A Decentralized Operations Concept for the European Payloads on the International Space Station

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Abstract

The European Module Columbus of the International Space Station (ISS) is planned to be launched 2004. For its exploitation phase as well as for the early utilisation of the Space Station starting from 2003 onwards the operations procedures are now being defined in detail and the implementation of specific infrastructure has started.

A decentralised operations concept will allow the investigators to perform their experiments using the telescience technique of remote experiment operations whenever feasible. User Support and Operation Centres (USOCs) will act as Facility Responsible Centres (FRC) performing the operations for multi user experiment facilities. The Columbus Control Centre (COL-CC) will perform the Columbus system operations, co-ordinate the European payload operations and provide the European Communications network. This paper gives an overview on the operations concepts and the tasks and set up of the involved sites.

1 Introduction

The International Space Station is a project based on world wide international co-operation. The operation of the station system as well as its experiment facilities and experiments is shared by the international partners of the project. The European contribution includes the laboratory module Columbus, as well as payloads in other international partners modules and on external mounting sites. Their operations, currently under preparation, will be presented in this paper. However, the operations of other European contributions like the Automated Transfer Vehicle (ATV) will not be covered here.

A decentralised operations concept with 3 layers of responsibility will be implemented for

- experiment operations by the Principal Investigator (PI),
- operations of multi-user facilities by User Support and Operation Centres (USOCs),
- Columbus system operations and European payload operations co-ordination by the Columbus Control Centre.

This concept has been developed for real missions in Europe by the first User Support and Operations Centres MUSC and MARS /1/ and further defined by the European User Support Organisation (USO) /2/ and the group of European User Centres /3/.

The investigators performing experiments onboard the International Space Station will rely on telescience techniques /4/ for interactive operations. Telescience Consoles will allow the investigators at remote sites to interact with their experiments executed in a multi-user facility supervised by the Facility Responsible Centres.

The operations of a multi-user facility and the scientific, technical and operational support for the users of this facility will be provided by a Facility Responsible Centre FRC and related Facility Support Centres FSC and Experiment Support Centres ESC/3/. These User Support and Operations Centres will also provide scientific consultation and support for its users as well as technical support in adjusting the investigator's requirements to the multi-user facilities and their control software.

The Columbus Control Centre will perform the operations of the Columbus system /5/, a subject not covered in detail in this paper. In addition, the Columbus Control Centre will set up a European communications infrastructure to allow the exchange of telemetry and telecommand data, voice communication and video distribution. The COL-CC will set up communication links to both FRCs and investigator sites for those payloads that interface directly to the Columbus Laboratory (referred to as Class 1 payloads, in opposition to Class 2 payloads, which interface with Class 1 payloads). The definition and implementation of the COL-CC will be performed under ESA contract, whereas for the exploitation phase of the Columbus Module after its assembly to the ISS, the COL-CC will act under contract of an industrial consortium.

2 Overview of Decentralised Operation Scheme: Columbus operations sites

The decentralized Columbus operations require mission management (see 2.1.), control centre services and facilities (see 2.2.), and decentralized user support centre services and facilities (see 2.3).

2.1 The Management of ESA's Utilisation Programme during ISS Payload Operations

The ESA Program Management functions w.r.t. the management of ISS Payload Operations Utilisation include:

- Overall management and integration of the Exploitation Program.
- Operations and utilisation planning, including strategic and tactical planning, and execution level planning with support of the relevant Control centres.
- Increment preparation management for the ESA payload complement on the ISS, including overall mission / increment planning and co-ordination.
- Supervision of real-time mission management at the control centres.
- Management of utilisation related activities, including co-ordination of preparation, integration and operations of the various European payloads.
- Provision of real-time Science Co-ordination Function.

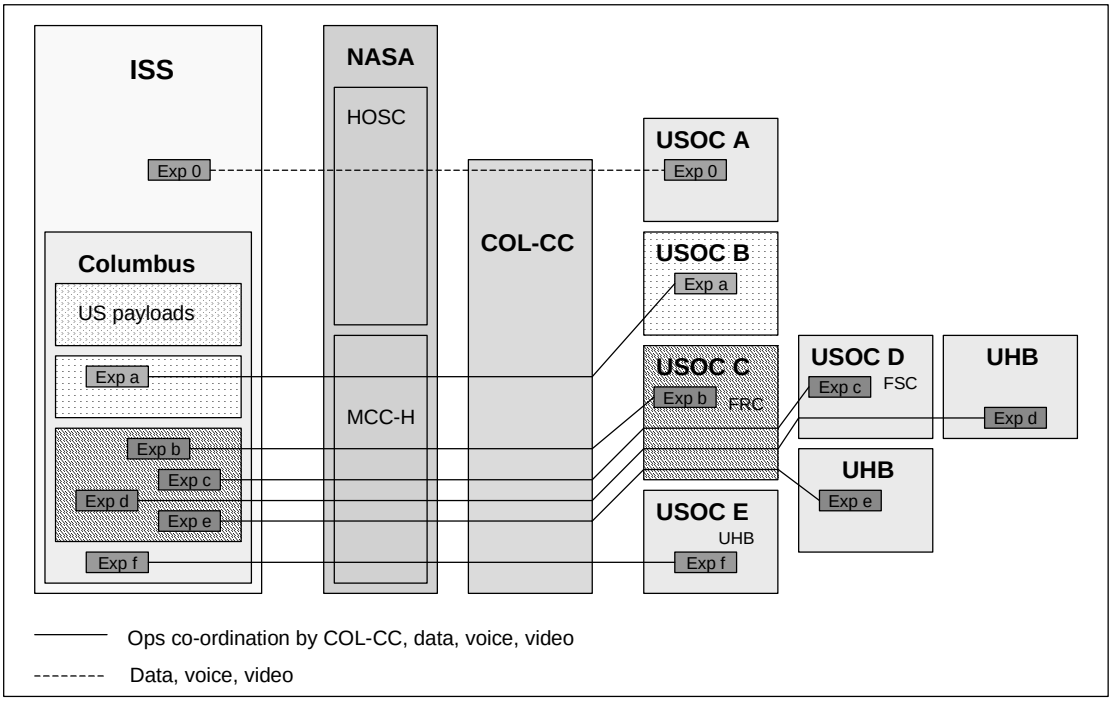
ESA is presently in the process of establishing the framework within which the USOCs can conduct their user support and operations activities. In addition to the set-up and provision of an adequate mission management scheme, this includes the implementation of technical capabilities, which enable assigned USOCs to conduct payload operations. Under this assignment USOCs are responsible for facility/experiment operations preparation, planning and execution.

During the increment preparation phase, ESA's Utilisation Management Team will be responsible for concluding all payload interface and operations agreements, for ensuring the generation of all payload documentation and carrying out final payload acceptance for flight. ESA Utilisation Management will supervise the system-level test activities at the Payload Integration Centre, and will subsequently be responsible for the shipment of payloads to the launch site. ESA Utilisation Management will also be responsible for receiving and dispatching hardware that returns from orbit, including samples, specimens, collectors, as well as instruments and facilities if required.

Real time operations activities for payloads will be performed directly from the User Centres responsible for a payload. These activities are performed under the overall payload operations co-ordination and management of ESA. The ESA payload operations management will supervise and co-ordinate payload operations on the ESA payload complement level.

Though geographically decentralised, functionally the set-up of the management of the ESA payload complement will be performed in an integrated end-to-end manner. The USOCs will therefore play in integral role in the management of ISS payload operations.

Figure 2. Decentralized Operations Scheme



2.2 The Columbus Control Centre (COL-CC)

The Columbus Control Centre is responsible for Columbus system operations and provides payload operations co-ordination services. A communication network links the Columbus Control Centre to its users and to operation facilities of the International Space Station partners.

2.2.1 Tasks and Services of the Columbus Control Centre

Columbus system operations will be carried out by the Columbus Control Centre team within the overall ISS schedule as co-ordinated by the NASA Mission Control Centre in Houston (MCC-H). In addition, teams of analysts and planners will follow the operations, and perform all necessary in-depth diagnostics and maintenance analyses of the Columbus system.
The Columbus network operations task will be carried out under the responsibility of the COL-CC team as well.
Columbus system operation will not be further described in this paper.

For the European Users of the ISS, the Columbus Control Centre offers the following services:

Support Services, Consulting and Training
The interconnection of USOCs to the COL-CC services will be supported by the COL-CC for integration and checkout of communications interfaces. The generation of the necessary procedures for the User sites and training of personal in integrated operations will be supported as well.

Reliable Ground System Control
In order to provide an optimised environment for efficient experimentation, the COL-CC will ensure ground system configuration for data links, voice and video transmission.

Experiment Resource Re-Planning and Operations Scheduling
COL-CC will facilitate direct experiment real-time operations (Telescience) for the decentralised European User sites as pre-planned. To guarantee the operations of all the experiments in the Columbus module without interference within the allocated resources, it is essential to co-ordinate all experiment operations. Crew time, power, up- and downlink of data are examples of such on-board resources. Extensive planning of the use of these resources has to be performed. During execution of payload operations, it is the task of the COL-CC to ensure that these resources are not exceeded by one experiment if such changes might consequently disturb or postpone the execution of other experiments or might be critical for Columbus module system operations.
In case of requested operations changes from the planned activities, the COL-CC will co-ordinate these changes with all affected parties, and introduce them into the current on-board Master Timeline (MTL) if needed.
The current status of operations and planned activities will be made available to the users via a Web-interface.

Contingency and Maintenance Support
In case of problems during operations of an European experiment – independent of the location on-board – the COL-CC will support all necessary activities, e.g. negotiation of priorities, power supply, cooling, crew intervention, additional communications support, etc. to resolve the problem in the most efficient manner. Similar support services will be provided for experiment maintenance.

Payload Commanding
The COL-CC co-ordinates the transmission of commands to the European experiments within the Columbus module. All Columbus payload commands generated at the user sites are checked for proper source/destination codes. In addition, protocol translation and metering is performed to guarantee conflict free transmission to the NASA interface.
Safety critical (hazardous) payload commands – if any - will be initiated by the COL-CC only after authorisation by NASA. In addition, COL-CC offers the possibility to generate and send commands to payloads when required by the experimenter, e.g. during weekends or nights (if the appropriate payload command database is available).

Status Monitoring
The COL-CC will facilitate the access to the current status of all parameters processed at the COL-CC by providing both a data services interface and a Web-interface to the user sites. This includes information about the status of the systems on the ISS, in particular those in the Columbus module, an of the ground network.
The COL-CC will ensure the necessary system operations support (e.g. power, cooling and data) is provided by monitoring the execution of the Master Timeline and over-ride the timeline, in case of contingencies.
The COL-CC will also provide operations progress monitoring services, including the near real-time dissemination of completed activities via a Web-based tool.

Voice and Video Co-ordination
The COL-CC will provide external users with remote keysets for accessing the necessary ISS and Columbus operations voice conferences and services, and will provide video feed for users to receive real-time and playback video from any of a

number of sources. All voice and video links from the user to the NASA control centres will be configured and co-ordinated as pre-planned in the integrated planning process. This includes the co-ordination of all voice traffic with the astronauts. Additionally, desktop or room-based video conferencing is provided for the scientific community as scheduled or requested, depending upon the type of conference and number of participants.

Storage, Archive and Retrieval

All received information (including data, voice and video, as well as operational support data, e.g. orbit and attitude data), are archived at the COL-CC. In addition, the COL-CC will store all handled commands and all received low rate housekeeping data of experiments located within the Columbus module. The users will have access to these archives at any time, via a Web-browser interface.

Accommodation of European Users at the COL-CC

Users wanting to control their experiments at the COL-CC facilities will be provided with the basic tool (e.g. consoles workstations, voice keysets and video monitors). The COL-CC also offers the accommodation of user proprietary equipment.

Post-Operations Evaluation Support

Following the completion of a weekly execution period, the COL-CC will support the generation of an "as-flown timeline", and upon completion of an increment, will provide inputs to the Post-Increment Evaluation Report (PIER).

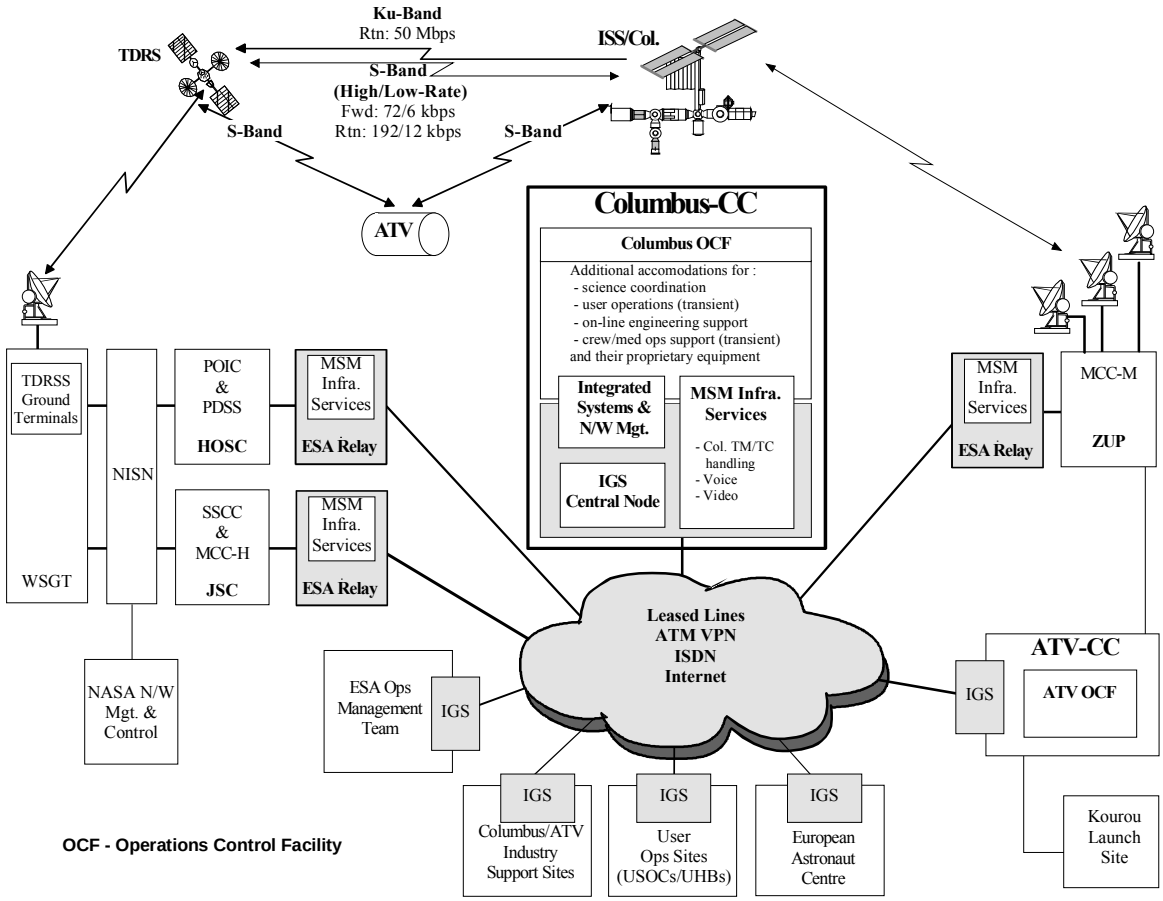
Note: Increment Definition

The time period covering the launch of designated flight crew to the undocking of the return vehicle for that crew.

2.2.2 The Columbus Communication Network

The steady-state operations of the Columbus systems and the European Payloads located within the Columbus will be supervised by a number of organizations, teams and ground segment facilities both in Europe and the US as depicted in Fig. 2.2. Each facility is interconnected with the Columbus Control Centre by means of MSM ground network also known as the Interconnection Ground Subnetwork (IGS). This wide area network will be implemented around a central node in Europe, with relays at the major points of data entry (MCC-H, HOSC Huntsville Operations Support Center and MCC-M Mission Control Center Moscow) and nodes at each of the sites in Europe involved in Columbus operations. It will be based on a combination of leased lines, public service based on Asynchronous Transfer Mode (ATM) Virtual Private Network (VPN) and Integrated Services Digital Network (ISDN).

Figure 2.2. Columbus Ground Segment



Since the Council decision in December 1998 to allocate the responsibility of implementing and operating all the communication services for Columbus and ATV Operations to the COL-CC, the former ESA operated Interconnection Ground Subnetwork (IGS) will be integrated with the COL-CC Network management system, enabling the COL-CC to provide data services for all European participants in ISS operations.
The COL-CC concept is to make commercial service providers responsible for the operational monitoring and control of those services, providing the COL-CC with enough status information and control capabilities to exercise its communications responsibility. This will reduce the management effort on the Project side and capitalises on the commercially available experience.
Appropriate studies are well under way and the dynamic developments in the communication market will provide definite cost advantages over an Agency operated network.

The COL-CC will provide a fully integrated system and network management system which will allow central monitoring and control of all its systems and the appropriate monitoring and control of the Manned Space flight and Microgravity (MSM)-IGS network in co-ordination with the commercial service provider. This will be developed according to the implementation strategy using commercial off the shelf (COTS) products to a maximum extent as outlined above and using commercially available services. The implementation will be based on a conforming system and network management platform. This management platform is HP Openview, which provides today the best level of application integration and the opening to the largest palette of proprietary and third party products.
The system will provide access to different features from a single console position: system & network administration, Accounting management, health & status monitoring, fault management, performance management, configuration management, security management, and troubleshooting.

2.3 The USOCs: Decentralised User Support and Payload Operations in Europe

The decentralised payload operations scheme has been part of ESA mission operations for almost ten years. In 1992, ESA instituted a program to evaluate remote science operations for ISS using Spacelab and MIR flights.
For Spacelab this was implemented during the four missions ATLAS-2, IML-2, ATLAS-3 and LMS. The program was continued for two ESA MIR missions. During Euromir94 and Euromir95 a distributed ground infrastructure was implemented and successfully operated.
Each mission availed of more advanced capabilities in terms of communication link and commanding. Science operations were efficiently operated by teams in the Control Centre and at the remote sites, and significant benefits were realised in terms of involvement of additional science personnel and troubleshooting support using representative hardware, such as engineering models at the remote sites.
The ESA payloads to be accommodated onboard the ISS will serve a multi-user community which needs to be supported by a harmonised ground infrastructure, throughout all phases of the payload's life-cycle. To support the ISS User community for the Columbus payload flight operations, the formerly tested decentralised approach has been selected, based on existing and nationally funded USOCs under the overall management of ESA. With decentralised operations support, it is ensured that focal points for the preparation and conduct of ESA payload operations exist, which are both very close to the payload operations onboard the Space Station and to the scientific user groups. Furthermore, by linking scientific groups through distributed support centres, the efficiency of payload operations is significantly increased during all phases.

2.3.1 Definition of USOC Categories

USOCs will be part of the European ground segment for the preparation and operations for payloads in a decentralised way. Depending on the task assigned to the centre it will either become an FRC (Facility Responsible Centre), an FSC (Facility Support Centre) or an ESC (Experiment Support Centre). In addition, UHBs (User Home Bases), i.e. single user sites such as university labs, will be part of the decentralised experiment operations concept.

FRC
The FRC is defined as a centre that is delegated the overall responsibility for a Class 1 payload. Its functions focus on payload system aspects. The FRC technical infrastructure is specialised for user support purposes, as well as for the operational utilisation for the Class 1 payload during its entire operational life cycle.
In general, FRC payload operations will be supported by support centres (FSCs / ESCs). Interactions and collaborations on class 2 payload, such as specific instrument modules or experiments, are possible on a case by case basis.
The FRC has by definition ESC capabilities for that payload and behaves towards the user as an ESC. For experiment operations, the FRC will provide the user with a communication and data processing infrastructure that allows real-time data monitoring and control. This can be achieved by providing him access to the equipment available at the FRC.
In case of a requirement for telescience from the user's home lab, the FRC is responsible for the interface co-ordination and supports the set-up of

an adequately equipped User Home Base at the investigator's location.

FSC
A Facility Support Centre (FSC) is defined as a USOC, which has been delegated the responsibility for a class 2 payload or an instrument in a class 1 payload. The FSC assignment is always related to a respective hardware assignment. The responsibility for the overall co-ordination of the class 1 payload rests with the FRC. The FSC will work in an integrated manner both with the FRC and the users of the class 2 payload. An FSC will perform the class 2 payload operations during the pre-, post- and in-flight phase.
In general, a ground model of a specific class 2 payload will be located at the FSC in charge of this subrack unit, drawer, rack subsystem, or instrument. The detailed assignment will be determined on a case by case basis and has to be endorsed by ESA.

ESC
An Experiment Support Centre (ESC) is a USOC delegated the responsibility for single experiments, whether they use dedicated instruments or not. They can be responsible both for the support of self standing experiments utilising experiment specific equipment or individual experiments performed in a facility. In addition, ESCs can be delegated tasks from the corresponding FRC or FSC, mainly focussing on science and experiment operational matters.

UHB
The User Home Base (UHB) is defined as the home laboratory of the user, which is equipped to perform on-line experiment data monitoring or experiment control. Unlike the USOCs, which can be considered as permanent institutions, a UHB is an operational centre for a limited duration, e.g. one ISS increment.
The participation of UHBs in the European ISS payload operations will be co-ordinated through either FRC or FSC. The UHBs represent for individual PIs a possibility to participate in the experiment planning and re-planning cycles and to follow and support the operation of his experiment without necessarily being located at a USOC.

2.3.2 Mission / Increment Preparation Functions

2.3.2.1 Payload Related Functions

All the activities carried out by the USOCs w.r.t. to the payload and the related technical infrastructure encompass both the ground and the flight segment:

- Ground Segment - the major aspect within the ground segment is the provision of laboratory infrastructure necessary for the preparation, the operation of the payload models and meeting the specified communication interfaces.
- Flight Segment - the main issues within the flight segment are the payload and USOC quality assurance, the safety assessment for both the ground and flight operations as well as all payload logistics. These processes encompass all functions required to prepare payloads and the payload complement for acceptance, integration, launch, return to earth and return of payloads to their providers.

One of the main tasks of the USOCs will be to provide support during the mission/increment preparation of a payload. The payload preparation support includes the transformation of the initial scientist's idea into an experiment protocol, and the support to experiment design, training, and engineering functions. The USOCs functions w.r.t. payload related activities can be summarised as follows:

- payload operations planning
- operation of the Science Reference Model (SRM) or Engineering Model (EM) for payload and experiment preparation
- payload procedure development / refinement
- support to payload and experiment crew training
- user/PI interface for experiment development
- experiment interface to the COL-CC and MMT for mission/increment preparation
- experiment validation and qualification
- crew procedure validation
- user/PI training on facility and operational tasks

Moreover, the scientists involved will be given the opportunity to participate in the science and experiment related activities at the USOCs during mission/increment payload preparation and will be expected to be present at particular milestones.

2.3.2.2 Experiment Related Functions

The experiment and science related activities of the USOCs for the experiment preparation aim at the experiment validation for flight.

In the early phase of preparation, the USOCs are responsible for all the activities that lead to the definition of the experiment requirements. The experiment parameters relevant for the facility are collected and a feasibility assessment is performed with respect to facility characteristics, safety requirements, International Space Station and ground segment specifications and resources.
According to the facility, this process can become complex and may need more iteration cycles, since in order to consider aspects such as power consumption and automatic handling requirements, the experiment specific hardware and its performances have to be defined to a certain level of details. A negative result of the accommodation

assessment could lead to modifications of the experiment requirements and of the experiment specific hardware, which have to be considered in a second accommodation study.
Once the dedicated hardware and software is compatible with the facility characteristics, and are seemingly within the limits and constraints of the facility in the Space Station environment, the investigator is supported with early testing of his experimental system to verify the preservation of the scientific significance of the experiment.

In a second stage of the preparation phase, the experiment protocol is translated into mission timeline. Aspects such as facility parameters, automatic and manual procedures (e.g. handling, diagnostic, observation), resources allocation such as crew time, power consumption, up- and download mass and volume, telemetry and data handling, remote operation in case of nominal telescience as well as in case of contingency intervention (experiment replanning) are regarded.
At the same time experiment specific hardware and software are defined and tested, while necessary ground equipment is identified.

In case that more than one experiment are to be performed in the same increment, their compatibility in terms of facility and ISS resources is to be assessed as well. If feasible, an increment timeline as result of the integration of the single experiment timelines in a complex balance of requirements and ISS intrinsic limitations will be established.

The final result of this process is the scientific and operational experiment validation, which will be assessed by ESA payload utilization and operation management teams.

2.3.3 Mission / Increment Execution Functions

During mission execution, the main function of USOCs is to ensure a good support to scientists allowing them to successfully perform experiments onboard the ISS. In order to do this, a large number of payload or science related tasks have to be performed throughout all phases of experiment preparation and execution.

2.3.3.1 Payload Related Functions

During the mission execution phase the USOCs will be in charge of receiving housekeeping and scientific data from the payloads, whose significance needs to be crosschecked with the facility configuration at every time. In nominal situations and if required they will have to prepare and send telecommands to the facility to automatically perform specific tests or experiments.
In non nominal situations, the USOCs will be responsible for failure analysis using the EM located at FRCs and respective hardware located at the FSCs. They will perform troubleshooting with the support of the industrial team if necessary, and then propose solutions in term of maintenance or timeline modifications. These solutions will be discussed with the COL-CC Operation Team in order to decide for their implementation. Preventive maintenance or onboard crew training for some specific experiments are foreseen in nominal operation and are performed under USOCs responsibility.
In support to these activities, the USOCs will avail of different ground models for each facility: the Engineering Model (FM), the Science reference Model (SRM), the Training Model (TM), and the Baseline Data Collection Model (BDCM). Some of these models (or parts of them) may be located at different places (USOCs, training sites, launch pad, industrial sites). Management of the configuration of these models will be an important function of USOCs during operations.
Another permanent function will be the management of the facility database. Every data coming from one facility or related to it must be treated and stored in one database under FRC responsibility. USOCs, scientists and industrial representatives will have to have permanent access to this database.

2.3.3.2 Experiment Related Functions

During the execution of the mission/increment, the different USOCs will perform several experiment/science related activities both during and after the experiment execution.

During flight the activities include support to the scientist in experiment execution, experiment replanning, development of contingency procedures following the evaluation of preliminary results, monitoring of experiment execution to check its correct performance, scientific data archiving and quick look analysis of the results.
After the experiment execution (mainly after the increment) the activities include: scientific data validation and evaluation, scientific data handling co-ordination and scientists support, and scientific data archiving and dissemination (when restrictive rights of experimenters allow for it). In addition, USOCs will recover samples, perform if necessary other ground reference measurements (BDC for physiological experiments) and edit final reports relative to the increment.

2.3.4 USOC Interfaces in decentralised Payload Operations

The decentralised operations concept requests all centres to have physical links with the IGS-network. In addition organisational, management and specific technical interfaces will be established for the USOCs with:

- **FRC, FSC, ESC or UHB:** A fix connection will be established between FRCs and FSCs, while the connections to the ESCs and UHBs will be more dynamic.
- **Col-CC:** The planned communication connections will be established between the USOCs and the COL-CC, in the most cost efficient manner.
- **EAC:** Every USOC will cooperate to the training process, which is under the responsibility of the European Astronaut Centre (EAC). The FRCs are in charge of nominating a Training Responsible, supported by the ESC or FSC personnel dealing with specific experiments and Class 2 payloads, who will work in collaboration with his counterpart at the EAC.
- **ESA Utilization Management Team:** The activities of this team have been outlined in section 2.1. The dedicated procedures to be developed include:
  - *Operations and utilisation planning*
  - *Management of utilisation related activities.*
  - *Supervising of payload interface and operations agreements*
- **Industry:** The interface will depend on the type of industry classified into the Payload Development, the Facility Integration and the Engineering Support.
- **Information centres:** The USOCs will collaborate with the Erasmus User Information Centre at ESTEC in providing common services and products for general ISS information and promotion. This includes general ISS news updates, general announcements of opportunities for using ESA facilities and reuse of tele-media facilities available or under development.

2.3.5 USOC specific task outline at national sites

B-USOC

The Belgian User Support and Operation Centre (B-USOC) is located at Bruxelles. The role of the B-USOC consists in providing information related to space research/flight opportunities; providing support to the development of space payloads from all disciplines; performing and/or supporting operations of experiments/payloads; performing post-operation activities; and providing scientific support. In this context, a large number of experiments/facilities have already been operated from B-USOC or from User Home Bases (UHBs) located at universities or institutes since 1983.
B-USOC will act as FRC for the SOLAR experiment group (EXPRESS Pallet), and as supporting centre for the EDR-FRC and EuTEF. In addition, B-USOC will provide ESC functions for the Microgravity Facilities for Columbus (FSL, MSL, EPM and Biolab) and gives telescience and teleoperation support to 'User Home Bases' in Belgium.

CADMOS

CADMOS (Centre d'Aide au Développement de la Microgravité et aux Opérations Spatiales) located at Toulouse (France) is a dedicated centre for preparation, validation and operation of scientific and technical experiments which need microgravity environment. In order to perform its activities, CADMOS consists of a Main Control Room and a large laboratory area. Specific data systems allow audio, video and telemetry dispatching in these different areas. It is foreseen to improve this configuration in order to use it as an USOC for the ISS. CADMOS will be in charge of the FRC functions for the European Physiology Modules (EPM) and the Material Science Laboratory including the Solidification and Quenching Furnace (MSL/SQF) and the physical experiment Atomic Clock Ensemble in Space (ACES).

DAMEC

The Danish USOC at the Danish Aerospace Medical Centre of Research (DAMEC Research A/S) will act as a Facility Support Centre (FSC) for the European Physiology Modules (EPM) contribution to NASA's Human Research Facility (HRF). The system called Pulmonary Function System (PFS) is a new version of a series of gas analysers developed for space. The PFS is planned for inclusion in the HRF-2 rack and is currently scheduled for launch in the early part of the space stations assembly sequence. DAMEC will as FSC act in close cooperation with CADMOS, which is the Facility Responsible Centre (FRC) for the EPM, and will support all the different activities for PFS. During payload operations DAMEC will play a significant role in monitoring and controlling the equipment and the experiments from the Centre in Copenhagen, Denmark.

DUC

Since 1989 the Dutch Utilisation Centre activities at NLR (NLR-DUC) are focussed on projects to support scientists and industrial/commercial users of space platforms. NLR-DUC contributes to an operational infrastructure in co-operation with the Dutch agencies NIVR and SRON, Dutch industries and scientists, who all take part in the DUC steering committee since 1998. NLR-DUC is preparing, in co-operation with B-USOC, and with Dutch and Belgium industrial partners, the operational ground concept for the EDR-FRC at the Erasmus User Centre at ESTEC. In the European Drawer Rack (DER) operational ground segment NLR-DUC acts in the role of both FSC and ESC.

ETH Biotesc

Since 1977 the ETH Space Biology Group in Zurich has been researching space cell biology for a

total of 25 flight experiments on microgravity missions. During these years the group has achieved a considerable expertise in the field of biotechnology, still growing based on present activities and new techniques.
In May 2000, according to the European Decentralization Operations Scheme, the Space Biology Group has been assigned the role of Facility Support Centre for Biolab as part of the international ground segment under development for the International Space Station (ISS). The centre has been named ETH-Biotesc, and will function as support to the Biolab FRC, located at MUSC/DLR in Cologne. The FRC and the FSC functions will grow together into a differentiated and efficient Biolab support, which will enable optimal exploitation of the ground resources and of the facility onboard the ISS.

IDR UPM
IDR/UPM is the Spanish USOC and is the Facility Support Centre for the Fluid Science Laboratory. The services provided to FSL users include logistic, planning and re-planning, experiment operations simulation, facility operations, troubleshooting and upgrading activities, crew and ground personnel training, communications infrastructure, data archiving and dissemination.
Besides the services provided at European level for the Fluid Science community, at national level IDR/UPM supports users of any discipline (not restricted to Fluid Science) and act as the Spanish national point of contact for ISS utilisation. IDR/UPM will provide the services of promotion, familiarisation and information provision.

MARS
MARS Centre is a Consortium between the University of Napoli Federico II and Alenia-Finmeccanica, established in 1988 to create a research centre active in microgravity Fluid Science research and a support Institution to offer the necessary assistance for the preparation, execution and post-flight analysis of space experiments. The centre is equipped with a Fluid Science laboratory, a computational centre and a telescience control centre. From there, several experiments were conducted or controlled in space missions. MARS Centre researchers participated to microgravity missions gaining experience with most of the available space research platforms.
MARS has been assigned the role of Facility Responsible Centre (FRC) for the Fluid Science Laboratory (FSL). The Fluid Science Laboratory (FSL) is a multi-user Laboratory for conducting research in the different fields of Fluid Science, including Fluid dynamics, Critical Point Phenomena, Boiling, Dynamics of Inclusion.

MUSC
Since 1979 MUSC has supported numerous experiments in materials and life sciences under microgravity in more than 40 missions on various carriers. For ISS payload operations, MUSC will perform the FRC role for the facilities Biolab and MSL/LGF. MUSC will also provide ESC activities for the German CARDIOLAB contribution to EPM and for FSL. In addition, the Centre is the focal point of contact for national user support activities in Germany.
The facility responsibility for MSL will be shared by MUSC (LGF) and CADMOS (SQF). The operation of the US-provided furnace inserts in the MSL is foreseen in support of NASA experiments. For the BIOLAB facility, MUSC has set up scientific-technical infrastructure to enable and support the life science specific hyper-g and µg simulation as well as flight parallel 1-g reference experiments

2.4 Telescience Experiment Operations

Telescience is the concept of remote, interactive and real-time operation of an experiment in space by the ground-based researchers. Telescience thus provides the capability to perform science in a flexible laboratory-like fashion. The feasibility and usefulness of telescience have been demonstrated for the first time during previous sounding rocket missions (Texus). Experiments were monitored and controlled by the investigators in real time from the German Centre MUSC as well as from the Italian Centre MARS during pilot remote missions. This concept has been further developed and applied during International Space-Lab missions involving various European USOCs and User Home Laboratories. For the upcoming Space Station utilisation, telescience is now considered the baseline for remote experiment operations scenarios.

2.4.1 USOC support for telescience experiment operations

The real-time control of a payload is performed by using the infrastructure implemented at the FRC. The user conducting his experiment may be located either at his location (User Home Base), or at a USOC (FRC, FSC, ESC). If required, the COL-CC may also provide a limited user accommodation. Remote operations are possible within an operational window, according to a resource envelope defined in the timeline on the basis of a set of previously validated commands. The user will be able to monitor all payload data.

For the experimenters the USOCs will provide experiment operations interface. The USOCs will also invite the researchers to participate in Class 2 payloads simulation and training programs and to perform monitoring and control of the class 2 payloads.

Payload commanding may be performed either with direct "ad hoc" commands from the USOCs and associated UHBs, from the COL-CC if required, POIC cadre for ESA payload in the US segment or crew, or with pre-planned commands issued by the on-board Master Timeline (MTL). Payload commanding is always co-ordinated between the COL-CC and the FRC. The COL-CC or crew can issue payload commands in response to contingencies or anomalies according to pre-defined procedures.

The commanding concept, responsibilities and authorities for a given payload are assigned to the FRC during the process of payload analytical integration (PAI). As verified during PAI, during the mission the FRCs will be responsible for issuing authorised commands to their payloads within predefined periods, or "operational windows". They will co-ordinate, check and supervise the commanding activities by FSCs or ESCs and UHBs during class 2 payload operations.

Direct payload commands from FRCs will be checked by the COL-CC versus the scheduled operations command path and window. The Flight Control Team at the COL-CC is in charge of enabling or disabling the command path. Payload commanding activities may be preceded by "external" control activities to support the appropriate system set-up prior to the payload "internal" control activities. Scheduling of commands to an ESA payload accommodated in the US Segment will be co-ordinated with the POIC.

Command data files for payload internal timelines generated and validated by the FRCs will be uploaded during their operations windows. Safety critical payload commands, as identified during PAI, will be approved and issued by the Columbus Control Centre, POIC or SSCC. For payload commands, receipt and execution acknowledgements will be sent to ground and forwarded to the originating centre. The FRCs will monitor and verify that the commands have been both enacted and have produced the desired results.

Payload operations for a given Class 1 payload will be performed under the responsibility of the assigned FRC. They will ensure that throughout the operations the payload stays within the agreed resource envelope. Whenever anomalies or faults are detected by this monitoring process, the FRC in charge of the overall Class 1 payload operations will inform the Flight Control Team (FCT) at Columbus-CC and/or the POIC and contingency procedures will be carried out as appropriate.

Additionally, resources consumption by each major ESA payload will be monitored by the COL-CC via the rack-level interface, enabling them to detect any major excursions in time and to take appropriate measures. Either the FRC will have to initiate the reduction of the consumption back or co-ordinate for enhancement with the COL-CC. In case of unresolved priority conflicts COL-CC might have to load reduction or termination by either crew or ground command. European payloads outside the Columbus will be monitored in a similar way, coordinated between the POIC and the responsible ESA FRCs in case of anomalies.

3 Implementation Planning of the Decentralised Columbus Operations Infrastructure

3.1 Implementation Schedule for COL-CC

The Phase B2 Extension of the Columbus Control Centre definition study within DLR has the objective to provide the initial design and programmatic specification of the control centre itself, and of the Manned Spaceflight and Microgravity (MSM) communications infrastructure for the interconnection with the other control and support centres involved in operating the ESA ISS elements and payloads. This specification allows starting the detailed design, development/integration and operations preparation (Phase C/D) activities end 2001 under DLR/GSOC responsibility.
The main phases for the development of the Columbus Control Centre are shown in Figure 3.1.

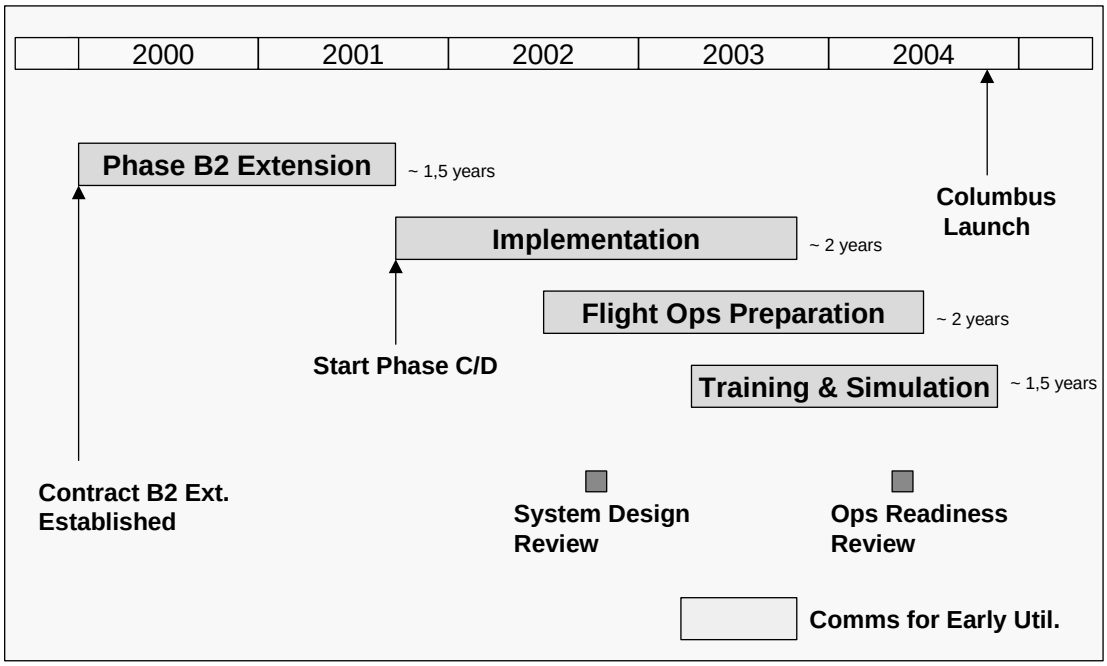


Figure 3.1. Implementation Schedule (COL-CC)

3.2 Implementation Schedule for USOCs

For the development of the European user centre infrastructure a phased implementation approach has been defined. The implementation is divided into a Definition Phase, an Implementation Phase, and a Validation Phase. Figure 3.2 provides a sketch of the schedule for the phased implementation approach.

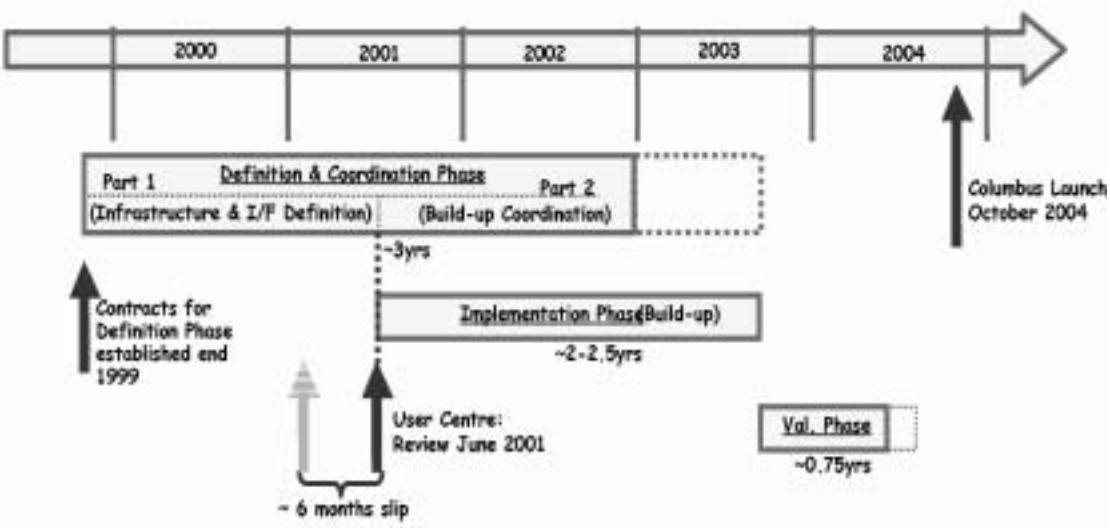
The ESA Utilisation Management, with the active participation of the User Centres manages and co-ordinates the project. The following sections describe these phases.

Figure 3.2. Overall Implementation Schedule for Decentralised USOC Network

<u>The Definition Phase</u>

This phase is concerned with the conceptual and requirements definition activities in preparation of the subsequent hardware and software related activities. The phase will establish a technical and programmatic baseline for the user centres and prepare the build-up of the centres with respect to the definitions, roles and responsibilities of the different types of user centres. A set of USOC baseline documentation will be generated providing requirements, interfaces control, and architectural design documentation.

The phase was initiated in December 1999 and is planned to continue for approximately 3 years. The objective of the Definition Phase is to define the technical and programmatic basis for the implementation of the USOCs.



The Implementation Phase

The majority of the activities is concentrated in the Implementation Phase which is concerned with the actual build-up and hardware/software implementation at the USOCs. The communications and data infrastructure will be established in parallel with the preparation of the local infrastructure in the centres. This phase will also cover the preparation of the validation and qualification of the centres and the preparation of operational documentation.

The Implementation Phase commences following the successful conclusion of the User Centre Review, planned for the second quarter of 2001. This review establishes the development baseline for the User Centres.

The Validation Phase

This phase covers the operational validation of the payload operations infrastructure at the user centres. The communications infrastructure and operational interfaces will be validated. During this final stage of the implementation, the performance of all hardware and software installations at the USOCs are verified. In addition, during this phase the operations preparation for the Columbus Commissioning phase is performed.

4 Conclusion

The decentralized operatoins concept for European payloads on the International Space Station relies on

- intensive conceptual work
- experience in user support and telescience operations for Spacelab and MIR missions in European USOCs
- experience of the German Space Operations Centre in manned mission operations
- experience of ESA in utilisation co-ordination.

Implementation has started in co-operation with the involved sites all over Europe.

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