ESA's Manned Spaceflight Ground Segment

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Introduction and Scope

ESA's Manned Spaceflight Ground Segment will provide the control facilities and communications infrastructure for Columbus and the Automated Transfer Vehicle (ATV), as well as communications for the distributed ESA payload operations. The ESA Council decided on 16 December 1998 that the Columbus Control Centre (COL-CC), together with ground communications management and central node, will be located at DLR/Oberpfaffenhofen (D), while the ATV mission control centre (ATV-CC) will be at CNES in Toulouse (F). ESA payload operations will be conducted from a number of User Support and Operations Centres (USOCs) in participating countries. ATV and Columbus operations will also be supported by a number of industrial sites and from ESTEC, where the Operations Management Team (OMT) function will reside. The ground segment also provides facilities for ATV and Columbus crew training and for payload compatibility testing with the Columbus infrastructure. The training facilities for Columbus and ATV will be at the European Astronaut Centre (EAC) in Cologne (D), and a second Columbus training facility will be integrated with the Space Station Training Facility (SSTF) in Houston. The Rack Level Test Facility (RLTF) for payloads-to-Columbus compatibility testing will be located in Bremen (D), at the Astrium integration site.

Development of the control and communications system for ESA's Station elements and payloads is well advanced...

Fig. 1. DLR control room to be used for COL-CC (seen here before installation of the Columbus-specific facilities).

Columbus Control Centre (COL-CC)

COL-CC will be an ESA facility hosted at and making use of the resources/infrastructure provided by DLR/Oberpfaffenhofen. It will adapt the DLR mission control building previously used for the operations of the Spacelab-D2 and Euromir missions (Fig. 1).

COL-CC will operate Columbus in close cooperation with the Space Station Control Center, Houston (MCC-H) and the Payload Operations and Integration Center (POIC) at the Huntsville Operations Support Center (HOSC). It will also provide support functions for payload operations such as:

- routing of telecommands from the payload operations site to Columbus,
- distribution of support data to the USOCs;
- archiving of low- (S-band) and medium-rate (Ku-band) telemetry, telecommands, audio and video, and
- local payload operations rooms.

Columbus system and payload commands will be uplinked via MCC-H. Columbus telemetry downlinked via S- and Ku-band will be received respectively from MCC-H and HOSC for processing. COL-CC will also receive processed data on overall ISS status and the space-to-ground links to MCC-H, POIC/HOSC,

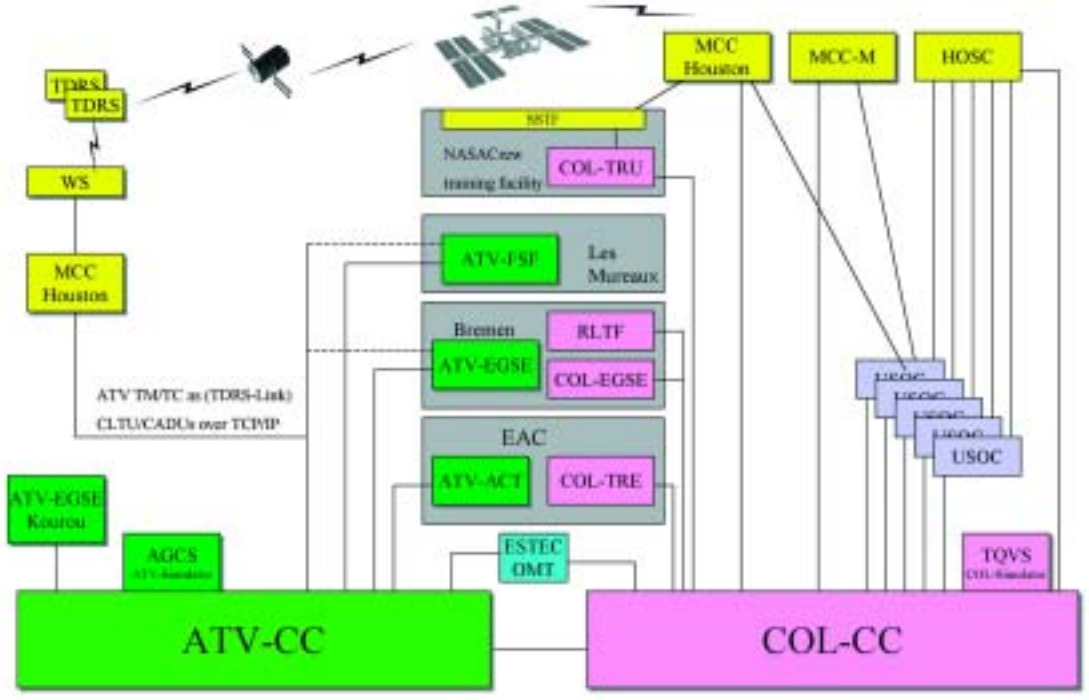

Fig. 2. The overall ground network architecture.
ACT: ATV Crew Trainer.
AGCS: ATV Ground Control Simulator.
CLTU/CADUs are CCSDS-standard (Consultative Committee for Space Data Systems) frames for telemetry & telecommand.
FSF: ATV Functional Simulation Facility.
TDRS: Tracking & Data Relay System.
TQVS: Columbus Training, Qualification & Validation Subsystem.
TRE: Columbus Trainer in Europe.
TRU: Columbus Trainer in USA.
WS: White Sands, New Mexico, USA (TDRS ground terminal).
Other acronyms are explained in the text.

and the Russian Mission Control Centre (MCC-M).

For the COL-CC monitoring and control subsystem, the Columbus Ground Software (CGS) support package will be used, expanded for control centre operations. The TQVS (Training, Qualification & Validation Subsystem) flight system simulator – part of COL-CC and used for ground operator training – will also be based on CGS.

CGS was developed for Columbus and is already in operational use as part of different flight system development and verification support systems, as well as other systems part of the Columbus ground segment.

The following ground support systems are based on CGS:

- Columbus Electrical Ground Support Equipment (EGSE),
- Columbus software integration and validation facilities (SITE),
- crew trainers (TRE & TRU),
- Columbus flight system simulator at the NASA Software Development and Integration Laboratory (Software Verification Facility),
- the Columbus facility for payload compatibility tests (RLTF).

CGS software is also used by NASA for its ISS Software Verification Facility and the ISS Mission Build Facility, and by ESA for DMS-R, ATV and other spacecraft ground support systems.

Using the CGS-based monitoring and control system, together with the qualified CGS-based Columbus Mission Database from the Columbus Phase-C/D at COL-CC, reduces the risk of incompatibility between the ground and flight systems.

Ground Communication Network

The resources and services of the ground communication network will also be monitored and controlled from DLR/Oberpfaffenhofen. This includes the management of the switching nodes, the provision and monitoring of connectivity for data, audio and video services, and the related audio and video equipment as well as the Data Services System (DaSS). Columbus and ATV will be using NASA and Russian space-to-ground links, so ESA's ground network will have to interface with a number of existing NASA and Russian facilities. The ground network data support service system will therefore need to support a number of different interface data protocols.

Nonetheless, the DaSS will provide a single standardised protocol to all Columbus payloads for telecommanding, telemetry (low- and medium-rate), and processed data from the different ISS mission control centres. The standardised and secure DaSS interface is also foreseen for ATV as the interface for ISS processed data and the telemetry/ telecommand link via Moscow.

To summarise, ESA's ground network will provide interfaces to:

- Mission Control Centres: COL-CC, ATV-CC, MCC-Houston, MCC-Moscow, POIC/ HOSC,

– crew training facilities: EAC-Cologne and SSTF-Houston,
– engineering support centres: Astrium GmbH, Bremen (D); EADS-LV, Les Mureaux (F); Astrium SAS, Toulouse (F); ALTEC, Torino (I),
– ATV launch site: Kourou (via the French ICARE network),
– Operations Management Team: ESTEC,
– payload operations centres (USOCs/Facility Responsible Centres): MUSC, MARS, CADMOS, Erasmus, DAMEC, DUC, BIOTESC, B-USOC and IDR.

These interfaces will use rented and on-demand available lines. Fig. 2 shows that most communications are routed via COL-CC. , However, telecommands and telemetry for payloads not aboard Columbus will be routed directly between the MCC-M or POIC/HOSC to the payload operations locations. Also, the Columbus payload high-rate Ku-band data will be routed directly from POIC/HOSC to the payload control centres. Nevertheless, all those links will be controlled from COL-CC.

Fig. 3. The ATV control centre, now being built, will be hosted at CNES premises in Toulouse (F).

ATV Control Centre (ATV-CC)

Although ATV is a highly automated spacecraft, some onboard functions need to be controlled by the ground. In particular, the flight dynamics will be a shared activity between the onboard software and the ground. ATV-CC (Fig. 3) will have a sophisticated set of flight dynamics support functions, in addition to conventional monitoring and control.

Telecommand and telemetry routing are dependent on the different ATV operations phases (free-flying, docking, docked). ATV command and control will follow three different paths:

– NASA TDRS satellites, via MCC-H during free-flight,
– radio-frequency proximity link, via the Russian Zvezda module and MCC-M during the approach and docking phase,
– bus connection with Zvezda via MCC-M when ATV is docked (Fig. 4).

ATV-CC exchanges telecommands and telemetry with MCC-M in the form of CCSDS-standard packets over a DaSS protocol. The DaSS protocol ensures the necessary security level as well as standardisation of the MSM data exchange. On the TDRS link, via MCC-H, ATV-CC delivers telecommands in the form of encrypted packets embedded in CCSDS CLTUs and receives ATV telemetry in the form of CCSDS CADUs. These CCSDS data frames are exchanged between ATV-CC and MCC-H over a standard protocol. At the MCC-H interface, CNES equipment converts the CCSDS data in both directions as a clocked serial bit-stream. The space/ground communication path with ATV is then established via the TDRS satellites.

ISS and ATV onboard data and ground segment data from MCC-H, MCC-M and ATV-CC are collected by the ground communication network and exchanged between the three control centres in the form of processed data over a DaSS protocol.

ATV-CC hosts the ATV mission database. The ATV-CC operational database used by the monitoring and control subsystem, as well as by the flight dynamics subsystem, directly uses the data definitions provided by this qualified database. As for COL-CC, ATV-CC will also be equipped with a flight element simulator, to support ATV-CC verification, operations procedures verification and ground operator training. The simulator will also support joint multi-segment training involving ATV-CC, MCC-H, MCC-M and COL-CC.

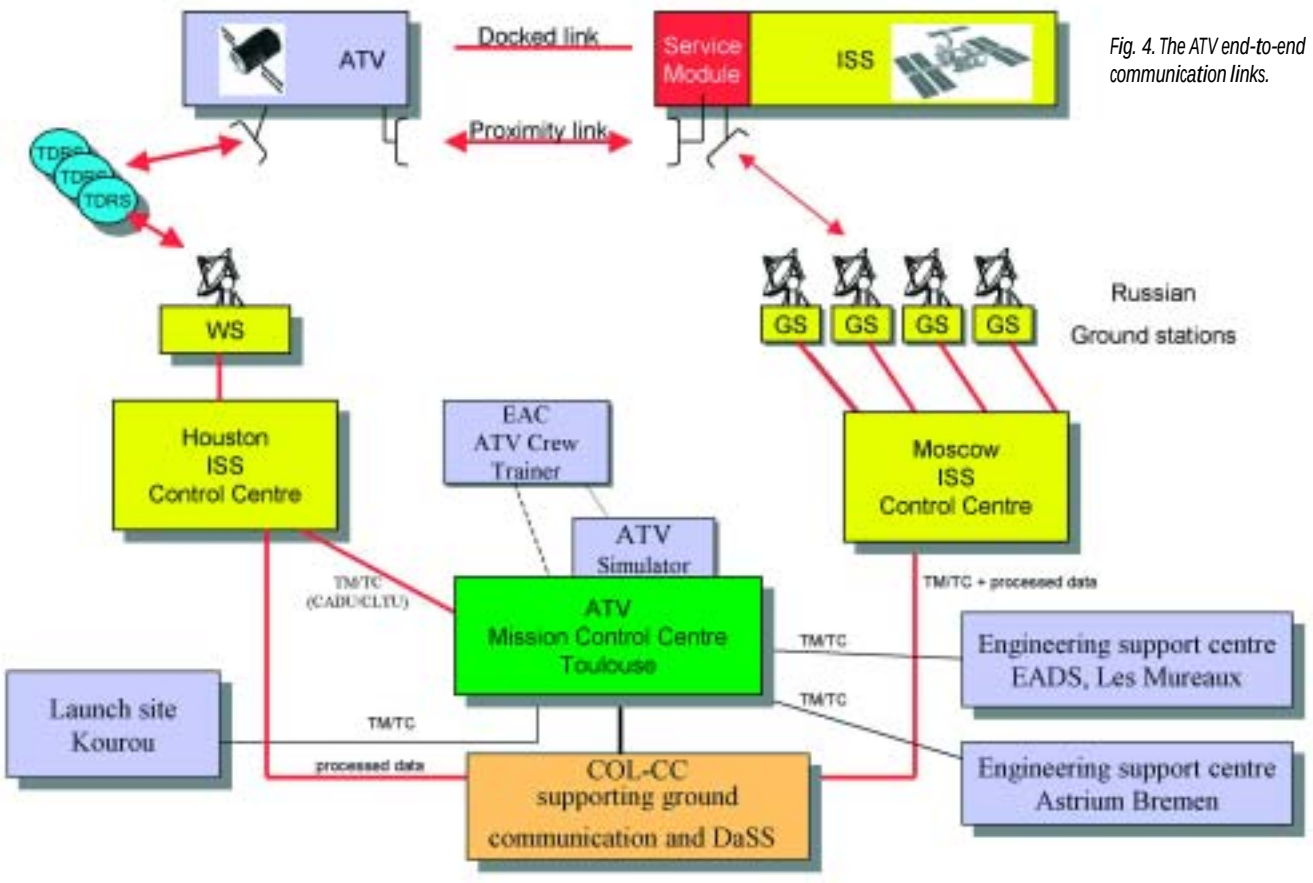

Fig. 4. The ATV end-to-end communication links.

Crew Training Support Facilities

The MSM ground infrastructure will provide crew training facilities for Columbus and ATV, including space elements at EAC and integrated training with ground controllers. These EAC simulators will be linked via the ground network with ATV-CC and/or COL-CC.

The ground segment will also provide a Columbus training facility for integration with SSTF in Houston, linked with MCC-H and COL-CC for integrated training of ground operators.

Ground System Acceptance and Validation

The complete ground segment will tested and qualified, using simulated external elements. Final tests will use the real flight elements in the loop before launch. These System Validation Tests will verify the compatibility between the control centres and the flight elements, and address the monitoring and control system (telecommand and telemetry). They also cover other aspects such as the uplink of telecommands with verification of correct onboard reception and the operational communication links. In addition, for ATV, the system validation will include tests of the data encryption test of the real TDRS spacecraft communication links and tests of the special processing by Zvezda.

Development Status

The System Requirement Reviews for ATV-CC, COL-CC, the ground communication network and the ATV ground segment simulator and training facilities were successfully completed earlier this year. The Request for Quotation (RfQ) for ATV-CC is being prepared, the RfQ for COL-CC has been released and the RfQs for the different subsystems are under development by DLR. The RfQ for the ATV simulators has been released and the proposal is under review. The simulators for Columbus crew training and the facility for Columbus payload compatibility testing (RLTF) are already in production.

A basic communications infrastructure is already in use, based on a prototype network infrastructure for communications and data services (Phase-1 of the ground segment), which provided proof-of-concept by supporting Spacelab precursor flights and the Euromir-95 mission. This infrastructure will continue to support ESA payload operations until the DLR-provided infrastructure becomes operational. ■