The ISS Operations and Exploitation Programme

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The assembly of the International Space Station (ISS) is well under way, with a crew of three in permanent residence. A significant step in the utilisation of the ISS was made with the launch of the US laboratory 'Destiny', which is now outfitted with a number of scientific payloads that, despite the limited resources of the current Station, are providing NASA with a valuable initial research programme. With Europe's main contributions to the ISS, the Columbus laboratory and the Automated Transfer Vehicle (ATV), scheduled for launch in 2004, ESA's ISS Exploitation Programme has already begun and the operations preparation for the ESA programme elements is gaining momentum.

ESA's rights and obligations in the ISS Operations and Utilisation Programme

By providing the Columbus laboratory, ESA contributes to the overall utilisation capabilities of the ISS. In return, Europe receives the right to use 50% of the payload accommodations afforded by Columbus (i.e. four payload rack positions and two external payload sites) and 8.3% of the total resources of the non-Russian part of the ISS. The latter is the result of the application of a complex formula that takes into account the contributions to the ISS infrastructure made by the different International Partners.

The ISS resources consist primarily of astronaut crew time and electrical power to perform payload operations. However, to exercise the right to use these resources Europe must also pay 8.3% of the cost for the 'common operations' of the ISS. Europe also has the right to purchase 8.3% of the services provided by the Space Shuttle for transportation of payloads, and 8.3% of the payload high-rate data services provided by NASA's Tracking and Data Relay Satellite System (TDRSS).

Rather than pay for ISS resources and NASA services in cash, ESA has elected to offset the charges by transporting cargo (spares, payloads, crew supplies, propellant, gases and water) to, removing trash from and raising the altitude of the ISS by means of the ATV. Current estimates show that between seven and eight ATV missions from 2004 to 2013 will be required to completely offset ESA's obligations.

Another key aspect of the ISS Programme is the principle that each Partner is responsible both financially and operationally for the operation and maintenance of the elements it brings to the Station. Consequently, the so-called 'common operations' relate mainly to the transportation and maintenance in orbit of the ISS crew as well as ground operations involving several Partners. An extension of this principle is that each Partner is responsible for training ISS astronauts on its elements and payloads.

ESA's ISS ground segment

As part of ESA's ISS Development Programme, a set of ground facilities are being developed to support the operations of the European ISS elements. Those for in-flight operation of the European elements are derived from the overall operations concept for ISS. At the outset of the ISS Programme, a concept of operations fully centralised at the Mission Control Centre, Houston (MCC-H) was envisaged whereby all International Partner elements of the ISS were controlled by a single, international Flight Control Team and all payloads operations were coordinated from the Payload Operations Integration Centre (POIC) at NASA's Marshal Space Flight Centre (MSFC) in Huntsville, Alabama. However, as a result of the extensive ISS redesign activity that took place in 1993 and brought the Russians into the Programme, ESA together with the other Partners insisted on a more devolved concept in which each Partner controls its own elements and payloads from its own facilities. In this concept, NASA coordinates the activities of the Partner centres and looks after safety-critical operations. The resulting ESA ground segment for flight operations, which is part of the overall ISS ground segment, is illustrated in Figure 1 and is comprised of the following major elements:

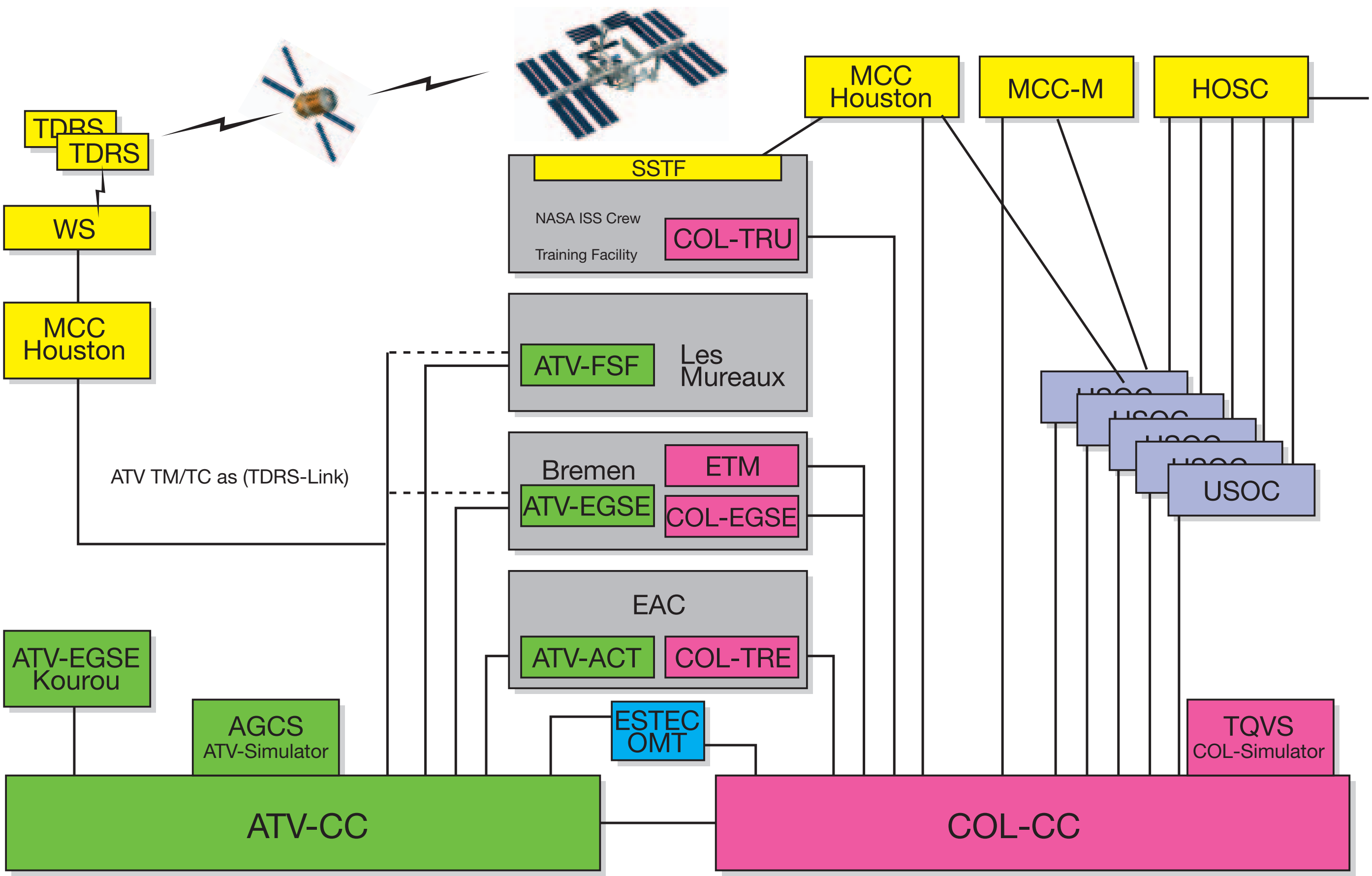

Figure 1. The overall ISS ground-segment architecture

The Columbus Control Centre

In 1997, the decision was taken by the ESA Council that the control centres for the main ESA ISS elements should be located at DLR/GSOC in Oberpfaffenhofen (D) for Columbus and at CNES in Toulouse (F) for the ATV.

The Columbus Control Centre (COL-CC) is housed in the facilities constructed originally to support the German Spacelab-D2 mission, but consists of a totally new development of the constituent systems. Of special note is the design of the Monitoring and Control System, which is based on the Columbus Ground Software (CGS) system. CGS has been developed from the outset of the Columbus Programme as an end-to-end data system from which all the Columbus software development, simulation and test facilities have been derived. In particular, CGS uses a single Mission Data Base (MDB) as a repository of the key Columbus data throughout the programme, thereby ensuring consistency and configuration control through development, integration and testing, and finally operations. So successful has this concept proved that NASA has adopted the CGS MDB software for its Mission Build Facility in which the entire ISS data is stored.

At the time of the decision on the location of the control centres, it was also decided that the development and operation of the ESA ISS ground communications network or IGS (Interconnection Ground Sub-network) should also be carried out by DLR/GSOC. The IGS is a Wide Area Network (WAN) using ATM technology that connects via relays the data sources and command destinations at MCC-Houston (MCC-H), MCC-Moscow (MCC-M) and the POIC with the European sites consisting of the ATV and Columbus Control Centres, engineering support sites, the launch sites, the User Support and Operations Centres (USOCs) and the European Astronaut Centre (EAC). On top of the basic network communications services, the IGS also provides high-quality secure data, voice and video infrastructure services.

The development of the Columbus Control Centre is now well under way, with the procurement of most subsystems already started. According to the current ISS Assembly Sequence, the first major operational event for COL-CC will be the support of the first ATV mission in August 2004, for which the IGS-related elements of the COL-CC must be at flight-readiness status.

The ATV Control Centre

The ATV-CC is under development at CNES in Toulouse, and in this case even the buildings are being newly constructed. The ATV-CC relies for its communications services on the

COL-CC, with the internal voice conferencing system and the IGS communications node being purchased under the umbrella of the COL-CC contracts. In common with the Columbus Programme, the ATV also uses the CGS and in particular the MDB. However, although the ATV-CC uses the MDB provided by the ATV developer as its basic data source, the ATV-CC monitoring and control system is not CGS-derived. A particularly important part of the ATV-CC is the flight-dynamics subsystem, which is used to compute trajectories and manoeuvres for the ATV during its free-flying phase and to monitor its trajectory during the critical rendezvous and docking sequence.

The ATV-CC will be completed in early 2004 to support validation testing, training and simulations prior to the first mission.

The User Support and Operations Centres
From the outset of the ISS Programme, a decentralised scheme for the utilisation of European payloads on board the ISS has been envisaged. USOCs located in various participating countries will act as the link between the user community and the ISS utilisation organisation.

During the pre-launch phase, the USOCs will be concerned with activities such as ground-model operations, experiment-procedure development, payload and experiment optimisation and calibration, and support to crew training activities. During the in-orbit payload operations, the USOCs will receive facility and experiment data and perform, in coordination with the Columbus Control Centre or the POIC, the operations of the payloads for which they are responsible. In addition, the USOCs will be responsible for the interaction with the scientists in the User Home Bases in disseminating experiment data to them, and receiving and processing requests for experiment scheduling and direct commanding.

Depending on the scope of the task assigned to a USOC, it can assume three basic levels of responsibility. The first level is to operate in support of users from the country in which the USOC is situated, in preparing and conducting an experiment. The second level is to operate as a Facility Support Centre (FSC) supporting particular functions of an Agency-provided multi-user facility. The third level is to operate as a Facility Responsible Centre (FRC) with full responsibility for the operation of a payload facility. The assignment of USOCs to ESA payload facilities is summarised in Table 1.

ESA provides the standard communication facilities and payload ground models (engineering models and/or science reference models) of the facilities for which a USOC is responsible as an FRC or is supporting as an FSC.

Engineering Support Centres
The main development facilities at Astrium (Bremen, D) for Columbus and EADS (Les Mureaux, F) for the ATV will be used during the operations phase to develop operations products and to support the control centres in troubleshooting and anomaly resolution. In particular, the software development and integration facilities at each site will be used to generate and test the respective flight software and data loads and the Electrical Test Model (ETM) for Columbus and the Functional Simulation Facility (FSF) for the ATV will be used for verification of software/data loads and troubleshooting problems during the respective missions. Both Bremen and Les Mureaux will be capable of receiving telemetry from the spacecraft via connections to the IGS.

ALTEC Logistics Centre
The ALTEC Centre is a joint venture between the Italian Space Agency (ASI) and Italian Industry. It has successfully supported the missions of ASI's Multipurpose Logistics

Table 1. Assignment of USOCs to payloads

	USOC	
Model Type/Facility	**Facility Responsible Centre (FRC)**	**Facility Support Centre (FSC)**
Pressurised Facilities		
BIOLAB	MUSC, Cologne (D)	Biotesc, Zurich (CH)
FSL	MARS, Naples (I)	Inst. DaRiva, Madrid (E)
EPM	CADMOS, Toulouse (F)	DAMEC, Copenhagen (DK)
EDR	ERASMUS, Noordwijk (NL)	B-USOC, Brussels (B) DUC, Emmeloord (NL)
MSL – SQF	CADMOS, Toulouse (F)	MUSC, Cologne (D)
MSL – LGF	MUSC, Cologne (D)	CADMOS, Toulouse (F)
EMCS	BPS, Trøndheim (N)	- / -
Unpressurised Facilities		
ACES	CADMOS, Toulouse (F)	- / -
SOLAR	B-USOC, Brussels (B)	- / -
EuTEF	ERASMUS, Noordwijk (NL)	- / -
SPORT	MARS, Naples (I)	- / -
EXPOSE	MUSC, Cologne (D)	- / -

Module (MPLM) and will be used to support the logistics of all ESA's ISS elements. The Centre has facilities that can be used for warehousing, packing and shipping of spare parts, depot maintenance activities, logistics planning and is also capable of receiving telemetry and processed ISS data to support real-time logistics activities.

ATV Production Facilities
The main facilities and ground-support equipment used for the manufacture, assembly, integration and testing (MAIT) of the ATV protoflight unit, will be maintained and used for the subsequent production programme, which is planned to span at least nine years. These include MAIT facilities for the integrated cargo carrier at Alenia in Turin (I), for the propulsion module structure at Contraves in Zurich (CH), for the avionics bay at Astrium in Toulouse (F), for the propulsion module and overall spacecraft integration and test at Astrium in Bremen (D), and for final spacecraft assembly and check-out at the launch facilities in Kourou, French Guiana.

Figure 2. The European Astronaut Centre (EAC)

Crew Training Facilities
ESA is responsible for training ISS astronauts to operate the European elements and payloads. To increase the efficiency of a desperately congested training programme for Station crews, the European training facilities are centralised at the European Astronaut Centre (EAC) in Cologne, Germany. These facilities consist of: the Columbus Trainer, which is a high-fidelity software simulation of the Columbus module systems housed in a mechanical mock-up; the ATV Crew Trainer, which is a software simulator of the ATV, which together with a simulation of the Russian Service Module crew workstation, provides an environment for training ISS crews on the ATV rendezvous operations; a high-fidelity mock-up of parts of the Columbus module for maintenance training; a high-fidelity mock-up of the ATV interior for training of cargo-transfer operations; and high-fidelity training models of the Columbus payload facilities.

In addition, a replica of the Columbus Trainer is installed in the Space Station Training Facility in Houston to support integrated ISS training, and a Russian-developed ATV training facility at the Gagarin Crew Training Centre will provide additional training capability for ATV rendezvous operations.

ISS operations preparation and integration
Although more modest schemes are currently being discussed in the light of the NASA budgetary problems, the nominal scenario for steady-state ISS operations foresees a crew of seven astronauts operating a fully complete Station, serviced annually by a total of five US Space Shuttles, two Soyuz and four Progress Russian vehicles, two Japanese HTV cargo vehicles and one ATV. During steady-state operations, three of the crew are Russian cosmonauts dedicated to operating the Russian part of the ISS, whilst the remaining four US, European, Japanese and Canadian astronauts are charged with operation of the non-Russian segment. The flight opportunities available to the non-Russian Partners are proportional to their contributions to the ISS. Europe's share of 8.3% buys approximately one flight for one ESA astronaut per year.

Whereas the Russian crew is rotated twice per year via the two Soyuz missions, a more complex scheme is planned for the rotation of the four non-Russian crew members via the Shuttle. The five Shuttle flights comprise four equally spaced (i.e. every three months) MPLM missions and one carrying only unpressurised external cargo. On each MPLM flight, three crew are rotated, leaving the fourth ISS crew member in orbit as the Commander for the next 'Increment', which is defined as the mission period between two crew-rotation flights of the Space Shuttle. The advantage of such a scheme is that it provides crew continuity from Increment to Increment.

The notion of the Increment is a key part of the overall ISS operations preparation and planning process. This is largely due to the fact that the Shuttle takes some 8 metric tons of dry cargo to the ISS with each MPLM flight and this cargo, which consists of payloads, spare parts and crew supplies, has a strong influence of the activities that will be carried out during the following Increment. Much of the preparation of an Increment is therefore related to the definition and preparation of the Shuttle cargo, as well as the cargo carried by some of the smaller vehicles visiting the Station during the course of an Increment.

Planning for a given increment starts five years before with the development of the strategic plan, which defines the resources available for the increment as well the planned utilisation. The strategic planning is progressively refined until two years before the Increment start, at which time the tactical planning process develops a set of detailed requirements for the Increment. These detailed requirements, which are baselined 18 months before Increment start, address the payload-utilisation and system-maintenance activities to be accomplished within the Increment, together with the associated resource requirements (crew time, electrical power, heat rejection, data and communications), the payload and system cargo items to be transported to and from the ISS, Extra Vehicular Activities (EVAs) to be performed, etc.

Based on these requirements, a detailed plan for the preparation of the Increment is drawn up by each Partner in line with a template, by means of which the overall ISS operations integration is carried out. The Increment operations preparation and integration covers the following activities:

- development and qualification of new payload hardware and software
- procurement and preparation of spare parts
- ground processing and cargo integration of flight hardware to be transported to the ISS
- analytical accommodation and engineering analysis of the compatibility of new payloads including the derivation of operational constraints
- preparation of flight and ground databases defining the telemetry and telecommands and associated data to be used during the increment
- preparation of flight and ground procedures and displays
- configuration of the ground segment and its facilities for the specific requirements of the increment
- training of the astronauts to operate the payloads and carry out the maintenance activities planned for the increment
- training of the flight-control and other ground-operations personnel on the specific increment operations
- detailed executional level planning of the activities scheduled for the increment
- simulations involving both ground- and flight-operations personnel.

To ensure that each of the above activities has been successfully concluded, a process called ‘Certification of Flight Readiness (CoFR)’ is employed. This process, which relies on a series of reviews, detailed status checks and inspections, is carried out by each Partner for its own part of the Programme. Overall certification is achieved via a series of ISS level reviews at which the status of Partner certification is incrementally checked. These reviews culminate in the Flight-Readiness Review at around launch minus 3 weeks, at which the final certification is achieved.

Figure 3. The Columbus laboratory

Although the operations integration activities described above relate mainly to the ESA elements that form an integral part of the ISS, i.e. Columbus and the payload facilities, this process also includes the following aspects of ATV operations:

- Since the ATV cargo is completely determined by the ISS manifesting process and the cargo items are provided by all international Partners, the entire ATV cargo integration process becomes entwined with the ISS operations integration. ISS databases interact with ATV cargo information systems to provide essential information on cargo items, ATV cargo layouts become an integral part of the ISS cargo operations procedures, ATV inventories are entered into the ISS Inventory Management System and the safety of the ATV cargo becomes part of the overall ISS safety review.
- Since the ATV has to rendezvous and dock with the ISS, ATV flight-dynamics operations and mission planning have to be integrated with those of the ISS so that the ATV launch windows can be properly computed and ATV flight trajectories designed and executed to achieve RVD opportunities compatible with ISS operations.
- The ISS crew and the MCC-M, and to some extent the MCC-H, flight controllers have to be trained to support the ATV operations. Due to the six months stay time at the ISS, at least two ISS crews have to be trained for

most ATV missions, and this has to be carefully planned into the Increment preparation schedule.

Sustaining engineering

ESA's ISS Operations and Exploitation Programme is the most extensive, long-term operations support undertaking ever attempted by the Agency. The flight elements that have to be supported for 10 years or more are:

– the Columbus laboratory
– the Microgravity Facilities for Columbus (MFC), consisting of the Biolab, the Fluid Science Laboratory (FSL), the Material Science Laboratory (MSL), the European Physiology Module (EPM) and the European Drawer Rack
– the Laboratory Support Equipment (LSE), comprising the Minus Eighty Degree Freezer (MELFI), the Microgravity Science Glove Box (MSG) and the Hexapod
– the Cupola
– the European Robotics Arm (ERA)
– the Data Management System for the Russia Service Module (DMS-R)
– the Automated Transfer Vehicle (ATV).

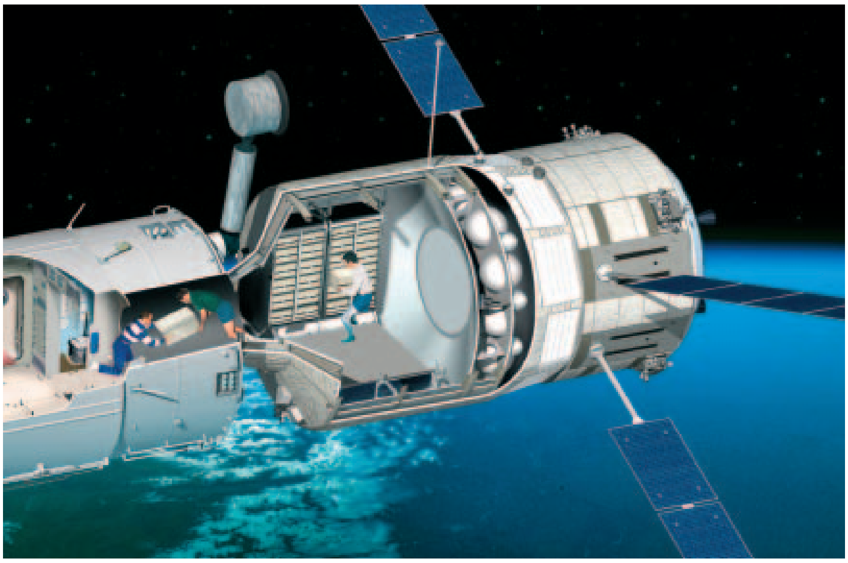

Figure 4. The Automated Transfer Vehicle (ATV)

In addition, the ground facilities supporting each of these flight elements have to be supported for the same period.

For each element, sustaining-engineering services have to be bought from the appropriate industrial contractors. However, the type and extent of the sustaining engineering varies greatly from element to element, depending on its complexity and in particular ESA's role in and obligations to its operation.

The simplest form of sustaining engineering is the on-demand provision of engineering expertise to support troubleshooting and anomaly resolution. This type of support is typically required for those elements such as the Laboratory Support Equipment that have been provided to NASA as constituents of a barter deal. However, even in these cases it is not straightforward to obtain commitments from the companies involved to maintain the necessary expertise for more than 10 years. Even if the Prime Contractors are willing to do this, the subcontractors are often not interested and so transfer of expertise, equipment and documentation is inevitable in most cases. Furthermore, due to the limited budgets available for sustaining engineering and the limited interest of staff in this type of work, companies cannot in general keep staff working full-time on these activities. Consequently, the access to experienced staff for troubleshooting and anomaly resolution is difficult to guarantee.

The Columbus laboratory represents the other extreme in sustaining engineering. In addition to the ad-hoc type of support required for troubleshooting described above, a more continuous effort is required to: prepare software and data updates for each Increment; perform analyses of the integrated payload and system performance to ensure that the planned payload complement can be operated and to derive operational constraints; develop and update operations procedures; and carry out software maintenance as well as maintenance of the Columbus ground facilities. A number of the facilities used in the Columbus development programme are maintained and used for sustaining engineering. These include the Electrical Test Model used for troubleshooting, software, data and procedure qualification, and the Software Development and Integration facilities.

Software maintenance over such a long period presents some challenges of its own, especially where commercial COTS products have been chosen. Due to the sometimes unpredictable evolution of the commercial markets, essential on-board software products may eventually no longer be supported by the vendors. A typical example of this is the on-board display software (SAMMI) chosen for Columbus, which even before launch has become obsolete. As a consequence, the opportunity is being taken to review the entire Columbus laptop display architecture with a view to implementing XML technology.

Owing to the significant delays in the ISS Programme, several ESA flight elements that should already be in orbit have completed development but have not yet been launched. Nevertheless, their sustaining-engineering programmes have already started and in particular software maintenance is being carried out.

Logistics and maintenance
Most of the ESA elements listed above are maintained in orbit by exchanging failed equipment with working units. To facilitate this, the design of each element includes a number of Orbit Replaceable Units (ORUs) that contain the parts most likely to fail and require replacement. Each ORU has its own maintenance concept supported by the required stock of spares, EEE parts, maintenance tools and facilities, test equipment, documentation and trained personnel.

The maintenance approach for each ORU has been arrived at as a result of logistics analyses, and negotiations with equipment and parts vendors with regard to their willingness to support a long-term maintenance programme. Maintenance concepts range from buying sufficient spare ORUs to cover all failures throughout the lifetime and thereby avoiding the need for long-term vendor support, to purchasing two ORUs and sufficient EEE parts and/or pre-assembled PCBs to allow the repair of the ORUs for 10 years. The latter concept relies on exchanging one ORU for the other in orbit following a failure, and transporting the failed ORU to the appropriate maintenance site for repair so that it is then available for exchange should the other ORU fail.

One of the problems with ISS maintenance is the access to launch services for transporting spares to the Station. The manifest for any flight is decided by prioritising cargo items based on their criticality, so that it is unlikely that a unit that fails in Columbus or a payload towards the end of an increment will be replaced during the following two increments.

A major problem influencing maintenance approaches and spares procurement is that of parts obsolescence. Due to the length of the ISS Development Programme, most of the designs that are now qualified use technologies that are out-of-date and parts that are either now obsolete or will become so in the near future. As a result, difficult decisions are currently being taken as to whether to make lifetime buys of obsolete parts or to plan on upgrading the technology. Such decisions are complicated by the quality of the data on which such decisions have to be based. This is mainly the failure-rate data, which is notoriously inaccurate due to the lack of real statistics based on large sample sizes.

The procurement of most spare parts has already been initiated due to the cost benefits of manufacturing them together with the initial flight units. In general, sufficient spares are being procured to support lifetime operations although in one or two cases, e.g. upgrading of mass storage technology from Winchester disk to solid-state devices, it has been decided, due to the low risk involved, to implement newer technology.

The ALTEC Centre in Turin will be the focal point for all European logistics activities for the ISS Exploitation Programme. ALTEC is currently supporting the MPLM logistics operations, but will gradually take on the role of integrated logistics operations for all European elements of the ISS.

Columbus flight operations
In-orbit operation and control of the Columbus laboratory systems will be conducted by flight controllers in the Columbus Control Centre (COL-CC) at DLR/GSOC in Oberpfaffenhofen. Because Columbus will be outfitted with a mixture of European and US payload facilities of various disciplines and consequently a wide range of operating periods and degrees of interaction, it is a priori impossible to predict when COL-CC be required to change the system configuration. Consequently, it is planned to operate for 24 hours per day, 7 days per week using three shifts per day. The flight controllers will be supported in their operations by on-site engineering support personnel provided by the development contractors. These engineers will provide a deeper level of knowledge of the Columbus systems and will play a major role in key system operations, such as assembly and activation as well as system-maintenance activities. They will also perform troubleshooting and anomaly resolution for failures that cannot be handled by the flight control team.

In addition to its system-management role, the COL-CC flight control team also coordinates the operations of the Columbus payload facilities and the experiments conducted within them. Operations of the Columbus payload facilities and their experiments are conducted from the 11 User Support and Operations Centres (USOCs).

The Columbus flight-control team works in close cooperation with the NASA ISS flight-control team at MCC-Houston for all operations that affect overall ISS resource management and multi-element and safety-related operations, and with the POIC flight controllers for overall ISS payload coordination.

The overall compatibility of the distributed operations carried out by the different Partner Control Centres is ensured by the use of a single integrated execution-level plan. This plan is integrated by NASA based on the Element-level plans provided by Russia, ESA and Japan. The Partner plans are compiled using a common tool, which is also used by NASA to perform the integration into a single ‘Short Term Plan’ (STP). The STP nominally spans one week of activities comprising both system and payload operations. The COL-CC flight control team’s main objective is to execute the STP within the approved flight rules, and within this domain it can operate more or less autonomously. However, if malfunctions or significant changes in payload objectives cause significant deviations from the STP, the Programme Operations Management will be called upon to decide on how to continue operations.

The COL-CC also manages the ESA ISS ground communications network, which in addition to providing operational data to the Control Centres and engineering support sites, also provides higher rate scientific data to the USOCs.

ATV flight operations

The ATV will be operated and controlled by a team of flight controllers in the ATV Control Centre (ATV-CC) at CNES in Toulouse (F). Similar to Columbus, the ATV flight controllers will be supported in their operations by on-site engineering support personnel provided by the development contractors. The ATV-CC flight control team will interface closely with the MCC-M flight controllers during the final stages of rendezvous, at which time commands and telemetry will be routed either via the TDRSS or via the MCC-M and the Russian ground stations.

The level of interaction between the ATV and its Control Centre varies greatly with the phase of the mission. During the free-flying phases, the ATV-CC is responsible up to the final approach for determining the ATV trajectory and for calculating and executing the manoeuvres required to rendezvous with the ISS at the planned time and coordinates. During the final approach, the ATV trajectory is controlled by the ATV on-board software, which receives inputs from the ATV rendezvous sensors. During this phase, the ATV-CC monitors the vehicle’s trajectory and attitude to ensure that it is within the allowed safety envelopes. After docking, the ATV-CC monitors the vehicle’s systems and supports cargo transfer, ISS reboost and propulsive attitude-control operations. Finally, after undocking of the ATV from the ISS, the ATV-CC controls the destructive re-entry manoeuvre operations.

Like the Columbus Control Centre, the ATV-CC will operate 24 hours/day, 7 days per week during an ATV mission.

Operations management

To coordinate, integrate and manage the various operations activities described above, an Operations Management function led by ESA has been implemented. In addition to managing the operations phase programme, Operations Management: performs operations planning; organises and conducts ESA-level technical reviews and operations boards; participates in the ISS operations and utilisation control boards; coordinates and consolidates data and products provided to the ISS Partners and other external interfaces during operations preparation and execution; manages the procurement of ATVs and Ariane launch services; manages the user interfaces and coordinates payload data collection; performs science coordination; and manages the training activities, as well as ESA crew operations and medical-support activities. In particular, Operations Management oversees the overall ESA Certificate of Flight Readiness process.

During operations, Operations Management representatives will be stationed at the Control Centres to provide rapid Programme-level decision-making capabilities to support the ATV or Columbus Flight Directors and ISS Control centres in the event that the operations can no longer be carried out within the established plans, procedures and flight rules. Operations Management at the Columbus Control Centre will also be responsible for coordinating the real-time scientific objectives and for ruling on conflicts, should they arise. This function will also support the operations of ESA payloads in the US Segment.

Organisation of the Exploitation Programme

The intention is to eventually conclude a single contract with Industry to carry out the operations activities described in this article as a set of end-to-end services. However, due to the uncertainties in the scope of the activities, the transition from Development to Exploitation Programme, as well as overall programme situation, the risks are currently too great for Industry to enter into such a service contract. This will therefore be postponed until steady-state operation of both Columbus and the ATV has been achieved.

In the meantime, ESA, in addition to managing the overall Exploitation Programme, will take responsibility for the Operations Management and integration functions.