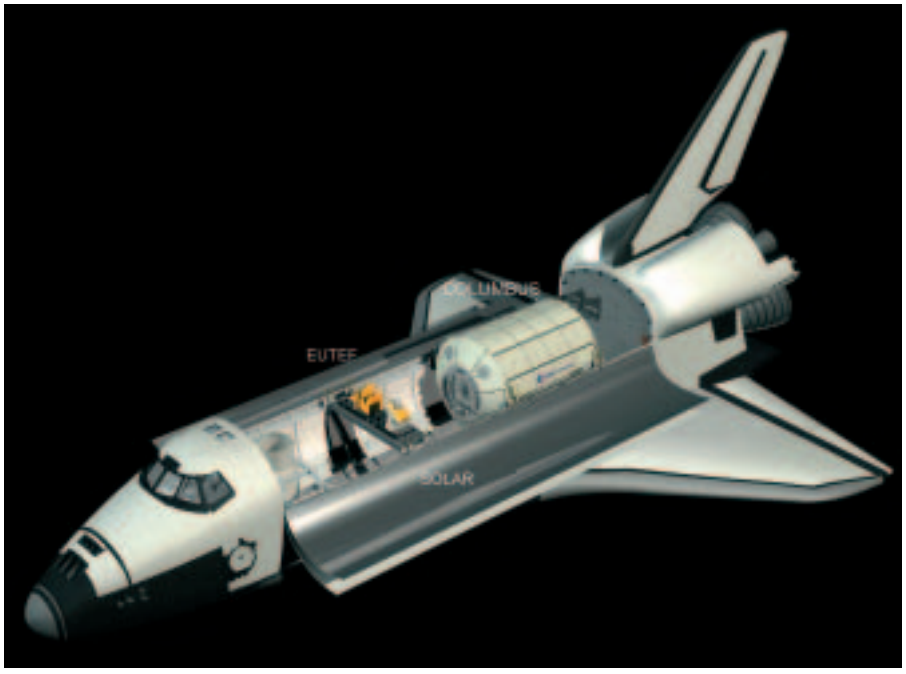
There are three basic levels of responsibility within the USOCs:

– Facility Responsible Centres (FRC) are delegated overall responsibility for a rack-level payload.
– Facility Support Centres (FSC) are delegated responsibility for a particular sub-rack payload, such as a facility insert, experiment container, drawer payload, or bioreactor.
– Experiment Support Centres (ESC) are delegated responsibility for single experiments.

The USOCs' current major activities involve the completion of infrastructure build-up and operations preparations. The former is almost complete, with the remaining part being mainly related to the installation of the common equipment supplied by ESA. Some of the USOCs have already started preparations for experiments in the framework of the early ISS activities before Flight 1E, in order to gain early experience of ISS operations.

The Operations Preparations

Onboard and ground Operations Products such as procedures and displays are close to finalisation. The verification of procedures began in September 2004, and



Columbus in the Space Shuttle's cargo bay (artist's impression)

The Space Shuttle's Return to Flight

The tragic loss of 'Columbia' in February 2003 caused a major perturbation in the planned Shuttle mission schedule. The causes of the accident have been identified by the Columbia Accident Investigation Board (CAIB), whose report listed 15 recommendations that had to be implemented before the Space Shuttle's return to flight.

NASA then established an Implementation Plan that addressed each of these recommendations in turn, as well as an additional 24 recommendations not related to the return to flight, coming either from the CAIB or from internal considerations. At the time of writing (December 2004) five of the 15 recommendations are formally closed out. A further five are in the final paperwork verification stage, and the final five are still being in work, albeit at an advanced stage.

The first return-to-flight Shuttle mission is currently planned for mid-May to mid-June 2005, subject to successful completion of the modifications to the thermal-protection insulation on the Large External Tank, debris from which caused the critical damage to the leading edge of Columbia's wing.

some of them have been used for system validation. The flight operations teams from ESA, DLR and NASA have already conducted simulations of the assembly procedures for the Flight 1E mission.

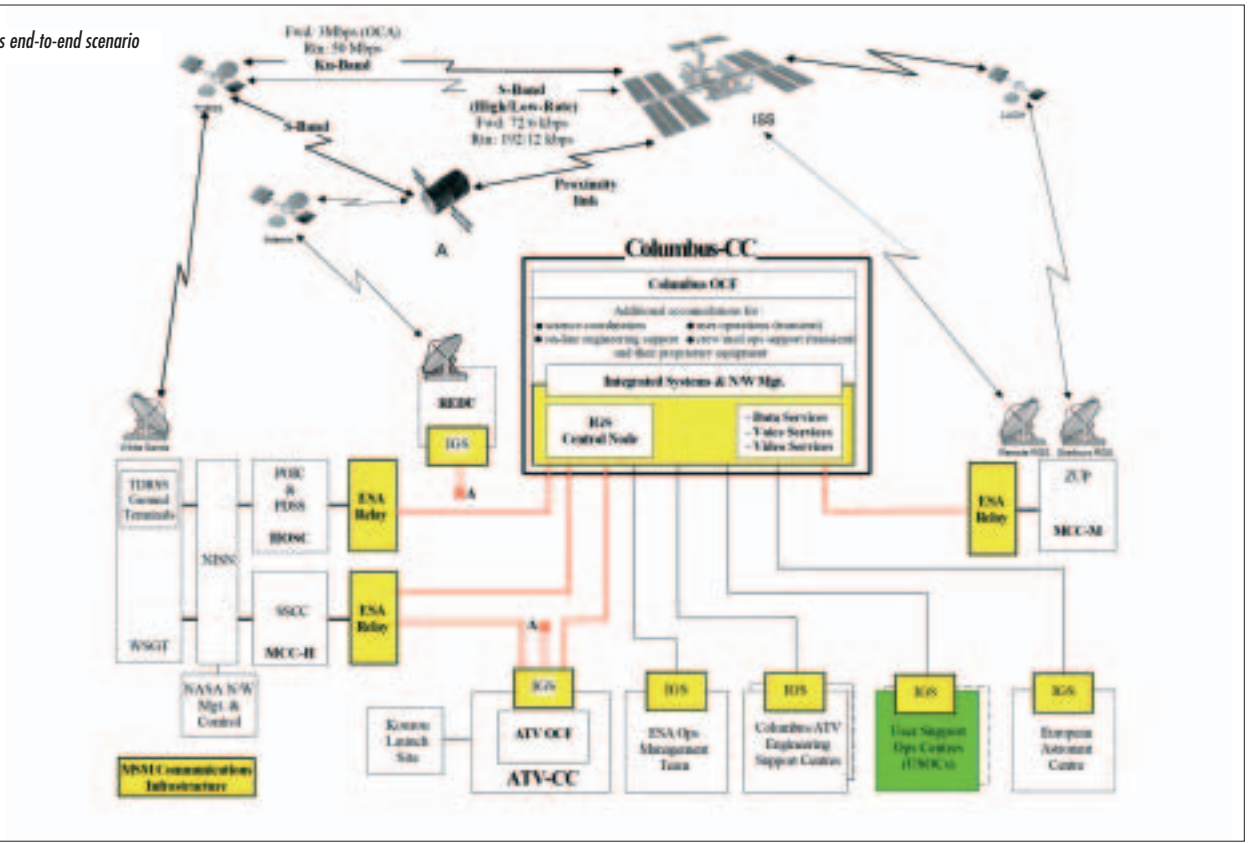
The Crew Training

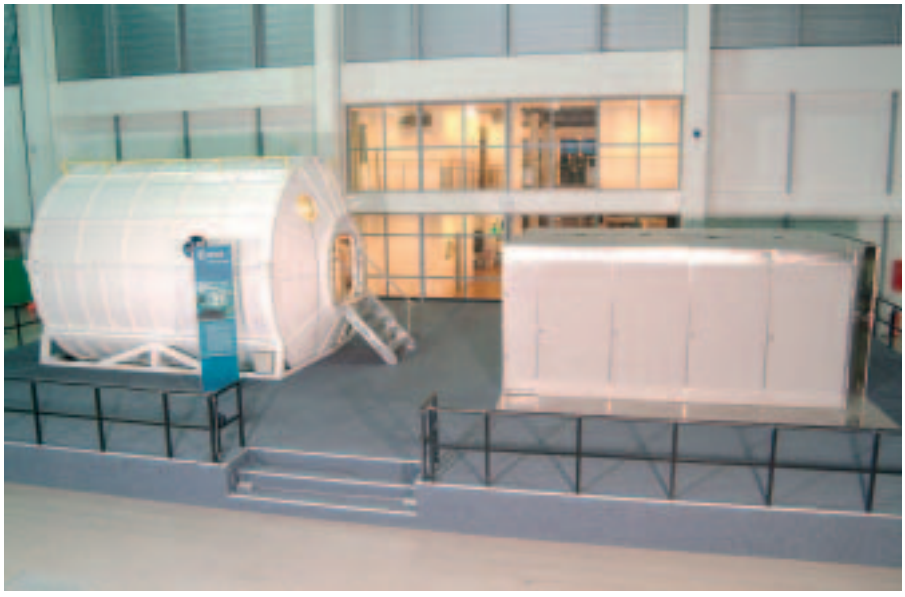
The development of the training for astronauts working with the Columbus systems was completed in 2004. The payload training itself will be concluded in spring 2005. A Columbus training simulator running the Data Management System (DMS) flight software and a Columbus Mock-up for hands-on training activities are ready for use. Stand-alone training facilities for the EPM, EDR, Biolab and FSL are ready to support generic payload training.

During the past three years an industrial instructor team has been trained and certified for crew training, and about 350 hours of astronaut training have been developed. The instructor team became fully operational in 2004 and has already conducted two courses for advanced astronaut training for six astronauts, and five training courses for a total of sixty ESA and NASA flight controllers and operations personnel.

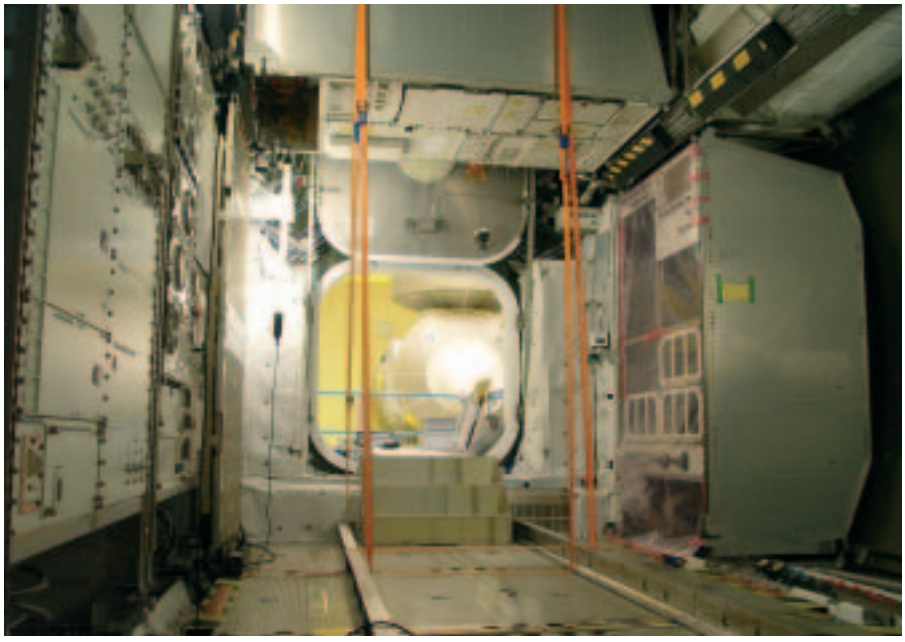
The Columbus Simulator and the Columbus Mock-up located at the European Astronaut Centre (EAC) in Cologne-Porz (D) constitute the two main facilities for the training of astronauts on Columbus systems.

The Columbus end-to-end scenario





The Columbus Mock-up (left) and the Columbus Simulator (right) at the European Astronaut Centre (EAC)



The interior of the Columbus flight model

The Integration for Flight 1E

The declaration of Flight 1E readiness requires the integration of, and the verification of the interfaces between, the various ESA-provided elements described above. The originally planned October 2004 launch date, prior to the 'Columbia' tragedy, would have ensured a smooth transition from the Columbus development stage to the operations phase. The Shuttle's grounding and the resulting two-year delay for Flight 1E have required a total reworking of the planning. Instead of slowing down the development programme, it was decided to complete the baselined set of activities according to the original planning, which involved in particular the completion of the Flight and Ground Segment Development together with the testing of their interfaces (see accompanying figure). This has minimised the impact on the development contracts and allowed the early identification of potential interface issues well before the new Flight 1E launch date. This in turn will reduce the remaining technical risks in the programme.

The payload integration and testing has therefore been followed by the System Validation Tests 1 and 2, to verify the interfaces between the space and ground segments.

Payload Integration

Payload integration took place between April and June 2004. During this period, the interface compatibility between Columbus and its pressurised payloads has been verified on the Columbus flight model. This test campaign involved the execution of individual tests for each Payload Facility, followed by an Integrated System Test.

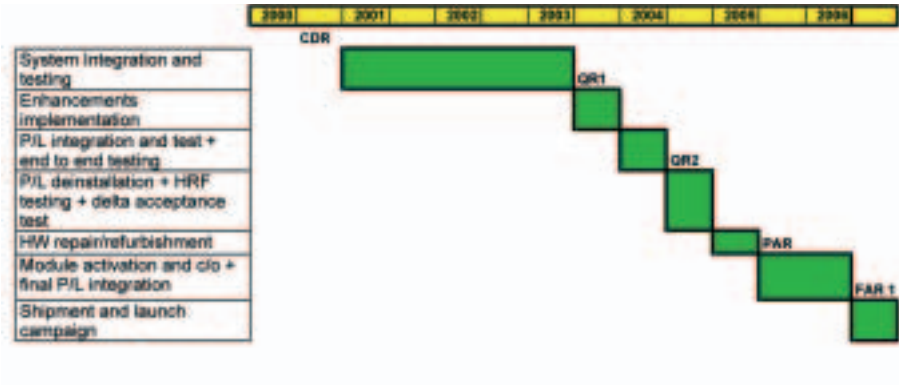
System Validation Testing

Following payload integration, the interfaces between the flight and ground segments have been tested by so-called System Validation Tests (SVT): SVT 1 used the Columbus Electrical Test Model (ETM) together with the Columbus Ground Segment, and SVT 2 the Columbus Proto-flight Model (PFM) outfitted with the pressurised payloads, in combination with the Columbus Control Centre and the USOCs.

SVT 2 was the first time that all of the major programme elements had been tested together. The functional configuration for the test was therefore extremely complex and its execution was very challenging due to the many interfaces involved. Its successful completion therefore represented a major milestone in the progress of the overall programme.

The Shipment of Columbus to KSC

Following the completion of the System Validation Tests, the items making up the European payload complement have been shipped back to their respective industrial contractors for refurbishment and enhancement. The Columbus Module itself



The Flight 1E Columbus integration and launch-preparation programme

will also undergo some refurbishment. In order to reduce the programme risks still further, some extra testing is being planned, which will include end-to-end testing of the external payload elements and extended software endurance testing.

Thirteen months prior to launch, the Columbus Module and its Payload will undergo a second round of integration and testing, in preparation for their shipment to Kennedy Space Centre (KSC). The integration phase, together with the packing activities, will be timed to allow the Columbus Laboratory to undergo a seven-month launch campaign at KSC.

Conclusion

With the completion of the Payload Integration and Test and end-to-end Test Campaigns (SVT1/SVT2), Columbus has successfully passed its Qualifications Reviews (QR1/QR2), thereby officially completing the development phase. Activities in 2005 will focus on completion of the remaining integration work, on some extra testing aimed at further reducing the mission risks, and on the final launch preparations. Current planning by ESA and EADS-ST foresees the packing and shipment activities to start in Europe in the December 2005/January 2006 time frame, in order to allow the shipment to Florida of the Columbus Module, with the Payload Racks already installed, in the first quarter of 2006 in good time for the final launch preparations.